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REMEDIAL INVESTIGATION REPORT

FOR

USATHAMA - RATSS
LAKE CITY ARMY AMMUNITION PLANT
INDEPENDENCE, MISSOURI

Carlos J. Serna, P.G.
RFW-Senior Project Hydrogeologist

Stephen Schuyler, P.E.
RFW-Task Manager

Glenn Johnson, P.E.
RFW-RATSS Sr. Project Manager

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Prepared By

Roy F. Weston, Inc.
West Chester, Pennsylvania

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This report presents the results of the Phase I Remedial Investigation (RI) conducted at the Lake City Army Ammunition Plant (LCAAP). The objectives of this RI have been achieved through an extensive sampling and analysis program and evaluation of the presence, magnitude, and in most cases, extent of groundwater, surface water, sediment and soil contamination. In summary, many of the same chemicals suspected of being disposed in potential source areas were found in groundwater samples from LCAAP water production wells, groundwater collected from monitoring wells installed across the plant, surface water, and sediment samples collected in ditches across the plant and sump and sump outflow sediment samples. Explosive compounds such as RDX and HMX and heavy metal compounds such as arsenic, beryllium, cadmium, chromium, copper, lead, nickel, silver, and zinc were identified as chemicals of potential concern in nearly all media sampled, and thus, may be considered fairly widespread chemical contaminants at the LCAAP site. In general, volatile contaminants were identified as as chemicals of concern in media that were collected near suspected solvent disposal source

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NAME OF RESPONSIBLE INDIVIDUAL
Mary Ellen Heppner

22b. TELEPHONE *(Include Area Code)*
(301) 671-3460

22c. OFFICE SYMBOL
CETHA-IR-D

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areas. The analytical information has been used to evaluate the potential risk to the environment and the public health and welfare. Based on conclusions of this RI, recommendations have been made to further evaluate the extent of contamination and source characterization at specific areas.

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LIST OF APPENDICES

Acronyms and Abbreviations

LIST OF ACRONYMS AND ABBREVIATIONS

AG	Silver
ALPHAG	Gross alpha activity
ANAPNE	Acenaphtene
ANTRC	Anthracene
ARAR	Applicable or relevant and appropriate requirement
AS	Arsenic
AWQC	Ambient Water Quality Criteria
BA	Barium
BAANTR	Benzo[a]anthracene
BAFANT	Benzo[a]flouranthene
BAPYR	Benzo[a]pyrene
BE	Beryllium
B2EHP	Bis(2-ethylhexyl)phthalate
BETAG	Gross beta activity
BCF	Bioconcentration factor
BKFANT	Benzo[k]fluoranthene
BNA	Base neutral acid extractable compound
BRDCLM	Bromodichloromethane
CAG	Carcinogenic Assessment Group
CCL4	Carbon tetrachloride
CD	Cadmium
1CDPYR	1-C,D-Pyrene
CDI	Chronic daily intake
C6H6	Benzene
CHBR3	Bromoform

C2H3CL	Chloroethene/Vinyl chloride
CH2CL2	Methylene chloride
CHCL3	Chloroform
CHRY	Chrysene
CLC6H5	Chlorobenzene
CLP	Contract Laboratory Program
CNS	Central nervous system
CPAH	Carcinogenic polyaromatic hydrocarbon
CR	Chromium
CRL	Certified reporting limit
CRQL	Contract-required quantitation limit
CU	Copper
CYN	Cyanide
DBAHA	Dibenz[a,h]anthracene
DBRCLM	Dibromochloromethane
11DCE	1,1-Dichlorethylene
12DCLB	1,2-Dichlorobenzene
11DCLE	1,2-Dichloroethane
DEHP	Di-(ethylhexyl)phthalate
DMP	Dimethyl phthalate
DNOP	Di-n-octylphthlate
24DNT	2,4-Dinitrotoluene
26DNT	2,6-Dinitrotoluene
EA	EA Engineering, Science, and Technology, Inc.
ECD	Electron-capture detector
EM	Electromagnetometry

ETC6H5	Ethylbenzene
FANT	Fluoranthene
FID	Flame ionization detector
FLRENE	Fluorene
GC	Gas chromatograph
GOCO	Government-owned contractor-operated
gpm	Gallons per minute
GPR	Ground-penetrating radar
HA	Health advisory
HEA	Health effects assessment
HG	Mercury
HMX	Cyclotetramethylenetetranitramine
HRS	Hazard Ranking System
ID	Inside diameter
IRP	Installation Restoration Program
IWTP	Industrial waste treatment plant
LCAAP	Lake City Army Ammunition Plant
LOEL	Lowest observed effect levels
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
MEC6H5	Toluene
MDNR	Missouri Department of Natural Resources
MDWS	Missouri Drinking Water Standard
MGS	Missouri Groundwater Standard
MGWQS	Missouri Groundwater Quality Standard
MSL	Mean sea level

NAP	Naphthalene
NAS	National Academy of Sciences
NB	Nitrobenzene
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NCPAH	Noncarcinogenic polyaromatic hydrocarbon
NI	Nickel
NNDPA	N-nitrosodiphenylamine
NOAA	National Oceanographic and Atmospheric Administration
NOEL	No observed effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
PACT	Powdered activated carbon treatment
PAH	Polyaromatic hydrocarbon
PA/SI	Preliminary assessment/site inspection
PB	Lead
PHANTR	Pheneanthrene
PHENP	Phenol
PID	Photo-ionization detector
POTW	Publicly-owned treatment works
PPL	Priority Pollutant List
PYR	Pyrene
RBC	Rotating biological contactory
RCRA	Resource Conservation and Recovery Act
RDX	Cyclotrimethylenetrinitramine/Cyclonite
RfD	Reference dose
RI	Remedial investigation

SARA	Superfund Amendments and Reauthorization Act of 1986
SB	Antimony
SE	Selenium
SRL	Standard reporting level
TCE	1,1,1-Trichloroethene
111TCE	1,1,1-Trichloroethane
T12DCE	Trans-1,2-dichlorethylene
TCLEA	Tetrachloroethane
TCLEE	Tetrachloroethylene
Tetryl	Nitramine
TL	Thallium
135TNB	1,3,5-Trinitrobenzene
TRCLE	Trichloroethylene/Trichloroethene
TRV	Toxicity reference value
USATHAMA	United States Toxic and Hazardous Materials Agency
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compound
WESTON	Roy F. Weston, Inc.
ZN	Zinc

Executive Summary

EXECUTIVE SUMMARY

Introduction and Objectives

This report presents the results of the Phase I Remedial Investigation (RI) conducted by Roy F. Weston, Inc. (WESTON) at the Lake City Army Ammunition Plant (LCAAP). The RI was conducted under the authority of the United States Army Toxic and Hazardous Materials Agency (USATHAMA) as part of the Installation Restoration Program (IRP). This investigation provides the initial basis for the ultimate design and implementation of a corrective action(s).

LCAAP is located approximately 4.5 miles northeast of Independence, Missouri, in Jackson County (Figure ES-1). Plant operations include the manufacturing of small arms ammunition, storage, and test firing of ammunition. Operations also include waste treatment and disposal of associated manufactured waste byproducts and general plant refuse. LCAAP is a government-owned, contractor-operated (GOCO) facility, and is currently operated by Olin Corporation.

There are 28 individual study areas at LCAAP, and based on evaluation of potential contamination at each site and the results of previous investigations, 18 sites were selected to be investigated as part of this RI. The major objective of the RI was to evaluate the potential extent and magnitude of contamination both plant-wide and at 18 individual areas and use this information to evaluate the potential risk to the environment and public health and welfare. A site plan of all developed portions of LCAAP, including Areas 1 through 18, is shown in Figure ES-2. In order to achieve the project objective, the following tasks were performed:

- Geophysical surveys.
- Soil gas survey.
- Monitoring well installation.
- Groundwater sampling and analysis.
- Surface water and sediment sampling analysis.
- Surface and subsurface soil sampling and analysis.
- Sump, sewer, and outflow sampling and analysis.
- Groundwater and surface water elevations survey.
- Aquifer testing.

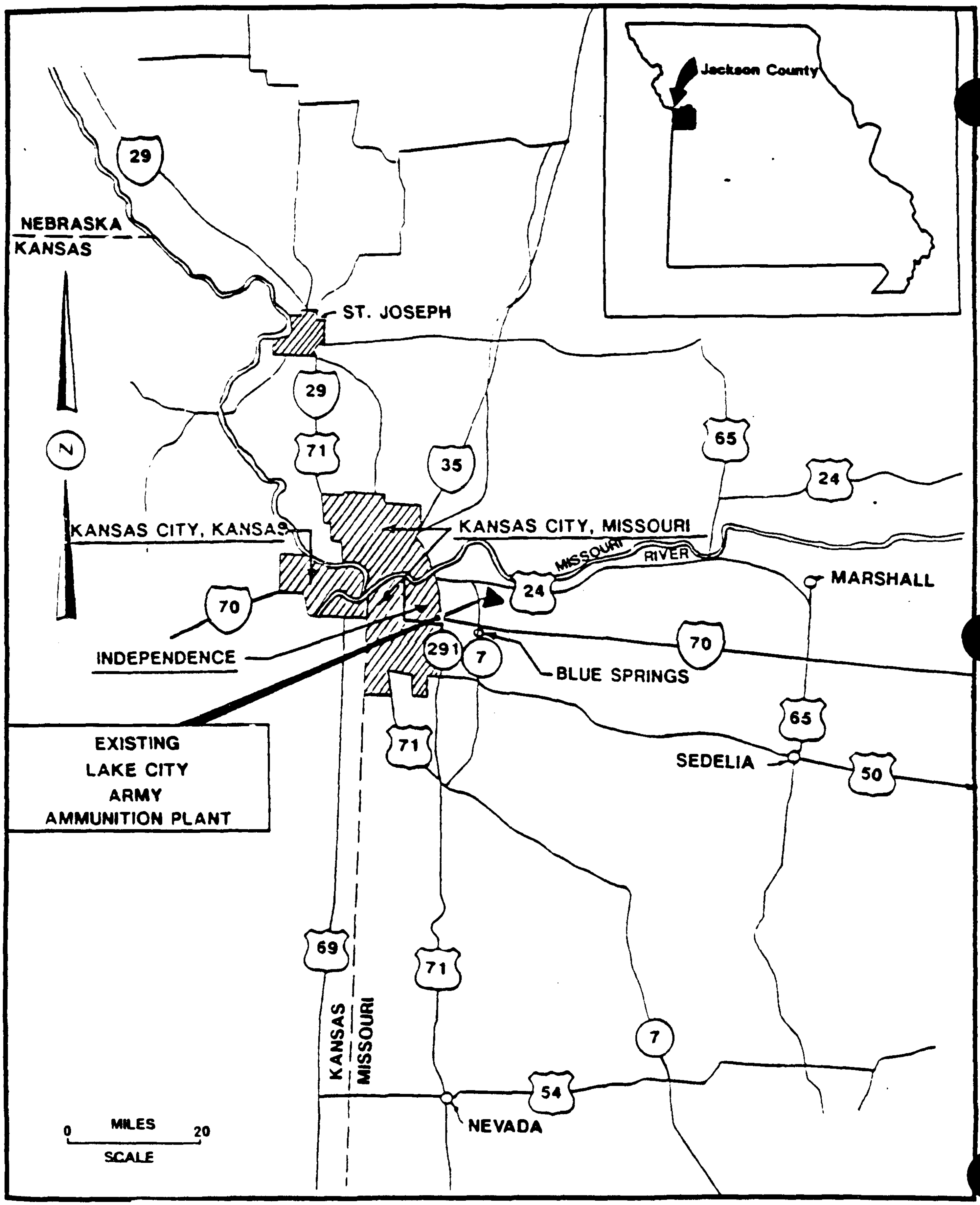


FIGURE ES-1
LCAAP LOCATION MAP

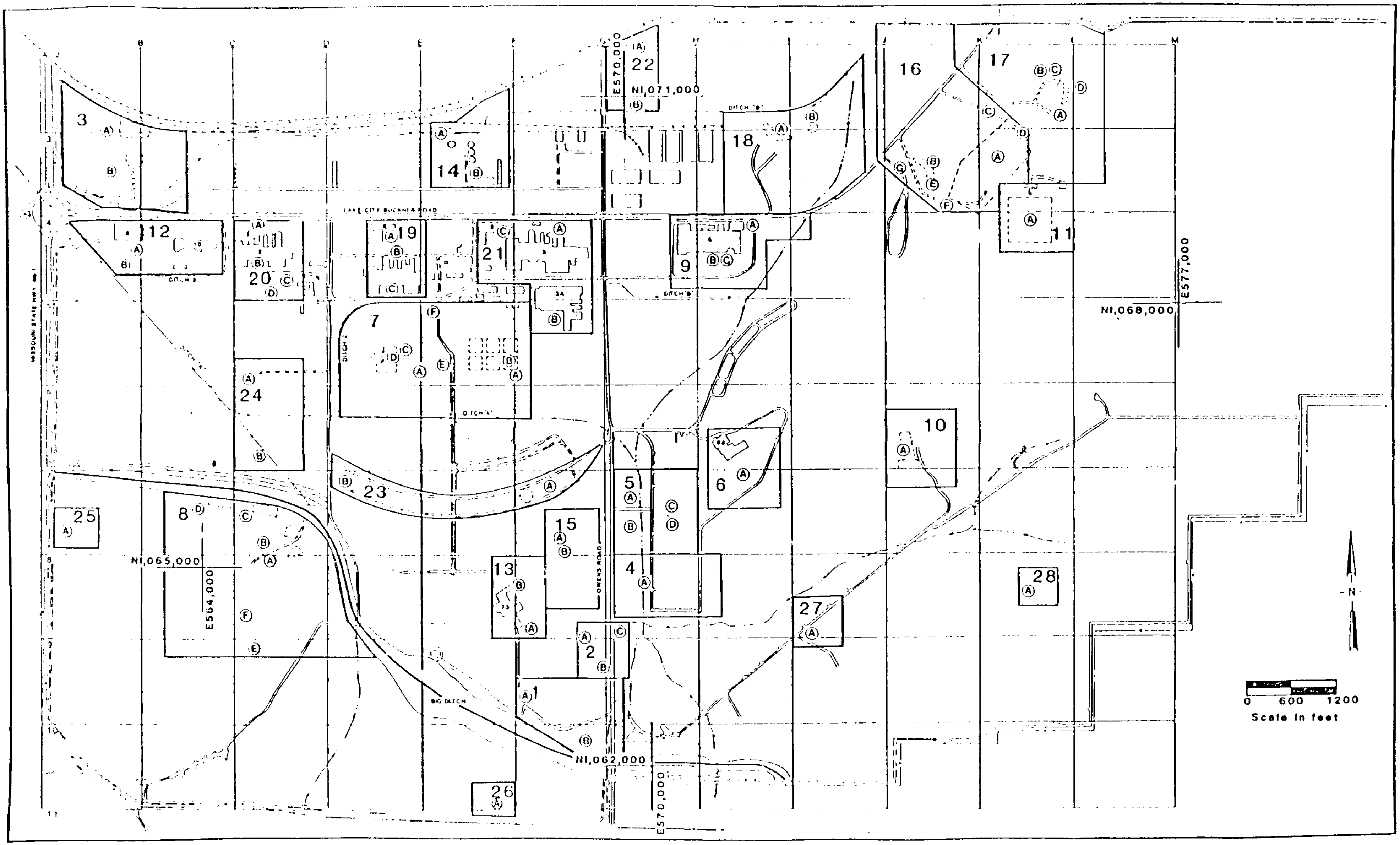


FIGURE ES-2
STUDY AREA LOCATIONS

Physical Characteristics of Study Area

The topography at LCAAP can be characterized as lowland and upland areas. The northern and western portions of the plant are characteristic lowland areas exhibiting a nearly flat topography. These lowland areas are composed of alluvial silty clay and sand deposited in a fluvial environment within the valley. The southern and eastern portions of the plant are the upland areas. The upland areas are silty clay and Pennsylvanian sedimentary strata and exhibit moderate relief with narrow crested ridges.

The results of the field investigation have identified the following stratigraphic units:

- Fill material present at most of the developed areas, especially the landfill areas ranging in thickness from 5 to approximately 20 feet.
- Loess deposits encountered predominantly in the upland areas, ranging in thickness from 0 to 3.5 feet.
- Colluvial silt and clay encountered in the upland areas, not usually more than a few feet thick.
- Alluvial silty clay ranging in thickness from approximately 5 to 44 feet.
- Alluvial sand ranging in thickness from approximately 0 to 82 feet.
- Limestone and shale bedrock encountered at or near the surface in the uplands and up to 100 feet below the surface in the alluvial valley.

From these stratigraphic units, three hydrostratigraphic units have been identified and include:

- The silty clay unit, which is unsaturated in several areas across the site, ranges in thickness from 5 to 44 feet, and lies between an overlying unsaturated fill layer (existing primarily in developed portions of the site) and the saturated alluvial sand layer.
- The alluvial sand unit, which is as much as 80 feet thick in the lowland areas, pinches out in the upland areas, and lies between the silty clay and weathered bedrock.
- The weathered bedrock unit, which is up to 100 feet below the surface in the lowland areas and crops out in the upland areas.

The silty clay and weathered bedrock unit act as upper and lower confining layers, respectively, for the alluvial sand aquifer which is the primary water-producing aquifer at the plant. Groundwater within the alluvial sand aquifer generally flows in a northwest to westerly direction. However, it has been assessed from pumping test data and from capture zone analysis of nine on-site production wells that, except for groundwater located beneath Areas 3, 8, 16, and 17, the capture zones of the production wells may intercept nearly all groundwater beneath LCAAP (Figure ES-3). Therefore, groundwater contaminants at Areas 3, 8, 16, and 17 may potentially migrate off-site, whereas groundwater contaminants beneath all other locations of the plant would be intercepted by the production wells.

Contaminants of Concern

Groundwater Contaminants of Concern. Chemicals of potential concern identified for groundwater in the production wells (treated and untreated water), the monitoring wells with groundwater potentially reaching the production wells, and the 16 study areas are shown in Table ES-1. Chemicals of potential concern identified for groundwater in the off-site residential wells are summarized in Table ES-2. As may be seen from these tables, bis(2-ethylhexyl)phthalate, RDX, and HMX were the organic chemicals of potential concern in the most study areas across the site. RDX and HMX were not detected in the production wells during the RI; however, they were detected in groundwater samples from wells within production well capture zones. Although bis(2-ethylhexyl)phthalate is a common laboratory contaminant, detected concentrations were elevated above blank levels and varied considerably in the different study areas. RDX concentrations in groundwater also fluctuated widely in the different study areas, being highest in Areas 3, 7, 11, and 12. The highest concentration of HMX was detected in Area 7.

Carbon tetrachloride (Area 16), chrysene (Area 18), chloroform (Area 17), 1,2-dichlorobenzene (Area 16), 1,2-dichloroethane (Area 16), dimethylphthalate (Area 16), nitrobenzene (Area 16), and 1,1,2,2-tetrachloroethane (Area 16) were detected in groundwater in only 1 study area, and in only 1 or 2 samples within the samples collected in these areas. Carbon tetrachloride, 1,2-dichloroethane, 1,2-dichlorobenzene, dimethylphthalate, nitrobenzene, and 1,1,2,2-tetrachloroethane were detected at very low concentrations (i.e., near or below the CRL or SRL values). Benzene, trans-1,2-dichloroethene, bis(2-ethylhexyl)phthalate, trichloroethene, and vinyl chloride, the organic chemicals of potential concern in untreated production well groundwater, were also detected in monitoring well samples.

Finally, all of the organic chemicals (i.e., carbon tetrachloride, 1,2-dichlorobenzene, 1,4-dichlorobenzene, HMX, RDX, toluene, and trichloroethene) detected in the off-site residential wells north

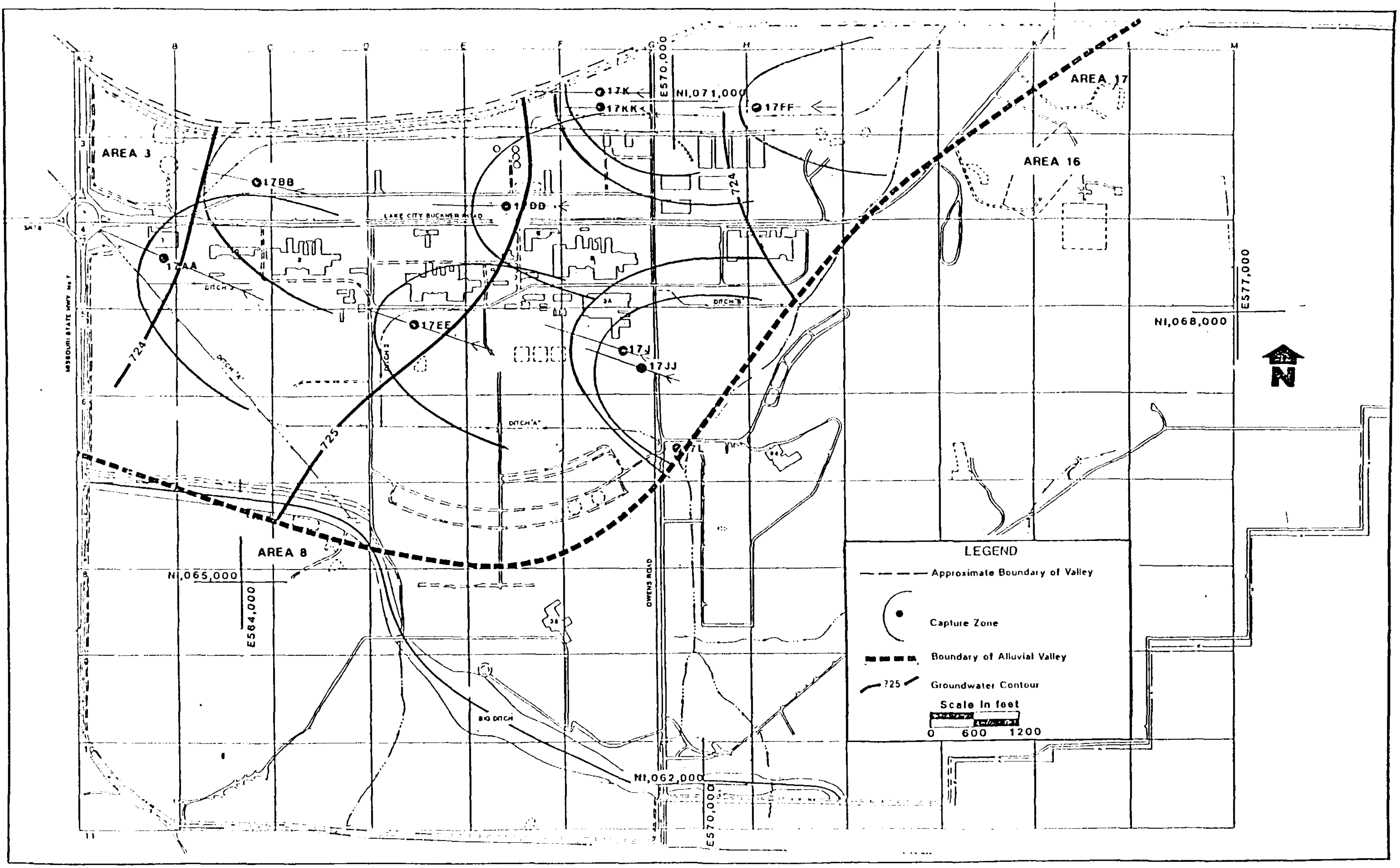


FIGURE ES-3
PRODUCTION WELL GROUNDWATER CAPTURE ZONES

TABLE ES-1

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT LCAAP
LAKE CITY, MISSOURI

Chemical	Treated Prod. Wells	Untreated Prod. Wells	Monitoring Well/Prod. Well Capture Zone	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	Area 11	Area 12	Area 14	Area 16	Area 17	Area 18
Organics:																			
Benzene		X	X							X							X	X	
Bromodichloromethane	X																		
Bromoform	X																		
Carbon tetrachloride																	X		
Carcinogenic PAHs (chrysene)			X																X
Chloroform	X																	X	
1,3-DNB			X						X								X		
2,4-DNT			X			X			X										
2,6-DNT			X		X													X	
Dibromochloromethane	X																		
1,2-Dichlorobenzene																	X		
1,1-Dichloroethane			X					X									X		
1,2-Dichloroethane			X														X		
1,1-Dichloroethene			X			X		X									X		X
trans-1,2-Dichloroethene		X	X					X		X	X						X	X	
1,2-Dichloroethene (total)	X																		
Dimethylphthalate																	X		
Ethylbenzene																	X	X	
bis(2-Ethylhexyl)phthalate		X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X
HMX			X			X	X		X	X				X	X			X	X
Methylene chloride			X							X								X	
Nitrobenzene																	X		
N-nitrosodiphenylamine			X								X				X				
RDX			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1,3,5-TNB			X				X			X		X			X			X	
1,1,2,2-Tetrachloroethane																	X		
Tetrachloroethene																	X	X	
Tetryl			X												X			X	
Toluene											X						X	X	
1,1,1-Trichloroethane	X		X					X									X	X	
1,1,2-Trichloroethane																	X	X	
Trichloroethene	X	X	X					X		X	X						X	X	
Trihalomethanes (total)	X																		
Vinyl chloride		X	X					X		X							X		

TABLE ES-1 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT LCAAP
LAKE CITY, MISSOURI

Chemical	Treated Prod. Wells	Untreated Prod. Wells	Monitoring Well/Prod. Well Capture Zone	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	Area 11	Area 12	Area 14	Area 16	Area 17	Area 18
Inorganics:																			
Antimony			X	X			X	X			X		X				X	X	
Arsenic		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	
Barium		X	X	X		X		X		X	X		X		X	X	X	X	X
Beryllium		X	X	X	X	X		X	X		X		X	X	X	X	X	X	
Cadmium			X	X	X		X	X			X	X	X	X		X			
Chromium			X		X	X	X	X	X	X	X			X	X	X	X		
Copper		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
Lead		X	X	X	X	X		X	X	X	X		X				X	X	X
Mercury	X		X	X															
Nickel		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Selenium			X		X					X									
Silver	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Thallium	X																		
Zinc		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Radiological Parameters:																			
Alpha Radioactivity	X	X	X								X					X	X	X	
Beta Radioactivity	X	X	X			X		X			X					X	X	X	
Radon-226 and -228	X																		
U-234		X	X			X		X			X					X	X	X	
U-238		X	X			X		X			X					X	X	X	
Total Uranium			X								X					X		X	

TABLE ES-2

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER FROM THE OFF-SITE RESIDENTIAL WELLS LOCATION NORTH OF THE NORTHERN LCAAP BOUNDARY LAKE CITY, MISSOURI

Chemical	Danner	Ferguson	Hedrickj-A	Hedrickj-B	Hedrickv	Lirely	Pennington	Tcarlton	Turley	Ure	Carlton	Area North of Area 17
Organics:												
Carbon tetrachloride										X		
1,2-Dichlorobenzene										X		
1,4-Dichlorobenzene										X		
HMX	X		X	X	X	X	X		X	X	X	
RDX			X						X	X		
Toluene												X
Trichloroethene										X		
Inorganics:												
Barium	X	X	X	X	X	X	X	X	X	X	X	
Chromium												X
Copper	X	X	X	X	X	X			X			X
Lead		X						X				
Mercury	X	X	X	X		X	X		X	X	X	
Nickel												X
Zinc	X	X	X	X	X	X	X		X	X	X	X

of LCAAP were detected in other groundwater samples on-site with the exception of 1,4-dichlorobenzene. Toluene detected at a low level (i.e., near the CRL or SRL) in the residential well just north of Area 17, was also detected in Area 17 groundwater at levels far above its respective CRL.

Although in general, concentrations of radiological parameters did not exceed normal Missouri state activity levels (site background samples were not analyzed for radiological parameters), all radiological parameters were selected as chemicals of potential concern at the request of EPA due to the burial of radioactive wastes on-site. Radium-226 and -228 was only analyzed for in treated production well water, and no background values were available. Only treated production wells, untreated production wells, and Areas 3, 5, 8, 14, 16, and 17 were analyzed for radiological parameters.

Gross alpha radioactivity was detected in treated production wells, untreated production wells, the production well capture zone, and Areas 8, 14, 16, and 17 at a maximum concentration of 23 pCi/L in production well capture zone water. Gross beta radioactivity was detected in treated production wells, untreated production wells, the production well capture zone, and Areas 3, 5, 8, 14, 16, and 17 at a maximum concentration of 96 pCi/L in Area 8. Uranium (total uranium, U-234, and U-238) were detected in untreated production wells, the production well capture zone, and Areas 3, 5, 8, 14, 16, and 17 at maximum concentrations of 1.9 pCi/L and 1.7 pCi/L, respectively, and at a maximum concentration of total uranium of 1.5 pCi/L in the production well capture zone.

Of the inorganic chemicals of potential concern in groundwater, arsenic, barium, beryllium, chromium, copper, lead, nickel, silver, and zinc were detected at concentrations above background levels in groundwater in most on-site study areas and in the production wells. Antimony and cadmium were of potential concern in seven and nine of the on-site study areas, respectively, and were elevated above background in the production wells. Mercury and selenium were found in only one and two, respectively, of these off-site wells.

<u>Surface and Subsurface Soil Contaminants of Concern</u>. Table ES-3 presents a summary of the chemicals of potential concern in surface and subsurface soil at LCAAP, based on the preliminary sampling conducted during the RI. As may be seen in this table, only 2,6-DNT and oil and grease are at levels of concern in soils. The compound 2,6-DNT, detected in only one area (Area 8) and in only one subsurface soil sample from that area at a concentration near the CRL, was not of potential concern in groundwater in Area 8. The compound 2,6-DNT was detected in only a few groundwater samples across the site (i.e. Areas 2 and 17) at concentrations near the CRL.

Mercury and zinc were found at relatively high concentrations in Area 9 (i.e., relative to levels in soil samples collected in Area 8, the only other study area with levels of mercury and zinc above background). Mercury was a chemical of potential concern in Area 1 and in treated production well water. Antimony was of potential concern only in Area 15 soils. Area 9 surface soils were the only soils containing detectable levels of selenium.

Surface Water and Sediment Contaminants of Concern. Organic and inorganic chemicals of potential concern in surface water and sediment samples generally varied depending on the study area as shown in Table ES-4; few chemicals were seen in all areas. Exceptions are copper and lead which were seen at above background levels in most ditches and surface water/sediment samples across the site. Several chemicals of potential concern (e.g., chloroethane, 1,1-dichloroethane, ethylbenzene, methylene chloride, phenol and toluene) were detected only in the surface water sample from the in Area 16 leachate seep. Several of these chemicals were also detected in groundwater samples in this and other study areas, although groundwater samples were relatively infrequent and groundwater concentrations generally low.

Sump, Sewer and Outflow Sediment Contaminants of Concern. Table ES-5 presents a summary of the chemicals of potential concern identified in sump and sump outflow sediment samples at LCAAP, based on the preliminary sampling conducted during the RI. The explosive compound 2,4-DNT, oil and grease, and several inorganic chemicals including barium, cadmium, chromium, copper, lead, mercury, and zinc were often identified as chemicals of potential concern in sump and sump outflow sediment. No VOCs were detected in sump and sump outflow sediment samples, as shown in Table ES-5.

Summary of Contaminants of Concern. In summary, many of the same chemicals suspected of being disposed in potential source areas at the site were found in groundwater sampled from the production wells, groundwater collected from the monitoring wells installed across the site, surface and subsurface soil collected in various areas at the LCAAP site, surface water and sediment samples collected in different ditches across the site, and sump and sump outflow sediment samples. As shown in Table ES-1, ES-2, ES-3, ES-4, and ES-5, explosive compounds such as RDX and HMX and heavy metal compounds such as arsenic, beryllium, cadmium, chromium, copper, lead, nickel, silver, and zinc were identified as chemicals of potential concern in nearly all media sampled, and thus may be considered fairly widespread chemical contaminants at the LCAAP site. In general, volatile contaminants were identified as chemicals of potential concern in media that were collected near suspected solvent disposal source areas.

Quantitative Risk Characterization. Quantitative risk assessment involves estimating intakes by potentially exposed populations based on the assumed exposure scenario. These intakes are then

TABLE ES-3

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE AND SUBSURFACE SOILS AT LCAAP
LAKE CITY, MISSOURI

	Surface Soil		Subsurface Soil			
Chemical	Area 9	Area 13	Area 8	Area 9	Area 14	Area 15
Organics:						
2,6-DNT			X			
Oil and Grease			X		X	X
Inorganics:						
Antimony						X
Arsenic	X	X	X		X	X
Barium	X	X	X		X	X
Beryllium	X		X			X
Cadmium	X		X		X	X
Chromium	X	X				
Copper	X		X			X
Cyanide	X			X		
Lead	X	X	X			X
Mercury	X		X	X		
Nickel			X			
Selenium	X					
Zinc	X		X	X		

TABLE ES-4

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER AND SEDIMENT AT LCAAP
LAKE CITY, MISSOURI

	SW	Sediment	SW	Sediment	SW	Sediment	SW	Sediment	SW	Sediment	SW	Sediment	SW	Sediment	Sediment	Sediment
Chemical	Area 13 Drainage Ditch		Area 16 Leachate Seep		Area 16 Drainage Ditch		Cattle Pond		Ditch A		Ditch B		Big Ditch		Unnamed Ditch	Ditch 2
Organics:																
Benzene			X										X			
Carcinogenic PAHs		X		X		X		X				X				
Chloroethane			X													
2,4-DNT										X						
1,1-Dichloroethane			X													
trans-1,2-Dichloroethene			X		X											
Di-n-butyl phthalate						X				X						
Ethylbenzene			X													
bis(2-Ethylhexyl)phthalate	X				X						X					
HMX									X							
Methylene chloride			X													
Noncarcinogenic PAHs		X				X		X				X				
Oil and Grease										X		X				X
Phenol			X													
1,3,5-TNB	X				X											
Toluene			X													
Trichloroethene			X		X								X			
Inorganics:																
Antimony	X						X				X					
Arsenic		X		X		X	X				X	X		X		
Barium		X		X		X						X				
Beryllium			X			X					X	X				
Cadmium		X				X						X			X	X
Chromium	X	X				X				X		X		X	X	X
Copper	X	X	X		X	X	X	X	X	X	X	X	X			X
Lead	X	X	X		X	X		X		X	X	X			X	X
Mercury		X								X		X				
Nickel	X	X	X		X				X		X					
Selenium											X					
Silver			X						X							
Zinc		X	X						X	X	X	X	X			

TABLE ES-5

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN SUMP AND SUMP OUTFLOW SEDIMENT SAMPLES AT LCAAP
LAKE CITY, MISSOURI

	Buildings 1 and 2			Building 3		Building 4		Buildings 94, 97 & 97A	
Chemical	Bldg. 1 Sumps	Bldg. 2 Sumps	Sump Outflows	Sumps	Sump Outflows	Sumps	Sump Outflows	Sumps	Sump Outflows
Organics:									
2,4-DNT				X	X	X	X		X
2,6-DNT				X					X
HMX									X
Nitrobenzene	X								
Oil and Grease	X	X	X	X	X	X	X	X	X
RDX									X
1,3,5-TNB				X					
Inorganics:									
Antimony									X
Barium		X		X	X	X	X	X	X
Beryllium					X				
Cadmium		X	X	X	X	X	X	X	X
Chromium		X	X	X	X	X	X	X	X
Copper	X	X	X	X	X	X	X	X	X
Lead	X	X	X	X	X	X	X	X	X
Mercury		X	X	X	X	X	X		X
Nickel				X					
Silver				X	X	X			
Zinc		X	X	X	X	X	X	X	X

combined with reference doses (RfDs, defined as acceptable daily doses for noncarcinogens) or cancer potency factors (for carcinogens) to derive estimates of noncarcinogenic hazard or excess lifetime cancer risks of the potentially exposed populations. For carcinogens, the excess lifetime cancer risk is expressed as a probability. A 10^{-6} risk indicates that, as a result of the exposure being considered, an exposed individual has a probability of one in a million of getting cancer. A risk range of 10^{-6} to 10^{-4} is often used as a range for health protectiveness by regulatory agencies (EPA 1990).

The major conclusions of the quantitative risk characterization are presented below.

- Ingestion of treated groundwater from the production wells by on-site workers yielded total excess lifetime cancer risks of approximately 10^{-5} for the plausible maximum case. Bromodichloromethane, chloroform, dibromochloromethane, trichloroethene, and radium 226 and radium 228 were the only suspected carcinogenic compounds detected in treated water, above the detection limit.. The hazard index for the maximum case was below a value of one, when thallium was excluded. The CDI:RfD for TL was 10 for the RME case. However, thallium was not detected in any groundwater samples collected for the RI or in any other media. Therefore, the presence of thallium is not considered likely to be due to waste disposal practices at the LCAAP site.

- Ingestion of treated groundwater from the production wells by on-site residents yielded total excess lifetime cancer risks of approximately $10-^{4}$ for the RME case. Bromodichloromethane, chloroform, dibromochloromethane, trichloroethene, and radium 226 and radium 228 were the only suspected carcinogenic compounds detected in treated water, above the detection limit. The hazard index for the maximum case was below a value of one, when Thallium was excluded. The CDI:RfD for Thallium was 30 for the RME case. However, thallium was not detected in any groundwater samples collected for the RI or in any other media. Therefore, the presence of thallium is not considered likely to be due to waste disposal practices at the LCAAP site.

- Hypothetical ingestion of untreated groundwater from the production wells by on-site residents yielded total excess lifetime cancer risks of approximately 10^{-3} for the RME maximum case. Vinyl chloride and arsenic were the chemicals primarily driving the risk. Vinyl chloride was detected only in production well 17FF, while arsenic was detected in several production wells across the site. The hazard indices for the RME case was below a value of one. It should be noted that the LCAAP plant currently treats the production well groundwater, and therefore these risks are only applicable if the current treatment system is not used. These estimated risks can be used to indicate the need for continued treatment of production water at LCAAP. Based on available exposure assumptions, it should be noted that potential risks of exposure to facility workers from this pathway would be approximately three times lower than the risks to on-site residents.

- Hypothetical ingestion of untreated groundwater by on-site residents using groundwater from the production well capture zone yielded a total excess lifetime cancer risk of approximately 10^{-3} for the RME case. Chrysene, vinyl chloride, arsenic, and beryllium were comprising the majority of the risk. Similar carcinogenic risks were found for both the production wells and capture zone production wells. This may indicate that there may be no increased risk to ingestion of production well water even if all of the groundwater currently downgradient of potential source areas was drawn into the production wells. The hazard indices for the RME case was 0.6. It should be noted that the LCAAP plant currently treats the production well groundwater, and therefore these risks are only applicable if the current treatment system is not used. Based on available exposure assumptions, hypothetical risks of exposure to facility workers from this pathway would be approximately three times lower than the risks to on-site residents.

- Ingestion of groundwater by residents in off-site areas using residential wells Hedrickj-A, Turley, and Ure, yielded carcinogenic risks ranging from approximately 10^{-7} to 10^{-5}. Carbon tetrachloride, 1,4-dichlorobenzene, RDX, and trichloroethene were the only carcinogenic chemicals of potential concern detected in the off-site wells located along the northern LCAAP boundary. Ingestion of groundwater by residents in the off-site area near Area 17 yielded the highest hazard indices of all off-site wells (0.6 for the RME case). No hazard index was greater than one for any of the off-site residential wells sampled.

- Hypothetical ingestion of groundwater located along the western border of the plant (residential wells are located beyond the western border of the plant) yielded an excess lifetime cancer risk of 10^{-3}. Arsenic and beryllium accounted for the majority of the risk for the RME case. The hazard index for the RME case was 2. Antimony and arsenic accounted for the majority of the noncarcinogenic risk for the RME case. Several source areas within Areas 3 and 8 may be contributing to the contamination of the chemicals that significantly contributed to these risks. It should be noted that the potential dilution and degradation of chemicals of potential concern during off-site migration of this perimeter groundwater was not considered, and thus the risks presented for this pathway most likely presents upperbound preliminary estimates of potential exposure for off-site residents.

- Section 5.5.2.2 presents in detail the estimated hypothetical risks from ingestion of groundwater by on-site residents from wells that in the future may be installed downgradient of each study area. Although such use of groundwater in this area is considered highly unlikely they were evaluated for the following reasons: (1) evaluation of the potential degradation of groundwater as a potential resource in each study area; (2) identification of specific sources that may be contributing significantly to groundwater chemicals that are driving the risk assessment. In general, total excess lifetime cancer risks for the RME case ranged from 10^{-2} to 10^{-4}, with the risk for most areas at 10^{-3}. Often arsenic accounted for the majority of the cancer risk in the different study areas. For certain areas, chemicals of potential concern that were significantly contributing to the cancer risks include beryllium, bis(2-ethylhexyl)phthalate, RDX, trichloroethene, and vinyl chloride. The hazard indices for the RME case exceeded one in all of the sixteen areas with the exception of Area 6 and Area 18. In areas where the hazard indices exceeded a value of one, the values ranged from 2 (from Areas 11 and 16) to 400 (from Area 17). Chemicals of potential concern with CDI:RfD ratios that exceeded a value of one include: antimony, arsenic, barium, bis(2-ethylhexyl)phthalate, cadmium, chromium, trans-1,2-dichloroethene, RDX, 1,3,5-TNB, and trichloroethene. Potential source areas that may be significantly contributing to groundwater chemicals that are contributing to the risk assessment are discussed in detail in Section 5.5.2.2. Based on available exposure assumptions, hypothetical risks of exposure to facility workers from this pathway would be approximately three times lower than hypothetical risks to on-site residents.

- Volatile chemicals present in tap water may also be emitted into indoor air, for example as a result of showering, laundering, and dishwashing. Inhalation of these volatilized chemicals may be associated with risks similar to those associated with direct ingestion (Foster and Chrostowski 1987). Therefore, the risks presented above for the groundwater ingestion scenarios may be slightly higher due to showering, laundering, etc. However, the risks would not be altered by more than an order of magnitude, which is within the range of uncertainty of a risk assessment.

Environmental Assessment. Absolute conclusions regarding the potential environmental impacts of the chemicals of concern at LCAAP cannot be made because there are a number of uncertainties associated with the estimates of toxicity and exposure and these should be noted when reviewing the conclusions for the LCAAP study areas. However, given the available data and limitations the general conclusions regarding the potential for environmental impacts are summarized below.

Plants. In the one area evaluated for toxicity to plants (Area 13), no adverse effects to plants are expected. Although the levels of arsenic and chromium exceed the plant-TRVs, grass species in the vicinity of Area 13 do not appear to be adversely affected.

Terrestrial Wildlife. No adverse effects to terrestrial wildlife are expected from ingestion of surface water in site ditches. However, rabbits that ingest surface water from the Area 16 seep may experience adverse chronic effects from exposure to high levels of phenol. Sufficient toxicity information was not available for mammals for chloroethane and HMX and therefore potential risk from exposure to these chemicals could not be evaluated. Toxicity information was not available for birds for benzene, beryllium, bis(2-ethylhexyl)phthalate, chloroethane, 1,1-dichloroethane, ethylbenzene, HMX, methylene chloride, tetrachloroethene, toluene, selenium, trans-1,2-dichloroethene, trichloroethene, and 1,3,5-TNB. Therefore, the potential risks to birds from exposure to these chemicals could not be further evaluated. No adverse effects are expected to wildlife consuming soil organisms that may bioaccumulate contaminants in soil. However, earthworm bioconcentration factors were not available for arsenic and barium, thus potential risks from exposure to these chemicals could not be evaluated, although arsenic and barium in the food of birds and mammals does not bioaccumulate and is readily excreted.

Aquatic Organisms. The measured concentrations of copper, silver, and zinc in Ditch A exceed the chronic AWQCs. In Ditch B, the levels of bis(2-ethylhexyl)phthalate, copper, lead, selenium, and zinc exceed the chronic AWQCs. The level of zinc in Big Ditch is greater than the chronic AWQC. Thus, potential adverse chronic effects to some species of aquatic organisms could occur from exposure to these chemicals at the measured concentrations. The measured concentrations of zinc (in all three ditches) exceed the acute AWQC by two to four times and thus adverse acute effects could occur in sensitive aquatic organisms such as microcrustaceans (such as *Daphnia magna*) and some species of juvenile fish. Concentrations in sediments were not evaluated because interim sediment quality criteria were not available for the chemicals of concern. In evaluating these results it should be noted that these on-site ditches have not been classified by the State of Missouri and the relevance of AWQC to these water bodies is questionable. Potential impacts to aquatic organisms downstream of the sampling points in classified water bodies would be reduced as the chemical concentrations decline as a result of dilution and any transformation processes that may occur.

Summary

The objectives of this remedial investigation have been achieved through conducting an extensive sampling and analysis program and an evaluation of the presence, magnitude, and in most cases, the extent of groundwater, surface water, sediment, and soil contamination. The analytical information has been used to evaluate the potential risk to the environment and the public health and welfare. Based on the conclusions developed during this investigation, recommendations have been made to further evaluate the extent of contamination and source characterization at specific areas. Conclusions and recommendations are presented in Section 7 of this report.

Introduction

SECTION 1

INTRODUCTION

The Lake City Army Ammunition Plant (LCAAP) is located northeast of Independence, Missouri. LCAAP is a U.S. Army Armament, Munitions and Chemical Command installation. Operations at the plant include the manufacturing of small arms ammunition, and the storage and test firing of ammunition. Plant operations also include waste treatment and disposal of associated manufactured waste byproducts and general plant refuse.

1.1 INVESTIGATIVE SUMMARY

1.1.1 Initiation of Remedial Investigation Activities

Roy F. Weston, Inc. (WESTON) was issued the assignment to perform the Phase I Remedial Investigation (RI) at LCAAP. The RI was initiated through the authority of the United States Army Toxic and Hazardous Materials Agency (USATHAMA) as part of the Installation Restoration Program (IRP). On 1 June 1987, WESTON received the authorization to proceed with the RI planning. The work scope was finalized in October 1987, and the final Technical Plan was submitted in May 1988. The final Data Management Plan was submitted in June 1988; and the final Quality Assurance/Quality Control Plan and Health and Safety Plan were submitted in June 1988 and April 1988, respectively.

1.1.2 Purpose of the Remedial Investigation

LCAAP comprises 28 individual study areas and based on an evaluation of potential contamination at the sites and results of previous investigations, study areas 1 through 18 were selected to be investigated as part of this RI (Figure 1-1). The 10 sites that are not included as part of this investigation will be considered for future investigation conducted as additional phases of the RI. Table 1-1 identifies and describes the areas not investigated during Phase I.

The purpose of the RI was to evaluate the potential extent and magnitude of contamination both plant-wide and at 18 designated sites, and use this information to evaluate the potential risk to the environment and public health and welfare. The objectives of the RI can be characterized by review of the sampling program. The sampling program included:

1. Sampling and analysis of groundwater; conducted to evaluate the plant-wide presence, character, and extent of groundwater contamination.

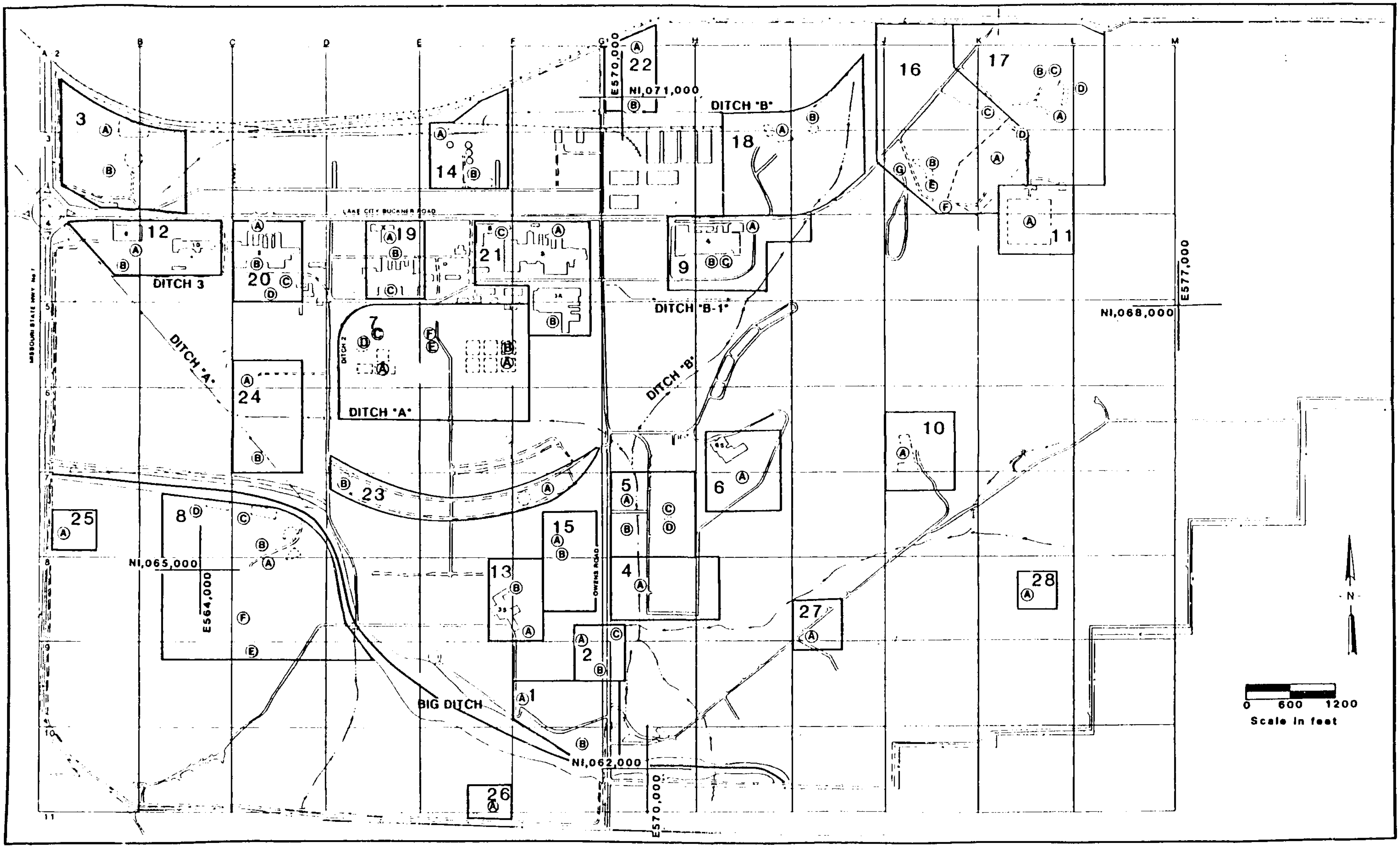


FIGURE 1-1
STUDY AREA LOCATIONS

TABLE 1-1

STUDY AREAS NOT INCLUDED IN RI

Study Area	Site Description
19	A Percolation sumps B Laboratory waste tank C Leaking waste lines
20	A Percolation sumps B Leaking waste lines C Herbicide mixing site D Acid spill
21	A Percolation sump B PCB soils C Mercury waste tank
22	A Demolition waste pump B Ditch "B"
23	A IWTP surface impoundment B Asbestos residue from fire
24	A Sanitary waste water treatment B Ditch "A"
25	A Demolition waste dump
26	A Demolition waste dump
27	A Firing range
28	A Pipe line leak

2. Sampling and analysis of surface water and sediment; conducted to evaluate the plant-wide presence, character, and extent of contamination.

3. Sampling and analysis of surface soil; conducted to evaluate the presence, character and extent of surface soil contamination at selected areas.

4. Sampling and analysis of subsurface soil; conducted to evaluate the presence, character and extent of subsurface soil contamination at selected areas.

5. Sampling and analysis of the wastes from the discharge sumps and the soil from areas receiving such discharges; conducted to evaluate the presence and character of the plant effluents.

6. Electromagnetic and ground penetrating radar geophysical surveys; conducted to assess the location and extent of selected subsurface waste management units and facilitate the proper placement of monitoring wells.

7. A pumping test and slug tests; conducted to evaluate the hydraulic conductivity of the aquifer and the rates of groundwater migration.

8. A soil gas survey; conducted to assess the presence and extent of organic soil vapors in the subsurface soils at Area 12.

9. Groundwater elevation and surface water elevation surveys; conducted to determine the position and configuration of the potentiometric surface and its relationship to surface water bodies on a plant-wide scale.

1.1.3 Scope of Work

The field activities at LCAAP were conducted over four separate time intervals, from December 1987 to August 1988. The first field activity was conducted from 7 to 16 December 1987 and included the soil gas survey and the geophysical surveys. The second field investigation activity was conducted from 19 January to 24 February 1988 and included the monitoring well installation activities. The third investigation activity was conducted from 25 April to 3 June 1988 and included the first round of groundwater sampling, pumping test, subsurface soil sampling, surface soil sampling, surface water/sediment sampling, and groundwater/surface water elevation surveys. The last field investigation activity included the second round of groundwater sampling and was conducted from 8 to 31 August 1988. Sampling for all tasks was performed by a WESTON field team and all activities were conducted following sampling methods and

QA/QC procedures approved by USATHAMA, the Missouri Department of Natural Resources (MDNR) and the United States Environmental Protection Agency (USEPA). A detailed description of the site investigation procedures are presented in Section 2.

1.2 SITE BACKGROUND

1.2.1 Facility Location

LCAAP is located northeast of Independence, Missouri, in Jackson County and more specifically, in Township 50 North, Range 30 West. Figure 1-2 is a location map identifying LCAAP within the State of Missouri and Figure 1-3 is a plant base map showing the present plant configuration. The plant is approximately 19 miles east of Kansas City, Missouri, and located within the Lake City alluvial valley. The Town of Lake City consists of a small cluster of approximately a dozen homes north of LCAAP. The plant is bordered to the west by State Highway No. 7, to the south by Truman Road, to the east by woodlands, and to the north by the Missouri Pacific Railroad. The plant occupies approximately 3,955 acres or 6.2 square miles. LCAAP is situated approximately 4.5 miles northeast of Independence, 3 miles north of Blue Springs, and 2 miles southwest of Buckner.

1.2.2 Site Description and Site History

LCAAP is a government-owned, contractor-operated (GOCO) facility, and is currently operated by Olin Corporation. It has manufactured, stored and tested small arms ammunition continuously since 1941, with the exception of a five-year period of stand-by status from 1945 to 1950. Operations include: cartridge case drawing, annealing, pickling and forming; case priming; and cartridge loading and assembly. Penetrators for armor-piercing rounds and spotter rounds were formerly made from depleted uranium. Principal wastes from the manufacturing area are soluble oils, alkali cleaners, and hydraulic oil from extrusion processes. Chemicals used or previously used on site for production include: soaps, detergents, bleaches, hydrochloric acid, sulfuric acid, nitric acid, explosive compounds (e.g., lead azide, 2,4-dinitrotoluene (24DNT) and lead styphnate), phosphate cleaners, petroleum and lubricating oils, 1,1,1-trichloroethane (111TCE), trichloroethylene (TRCLE), and other cleaning solvents. The wastes from the production areas include mixtures and reaction products from these chemicals.

During its entire period of operation, virtually all waste treatment and disposal has been on site. Wastewater treatment and solid waste disposal practices have relied heavily on unlined lagoons, landfills, and burn pits. Landfills were constructed by the trench method, whereby a trench is cut into the side of a slope, with the longitudinal axis of the trench aligned with the fall line. Burn pits have been used for the destruction of waste

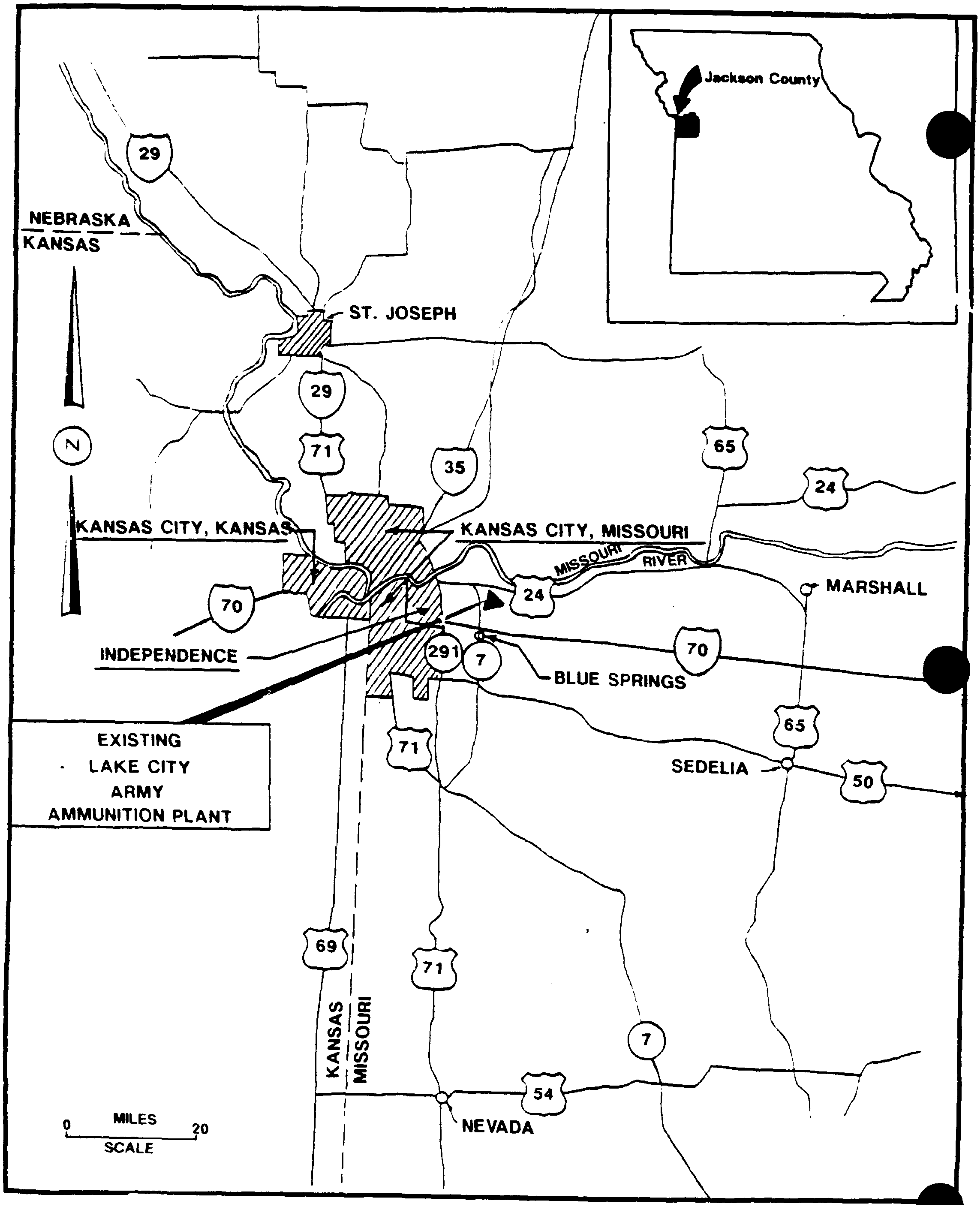


FIGURE 1-2
LCAAP LOCATION MAP

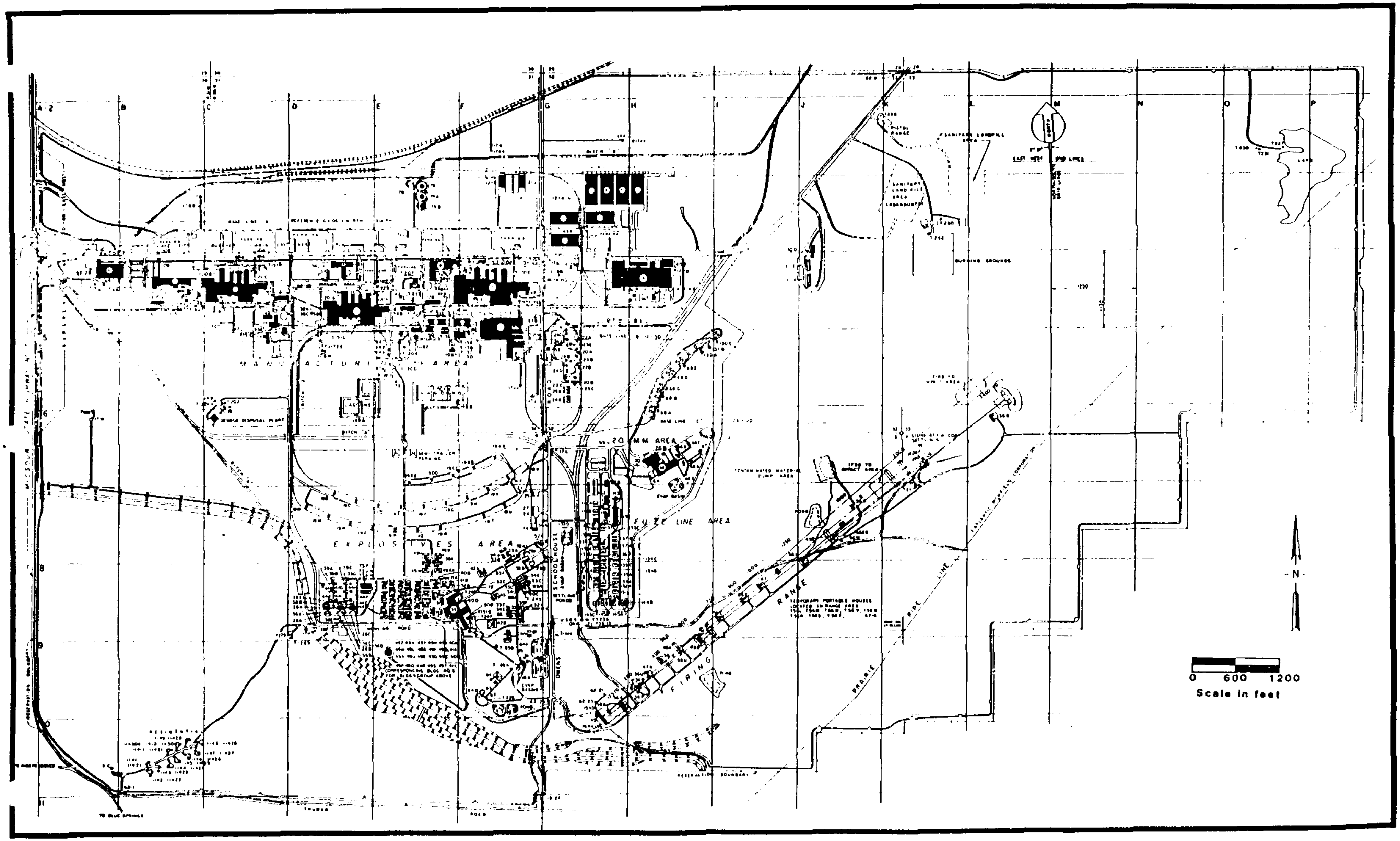


FIGURE 1-3
LCAAP BASE MAP

oil and grease, waste solvents, small arms ammunition, and combustible plant refuse. Floor drains from manufacturing buildings were generally directed to outside catch basins, where the wastewater was passed through a fabric filter and discharged to grade. As a result of these practices, numerous sites throughout the facility may have become contaminated.

1.2.3 Previous Investigations

The overall plant was evaluated by USATHAMA in May 1980 and issued a report in May 1980, entitled "Installation Assessment of Lake City Army Ammunition Plant - Report No. 162." That report documented the history of the plant, the materials used and wastes produced, and the existing treatment facilities. It also discussed site biota, geology, and groundwater. No sampling was conducted, although limited data was presented from previous monitoring. The intent of the study was to evaluate the plant, based on existing data. The conclusions were that most contaminated burial sites were situated in impermeable clay strata, and therefore, not subject to migration. One area, in the northwest corner of the plant, was noted as a possible area of contaminant (heavy metal) migration, due to its location in a sandy soil.

In 1986, USATHAMA contracted EA Engineering, Science, and Technology, Inc. (EA) to prepare another assessment. The "LCAAP Preliminary draft of the LCAAP Preliminary Assessment/Site Investigation (PA/SI) Final Report" was issued in January 1989. As part of that PA/SI Report, EA installed 24 new monitoring wells on site. Seven areas within the plant were evaluated by collecting soil samples, surface water samples, and groundwater samples from the 24 new wells and selected existing on-site monitoring wells. Samples were analyzed for volatile organics, semi-volatile organics, explosive compounds, inorganics, and radiological parameters. Elevated values of one or more of the analytical parameters were detected in samples from all seven areas. The PA/SI Report also contained a summary of all environmental investigations at LCAAP, including previous groundwater monitoring and determination of hazardous waste classifications under RCRA. The PA/SI study was not intended to identify the sources and extent of all contamination. Rather, it was meant to show whether contamination existed on a plant-wide basis. The conclusion of the report was that such contamination did exist.

One of the plant sites, a lagoon constructed in the 1950's, was used to contain waste from the chemical laboratories. These included the hazardous constituents barium, chromium, lead, mercury, silver, antimony, and small quantities of laboratory chemicals. The total waste quantity is estimated to be 5,000 gallons. This site is included on the National Priorities List (NPL). The basis for its nomination to that list was one groundwater analysis in another plant area (approximately 1,000 feet to the north), which showed a silver concentration above drinking water standards. Subsequent monitoring has not verified this result.

In addition to the NPL lagoon, USATHAMA has identified 72 other sites, plant-wide, as known or potential candidates for remediation. Due to the large number of sites, they have been grouped together for a total of 28 areas, of which 18 (1 through 18) were evaluated and studied for potential contamination problems during the investigation. Figure 1-1 shows the location of the 28 areas.

Both the assessment and PA/SI reports characterized the site geology. Two general geological regimes exist: the upland areas and the alluvial flats. Almost all of the plant manufacturing buildings are located on the alluvial flats. Typically, these soils contain silt and clay near the surface and sand at greater depths. The uplands consist of silty clay soils overlying predominantly shale and limestone bedrock.

Groundwater contours presented in the PA/SI report and based on data collected from 72 wells, showed a general direction of flow to the north and northwest.

1.3 REPORT ORGANIZATION

1.3.1 Study Area Investigation

Section 2 of this report describes the field investigation procedures conducted during the RI. This section includes a discussion of each of the following field investigation procedures: soil gas survey, geophysical surveying, drilling, well installation and construction, well development, ground surveying, staff gauges, aquifer tests, and environmental media sampling procedures. Also included within each subsection is the rationale behind each of the investigative tasks performed at each of the sites.

1.3.2 Physical Characteristics of the Study Area

Section 3 of this report presents the physical characteristics of the study area. The presentation includes discussion of surface features, meteorology, surface water hydrology, soils, geology, hydrogeology, natural resources, water supplies, demography, and land use. This section provides particular information necessary to evaluate the applicability of potential remedial alternatives at the LCAAP.

1.3.3 Nature and Extent of Contamination

Section 4 of this report presents the site description, field investigation activities, and site investigation results for the 18 study areas and various plant-wide sampling programs. The site description and field investigation for each study area are described and include discussions regarding the field investigation program, land use, site geology, hydrology, and hydrogeology. The results of the site investigation for each study area include a summary of all detected analytical data, the evaluation of this data to assess the extent and magnitude of potential waste constituents, and an overview, or summary, of all significant findings for a particular study area.

1.3.4 Risk Assessment

Section 5 of this report presents a risk assessment for the entire LCAAP. The risk assessment is designed to evaluate the potential risk to public health and the environment associated with the release of hazardous substances from the LCAAP. The risk assessment discusses the selection of indicator chemicals, the subset of chemicals detected at the site that will be used in the risk assessment, and also discusses the risks at the sites assuming current use patterns remain unchanged and the risks involved assuming current use patterns are altered.

1.3.5 Preliminary Evaluation of Remedial Technologies

Section 6 presents the results of a preliminary evaluation of the applicability of various remedial technologies to source and contaminant conditions in various media at the site. The media considered are soil, surface water, sediment, and groundwater. This evaluation takes into account the volume, concentration, and locations of contaminants at the site.

1.3.6 Conclusions and Recommendations

Section 7 summarizes the remedial investigation and presents conclusions supported by the existing data. Specific issues addressed in this section includes areas of significant contamination, extent and magnitude of contamination, potential migration pathways, possible remedial technologies, and recommendations for additional data collection.

Study Area Investigation

SECTION 2

STUDY AREA INVESTIGATION

The field investigation program at the LCAAP included seven types of field investigations. These investigations included:

- Site Reconnaissance.
- Geophysical Investigations.
- Surface Water and Sediment Investigations.
- Soil and Vadose Zone Investigations.
- Groundwater Investigations.
- Ground Surveying.
- Staff Gauges.

A summary of the field investigation task performed at each of the study areas investigated is presented in Table 2-1.

2.1 Field Activities and Procedures

The field investigation activities were conducted in four separate phases from December 1987 through August 1988.

- The first phase was carried out from 7 through 16 December 1987 and included a soil gas survey, a geophysical survey, and staff gauge installation.

- The second phase was carried out from 19 January through 19 February 1988 and included the drilling, installation and development of 28 monitoring wells. It also included elevation surveying for all the newly installed wells and the existing RCRA wells.

- The third phase of the investigation was conducted from 25 April through 3 June 1988 and included aquifer testing, surficial soil and sediment sampling, subsurface soil sampling, surface water sampling, groundwater sampling, sewer system sampling, and groundwater and surface water elevation measurements.

- The fourth and last phase of the investigation was conducted from 8 August through 26 August 1988 and included the second round of groundwater sampling, plus groundwater and surface water elevation measurements.

The following subsections describe each of the field investigation procedures conducted at the Lake City Army Ammunition Plant.

TABLE 2-1

Summary of Remedial Investigation
Field Work
Lake City Ammunition Plant

Task	Area 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Monitoring well	---	1 well	1 well	---	1 well	---	3 wells	3 wells	---	---	---	2 wells	---	4 wells	---
depth - shallow	---	1x24'	1x82'	---	1x50'	---	2x32'	3x36-45'	---	---	---	1x34'	---	3x20-34'	---
- deep	---	---	---	---	---	---	1x83'	---	---	---	---	1x86'	---	1x78'	---
Groundwater samples	9	7	8	6	7	7	13	13	4	5	4	5	---	4	---
analysis	A	A	A	A	A	A	A	A	A	A	A	A	---	A	---
Surface soil	---	---	---	---	---	---	**	---	**9	---	---	**	3	---	---
analysis	---	---	---	---	---	---	---	---	E	---	---	---	B	---	---
Subsurface soil	---	---	---	---	---	---	3	6	8	---	---	---	---	3	2
analysis	---	---	---	---	---	---	D	B	E	---	---	---	---	B	B
Ditch sediment	---	---	---	---	---	---	---	---	5	---	---	4	4	---	---
analysis	---	---	---	---	---	---	---	---	C	---	---	F	C	---	---
Surface water	---	---	---	---	---	---	---	---	---	---	---	3	4	---	---
analysis	---	---	---	---	---	---	---	---	---	---	---	F	C	---	---
Geophysical survey	---	---	---	---	---	---	---	EM&GPR	---	---	---	---	---	EM&GPR	---
station (linear yds)	---	---	---	---	---	---	---	160/2500	---	---	---	---	---	200/4220	---
Pump test	---	---	---	---	---	---	---	---	---	---	---	(1)72-hr t	---	---	---
Slug test	---	1	2	---	3	1	5	2	2	---	---	6	---	2	---
Soil gas survey	---	---	---	---	---	---	---	---	---	---	---	1 survey	---	---	---
Staff gauges	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Radiological survey	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

TABLE 2-1
(continued)

Summary of Remedial Investigation
Field Work
Lake City Ammunition Plant

Task	Area 16	17	18	19	20	21	22	23	24	25	26	27	28	Plant Wide	Total
Monitoring well	8 wells	4 wells	1 well	---	---	---	---	---	---	---	---	---	---	---	28 wells
depth - shallow	4x20-32'	3x17-28'	1x94'	---	---	---	---	---	---	---	---	---	---	---	---
- deep	4x50-94'	1x86'	---	---	---	---	---	---	---	---	---	---	---	---	---
Groundwater samples	13	7	7	---	---	---	---	---	---	---	---	---	---	7	2x126
analysis	A	A	A	---	---	---	---	---	---	---	---	---	---	A	---
Surface soil	---	---	---	**	**	**	---	---	---	---	---	---	---	37*	49
analysis	---	---	---	---	---	---	---	---	---	---	---	---	---	8	---
Subsurface soil	---	---	---	---	---	---	---	---	---	---	---	---	---	---	20
analysis	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ditch sediment	4	---	---	---	---	---	---	---	---	---	---	---	---	11	28
analysis	C	---	---	---	---	---	---	---	---	---	---	---	---	C	---
Surface water	3	---	---	---	---	---	---	---	---	---	---	---	---	7	17
analysis	C	---	---	---	---	---	---	---	---	---	---	---	---	C	---
Geophysical survey	EM	EM&GRP	---	---	---	---	---	---	---	---	---	---	---	---	4-E,.3-GPR
station (linear yds)	365	100/1666	---	---	---	---	---	---	---	---	---	---	---	---	825/8386
Pump test	---	---	---	---	---	---	---	---	---	---	---	---	---	---	(1) 72-hr test
Slug test	13	9	6	---	---	---	---	---	---	---	---	---	---	---	52
Soil gas survey	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1 survey
Staff gauges	---	---	---	---	---	---	---	---	---	---	---	---	---	11	11
Radiological survey	1 survey	---	---	---	---	---	---	---	---	---	---	---	---	---	1 survey

*34 Building sump discharge areas: Analysis B.
4 Background soil samples: Analysis C.
**Building sump discharge area (number unknown).

Analysis A: VOC, Semivolatile, Metals (total and dissolved), Explosives
Analysis B: Metals, Explosives, Oil and Grease
Analysis C: VOC, Semivolatile, Metals, Explosives
Analysis D: Oil and Grease
Analysis E: Mercury, Cyanide and Zinc
Analysis F: VOC

2.1.1 Site Reconnaissance

The initial step in the site reconnaissance at the LCAAP was a site visit conducted by WESTON personnel during August 1987. A literature search and review of records were performed to correlate and evaluate existing regional, installation, and site-specific data. Further information was gathered through interviews with Olin Corporation employees who had knowledge of past waste handling practices. The review of records included an examination of previous reports, drilling logs, site plans, drawings, and aerial photograph interpretations. The literature search included the collection and review of various publications describing local and regional geologic features.

2.1.2 Geophysical Investigations

The geophysical investigation program included the use of two geophysical techniques; electromagnetic (EM) terrain conductivity, and ground-penetrating radar (GPR).

2.1.2.1 Electromagnetic Terrain Conductivity Survey

To define the lateral extent of soil contamination and the geometry of closed lagoons and landfills, an electromagnetic terrain conductivity survey was performed over several areas at LCAAP. These included the Industrial Waste Treatment Plant (IWTP) waste disposal area (Area 8), the sludge disposal area (Area 14), the abandoned landfill (Area 16), and the sanitary landfill and solvent pits (Area 17).

Electromagnetic techniques of measuring terrain conductivity operate by imparting an alternating current to a transmitter coil placed on the earth's surface. As the current passes through the transmitter coil, it produces a magnetic field, which, in turn, induces small currents in the underlying strata. Currents within the geologic materials produce a secondary magnetic field that is sensed by a receiver coil. It has been shown that the ratio of the magnetic field detected by the receiver coil to the magnetic field produced by the transmitter coil is directly proportional to terrain conductivity. This allows terrain conductivity to be read directly from the instrument in millimhos per meter (mmhos/m).

There are two orientations, or modes, in which EM conductivity measurements can be taken: the horizontal dipole mode and the vertical dipole mode. In the horizontal mode, most of the instrument response, which is an integrated measurement over the effective depth of exploration, is due to near-surface materials. In the vertical mode, most of the instrument response is due to materials at greater depths, with the largest contribution from a depth of 0.4 times the coil separation. In addition to dipole orientation, the distance between the two coils controls the depth of subsurface materials contribution to the instrument response.

The greater the coil separation, the greater the effective depth of exploration.

At each study area of concern, a Model EM-34 was used to delineate areas of elevated conductivities in the soils and to define the lagoons, pits and landfill boundaries. The surveys also provided rationale for the proper placement of monitoring wells downgradient from potentially identified disposal areas.

At Areas 8, 14, 16 and 17, grids with 100-foot centers were established. The EM-34 readings were initially taken at 50-foot intervals and additional readings were taken at 25-foot intervals within areas where supplemental information was needed. Measurements were taken in both the vertical and horizontal modes. The vertical and horizontal conductivities were recorded in a logbook, plotted n graph paper, and hand contoured. This was done in order to evaluate the need to collect further data points (25-foot intervals) to refine anomalous areas. Subsections 4-8, 4-14, 4-16, and 4-17 present the results of the geophysical surveys.

2.1.2.2 Ground-Penetrating Radar Survey

GPR was used upon completion of the EM-34 surveys to further define subsurface conditions. GPR profiles were collected at each study area where the EM-34 was used, with the exception of the abandoned landfill (Area 16). The depth of the landfill was expected to exceed the range of the GPR. Also, the roughness of the terrain, due to vegetation and erosion, was not conducive to the use of GPR. Particular emphasis was given to those areas where the EM-34 failed to delineate the extent of the trenches or pits. The GPR is useful in distinguishing between natural soil horizons and buried trenches. The maximum penetration depth of the GPR in silty sand was estimated to be 10 to 12 feet.

The GPR survey was implemented using a Geophysical Survey System, Inc., Model SIR System 3, with a Model 3105AP 300-MHz antenna. The system provided a continuous profile of subsurface conditions by radiating electromagnetic pulses into the earth and displaying the reflection from surface and subsurface interfaces on a strip chart recorder. The result was a hard copy subsurface profile that was evaluated in the field. Prior to the survey, the GPR unit was calibrated for on-site soil and moisture conditions using the following mathematical relationship:

$$\text{Depth of Penetration} = \frac{\text{Range (nanoseconds)}}{\text{Round Trip Impulse Rate (nanoseconds/foot)}}$$

The GPR antenna was pulled across the subject areas along the established grids. Within areas where anomalies were observed, further GPR profiles were performed. Subsections 4-8, 4-14 and 4-17 present the results of the GPR surveys.

2.1.3 Surface Water and Sediment Investigations

Surface water samples were collected from 15 ditch locations and 1 pond location at LCAAP. Surface water samples were collected from the edges of the ditches or pond. At these locations, sampling consisted of submerging the sample bottle directly into the water. Sample bottles were triple rinsed with the water to be sampled. For all surface water samples, field measurements of pH, specific conductance, and temperature were performed.

Sediment samples were collected from 21 ditch locations and 1 pond location at LCAAP. At sediment sampling sites where surface water existed, a surface water sample was also obtained. Surface water was not present at six sediment sampling locations.

Sediment samples were collected from the edges of the ditches and pond, using a disposable spatula. Sample depths were within a range of zero to six inches. The contents were emptied into sample bottles and qualitatively screened for organic vapors with a photoionization detector. Samples for volatile analysis were placed directly into the sample container and capped. The instrument readings and soil material descriptions were entered on the field sampling sheet.

2.1.4 Soil and Vadose Zone Investigations

2.1.4.1 Soil Gas Survey

A soil gas survey was conducted at Area 12, which is known as the closed chemical laboratory waste lagoon. An unknown source of trichloroethylene (TRCLE) had been identified in monitoring well 12-4 and production wells 17-AA and 17-CC. The concentration of TRCLE in these wells is approximately 20 ug/l. The closed chemical laboratory waste lagoon was not considered a source of TRCLE because the compound was identified at the upgradient monitoring well 12-4. In an attempt to identify the source, a soil gas survey was conducted. The soil gas survey was performed south of building 6 and north of Ditch 3. A grid at 100-foot intervals was installed within the investigation area. In order to effectively screen the site and maximize data coverage, the soil gas probes were initially spaced 100 feet apart. Subsequent sample locations were determined as analytical results were obtained from successive sampling points. Samples were collected for this study at a total of 68 sites.

The probes were installed to an approximate depth of 3 feet using a hand-held piston-hammer. A Teflon tube encased in copper tubing was installed in each hole and sealed from the ambient air. In order to obtain a sample representative of the soil gas in the vicinity of the shallow borehole, a portable vacuum pump operated at a low flow rate was used to evacuate the soil gas.

The soil gas samples were then collected in gas-tight sampling bulbs directly connected to the Teflon sample line upstream of the vacuum pump and flow meter. The soil gas samples contacted only Teflon, glass and stainless steel prior to chemical analysis.

The soil gas samples were analyzed on-site using a Varian 3600 gas chromatograph (GC) equipped with an ECD (Electron Capture Detector) and either a FID (Flame Ionization Detector) or a PID (Photoionization Detector). Samples were delivered for analysis in 250-ml gas-tight sampling bulbs, from which syringe samples were drawn; the syringe samples were then directly injected into the gas chromatograph. Samples were analyzed for TRCLE, vinyl chloride, and 1,2-trans-dichloroethylene (T12DCE).

Chromatography consisted of runs starting at 120°C for 2 minutes, then increasing by 15°C per minute until reaching 220°C, and then holding at 220°C until the completion of the analysis. A 6-foot long, 2-mm wide column packed with one percent SP1000 on 80/100 mesh Carbopack B was employed. A carrier flow of approximately 40 ml/min of nitrogen was maintained through the column. The injection port temperature was 200°C, and the detector was maintained at 300°C. A Varian BS650 computer was interfaced to the detector for purposes of identification, quantification and GC control.

Quantification was accomplished using analyte peak height in comparison to a calibration curve. A three-point calibration was run when the equipment was initially set up; two-point calibration standards were then run at the beginning and end of each day. Sample blanks were analyzed each day and a bulb spike was run at the beginning and end of the study. Several samples were run in duplicate and all samples were run on at least two detectors. Discussion regarding the conclusions is presented in Subsection 4.1.2.

2.1.4.2 Subsurface Soil Samples from Soil Borings

Soil borings were performed at five areas to characterize the nature, extent, and volume of waste and soil contamination. A total of 34 subsurface soil samples were collected. Most samples were collected using a 3-inch diameter split-spoon sampler that was driven into the soil at 18-inch intervals. The oversized split-spoon was needed to provide sufficient sample volume for chemical analysis. These borings were advanced using hollow stem augers.

Upon recovery of the sampler from the borehole, the sampler was placed on a polypropylene sheet. As the sampler was opened, the soil was qualitatively screened with a flame ionization (OVA) or a photoionization detector (HNu) and described by a qualified geologist or geotechnical engineer. The instrument readings and soil descriptions were entered in the sampling logbook. The sample was then peeled and placed into the appropriate sample bottle.

(Peeling is a process whereby that portion of the sample which was in direct contact with the sampler, as well as the ends of the sample, are removed and discarded.) The split-spoon samplers were decontaminated between each sample collection. The drilling rig and all related equipment and tools used at each boring were steam cleaned prior to re-use. The soil borings at Area 15 were performed using a gasoline-powered auger. Samples were collected from the soil cuttings as they came up along the augers; split-spoon samplers were not used. Power auger sampling was deemed adequate for the Area 15 sample collection since the objective was to assess the existence of contamination within five feet of the surface, not the exact horizon of soil contamination. The drill cuttings were qualitatively screened for organic vapors and the soil was evenly distributed to form a layer less than one-half inch thick.

2.1.4.3 Surficial Soil Sampling

A total of twelve samples of surficial soil were collected throughout the plant, including four background samples. All samples were collected from 0 to 6 inches in depth, using disposable spatulas. All grass, twigs, and rocks were removed prior to collecting the sample. The contents were emptied directly into sample bottles and qualitatively screened for organic vapors with an HNu. Any samples collected for volatile analysis were placed directly into the sample container and capped. The instrument reading and soil material descriptions were entered onto the field sampling sheet.

2.1.5 Groundwater Investigation

2.1.5.1 Drilling

The objective of the drilling activities at LCAAP was to further assess the lateral and vertical distribution of contaminants in the groundwater and to further define the site stratigraphy at LCAAP. This was accomplished through the installation of monitoring wells, followed by subsequent groundwater sampling.

Eighteen shallow and ten deep monitoring wells were installed in the saturated portion of the alluvial deposits.

All shallow wells and all deep wells to a depth of 40 feet were installed using a hollow stem auger drilling technique. The following procedures were used to install these monitoring wells:

- The working end of the drilling rig and all equipment, tools, and materials were steam-cleaned prior to drilling at each location. Provisions were made to keep the equipment, tools, and materials from coming into contact with surficial soils during drilling and well installation.
- The borehole was advanced using 6.5-inch or 8.25-inch inside diameter (I.D.) hollow stem augers.

- Samples were collected using standard split-spoon samplers. If no wells existed at the location prior to drilling, samples were collected at 2.5-foot intervals to a depth of 20 feet, and at 5-foot intervals to the bottom of the boring.

- If a two-well cluster was being installed by WESTON, the shallow well was installed first. This well was sampled at the intervals described above. Sampling for the deep well started at the depth where sampling of the shallow well stopped. If a deep well was being installed next to an existing well, the entire depth of the well was sampled at the intervals previously described.

- As each sample was recovered, it was qualitatively screened for organic vapors using OVA and/or HNu instruments. The instrument readings and soil descriptions were entered into a sampling logbook.

- The drill cuttings were qualitatively screened for organic vapors; the soil was evenly distributed to form a layer less than one-half inch thick.

Mud rotary drilling techniques were used for the deep monitoring wells installed at a depth greater than approximately 40 feet. Mud rotary techniques involved the use of bentonite as a drilling mud. The bentonite was introduced into the borehole and circulated during drilling. This method carries away drill cuttings and stabilizes the borehole walls. Continuation of deep boreholes occurred as follows:

- At a depth of 40 feet, sufficient bentonite was added in the borehole to stabilize the borehole walls. A sand and gravel rotary bit was telescoped through the hollow stem augers and the borehole advanced to the next sampling depth. Samples were collected every five feet using a standard size split-spoon sampler and were screened for organic vapors and described by a qualified geologist.

- After sample collection, the borehole was then advanced to the next sampling depth.

- Drilling and sampling of the deep monitoring wells was continued until the borehole reached bedrock. Auger refusal was not used to identify the bedrock surface, but was identified by such means as visual observations of drill cuttings, the difficulty of borehole advancement, and comparison of historical information regarding the depth of bedrock. Upon completion and prior to well installation, the boreholes were flushed with clean water.

2.1.5.2 Well Installation and Construction

Figure 2-1 illustrates construction details for the monitoring wells constructed at LCAAP. For uniformity, the materials and methods used in well construction included the following:

- Four-inch I.D. well casing constructed of Schedule 40 PVC with flush-threaded joints.
- The bottom of the monitoring well was fitted with a threaded PVC end cap.
- One 10-foot section of 4-in. I.D. PVC well screen was used. The screens were commercially manufactured with slotted openings of 0.02-in.
- The screen filter pack material used was a 0.45 to 0.55 mm siliceous sand material compatible with the screen size and aquifer material.
- The sand pack extended from approximately 6 inches below the well to approximately 3 to 5 feet above the top of the screen.
- Bentonite slurry approved by USATHAMA prior to use was used as a bentonite seal over the sand pack. The slurry was placed using a tremie pipe, and had a "batter-like" consistency. The bentonite seal was placed directly atop the sand pack.
- The annular space grout seals were composed of a 20:1 cement/bentonite mixture. Cement was a commercial Portland cement, Type II and V. A maximum of 8 gallons of approved water (production well 17-KK) per 94-pound bag of cement was used to make the grout slurry. The grout was placed using tremie techniques, and extended from the top of the bentonite slurry seal to ground surface.
- The tremie techniques followed the guidelines described in the USATHAMA Geotechnical Requirements for Drilling Monitor Wells, Data Acquisition, and Reports, March 1987.
- The top of monitor well casing was fitted with a PVC slip-cap and labeled with the well identification.
- A 5-foot length of 6-in. I.D. steel pipe was used as a protective casing over the 4-inch PVC casing. This protective casing included a hinged locking cap and was set approximately 3 feet into the grout seal. The casing

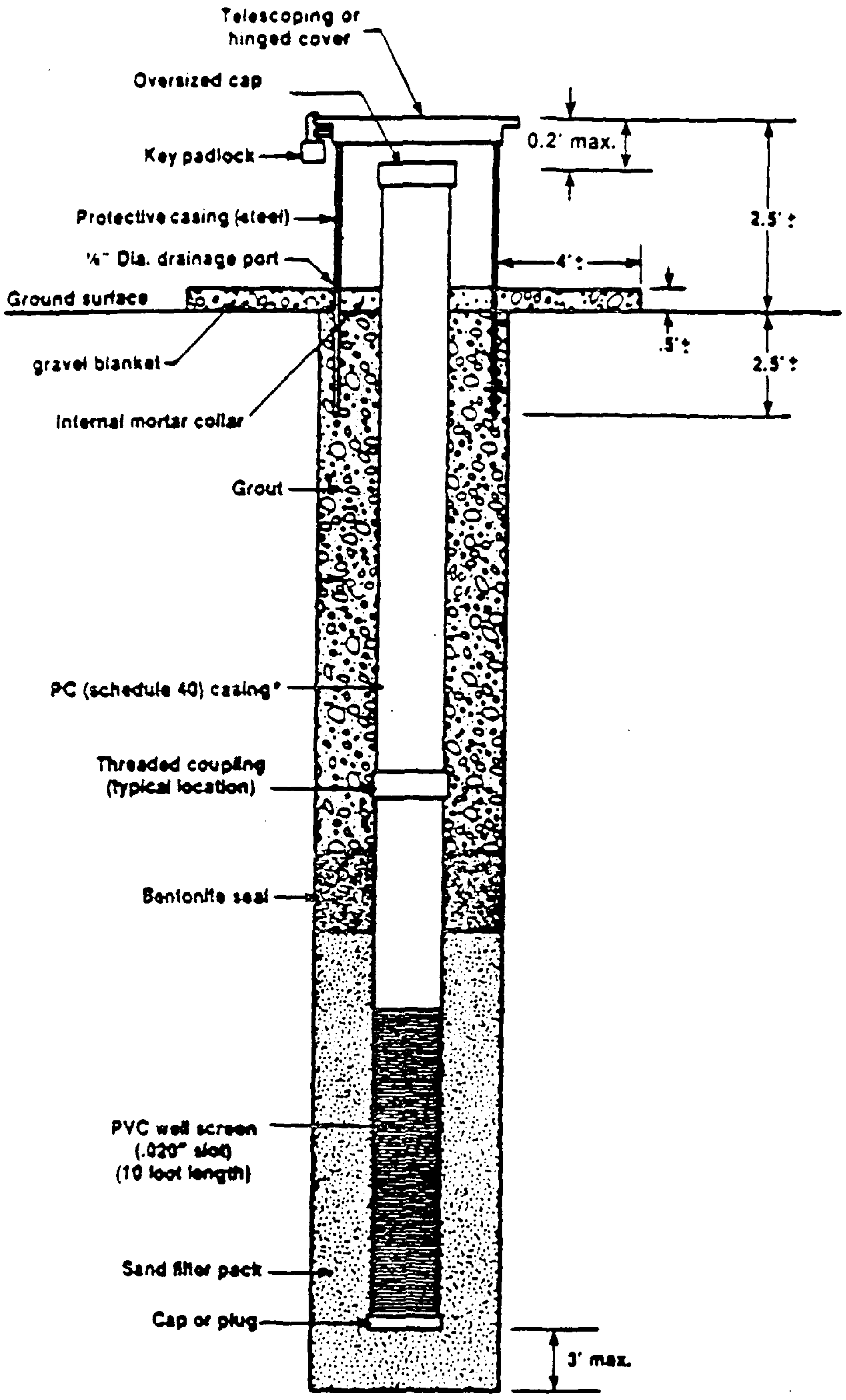


FIGURE 2-1
SCHEMATIC CONSTRUCTION OF MONITOR WELL
(ALL WELLS ARE 4" IN DIAMETER)

was painted orange, and the well number was painted with white paint.

- Wells were identified with painted well numbers on the protective casing.
- A measuring point notch was marked on the top of the PVC casing of each well and was identified in the notes.
- Areas disturbed during drilling were regraded.
- Each well was surrounded by four steel pickets, each radially located four feet from the well, extending three feet below grade and three feet above grade. The pickets were painted orange. In areas of high vegetation, flagging was attached to the pickets.
- In areas which had been used for cattle grazing, the pickets were supplemented with three strands of barbed wire.

During installation, the augers were extracted in a manner that ensured a continuous placement of sand pack, bentonite seal, and grout. Abandoned holes were grouted in the same manner, with grout extending from the bottom of the borehole to the ground surface. Installed wells were checked after the grout had set for grout subsidence. If this occurred, the depression was filled with a similar grout mix and the process repeated until firm grout remained at ground surface. A 6-inch gravel blank was placed around each well, extending 2 feet from the well.

2.1.5.3 Well Development

In order to remove drilling fluids and cuttings from the wells and to set the sand packs around the screens, wells were developed after the grout had set (at least 48 hours after well completion). The following guidelines were followed:

- A bottom discharge bailer was initially used. This served to remove any material from the bottom of the well, and to set the sand pack.
- A submersible pump capable of 2 to 50 gallons per minute (gpm) at a maximum head of 100 feet was temporarily installed after the bailing effort. The pump was operated continuously at its maximum sustainable flow rate until the water was clear. This flow rate was measured and recorded in the field logbook.
- The total volume of water removed from the well during development was measured and recorded in the field logbook.

- At a minimum, five times the standing water volume in the well, which included the screen and casing plus the saturated annulus (assuming 30 percent porosity), was removed during well development. In the case where mud drilling fluid was added during drilling, five times the amount of lost water (in addition to five times the standing water volume) was removed.

- Pumps and bailers were decontaminated with water from the approved water source before each well was developed.

- The entire well cap and the interior of the well casing above the water table was washed using only water from the well. The washing was conducted before and/or during development.

- The following data were recorded as part of well development and are presented in Appendix A.

  - Water levels at start and finish.

  - Types of bailers or pumps used.

  - Time development started and finished.

  - Description of sediments flushed from the wells and other physical changes in water.

  - Total amount of water removed from each well.

2.1.5.4 Groundwater Sampling

Groundwater samples were collected from all the monitoring wells installed for this investigation, plus existing monitoring and production wells. Samples were collected using the following procedures:

- The depth to the water level in the well (from the well casing, not the protective casing) and the depth of the well was measured with an electrical sounding device and measured to an accuracy of 0.01 foot. The depth to water, total well depth, and the time of measurement were recorded.

- Based on the water level measurement and the depth of the well, the volume of standing water in the well was calculated.

- A sample of groundwater was then obtained for temperature, conductivity, and pH measurements. These measurements were then recorded in the logbook.

- The well was purged using a pump or bailer that was constructed of chemically inert materials and had been decontaminated in accordance with the standard protocol. The standard purging procedure included pumping until five casing volumes had been removed. For the production wells, it was assumed that the entire casing was full and the pump was run until five casing volumes were evacuated. Four production wells samples were collected after the well had been pumped for at least a period of 30 minutes.

- If the well pumped dry before five volumes had been removed, the well was allowed to recover to its original level and then pumped dry again before sampling. However, if recovery was very slow, samples were obtained as soon as sufficient volume was present.

- The time required to purge the well was recorded in the field logbook.

- During and at the completion of purging, two additional samples for temperature, pH, and conductivity were measured. These measurements were recorded in the logbook.

- The samples were obtained with dedicated PVC bailers (i.e., a separate bailer was used for each well) that had been decontaminated in accordance with the standard protocol. The bailer was lowered into the well using polypropylene cord. A new length of polypropylene cord was used at each location.

- Sample containers were triple-rinsed with the water to be sampled prior to filling with the sample to be analyzed.

2.1.5.5 Aquifer Tests

Slug Tests

The hydraulic conductivity of the penetrated aquifer was estimated by conducting slug tests of the newly completed WESTON wells, the EA wells, and 10 LCAAP wells. The basic concept behind these tests is that the rate of change of the water level in a well after an "instantaneous" removal of a "slug" of water is a function of aquifer hydraulic conductivity. Thus, by measuring water levels at various times following removal of the slug, the hydraulic conductivity can be calculated. Water level readings were recorded until the water level stabilized, typically within 1/2 hour to 4 hours. The basic requirement of a slug test is the ability to quickly remove a fairly large volume of water and to readily and accurately measure water levels in the well. Analysis of test data should use appropriate computational methods, such as that presented by Bouwer and Rice (1977).

Hydraulic conductivity testing was performed at the site as follows:

- All equipment inserted into the well was cleaned according to USATHAMA protocol.
- An initial measurement of static water level was made.
- A volume of water was removed as rapidly as possible using a 3-inch diameter bailer.
- Using the In-Situ Hermit data logger outfitted with a pressure transducer, water level measurements were recorded until recovery had occurred.
- After the water level had recovered, the test was stopped.
- The data was transferred to a computer file in the field and reduced in the office.

Note: Initial testing involved the "instantaneous" displacement of a slug of water using a decontaminated 3-inch diameter PVC slug. Comparable test results favored the use of the bailer method which was consequently utilized at each test location. The bailer removed approximately one gallon of water from the well and water level measurements were recorded at the following intervals; 34 measurements within the first minute, 12 measurements from 1 to 2 minutes, 6 measurements from 2 to 5 minutes and every 30 seconds after 5 minutes until static was reached.

Pumping Tests

An aquifer pumping test program was conducted at LCAAP to evaluate the hydrogeological/hydraulic properties of the unconsolidated aquifer at the site. Data interpretation includes drawdown curve construction and analysis and the estimation of the following aquifer parameters:

- Hydraulic conductivity (K).
- Transmissivity (T).
- Storage coefficient (S).
- Leakage (vertical communication).
- Anisotropy (if any).

The pumping test was conducted at Area 12 -- the NPL Lagoon. Production well 17-AA is approximately 90 feet deep and was designated as the pumping well. This well was pumped at a constant rate for 72 hours. During the pumping of 17-AA, the water levels in existing wells 12-2, 12-3, 12-4, 12-5 and 12-6, plus production well 17-A, were continuously monitored through the use of the In-Situ SE-2000 Hydrologic Analysis System. This system automatically records water levels through the use of continuously recording pressure transducers.

The detailed test procedures were as follows:

- Pumping well 17-AA was shut off for 48 hours prior to beginning the test.

- The static water levels in the pumping well and in the observation wells were measured just prior to initiating the pumping well.

- A 4-inch flow orifice was installed on the piping from the pump discharge to measure the constant pumping rate. A step-drawdown test was performed to evaluate the optimum pumping rate for the pumping well and aquifer.

- The proper maximum discharge rate was estimated for the pumping well. The pump was activated and its discharge set at the maximum rate that could be continuously sustained (504 gpm). Maintaining a constant discharge rate for the entire pumping duration was crucial to the success of the aquifer test.

- For the 72-hour test, the depth to the water within the test well was measured and recorded with an electric water level probe every 15 to 20 minutes. Readings were also collected in the observation wells as a check on the pressure transducers.

- During the test, the rate of discharge from the pumping well was measured and recorded at least once every hour for the first 24 hours and then every two hours for the remainder of the test.

- At the end of the 72-hour pumping period, the pump was turned off and monitoring of the recovery phase began in the pumping well and in the observation wells.

Following the execution of the aquifer test program, the data was reduced, plotted, and analyzed using appropriate techniques. Based on the hydrostratigraphy and the data plots, appropriate analytical techniques were employed to evaluate the aquifer test data. Evaluation of the data is presented in Subsection 3.6.

2.1.5.6 Groundwater Level Measurements

The depth to groundwater under static conditions was measured to the nearest one-hundredth of a foot at each monitoring well. An electronic water level probe was used for groundwater level measurements. The top of the PVC casing served as the reference point for all monitor well measurements. These data, based on top of casing elevations obtained from the topographic survey, were converted to reference mean sea level (MSL). This allowed comparison and evaluation of the depth-to-water measurements.

2.1.6 Chain-of-Custody

WESTON chain-of-custody procedures were used to preserve the integrity of samples collected at LCAAP. Chain-of-custody describes the sequential possession and transfer of sample(s) by the individuals who were in control or possession of a sample or group of samples. A written record of the chain-of-custody facilitates the identification and tracking of a sample from the time it is collected until the time it is analyzed.

Sample containers prepared and supplied by the WESTON laboratory were accompanied by a chain-of-custody form. Individual samples were entered on the forms following collection (and prior to sampling the next location). Information that was entered included:

- Date of collection.
- Sample identification number.
- Sample description and matrix type.
- Type of container and preservative.
- Analyses requested.

Each shipment of samples that left the site was accompanied by a completed and signed custody form. The back page of the multi-copy form was retained by the field team leader. The remaining copies of the form were placed in a waterproof bag inside the shipping cooler. The cooler(s) were subsequently sealed with strapping tape. Sample custody was further guaranteed by securing the lid with custody tape on two opposing sides.

The laboratory managed each sample received from the site according to WESTON Standard Practices 21-20-010 (Sample Receipt), 21-20-011 (Sample Storage), and 21-20-012 (Sample Tracking). The sample was logged into a bound logbook as follows:

- Field sample number.

- Time of receipt at laboratory.

- Observations.

- Indication that the chain-of-custody document was received and signed.

- Indication that a lot chain-of-custody document has been attached to the properly completed Request for Analysis form.

The original signed chain-of-custody document was maintained in the laboratory files.

2.1.7 Preservation and Shipment

In preparation for shipment to the analytical laboratory, all samples were packaged in accordance with the following procedures.

- The water samples were preserved in accordance with the standard procedures presented in the "QA/QC Plan" dated January 1988.

- A check was performed to see that the caps were securely tightened and the liquid levels marked if bottles were partially filled.

- The sample containers were properly marked with sample number, parameter, and time of collection.

- Containers were placed in zip-loc bags and in a cooler lined with two inches of vermiculite or equivalent absorbent material; each sample was surrounded and remaining space in cooler was filled with additional packing material and ice packs.

- Chain-of-custody forms and traffic reports were placed in a manila envelope; this envelope was placed in a zip-loc bag and taped to inside of cooler lid.

- The cooler was closed and sealed shut with strapping tape; if the cooler had a drain port, it was sealed shut with tape. Custody seals were placed across the closure at the front of the cooler.

- The airbill with shipper's and consignee's addresses was affixed to the top of the cooler; if samples were liquid, "This End Up" labels were placed appropriately.

Organics samples were shipped within 24 hours of collection via Federal Express for next day delivery. Inorganics samples were shipped within 48 hours of collection for two-day delivery. The laboratory was notified of each shipment as it was made.

2.1.8 Methods of Analyses

For a description of the analytical methods used, refer to the Lake City Army Ammunition Plant QA/QC Plan, April 1988.

2.1.9 Ground Surveying

Five grid surveys were established at the Lake City Army Ammunition Plant. This included one grid at each location where geophysical surveys were being performed and one grid at the area of the soil gas survey (Area 12). In addition, 28 monitoring wells and 11 staff gauges were surveyed for locations and elevations. Elevations were also established for approximately 40 existing wells.

Specific ground surveying requirements were followed:

- A 100-foot grid system was established at five separate locations at the site. The grid was set up with a coordinate system starting with a 00+00 location. The grid dimensions were as follows:

  Area 8 - 600 ft x 780 ft

  Area 12 - 600 ft x 600 ft

  Area 14 - 420 ft x 1,720 ft

  Area 16 - 1,200 ft x 1,200 ft

  Area 17 - 500 ft x 400 ft

- Each of the 100-foot interval grid locations were marked with a 1-in. x 1-in. stake driven into the ground and marked with the coordinates. Also, a lath with a surveying ribbon was driven into the ground next to the stake with the coordinates also marked on the lath.
- Elevations of 11 staff gauging locations were provided.
- The ground surveying also provided elevations for the top of the outside casing, the inside well casing, and ground surfaces for all 28 newly installed monitoring wells and for approximately 40 existing wells.

The surveying specifications for vertical control were accurate to 0.01 foot for the top of the inside well casing and the outside protective casing. The ground surface and the water surface elevations at the gauging stations were accurate to within 0.1 foot. The survey elevations are based on the National Geodetic Vertical Datum. The horizontal control for locating monitoring wells and staff gauging stations were accurate to within 2 to 5 feet. The monitoring well and staff gauging elevations are provided in Appendix B.

2.1.10 Staff Gauges

As mentioned above, 11 staff gauges were installed at LCAAP. These gauges were installed for the purpose of recording the ditch water levels and evaluating the hydraulic connection of the ditches with the groundwater system.

The staff gauges were installed by driving a metal post into the stream bed and surveying the elevation of the top of the staff gauge. The locations of the staff gauges and related discussions are presented in Subsection 3.3.

Physical Characteristics of the Study Area

SECTION 3

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The following section includes a description of the surface features, meteorology, surface water hydrology, soils, geology, hydrogeology, natural resources, water supplies, demography and land use. These physical characteristics will provide necessary information to evaluate the analytical contaminant results and the potential contaminant migration pathways, as well as aid in the preliminary selection of remedial alternatives.

3.1 SURFACE FEATURES

The installation topography can be characterized as lowland and upland areas. This topography is influenced by the underlying geology. The northern and western portions of the plant are characteristic lowland areas exhibiting a nearly flat topography (Figure 3-1). These lowland areas are composed of alluvial silty clay and sand and gravel deposited in a fluvial environment within the valley. The southern and eastern portions of the plant are the upland areas or the shoulders of the valley (Figure 3-1). The upland areas are resistant Pennsylvanian sedimentary strata and exhibit moderate relief with narrow crested ridges with 250 to 300 feet of relief from the ridge top to the valley floor.

Certain topographical features have been altered during construction of LCAAP, such as the flood-control ditch system throughout the installation and the channelization of West Fire Prairie Creek into what is now termed the Big Ditch. Landfilling activities in the northeast and southwest portions of the site have also altered topographic features.

3.2 METEOROLOGY

According to data obtained from the U.S. Department of Commerce, the National Climatic Data Center, and the Kansas City International Airport, the climate for Jackson County is classified as warm and humid continental, with a wide temperature range from summer to winter. Monthly mean temperatures range from 29.0°F in January to 79.5°F in July. Extreme temperatures have ranged from -21°F in December 1983 to 109°F in August 1984.

The mean annual precipitation for Jackson County is 36.85 inches. The three winter months (December, January, and February) are the driest, with a mean precipitation of 1.4 inches per month. The spring months of May and June are normally the wettest, averaging approximately 4.8 inches per month of precipitation. The fall month of September is also above average, with approximately 4.3 inches of precipitation. The greatest monthly rainfall was 11.34

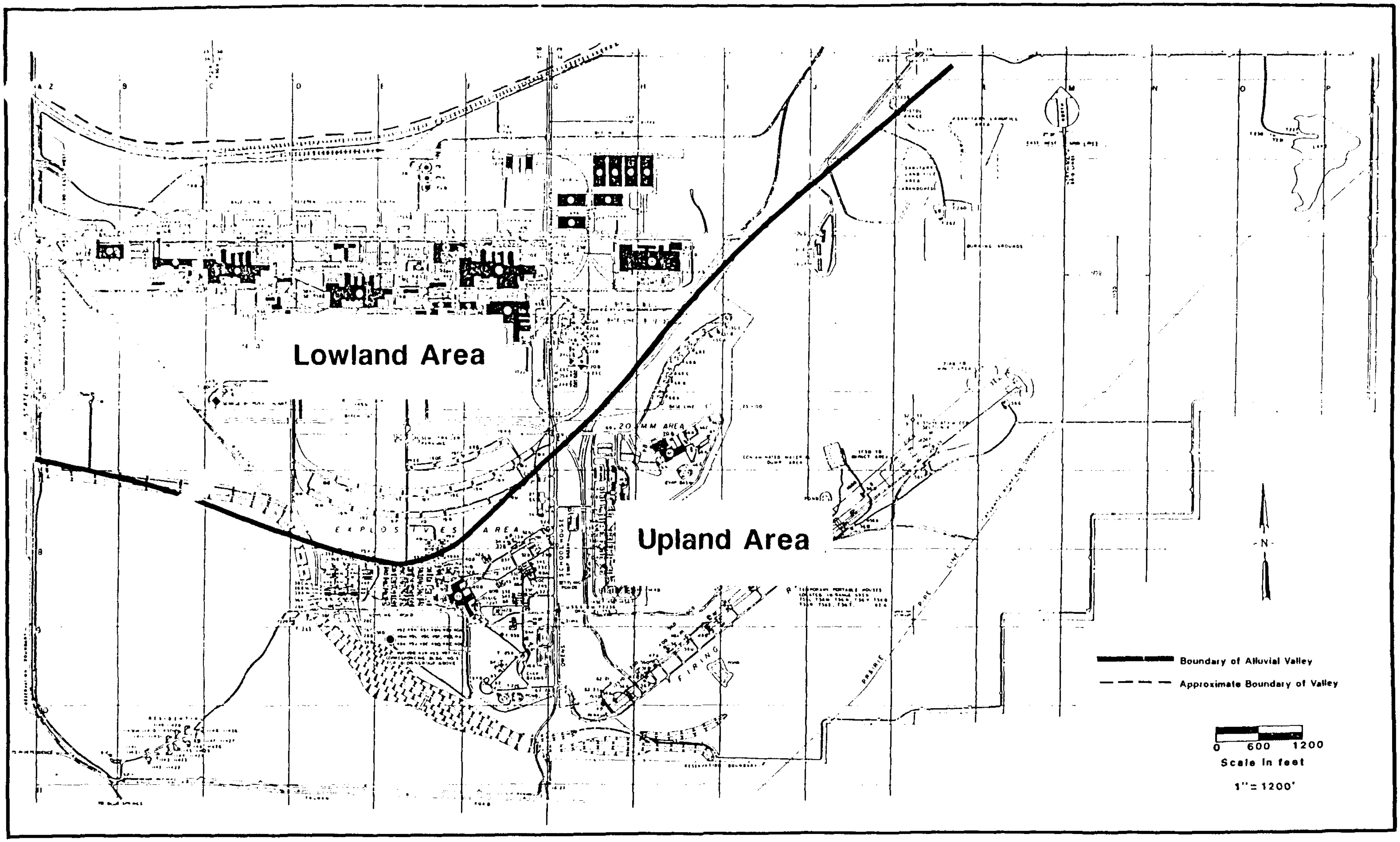


FIGURE 3-1
LOWLAND AND UPLAND AREAS

inches recorded in September 1977. Snowfall occurs between November and April, with December and January having monthly means of 4.6 and 5.9 inches, respectively. The maximum monthly snowfall was 30.5 inches recorded in January 1962.

The average annual relative humidities in mid-afternoon and dawn are 60 percent and 81 percent, respectively. The sun shines 70 percent of the time in the summer and 55 percent in the winter. The prevailing wind is from the south, and the mean wind speed is highest in the spring at 12 mph.

Thunderstorms occur approximately 53 days per year, usually during summer. Severe weather, such as strong thunderstorms, tornadoes, and hailstorms, occurs occasionally, but these storms are sporadic and of short duration.

3.3 SURFACE WATER HYDROLOGY

3.3.1 Regional Hydrology

LCAAP is situated in the Lower Missouri-Blackwater-Lamine River basin of the Osage Plains region of the Central Lowland Physiographic Province. The Blue River, Little Blue River, and Sniabar Creek are the major tributaries of the Missouri River in Jackson County and provide drainage for most of the county. These rivers and most of the other streams in the county flow in a northeasterly direction toward the Missouri River. All three major tributaries contain permanent flow toward their junctions with the Missouri River and contain intermittent flow with permanent pools nearer their respective headwaters. Most tertiary streams in Jackson County have intermittent flow with fewer permanent pools. In general, most major streams in west-central Missouri formerly flowed in meandering channels on broad, poorly drained flood plains. The alluvial channels are usually formed in cohesive silt and clay as in the Lake City alluvial valley. Within the past century, many of these stream channels have been straightened by channelization projects and their gradients have been thereby steepened (Missouri Department of Natural Resources, 1986). The three major tributaries mentioned above, along with East and West Fire Prairie Creek on the LCAAP property, have all undergone some amount of channelization. Stream recharge in Jackson County is maintained as a result of moderate and well-distributed precipitation.

Monthly discharge data for the Little Blue River are available from a gauging station located 1 mile west of LCAAP. Since 1948, when regular record keeping began, flow extremes in the Little Blue River have ranged from a maximum of 42,300 ft^3/sec on 13 August 1982 to a minimum of no flow, with an average flow of 152 ft^3/sec over the 38 years of record keeping. The highest mean of monthly flows for the period of October 1985 to September 1986 occurred during the months of October and November 1985, and September 1986, which had discharges of 635, 348, and 844 ft^3/sec, respectively. The lowest mean monthly flows occurred during January and August which had mean discharges of 61.2 and 11.8 ft^3/sec, respectively.

In 1961 the Little Blue River was recorded at its maximum flood stage when it rose to an elevation of approximately 747 feet (MSL). A flooding episode of this magnitude would flood portions of LCAAP. The frequency of this flooding event has not been established. The normal elevation of the Little Blue River is approximately 725 feet (MSL). The Big Ditch has been constructed for flood control and has been designed for a 100 year flood episode.

3.3.2. Local Hydrology

LCAAP is located on the Little Blue River floodplain and is situated 1 mile east of the river channel. Other surface water bodies within the study area are West Fire Prairie Creek (locally designated as the Big Ditch where it has been channelized across the site), the drainage-control ditch system (consisting of Ditches A and B), a few small ponds on the eastern and southwestern portions of the site, a 30-acre lake located on the east end of the site, and a number of man-made lagoons used for disposal of process wastewaters.

In order to control the potential flooding at the plant, modifications to the natural drainage system were installed. During the original land development, natural depressions were enhanced by construction of Ditches A and B. Ditch A is a man-made channel of the West Fire Prairie Creek, which was further channelized by the U.S. Army Corps of Engineers and is now locally called the Big Ditch. Ditch B is a man-made channel of the East Fire Prairie Creek.

Surface water drainage from the southwestern portion of the plant flows toward the West Fire Prairie Creek (Ditch A). The drainage emanating from the northeastern portion of the plant flows toward the East Fire Prairie Creek (Ditch B). The East Fire Prairie Creek discharges to the Missouri River. The West Fire Prairie Creek discharges to the Little Blue River and eventually to the Missouri River.

At the western half of the plant, surface water bodies are characterized as groundwater recharge zones while, at the eastern half of the plant, they are characterized as groundwater discharge zones. In a recharge zone, the water table elevations are lower than the surface water elevations; therefore surface water infiltrates to the groundwater. A few locations on site are characterized as groundwater discharge zones. In a discharge zone, the water table elevations are higher than the surface water elevations. Streams located in recharge zones are termed influent, or losing streams. Streams located in discharge zones are termed effluent, or gaining streams. Figure 3-2 shows the groundwater recharge and discharge zones on-site as determined from groundwater and surface water level elevations collected on 1 June 1988 and presented in Appendix B. The character and extent of these zones will change with the seasonal fluctuations of the water table and surface water elevations.

The water level measurement were collected during a drought event, and therefore, represent low groundwater and surfacw water elevations. As indicated in Figure 3-2, four of the surface water locations are dry. This was the only period in which all groundwater and surface water elevations were recorded.

3.4 SOILS

LCAAP is comprised of two soil associations; the Snead-Menfro-Oska association and the Kennebec-Colo-Bremer association. Each soil association is a unique natural landscape. An association consists of one or more major soils and some minor soils. It is named for the major soils.

The Snead-Menfro-Oska association is described as having moderately deep to deep, gently sloping to steep, well drained to moderately drained soils that formed in loess or residuum from shale and limestone. This association is prevalent across the southern portion of the site where bedrock highs are located. In this upland area the specific soil types found are the Menfro Silt Loam and the Snead-Rock outcrop complex.

The Kennebec-Colo-Bremer association is described as having deep, nearly level, moderately well drained and poorly drained soils that formed in alluvium on floodplains and terraces. This association is prevalent across the central and northern portions of the site on the buried valley region. In this former floodplain area the specific soil types found are the Iota Silt Loam, the Zook Silty Clay Loam, and the Kennebec Silt Loam (U.S. Department of Agriculture, 1984).

3.5 GEOLOGY

3.5.1 Regional Geology

LCAAP lies within the Osage Plains Section of the Central Lowlands Physiographic Province. This section is characterized by low relief with gently rolling topography comprised of broad shallow valleys and low gradient meandering streams. It is underlain by nearly flat-lying, late Paleozoic (predominantly Pennsylvanian age) sedimentary strata, which dip gently westward at approximately 3 degrees or less.

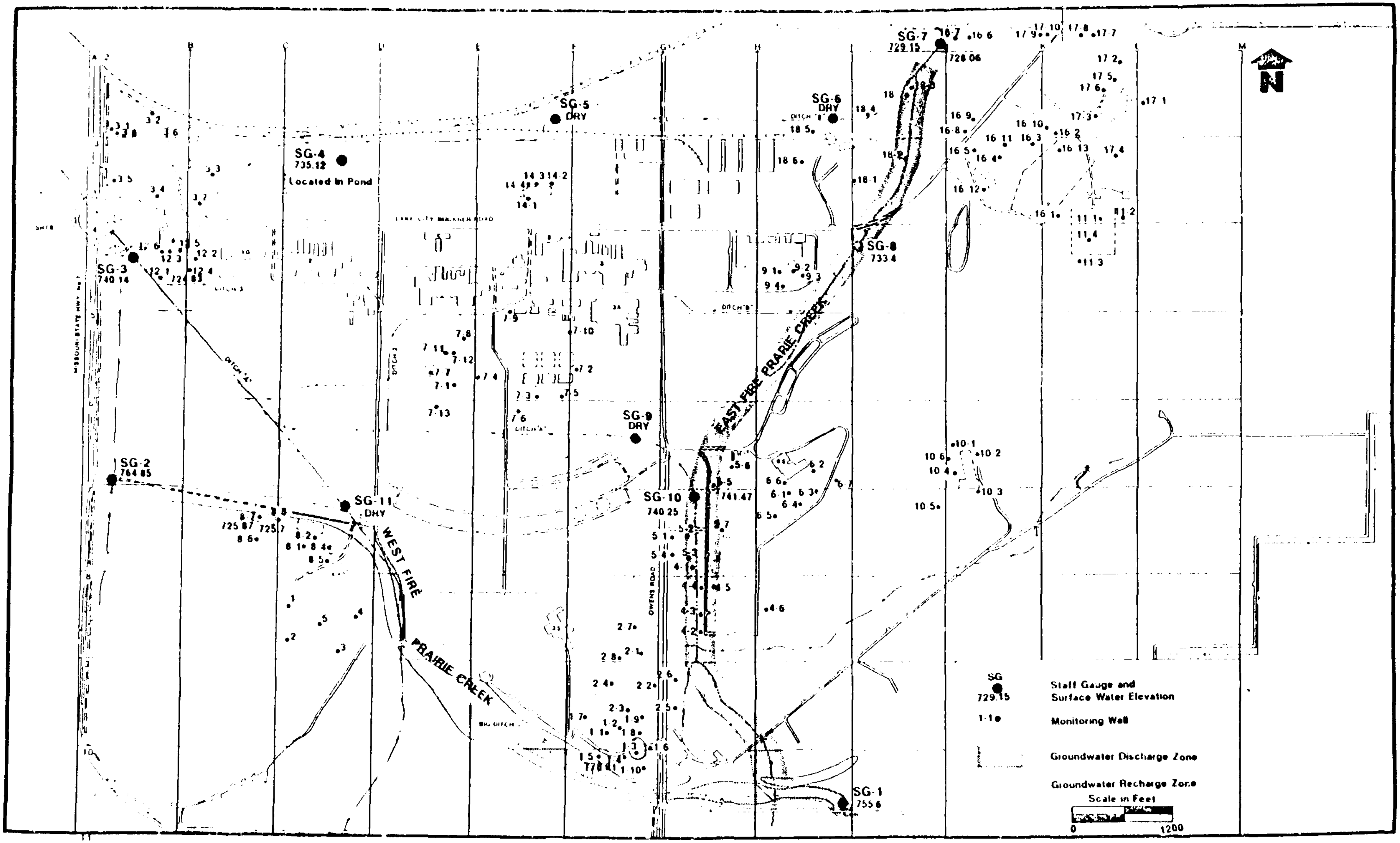


FIGURE 3-2

INFLUENT AND EFFLUENT STREAM CONDITIONS - 1 JUNE 1988

The topographic surface consists of rolling uplands traversed by broad valleys and floodplains of the Missouri River, the Little Blue River, and the abandoned Lake City Valley. The floodplain of the Missouri River averages about three miles in width in this area, with the surface elevation approximately 715 feet above sea level. Surface elevations within the Little Blue River Valley and the abandoned valley at Lake City range from 715 to 740 feet.

Surface elevations at the upland areas average between 800 and 900 feet and seldom exceed 950 feet. Bedrock is locally dissected by stream systems to create moderate relief. Valley walls are gently sloping except for some bluffs along the Missouri River and scarps formed by resistance to weathering of some limestones (Anderson and Greene, 1948).

Paleozoic sedimentary strata and geologically recent unconsolidated sediments comprise the stratigraphic sequence underlying the region. Figure 3-3 graphically illustrates the sequence. From oldest to youngest, Cambrian and Ordovician strata are mostly dolomite, Devonian strata are shale, Mississippian strata are predominantly limestone with some shale and sandstone, and Pennsylvanian strata are combinations of shale and limestone with some occurrences of sandstone and coal (Gann, 1974). Due to the nearly flat-lying structure of underlying bedrock and moderately dissected relief, only the uppermost stratigraphic units of Pennsylvanian age crop out in the area. The westward dip is due to an asymmetrical uplift, the Ozark Dome, to the southeast. Although no major faulting is known to exist in the area, regional jointing may exist, possibly related to the uplift event (EA Report, 1987).

Unconsolidated Quaternary deposits include: alluvium, till and windblown loess. Although the area now known as Lake City was unglaciated, the region was affected by nearby Kansan glaciation during the Pleistocene Epoch. During the Kansan glaciation, a glacial lobe dammed the Missouri River northwest of LCAAP. The ancestral Missouri River rerouted its course through the Little Blue River Basin, then back to the existing Missouri River Basin. This ancient river valley encompassed the north and west portions of the installation. As the glacier receded, the Missouri River began to shift back to its original course. Alluvial gravels, sands, and silts were deposited and eventually filled the river channel (Anderson and Greene, 1948).

3.5.2 Site Stratigraphy

The stratigraphy of the LCAAP site was interpreted from both pre-existing boring logs and the 28 new boring logs presented in Appendix C. The site stratigraphy consists of: fill material, wind-blown loess deposits, alluvial silty clay depositions, alluvial sand deposits, and the underlying bedrock formation. From

FIGURE 3-3

REGIONAL STRATIGRAPHIC SECTION
(Source: Gann, 1974)

System	Series	Geological Unit	Thickness (feet)	Lithology	Age (million years)
Quaternary	Holocene	Alluvium	0-70	Clay, silt, sand, and gravel	
	Pleistocene	Alluvium and drift	0-200		
Pennsylvanian	Missouri	Lansing Group Kansas City Group Pleasanton Formation Warrensburg Sandstone Member	0-570	Limestone, shale, and sandstone-siltstone	
	Des Moines	Marmaton Group Cherokee Group	0-550	Shale, siltstone, sandstone, coal, and limestone	
	Atoka	Riverton Formation Burgner Formation	0-90 0-45	Shale, coal Coal, black, siltstone, limestone	
	Morrow	Hale Formation	0-65	Sandstone	300

the surface downward, the stratigraphic units and approximate thicknesses are as follows:

- Fill material present at most of the developed areas, especially the landfill areas, ranging in thickness from 5 to approximately 20 feet.
- Loess deposits encountered predominantly in the upland area, ranging in thickness from 0 to 3.5 feet.
- Colluvial silt and clay encountered in the uplands areas, not usually more than a few feet thick.
- Alluvial silty clay ranging in thickness from approximately 5 to 44 feet.
- Alluvial sand ranging in thickness from approximately 0 to 82 feet.
- Bedrock formation encountered at or near the surface in the uplands and up to 100 feet below the surface in the alluvial valley.

The stratigraphic relationships and distributions of these units at the site are shown in cross-sections prepared for the trace lines shown in Figure 3-4. The cross-sections are presented in Figures 3-5 through 3-9. Appendix A presents the boring logs used to prepare the geologic cross-sections. The cross-sections are based on most of the 28 monitoring wells installed by WESTON in 1988, plus numerous monitoring wells installed previously. Table 3-1 shows the Unified Soil Classification System used to classify the soil units shown in the cross-sections. The following subsections describe each of the stratigraphic units present at LCAAP.

3.5.2.1 Fill Material

Currently most of the developed plant areas possess approximately five to ten feet of soil material that has been added as fill to raise the topography. This fill material generally consists of a silty clay to clayey silt soil. The unstructured nature of the soil indicates it is a fill even though it is similar in grain size to the underlying alluvial silty clay.

Fill material is also present where landfill waste has been deposited. This would include Areas 16 and 17. The fill/ waste in these areas is approximately 15 to 20 feet thick and lies stratigraphically on top of the weathered shale material. The waste material consists of general plant solid waste such as metal and paper and also potentially includes chemical waste such as solvents.

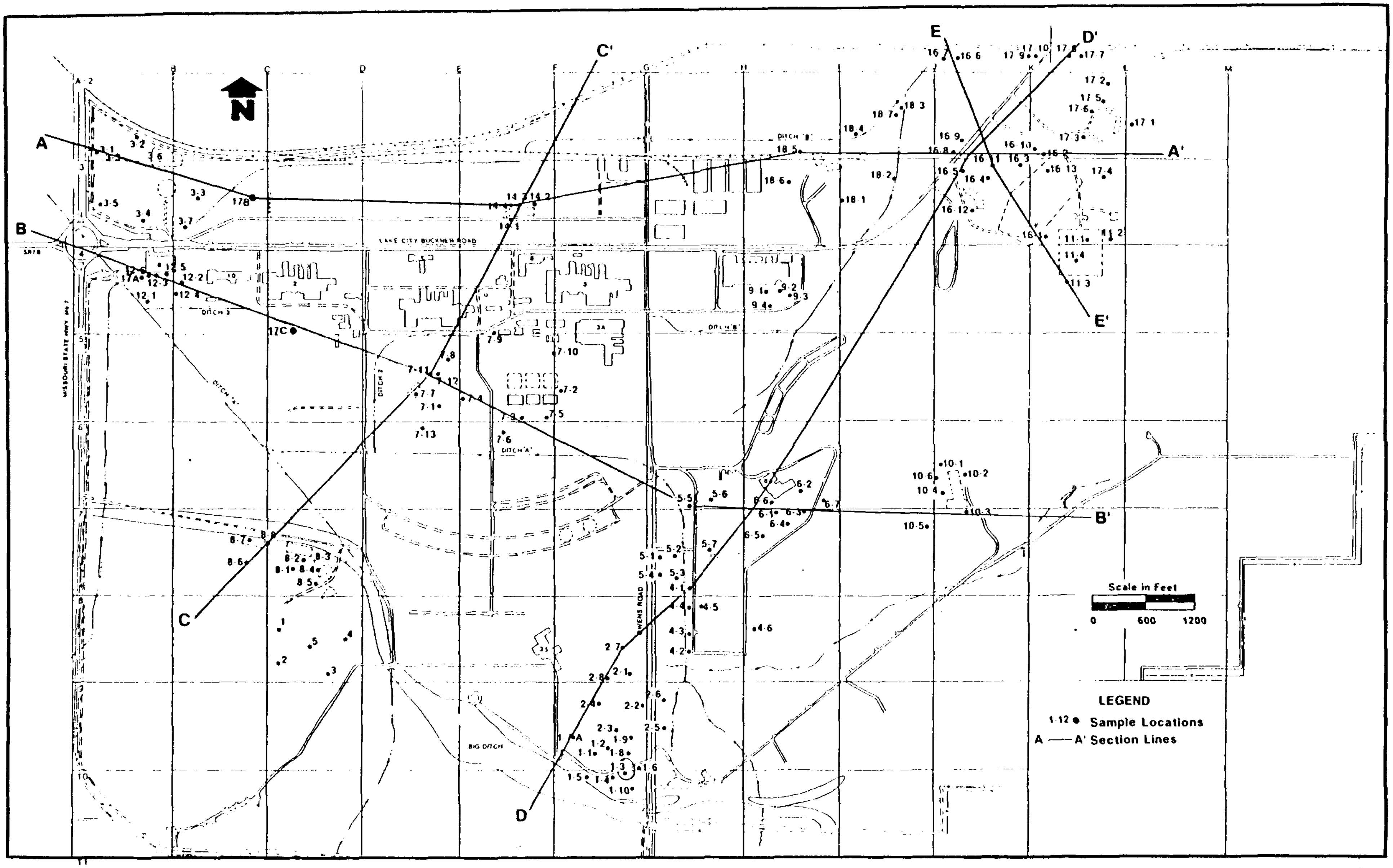
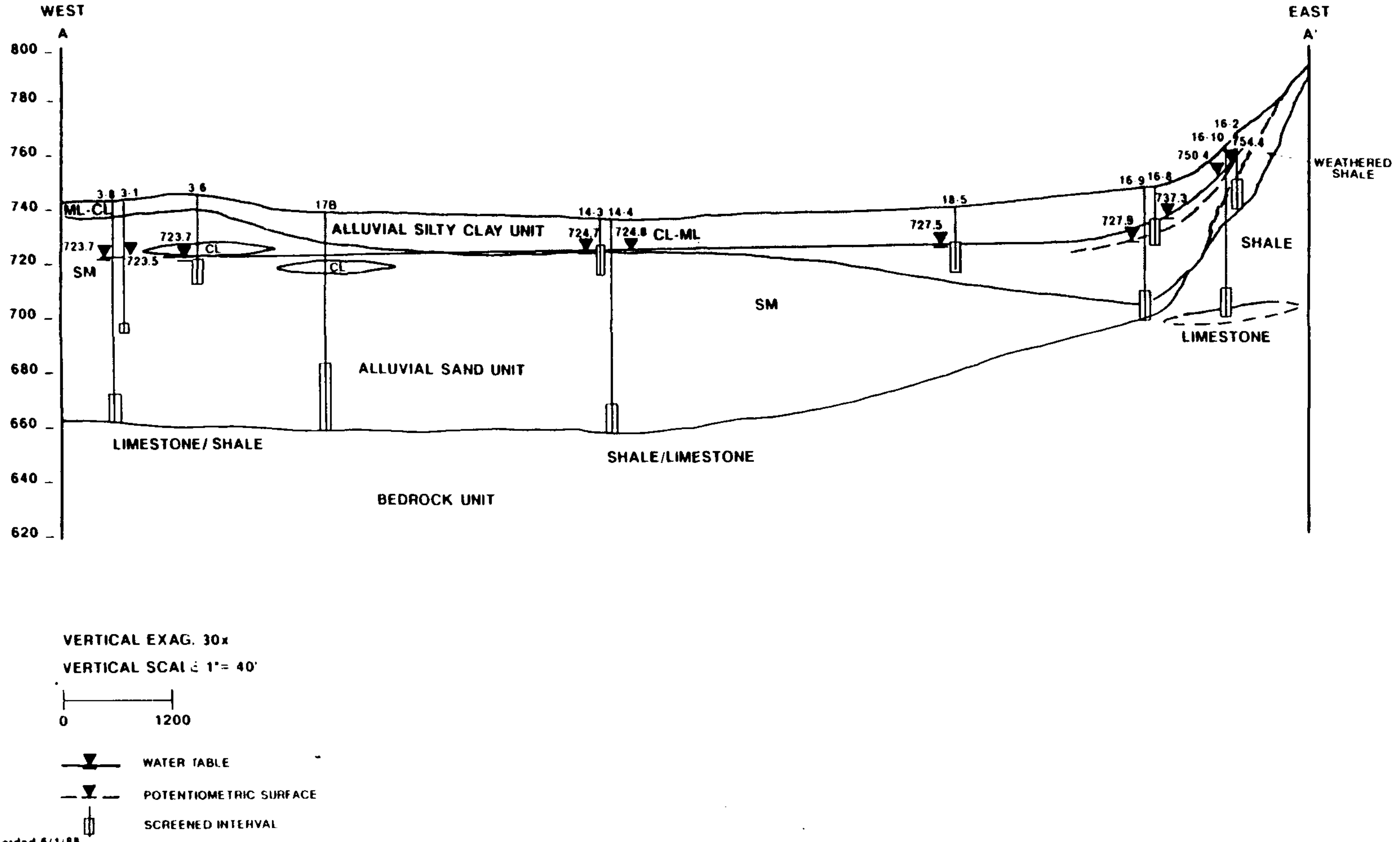
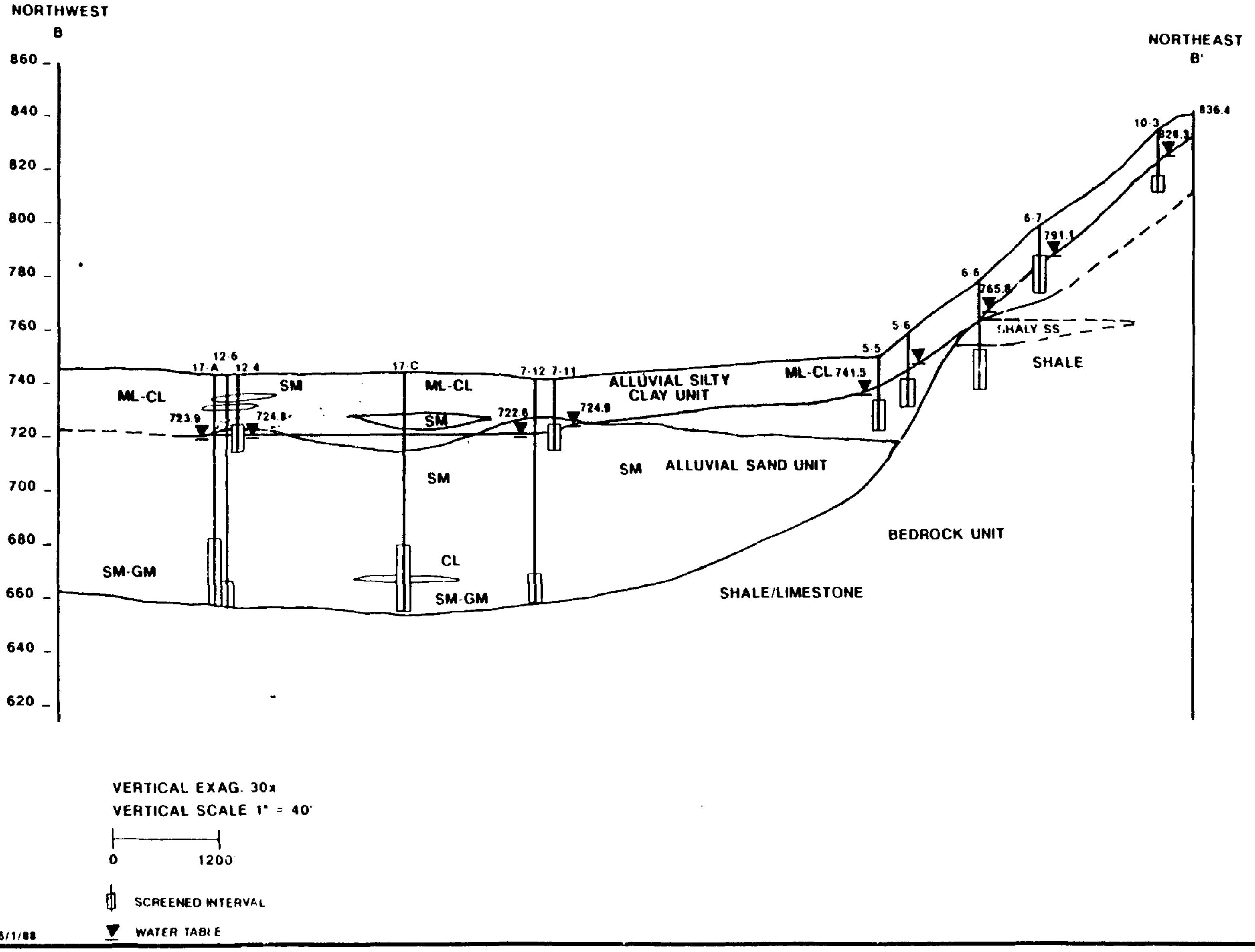


FIGURE 3-4
MONITORING WELLS AND
GEOLOGIC CROSS-SECTION LOCATIONS



Ground water Elevations Recorded 6/1/88

FIGURE 3-5
GEOLOGIC CROSS-SECTION A - A'



Groundwater Elevations Recorded 6/1/88

FIGURE 3-6
GEOLOGIC CROSS-SECTION B - B'

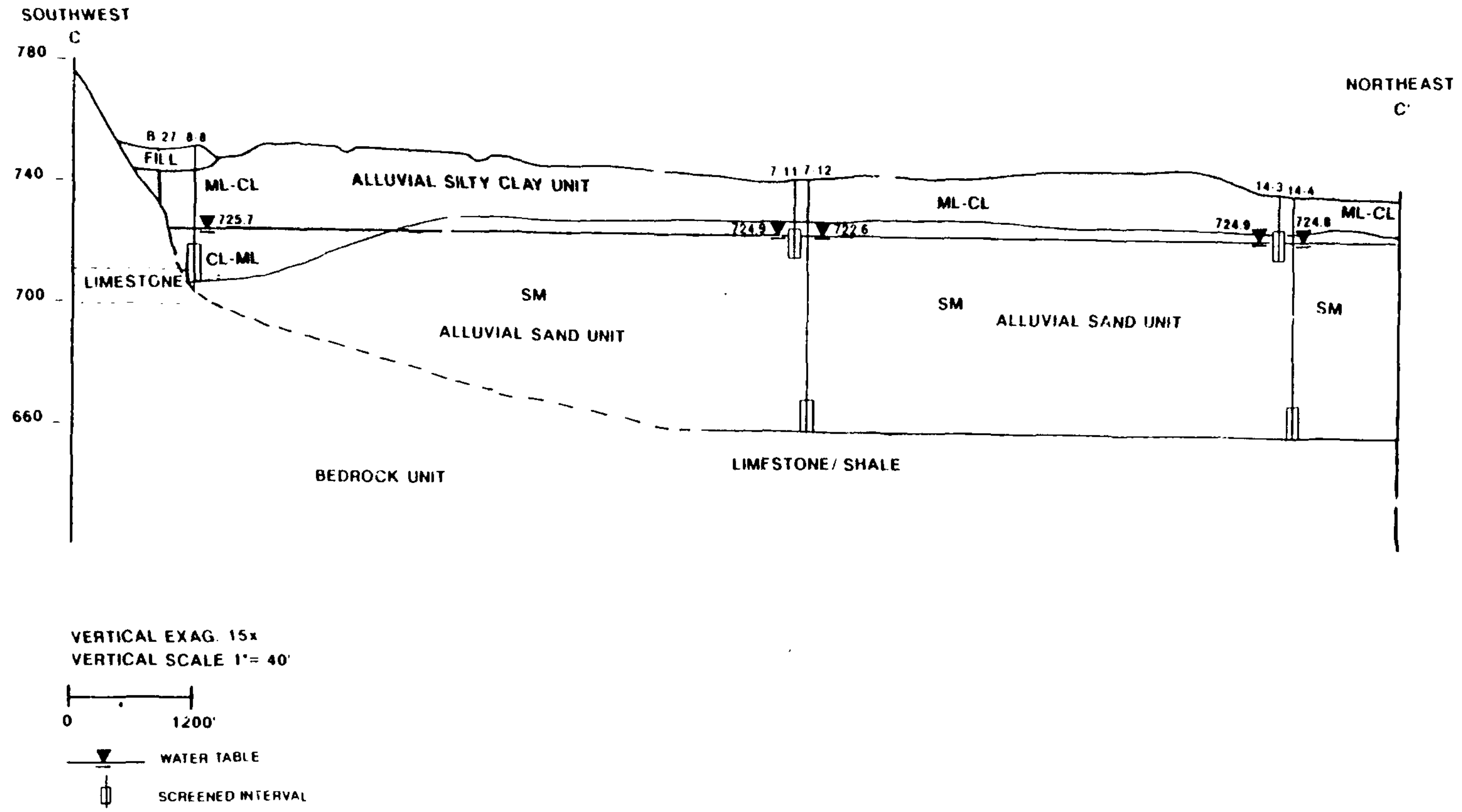
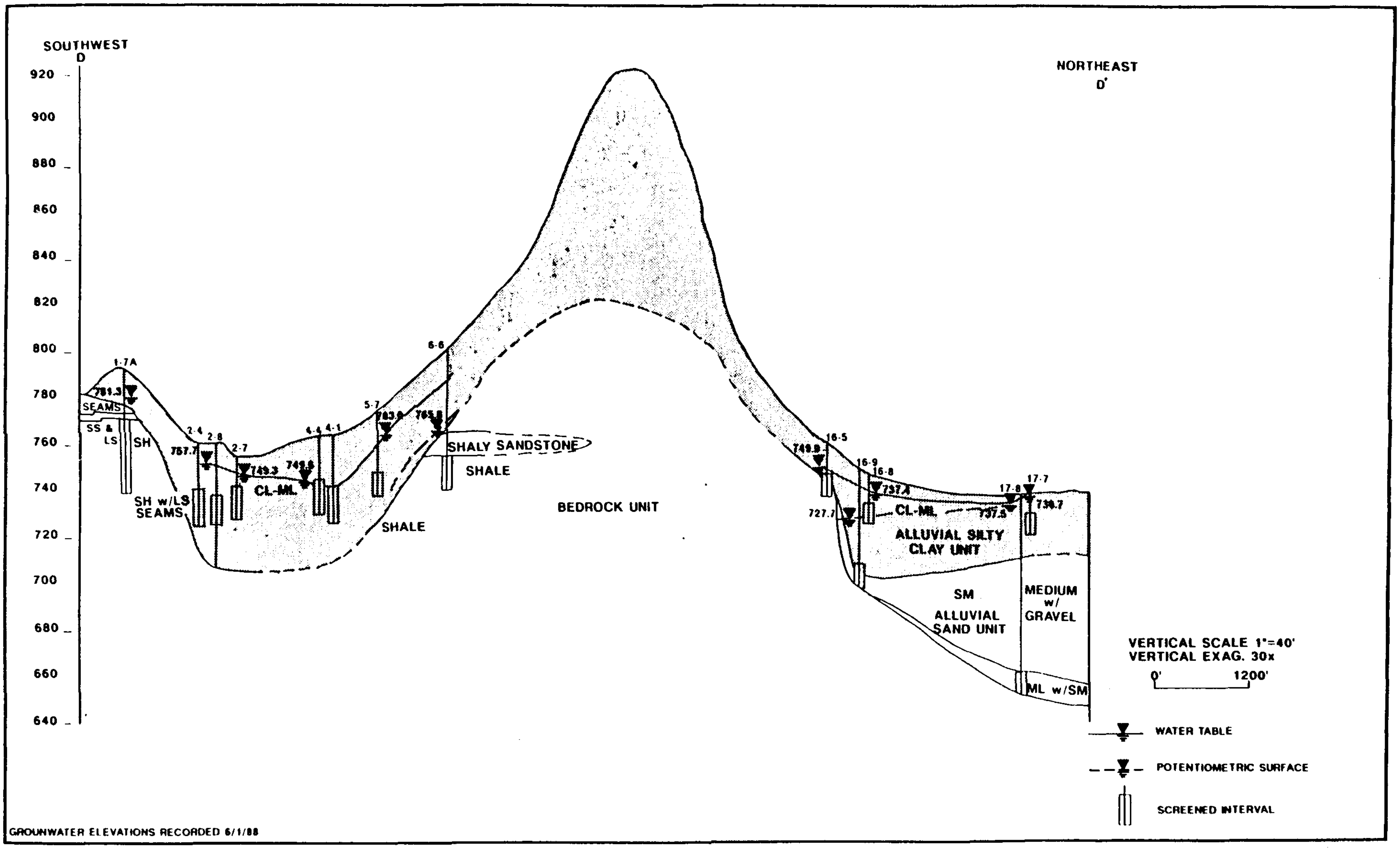
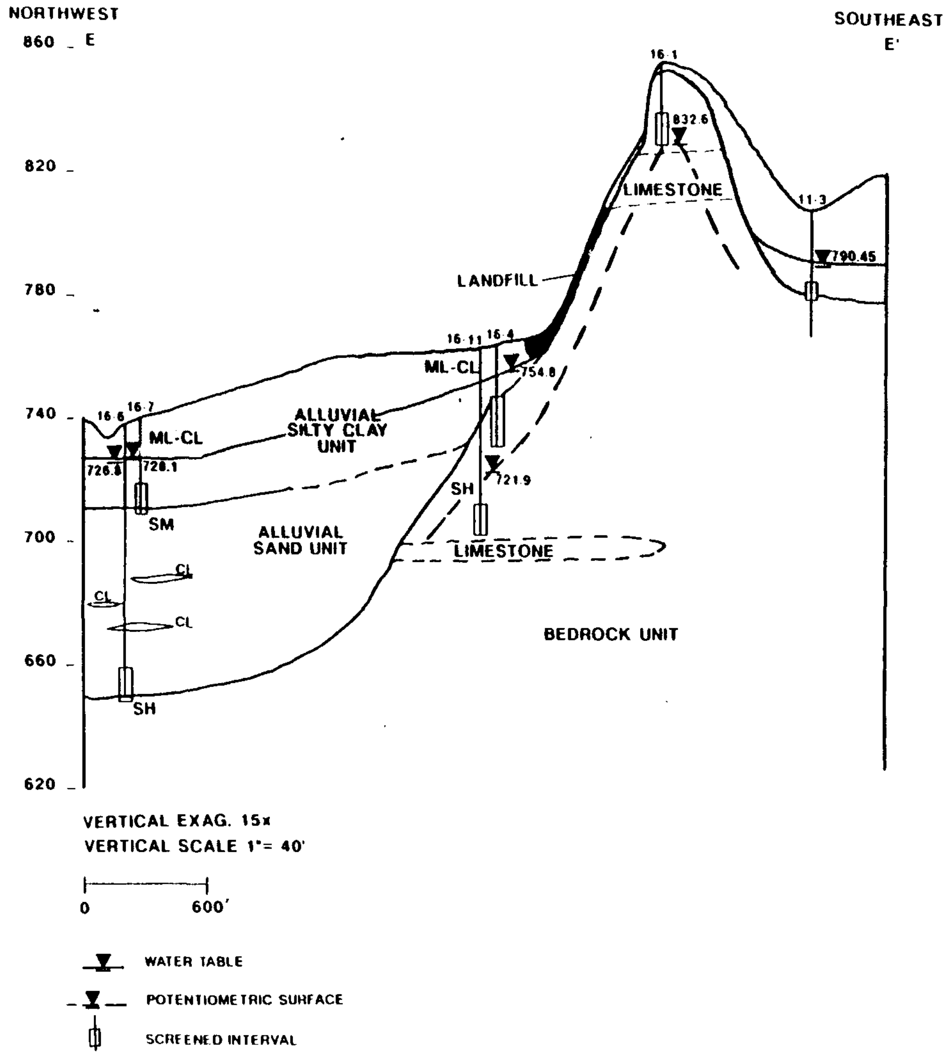


FIGURE 3-7
GEOLOGIC CROSS-SECTION C - C'



GROUNWATER ELEVATIONS RECORDED 6/1/88

FIGURE 3-8
GEOLOGIC CROSS SECTION D - D'



Groundwater Elevation Recorded 6/1/88

FIGURE 3·9
GEOLOGIC CROSS-SECTION E - E'

Table 3-1

UNIFIED SOIL CLASSIFICATION

Major Division		Group Symbol	Soil Description
Coarse-grained (over 50% by weight coarser than No. 200 sieve	Gravelly soils (over half of coarse fraction larger than No. 4)	GW	Well-graded gravels, sandy gravels
		GP	Gap-graded or uniform gravels, sandy gravels
		GM	Silty gravels, silty sandy gravels
		GC	Clayey gravels, clayey sandy gravels
	Sandy soils (over half of coarse fraction finer than No. 4)	SW	Well-graded, gravelly sands
		SP	Gap-graded or uniform sands, gravelly sands
		SM	Silty sands, silty gravelly sands
		SC	Clayey sands, clayey gravelly sands

Fine-grained (over 50% by weight finer than No. 200 sieve)	Low compressibility (liquid limit less than 50)	ML	Silts, very fine sands, silty or clayey fine sands, micaceous silts
		CL	Low plasticity clays, sandy or silty clays
		OL	Organic silts and clays of low plasticity
	High compressibility (liquid limit more than 50)	MH	Micaceous silts, diatomaceous silts, volcanic ash
		CH	Highly plastic clays and sandy clays
		OH	Organic silts and clays of high plasticity
Soils with fibrous organic matter		Pt	Peat, sandy peats, and clayey peat

SOURCE: AMERICAN GEOLOGICAL INSTITUTE.

3.5.2.2. Loess Deposits

Loess deposits are encountered at both the lowland and upland areas, but are thicker and more prevalent in the upland area. These deposits are a light brown, unstructured silt deposit that were originally deposited by wind. These silt deposits are between 0 and 3.5 feet thick.

3.5.2.3 Alluvial Silty Clay Deposits

At LCAAP, the alluvial silty clay deposits are the first major stratigraphic layer encountered within the buried valley, and range in thickness from five to forty-four feet. These alluvial silty clay deposits are thickest along the margins or shoulders of the valley and in low, poorly drained portions of the valley. The deposition of this material occurred from low energy overbank and backwater currents, which carried only the finer silt and clay soil particles. Standing water also helped in breaking down the soil into still finer particles (McCourt, Albertson, and Benne, 1917). Figure 3-10 is an isopach map showing relative alluvial silty clay thickness across the plant. This isopach indicates that the thickest deposits, greater than 40 feet, are at the south central portion of the plant at Areas 1 and 2 and at the northeastern portion of the plant at Area 16. These areas are located along the valley walls, where low energy deposition of fine particles is expected to occur. The alluvial silty clay deposits are approximately 30 feet thick along the entire southern half of the lowland area. The silty clay layer progressively thins to the north and northwest. At Area 3 and well location 3-8 the silty clay is only five feet thick.

The proportion of silt to clay varies at the study area both laterally and vertically. Overall, the unit is characterized as a silty clay with traces of fine sand and lignite fragments. It has low to moderate plasticity and exhibits some dark gray mottling. The presence of lignite is a distinguishing feature of Missouri River alluvial material indicating that sediments were deposited as a result of the rerouted course of the ancestral Missouri River.

Grain size analyses for both sieve and hydrometer tests were performed in 1983 (Layne Western) on ten fine grained alluvial samples. Appendix D provides the geotechnical index testing results for the silty clay alluvial deposits. The results indicated this unit has a content range of 0 percent gravel, 0 to 17 percent sand, 59 to 84 percent silt, and 13 to 41 percent clay. The alluvial silty clay is stiff with low to medium plasticity. According to the Unified Soils Classification, the unit is CL, ML, and CH. The fine-grained alluvial deposits at Areas 16 and 17 (northeast portion of plant) are considered ML soil types, which are characteristically clayey silts with low plasticity. The fine-

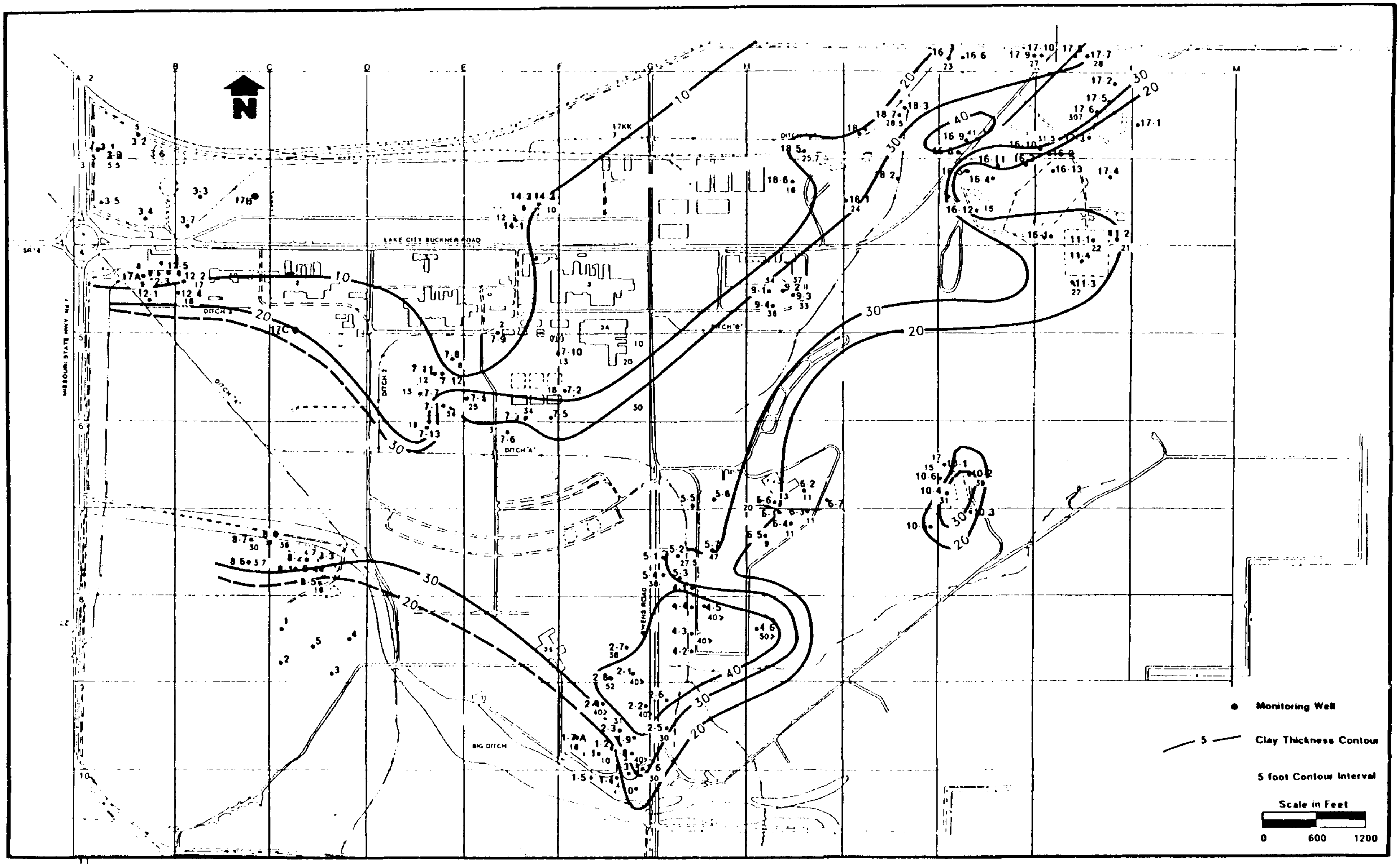


FIGURE 3-10
ALLUVIAL SILTY CLAY ISOPACH CONTOUR MAP

grained alluvial soils that occur at the south central and western portion of the plant are considered CL and CH soil types, which are characteristically silty clays with medium plasticity. Laboratory permeability testings were performed on the same ten soil samples; they yielded a mean permeability of 5.4 x 10^{-8} cm/sec. These hydraulic conductivity values are characteristic of impermeable deposits and indicate a very slow rate of fluid migration.

Field derived hydraulic conductivities from the silty clay unit were obtained by performing slug tests on 18 wells screened within the silty clay deposits. The average value derived from the slug tests was 7.35 x 10^{-5} cm/sec. This indicates the slug tests have three orders of magnitude greater hydraulic conductivity than the laboratory derived values. The laboratory derived values generally measure the vertical component of permeability, whereas the field derived values measure the horizontal component of permeability. Therefore, this may indicate that the silty clay unit is more permeable in the horizontal direction.

Throughout most of the plant, with exception of the northeastern and southern portions, the fine-grained alluvial deposits are underlain by the alluvial sand deposits. The fine-grained alluvial material is present under all of the existing lagoons and landfills at the plant with exception of the now-closed lagoons in the northwest portion of the plant at Area 3, which are partially underlain with sand.

3.5.2.4 Alluvial Sand Deposits

The alluvial sands of the alluvial valley are the most voluminous of the unconsolidated strata on site. They lie unconformably above the Pleasanton and Marmaton Formations, and below the alluvial silty clay deposits. The sand is thickest toward the center of the valley, where it is greater than 80 feet thick, and pinches out totally toward the shoulders of the valley. Figure 3-11 is an isopach map of the sand unit. This figure indicates that the thickest portion of the sand deposits occurs in the northwest and north central areas of the plant. These clastic sediments exhibit a fining upward sequence, indicative of alluvial sedimentation. Sand grain size generally grades from fine to coarse, with increasing depth, and gravel percentages also increase with depth. The alluvial sands can be characterized as brown to gray, fine to coarse sand with little silt and traces of clay and lignite. Very thin (one to three inch) discontinuous silty clay zones are present at various depths throughout this unit. Fragmented lignite is commonly found in concentrated beds or dispersed in lower percentages among the sand deposits.

Particle size analysis of the deposits were performed on four samples in 1981 by Layne Western Company. This geotechnical data is presented in Appendix D. These samples were collected from

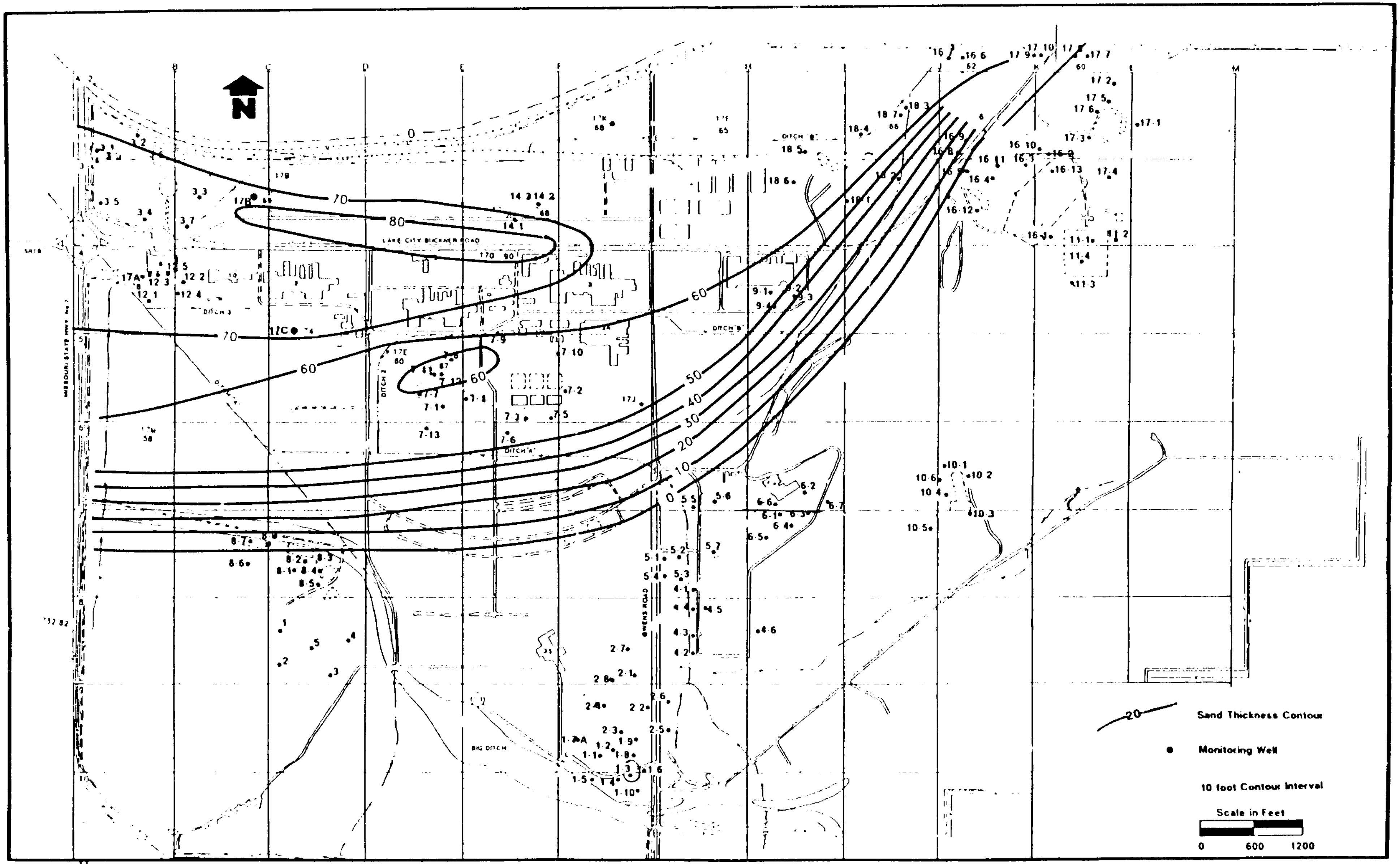


FIGURE 3-11
ALLUVIAL SAND ISOPACH CONTOUR MAP

Areas 3 and 7 and indicate a range of 0 to 3 percent gravel, 5 to 39 percent medium to coarse sand, 14 to 92 percent fine sand, and 3 to 44 percent silt and clay. According to the unified soils classification, the unit is an SM. Laboratory permeability testing was performed on two sandy soils from Area 9 and yielded a mean hydraulic conductivity value of 1.0 x 10^{-2} cm/sec. These values are characteristic of a permeable deposit and indicate a relatively quick rate of fluid migration. Field derived hydraulic conductivities from the sand unit were obtained by performing slug tests on 27 wells. The average value derived from the slug tests was 3.59 x 10^{-3} cm/sec. The fact that the laboratory derived hydraulic conductivities are an order of magnitude greater than the field derived may indicate that the sands are more permeable in the vertical direction or, more likely, that the laboratory sand sample was disturbed and thus, indicated a higher permeability. Further discussions regarding the hydraulic characteristics of the sand aquifer are discussed in Subsection 3.6.

3.5.2.5 Bedrock Formation

The bedrock encountered in borings and at outcrops at LCAAP is part of the Pennsylvanian age Kansas City and Pleasanton Groups, composed principally of alternating beds of limestone and shale. The older Pleasanton Group, which underlies the Kansas City Group, is predominantly shale with minor units of limestone and sandstone (Howe, 1961). The Kansas City Group is predominantly limestone with alternating shale units.

The upland areas in the southern and eastern portions of the plant are capped by resident limestone deposits of the Kansas City Group. The members of the Kansas City Group include either the Bethany Falls Member of the Swope Formation (Fent, 1979) or by the Winterset Member of the Dennis Formation (Anderson and Greene, 1948). The exact contact between the Pleasanton and Kansas City Groups is indistinct. However, the thicknesses of individual beds comprising these groups were measured from local outcrops during a 1948 site investigation by Anderson and Greene, suggest a contact of approximately 875 feet MSL.

The largely clastic Pleasanton Group is characterized by variable shales with thin, impure limestones about 30 feet from the top. These limestones are argillaceous and silty to sandy. Channel-fill deposits known as the Warrensburg and Moberly Sandstones may also exist within the Pleasanton Group beneath the site. Other sandstone deposits occur in older Pennsylvanian strata beneath the Pleasanton Group.

A contour map of the bedrock surface was drawn from information collected during installation of deep wells, all of which extended to bedrock. Figure 3-12 shows that the bedrock slopes downward to the north at the west-central portion of the plant and slopes

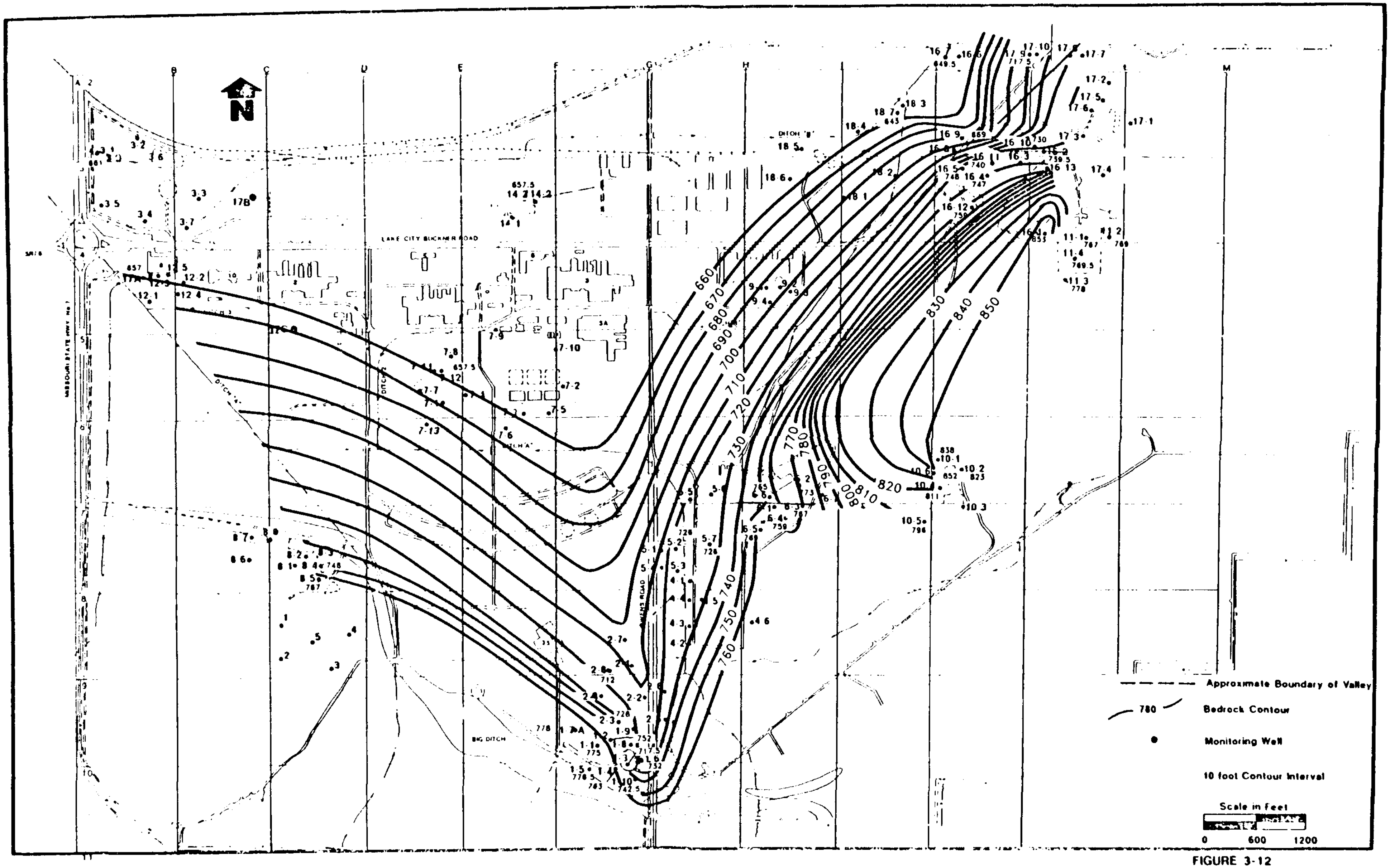


FIGURE 3-12
BEDROCK SURFACE CONTOUR MAP

downward to the northwest at the northeastern portion of the plant. Total relief from the highest to lowest points are approximately 300 feet, from an elevation of 850 feet MSL to 645 feet MSL.

3.6 HYDROGEOLOGY

Three hydrostratigraphic units have been identified at LCAAP. They include, in descending order, the silty clay unit, the sand unit and the weathered bedrock unit. The silty clay unit overlies the sand unit within the alluvial valley and the weathered bedrock in the upland areas. The sand unit is present within the alluvial valley and is situated between the silty clay unit and the weathered bedrock unit. The weathered bedrock unit is situated below the sand in the valley and below the silty clay along the margin of the alluvial valley. A detailed discussion of the hydrogeology of each unit is presented in the following subsections.

3.6.1 Silty Clay Hydrostratigraphic Unit

The silty clay is the uppermost unit encountered at LCAAP. In the alluvial valley, the silty clay ranges in thickness from 5 to 20 feet. At the margins of the valley and in the upland areas, the thickness ranges from 20 to 44 feet.

The potentiometric surface at the eastern half of the alluvial valley is present within the silty clay unit. At the western half of the alluvial valley, the potentiometric surface is below the silty clay unit and present within the underlying sand unit. Within the western half of the valley, the potentiometric surface may have, at one time, been within the silty clay unit, but as a result of the groundwater usage over the last 50 years, the potentiometric surface has dropped below the silty clay unit. Figure 3-13 identifies the areal extent of the unsaturated silty clay unit.

At the margins of the valley and in the upland areas monitoring wells are screened in the silty clay unit. On 1 June 1988, static water level elevations were recorded and a groundwater contour map was generated (Figure 3-14). From this contour map, it is evident that at the southwestern portion of the plant, groundwater is flowing toward the north and at the remainder of the plant, the groundwater is flowing toward the northwest. The water table contour lines closely follow the surface and bedrock topography.

Within the uplands areas, the relatively steep horizontal hydraulic gradient ranges from 0.03 ft/ft to 0.13 ft/ft, with an average of 0.07 ft/ft. Within the lowland areas, the relatively flat horizontal hydraulic gradient ranges from 6.25×10^{-4} ft/ft to 1.00×10^{-2} ft/ft, with an average of 3.75×10^{-3} ft/ft. These gradients were measured from water levels represented in Figure 3-14 where

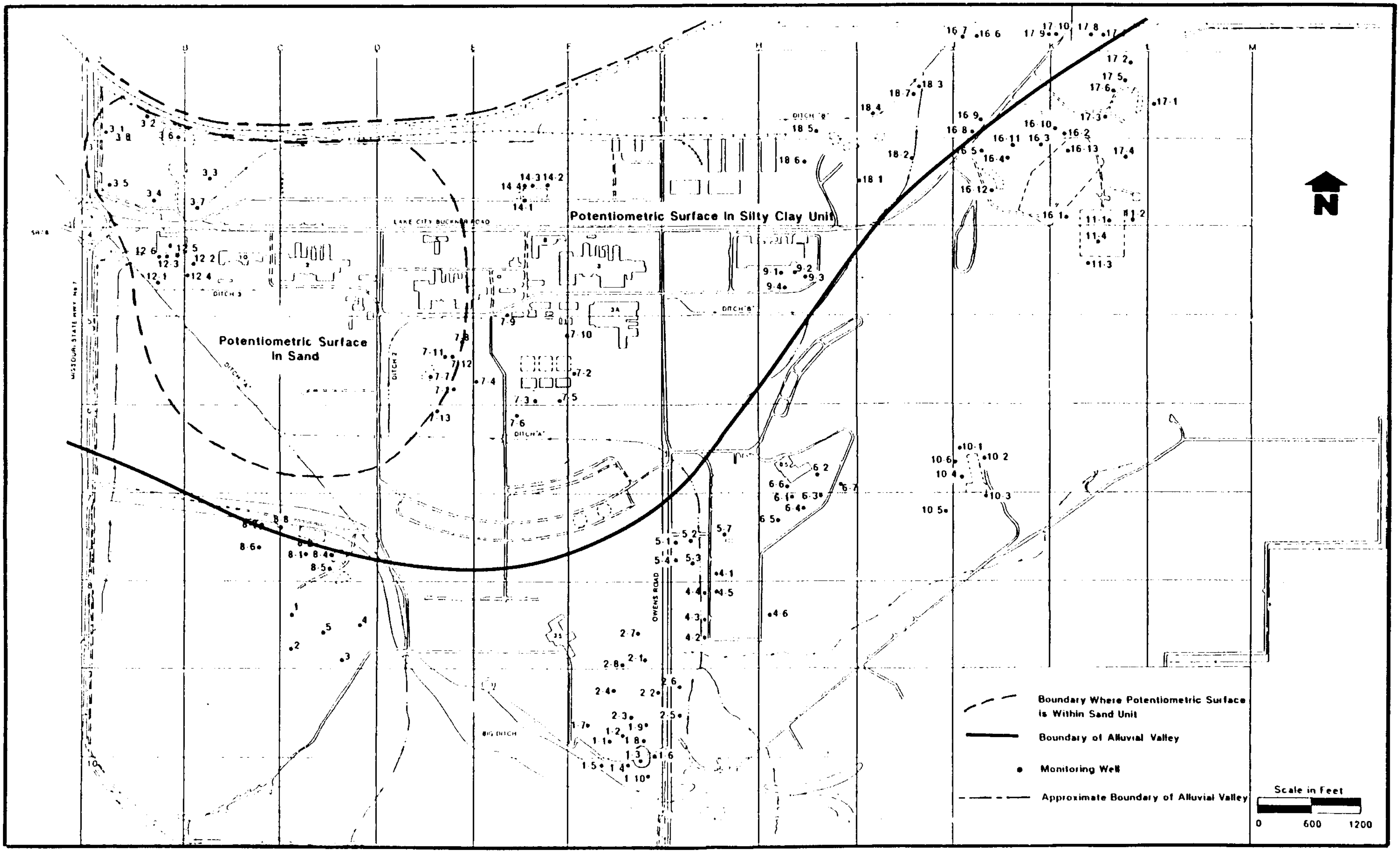


FIGURE 3-13
OCCURRENCE OF POTENTIOMETRIC SURFACE

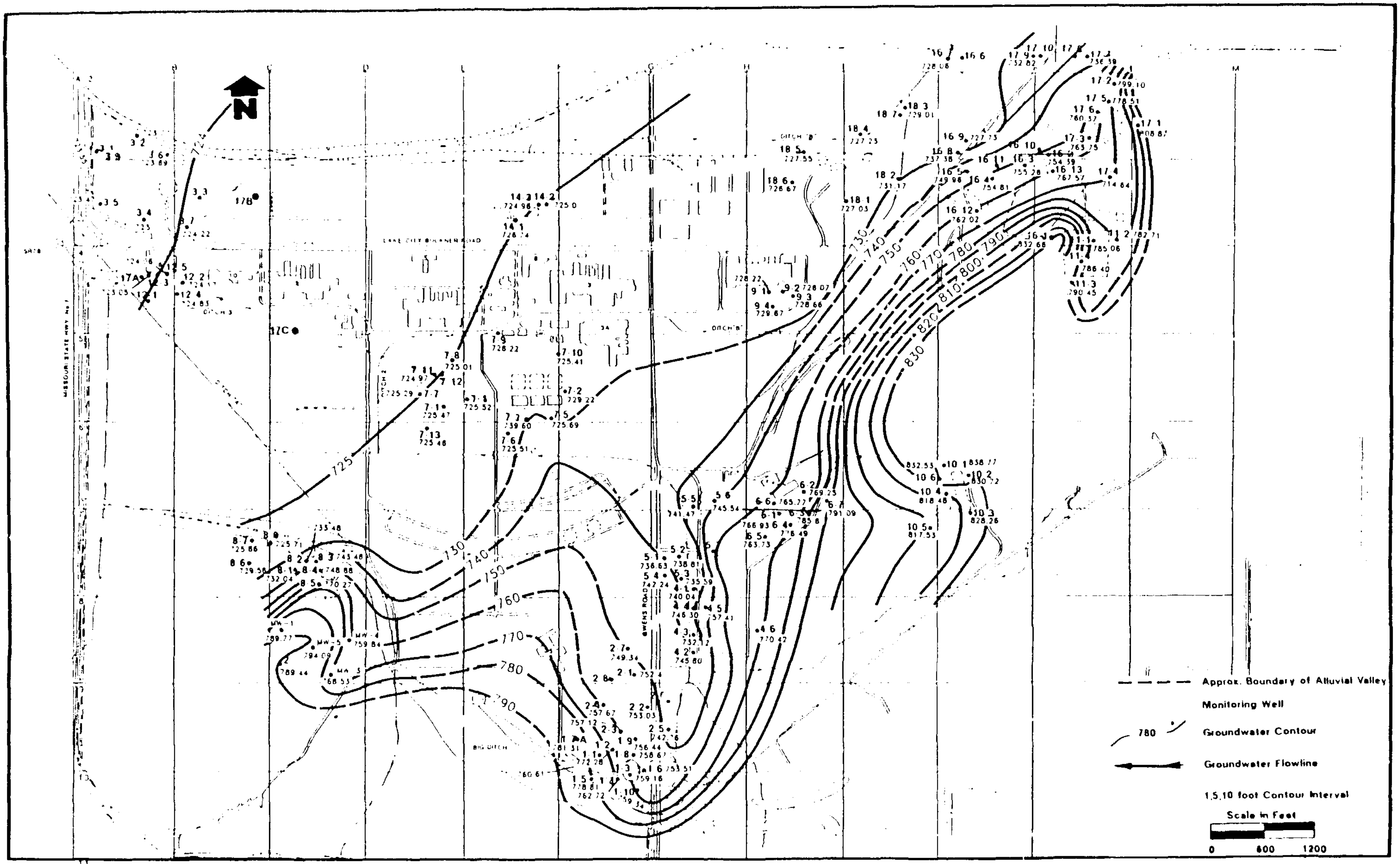


FIGURE 3-14
SHALLOW PIEZOMETRIC CONTOUR MAP

the water table is present within the silty clay hydrostatigraphic unit. This horizontal gradient is an apparent gradient. The true hydraulic gradient is the vector sum of the horizontal gradient and the vertical gradient.

The hydraulic conductivity of the silty clay unit was obtained from field and laboratory permeability tests and is summarized in Table 3-2. Laboratory permeability tests were performed by Layne Western in 1981 on ten silty clay soil samples, yielding a mean vertical permeability of 5.4 x 10^{-8} cm/sec and a range of 1.61 x 10^{-7} to 7.41 x 10^{-9} cm/sec. The low hydraulic conductivity values are characteristic of clay deposits. Field derived hydraulic conductivities were obtained by performing slug tests on 18 monitoring wells screened within the silty clay unit. The mean horizontal permeability value derived from the slug tests was 7.35 x 10^{-5} cm/sec with a range of 9.13 x 10^{-5} to 6.0 x 10^{-5} cm/sec. Laboratory test methods generally measure the vertical component of permeability, whereas the field methods measure the horizontal component of permeability. These results may indicate that the silty clay unit is more permeable in the horizontal direction. Also, the field testing method derives the values from a large radius of influence rather than the laboratory test method, which derives values from a very small portion of the aquifer.

The velocity at which water can flow through a porous medium is shown by a modified version of Darcy's law, wherein velocity (V) is a function of the hydraulic conductivity (K), hydraulic gradient (i) and effective porosity (n):

$$V = \frac{Ki}{n}$$

Estimating the velocity of groundwater flow in the uplands, the average horizontal hydraulic gradient is 0.07 ft/ft. An estimated effective porosity (n) of a silty clay till is 45% (Todd, 1959). Using the laboratory derived hydraulic conductivity (K) value, the vertical component of velocity is estimated to be 2.4 x 10^{-5} ft/day or 8.7 x 10^{-3} ft/year. Using the field derived hydraulic conductivity (K) value, the horizontal component of velocity is estimated to be 3.2 x 10^{-2} ft/day or 11.8 ft/year. These results indicate the groundwater flow velocity is greater using the field derived hydraulic conductivity value. Since the field tests generally measure the horizontal component of permeability, the results indicate groundwater will migrate much faster in the horizontal direction. An average velocity using both the laboratory and field derived values indicate the groundwater may be migrating in the silty clay unit at 1.6 x 10^{-2} ft/day or 5.8 ft/year.

TABLE 3-2

SILTY CLAY HYDRAULIC CONDUCTIVITIES

UPLANDS AREA

Field Derived Values (Slug Test Values)

Mean (x) = 7.35×10^{-5} cm/sec

Standard deviation (s) = 1.31×10^{-5} cm/sec

Range = 9.13×10^{-5} cm/sec to 6.0×10^{-5} cm/sec

Velocity = 3.2×10^{-2} ft/day
11.8 ft/year

Laboratory Derived Values (Shelby Tube Sample Values)

Mean (x) = 5.4×10^{-8} cm/sec

Standard deviation (S) = 7.11×10^{-8} cm/sec

Range = 1.61×10^{-7} to 7.41×10^{-9} cm/sec

Velocity = 2.4×10^{-5} ft/day
8.7×10^{-3} ft/year

It should also be noted that these velocities are representative of flow in the upland area where steep gradients exist. In the alluvial valley the hydraulic gradient expressed by the water table is approximately 3.75 x 10^{-3} ft/ft. Using this hydraulic gradient and the above mentioned effective porosity and mean hydraulic conductivities (field and laboratory derived), the velocity of groundwater in the silty clay deposit in the alluvial valley is estimated to be 8.7 x 10^{-4} ft/day or 0.32 ft/year. Groundwater in the silty clay deposits of the alluvial valley will travel much more slowly due to the relatively flat hydraulic gradient. These velocities were calculated using 1 June 1988 static water levels. Variations in production well pumping will alter the horizontal and vertical hydraulic gradients which will then alter flow velocities.

3.6.2 Alluvial Sand Hydrostratigraphic Unit

The sand within the alluvial valley lies below the silty clay and above bedrock. The sand thickens toward the center of the valley and pinches out toward the margins. The alluvial sand is the major aquifer in the plant area and supplies LCAAP with as much as 1,400,000 gallons of water per day.

The potentiometric surface of the aquifer may be above the sand or within the sand, depending on the location within the valley. Using 1 June 1988 water level measurements at the eastern half of the plant, the potentiometric surface is above the sand unit and thus, the sand aquifer is under confined conditions. This sand at the eastern half of the plant, is therefore, completely saturated and under pressure greater than atmospheric due to the overlying, relatively impermeable silty clay unit. At the western half of the alluvial valley, the potentiometric surface is below the clay unit and within the sand unit and thus may be under unconfined to semi-confined aquifer conditions. The monitoring wells at Area 12 show the relationship between the potentiometric surface and the clay/sand unit interface. Figure 3-15 graphically demonstrates the location of the potentiometric surface below the clay unit during three water level measurement events. Monitoring wells 12-2, 12-3 and 12-4 show the potentiometric surface between six inches and five feet from the clay and sand unit interface. Monitoring well 12-5 identifies the potentiometric surface between 13 and 16.5 feet below the interface. A dry well (12-1) at the site is screened in the silty clay. This well indicates that the silty clay above the sand is unsaturated and therefore, water table conditions do not exist within the silty clay unit. This condition may be the result of years of pumping the aquifer and causing a decrease in the potentiometric surface to the point where it is below the silty clay confining bed. Pumping of production well 17-AA at Area 12 has caused the potentiometric surface to drop below the silty clay unit. Figure 3-13 shows the approximate areas where the potentiometric surface is within the sand unit and within the silty clay unit.

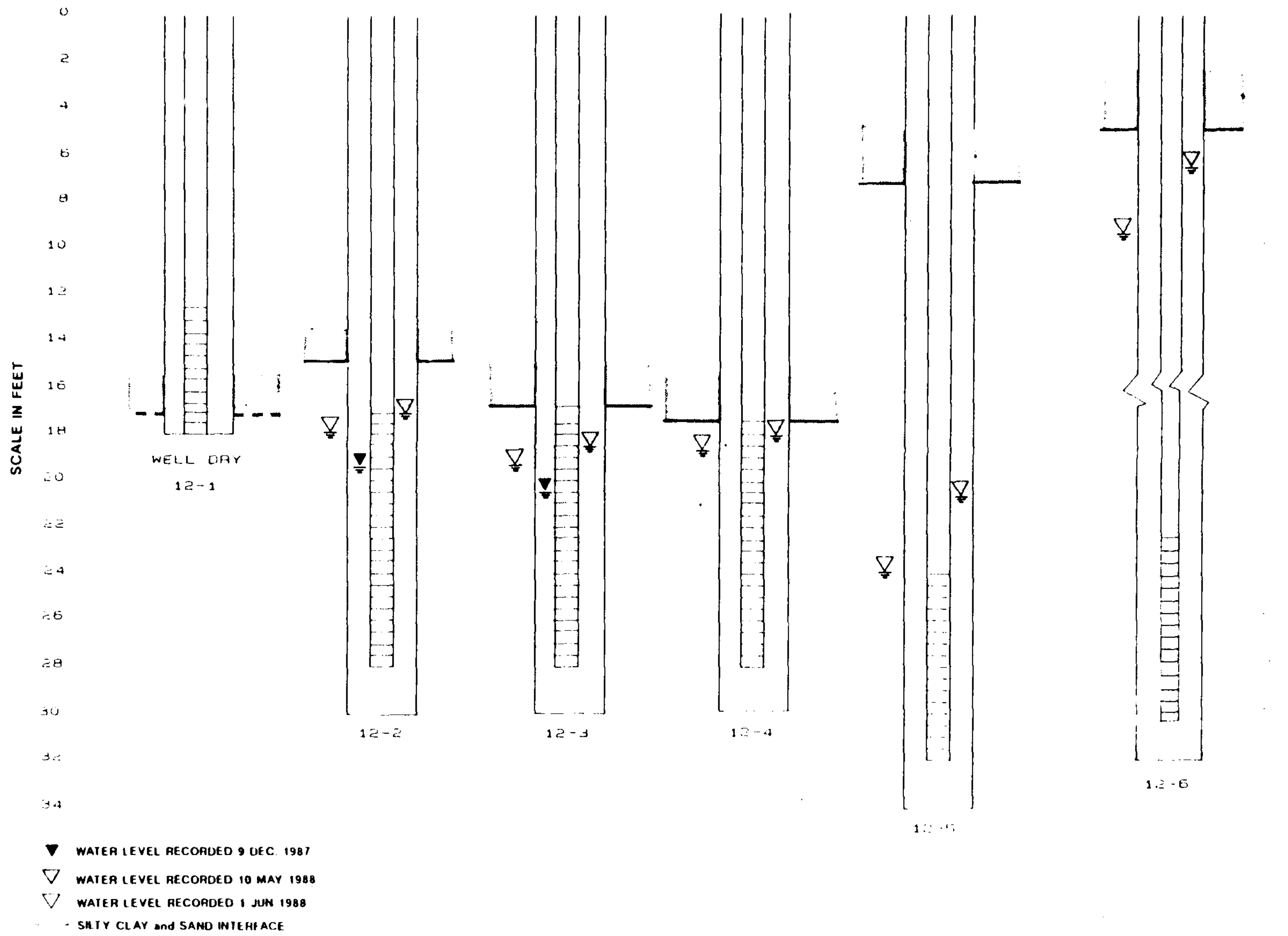


FIGURE 3-15
AREA 12 POTENTIOMETRIC SURFACE AND INTERFACE RELATIONSHIP

On 1 June 1988, water level elevations were recorded from monitoring wells screened within the alluvial sand. From this data, the contour maps were drawn for the top and bottom portions of the aquifer (Figures 3-16 and 3-17). The contour map constructed using only the alluvial sand wells screened at the top of the aquifer indicates that the groundwater is flowing to the west. The contour map constructed using only the alluvial sand wells screened at the bottom of aquifer indicates that the groundwater is flowing to the west and southwest. The greater southerly component of flow in the lower portion of the aquifer may be due to the influence of the pumping of the production wells. The water level recorded at well 7-8 accounts for much of the southerly component of groundwater flow. This static water level was potentially affected by the pumping of production well 17-EE, which was pumping at 275 gpm from 8:30 A.M. to 2:00 P.M. on the day the water level was recorded. In order to account for the additional drawdown associated with the pumping of well 17-EE, the non-equilibrium well equation was used (Driscoll, 1986). When the non-equilibrium well equation is applied to well 7-8, it is calculated that 0.92 feet of drawdown will occur at this well as a result of pumping production well 17-EE. Adding the calculated drawdown to the static water level recorded at well 7-8, the effect of pumping from 17-EE is negated. The new calculated static water level is 723.52 feet above MSL. Figure 3-17 shows the contour lines redrawn to reflect the new water level. The groundwater flow lines still indicate a southerly groundwater flow direction in the deep portion of the sand, but to a somewhat smaller degree.

The horizontal hydraulic gradient in the sand unit is determined to be toward the west to southwest. The gradient within the alluvial valley is not as steep as that observed at the margins of the valley. The hydraulic gradient calculated for the shallow portions of the aquifer is approximately 6.0×10^{-4} ft/ft. The hydraulic gradient calculated for the deep portion of the sand aquifer is 6.3×10^{-4} ft/ft. These low values represent a nearly flat potentiometric surface.

The vertical hydraulic gradient within the sand aquifer can be determined by comparing static water levels from a well cluster screened at the bottom and top of the aquifer. In the alluvial valley, four two-well clusters exist within the sand aquifer. These two-well clusters are located at Areas 3, 7, 12, 14, and 16. These five clusters were used to evaluate the vertical component of flow in the aquifer. Table 3-3 summarizes the static water levels in the deep and shallow wells. At Areas 7, 12 and 14, production wells are within 600 feet of the monitoring wells. During the measurements of the static water levels at Areas 7, 12 and 14, their respective production wells, 17EE, 17AA and 17DD, were pumping. As previously discussed, the non-equilibrium well equation was used to adjust the measured water levels to negate the

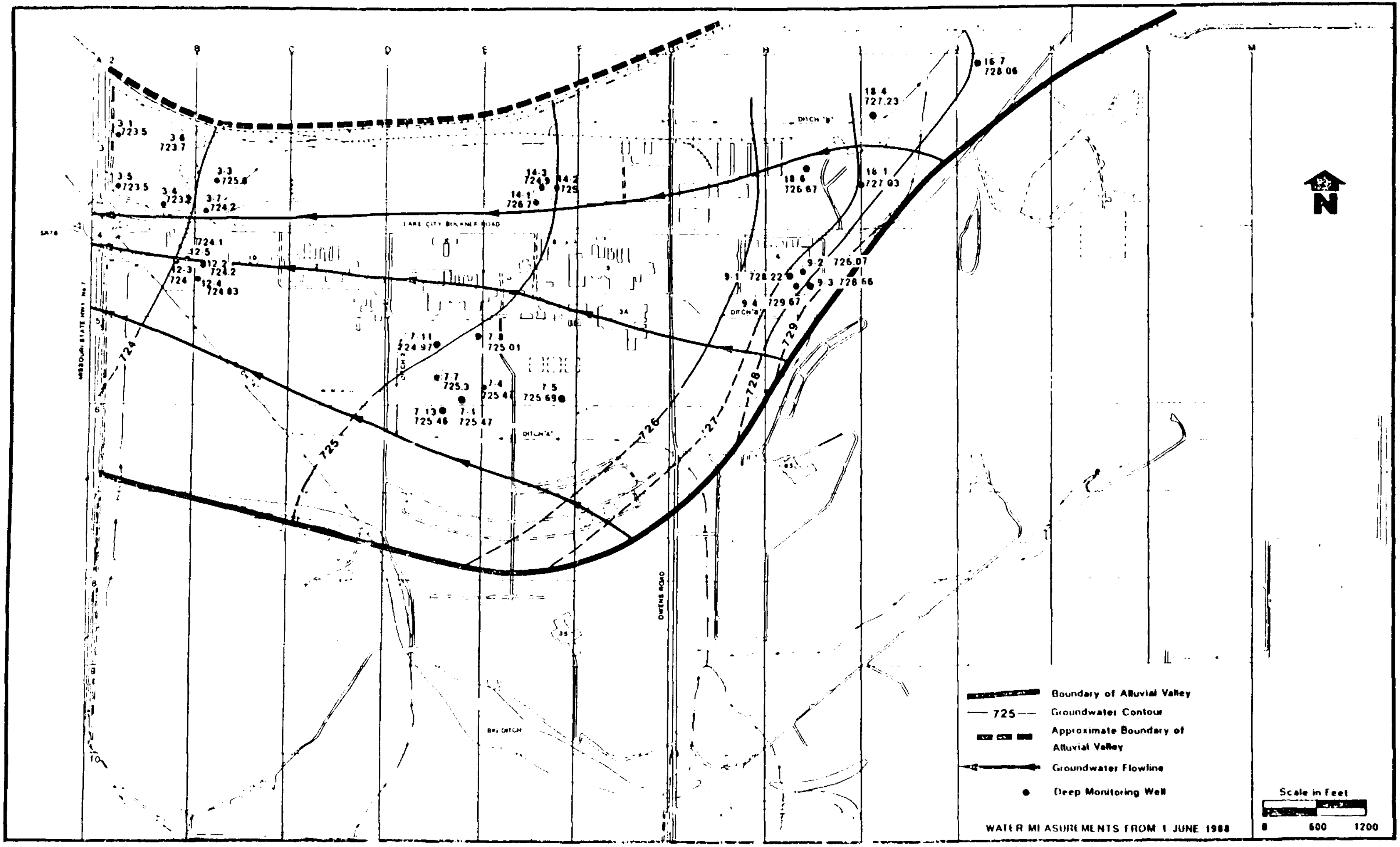


FIGURE 3-16

GROUNDWATER CONTOUR MAP
USING SHALLOW ALLUVIAL SAND WELLS

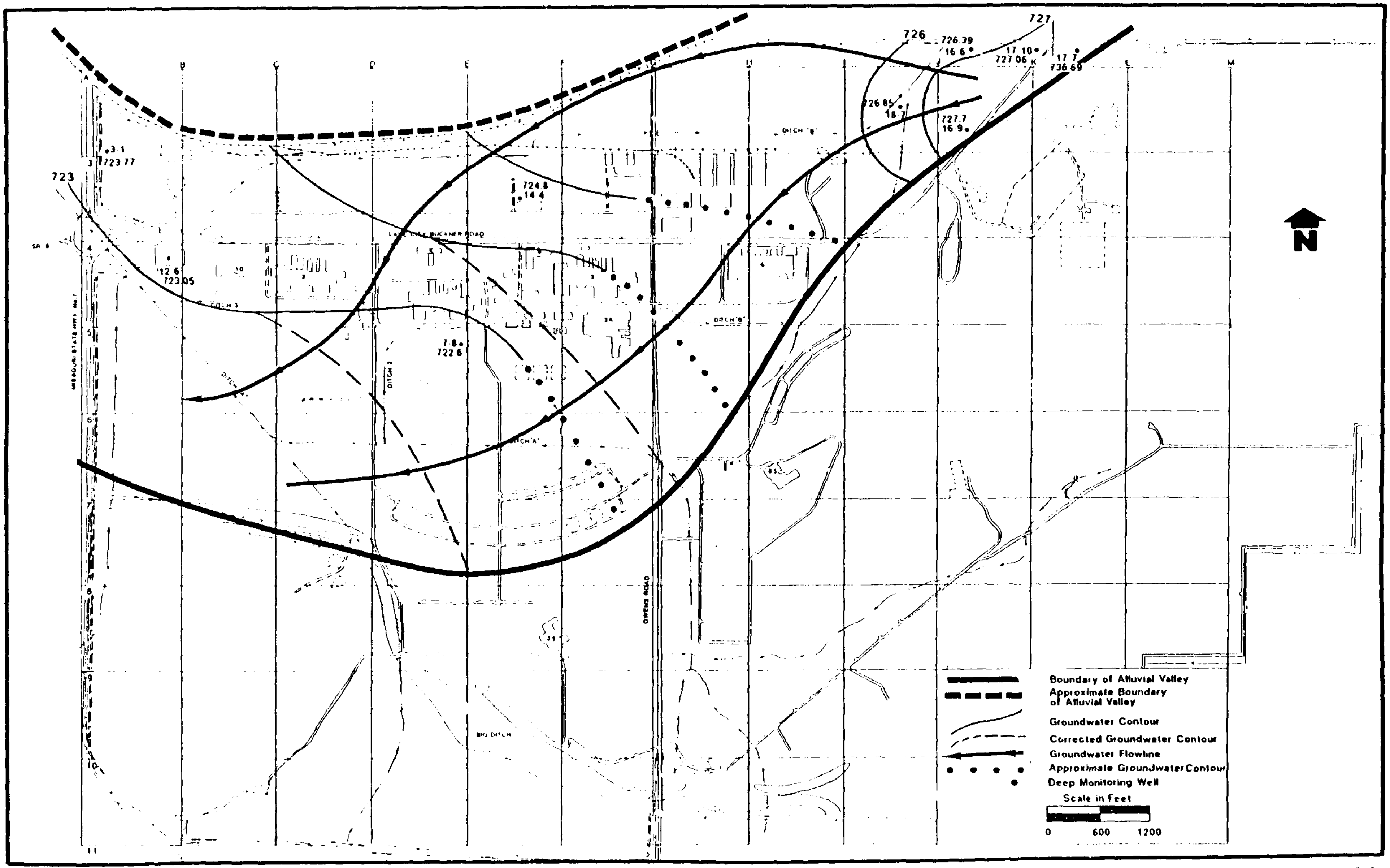


FIGURE 3-17
GROUNDWATER CONTOUR MAP
USING DEEP MONITORING WELLS

TABLE 3-3

SUMMARY OF STATIC WATER LEVELS AT TWO-WELL CLUSTERS

1 June 1988

SHALLOW		DEEP		
Well ID	Water level Elevation	Well ID	Water Level Elevation	Vertical Gradient
3-1	723.05	3-8	723.77	upward
7-11	725.38* (724.97)	7-12	723.52* (722.60)	downward
12-3	724.01* (723.05)	12-6	725.43* (723.96)	upward
14-3	725.02* (724.96)	14-4	725.03* (724.82)	equal
16-8	737.3	16-9	727.9	downward

* Water level corrected for non-equilibrium conditions.

() Uncorrected water levels.

Note: Wells at Area 3 are greater than 2000 feet from a production well, and therefore, are not effected by the drawdown and did not need to be corrected.

short-term effects of pumping. The static water levels identified in Table 3-3 have been corrected using this equation. According to Table 3-3, groundwater at Areas 3 and 12 have an upward component of flow. At Areas 5, 7, and 16, groundwater has a downward component of groundwater flow. At Area 14, the static water levels indicate no upward or downward component of flow.

Vertical flow between the overlying silty clay unit and the alluvial sand aquifer was also evaluated at Area 16, which is at the east margin of the alluvial valley. The well cluster at Area 16 consisted of a deep well screened in the sand and a shallow well screened in the clay. Water levels from this cluster indicate a downward gradient between the clay and the sand. These data suggests that the center and margins of the alluvial valley were at one time groundwater discharge zones, but, as a result of pumping the aquifer and channelization of surface water, vertical gradients have been reversed to create a downward gradient. In contrast, in Areas 3 and 12, the vertical gradients are upward indicating the relationship of this area as to groundwater discharge zones. The magnitude of the upward gradient has most likely decreased with time as a result of pumping and channelization.

The hydraulic conductivity of the sand unit was obtained by laboratory permeability tests, slug tests and a pumping test. The test results are summarized in Table 3-4. The laboratory permeability tests were performed in 1983 by Layne Western on two sandy soils from Area 9 and yielded a mean hydraulic conductivity value of 1.0×10^{-2} cm/sec (Appendix D). Slug tests were performed on 27 wells screened within the sand unit. The mean value derived from the slug tests was 3.59×10^{-3} cm/sec. The pumping test was conducted at Area 12 and yielded a hydraulic conductivity value for the shallow sand zone of 7.2×10^{-2} cm/sec and for the deep sand zone of 1.5×10^{-1} cm/sec. These values indicate that the laboratory and pumping test values are one to two orders of magnitude greater than the slug test values. The most reliable hydraulic conductivity value would be obtained from the pumping test and therefore, the hydraulic conductivity value which is most representative of the sand aquifer is an average of the shallow and deep sand hydraulic conductivities, which is 1.09×10^{-1} cm/sec. This value is characteristic of permeable sand deposits. A more detailed discussion of pumping test data analysis is presented in Subsection 3.6.4.

Using the pumping test drawdown curves for partially penetrating wells in a confined aquifer, the vertical and horizontal permeability ratio (P_v/P_h) can be calculated. It was calculated that in the upper portion of the sand aquifer the P_v/P_h was approximately 0.033 (average value) which indicated that vertical permeability was about one third of the horizontal permeability and, therefore preferential groundwater flow is in the horizontal

TABLE 3-4

SAND HYDRAULIC CONDUCTIVITIES

Field Derived Values

Mean (x) = 3.59×10^{-3} cm/sec
Standard deviation (s) = 3.93×10^{-3} cm/sec
Range = 1.41×10^{-4} to 1.2×10^{-2} cm/sec
Velocity = 1.81×10^{-2} ft/day
6.61 ft/year

Laboratory Derived Values (Layne Western 1982)

Mean (x) = 1.0×10^{-2} cm/sec
Standard deviation (s) = 1.4×10^{-3} cm/sec
Range = 1.1×10^{-2} to 9.0×10^{-3} cm/sec
Velocity = 5.1×10^{-2} ft/day
18 ft/year

Pumping Test Derived Values

Shallow

Mean (x) = 7.16×10^{-2} cm/sec
Standard deviation (s) = 3.17×10^{-2} cm/sec
Range = 3.52×10^{-2} to 1.12×10^{-1} cm/sec

Deep

Mean (x) = 1.47×10^{-1} cm/sec
Standard deviation (s) = 4.84×10^{-3} cm/sec
Range = 1.52×10^{-1} to 1.59×10^{-1} cm/sec

Average Shallow/Deep

Mean (x) = 1.09×10^{-1} cm/sec
Velocity = 0.76 ft/day
280 ft/year

direction. Within the lower portions of the aquifer, P_v/P_h was approximately 0.004 which suggested little to no vertical component of flow. For further discussion regarding the permeability ratio refer to Subsection 3.6.4.

The velocity of groundwater is calculated using a modified version of Darcy's law. Since flow is predominantly in the horizontal direction, the horizontal component of velocity was calculated. To calculate velocity, Darcy's law uses the hydraulic conductivity, effective porosity and hydraulic gradient. According to previous calculations, the hydraulic gradient was an average of 6.2 x 10^{-4} ft/ft, using an estimated effective porosity of a sand aquifer of 25% (Todd, 1959) and the hydraulic conductivity value of 1.09 x 10^{-1} cm/sec or 309 ft/day. Therefore, the calculated velocity of groundwater migrating in the sand aquifer is 0.77 ft/day or approximately 280 ft/year.

3.6.3 Weathered Bedrock Hydrostratigraphic Unit

The weathered bedrock unit at LCAAP was observed at Areas 6 and 16. This unit is composed predominantly of weathered shale with interbedded limestone. The weathered shale at Areas 6 and 16 is saturated but may be classified to some degree as a confining layer and exhibits midrange low permeabilities.

At Area 16, six monitoring wells are screened in the weathered shale. On 1 June 1988, the water levels were recorded and used to assess the direction of groundwater flow. Figure 3-14, which was based on these water levels, indicates that the direction of groundwater flow within the weathered shale at Area 16 is toward the northwest. The horizontal component of hydraulic gradient of the potentiometric surface is approximately 5.9 x 10^{-2} ft/ft. The vertical component of hydraulic gradient within the shale can be estimated from the well cluster 16-4 and 16-11. A 32.9-foot difference in head between these wells exists and indicates a significant downward gradient between the upper and lower weathered shale. This vertical hydraulic gradient was calculated to be 9.7 x 10^{-1} ft/ft.

A total of five hydraulic conductivity values were generated for the weathered shale. This data is presented in Appendix D. These values were determined by performing slug tests and yielded an average hydraulic conductivity value for the weathered shale of 4.4 x 10^{-4} cm/sec with a range from 1.51 x 10^{-3} to 9.01 x 10^{-5} cm/sec.

The horizontal component of flow can be calculated by using the modified version of Darcy's law. The horizontal component of the hydraulic gradient was determined above to be 5.9 x 10^{-2} ft/ft. The porosity of an unweathered shale is approximately 10% (Todd, 1959), although the porosity of a weathered shale maybe in the order of 40%. Using the average hydraulic conductivity value of 4.4 x 10^{-4}

cm/sec and the above-mentioned values, the horizontal component of velocity of groundwater in the weathered shale is calculated to be on the order of 0.18 ft/day or 67 ft/yr.

The vertical component of velocity can be calculated by using the vertical component of hydraulic gradient (9.7×10^{-1} ft/ft) and the above-mentioned porosity and hydraulic conductivity. Based on these parameters, the vertical component of velocity of groundwater in the unweathered shale is 3 ft/day or 1,104 ft/year. This indicates a potentially faster vertical rate of groundwater migration compared to the horizontal component of velocity.

3.6.4 Pumping Test

As part of the LCAAP remedial investigation, a pumping test was performed to evaluate aquifer characteristics of permeability (K), transmissivity (T), storage (S), and anisotropy (P_v/P_h) for potential subsequent modeling.

Permeability and transmissivity define the ease of movement of groundwater through aquifers or aquitards. Transmissivity is the rate of flow of water through a one unit wide strip of the aquifer, and is therefore equal to the permeability multiplied by the saturated thickness of the aquifer. Storage is defined as the volume of water the aquifer releases from or takes into storage per unit surface area per unit change (increase or decrease) in head. The anistropy of an aquifer is quantified by the ratio of the vertical and horizontal components of aquifer permeability. All of these aquifer properties are important to quantify on a site-specific basis for numerical modeling input parameters and remediation design, if necessary.

The pumping test was performed using production well 17-AA located in Area 12 of the plant. This location was chosen because Area 12 received a Hazard Ranking System (HRS) score of sufficient magnitude to place the site onto the NPL. This section provides the test procedures, test results, and data analysis of the pumping test.

3.6.4.1 Procedures

One pumping well (17-AA) and six observation wells, namely 12-2, 12-3, 12-4, 12-5, 12-6, and 17-A were used during the pumping test. The location of the observation wells as well as the radial distances from the pumping well are shown on Figure 3-18. To obtain water level measurements during the test, pressure transducers were placed in each of the six observation wells. Transducers from five of the six observation wells (12-2, 12-3 12-4, 12-6, and 17-A) were connected to an In-Situ SE2000 data logger. Because monitoring well 12-5 was located in a heavy traffic area which did not allow for cables to be stretched across the pavement,

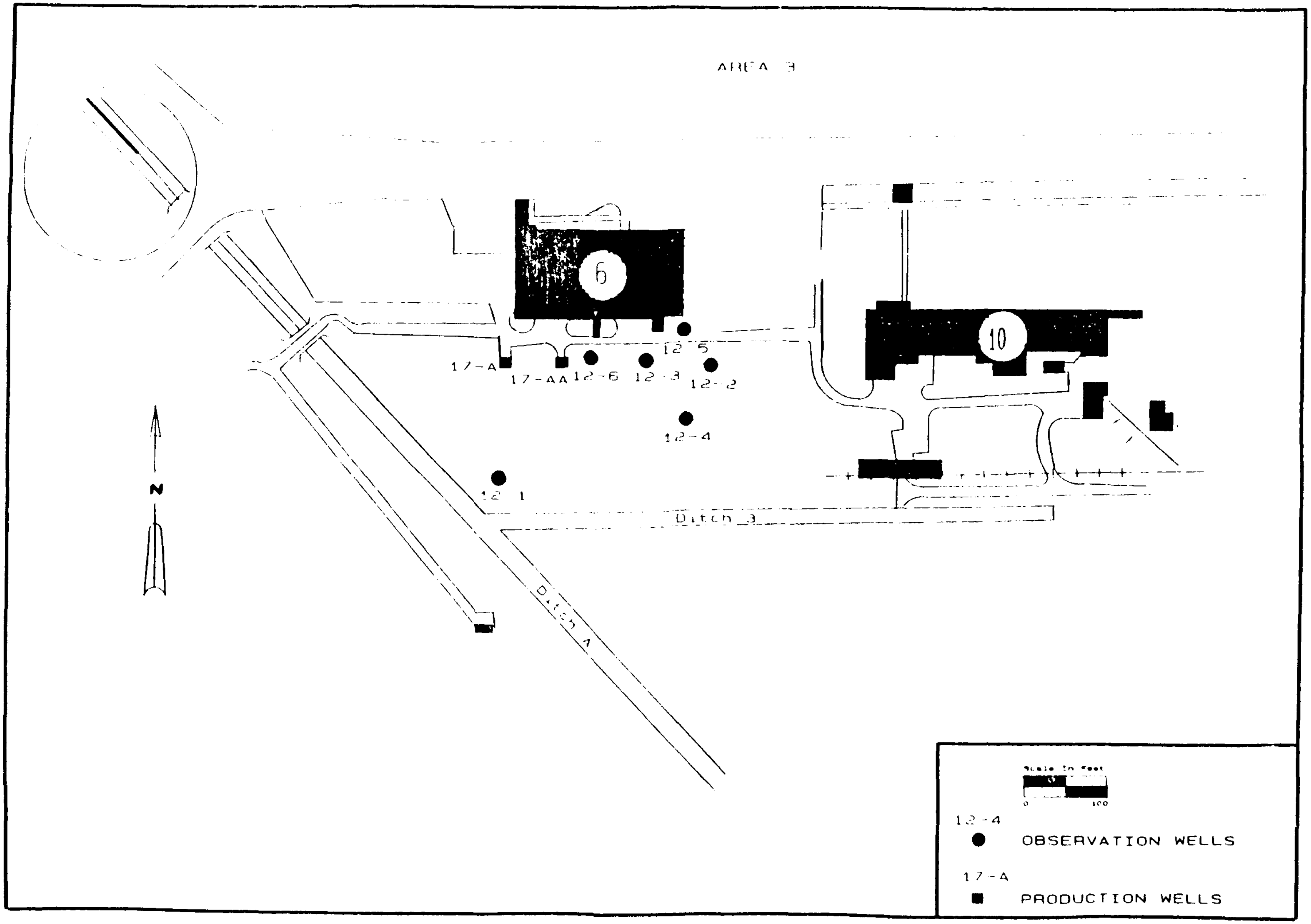


FIGURE 3-18
SITE MAP FOR PU[illegible]G TEST - AREA 12

a single In-Situ Hermit SE1000 unit was used at that wellhead with a transducer placed in the well.

The water from the pumping well was discharged approximately 300 feet away from the site to a roadside drainage ditch through a 6-inch hose. Prior to the final discharge point, the water was passed through an orifice weir consisting of a 6-inch steel pipe, the end of which was fitted with a 4-inch orifice plate to allow for accurate discharge measurements. The pumping test consisted of four tasks:

- Task 1 - Collection of static water level data.
- Task 2 - Step drawdown test.
- Task 3 - 72-hour constant discharge test.
- Task 4 - Measurement of recovery.

Prior to initiating the pumping test, static water levels were obtained on a continuous basis for 5 days from one shallow observation well (12-3) and one deep observation well (12-6). Static water level trends were used to evaluate impacts of external variables on water level fluctuations, in order to help prevent erroneous interpretations of drawdown curves.

To determine the optimum pumping conditions to sufficiently stress the aquifer, a step-drawdown test was performed prior to initiating of the 72-hour constant discharge test. The step-drawdown test consisted of pumping production well 17-AA at three separate discharge rates (100 gpm, 300 gpm and 500 gpm) for a period of approximately one hour per step. Based on water level measurements from the pumping well and observation wells, it was determined that the maximum discharge of approximately 500 gallons per minute (gpm) could be sustained during the constant-discharge phase of the test, thereby providing maximum hydraulic stress to the aquifer.

After allowing the aquifer to recover to static conditions, a 72-hour constant-discharge test was initiated at a discharge rate of 504 gpm. The transducers and the monitoring wells were programmed to obtain water level measurements on a logarithmic time scale, with a maximum interval between readings of 100 minutes. Water levels in the pumping well were obtained manually throughout the course of the test. The discharge rate was monitored using a manometer attached to the orifice weir. Published tables were used to determine the discharge rate based on the head measurement in the manometer. Manometer readings were obtained on 30-minute intervals throughout the course of the pumping test.

After 72 hours of pumping, the transducers were turned off and the data were transferred to a floppy disk. The units were reprogrammed for subsequent recovery measurements. After reconnecting the transducers, the pump was shut off and readings were simultaneously initiated to obtain recovery measurements. As with the pumping test, recovery measurements were taken on a logarithmic time scale with a maximum interval between readings of 100 minutes. Recovery measurements were collected for approximately 48 hours.

3.6.4.2 Analysis of Static Water Levels

The first step in evaluating the pumping test data was to plot the static water level data, which had been obtained for five days prior to the test, on an arithmetic plot of time versus water level. The plots obtained for the shallow and the deep well are shown in Figure 3-19. Two trends are apparent in the static water level data. The first trend is a very cyclic and abrupt change in water level. The second trend is a very gentle, long-term rise or fall in water level. These trends are more apparent in water levels obtained from the deep well (12-6) than the shallow well (12-3). The cause for the abrupt cyclical fluctuations in water levels was determined to be the surrounding production wells used during plant operation hours. The gradual rise and fall in water level was identified to be related to changes in barometric pressure, but not precipitation events. Each item is discussed in more detail below.

Effects of Surrounding Production Wells

To evaluate the water level fluctuations noted during static water level measurements, the pumping schedules for on-site production wells were obtained. A total of eleven production wells are located at the plant, of which eight were actively pumping at certain times during the five-day period of static water level measurements. This included eight pumping periods of production well 17-AA, which was located near the monitoring wells used for static water level data. The pumping cycles in relation to the water level measurements are shown in Figure 3-20. As expected, the impact of adjacent production well 17-AA is readily obvious from both the deep and shallow static water level data. Of particular interest, is the pumping sequence of four remote wells during the second day of static water data collection. During this time, production well 17-AA was not pumped, however, the impact of the four remote wells is clearly imprinted on the static water levels obtained from the deep monitoring well 12-6. It should be noted that this fluctuation was not observed in static water levels obtained from the shallow monitoring well. Based on these observations, it is apparent that the pumping from the remote wells impacted observed water levels from the base of the aquifer, in the vicinity of Area 12, by as much as 0.2 to 0.3 feet. Smaller fluctuations can also be related to the normal cycle of individual wells during an 8-hour pumping period (i.e., a well does not pump continuously throughout an entire shift).

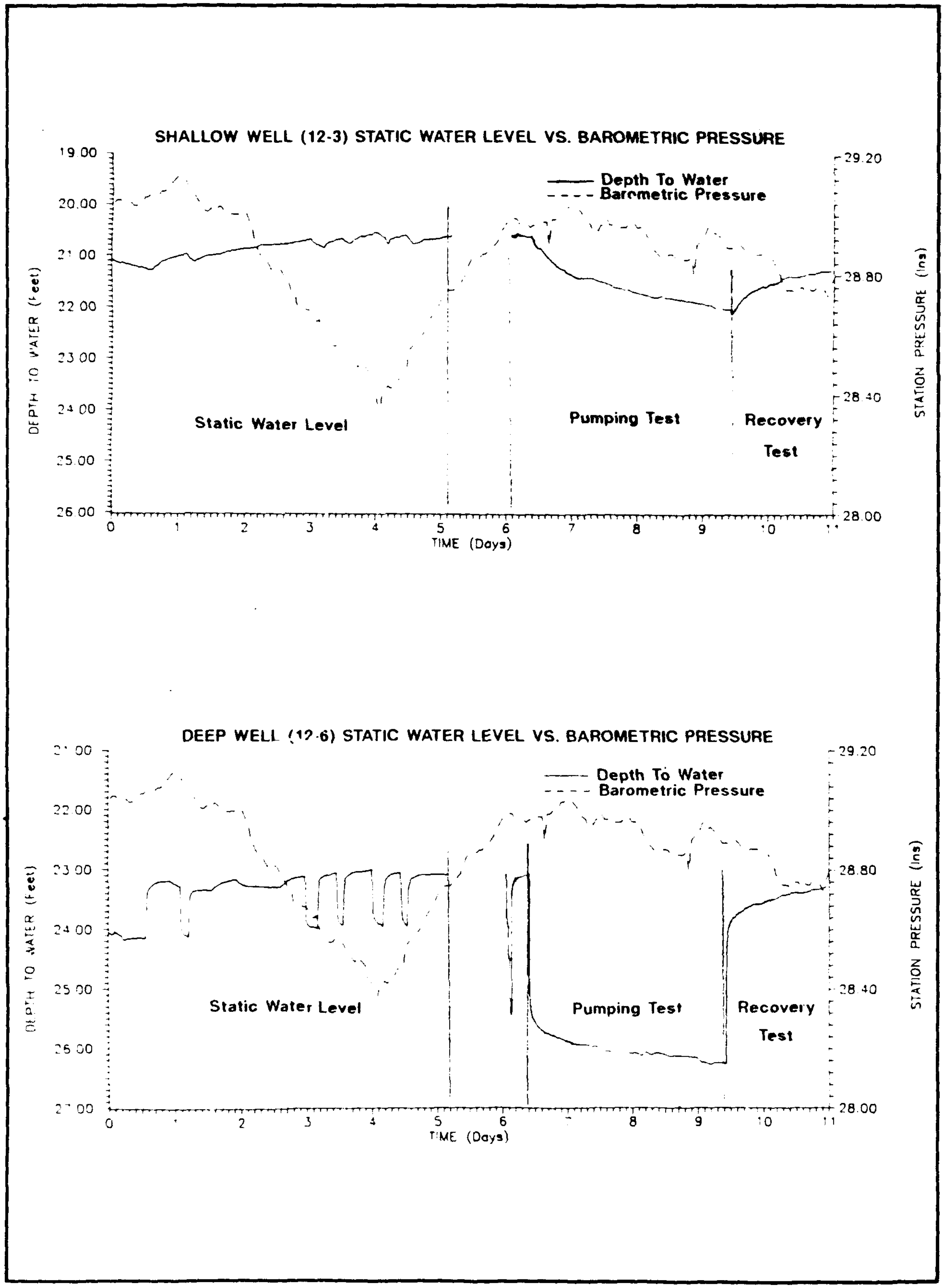
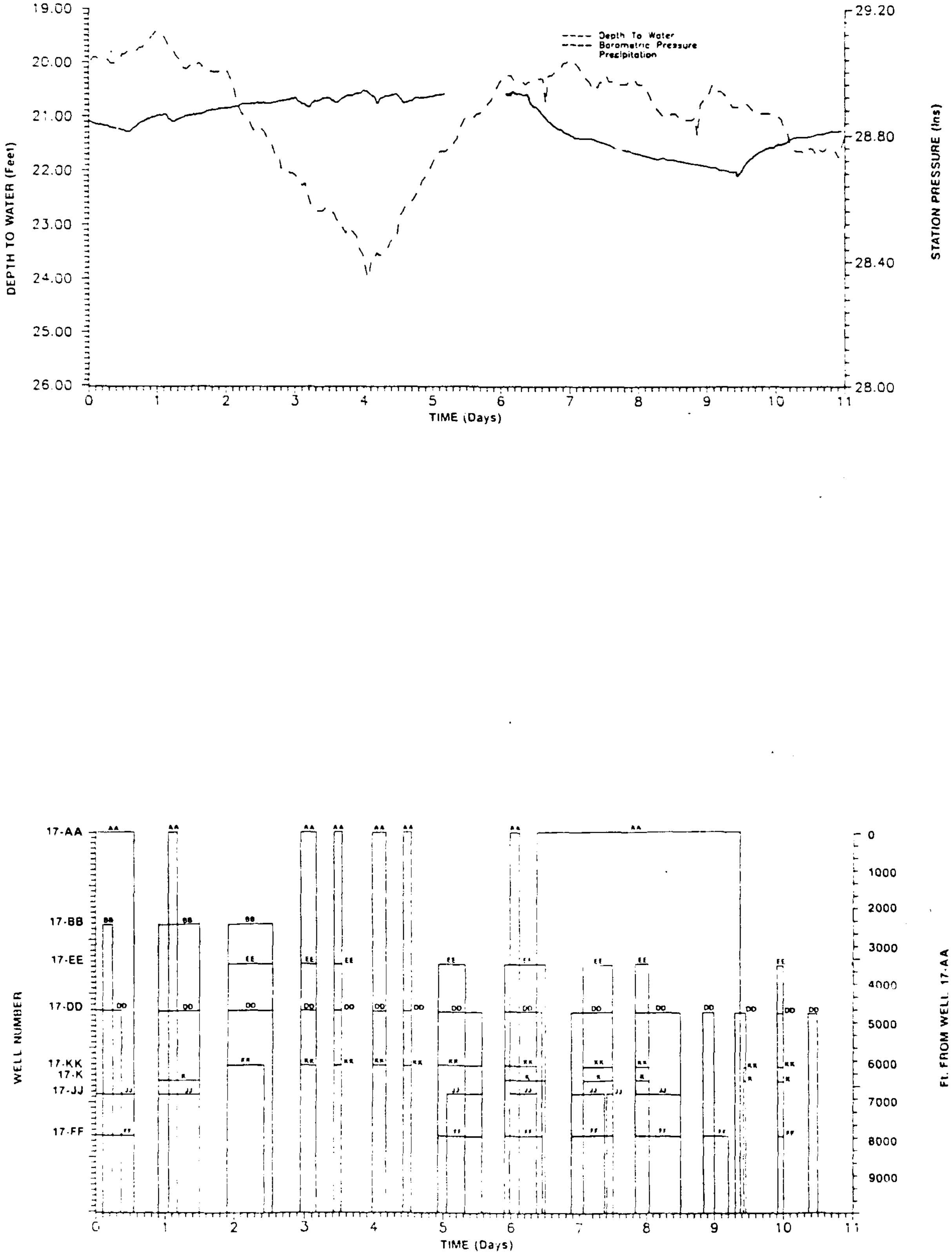


FIGURE 3-19 WATER LEVEL MEASUREMENTS FOR DURATON OF PUMPING TEST



SHALLOW WELL 12-3 STATIC WATER LEVEL VS. BAROMETRIC PRESSURE

FIGURE 3-20
PLANT PUMPING SCHEDULE IN RELATION TO WATER LEVEL MEASUREMENTS

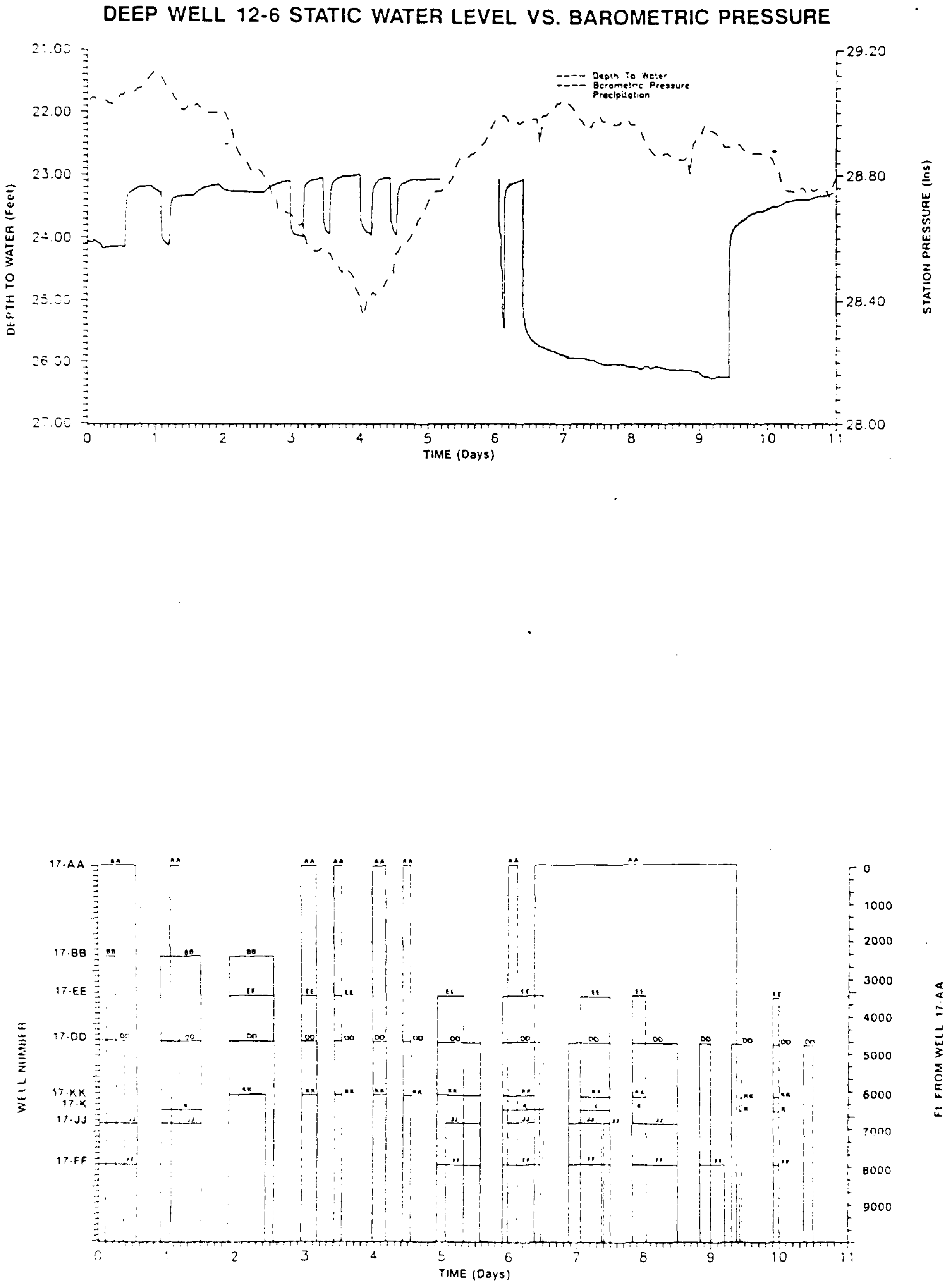


FIGURE 3-20(CONT.)
PLANT PUMPING SCHEDULE IN RELATION TO WATER LEVEL MEASUREMENTS

Effects of Barometric Pressure Changes

To evaluate the gradual rises and falls in static water levels, meteorological data was obtained for Independence, Missouri and the Kansas City Airport through the National Oceanographic and Atmospheric Administration (NOAA). A review of the precipitation records indicated only two minor precipitation events (0.05 and 0.61 inches) during the static water level measurements. These did not impact the noted water levels. There was no rain for over two weeks prior to the initiation of water level measurements.

Barometric pressure changes have been documented in the literature to affect water level measurements in confined and semi-confined aquifer systems. Barometric affects are generally dispersed and negligible in unconfined conditions. The two observation wells used for static water level measurements showed unconfined to semi-confined conditions based on boring log and water level data, (production well pumping has altered Area 12, from having confined to having semi-confined or unconfined upper aquifer conditions). Therefore, the potential affect of barometric changes on static water level measurements was evaluated. Hourly barometric pressure readings, for the entire duration of the pumping test, were obtained from the Kansas City Airport (the Independence, Missouri NOAA station does not keep detailed barometric pressure records). For the five days of static water level measurements, scatter diagrams were made for water level versus barometric pressure (Figure 3-21). Only water level readings which are believed to be unaffected by pumping of on-site production wells were chosen for the analysis. A regression analysis was performed to determine the correlation between the two variables. For the shallow well, a correlation coefficient (r) of 0.89 was calculated with 80% of the variance (r^2) being explained by the best-fit line. The relationship between the water level and barometric pressure in the deep well shows a correlation coefficient of 0.98 with a 95.6 percent explained variance.

As there appears to be a good relationship in changes between the barometric pressure and water level measurements, a determination was made of the maximum impact that observed barometric pressure changes could have had on water levels in both shallow and deep observation wells during the constant discharge and recovery tests. The maximum and minimum barometric pressure readings during the course of the 72-hour pumping test and 48-hour recovery test were determined to be 29.04 and 28.74 inches of mercury, respectively (Figure 3-19). Using the relationships defined between water level and barometric pressure, the noted range of barometric change could have a maximum impact of approximately 0.1 feet on water levels in shallow wells and approximately 0.2 feet on water levels in deep wells in the vicinity of the pumping test.

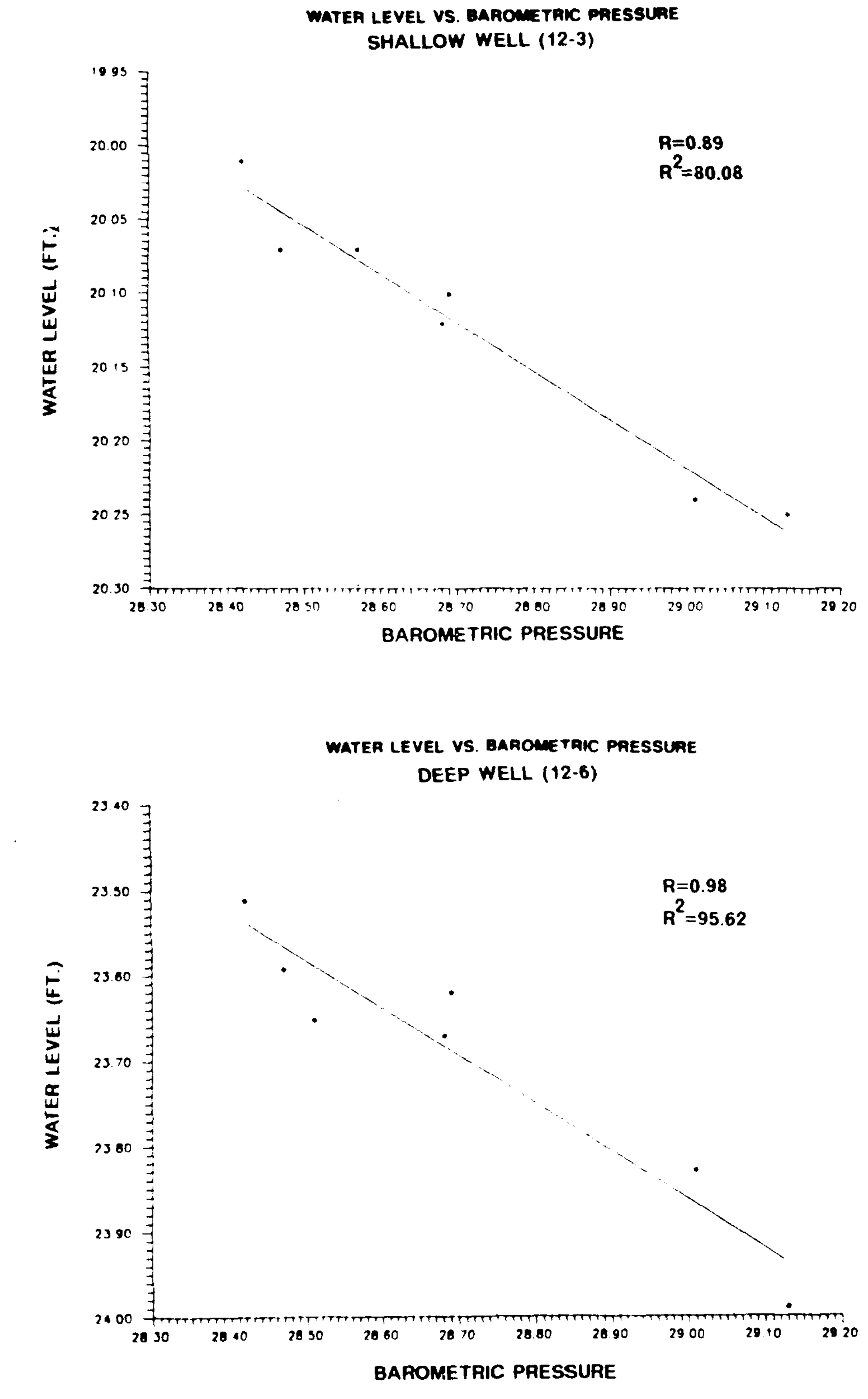


FIGURE 3-21 STATIC WATER LEVEL VS. BAROMETRIC PRESSURE SCATTER DIAGRAMS

Water level response to barometric pressure changes can also be used to estimate the aquifer coefficient of storage (S). The estimate of storage is based on the barometric efficiency (BE) calculated from the static water level data. Barometric efficiency (nondimensional) is defined mathematically as;

$$BE = \frac{wdh}{dPa} \quad \text{where,}$$

w = Unit weight of water
dh = change in head
dPa = change in atmospheric pressure

The barometric efficiency for shallow wells was determined to be approximately 0.29 and for the deep wells 0.008. Aquifer storage (S) was then estimated using the following relationship:

$$S = \frac{nBPwg}{BE} \quad \text{where,}$$

n = porosity
B = aquifer compressibility
Pw = density of water
g = gravitational constant

Assuming a porosity of 0.25 (Todd, 1959) and an average aquifer compressibility of 2.36 x 10^{-8} ft^2/lb. (Domenico, 1972), the coefficient of storage for the shallow portion for the aquifer is estimated to be approximately 1.3 x 10^{-6} and for the deeper portion for the aquifer 4.6 x 10^{-5}.

3.6.4.3 Pumping Test Data Analysis

Based on boring logs and water level observations from monitoring wells around the plant, a series of conceptual hydrogeologic models were developed with which to analyze the pumping test data. As shown in cross-sections presented in Figures 3-5 through 3-9 and discussed in Section 3.6.1 and 3.6.2, the potentiometric surface of the central portion of the upper aquifer was within the sand unit, suggesting unconfined to semi-confined conditions. The eastern portion of the plant showed the potentiometric surface within the clay unit suggesting confined conditions. The locations of the pumping test wells are within the transitional area between potentially unconfined and confined conditions where, depending on the seasonal water level variations, and local pumping rates, the aquifer could be under confined conditions or under semiconfined/unconfined conditions.

Data analysis was, therefore, initiated using four conceptual models:

- A An unconfined system.
- B A simple confined system with partially penetrating wells.
- C A leaky system with no release from storage of the confining layer and partially penetrating wells.
- D A leaky system with release from storage from the confining layer with partially penetrating wells.

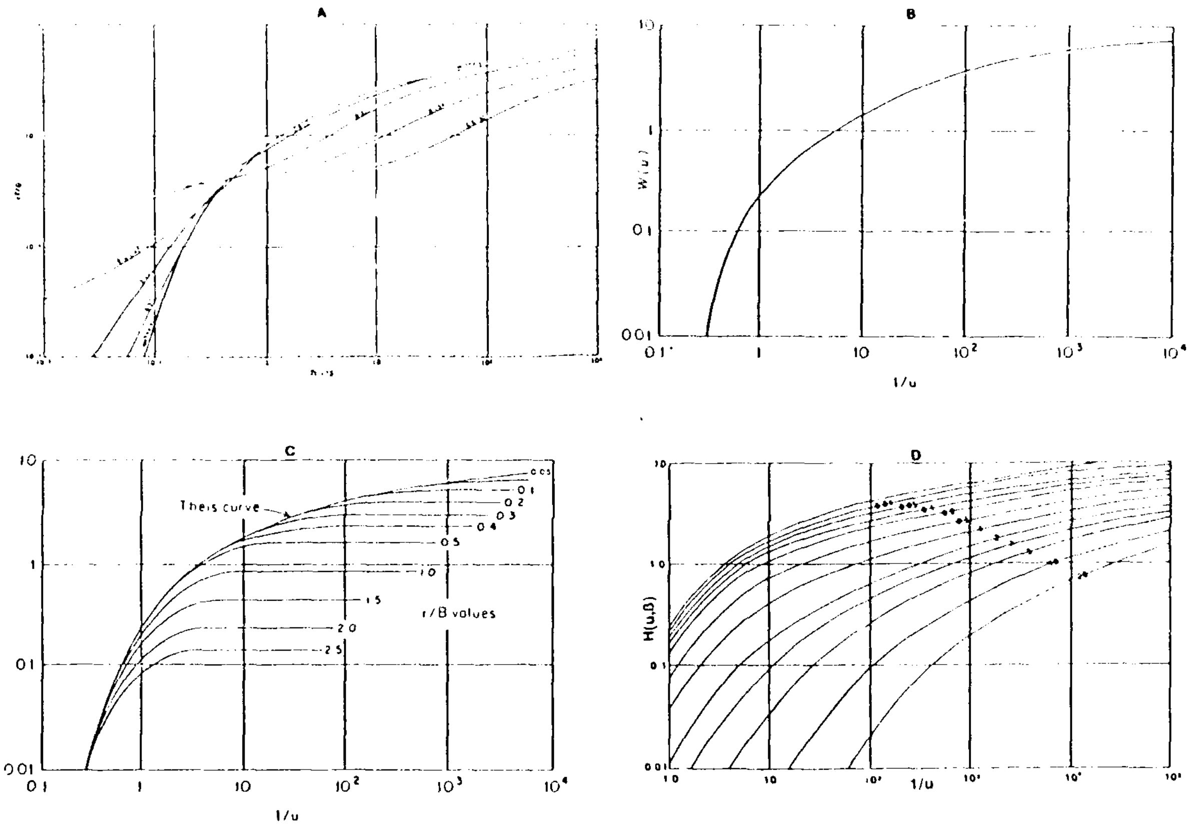
Type curves showing aquifer behavior for each model system are presented in Figure 3-22. All type curves except for curve set A (unconfined system curves) assume the ideal situation with fully penetrating wells. Appropriate mathematical adjustments were made to account for the specific partial penetration geometry of the pumping test. The type curve set A presented in Figure 3-22 already accounts for the effects of partial penetration.

For each monitoring well, drawdown was plotted vs. time on a log-log scale. The six drawdown curves are shown in Figure 3-23. An inspection of the drawdown curves indicates that the deeper portion of the aquifer (monitored by wells 12-6 and 17-A) is reacting differently than the shallow portion of the aquifer (monitored by wells 12-2, 12-3, 12-4, and 12-5) to the pumping of well 17-AA. Recovery curves mimic the drawdown curves. The upper and lower portions of the aquifer are discussed separately below.

Deep Monitoring Well Curves

The deep monitoring wells produced well developed curves typical of confined systems, however, the later portion of the curves flatten out relative to the ideal Theis situation which assumes non-leaky confined conditions with fully penetrating wells (Figure 3-22, curve set B). The slight fluctuations noted after the 1000-minute portion of the test are related to pumping sequences and changes in barometric pressure.

Although initial water levels from the wells suggested potentially unconfined conditions, comparing the shape of the drawdown curves to the type curves for unconfined conditions (Figure 3-22, curve set A) indicates that the response of the deeper portion of the aquifer is not that of an unconfined system. The curves are also not representative of a simple confined system as defined by the Theis curve (Figure 3-22, curve set B). The trends of the drawdown curves are best represented by the family of curves developed for a leaky confined system (Figure 3-22, curve sets C and D).



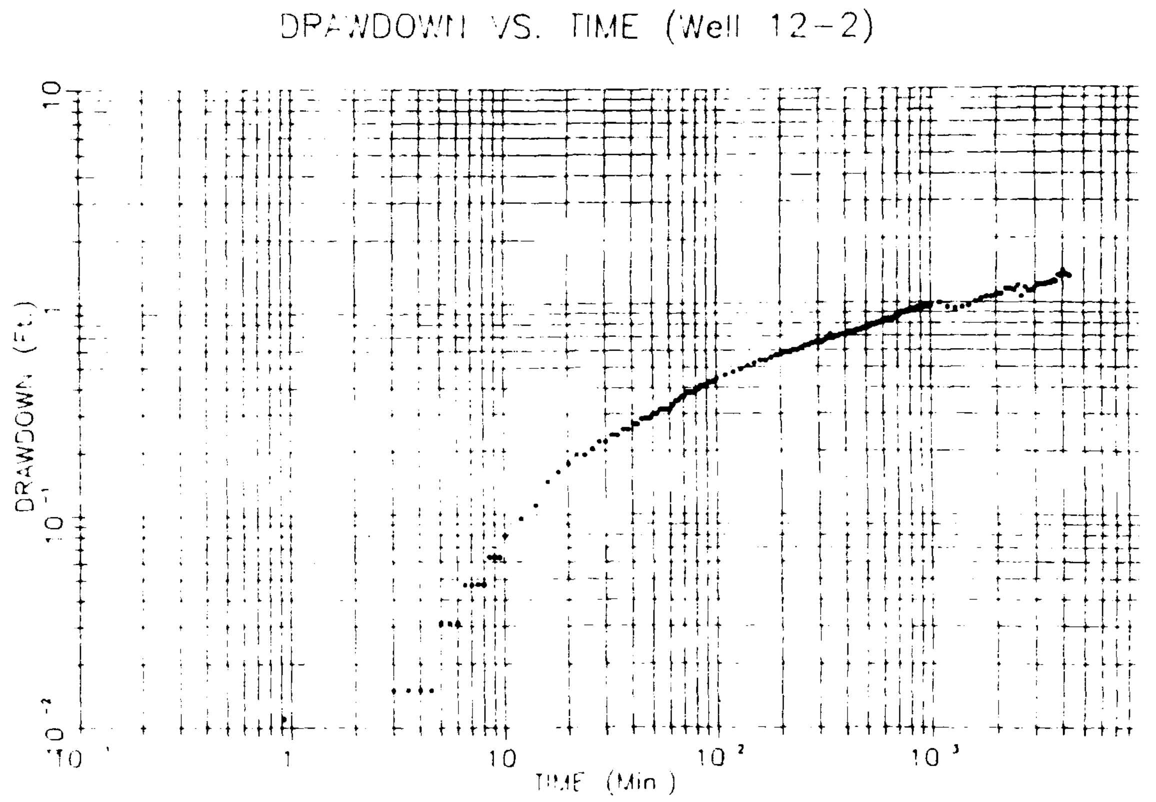
A · Type curves showing nondimensional response to pumping a well *penetrating the bottom three-tenths of an unconfined aquifer* with the observation well screened within the upper one-tenth of the aquifer. (Stallman 1965)

B · Theis curve for a simple confined system with fully penetrating wells.

C · Type curves for a leaky confined aquifer with fully penetrating wells and negligible aquitard storage.

D · Type curves for a *leaky confined aquifer with fully penetrating* wells and water being released from aquitard storage.

FIGURE 3-22
TYPE CURVES FOR FOUR CONCEPTUAL MODELS OF AQUIFER RESPONSE



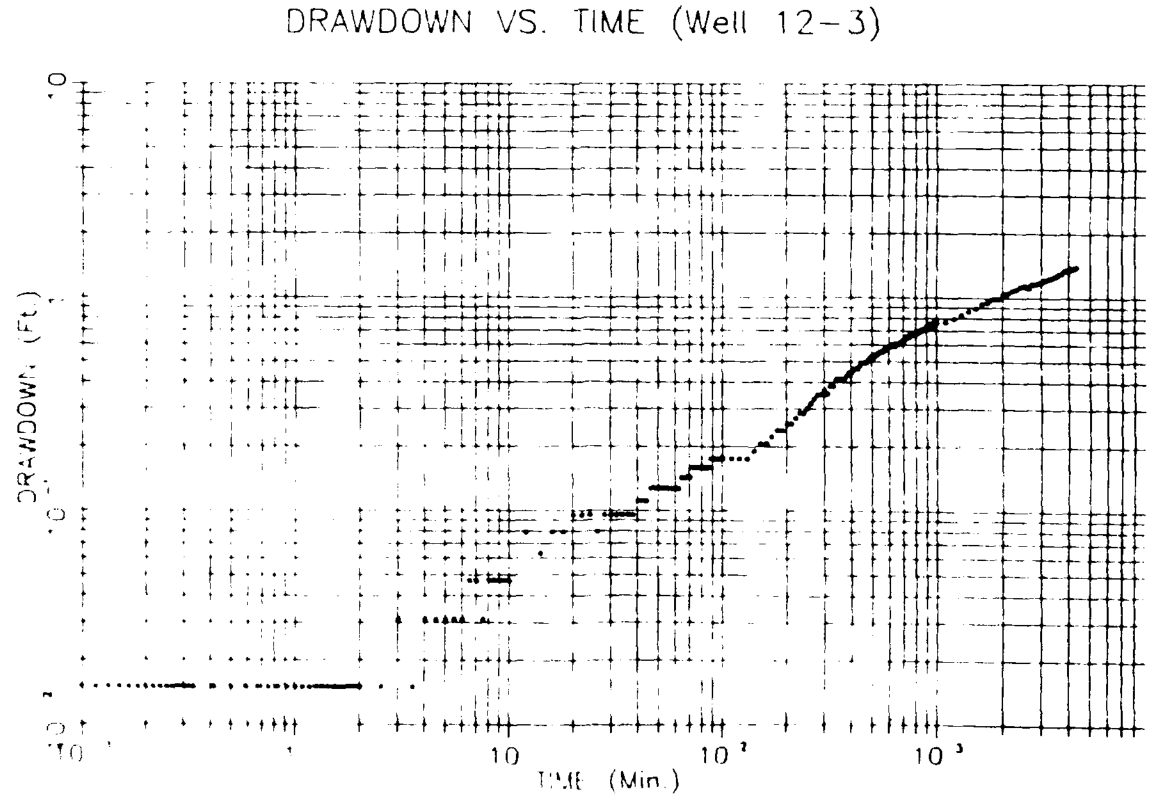
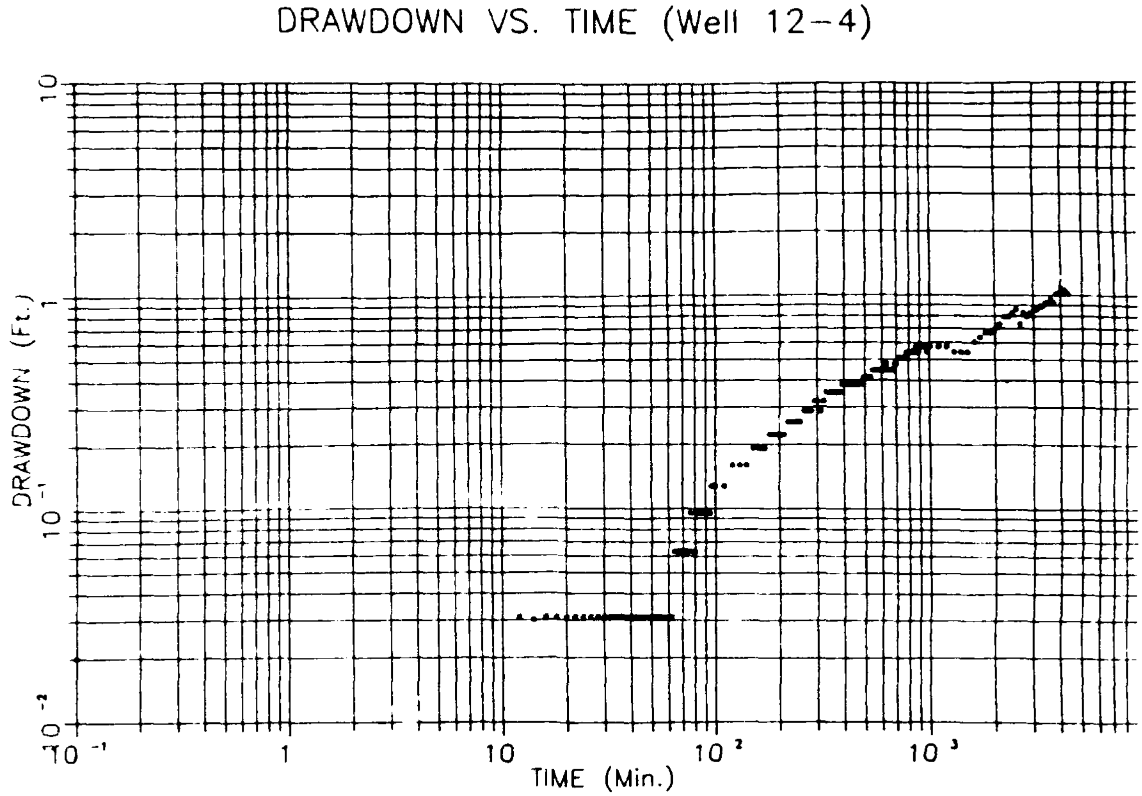


FIGURE 3-23 OBSERVATION WELL DRAWDOWN CURVES - SHALLOW WELLS



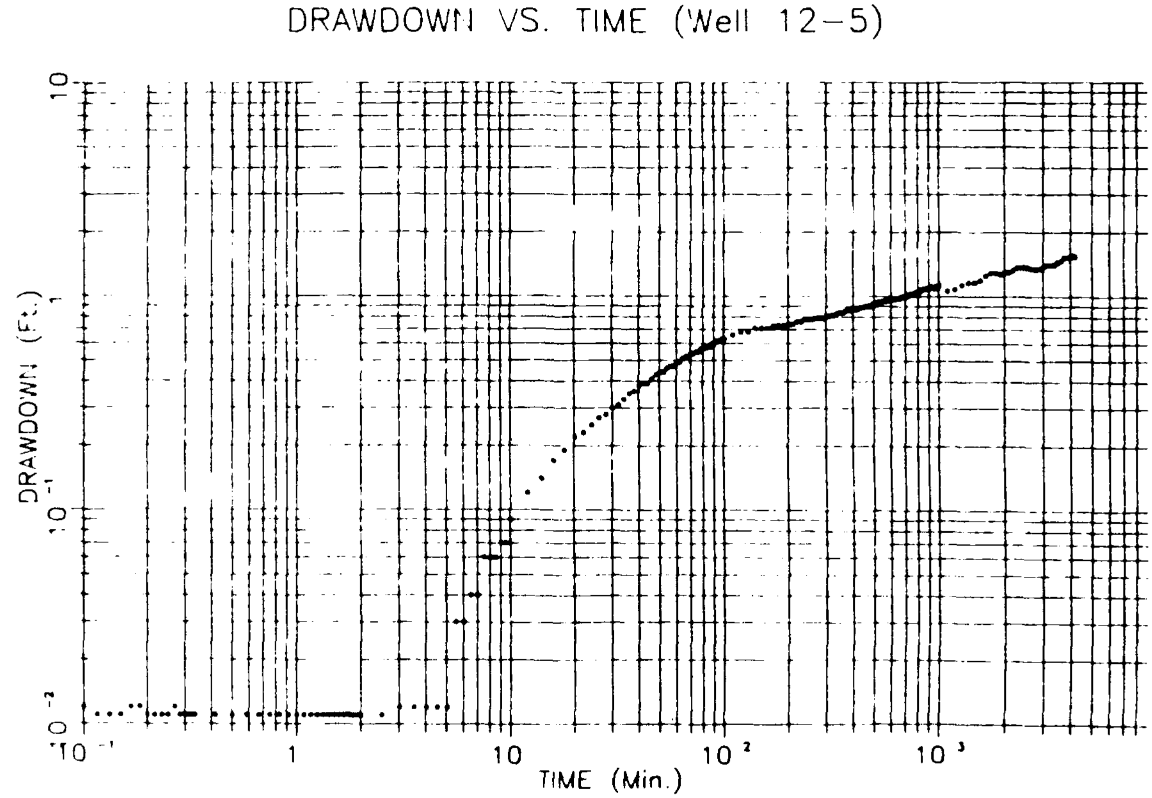
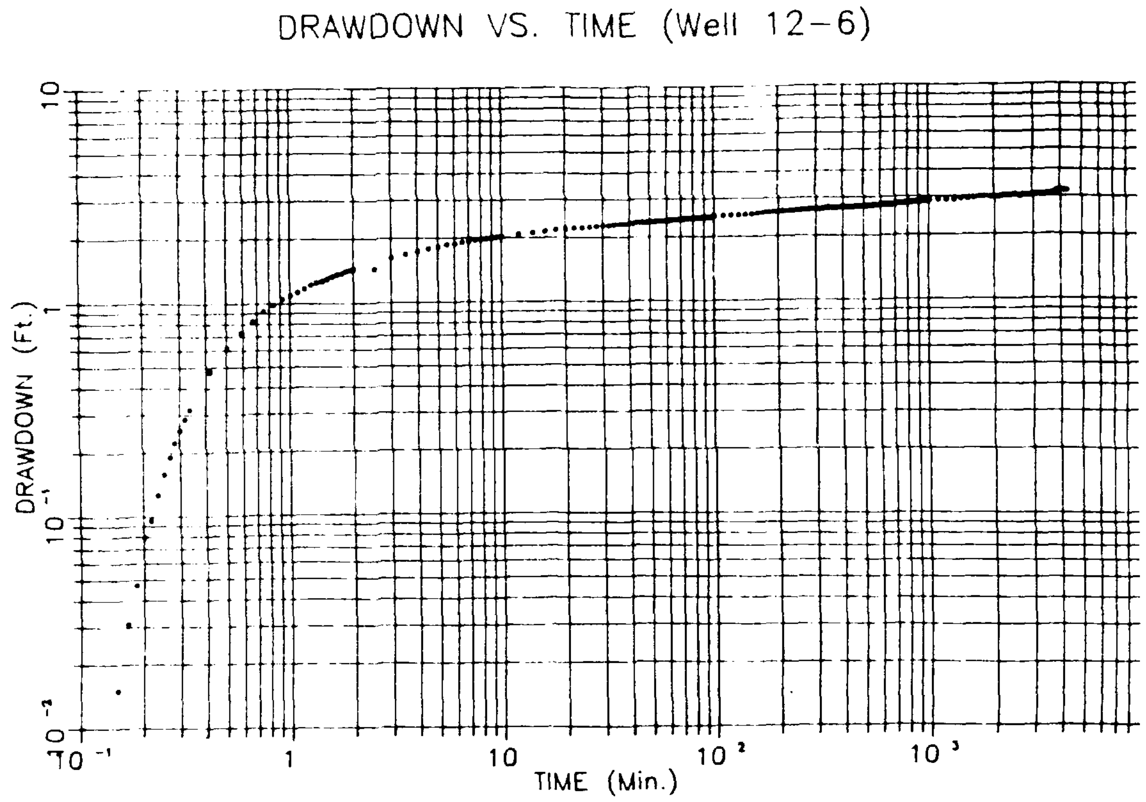


FIGURE 3-23(CONT.) OBSERVATION WELL DRAWDOWN CURVES - SHALLOW WELLS



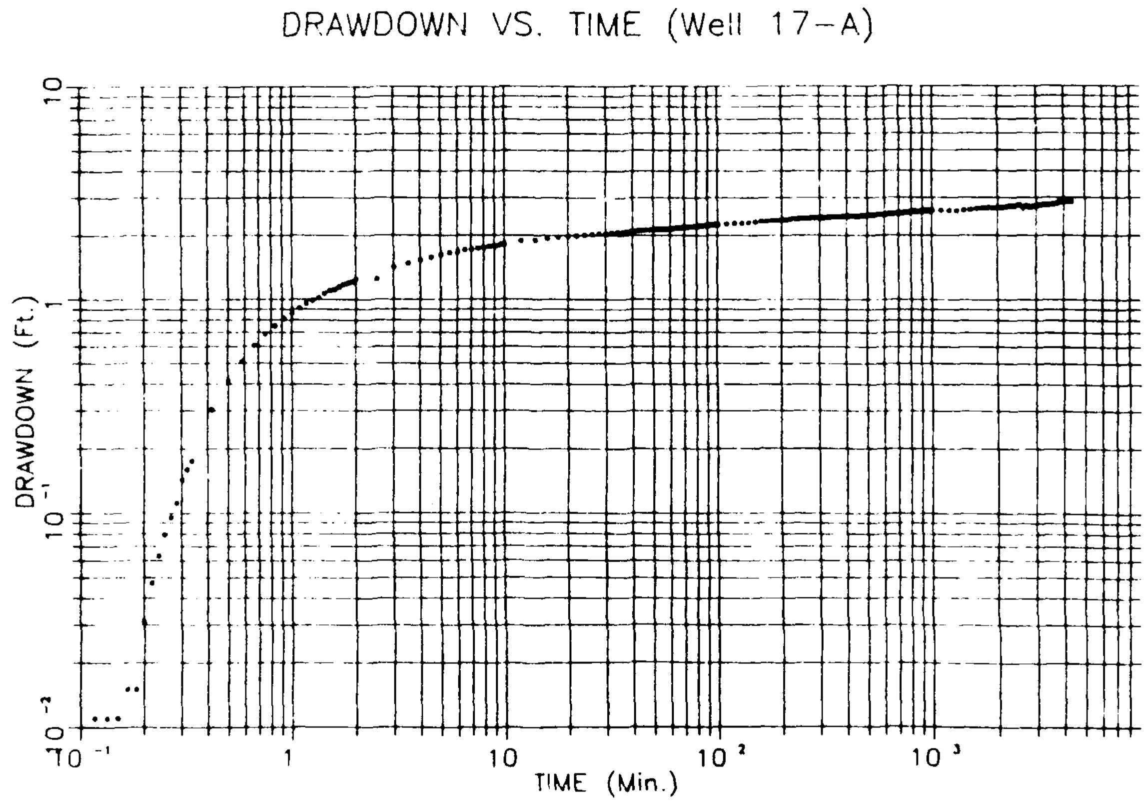


FIGURE 3-23(CONT.) OBSERVATION WELL DRAWDOWN CURVES - DEEP WELLS

Curve matching techniques were used to evaluate best fit matches in order to determine transmissivity and storage for the lower portion of the aquifer. The best fit match was obtained using the type curves for a leaky system with release from storage from the aquitard layer as illustrated in Figure 3-24. The transmissivity and storage values calculated for each well are given in Table 3-5. It should be noted, however, that the ideal leaky system for which the type curves were developed assumes fully penetrating production and observation wells. As neither the production well nor the observation well used during this pumping test were fully penetrating, a correction was made for the site specific partial penetration geometry using a relationship developed by Hantush (1964) and presented in Walton (1979) (refer to Appendix E).

Based on a best fit match to the partial penetration adjusted curve of $(r/m)(P_v/P_h) = 0.10$, transmissivity values were determined to range from 30,600 ft^2/day to 34,800 ft^2/day. Assuming an average aquifer thickness of 68 feet, permeability values range from 450 to 512 ft/day.

Storage coefficient values were calculated using the Theis relationship.

Storage coefficient values ranged from 5.03×10^{-5} to 3.03×10^{-5}. It should be noted that these storage coefficient values are in close agreement with the estimate of storage determined using the barometric efficiency data in Section 3.6.4.2.

Since the data best fit match was to the partial penetration adjusted curve for $(r/m)(P_v/P_h) = 0.10$, and knowing the values of r and m, the vertical to horizontal permeability ratio can be determined by rearranging the equation as follows:

$$\frac{P_v}{P_h} = \frac{m\ 0.10^2}{r}$$

For the lower portion of the aquifer in the vicinity of production well 17-AA, the vertical to horizontal permeability ratio was determined to range from 0.005 to 0.003 indicating strong preferential horizontal flow.

Shallow Monitoring Well Curves

The curves for shallow monitoring wells (12-2, 12-3, 12-4, and 12-5) appear quite different in shape from those of the deep monitoring wells. In general, the early portion of the curves are less steep and the later portion of the curves do not flatten out as noted in the deeper wells. The curves for monitoring wells 12-3 and 12-5 both show an inflection point at approximately 150 minutes, which is not related to other on-site pumping activities. This is not a boundary effect as it is not noted in either deep

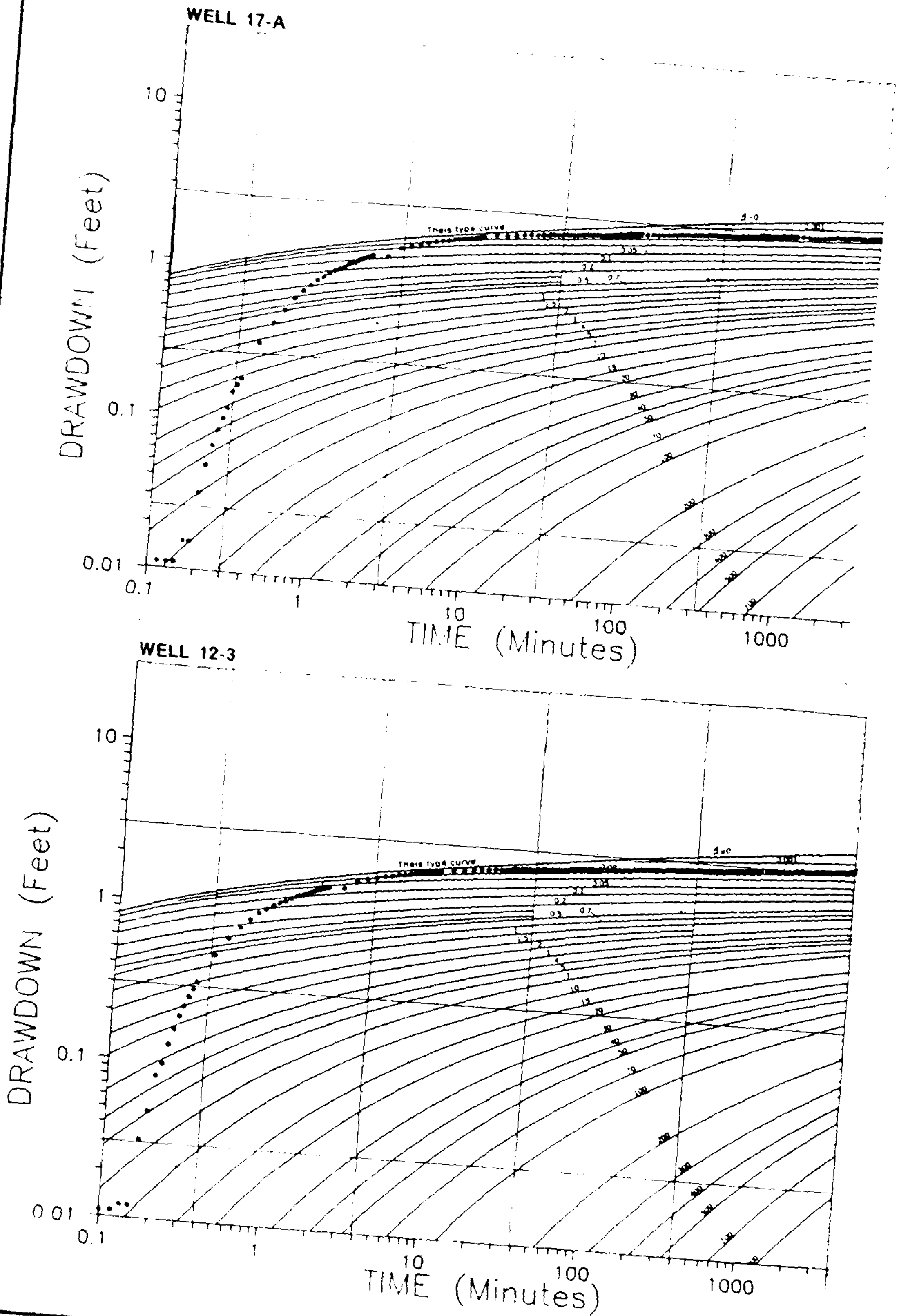


FIGURE 3-24 BEST-FIT MATCH FOR DEEP WELLS USING TYPE CURVES FOR A CONFINED LEAKY SYSTEM WITH WATER BEING RELEASED FROM AQUITARD STORAGE

TABLE 3-5

SUMMARY OF AQUIFER CHARACTERISTICS

Based on curve matching to type curves for a confined leaky system with release from aquitard storage. Values given for an ideal system with fully penetrating wells and for site specific partial penetration effects.

Well No.	Transmissivity (ft^2/day)		Permeability (ft/day)*		Storage (dimensionless)	
	Fully Penetrating	Partial Penetrating	Fully Penetrating	Partial Penetrating	Fully Penetrating	Partial Penetrating
Deep Wells						
12-6	23,400	30,600	344	450	3.84×10^{-5}	5.03×10^{-5}
17-A	26,600	34,800	391	512	2.31×10^{-5}	3.03×10^{-5}
Shallow Wells						
12-2	26,300	21,700	387	319	0.004	0.003
12-3	8,000	6,800	118	100	0.021**	0.183**
12-4	17,200	14,500	253	213	0.046	0.039
12-5	18,000	15,200	265	224	0.005	0.004

* Assumes an average aquifer thickness of 68 feet.

** Calculated based on t_o from match to early part of curve.

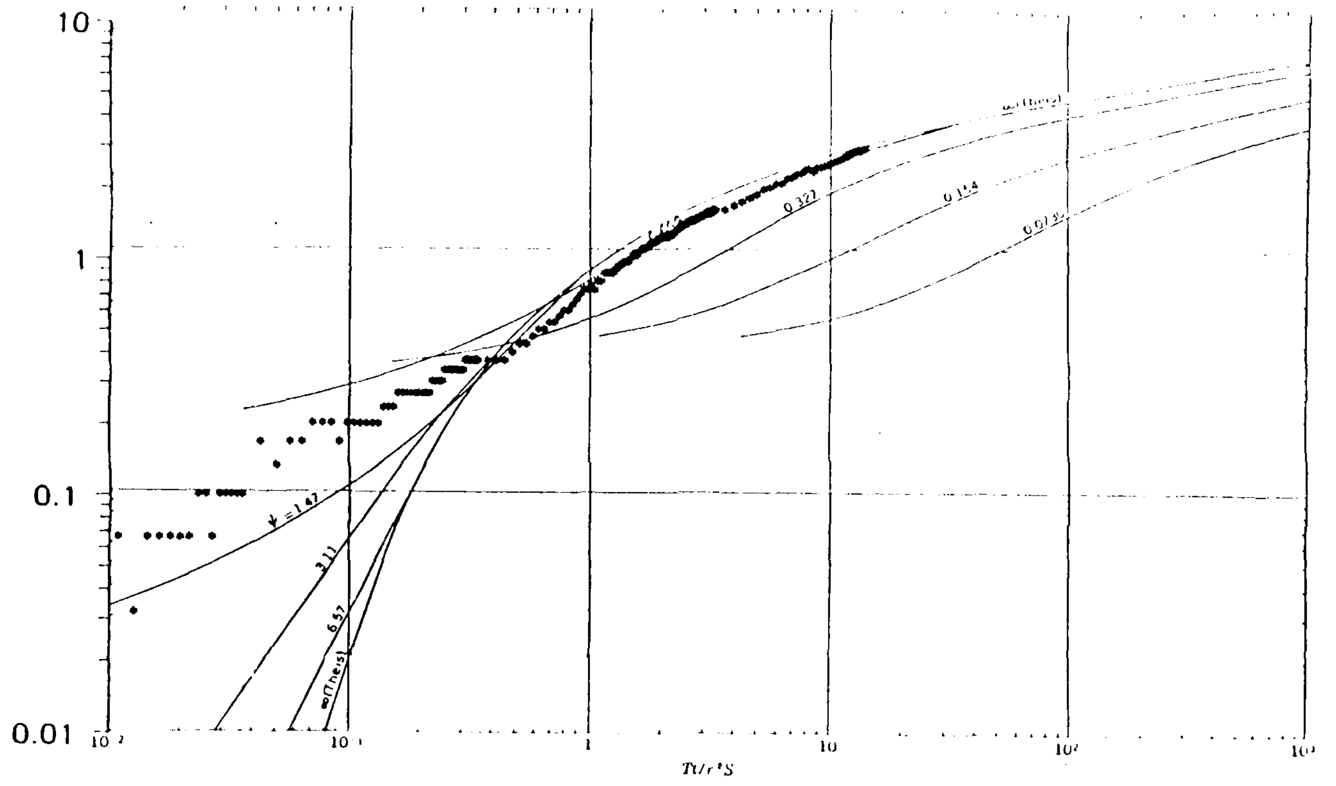
wells or other shallow monitoring wells. In addition, the change in slope is different for both wells. In well 12-3, there is an increase in the rate of drawdown between the early portion of the curve and the later portion of the curve. In well 12-5, there is a decrease in the rate of drawdown.

As previously discussed, based on static water levels from these monitoring wells, the aquifer at these locations may be under "apparent" unconfined conditions, however, based on the drawdown curves, the aquifer does not behave as an unconfined system. The only monitoring well showing a drawdown curve which may be reflective of unconfined conditions is that of well 12-3. The lower rate of drawdown at the early portion of that curve could be interpreted as an effect of delayed yield. This trend is not readily apparent in drawdown curves from wells 12-2 and 12-4. An opposite trend to that expected for unconfined conditions is noted in 12-5.

Drawdown data from well 12-3 were matched to the unconfined-aquifer type curves of Stallman (1965). These curves show nondimensional response to a pumping well penetrating the bottom three-tenths of an unconfined aquifer with an observation well in the upper 90 percent of the aquifer. The applicable Stallman curves are shown in Figure 3-25 with the best fit match for well 12-3 included on the figure. Although transmissivity values calculated from these curves were generally reasonable (5,700 to 25,800 ft^2/day), storage coefficient values were unreasonably high. The storage values for well 12-3 was calculated in excess of one, which is not physically possible.

Based on these results, it was concluded that the aquifer did not behave as if it were unconfined. Therefore, the drawdown curves for shallow monitoring wells were also matched to type curves for other conceptual models proposed for the aquifer. Despite the difference in appearance between the curves for shallow monitoring wells and deep monitoring wells, the best fit matches were obtained using the curves for a leaky aquifer system with release of storage from the confining layer, as shown in Figure 3-26. Based on a best fit match to the partial penetration adjusted curve for (r/m) x (P_v/P_h) = 0.80, transmissivity and storage values calculated for the shallow portion of the aquifer are summarized in Table 3-5. Transmissivity values were found to range from 6,800 ft^2/day to 21,700 ft^2/day. This results in a range of permeabilities from 100 ft/day to 319 ft/day. These values are generally slightly lower than those calculated from the deeper portion of the aquifer and may reflect the general coarsening downward trend noted in boring logs from this portion of the aquifer.

The storage coefficient values calculated for the upper portion of the aquifer ranged from 0.004 to approximately 0.05. The vertical to horizontal permeability ratios for the upper portion of the



Type curves showing nondimensional response to pumping a well penetrating the bottom three-tenths of an unconfined aquifer with the observation well screened within the upper one-tenth of the aquifer. (Stallman 1965)

FIGURE 3-25 BEST-FIT MATCH FOR WELL 12-3 WITH TYPE CURVES FOR UNCONFINED SYSTEM

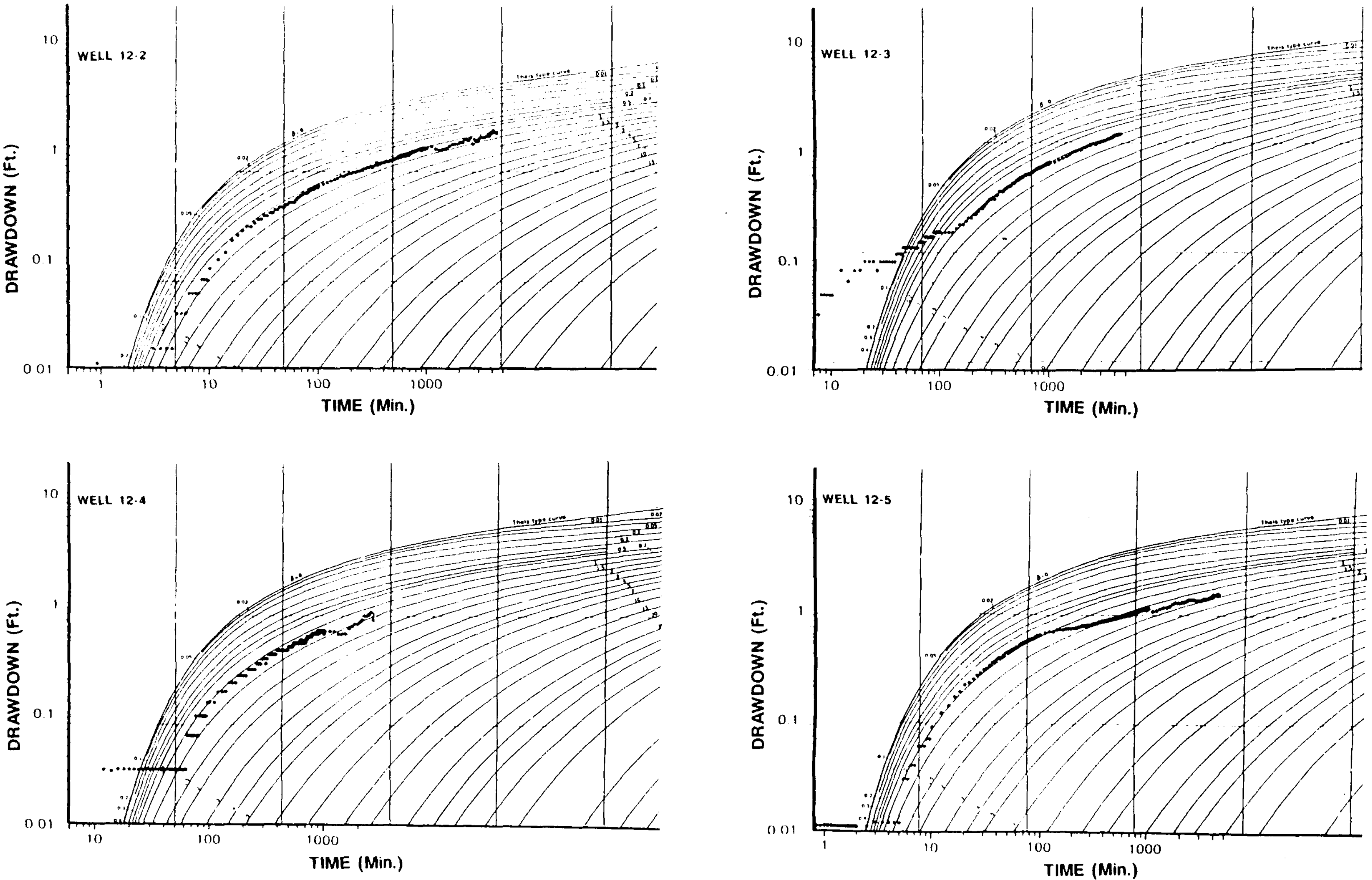


FIGURE 3-26
BEST-FIT MATCH FOR SHALLOW WELLS USING TYPE CURVES FOR A LEAKY SYSTEM WITH WATER BEING RELEASED FROM AQUITARD STORAGE

aquifer in the vicinity of production well 17-AA were calculated to generally range from 0.02 to 0.04, again suggesting a preferential horizontal component of flow. A ratio of 0.95, however, was calculated for well 12-3. This value is believed to be unrepresentative due to the proximity of this well to the production well and the transitional nature of the aquifer as discussed further below.

The storage values in the upper portion of the aquifer were substantially greater than the storage coefficient values calculated for the deeper portion of the aquifer and also greater than the estimate of storage in the shallow portion of the aquifer based upon barometric efficiency calculations. To compare the relative storage coefficient values, and negate the potential effect of radial distance from the pumping to the observation well, drawdown was plotted versus r^2/t for each well (Figure 3-27). This figure shows that the range in storage coefficient values is up to three orders of magnitude. The smallest storage values are from wells 12-6 and 17-A, both of which monitor the lower portion of the aquifer. The highest storage value is from well 12-3, which is essentially the same radial distance from the pumping well as observation wells 12-6 and 17-A; however, well 12-3 monitors the upper portion of the aquifer. This suggests that the difference in storage values is either the result of aquifer anisotropy or an external factor such as well hydraulics or long-term pumping effects. It is believed that the storage coefficient values for the lower portion of the aquifer (4.2×10^{-5} to 2.6×10^{-5}) are more representative of true aquifer conditions. The storage coefficient values obtained from curve matching of shallow monitoring well data may reflect the unique transitional situation between unconfined and confined conditions.

The transitional nature of the aquifer at this location is highlighted by the discrepancy between the initial water levels in monitoring wells, which suggested unconfined conditions, and the actual aquifer response to stress which indicated confined leaky conditions. A potential explanation for the discrepancy may be associated with the long-term withdrawal of water from the aquifer for plant production operations. The hydrostatic pressure within the upper portion of the aquifer may have been reduced to less than atmospheric pressures, which would yield an artificially low water level in the observation well. Under such conditions, the aquifer could still be completely saturated and, therefore, under confined conditions, with the water level in the well being below the base of the aquitard showing an "apparent" unconfined condition.

As the purpose of this pumping test analysis was to define aquifer characteristics for potential subsequent modeling, a more detailed analysis of the hydrogeologic system, to account for the transitional nature of the aquifer, may not be necessary at this point. The bracketed values for transmissivity, storage and

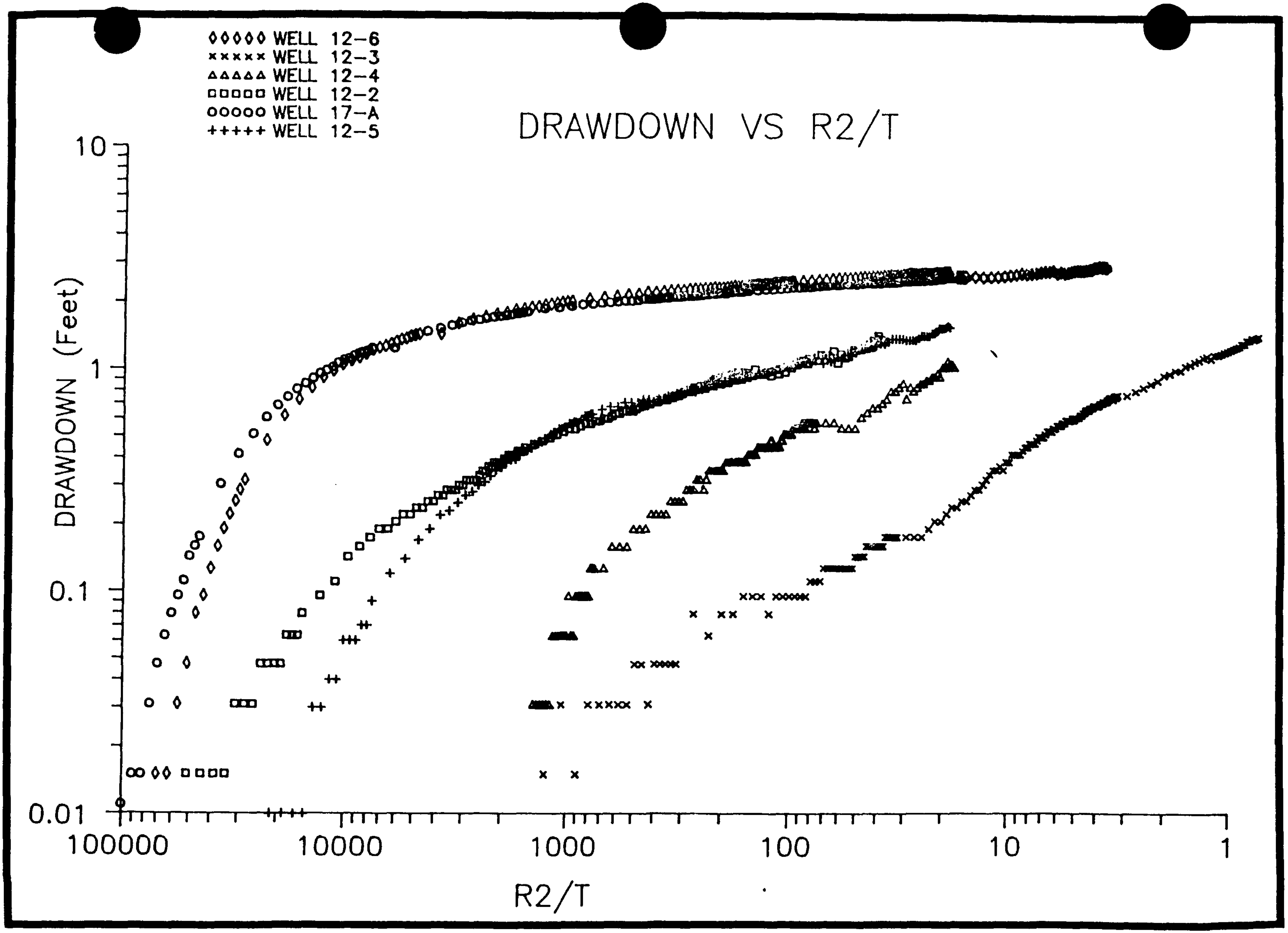


FIGURE 3-27
DRAWDOWN VS R2/T

permeability for the upper and lower portions of the aquifer are sufficient for the intended use of the data.

3.6.5 Production Well Capture Zones

LCAAP receives its water supply from the alluvial sand aquifer. The plant currently has a network of 11 production wells screened at the bottom of the alluvial valley. The standard operating practice is to alternate the pumping of these wells between 500,000 to 1,400,000 gallons per day. Appendix D (Geotechnical) presents the pumping rates for a 30 day period. As a result of pumping, a capture zone is created for each well. A capture zone results from the superposition of a cone of drawdown and a planar, sloping potentiometric surface. All groundwater within a capture zone is eventually drawn into the well. A computer program was used to define the edges of capture zones, based on a method described by Todd (1959). This program assumes the production wells are completely penetrating a confined, homogeneous and isotropic aquifer and does not take into account the boundary effects created by the alluvial valley.

The extent of each of the capture zones was predicted for nine of the most frequently used production wells. The conceptual model was run assuming a period of 8 hours and at pumping rates typical for each production well. The resulting capture zones for each production well were then drawn onto the contour map. Figure 3-28 identifies the estimated capture zones within the sand aquifer. The nine capture zones intercept practically all groundwater flowing through the alluvial valley. The only areas at the plant where potential contaminants may migrate off site is at Areas 3, 8, 16, and 17.

3.7 NATURAL RESOURCES

The economic natural resources of Jackson County are widely varied and include:

- Shale deposits.
- Crushed and broken limestone.
- Sand and gravel.
- Oil and gas.
- Water resources.

Shale from the Pennsylvanian Pleasanton Group is used in the production of red face brick. These shale deposits crop out throughout Jackson County and range from 30 to 60 feet thick. These raw materials supply a brick manufacturing company in Raytown, which is located approximately 15 miles southwest of the LCAAP.

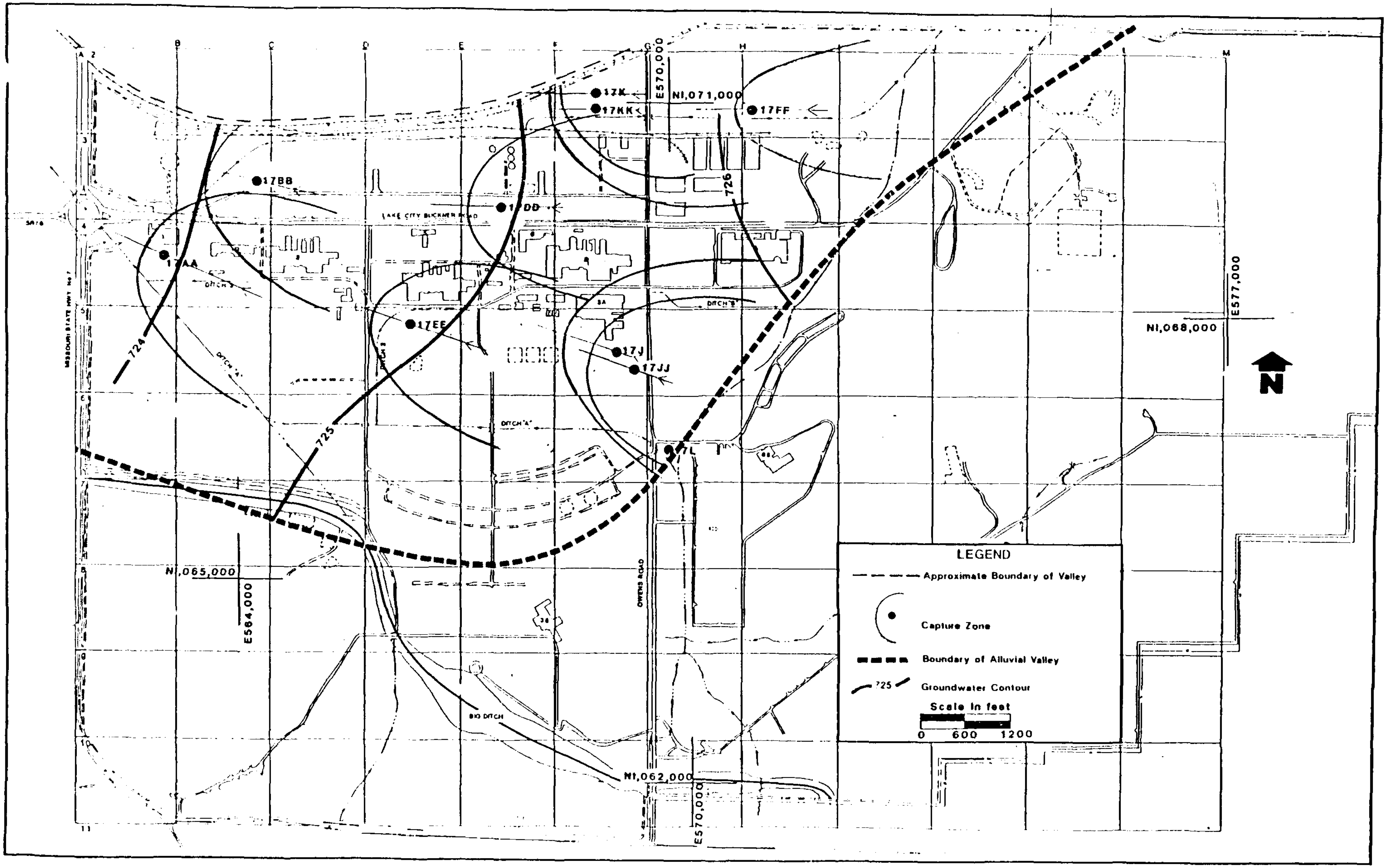


FIGURE 3-28

PRODUCTION WELL GROUNDWATER CAPTURE ZONES

Crushed or broken limestone has been a major economic mineral resource in Jackson County since the early 1900s. Limestones of middle Pennsylvanian age are mined for use as concrete and asphalt aggregate, riprap and agriculture lime.

Random sand and gravel deposits continue to be excavated throughout the county and reserves are considered abundant in the alluvial channels. Excavation of alluvial sand has occurred in the past at LCAAP.

Older Pennsylvanian strata have continued to produce low to moderate amounts of oil and natural gas since the early 1900s. The significant reserves are located near Lees' Summit approximately 7 miles southwest of the LCAAP, where the producing zone is known as the Longview Pool.

The groundwater and surface water resources of Jackson County are also important natural resources, supplying water for a variety of uses, including irrigation, livestock, industry and municipal supply (U.S. Geological Survey, 1967). Water supplies are discussed further in Section 3.8.

3.8 WATER SUPPLIES

Jackson County receives water from three sources: surface water, consolidated Pennsylvanian and Mississippian age bedrock aquifers, and unconsolidated sand and gravel aquifers. Jackson County is located in the Mineralized-Groundwater Province of west-central Missouri.

Water acquired from the Missouri River and other surface water bodies is the most frequently utilized water supply source within Jackson County. Kansas City uses the Missouri River water as its municipal water supply.

Groundwater from Pennsylvanian bedrock aquifers and from deeper bedrock aquifers in Jackson County are often highly mineralized and are generally unfit for most purposes. (Missouri Department of Natural Resources, 1986).

In contrast, the water from the unconsolidated Quaternary age aquifers is of much better quality. These aquifers have higher yield rates than those in the bedrock, and production costs are lower. Therefore, the unconsolidated aquifers are the dominant source of groundwater in Jackson County.

Communities not connected with the Kansas City municipal water supply have water supplies primarily derived from wells within the alluvial aquifer. The towns of Independence, Blue Springs, and Buckner are supplied with groundwater from 32 wells located in Independence, as reported in 1969. The Independence system does not supply the town of Lake City, nor does Lake City have a centralized municipal supply system. A few Lake City residents and nearby farms may receive their water supply from the alluvial aquifer. Typical residential wells yield between 10 and 30 gallons per minute and may, in some cases, be seasonally dry. Based on data from the Kansas City area, municipal well yields are between 500 and 1,500 gallons per minute and average about 1,000 gallons per minute (U.S. Department of Agriculture, 1984).

LCAAP receives its water supply from the alluvial sand and gravel aquifer. The plant has a network of 11 production wells screened at the bottom of the alluvial sand and gravel valley. The standard operating practice is to alternate the pumping of these production wells which yield a production rate of between 500,000 to 1,400,000 gallons per day.

3.9 DEMOGRAPHY AND LAND USE

LCAAP is located in a rural section of northeastern Jackson County, Missouri, approximately 4.5 miles northeast of Independence and 3 miles north of Blue Springs (Figure 1-1). Lake City and Buckner are two small communities located within close proximity to the plant. Lake City consists of a few single family residences along the northern boundary of LCAAP. Buckner is located approximately three miles northeast of LCAAP. No major industrial facilities exist in the local area except for the ammunition plant operations.

The site occupies approximately 3,909 acres, or 6.18 square miles, and is bordered on most sides by woodlands or agricultural land. The site itself was originally used as farmland. Eleven dwellings are located on the southwestern portion of the site, along Truman Road, and are used for military personnel residences.

As of October 1986, Jackson County, Missouri had an estimated population of 636,400 and the nearby communities Buckner and Blue Springs had populations of 3,040 and 33,230, respectively (U.S. Census Bureau Statistical Inquiries Division, 1980). Besides the 11 on-site residences, the majority of the population within one-half mile of the site resides in the small community of Lake City. Lake City is located north of the plant. An estimate of the number of people living within one-half mile of LCAAP is approximately 300.

Regional farmland is used for crops, orchards, and cattle grazing. Crops typical for the area are soybeans, wheat, and corn. Hilly land to the west and south of LCAAP is presently utilized for apple orchards. Prior to 1988, much of the unindustrialized flat land on the installation was leased for both crop production and beef cattle grazing. This practice has been discontinued and currently no LCAAP property is being used for grazing or crop production. Some southern and eastern parts of LCAAP are currently used for recreational and wildlife habitat purposes. A small lake is used for fishing, and numerous deer and wild turkeys inhabit the area. During the hunting season, limited hunting for deer and turkey is permitted at LCAAP.

Nature and Extent of Contamination

SECTION 4

NATURE AND EXTENT OF CONTAMINATION

The remedial investigation performed at the LCAAP was conducted to evaluate the potential extent and magnitude of contamination both plant-wide and at 18 individual sites. The information was also collected to evaluate the potential risk to the environment and public health and welfare. In order to achieve these objectives, a technical approach to address contamination was identified and conducted. The results of those investigations are presented in this section.

Evaluation and Presentation of Analytical Data

In order to evaluate the analytical data collected during the RI, established standards, background results, and/or statistical criteria were used.

Many inorganic constituents are naturally occurring in the environment; thus, an evaluation procedure was needed to indicate whether a detection was potentially a site-related contaminant. Three methods were used to evaluate whether or not a parameter was a site-related contaminant. The first method used multiple background sample locations and the Student t-test to determine whether the sample measurement was statistically greater than the background measurement. Such a detection will be termed statistically above background in this report. The second method employed a single background sample location and involved a direct comparison of analytical results. This method was used to evaluate on-site surface water quality, because only one background surface water location was available for comparison (SW-16). The third method compared the detected values to the following established standards: the Federal Drinking Water Maximum Concentration Limit (MCL), the Missouri Groundwater Standard (MGS), and the Missouri Drinking Water Standard (MDWS). These limits would not necessarily be site-related. If a surface water or groundwater inorganic parameter concentration exceeded an established standard, it was noted in the text.

Section 4.22 describes the collection and analysis of all of the samples used to formulate background inorganic values, including groundwater, surface water, and soil matrices. Appendix F shows the student t-test calculations used to formulate the statistical background inorganic values. Prior to utilizing these statistical calculations, the background inorganic data was log-normalized. This was done since there was a large variance in the inorganic concentrations and by log-normalizing the data, a more representative evaluation of statistically elevated concentrations could be accomplished. Table 4-1 provides the standards and background values used to evaluate the inorganic data.

Table 4-1A

Lake City Army Ammunitions Plant
Standards and Critiera

		Drinking Water Standards			Statistically Derived Criteria	
Parameters	Primary Interim Water Standards	MGS ug/l	MDWS ug/l	MCL ug/l	Background Groundwater ug/l	Background Soil ug/g
VOLATILES						
Benzene	---	---	---	5	---	---
Carbon tetrachloride	---	---	---	5	---	---
Dichlorobenzene p-	---	---	---	75	---	---
Dichlorobenzene o-,m-	---	---	---	600	---	---
1,2-Dichloroethane	---	---	---	5	---	---
1,1-Dichloroethylene	---	---	---	7	---	---
Ethylbenzene	---	---	---	700	---	---
Methoxychlor	---	---	---	400	---	---
Monochlorobenzene	---	---	---	100	---	---
Pentachlorophenol	---	---	---	200	---	---
Polychlorinated biphenyl (PCB)	---	---	---	0.5	---	---
Tetrachloroethylene	---	---	---	5	---	---
Toluene	---	---	---	2,000	---	---
1,1,1-Trichloroethane	---	---	---	200	---	---
Vinyl Chloride	---	---	---	2	---	---
Xylene	---	---	---	10,000	---	---
					DISS.TOT.	
INORGANICS						
Aluminum	---	---	---	---	---	---
Antimony	---	---	---	---	2.07/2.64	1.26
Arsenic	---	50	50	50	2.51/5.21	2.82
Barium	---	---	1,000	5,000	258/780	249
Beryllium	---	10	---	---	0.05/0.90	0.40
Boron	---	---	---	---	---	---
Cadmium	---	---	10	5	2.55/7.31	0.35
Chromium (total)	---	---	50	100	18.62/26.38	13.49
Copper	---	1,000	1,000	---	1.76/45.82	19.95
Cyanide	---	---	---	---	---	0.32
Fluoride	---	---	2,000	4,000	---	---
Lead (source)	---	---	50	50	2.91/23.58	13.49
Manganese	---	---	---	---	---	---
Mercury	---	---	2	2	0.08/0.08	0.05
Molybdenum	---	---	---	---	---	---
Nickel	---	200	---	---	9.66/62.23	32.36
Nitrate (as N)	---	---	---	10,000	---	---
Nitrite (as N)	---	---	---	1,000	---	---
Nitrate plus Nitrite	---	---	---	10,000	---	---
Selenium	---	---	10	50	3.24/3.02	1.05
Silver	---	---	50	---	0.09/0.19	0.32
Sodium	---	---	---	---	---	---
Strontium	---	---	---	---	---	---
Sulfate	---	---	---	---	---	---
Thallium	---	---	---	---	---	---
Vanadium	---	---	---	---	---	---

MGS - Missouri Groundwater Standard.
MDWS - Missouri Drinking Water Standard.
MCL - Maximum Contaminant Level (U.S. EPA).
--- - Standards or data not available.
Note: Lead has a proposed MCL of 5 ug/l.

Table 4-1A (Cont.)

Lake City Army Ammunitions Plant
Standards and Critiera

Parameters	Primary Interim Water Standards	Drinking Water Standards MDWS ug/l	MCL ug/l	Proposed MCL ug/l	Statistically Derived Criteria Background Groundwater ug/l	Background Soil ug/g
BASE NEUTRAL AND ACID EXTRACTABLES						
Fluoranthene	---	40	---	---	---	---
1,2-Dichlorobenzene	---	---	---	640	---	---
Phenol	---	1	---	---	---	---
RADIOLOGICAL						
Gross Alpha	15pC/L	---	---	---	---	---
Gross Beta	4 mrem/yr	---	---	---	---	---

MDWS - Missouri Drinking Water Standard.
MCL - Maximum Contaminant Level (U.S. EPA).
--- - Standards or data not available.
Note: Lead has a proposed MCL of 5 ug/l.

Table 4-1B

Lake City Army Ammunitions Plant
Health Advisories
Explosive Compounds

	10-kg Child			70-kg Adult					
Explosives	One-day ug/l	Ten-day ug/l	Longer-Term ug/l	Longer-Term ug/l	RfD ug/kg/day	DWEL ug/l	Lifetime ug/l	ug/l at 10(4) Cancer Risk	Cancer Group
HMX	5,000	5,000	5,000	20,000	50	2,000	400	---	D
RDX	100	100	100	400	3	100	2	30	C

	Ambient Water Quality Criteria Freshwater Aquatic Life ug/l
2,4-DNT	230 - 330

D - Not classified
C - Possible human carcinogen.
--- - Standards or data not available.

Table 4-1C

Proposed and Official Regulatory Values and Classifications

Compound	ACGIH TLV[a] TWA[c] ppm[g]	 mg/m^3	OSHA/NIOSH PEL/REL[b] TWA[c] ppm[g]	 mg/m^3	 STEL[d] mg/m^3	HA DWEL[e] mg/L	Potency factor[f] (mg/kg/d)$^{-1}$	Carcinogen class[h]
TNT	---	0.5	---	1.5,(0.5)[i]	---	0.020	0.031	C
2,4-DNT	---	1.5	1.5	---	---	---	0.311[j]	B2
DNB	0.15	1	0.15	1	---	---	---	---
RDX	---	1.5	---	---	---	0.10	0.11	C
HMX	---	---	---	---	---	1.8	---	D
Tetryl	---	1.5	---	---	---	---	---	---
PA	---	0.1	---	0.1	0.3	---	---	---
NG	0.05	0.5	0.2	2	(0.1)[k]	0.005	0.0166	---
EGDN	0.05	0.3	0.2	1	(0.10)[k]	---	---	---
PGDN	0.05	0.3	---	---	---	---	---	---

---

a. American Conference of Governmental Industrial Hygienists threshold limit value [251].

b. Occupational Safety and Health Administration (OSHA) permissible exposure limit and National Institute of Occupational Safety and Health (NIOSH) recommended exposure limit [252].

c. Time weighted average for an 8-hour day, 5-day workweek [251].

d. Short-term exposure limit, usually 15 minutes, not to be repeated more than four times per day or at intervals of more than 60 minutes [251].

e. U.S. EPA Office of Drinking Water (ODW) drinking water equivalent level for lifetime exposure. DWELs have been published in the respective Health Advisories (HAs) [202,207,226,250].

f. Carcinogenic potency factor, q_1*, calculated by ODW. Multiplying q_1* in (mg/kg/day)$^{-1}$ by the daily exposure level in mg/kg/day gives the lifetime cancer risk, R. Thus, if one assumes an acceptable R of 10^{-6} (one excess cancer from a lifetime exposure of one million people), an acceptable daily exposure level is $10^{-6}/q_1$* mg/kg. Unless otherwise noted, values appear in the respective HAs [202,226,250].

g. Parts per million in the vapor phase, i.e., molecules per million molecules of air. At 25°C, ppm = (mg/m^3 x 24)/MW.

h. Group classifications as follows have been made by U.S. EPA.
   - B2: Probable human carcinogen; usually on the basis of adequate evidence in animals and inadequate evidence or insufficient data in humans.
   - C: Possible human carcinogen; limited evidence of carcinogenicity in animals and insufficient data in humans.
   - D: Not classified as carcinogen; insufficient evidence from animal studies.

i. Currently proposed by OSHA.

j. ODW has not yet issued HAs for 2,4- or 2,6-DNT. However, a tentative value of 0.311 (mg/kg/day)$^{-1}$ for the carcinogenic potency factor q_1* for 2,4-DNT has been cited [253]. Assuming a value of 10^{-6} for R (see footnote f), the acceptable exposure limit is 10^{-6}/0.311 or 3.2 x 10^{-6} mg/kg/day. Thus, for a 70 kg individual consuming 2 L of water per day, a concentration of 0.00011 mg/L is calculated.

k. Currently recommended by NIOSH for 20-min. STEL.

When evaluating organic data (VOCs, BNAs, explosives, and oil and grease), any detection was considered site-related because these parameters are for the purposes of this investigation not naturally occurring in the sample media. All organic detections are noted in the text, along with those organic detections which exceeded MCL, MGS, and/or MDWS values. Table 4-1 provides the standards used to evaluate the organic data. Specific organic compounds are discussed using accepted USATHAMA abbreviations. All plant-wide analysis for VOCs and BNAs included the Priority Pollutant List (PPL).

Various phthalate compounds were randomly detected across the entire site in soil and water samples. The BNA compound bis(2-ethylhexyl)phthalate (B2EHP) was most prevalent. It was detected in a few laboratory method blank analyses, although these method blank detections only account for a small percentage of the total number of investigative sample detections. Throughout Section 4, the various phthalate detections are quantitatively described, and are additionally noted as probable post-sampling or field contaminants. This assumption is based upon the ubiquitous occurrence of the phthalates across the site, their erratic detection locations between sampling rounds, and their characteristic occurrence as post-sampling contaminants during investigations other than LCAAP.

Each summary subsection contains a figure which illustrates the distribution of potentially site-related detections within each area. All detections of VOCs, BNAs, explosive compounds, and oil and grease are represented by abbreviations shown at the sample location on each figure. The detection of unknown organic compounds are not shown in the figures, since these detections are only estimated concentrations of unknown compounds. The presentation of inorganic detections varies with the sample matrix in which they were identified. For groundwater and surface water samples, only sample locations at which the inorganic concentrations exceeded the MGS, MDWS, and/or MCL are noted on the figures. For soil and sediment samples, all sample locations at which statistically elevated concentrations were measured are shown.

No field QA/QC samples were collected during the RI. Laboratory QA/QC included the standard protocols describe din the "WESTON Analytics Quality Assurance Plan" dated 3 October 1988, and the protocols described in the "Lake City Army Ammunition Plant Remedial Investigation QA/QC Plan" dated June 1988. Sample holding times were monitored throughout the sampling and analysis portions of the RI through record and group checks performed at the laboratory. Printed copies of the record and group checks were produced during the latter portions of the RI. A review of these records showed that all holding times were met. All information regarding sampling, extraction, and analyses dates for the entire RI is included in the IRDMS.

All chemical data collected and analyzed during this Phase I RI, including unknown compounds detected, are presented in Appendix G of this document. Analytical data is reported with the appropriate number of significant figures as required by USATHAMA QA protocol.

4.1 AREA 1 - BUILDING 83 WASTEWATER LAGOONS

4.1.1 Site Description and Field Investigations

4.1.1.1 Area 1A - Surface Impoundment

This site was a surface impoundment that used to contain treated wastes from Building 83 (Figure 4-1). The area was opened in the early 1950s and closed in the early 1970s. The estimated area of the impoundments is 5,000 square feet. The estimated quantity of wastes is 60,000 cubic feet. The waste is RCRA-listed waste K044 (wastewater treatment sludge from the manufacturing and processing of explosives). This sludge contains the RCRA hazardous constituent resorcinol, which is used in the manufacturing process for 2,4,6-trinitroresorcinol (246TNR).

The field investigation of Area 1A consisted of two rounds of sampling and analyzing the 11 previously existing monitoring wells. The monitoring well network at the time of this RI consisted of four upgradient wells (1-1,1-5, 1-7, and 1-7A), two sidegradient wells (1-4, 1-10) and five downgradient wells (1-2, 1-3, 1-6, 1-8, and 1-9). The sampling events were separated by an interval of approximately three months. All groundwater was analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. Wells 1-1, 1-3, 1-7, and 1-8 were abandoned as part of the 1989 Groundwater Quality Assessment Plan (GWQAP). Additional wells were subsequently installed.

4.1.1.2 Area 1B - Surface Impoundments

This site consists of three closed surface storage impoundments containing neutralized wastes from Building 83. Figure 4-1 shows the location of the closed impoundments. The first impoundment was 168 feet by 182 feet, the second impoundment was 129 feet by 195 feet, and the third impoundment was 265 feet by 312 feet. Their depths are unknown. The facility was closed in 1986 under a plan approved by the MDNR.

According to EPIC photographs, a fourth impoundment may have operated west of the first impoundment. It was not included in the Closure Plan approved by MDNR.

The field investigation of Area 1B consisted of two rounds of sampling and analyzing the 11 monitoring wells located within Area 1. The sampling events were separated by an interval of approximately three months. Analytical protocol followed those described for Area 1A.

4.1.2 Site Investigation Results

The results of this site investigation at Area 1 are discussed below on an area-wide basis. The presentation of data is

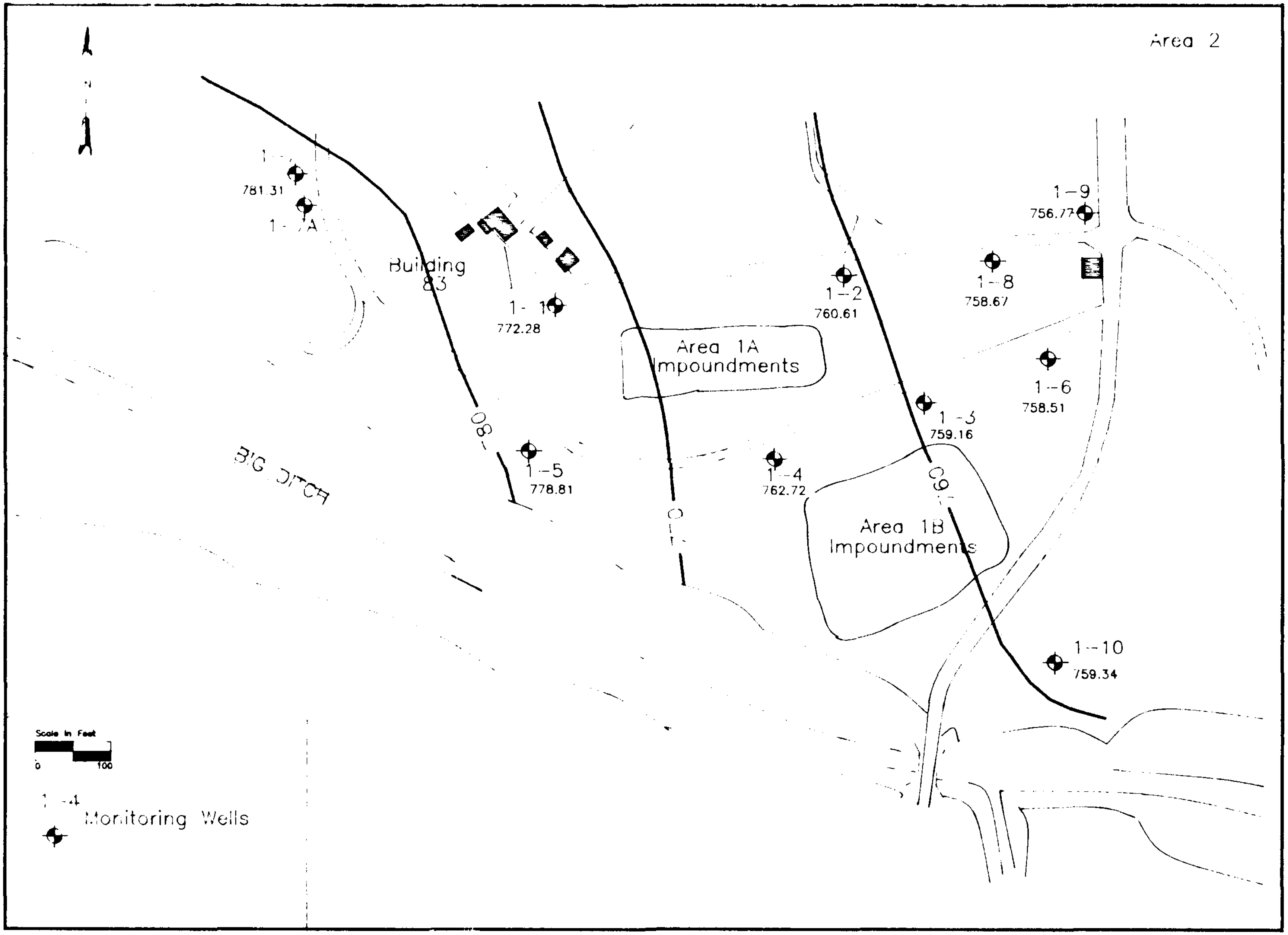


FIGURE 4-1
1

AREA1

organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.1.3). All organic and inorganic analytical data is presented in Table 4-2. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.1.2.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 1 identified two explosive compounds:

- Cyclonite (RDX).
- Nitramine (Tetryl).

Round 1 of the groundwater analysis detected RDX at the upgradient well location 1-7 and the downgradient well location 1-9, at respective concentrations of 2.75 and 1.94 ug/l.

Round 2 of the groundwater analysis detected Tetryl and RDX. Tetryl was detected at upgradient well location 1-7A at 3.45 ug/l. RDX was detected at downgradient well location 1-6 at a concentration of 1.38 ug/l.

Volatile Organic Compounds

Two VOCs were identified during the round 1 groundwater analysis:

- 1,1,1-trichloroethane (111TCE).
- 1,1-dichloroethane (11DCLE).

Both compounds were detected at upgradient well location 1-1. The compound 111TCE was detected at 7 ug/l and 11DCLE was detected at 20 ug/l. No VOCs were identified during round 2 analysis.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 1 identified one BNA compound: B2EHP.

B2EHP was detected in upgradient sample 1-5-2 and downgradient sample 1-9-2 at respective concentrations of 20 and 70 ug/l.

B2EHP was detected in the laboratory method blank for the sample batch consisting of samples 1-8-1 and 1-9-1. The detected concentrations in these investigative groundwater samples were less than 10 times the detected concentration in the method blank; therefore, B2EHP is not considered a valid detection and is not

TABLE 4-2
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #1
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	1-1-1	1-1-2	1-2-1	1-2-2	1-3-1	1-3-2
DEPTH (FT)	17	17	14.5	14.5	41	41
VOLATILES						
1,1,1-Trichloroethane	7	ND	ND	ND	ND	ND
1,1-Dichloroethane	20	ND	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
UNKNOWNS						
C6-C7 methyl alcohol	ND	ND	ND	ND	ND	*10
C6-C9 Cycloalkane	ND	ND	ND	ND	ND	*10
C8-C10 Methyl Alkene/Alkane	ND	ND	ND	ND	ND	*10
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL ND OR <CRL)					
INORGANICS						
Antimony, total	<3.00	4.09	<3.00	<3.00	<3.00	<3.00
Arsenic, dissolved	<5.00	<5.00	<5.00	<5.00	34.7	13.1
Arsenic, total	<5.00	<5.00	<5.00	<5.00	110	30.2
Barium, dissolved	NA	47.8	NA	205	NA	229
Barium, total	NA	31.4	NA	221	302	251
Beryllium, dissolved	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Beryllium, total	0.40	0.40	1.11	<0.10	1.01	<0.10
Cadmium, total	<5.10	6.44	<5.10	11.8	<5.10	<5.10
Copper, dissolved	5.47	<1.78	4.18	2.79	3.54	<1.78
Copper, total	12.3	6.86	25.5	17.6	41.5	<1.78
Lead, dissolved	<2.50	<2.50	<2.50	<2.50	4.45	<2.50
Lead, total	6.27	<2.50	6.17	<2.50	41.6	<2.50
Nickel, dissolved	74.7	<9.60	<9.60	<9.60	12.2	<9.60
Nickel, total	26.4	<9.60	20.9	19.6	62.7	<9.60
Selenium, total	<5.00	5.58	<5.00	<5.00	<5.00	<5.00
Silver, dissolved	0.53	0.21	<0.19	<0.19	<0.19	<0.19
Silver, total	0.32	0.21	<0.19	0.32	<0.19	<0.19
Zinc, dissolved	269	50.9	<17.20	39.4	452	25.4
Zinc, total	1100	70.2	1200	58.2	466	74.9
OTHERS	(ALL ND OR <CRL)					

CRL = CERTIFIED REPORTING LIMIT ND = NOT DETECTED NA = NOT ANALYZED

* INDICATES A GREATER THAN 90% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-2
LAKE CITY AMMUNITIONS PLANT
AREA #1
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	1-4-1	1-4-2	1-5-2	1-6-1	1-6-2	1-7-1
DEPTH (FT)	23	23	13	27	27	37
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	20	ND	ND	ND
UNKNOWNS						
C6-C9 Cycloalkane	ND	ND	ND	ND	*20	ND
C8-C10 Methyl Alkene/Alkane	ND	ND	ND	ND	*10	ND
2-(2-methoxyethoxy)ethanol [995]	ND	ND	ND	10	ND	ND
C30-C36 Oraganic Acid Derivative	ND	ND	*10	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	<0.66	<0.66	<0.66	<0.66	1.38	2.75
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, total	<3.00	<3.00	<3.00	77.2	<3.00	<3.00
Arsenic, dissolved	<5.00	<5.00	<5.00	27	15.3	<5.00
Arsenic, total	<5.00	<5.00	17.1	53	33.4	12.8
Barium, dissolved	NA	112	320	NA	139	68
Barium, total	NA	135	1470	NA	283	2700
Beryllium, total	2.92	0.50	0.55	1.06	<0.10	11
Cadmium, total	<5.10	<5.10	24.7	<5.10	<5.10	6.44
Chromium, total	<37.50	<37.50	49	<37.50	<37.50	124
Copper, total	71	10.9	200	52	8.47	160
Lead, dissolved	3.13	8.39	<2.50	<2.50	<2.50	42.7
Lead, total	57	<2.50	45	16.3	2.73	<2.50
Mercury, dissolved	0.2	ND	ND	ND	ND	0.2
Nickel, dissolved	14.2	<9.60	<9.60	<9.60	<9.60	<9.60
Nickel, total	79.3	<9.60	346	25.6	226	472
Selenium, dissolved	7.4	<5.00	<5.00	<5.00	<5.00	<5.00
Selenium, total	<5.00	5.58	<5.00	<5.00	<5.00	<5.00
Silver, total	<0.19	0.21	0.53	<0.19	0.21	0.74
Zinc, dissolved	444	33.3	20.9	277	<17.20	<17.20
Zinc, total	744	62	1100	199	484	1100
OTHERS	(ALL ND OR <CRL)					

CRL = CERTIFIED REPORTING LIMIT, ND = NOT DETECTED, NA = NOT ANALYZED

* INDICATES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-2
LAKE CITY AMMUNITIONS PLANT
AREA #1
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	1-7-2	1-7A-1	1-7A-2	1-8-1	1-8-2	1-9-1
DEPTH (FT)	37	41	41	26	26	21
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLE						
bis (2-Ethylhexy) Phthalate	ND	ND	ND	20	ND	20
UNKNOWNS						
2-(2-Methoxyethoxy) ethanol	ND	ND	ND	*10	ND	ND
3,4-Dimethyl-1-Pentanol [903]	ND	ND	ND	10	ND	ND
C2-C5 Organic Acid Ester	ND	ND	ND	*10	ND	ND
C7-C13 Methyl benzene	ND	*10	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	<0.63	1.22	<0.63	<0.63	<0.63	1.94
Tetryl	<0.66	<0.66	3.45	<0.66	<0.66	<0.66
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, dissolved	5.18	<5.00	<5.00	<5.00	<5.00	14.8
Arsenic, total	<5.00	<5.00	<5.00	7.25	<5.00	58
Barium, dissolved	123	122	148	400	149	NA
Barium, total	1010	544	396	NA	206	NA
Beryllium, total	4	5.6	1.71	0.1	<0.10	0.37
Cadmium, total	<5.10	6.44	<5.10	<5.10	<5.10	<5.10
Chromium, total	43.3	<37.50	<37.50	<37.50	<37.50	<37.50
Copper, dissolved	<1.78	<1.78	<1.78	2.89	5.04	2.57
Copper, total	<1.78	24.4	35	24.5	12.2	22
Lead, dissolved	<2.50	22	<2.50	<2.50	<2.50	<2.50
Lead, total	<2.50	<2.50	<2.50	4.15	<2.50	9.61
Mercury, dissolved	ND	0.2	ND	0.17	ND	0.17
Nickel, dissolved	<9.60	20.1	<9.60	<9.60	9.8	13.6
Nickel, total	174	155	113	16.3	15.2	10.3
Silver, dissolved	0.43	<0.19	<0.19	<0.19	<0.19	<0.19
Silver, total	0.21	<0.19	0.21	7.77	<0.19	0.21
Zinc, dissolved	72.9	2600	<17.20	240	53.1	236
Zinc, total	329	610	146	284	70.7	368
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-2
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #1
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	1-9-2	1-10-1	1-10-2
DEPTH (FT)	21	27	27
VOLATILES			
ALL		(ALL ND OR <CRL)	
BASE NEUTRAL & ACID EXTRACTABLES			
bis (2-Ethylhexyl) Phthalate	70	ND	ND
UNKNOWNS			
C4-C5 ethoxy alcohol	ND	*10	ND
Pentadecaden-1-01	ND	*40	ND
C5-C9 Cycloketone	*30	ND	ND
C10-methyl alkenelalkane	*10	ND	ND
C8-C10 Cyclic alklane	*10	ND	ND
C12-methyl alkane	10	ND	ND
2-ethyl-4-pentenal [691]	ND	ND	20
C8-C10 methyl alkene/alkane	ND	ND	*20
C6-C7 methyl alcohol	ND	ND	*10
(Phenoxymethyl) Benzene [741]	ND	ND	30
OTHERS		(ALL ND OR <CRL)	
EXPLOSIVE COMPOUNDS			
ALL		(ALL ND OR <CRL)	
INORGANICS			
Arsenic, dissolved	<5.00	28.4	8.8
Arsenic, total	21.1	33.7	19.3
Barium, dissolved	225	NA	108
Barium, total	294	NA	297
Beryllium, total	<0.10	1.22	0.5
Copper, dissolved	4.93	<1.78	3.54
Copper, total	13.3	48	15.2
Lead, total	<2.50	19.8	8.59
Nickel, dissolved	10.2	11.8	23.9
Nickel, total	35	36.5	37.3
Silver, dissolved	<0.19	<0.19	0.85
Silver, total	<0.19	0.21	<0.19
Zinc, dissolved	131	296	93.2
Zinc, total	284	446	251
OTHERS		(ALL ND OR <CRL)	
RADIOLOGICAL (PCI/L)			
Alpha	NA	<7	NA
Beta	NA	<9	NA
U-234	NA	NA	NA
U-235	NA	NA	NA
U-238	NA	NA	NA
Total Uranium	NA	0.6	NA

CRL = CERTIFIED REPORTING LIMIT; ND = NOT DETECTED; NA = NOT ANALYZED

* DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

likely to be present in the groundwater at well locations 1-8 and 1-9.

Unknown BNA compounds were detected in samples from seven different monitoring wells at Area 1. Wells 1-3, 1-5, 1-6, 1-7A, 1-8, 1-9, and 1-10 had concentrations ranging from 10 to 40 ug/l. Detections occurred in both sampling rounds.

Inorganics

The results of the two rounds of groundwater sampling at Area 1 identified 13 inorganics which exceeded statistical background concentrations. Seven of the 13 inorganics were detected at concentrations exceeding the MGS, MDWS, and/or MCL. Table 4-3 summarizes the site-related detections and lists the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in this table. The parameters which exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Dissolved arsenic exceeded the MCL of 30 ug/l in downgradient sample 1-3-1 with a concentration of 34.7 ug/l.

Total arsenic exceeded the MCL of 30 ug/l in downgradient samples 1-3-1, 1-3-2, 1-6-1, 1-6-2, and 1-9-1 and upgradient sample 1-10-1 with respective concentrations of 110, 30.2, 53.0, 33.4, 58.0, and 33.7 ug/l.

Total barium exceeded the MDWS of 1,000 ug/l in samples 1-5-2, 1-7-1, and 1-7-2 with respective concentrations of 1,470, 2,700, and 1,010 ug/l. The MCL of 5,000 ug/l was not exceeded.

Total beryllium exceeded the MGS of 10 ug/l in upgradient sample 1-7-1 with a concentration of 11.0 ug/l. MCL and MDWS standards for beryllium do not exist.

Total cadmium exceeded the MCL of 5 ug/l in upgradient, sidegradient, and downgradient samples 1-1-2, 1-2-2, 1-5-2, 1-7-1 and 1-7A-1 with concentrations of 6.44, 11.8, 24.7, 6.44, and 6.44 ug/l.

Total chromium exceeded the MDWS of 50 ug/l and the MCL of 100 ug/l in upgradient sample 1-7-1 with a concentration of 124 ug/l.

Total lead exceeded the MCL and MDWS of 50 ug/l in sidegradient sample 1-4-1 with a concentration of 45 ug/l.

Total nickel exceeded the MGS of 200 ug/l in samples 1-5-2, 1-6-2 and 1-7-1 with respective concentrations of 346, 226 and 472 ug/l. MCL and MDWS standards for nickel do not exist.

TABLE 4-3
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 1 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Antimony, total	1-1-2, 1-6-1	4.09 - 77.2	1-6-1	--
Arsenic, dissolved	*1-3-1, 1-3-2, 1-6-1, 1-6-2, 1-7-2, 1-9-1, 1-10-1, 1-10-2	5.18 - 34.7	*1-3-1	30.00
Arsenic, total	*1-3-1, *1-3-2, 1-5-2, *1-6-1, *1-6-2, 1-7-1, 1-8-1, *1-9-1, 1-9-2, *1-10-1, 1-10-2	7.25 - 110	*1-3-1	30.00
Barium, total	*1-5-2, *1-7-1, *1-7-2	1010 - 2700	*1-7-1	1000.00
Beryllium, total	1-2-1, 1-3-1, 1-4-1, 1-6-1, *1-7-1 1-7-2, 1-7A-1, 1-7A-2, 1-10-1	1.01 - 11	*1-7-1	--
Cadmium, total	*1-1-2, *1-2-2, *1-5-2, *1-7-1, *1-7A-1	6.44 - 24.7	*1-5-2	5.00
Chromium, total	1-5-2, *1-7-1, 1-7-2	43.3 - 124	*1-7-1	50.00
Copper, dissolved	1-1-1, 1-2-1, 1-2-2, 1-3-1 1-8-1, 1-8-2, 1-9-1, 1-9-2, 1-10-2	2.57 - 4.93	1-9-2	1000.00
Copper, total	1-4-1, 1-5-2, 1-6-1, 1-7-1, 1-10-1	48 - 200	1-5-2	1000.00
Lead, dissolved	1-3-1, 1-4-1, 1-4-2, 1-7-1, 1-7A-1	3.13 - 42.7	1-7-1	50.00
Lead, total	1-3-1, 1-4-1, 1-5-2	41.6 - 45	1-4-1	50.00
Mercury, dissolved	1-4-1, 1-7-1, 1-7A-1, 1-8-1, 1-9-1	0.17 - 0.2	1-4-1, 1-7-1, 1-7A-1	
Nickel, dissolved	1-1-1, 1-3-1, 1-4-1, 1-7A-1, 1-8-2 1-9-1, 1-9-2, 1-10-1, 1-10-2	9.8 - 74.7	1-1-1	200.00
Nickel, total	1-3-1, 1-4-1, *1-5-2, *1-6-2, *1-7-1, 1-7-2, 1-7A-1, 1-7A-2	79.3 - 472	*1-7-1	200.00
Selenium, dissolved	1-4-1	7.40	1-4-1	10.00
Selenium, total	1-1-2, 1-4-2	5.58	1-1-2, 1-4-2	10.00
Silver, dissolved	1-1-1, 1-1-2, 1-7-2, 1-10-2	0.21 - 0.85	1-10-2	50.00
Silver, total	1-1-1, 1-1-2, 1-2-2, 1-4-2, 1-5-2, 1-6-2, 1-7-1, 1-7-2, 1-7A-2, 1-8-1 1-9-1, 1-10-1	0.21 - 7.77	1-8-1	50.00
Zinc, dissolved	1-3-1, 1-4-1, 1-7A-1, 1-10-1	296 - 2600	1-7A-1	5000.00
Zinc, total	1-1-1, 1-1-2, 1-5-2, 1-7-1	1100 - 1200	1-1-2	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXIST

4.1.3 Summary

Potentially site-related detections were found at monitoring well locations across Area 1, as shown in Figure 4-2. VOCs and BNAs were detected downgradient of Area 1A surface impoundments. Explosive compounds were detected downgradient of Area 1A and 1B surface impoundments; however, explosives were also detected upgradient of Area 1A at well locations 1-7 and 1-7A, which may suggest an unknown source or a source associated with Building 83.

Inorganic parameters were detected in concentrations exceeding standards in numerous upgradient, sidegradient and downgradient wells within Area 1. Total arsenic, total barium, total beryllium, total cadmium, total chromium, total lead, and total nickel were all detected in sidegradient or upgradient wells at concentrations exceeding standards. Only dissolved arsenic, total arsenic, and total nickel were detected in downgradient wells at concentrations exceeding standards.

The inorganic results may indicate a potential upgradient source at Area 1. Another possible explanation may be that the high concentrations of inorganics are naturally occurring in the groundwater. All of the upgradient wells and most of the downgradient wells are screened within the shale or weathered shale bedrock which may be contributing naturally occurring inorganic constituents to the groundwater. All of the inorganic parameters showed randomly elevated concentrations at some of the background monitoring well locations.

One other explanation of the elevated detections at well locations 1-7 and 1-7A may be the local topography, which is bisected by an erosional depression northwest of the wells and Building 83. This local feature may cause some shallow groundwater to flow radially away from Building 83 toward the northwest and through the sensing zones of well locations 1-7 and 1-7A. Any former release of contaminants near Building 83 could therefore impact groundwater quality at these wells.

4.2 AREA 2 - BUILDING 85 WASTEWATER LAGOONS

4.2.1 Site Description and Field Investigations

4.2.1.1 Area 2A - Overflow of Lagoon

On 1 May 1983, severe storms accompanied by heavy rain caused extensive flooding of a large portion of the plant. A release of hazardous wastes and constituents to the environment reportedly occurred in Area 2 as a result of the flooding (Letter, LCAAP, 20 August 1987). The Building 85 north impoundment (Figure 4-3) overflowed and released approximately 70,000 gallons to surface drainage, which ultimately drained into the West Fire Prairie Creek. The released material was treated wastewater from the

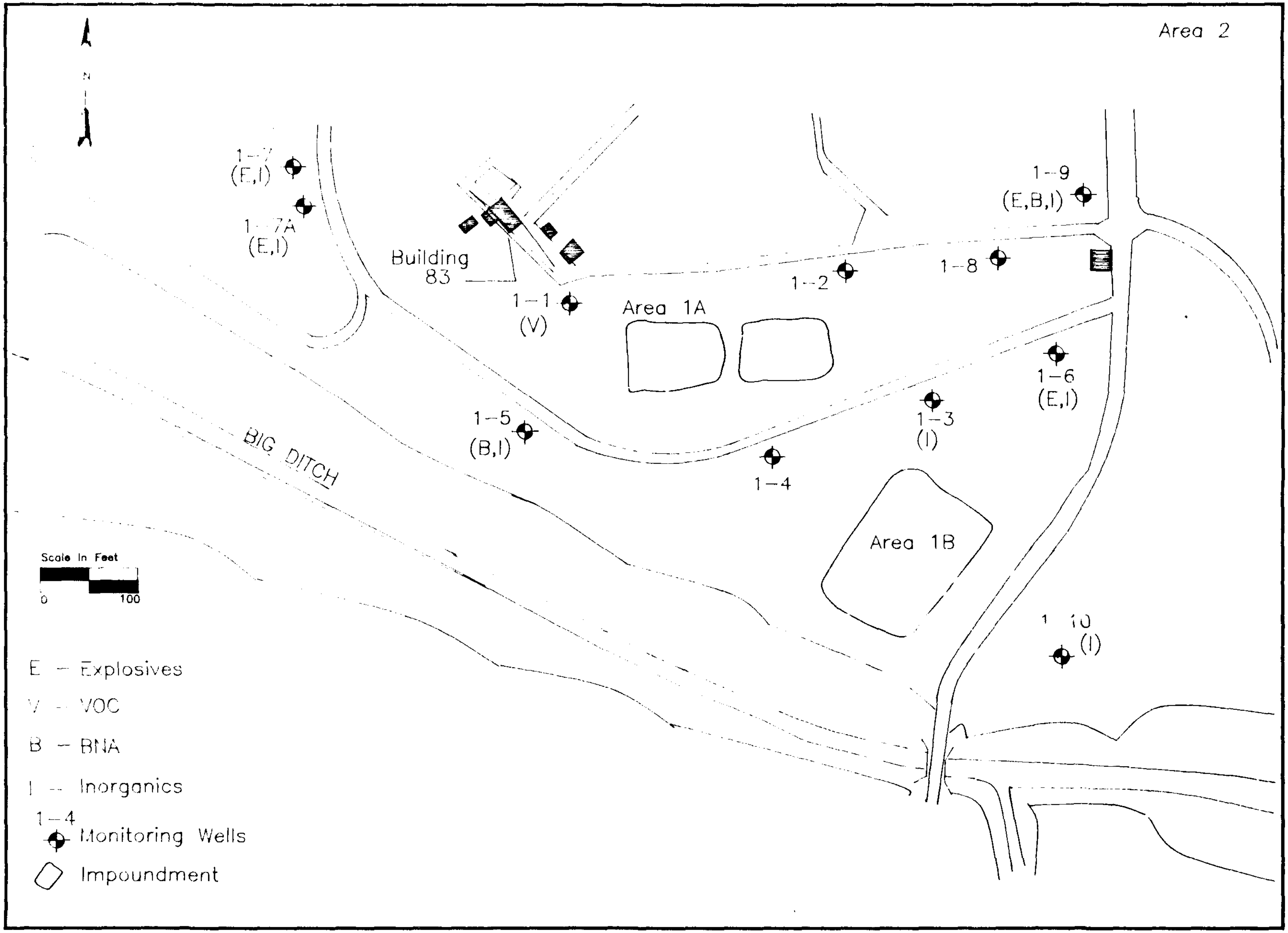


FIGURE 4-2
AREA 1 DETECTION LOCATIONS

manufacture of lead-based initiating compounds. Based on an analysis of the wastewater, this material contained 2.13 mg/l of lead. The total discharge of lead was estimated to be 1.24 pounds.

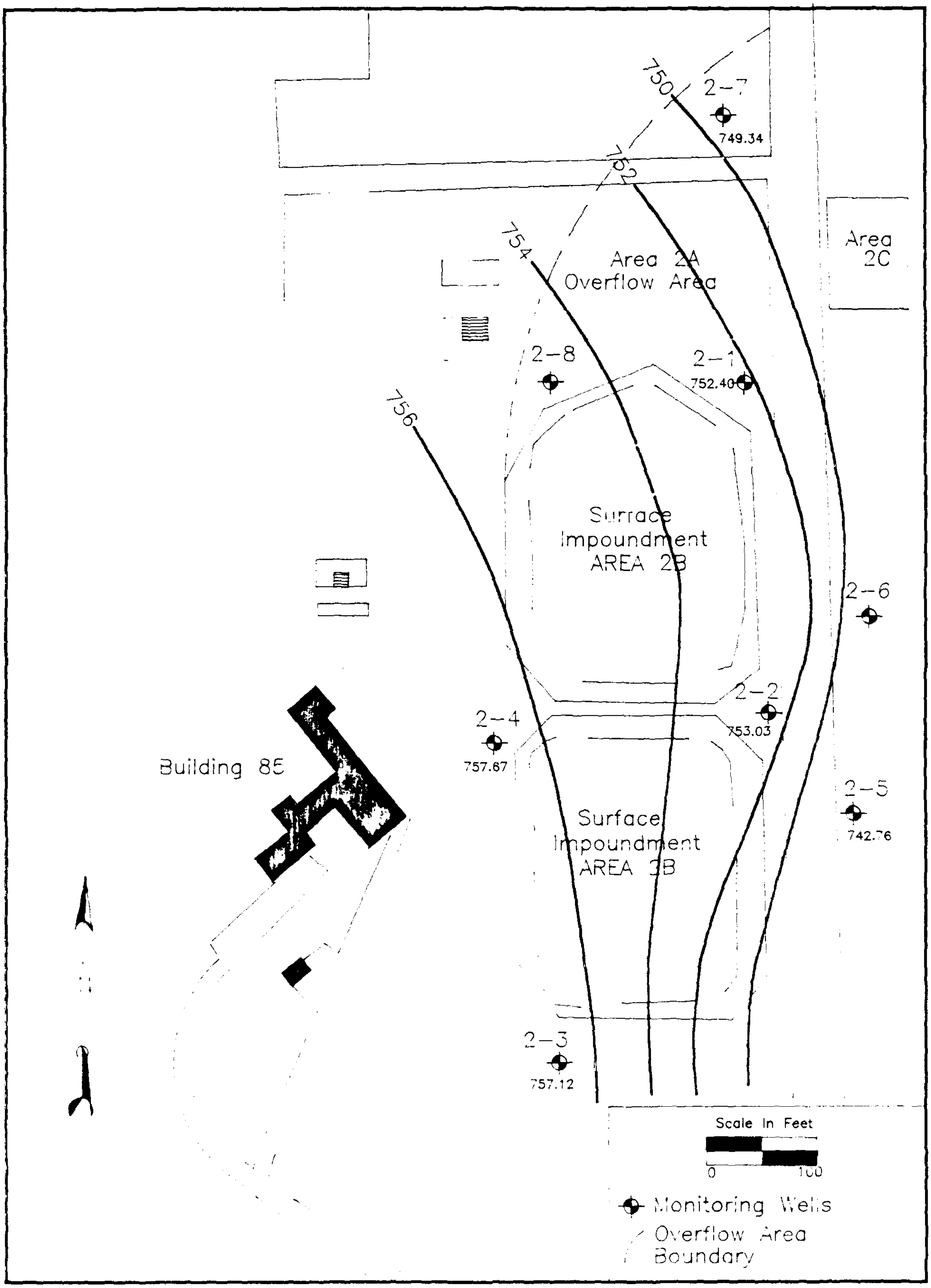
Groundwater sampling and analysis of seven monitoring wells was conducted in Area 2A. Two rounds of samples were collected, separated by a three-month interval. The groundwater was analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives.

4.2.1.2 Area 2B - Surface Impoundment

Area 2B, shown in Figure 4-3, consists of two surface storage impoundments which are currently undergoing RCRA closure. These impoundments contained neutralized wastes from Building 85. This building houses lead styphnate and tetrazene production operations. The north impoundment is 250 feet by 330 feet, and the south impoundment is 272 feet by 330 feet. The wastes are RCRA-listed wastes K044 and K046 (wastewater treatment sludge from the manufacturing, formulation, and loading of lead-based initiating compounds). The hazardous constituent is K046 lead.

Previous laboratory data confirmed that the two surface impoundments at Area 2B contained hazardous industrial wastes that exceed regulatory limits for characteristic hazardous wastes (EA Report, 1987). The two impoundments were hazardous with respect to EP toxicity based on lead concentrations. They also contained measurable concentrations of toluene and 246TNR, and would spark to a flame reactivity test. These lagoons were filled to capacity. To prevent overflowing, the wastewater was pumped out and trucked off-site on a regular basis.

Seven monitoring wells were previously located on all sides of the two impoundments, with the exception of the western side of the north impoundment. The wells ranged in depth from 25 to 40 feet. WESTON installed one additional monitoring well northwest of the north impoundment at Area 2B (Figure 4-3). This well (2-8) monitors the groundwater mounding effect of, and potential wastewater migration from, the impoundment. It is located downgradient of the impoundment and screened at the water table at about 19 feet below grade. This new well and six of the previously installed wells were each sampled twice and analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. The sampling events were separated by an interval of approximately three months. During the investigation, WESTON was unable to sample well 2-6 because its protective casing was damaged. Additional wells were installed subsequent to the RI field investigation as part of the 1989 GWQAP. Wells 2-1, 2-2, and 2-3 were abandoned.



AREA2

FIGURE 4-3
AREA 2

4.2.1.3 Area 2C - Surface Impoundment

This site is a surface impoundment constructed in the 1960s to receive treated wastes from Building 85. It was closed in 1972. The estimated area is 20,000 square feet. The estimated quantity of waste is 36,000 cubic feet. The waste is RCRA-listed hazardous waste K046.

4.2.2 Site Investigation Results

The results of this site investigation at Area 2 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.2.3). All organic and inorganic analytical data is presented in Table 4-4. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.2.2.1 Groundwater

Explosives

Rounds 1 and 2 of groundwater sampling at Area 2 identified two explosive compounds:

- 2,6-dinitrotoluene (26DNT).
- RDX.

During the first round of groundwater sampling, upgradient wells 2-3 and 2-4 and downgradient well 2-5 contained RDX at respective concentrations of 1.50, 4.88, and 4.70 ug/l. Downgradient well 2-7 contained the explosive compound 26DNT at 0.70 ug/l.

During the second round of groundwater sampling, these two explosive compounds were again identified. Upgradient well 2-3 contained 26DNT at a concentration of 0.75 ug/l, and downgradient well 2-7 contained RDX at a concentration of 0.66 ug/l.

Volatile Organic Compounds

The results of two rounds of groundwater sampling at Area 2 identified three VOCs:

- Benzene.
- Trans-1,2-dichloroethene (T12DCE).
- TRCLE.

These compounds were detected only during the first round of sampling. This may have occurred because the VOC concentrations at

TABLE 4-4
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #2
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	2-1-1	2-1-2	2-2-1	2-2-2	2-3-1	2-3-2
DEPTH (FT)	32.5	32.5	43	43	27.5	27.5
VOLATILES						
Benzene	<0.67	<0.67	<0.67	<0.67	0.89	<0.67
Trichloroethene	<0.71	<0.71	<0.71	<0.71	0.95	<0.71
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	300	ND	ND	ND
UNKNOWNS						
C8-C10-Methyl Alkene/Alkane	ND	ND	ND	*20	ND	ND
Heptanoic Acid Ester	ND	ND	ND	*20	ND	ND
2-(2,6-Dimethylheptyl) Cyclobutanone [477]	ND	ND	ND	50	ND	ND
4-Methyl-1-(1-Methylethyl)-Cyclohexanol	ND	ND	ND	*10	ND	ND
1-Hexahydro-Methyl-2H-Azepin-2-one	ND	ND	ND	*10	ND	ND
C6-C9 Cycloalkane	ND	ND	ND	*20	ND	ND
C6-C7 Methyl Alcohol	ND	ND	ND	*10	ND	ND
C13-C16 Hydrocarbon	ND	ND	ND	*20	ND	ND
1-heptyl-nonylamine [476]	ND	ND	ND	40	ND	ND
5,6-Decanedione [496]	ND	ND	ND	20	ND	ND
Benzene Propanoic Acid Ester	ND	ND	ND	*10	ND	ND
Unknown	ND	ND	ND	20	ND	ND
C6-C9 Cycloalkene/alkane	ND	*20	ND	ND	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	*10	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
26-DNT	<0.55	<0.55	<0.55	<0.55	<0.55	0.75
RDX	<0.63	<0.63	<0.63	<0.63	1.5	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	<5.00	<5.00	7.87	9.01	<5.00	<5.00
Barium, dissolved	102	150	26.5	NA	NA	186
Barium, total	425	234	568	263	NA	264
Beryllium, total	<0.10	<0.10	1.01	0.6	3.2	0.2
Cadmium, dissolved	<5.10	<5.10	<5.10	10.7	<5.10	<5.10
Cadmium, total	<5.10	<5.10	130	48.3	6.44	<5.10
Chromium, total	<37.50	<37.50	<37.50	<37.50	72.1	<37.50
Copper, dissolved	<1.78	<1.78	<1.78	<1.78	<1.78	37
Copper, total	5.89	10.2	37.9	19.4	34.5	9.65
Lead, dissolved	<2.50	<2.50	<2.50	<2.50	<2.50	2.53
Lead, total	3.24	4.65	9.3	11.2	<2.50	4.75
Nickel, dissolved	10.7	<9.60	15.1	30.1	48.3	<9.60
Nickel, total	26.8	61.7	82.7	45	139	66.9
Selenium, total	<5.00	<5.00	<5.00	10.8	<5.00	<5.00
Silver, total	<0.19	0.43	0.43	0.43	<0.19	<0.19
Zinc, dissolved	1200	43.7	820	32.1	800	51.4
Zinc, total	276	129	880	285	610	126
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-4
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #2
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	2-4-1	2-4-2	2-5-1	2-5-2	2-7-1	2-7-2
DEPTH (FT)	33.5	33.5	22.5	22.5	19	19
VOLATILES						
Trans-1,2-Dichloroethene	5.8	<1.72	<1.72	<1.72	<1.72	<1.72
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	200	ND	60	ND
UNKNOWNS						
C6-C9 Cycloalkane	ND	ND	ND	*20	ND	*20
C7-C10 Methylcyclohexane	ND	ND	ND	*10	ND	ND
C8-C10 Methyl Alkane/Alkene	ND	ND	ND	*20	ND	*30
C6-C7 Methyl Alcohol	ND	ND	ND	*20	ND	*40
C12-C14 Alkane Glycol	ND	*200	ND	ND	ND	ND
2-propyl-1H-Imidazole [907]	ND	20	ND	ND	ND	ND
1,3-Dihydro-1-phenyl-2H-Benzimidozol-2-one [907]	ND	10	ND	ND	ND	ND
Benzedicarboxylic Acid Ester	*10	ND	ND	ND	ND	ND
(Phenoxymethyl)-Benzene [710]	10	ND	ND	ND	ND	ND
OTHERS						
EXPLOSIVE COMPOUNDS						
26-DNT	<0.55	<0.55	<0.55	<0.55	0.7	<0.55
RDX	4.88	<0.63	4.7	<0.63	<0.63	0.66
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, total	7.61	9.55	<3.00	<3.00	<3.00	<3.00
Arsenic, total	<5.00	<5.00	<5.00	<5.00	8.18	<5.00
Barium, dissolved	NA	259	NA	155	128	143
Barium, total	NA	235	NA	238	595	219
Beryllium, total	12	0.3	0.49	<0.10	1.41	0.4
Cadmium, total	6.44	6.41	<5.10	<5.10	30.1	<5.10
Chromium, total	112	<37.50	51.9	<37.50	<37.50	<37.50
Copper, dissolved	<1.78	<1.78	<1.78	<1.78	4.07	<1.78
Copper, total	36.7	9.75	14.5	8.04	87	24
Lead, dissolved	<2.50	<2.50	<2.50	<2.50	3.94	<2.50
Lead, total	20.3	3.13	<2.50	4.85	12	7.48
Nickel, dissolved	116	<9.60	42.7	<9.60	14.1	<9.60
Nickel, total	349	14.9	23.2	<9.60	65.4	19.2
Silver, total	0.21	2.13	<0.19	0.21	1.6	0.21
Zinc, dissolved	980	46.4	306	24.6	488	22
Zinc, total	730	126	491	235	610	125
OTHERS	(ALL ND OR <CRL)					

[illegible] CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

[illegible] A GREATER THAN 90% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-4
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #2
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	2-8-1	2-8-2
DEPTH (FT)	24	24
VOLATILES	(ALL ND OR <CRL)	
ALL		
BASE NEUTRAL & ACID EXTRACTABLES		
bis (2-Ethylhexyl) Phthalate	500	ND
UNKNOWNS		
C10-C14 Unknown	10	ND
6H 8H-Benzo [10.11]	20	ND
C6-C9 Cycloalkane	*10	ND
3-Bromo-5-Methyl-1H-1,2,4-Triazole [978]	10	ND
3,5-Diphenyl-1,4,2-Diaxazole [790]	10	ND
1,3-Dihydro-1-phenyl-2H-Benzimidazol-2-one [930]	40	ND
Hexanedioic Acid Ester	10	ND
Benzenedicarboxylic Acid Ester	*10	ND
Bromacil	ND	*20
OTHERS	(ALL ND OR <CRL)	
EXPLOSIVE COMPOUNDS		
ALL	(ALL ND OR <CRL)	
INORGANICS		
Barium, dissolved	NA	169
Barium, total	NA	147
Beryllium, total	0.2	<0.10
Cadmium, total	<5.10	7.52
Copper, dissolved	4.1	<1.9
Copper, total	8.9	6.86
Lead, dissolved	3.94	<2.50
Lead, total	7.38	<2.50
Nickel, dissolved	29.2	12.3
Nickel, total	14.1	<9.60
Zinc, dissolved	53.6	35.5
Zinc, total	308	119
OTHERS	(ALL ND OR <CRL)	

[illegible] REPORTING LIMIT [illegible] NA = NOT ANALYZED

[illegible] GREATER THAN 99% CERTAINTY THAT THE COMPOUND IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH these well locations were very low, near the detection limits. Upgradient well 2-3 contained benzene at 0.89 ug/l and TRCLE at 0.95 ug/l. Upgradient well 2-4 detected T12DCE at 5.8 ug/l.

Base Neutral and Acid Extractable Compounds

The only BNA compound detected during the two rounds of sampling was B2EHP. This compound was detected during round 1 of sampling only, at downgradient well locations 2-2, 2-5, 2-7, and 2-8 at respective concentrations of 300, 200, 60, and 500 ug/l. Although phthalate compounds are common laboratory contaminants, no detections occurred in the laboratory method blanks associated with these samples. These detections were not duplicated during round 2. Therefore, the B2EHP detections remain anomalous.

Unknown BNA compounds were detected in samples from six different monitoring wells at Area 2. Wells 2-1, 2-2, 2-4, 2-5, 2-7, and 2-8 had concentrations ranging from 10 to 200 ug/l. Detections occurred in both sampling rounds.

Inorganics

The results of the two rounds of groundwater sampling at Area 2 identified 11 inorganics which exceeded statistical background concentrations. Five of the 11 inorganics exceeded the MGS, MDWS, and/or MCL. Table 4-5 summarizes the detections and lists the monitoring well samples in which they were identified. Wells which contained inorganics above a specific standard are flagged with an asterisk in this table. The parameters which exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Total beryllium exceeded the MGS of 10 ug/l in upgradient sample 2-4-1 with a concentration of 12 ug/l. No beryllium standards exist under MCL or MDWS.

Dissolved cadmium exceeded the MCL of 5 ug/l with a detection of 10.7 ug/l in downgradient sample 2-2-2. Total cadmium exceeded the MCL in samples 2-2-1, 2-2-2, 2-3-1, 2-4-1, 2-4-2, 2-7-1, and 2-8-2 with respective concentrations of 130, 48.3, 6.44, 6.44, 6.41, 30.1, and 7.52 ug/l.

Total chromium exceeded the MDWS of 50 ug/l in samples 2-3-1 and 2-5-1 with respective concentrations of 72.1 and 51.9 ug/l. Total chromium exceeded the MCL of 100 ug/l in sample 2-4-1 with a concentration of 112 ug/l.

Total nickel exceeded the MGS of 200 ug/l in sample 2-4-1 with a concentration of 349 ug/l. No standards exist under MCL or MDWS.

Total selenium exceeded the MDWS of 10 ug/l in sample 2-2-2 with a concentration of 10.8 ug/l. This value does not exceed the MCL of 50 ug/l. No standards exist under MGS.

TABLE 4-5
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 2 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Antimony, total	2-4-1, 2-4-2	7.61 - 9.55	2-4-2	--
Arsenic, total	2-2-1, 2-2-2, 2-7-1	7.87 - 9.01	2-2-2	30.00
Barium, dissolved	2-4-2	259	2-4-2	
Beryllium, total	2-2-1, 2-3-1, *2-4-1, 2-7-1	1.01 - 12	*2-4-1	--
Cadmium, dissolved	*2-2-2	10.7	*2-2-2	--
Cadmium, total	*2-2-1, *2-2-2, *2-3-1, *2-4-1, *2-7-1, *2-8-2, *2-4-2	6.44 - 130	*2-2-1	5.00
Chromium, total	*2-3-1, *2-4-1, *2-5-1	51.9 - 112	*2-4-1	50.00
Copper, dissolved	2-3-2, 2-7-1, 2-8-1	4.07 - 37	2-3-2	1000.00
Copper, total	2-7-1	87	2-7-2	1000.00
Lead, dissolved	2-7-1, 2-8-1	3.94	2-7-1, 2-8-1	50.00
Nickel, dissolved	2-1-1, 2-2-1, 2-2-2, 2-3-1, 2-4-1, 2-5-1, 2-7-1, 2-8-1, 2-8-2	10.7 - 116	2-4-1	200.00
Nickel, total	2-2-1, 2-3-1, 2-3-2, *2-4-1, 2-7-1	65.4 - 349	*2-4-1	200.00
Selenium, total	*2-2-2	10.8	*2-2-2	10.00
Silver, total	2-1-2, 2-2-1, 2-2-2, 2-4-1, 2-4-2, 2-5-2, 2-7-1, 2-7-2	0.21 - 2.13	2-4-2	50.00
Zinc, dissolved	2-1-1, 2-2-1, 2-3-1, 2-4-1, 2-5-1, 2-7-1	306 - 1200	2-1-1	5000.00
Zinc, total	2-2-1	880	2-2-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXIST.

4.2.3 Summary

Potentially site-related detections occurred at six of the eight monitoring well locations at Area 2, including both upgradient well locations. Figure 4-4 presents the Area 2 monitoring well locations and summarizes the distribution of detections.

VOCs were detected in trace quantities near the surface impoundment at Area 2B, in upgradient wells 2-3 and 2-4. No VOCs were detected downgradient of the surface impoundments, nor were any detected during the second round of sampling.

BNA compounds (phthalates) were identified only downgradient of the surface impoundments at concentrations ranging from 60 to 500 ug/l. This data tends to implicate the impoundments as potential source areas; however, the phthalate compounds were only detected during round 1.

Explosive compounds were detected both upgradient and downgradient of Area 2A (overflow area) and Area 2B (surface impoundments). Detections occurred in both rounds of sampling.

Inorganic concentrations exceeded standards at all four monitoring well locations around the southern surface impoundment of Area 2B. Downgradient well location 2-7 also contained a metal (cadmium) at a concentration exceeding standards. Most of the elevated detections occurred at well locations 2-2 and 2-4, especially with elevated values of cadmium and chromium. According to the water table contour map in Figure 3-14, well locations 2-3 and 2-4 are upgradient of the southern surface impoundment; however, these locations are potentially being affected by mounding and subsequent radial groundwater flow created by the wastewater in the impoundment. The overflow event (Area 2A) may have had a minimal effect at well locations 2-7 and 2-8. Samples from both locations contained a phthalate compound, and well location 2-7 also contained explosive and elevated inorganic concentrations.

4.3 AREA 3 - SAND PITS

4.3.1 Site Description and Field Investigations

4.3.1.1 Area 3A - IWTP Sludge Burial Site

This site, shown in Figure 4-5, is an IWTP sludge burial site. It was closed in 1962. The estimated area is 90,000 square feet. The estimated sludge content is 30,000 cubic yards. Possible RCRA hazardous constituents are lead and mercury.

At Area 3, WESTON installed one deep monitoring well next to the existing shallow well (3-1). This well (3-8) was installed to bedrock at a depth of approximately 82 feet and monitors the plant

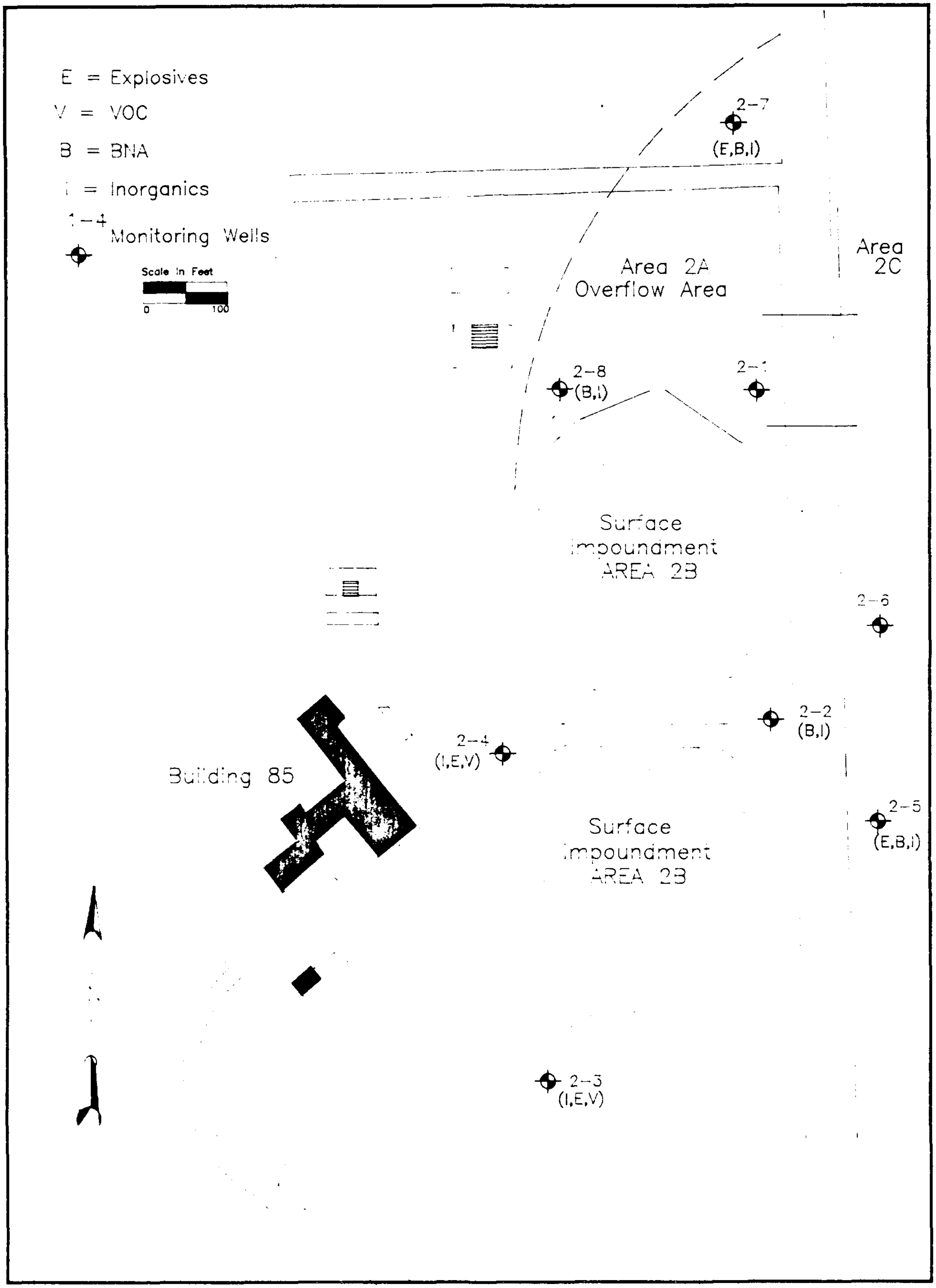
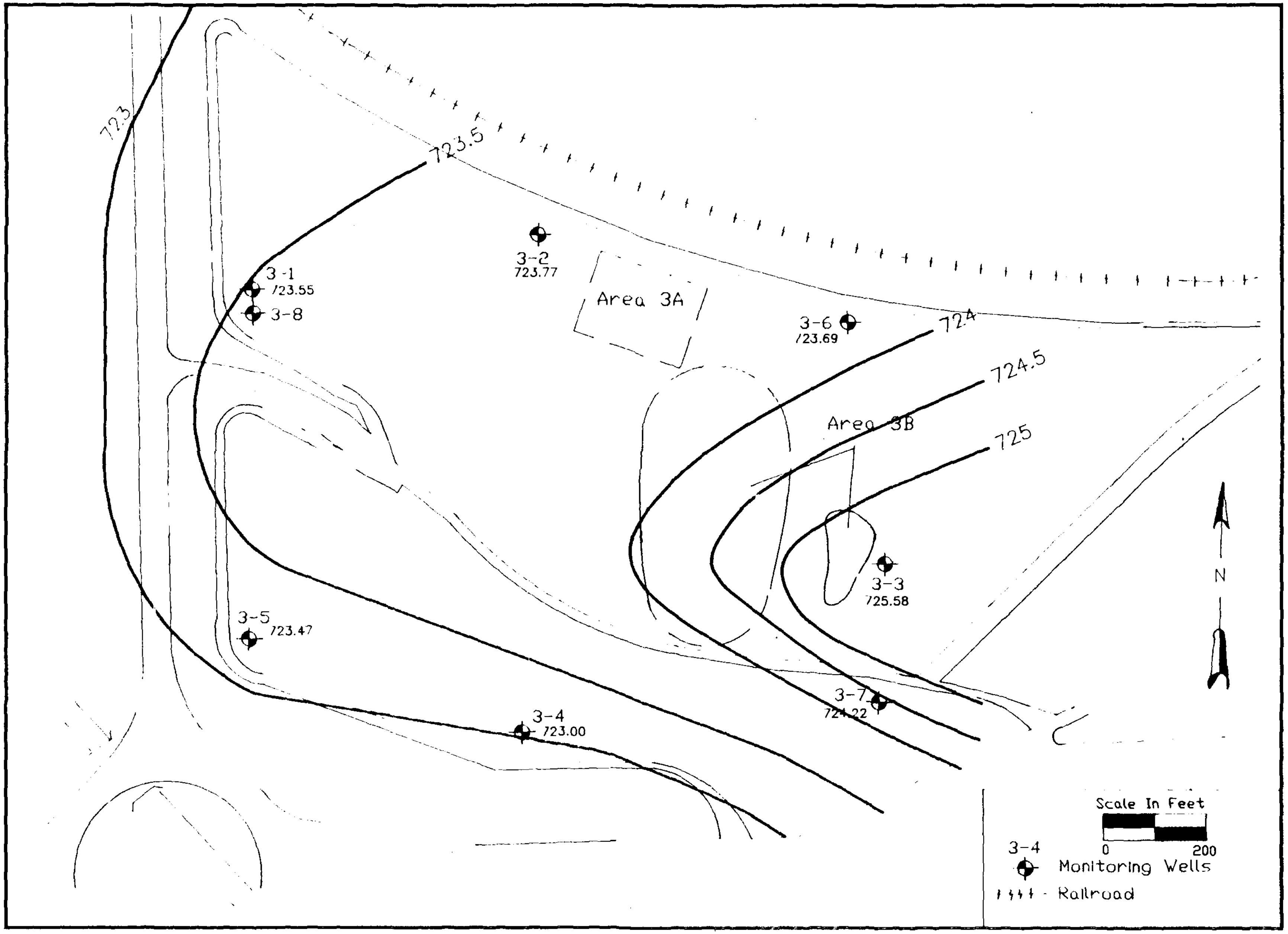


FIGURE 4-4
AREA 2 DETECTION LOCATIONS



area3

FIGURE 4-5
A 3

boundaries on the downgradient side of Area 3. It also provides important information regarding vertical gradients between the shallow and deep saturated zones. The previously existing seven wells at the site range in depth from 25 to 50 feet. The monitoring well network utilized during this RI consisted of three upgradient wells (3-3, 3-6, and 3-7), one sidegradient well (3-4), and four downgradient wells (3-1, 3-2, 3-5, and 3-8). The new deep well and the seven existing shallow wells were each sampled twice and analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. Additionally, six wells were analyzed for radiological activity during round 1 and two wells were analyzed for radiological activity during round 2. Radiological samples were collected upgradient and downgradient of Area 3 during both rounds. The sampling events were separated by an interval of approximately three months. Subsequent to this RI, three additional monitoring wells were installed as part of the 1989 GWQAP.

4.3.1.2 Area 3B

This site, also shown in Figure 4-5, includes two sand pits. IWTP sludge, oil and grease, and demolition waste were disposed in this area. The site was closed in 1966. The estimated area is 45,000 square feet, and the quantity of waste is unknown. Possible hazardous constituents are chromium, lead, and mercury. Also, installation personnel reported that waste related to the manufacturing of nuclear weapons may have been placed here by an outside defense contractor.

The field investigation for all of Area 3 (Areas 3A and 3B) was presented in Section 4.3.1.1.

4.3.2 Site Investigation Results

The results of this site investigation at Area 3 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.3.3). All radioactive, organic, and inorganic analytical data is presented in Table 4-6. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.3.2.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 3 identified five explosive compounds:

- Cyclotetramethylenetetranitramine (HMX).
- RDX.

TABLE 4-6
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #3
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	3-1-1	3-1-2	3-2-1	3-2-2	3-3-1	3-3-2
DEPTH (FT)	45	45	33	33	22	22
VOLATILES						
1,1-Dichloroethene	<1.92	<1.92	<1.92	11	<1.92	<1.92
OTHERS			(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	ND	40	ND	ND
UNKNOWNS						
C6-C9 Methyl Pentane/Pentene	ND	ND	ND	ND	ND	*20
C8-C10 Methyl Alkene/Alkane	ND	ND	ND	ND	ND	*20
2,6-Dimethyl-3-Octene [735]	ND	10	ND	ND	ND	ND
C8-C10 Methyl or Ethyl Alkene	ND	10	ND	ND	ND	ND
OTHERS			(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS						
2,4-DNT	<0.60	<0.60	<0.60	0.64	<0.60	<0.60
HMX	1.65	<1.30	<1.30	<1.30	<1.30	<1.30
RDX	46.5	<0.63	0.65	<0.63	<0.63	0.69
OTHERS			(ALL ND OR <CRL)			
INORGANICS						
Arsenic, total	<5.00	<5.00	8.59	<5.00	<5.00	11.4
Barium, dissolved	NA	140	NA	103	NA	257
Barium, total	NA	179	NA	296	NA	1050
Beryllium, dissolved	0.13	<0.10	0.11	<0.10	<0.10	<0.10
Beryllium, total	0.16	<0.10	0.64	<0.10	<0.10	2.62
Chromium, dissolved	<37.5	<37.5	<37.5	<37.5	<37.5	<37.5
Chromium, total	<37.50	<37.50	140	<37.50	<37.50	<37.50
Copper, dissolved	<1.78	5.68	10.4	15.9	<1.78	<1.78
Copper, total	39.3	10.6	26.5	18.6	<2.25	95
Lead, total	3.03	<2.50	10.4	<2.50	<2.50	57.4
Nickel, dissolved	38	<9.60	15	<9.60	18.8	<9.60
Nickel, total	43.3	64	34.9	28.3	30.9	78.3
Silver, total	<0.19	<0.19	0.21	<0.19	<0.19	0.32
Zinc, dissolved	41.2	69.5	262	18.8	<17.20	18.6
Zinc, total	559	203	98.7	134	536	377
OTHERS			(ALL ND OR <CRL)			
RADIOLOGICAL (PCI/L)						
Alpha	NA	NA	0+/-5	NA	0+/-5	NA
Beta	NA	NA	0+/-5	NA	0+/-5	NA
U-234	NA	NA	0+/-0.1	NA	0+/-0.1	NA
U-235	NA	NA	0+/-0.1	NA	0+/-0.1	NA
U-238	NA	NA	0+/-0.1	NA	0+/-0.1	NA
Total Uranium	NA	NA	NA	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT; ND=NOT DETECTED; NA=NOT ANALYZED

** INDICATES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-6
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #3
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	3-4-1	3-4-2	3-5-1	3-5-2	3-6-1	3-6-2
DEPTH (FT)	44	44	33	33	28.5	28.5
VOLATILES						
Trans-1,2-Dichloroethene	<1.72	<1.72	<1.72	<1.72	2.2	<1.72
Trichloroethene	<0.71	<0.71	<0.71	<0.71	26	<0.71
OTHERS			(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES						
UNKNOWNS						
2-(2-Methoxyethoxy) ethanol [924]	ND	ND	20	ND	ND	ND
C6-C9 Methyl Alkene/Alkane	ND	*10	ND	ND	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	*20	ND	ND	ND	ND
C8-C10 Methyl Alkene	ND	ND	ND	*30	ND	ND
C8-C12 Methyl or Ethyl Alkane	ND	ND	ND	20	ND	ND
OTHERS			(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS						
13-DNB	<0.61	<0.61	<0.61	<0.61	<0.61	0.68
135-TNB	<0.56	<0.56	<0.56	<0.56	<0.56	0.88
HMX	2.81	<1.30	<1.30	<1.30	<1.30	<1.30
RDX	<0.63	<0.63	4.93	<0.63	<0.63	<0.63
OTHERS			(ALL ND OR <CRL)			
INORGANICS						
Arsenic, dissolved	<5.00	<5.00	14.7	<5.00	<5.00	<5.00
Arsenic, total	<5.00	<5.00	13.9	15.1	7.76	<5.00
Barium, dissolved	NA	76	NA	81.4	NA	493
Barium, total	NA	82.5	NA	1180	NA	456
Beryllium, dissolved	<0.10	<0.10	1.59	<0.10	<0.10	<0.10
Beryllium, total	0.14	<0.10	1.29	1.01	0.19	<0.10
Chromium, dissolved	<37.50	<37.50	255	<37.50	<37.50	<37.50
Chromium, total	<37.50	<37.50	189	<37.50	<37.50	<37.50
Copper, dissolved	12	3.97	41.3	10.3	2.57	<1.78
Copper, total	9.54	6.54	31.8	49.6	9.65	6.65
Lead, dissolved	5.97	<2.50	28.1	<2.50	<2.50	2.53
Lead, total	6.77	2.53	25.1	29.8	<2.50	<2.50
Nickel, dissolved	14.4	<9.60	131	<9.60	20.4	31.9
Nickel, total	11.5	<9.60	95.4	93.5	38.5	27
Silver, dissolved	<0.19	<0.19	0.21	<0.19	<0.19	<0.19
Silver, total	<0.19	<0.19	0.21	0.21	0.21	<0.19
Zinc, dissolved	55.1	<17.20	255	82.4	176	<17.20
Zinc, total	96.8	76.8	171	285	77	360
OTHERS			(ALL ND OR <CRL)			
RADIOLOGICAL (PCi/L)						
Alpha	0+/-5	NA	0+/-5	NA	NA	NA
Beta	0+/-5	NA	0+/-5	NA	NA	NA
U-234	0+/-0.1	NA	0.1+/-0.1	NA	NA	NA
U-235	0+/-0.1	NA	0+/-0.1	NA	NA	NA
U-238	0+/-0.1	NA	0+/-0.1	NA	NA	NA
Total Uranium	NA	NA	NA	NA	NA	NA

CRL = CERTIFIED REPORTING LIMIT ND = NOT DETECTED NA=NOT ANALYZED

* DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-6
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #3
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	3-7-1	3-7-2	3-8-1	3-8-2
DEPTH (FT)	21.5	21.5	77.5	77.5
VOLATILES				
ALL	(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES				
UNKNOWNS				
Phenylene Ethanone	ND	ND	*10	ND
1-Propenyl Benzene [964]	ND	ND	30	ND
C6-C9 Cycloalkane	ND	ND	ND	*20
C8-C10 Methyl Alkene/Alkane	ND	ND	ND	*20
OTHERS	(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS				
HMX	<1.30	<1.30	3.04	<1.30
RDX	13.6	<0.63	120	<0.63
OTHERS	(ALL ND OR <CRL)			
INORGANICS				
Barium, dissolved	NA	171	NA	469
Barium, total	NA	119	NA	451
Beryllium, dissolved	0.15	<0.10	<0.10	<0.10
Beryllium, total	0.21	0.2	0.2	<0.10
Chromium, total	346	<37.50	88.5	<37.50
Copper, dissolved	2.36	6.86	<1.78	15.1
Copper, total	8.04	6.97	3.11	5.79
Lead, total	<2.50	2.93	5.97	<2.50
Nickel, dissolved	<9.60	<9.60	<9.60	15
Nickel, total	21.8	11.9	30.7	26.6
Silver, total	0.21	<0.19	<0.19	<0.19
Zinc, dissolved	193	<17.20	49.5	124
Zinc, total	231	111	585	105
OTHERS	(ALL ND OR <CRL)			
RADIOLOGICAL (PCI/L)				
Alpha	0+/-5	0+/-5	0+/-5	0+/-5
Beta	4+/-3	9+/-4	9+/-4	22+/-5
U-234	0.1+/-0.1	0.2+/-0.1	0+/-0.1	0.7+/-0.2
U-235	0+/-0.1	0+/-0.1	0+/-0.1	0
U-238	0.1+/-0.1	0.1+/-0.1	0+/-0.1	0.8+/-0.2
Total Uranium	NA	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

- 1,3-dinitrobenzene (13DNB).
- 1,3,5-trinitrobenzene (135TNB).
- 2,4-dinitrotoluene (24DNT).

The round 1 results indicated the presence of HMX and RDX. HMX was detected at the downgradient wells 3-1, 3-4, and 3-8 at respective concentrations of 1.65, 2.81, and 3.04 ug/l. RDX was detected at downgradient wells 3-1, 3-2, 3-5, and 3-8 and the upgradient well 3-7 at respective concentrations of 46.5, 0.65, 4.93, 120, and 13.6 ug/l.

The round 2 results indicated the presence of 13DNB, 135TNB, 24DNT, and RDX. The compounds 13DNB and 135TNB were detected at upgradient well 3-6 at respective concentrations of 0.68 and 0.88 ug/l. The compound 24DNT was detected at downgradient well 3-2 at a concentration of 0.64 ug/l. Upgradient well 3-3 contained RDX at 0.69 ug/l.

Volatile Organic Compounds

The results of two rounds of groundwater sampling at Area 3 identified three volatile organic compounds:

- T12DCE.
- TRCLE.
- 1,1-dichloroethene (11DCE).

The round 1 results indicated the presence of two VOCs: T12DCE and TRCLE. Both compounds were detected in upgradient well 3-6 at respective concentrations of 2.2 ug/l and 26 ug/l. The TRCLE MCL value of 5 ug/L was exceeded.

The round 2 results indicated the presence of one VOC: 11DCE at 11 ug/l in downgradient well 3-2. The 11DCE MCL value of 7 ug/l was exceeded.

Base Neutral and Acid Extractable Compounds

One BNA compound was detected during analysis of groundwater from Area 3. B2EHP was detected at downgradient well location 3-2 during round 2 at a concentration of 40 ug/l.

Unknown BNA compounds were detected in samples from six different monitoring wells at Area 3. Wells 3-1, 3-2, 3-3, 3-4, 3-5, and 3-8 had concentrations ranging from 10 to 30 ug/l. Detections occurred in both sampling rounds.

Inorganics

The results of the two rounds of groundwater sampling at Area 3 identified eight inorganics which exceeded statistical background concentrations. Three of the nine inorganics exceeded the MGS, MDWS, and/or MCL. Table 4-7 summarizes the detections and lists the monitoring well samples in which they were identified. Wells which contain inorganics above a specific standard are flagged with an asterisk in this table. The parameters which exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Total barium exceeded the MDWS of 1,000 ug/l in downgradient sample 3-5-2 and in upgradient sample 3-3-2 with respective concentrations of 1,050 and 1,180 ug/l.

Dissolved chromium exceeded both the MDWS of 50 ug/l and the MCL of 100 ug/l for total chromium in downgradient sample 3-5-1 with a concentration of 255 ug/l.

Total chromium exceeded both the MDWS of 50 ug/l and MCL of 100 ug/l in downgradient samples 3-2-1 and 3-5-1, and in upgradient sample 3-7-1 with respective concentrations of 140, 189, and 346 ug/l. Downgradient sample 3-8-1 exceeded the MCL but not the MDWS, with a concentration of 88.5 ug/l.

Total lead exceeded the MCL of 50 ug/l in upgradient sample 3-3-2 with a concentration of 57.4 ug/l.

Radiation Parameters

A total of eight radiological samples were collected during the two rounds from six wells at Area 3. All were in the normal range for groundwater activity. Further discussion of the radiological investigation is presented in Section 4.23.

4.3.3 Summary

Potentially site-related detections occurred at all eight monitoring well locations within Area 3, including upgradient and downgradient locations. Figure 4-6 presents the Area 3 monitoring well locations and summarizes the distribution of site-related detections.

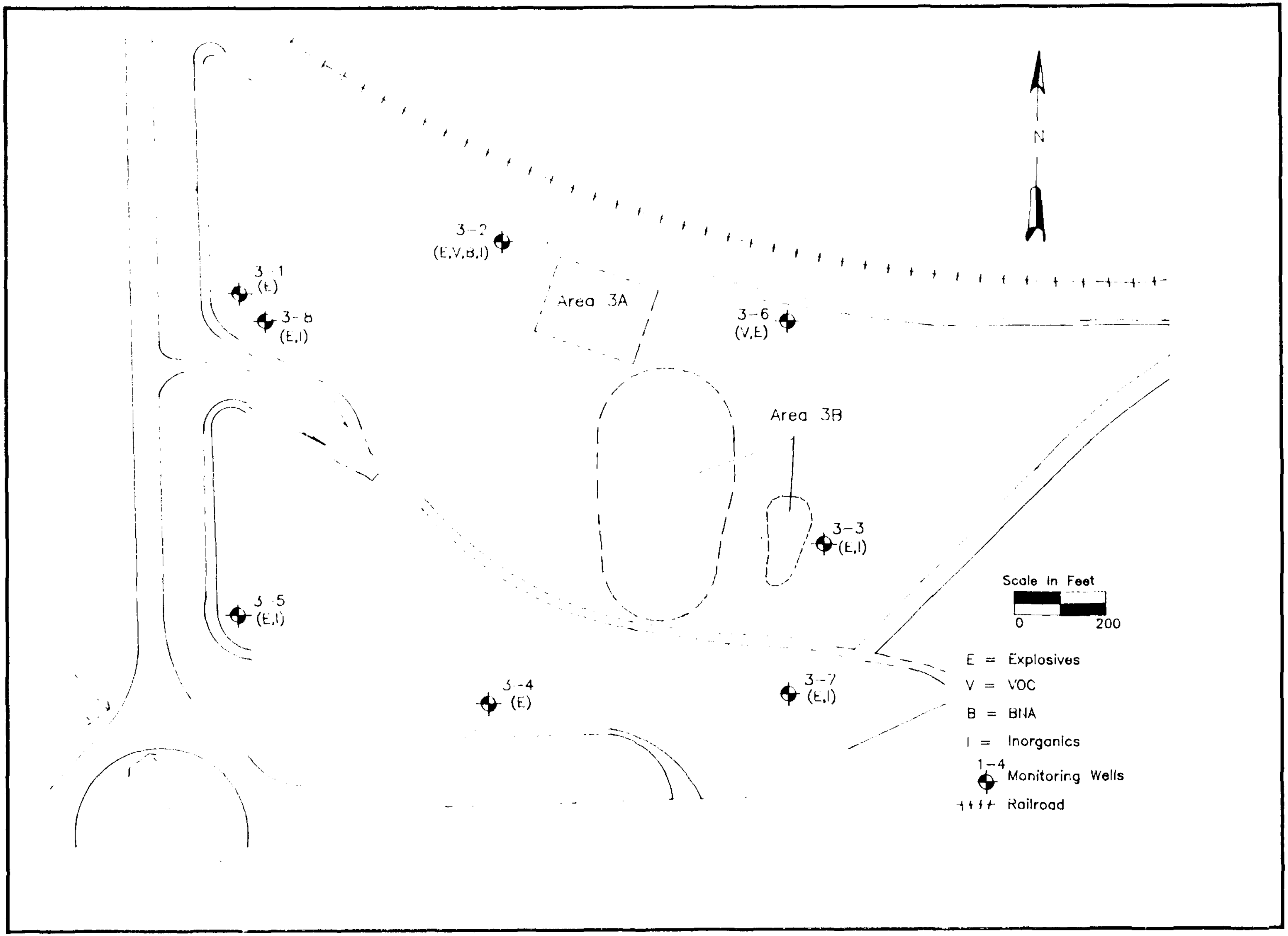
Volatile organic compounds were detected at moderate levels at monitoring well locations upgradient and downgradient of Area 3A (the IWTP sludge burial site). The upgradient detection occurred during round 1 and the downgradient detection occurred during round 2. The upgradient well (3-6) is located more than 200 feet from either Area 3A or Area 3B, and since neither area is associated with any groundwater mounding, the source of VOC contamination at well location 3-6 remains unknown. Areas 7, 12, and 14 are upgradient of well location 3-6.

The detection of B2EHP at downgradient well location 3-2 suggests the sludge burial site (Area 3A) as a potential source; however, this detection occurred during round 2 of sampling only.

TABLE 4-7
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 3 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Arsenic, dissolved	3-5-1	14.70	3-5-1	30.00
Arsenic, total	3-2-1, 3-3-2, 3-5-1, 3-5-2, 3-6-1	7.76 - 15.1	3-5-2	30.00
Barium, dissolved	3-6-2, 3-8-2	493	3-6-2	--
Barium, total	*3-3-2, *3-5-2	1050 - 1180	*3-5-2	1000.00
Beryllium, dissolved	3-1-1, 3-2-1, 3-5-1, 3-7-1	0.11 - 1.59	3-5-1	--
Beryllium, total	3-3-2, 3-5-1, 3-5-2	1.01 - 2.62	3-3-2	--
Chromium, dissolved	*3-5-1	255	*3-5-1	50.00
Chromium, total	*3-2-1, *3-5-1, *3-7-1, *3-8-1	88.5 - 346	*3-7-1	50.00
Copper, dissolved	3-1-2, 3-2-1, 3-2-2, 3-4-1, 3-4-2, 3-5-1, 3-5-2, 3-6-1, 3-7-1, 3-7-2, 3-8-2	2.36 - 41.3	3-5-1	1000.00
Copper, total	3-3-2, 3-5-2	49.6 - 95	3-3-2	1000.00
Lead, dissolved	3-4-1, 3-5-1	2.53 - 28.1	3-5-1	50.00
Lead, total	*3-3-2, 3-5-1, 3-5-2	25.1 - 57.4	*3-3-2	50.00
Nickel, dissolved	3-1-1, 3-2-1, 3-3-1, 3-4-1, 3-5-1, 3-6-1, 3-6-2, 3-8-2	14.4 - 131	3-5-1	200.00
Nickel, total	3-1-2, 3-3-2, 3-5-1, 3-5-2	64 - 95.4	3-5-1	200.00
Silver, dissolved	3-5-1	0.21	3-5-1	50.00
Silver, total	3-2-1, 3-3-2, 3-5-1, 3-5-2, 3-6-1, 3-7-1	0.21 - 0.32	3-3-2	50.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXIST.



AREA3C

FIGURE 4-6
AREA 3 DET[illegible]ON LOCATIONS

Explosive compounds were detected at all eight well locations within Area 3 at a wide range of concentrations. Round 1 results identified high values at the downgradient wells of 3-1 and 3-8, the only well cluster within Area 3. All of the round 2 concentrations were at trace quantities. The fact that the detections at wells 3-1 and 3-8 were by far the greatest within the area suggests that Area 3A and/or 3B have contributed explosive compounds to the groundwater. Monitoring well 3-8 is constructed at the base of the outwash, which indicates the downward migration of explosive compounds at Area 3.

Chromium concentrations exceeded standards during the first round of sampling only in one upgradient and three downgradient monitoring well locations. Barium and lead concentrations exceeded standards during round 2 at upgradient well location 3-3, which is located adjacent to the smaller of the two sand pits. Round 1 did not identify any lead at this location. The only other elevated barium and lead concentrations were detected at downgradient well location 3-5. The source of the barium, lead, and chromium groundwater contamination at Area 3 remains uncertain, although there appears to be some influence from Areas 3A (IWTP sludge burial pit) and 3B (sand pits). Area 12 results showed elevated inorganic concentrations in the groundwater. Since Area 3 is directly downgradient, Area 12 may be the source of the barium, lead, and chromium. No silver concentrations were detected above the standards.

4.4 AREA 4 - BUILDING 139 (SOUTH) TREATED EXPLOSIVE WASTE SURFACE IMPOUNDMENT AREA

4.4.1 Site Description and Field Investigations

4.4.1.1 Area 4A - Surface Impoundments

This site, shown in Figure 4-7, is a closed facility consisting of four surface storage impoundments containing neutralized wastes from Building 139. A closure plan was submitted in 1985 and the impoundments were subsequently closed in 1987. The wastes are RCRA-listed wastes K044 and K046. Hazardous constituents are lead and antimony.

The field activity for Area 4A involved two sampling events for the previously existing six wells in Area 4. These existing wells ranged in depth from 26 to 45 feet. Monitoring wells 4-1 and 4-4 are designated downgradient wells, well 4-3 is designated sidegradient, and wells 4-2, 4-5, and 4-6 are designated upgradient wells with respect to monitoring the surface impoundments. All groundwater samples were analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. Well 4-2 was also sampled and analyzed for radiation parameters during the first round of sampling. The sampling events were separated by an interval of

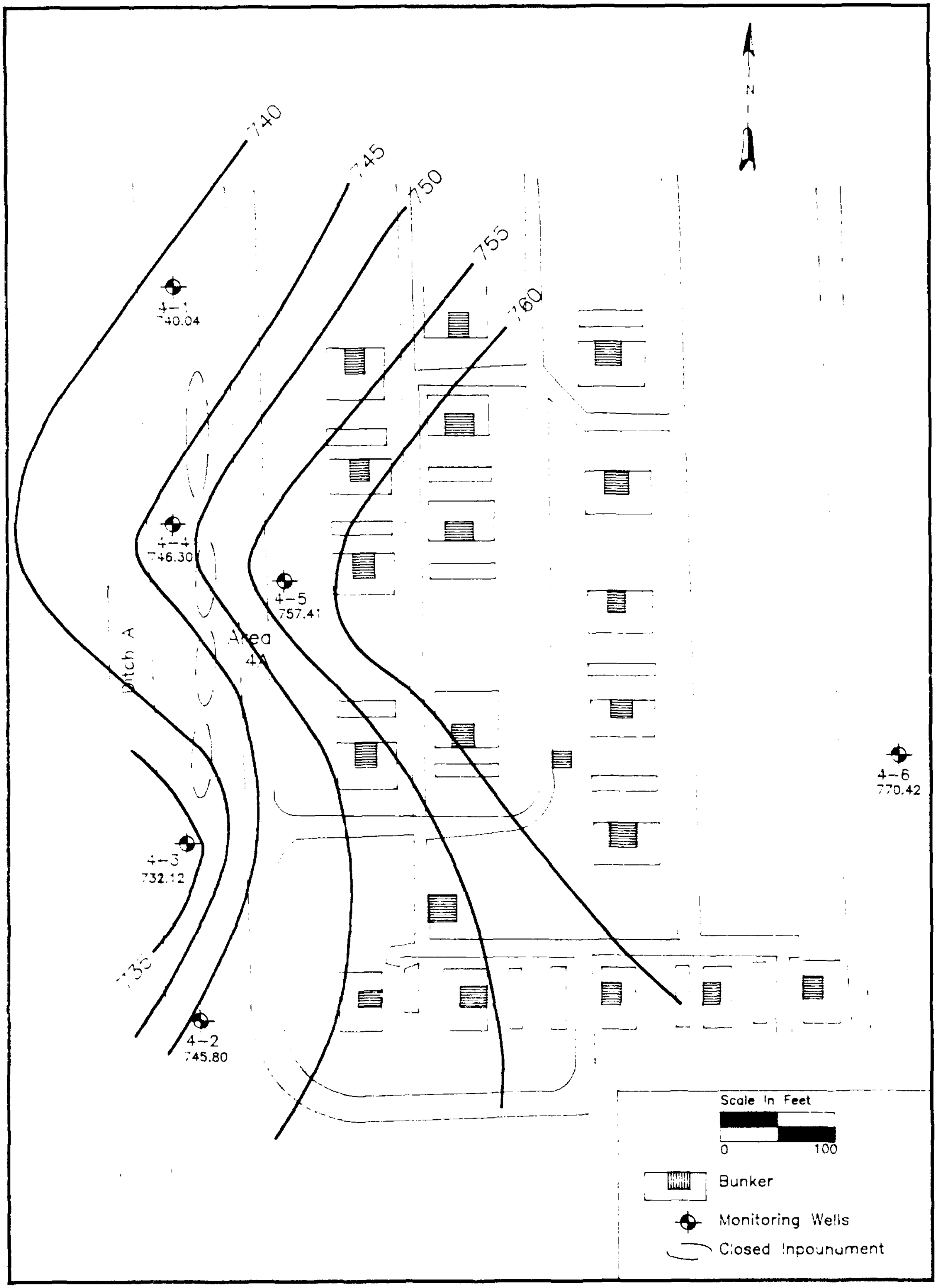


FIGURE 4-7
AREA 4

approximately three months. As part of the 1989 GWQAP, wells 4-1, 4-3, and 4-6 were abandoned and additional wells installed.

4.4.2 Site Investigation Results

The results of this site investigation at Area 4 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.4.3). All radiological, organic, and inorganic analytical data is presented in Table 4-8. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.4.2.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 4 detected four explosive compounds:

- 135TNB.
- HMX.
- RDX.
- 13DNB.

The round 1 results detected 135TNB at downgradient well location 4-1 at a concentration of 11.7 ug/l. HMX was detected at the downgradient well location 4-1 at a concentration of 3.24 ug/l. RDX was detected at the upgradient well locations 4-2, 4-5 and 4-6 and the downgradient well 4-4 at respective concentrations of 5.96, 1.97, 0.63, and 2.27 ug/l.

The round 2 results detected 13DNB at sidegradient well location 4-3 and at a concentration of 1.73 ug/l. The compound 135TNB was detected at well location 4-3 (sidegradient) and 4-5 (upgradient) at a concentration of 0.70 and 0.63 ug/l, respectively. RDX was detected at the upgradient well location 4-2 at a concentration of 1.97 ug/l.

Volatile Organic Compounds

No VOCs were identified during the two rounds of groundwater sampling at Area 4.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 4 identified one BNA compound: B2EHP.

TABLE 4-8
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #4
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	4-1-1	4-1-2	4-2-1	4-2-2	4-3-1	4-3-2
DEPTH (FT)	34	34	37.5	37.5	35	35
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	10	ND	ND	ND	ND
UNKNOWNS						
(Phenoxymethyl) Benzene [726]	ND	20	ND	ND	ND	ND
C14-C15 Methyl Cycloalkane	ND	*10	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
13-DNB	<0.61	<0.61	<0.61	<0.61	<0.61	1.73
135-TNB	11.7	<0.56	<0.56	<0.56	<0.56	0.7
HMX	3.24	<1.30	<1.30	<1.30	<1.30	<1.30
RDX	<0.63	<0.63	5.96	1.97	<0.63	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, total	<3.00	11.4	<3.00	<3.00	<3.00	<3.00
Arsenic, total	<5.00	<5.00	<5.00	<5.00	5.38	7.14
Barium, dissolved	83.1	115	NA	265	159	228
Barium, total	190	219	NA	417	621	877
Beryllium, total	0.4	0.81	0.33	0.5	1.21	2.41
Cadmium, total	<5.10	6.44	<5.10	<5.10	<5.10	7.52
Chromium, dissolved	<37.50	<37.50	49	<37.50	<37.50	<37.50
Chromium, total	<37.50	<37.50	81.7	<37.50	<37.50	61.5
Copper, dissolved	3.97	<1.78	<1.78	<1.78	<1.78	4.61
Copper, total	12	19.1	13.9	19.9	35.3	59
Lead, dissolved	<2.50	<2.50	<2.50	2.83	<2.50	<2.50
Lead, total	3.44	7.79	<2.50	4.15	8.9	15.9
Nickel, dissolved	<9.60	<9.60	<9.60	15	<9.60	14.5
Nickel, total	21.1	21.4	25	43.7	61.7	89.2
Silver, dissolved	14	<0.19	<0.19	<0.19	<0.19	<0.19
Zinc, dissolved	760	36	850	1400	1100	1100
Zinc, total	550	101	720	410	740	760
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCi/L)						
Alpha	NA	NA	<6	NA	NA	NA
Beta	NA	NA	<7	NA	NA	NA
U-234	NA	NA	NA	NA	NA	NA
U-235	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA
Total Uranium	NA	NA	1.5	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-8
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #4
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	4-4-1 29.5	4-4-2 29.5	4-5-1 23.5	4-5-2 23.5	4-6-1 37.5	4-6-2 37.5
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	ND	ND	ND	10
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
135-TNB	<0.56	<0.56	<0.56	0.63	<0.56	<0.56
RDX	2.27	<0.63	1.97	<0.63	<0.63	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, dissolved	<3.00	<3.00	3.41	<3.00	<3.00	4.66
Antimony, total	<3.00	<3.00	<3.00	<3.00	<3.00	11.4
Arsenic, total	<5.00	5.28	<5.00	<5.00	<5.00	<5.00
Barium, dissolved	NA	122	NA	92.2	NA	156
Barium, total	NA	303	NA	164	NA	131
Beryllium, total	8.3	0.6	1.45	0.4	0.2	0.2
Cadmium, total	7.52	<5.10	<5.10	<5.10	<5.10	33.3
Chromium, total	335	<37.50	60.6	<37.50	<37.50	34.4
Copper, dissolved	<1.78	<1.78	3.11	3.22	5.04	<1.78
Copper, total	48.3	14.9	25.3	10.6	14.1	3.86
Lead, total	15.3	8.19	9.71	4.95	3.54	<2.50
Nickel, dissolved	15.1	<9.60	89.8	9.7	16.7	<9.60
Nickel, total	285	26.2	40.4	30.9	14.4	9.8
Zinc, dissolved	1200	1100	590	650	269	30.4
Zinc, total	740	524	900	501	1100	703
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

B2EHP was detected during round 2 at the downgradient well location 4-1 and the upgradient well location 4-6, both at concentrations of 10 ug/l.

Although B2EHP was not detected in the laboratory method blanks associated with the investigative samples, it is a common field contaminant. The inconsistent detection of this contaminant suggests that it probably does not represent actual groundwater conditions.

Well 4-1 contained two unknown BNA compounds during round 2 at 10 and 20 ug/l.

Inorganics

The results of the two rounds of groundwater sampling at Area 4 identified ten inorganics which exceeded statistical background concentrations. Three of the ten inorganics exceeded the MGS, MDWS, and/or MCL. Table 4-9 summarizes the inorganic parameters which were determined to be site-related detections and lists the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in this table. The parameters which exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Total cadmium exceeded the MCL of 5 ug/l in upgradient samples 4-3-2 and 4-6-2 and downgradient samples 4-1-2 and 4-4-1 with detections of 7.52, 33.3, 6.44 and 7.52 ug/l, respectively.

Total chromium exceeded the MDWS of 50 ug/l in upgradient samples 4-2-1 and 4-5-1, and sidegradient sample 4-3-2 with respective concentrations of 81.7, 60.6, and 61.5 ug/l. Downgradient sample 4-4-1 exceeded the MCL of 100 ug/l with a concentration of 335 ug/l.

Total nickel exceeded the MGS of 200 ug/l in downgradient sample 4-4-1 with a detection of 285 ug/l. No standards exist under MCL or MDWS.

Radiation Parameters

There were no elevated radiological activities for the one sample (4-2) collected in this area. Alpha and beta activities were below the limit of detection (LOD). Further discussion of Area 4 radiological data is presented in Section 4.23.

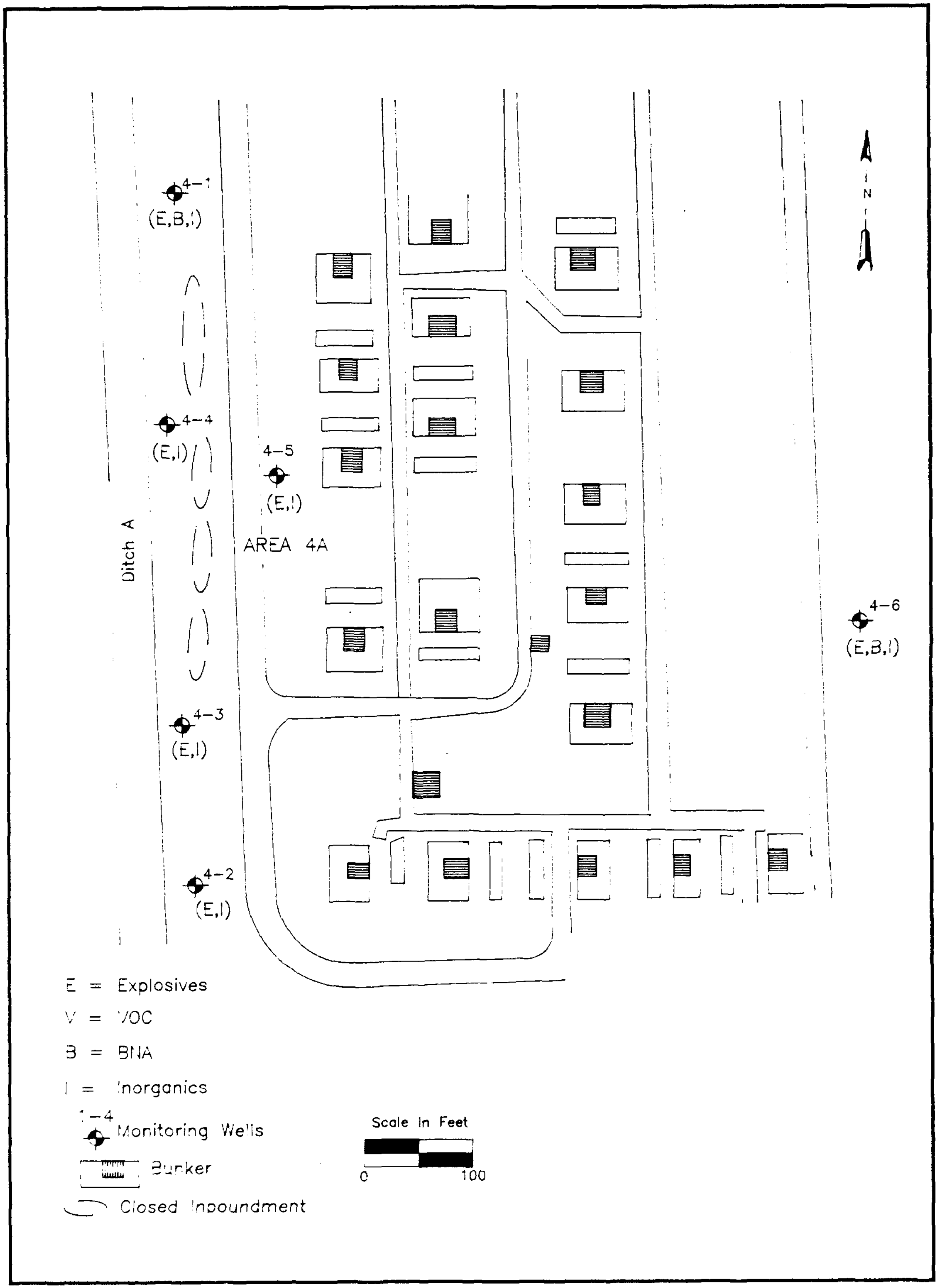
4.4.3 Summary

Potentially site-related detections occurred at all six monitoring well locations within Area 4, including upgradient and downgradient locations. Figure 4-8 presents the Area 4 monitoring well

TABLE 4-9
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 4 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Antimony, dissolved	4-5-1, 4-6-2	3.41 - 4.66	4-6-2	--
Antimony, total	4-1-2, 4-6-2	11.4	4-1-2, 4-6-2	--
Arsenic, total	4-3-1, 4-3-2, 4-4-2	5.28 - 7.14	4-3-2	30.00
Barium, dissolved	4-2-2	265	4-2-2	1000.00
Barium, total	4-3-2	877	4-3-2	1000.00
Beryllium, total	4-3-1, 4-3-2, 4-4-1, 4-5-1	1.21 - 8.3	4-4-1	--
Cadmium, total	*4-1-2, *4-3-2, *4-4-1 *4-6-2	6.44 - 33.3	*4-6-2	5.00
Chromium, dissolved	4-2-1	49	4-2-1	50.00
Chromium, total	*4-2-1, *4-3-2 , *4-4-1, *4-5-1, 4-6-2	34.4 - 335	*4-4-1	50.00
Copper, dissolved	4-1-1, 4-3-2, 4-5-1, 4-5-2, 4-6-1	3.11 - 5.04	4-6-1	1000.00
Copper, total	4-3-2, 4-4-1	48.3 - 59	4-3-2	1000.00
Nickel, dissolved	4-2-2, 4-3-2, 4-4-1, 4-5-1, 4-5-2, 4-6-1	9.7 - 89.8	4-5-1	200.00
Nickel, total	4-3-2, *4-4-1	89.2 - 285	*4-4-1	200.00
Silver, dissolved	4-1-1	14	4-1-1	50.00
Zinc, dissolved	4-1-1, 4-2-1, 4-2-2, 4-3-1, 4-3-2, 4-4-1, 4-4-2, 4-5-1, 4-5-2	590 - 1400	4-2-2	5000.00
Zinc, total	4-5-1, 4-6-1	900 - 1100	4-6-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXIST.



AREA4CO

FIGURE 4-8
AREA 4 DETECTION LOCATIONS

locations and summarizes the distribution of site-related detections.

The results of explosive compound analyses show some influence of Area 4 on local groundwater quality. Monitoring wells located along the western (downgradient) edge of the area showed higher concentrations than either monitoring well 4-5 or 4-6, which are located east (upgradient) of the closed impoundments. The explosive compound detections from wells 4-1, 4-3, and 4-4 are downgradient or sidegradient of the four closed surface impoundments and are potentially the result of a release from these sources. The explosive compounds detected upgradient of the closed impoundments in wells 4-2 and 4-5 may indicate a source upgradient of Area 4.

The known BNA compound B2EHP detected within Area 4 was not consistently identified between sample rounds. It is commonly found as a laboratory or field contaminant and therefore may not be reflective of actual groundwater chemistry at Area 4.

Potentially site-related inorganic concentrations were detected in each of the well locations at Area 4. The inorganic parameters which exceeded MGS, MDWS, and/or MCL include cadmium and chromium which were observed at the downgradient locations 4-3 and 4-4 and upgradient location 4-6. Nickel was also detected at well location 4-4 at elevated concentrations. The potential source of these detections are the four surface impoundments. Elevated chromium detections were observed at upgradient well locations 4-2 and 4-5. Potential sources of chromium and cadmium may be present upgradient of Area 4.

4.5 AREA 5 - BUILDING 139 (NORTH) TREATED EXPLOSIVE WASTE SURFACE IMPOUNDMENT AREA

4.5.1 Site Description and Field Investigations

4.5.1.1 Area 5A - Overflow Area

On 4 January 1984, a line leading from treatment tanks in the 139 Backline Area to a storage lagoon became plugged when exposed portions of the line froze. Treated wastewater from the processing of lead-based initiating compounds was released to the environment at a manhole located between a treatment tank and the lagoon. Approximately 1,260 gallons of treated wastewater containing 1.5 ppm lead (total of 0.02 pounds of lead) was released to Ditch A (Figure 4-9). The exposed drain line was wrapped with a steam line to prevent recurrence of this incident. The release was reported to the U.S. EPA and MDNR. Due to subsequent precipitative events, considerable flushing of potential contaminants has occurred since the spill.

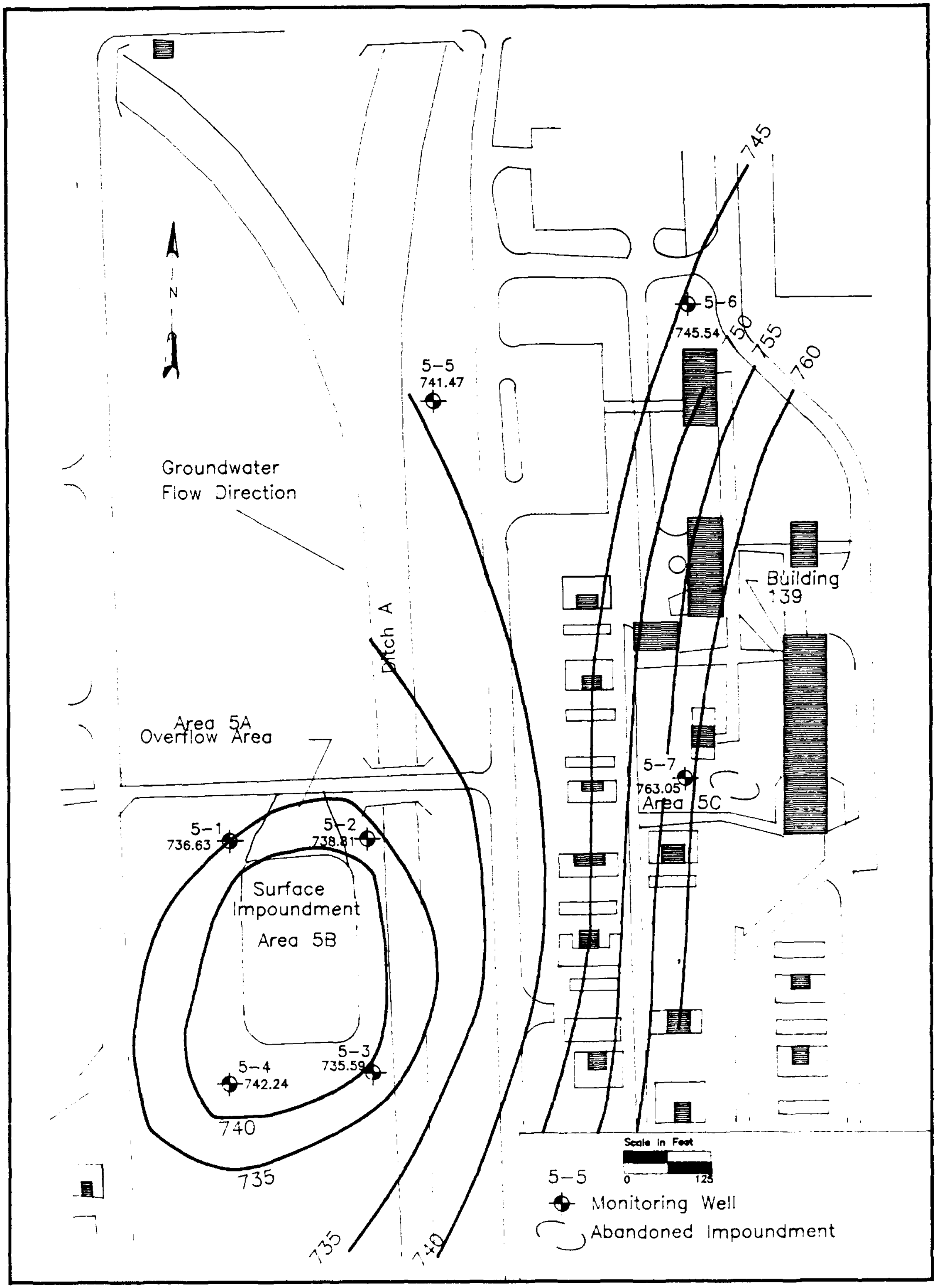


FIGURE 4-9
AREA 5

No field work was performed for this area during this phase of the remedial investigation. The amount of lead released was small, and, as noted, the area has been periodically flushed due to subsequent stormwater events.

4.5.1.2 Area 5B - Surface Impoundment

This area, also shown in Figure 4-9, is of one storage impoundment which is currently undergoing RCRA closure and in the past received neutralized wastes from Building 139. The impoundment is 139 feet by 211 feet. The wastes received were RCRA-listed wastes K044 and K046. Hazardous constituents were lead, barium, and antimony.

At the time of this RI, four wells monitored the shallow groundwater (20 to 40 feet deep) on all sides of the lagoon. Well 5-3 was the designated upgradient monitoring well, well 5-1 was the downgradient well, and wells 5-2 and 5-4 were the sidegradient wells. As part of the 1989 GWQAP, wells 5-2 and 5-3 were abandoned and replaced with additional wells.

The field work for Area 5B consisted of two rounds of sampling and analysis of the four existing monitoring wells. All samples were analyzed for VOCs, BNAs, inorganics, (total and dissolved), and explosives. The sampling events were separated by an interval of approximately three months. In addition, well 5-2 was sampled and analyzed for radiation parameters during both sampling events.

4.5.1.3 Area 5C - Surface Impoundment

Area 5C, also shown in Figure 4-9, was a surface impoundment used to receive treated wastes from Building 139 and the backline. The impoundment was located at the southwestern side of Building 139. It was operated during the late 1950s. The estimated quantity of waste is 36,000 cubic feet. The wastes are RCRA-listed wastes K044 and K046. Hazardous constituents are lead and antimony.

One monitoring well was installed at Area 5C. This well (5-7) is located on the western boundary of the former lagoon and monitors the groundwater downgradient from the lagoon. The well was screened below the water table at about 26 feet. Monitoring wells 5-5 and 5-6 monitor the shallow groundwater downgradient of the entire area. Figure 4-9 shows the location of these monitoring wells in Area 5. Two rounds of groundwater samples, separated by a three-month interval, were analyzed for VOCs, BNAs, inorganics, and explosives.

4.5.2 Site Investigation Results

The results of this site investigation at Area 5 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.5.3). All radiological, organic, and inorganic analytical data is presented in Table 4-10. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.5.2.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling in Area 5 detected the explosive compound cyclonite (RDX). Round 1 results detected RDX at well locations 5-1, 5-2, 5-4, 5-5, 5-6, and 5-7. The detected values of RDX ranged between 2.74 ug/l and 8.67 ug/l. The round 2 results detected RDX at well locations 5-1, 5-6, and 5-7 at respective concentrations of 0.69, 3.84, and 3.65 ug/l. Monitoring wells 5-1, 5-2, 5-4, 5-5, and 5-7 are all downgradient or sidegradient of potential sources. Wells 5-3 and 5-6 are upgradient wells.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at Area 5 identified eight VOCs:

- 111TCE.
- 11DCLE.
- 11DCE.
- Chloroethane.
- T12DCE.
- TRCLE.
- Vinyl chloride.
- Methylene chloride

During the first round of groundwater sampling, the compound 11TCE was detected at the sidegradient well 5-2 at a concentration of 7 ug/l.

The compound 11DCE was detected at downgradient well location 5-7 at a concentration of 4.6 ug/l. T12DCE was detected at the downgradient well locations 5-4 and 5-5 and at respective concentrations of 8.3 ug/l and 4.0 ug/l. At the downgradient well location 5-7, the compounds 11DCE, T12DCE, and vinyl chloride were detected at concentrations of 4.6 ug/l, 362 and 10 ug/l, respectively. The vinyl chloride MCL of 2.00 ug/l was exceeded.

During the second round of sampling, the sidegradient well 5-2 contained 111TCE and 11DCLE at 7 and 10 ug/l, respectively. Methylene chloride was detected at the sidegradient well location 5-3 at a concentration of 5 ug/l. T12DCE and TRCLE were detected at downgradient well location 5-7 at concentrations of 40 and 42

TABLE 4-10
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #5
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	5-1-1	5-1-2	5-2-1	5-2-2	5-3-1	5-3-2
DEPTH (FT)	32.5	32.5	26.5	26.5	39	39
VOLATILES						
1,1,1-Trichloroethane	ND	ND	7	7	ND	ND
1,1-Dichloroethane	ND	ND	20	10	ND	ND
1,1-Dichloroethene	<1.92	<1.92	<1.92	<2.08	<1.92	<1.92
Methylene Chloride	ND	ND	ND	ND	ND	5
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	40	ND	ND	20	ND	ND
UNKNOWNS						
C6-C9 Cycloalkane	ND	*20	ND	ND	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	*30	ND	ND	ND	ND
Benzene Methane Sulfonamide [727]	ND	ND	ND	30	ND	ND
Cyclododecanol [846]	ND	ND	ND	10	ND	ND
C7-C12 Methyl Alkene	ND	ND	ND	ND	ND	10
(Phenoxymethyl) Benzene [739]	ND	ND	ND	ND	ND	*10
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	8.1	0.69	4.72	<0.63	<0.63	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, total	<3.00	<3.00	<3.00	10.6	<3.00	5.91
Arsenic, dissolved	7.14	6.21	<5.00	<5.00	<5.00	<5.00
Arsenic, total	<5.00	11.5	<5.00	<5.00	<5.00	<5.00
Barium, dissolved	NA	216	303	307	204	256
Barium, total	NA	325	292	298	206	114
Beryllium, total	7.6	0.3	<0.10	0.2	<0.10	<0.10
Cadmium, total	20.4	<5.10	<5.10	<5.10	<5.10	<5.10
Chromium, total	119	<37.50	<37.50	<37.50	<37.50	<37.50
Copper, dissolved	90	<1.78	<1.78	<1.78	<1.78	<1.78
Copper, total	250	11.5	<1.78	10.5	5.47	7.29
Lead, dissolved	<2.50	4.95	<2.50	<2.50	<2.50	<2.50
Lead, total	12.6	17.4	3.34	<2.50	<2.50	<2.50
Nickel, dissolved	15.1	<9.60	15.9	11.5	<9.60	<9.60
Nickel, total	87.3	17.8	61.9	346	<9.60	9.8
Silver, total	<0.19	<0.19	0.21	<0.19	<0.19	<0.19
Zinc, dissolved	910	31.9	316	120	650	55.5
Zinc, total	900	160	228	125	486	68.2
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCI/L)						
Alpha	NA	NA	NA	0+/-5	NA	NA
Beta	NA	NA	NA	15+/-4	NA	NA
U-234	NA	NA	NA	0.9+/-0.2	NA	NA
U-235	NA	NA	NA	0+/-0.1	NA	NA
U-238	NA	NA	NA	0.6+/-0.2	NA	NA
Total Uranium	NA	NA	NA	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

* DENOTES A GREATER THAN 90% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-10
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #5
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	5-4-1	5-4-2	5-5-1	5-5-2	5-6-1	5-6-2
DEPTH (FT)	34	34	23.5	23.5	24	24
VOLATILES						
Trans-1,2-Dichloroethene	8.3	<1.72	4	<1.72	<1.72	<1.72
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
UNKNOWNS						
C6-C9 Methyl Alkene/Alkane						
C12-C14 Alkane Glycol	*300	*10	ND	ND	ND	ND
2,6,9-Trimethyl-1,6-Decadiene [960]	20	ND	*200	ND	*400	ND
C9-C11 Alkane Glycol	*10	ND	ND	ND	ND	ND
3,5 5-Trimethyl-1-Hexene [829]	ND	ND	10	ND	ND	ND
3-Methyl-6-Heplen-1-01 [938	ND	ND	20	ND	ND	ND
5-Tetradecen-1-01 [930]	ND	ND	10	ND	ND	ND
2-Methyl-1-propoxy-propane [873]	ND	ND	10	ND	ND	ND
Butyl Isopentryl Ether [936]	ND	ND	10	ND	ND	ND
Trimethyl Decane	ND	ND	*10	ND	ND	ND
Dimethyl Decane	ND	ND	*10	ND	ND	ND
Benzene Acid Derivative	ND	ND	ND	ND	ND	ND
4-Octenoic Acid Methyl Ester [982]	ND	ND	ND	ND	20	ND
3-Nonen-1-01 [942]	ND	ND	ND	ND	30	ND
C9-C16 Alkane Glycol	ND	ND	ND	ND	*20	ND
Paralblehyde [926]	ND	ND	ND	ND	20	ND
Benzededicarboxylic Acid Ester	ND	ND	ND	*10	ND	ND
(Phenoxymethyl)-Benzene [694]	ND	ND	ND	10	ND	*10
(Phenoxymethyl) Benzene [724]	ND	ND	ND	ND	ND	10
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	2.74	<0.63	4.56	<0.63	8.67	3.84
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, total	<3.00	<3.00	15.9	<3.00	<3.00	10.3
Arsenic, dissolved	<5.00	5.8	<5.00	<5.00	<5.00	<5.00
Barium, dissolved	NA	146	NA	256	NA	198
Barium, total	NA	247	NA	75.4	NA	186
Beryllium, total	1.71	0.3	0.57	<0.10	0.39	<0.10
Cadmium, total	<5.10	<5.10	<5.10	8.59	<5.10	7.52
Chromium, total	86.5	<37.50	46.2	<37.50	50	<37.50
Copper, dissolved	<1.78	<1.78	<1.78	<1.78	<1.78	3
Copper, total	19.4	9	10.9	<1.78	9.43	<1.78
Lead, total	<2.50	9.4	3.13	<2.50	2.93	<2.50
Nickel, dissolved	22.6	<9.60	19	<9.60	62.3	<9.60
Nickel, total	418	199	62.8	25.4	117	17.4
Silver, dissolved	<0.19	0.21	<0.19	<0.19	<0.19	<0.19
Zinc, dissolved	760	17.5	880	66.8	570	<17.20
Zinc, total	350	344	1000	221	425	137
OTHERS	(ALL ND OR <CRL)					

[illegible] CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

[illegible] DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-10
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #5
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	5-7-1	5-7-2
DEPTH (FT)	31	31
VOLATILES		
1,1-Dichloroethene	4.6	<1.92
Trans-1,2-Dichloroethene	362	40
Trichloroethene	<0.71	42
Vinyl Chloride	10	<3.86
OTHERS		(ALL ND OR <CRL)
BASE NEUTRAL & ACID EXTRACTABLES		
UNKNOWNS		
C6-C9 Cycloalkane	ND	*20
C8-C10 Methyl Alkene/Alkane	ND	*20
C9-C14 Alkane Glycol	*400	ND
C8-C10 Trimethyl Cycloalkane	*10	ND
C11-C16 Decen-1-01	*10	ND
OTHERS		(ALL ND OR <CRL)
EXPLOSIVE COMPOUNDS		
RDX	4.71	3.65
OTHERS		(ALL ND OR <CRL)
INORGANICS		
Barium, dissolved	NA	121
Barium, total	NA	129
Beryllium, total	0.43	<0.10
Copper, total	10.2	4.5
Lead, total	3.74	5.46
Nickel, dissolved	97.4	<9.60
Nickel, total	25.2	18.4
Silver, total	<0.19	0.21
Zinc, total	850	86.5
OTHERS		(ALL ND OR <CRL)

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

ug/l, respectively. The 11DCE MCL of 7.00 ug/l and the TRCLE MCL of 5.00 ug/l were exceeded.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 5 identified one BNA compound: B2EHP.

B2EHP was detected during the first round of sampling at downgradient well location 5-1 at a concentration of 40 ug/l. During the second round of sampling, it was detected at the sidegradient well location 5-2 at a concentration of 20 ug/l.

B2EHP was not detected in the laboratory method blanks associated with the investigative samples but is a common field contaminant. The inconsistent detection of B2EHP between sampling rounds suggests that it may not be representative of actual groundwater conditions.

Unknown BNA compounds were detected in samples from seven different monitoring wells at Area 5. Wells 5-1 through 5-7 had concentrations ranging from 10 to 400 ug/l. Detections occurred in both sampling rounds.

Inorganics

The results of the two rounds of groundwater sampling at Area 5 identified eleven metals which exceeded statistical background concentrations. Three of the eleven exceeded the MGS, MDWS and/or MCL. Table 4-11 summarizes the inorganic parameters which were determined to be site-related detections and includes the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in this table. The parameters which exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Total cadmium exceeded the MCL of 5 ug/l and the MDWS of 10 ug/l in downgradient sample 5-1-1 with a detection of 20.4 ug/l. Total cadmium exceeded the MCL in downgradient sample 5-5-2 and sidegradient sample 5-6-2 with detections of 8.59 and 7.52 ug/l, respectively.

Total chromium equalled or exceeded the MDWS of 50 ug/l in sidegradient samples 5-4-1 and 5-6-1 with respective concentrations of 86.5 and 50.0 ug/l. Total chromium exceeded the MCL of 100 ug/l in downgradient sample 5-1-1 with a detection of 119.0 ug/l.

Total nickel exceeded the MGS of 200 ug/l in sidegradient samples 5-2-2 and 5-4-1 with detections of 346 and 418 ug/l, respectively. No standards exist under MCL or MDWS.

TABLE 4-11
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 5 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Antimony, total	5-2-2, 5-3-2, 5-5-1, 5-6-2	5.91 - 15.9	5-5-1	--
Arsenic, dissolved	5-1-1, 5-1-2, 5-4-2	5.80 - 7.14	5-1-1	30.00
Arsenic, total	5-1-2	11.5	5-1-2	30.00
Barium, dissolved	5-2-1	303	5-2-1	30.00
Beryllium, total	5-1-1, 5-4-1	1.71 - 7.6	5-1-1	--
Cadmium, total	*5-1-1, *5-5-2, *5-6-2	7.52 - 20.4	*5-1-1	5.00
Chromium, total	*5-1-1, *5-4-1, 5-5-1, *5-6-1	46.2 - 119	*5-1-1	50.00
Copper, dissolved	5-1-1, 5-6-2	3 - 90	5-1-1	1000.00
Copper, total	5-1-1	250	5-1-1	1000.00
Lead, dissolved	5-1-2	4.95	5-1-2	50.00
Nickel, dissolved	5-1-1, 5-2-1, 5-2-2, 5-4-1, 5-5-1, 5-6-1, 5-7-1	11.5 - 97.4	5-7-1	200.00
Nickel, total	5-1-1, *5-2-2, *5-4-1, 5-4-2, 5-6-1, 5-5-1	62.8 - 418	*5-4-1	200.00
Silver, total	5-2-1, 5-7-2	0.21	5-2-1, 5-7-2	50.00
Silver, dissolved	5-4-2	0.21	5-4-2	50.00
Zinc, dissolved	5-1-1, 5-2-1, 5-3-1, 5-4-1, 5-5-1, 5-6-1	316 - 910	5-1-1	5000.00
Zinc, total	5-1-1, 5-5-1, 5-7-1	850 - 1000	5-5-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXIST.

Radiation Parameters

One radiological sample was taken from the sidegradient well 5-2. The analytical results were in the normal range of groundwater activities. Further discussion of the radiological results are presented in Section 4.23.

4.5.3 Summary

Potentially site-related detections occurred at all seven monitoring wells within Area 5, including upgradient and downgradient locations. Figure 4-10 presents the Area 5 monitoring well locations and summarizes the distribution of site-related detections.

The explosive compound RDX was identified consistently at moderate levels in the groundwater across Area 5. Areas 5A, 5B, and 5C may be potential source areas for explosive compounds. Additional source areas for explosive compounds may be located upgradient of Area 5, potentially at Area 6 or Area 10.

Volatile organic compounds were detected at five monitoring well locations within Area 5. Well location 5-7, which is downgradient of the surface impoundment formerly used to receive wastes from Building 139, showed the highest detections. This may identify Area 5C as a potential source of VOCs. Other VOC detections near Area 5B may be a result of groundwater mounding, especially since upgradient well location 5-3 detected VOCs. The low VOC detection at well location 5-5 may be due to its location downgradient of Area 5C.

The two inconsistent detections of B2EHP may be the result of field contamination and may not reflect actual groundwater quality; however, both detections occurred near Area 5B, and, if they are actual detections, may be due to the groundwater mounding away from the surface impoundment. Numerous unknown BNA compounds were detected across the area, with the highest total estimated concentration (400 ug/l) found at well 5-6.

The results of the inorganics analysis indicate that Area 5B may be contributing some inorganics to local groundwater. Cadmium, chromium, and nickel exceeded the MSG, MDWS, and/or MCL values in the downgradient wells 5-1 and 5-4, indicating that the Area 5B impoundment may be a source of cadmium, chromium, and nickel. Elevated concentrations of cadmium and chromium were also detected at well location 5-6. This well apparently is not downgradient of an Area 5 source, but may be indicating an unidentified source.

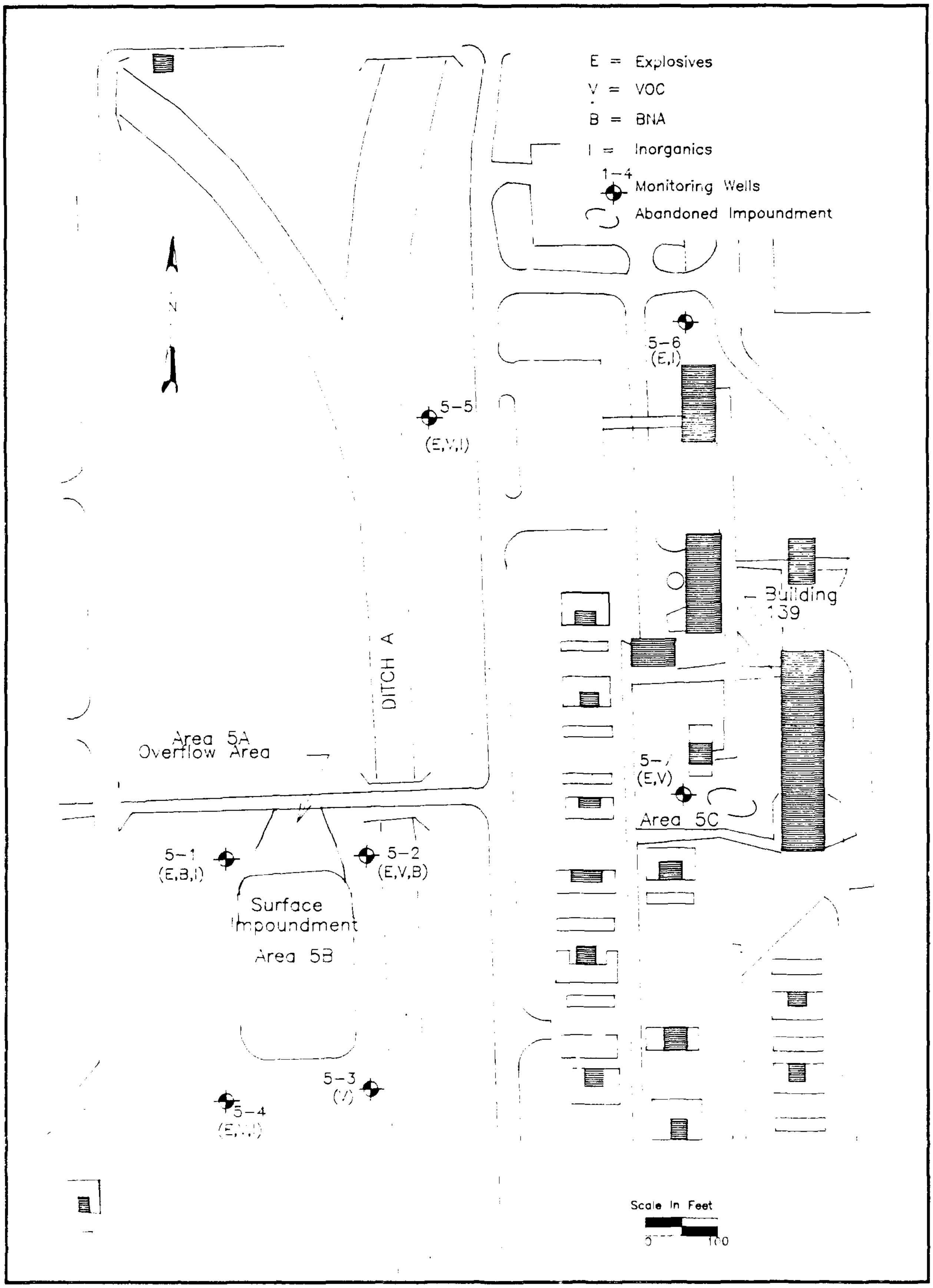


FIGURE 4-10
AREA 5 DETECTION LOCATIONS

4.6 AREA 6 - BUILDING 65 SURFACE IMPOUNDMENT

4.6.1 Site Description and Field Investigations

4.6.1.1 Area 6A - Surface Impoundment

This site, shown in Figure 4-11, consists of one surface storage impoundment which is currently undergoing RCRA closure and in the past contained neutralized wastes from Building 65, where 20-millimeter cannon shells are packed. The impoundment was 151 feet by 162 feet. The waste was RCRA-listed waste K044. The hazardous constituent was barium.

At the time of the RI field investigation, seven monitoring wells existed at Area 6A which were screened between a depth of 10 to 40 feet. Monitoring well 6-7 was the upgradient well, while the remaining wells were considered downgradient and sidegradient wells. Each well was sampled twice and analyzed for VOCs, BNAs, inorganics, and explosives. The two sampling events were separated by an interval of approximately three months. Wells 6-1, 6-2, 6-6, and 6-7 were abandoned as part of the 1989 GWQAP and replaced with additional wells.

4.6.2 Site Investigation Results

The results of this site investigation at Area 6 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.6.3). All organic and inorganic analytical data is presented in Table 4-12. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.6.2.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 6, identified five explosive compounds:

- 13DNB.
- 24DNT.
- HMX.
- RDX.
- Tetryl.

During the first round of sampling, the sidegradient and downgradient well locations 6-1, 6-3, 6-4, 6-5, and 6-6, and the upgradient well location 6-7 contained the explosive compound RDX at respective concentrations of 3.54, 8.12, 1.57, 2.60, 14.0, and

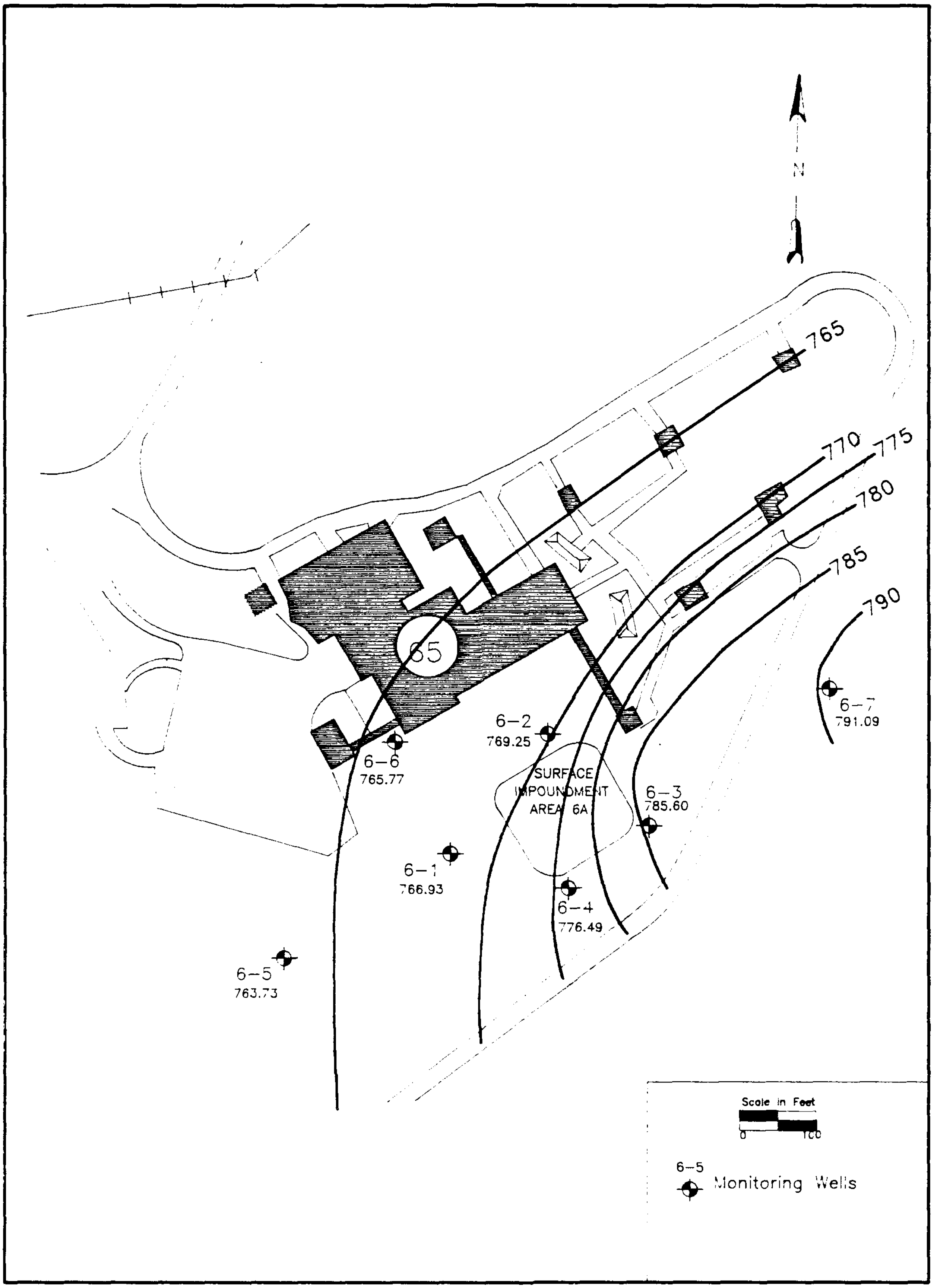


FIGURE 4-11
AREA 6

TABLE 4-12
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #6
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	6-1-1	6-1-2	6-2-1	6-2-2	6-3-1	6-3-2
DEPTH (FT)	22.5	22.5	22	22	20.5	20.5
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	ND	ND	30	ND
UNKNOWNS						
C6-C9 Cycloalkane	ND	ND	ND	ND	ND	*30
C8-C10 Methyl Alkene/Alkane	ND	ND	ND	ND	ND	*20
Methyl Propyl Cyclohexane	ND	ND	ND	ND	ND	*10
C9-C14 Alkane Glycol	ND	ND	ND	ND	*200	ND
C10-C13 Methyl Alkane	ND	ND	ND	ND	*20	ND
Iodopropane [666]	ND	ND	ND	ND	20	ND
C11-C13 Methyl Alkane	ND	ND	ND	ND	*10	ND
Paraldehyde [929]	ND	ND	ND	ND	10	ND
C15-C16 Methyl Alkane	ND	ND	ND	ND	*10	ND
1,3-Dioxane-2-Propanoic Acid [779]	ND	ND	ND	ND	10	ND
Methyl Pentadecane	ND	ND	ND	ND	*10	ND
C9-C13 Organic Acid Derivative	ND	ND	ND	ND	*20	ND
2,3,5-Trimethyldecane [949]	ND	ND	ND	ND	20	ND
Sulfur Dioxide	ND	ND	ND	ND	*40	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
24-DNT	<0.60	<0.60	0.62	<0.60	<0.60	<0.60
RDX	3.54	2.62	<0.63	0.99	8.12	10.7
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, dissolved	<5.00	<5.00	<5.00	<5.00	6.63	<5.00
Arsenic, total	<5.00	<5.00	<5.00	<5.00	15.4	7.35
Barium, dissolved	161	198	172	215	NA	291
Barium, total	201	215	235	191	NA	1450
Beryllium, dissolved	<0.10	<0.10	<0.10	0.3	<0.14	<0.10
Beryllium, total	0.3	0.3	0.3	<0.10	2.82	4
Chromium, total	72.1	<37.50	<37.50	<37.50	188	<37.50
Copper, dissolved	<1.78	4.18	<1.78	<1.78	6.22	<1.78
Copper, total	3.75	12	12.9	9.86	140	110
Lead, dissolved	<2.50	<2.50	<2.50	<2.50	<2.5	<2.50
Lead, total	<2.50	<2.50	2.53	<2.50	3.94	59.7
Nickel, dissolved	<9.60	<9.60	<9.60	<9.60	20.2	<9.60
Nickel, total	37.3	95.5	42.9	12.5	82.5	178
Silver, dissolved	<0.19	<0.19	<0.19	<0.19	0.2	<0.19
Silver, total	0.21	<0.19	<0.19	<0.19	<0.19	0.21
Zinc, dissolved	308	135	1100	51.9	950	<17.20
Zinc, total	316	163	600	193	1400	690
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-12
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #6
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	6-4-1	6-4-2	6-5-1	6-5-2	6-6-1	6-6-2
DEPTH (FT)	20.5	20.5	37.5	37.5	30	30
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
UNKNOWNS						
C9-C14 Alkane Glycol	*80	ND	*70	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
13-DNB	<0.61	0.85	<0.61	1.24	<0.61	<0.61
HMX	<1.30	<1.30	<1.30	<1.30	2.1	1.31
RDX	1.57	0.66	2.6	<0.63	14	1.05
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Barium, dissolved	NA	418	NA	305	125	191
Barium, total	NA	401	NA	326	441	190
Beryllium, total	0.42	<0.10	0.82	<0.10	1.91	0.2
Chromium, total	51	<37.50	123	<37.50	<37.50	<37.50
Copper, total	12.2	<1.78	14.5	7.29	15	5.68
Lead, dissolved	<2.50	9.2	<2.50	2.73	<2.50	<2.50
Lead, total	<2.50	<2.50	<2.50	<2.50	17.3	<2.50
Nickel, dissolved	82.5	39.5	<9.60	12	49.9	<9.60
Nickel, total	27.8	16.1	25.4	16.4	83.3	10
Silver, total	<0.19	<0.19	<0.19	<0.19	<0.19	0.32
Zinc, dissolved	1000	<17.20	1000	<17.20	1200	39.7
Zinc, total	960	23.7	930	<17.20	415	26.8
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-12
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #6
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	6-7-1	6-7-2
DEPTH (FT)	16	16
VOLATILES		
ALL	(ALL ND OR <CRL)	
BASE NEUTRAL & ACID EXTRACTABLES		
bis (2-Ethylhexyl) Phthalate	500	500
UNKNOWNS		
4,4-Dimethyl-2-Pentanol [908]	200	ND
Unknown	30	ND
OTHERS	(ALL ND OR <CRL)	
EXPLOSIVE COMPOUNDS		
RDX	2.63	<0.63
Tetryl	<0.66	1.07
OTHERS	(ALL ND OR <CRL)	
INORGANICS		
Antimony, total	<3.00	5.11
Barium, dissolved	74.9	134
Barium, total	709	432
Beryllium, total	3.4	0.1
Cadmium, total	11.8	<5.10
Chromium, total	51.9	<37.50
Copper, dissolved	4.39	<1.78
Copper, total	20.7	25
Lead, total	26.4	5.86
Nickel, dissolved	33.4	<9.60
Nickel, total	277	58.4
Silver, total	<0.19	4.9
Zinc, dissolved	421	50.9
Zinc, total	454	250
OTHERS	(ALL ND OR <CRL)	

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

[ ] DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

2.63 ug/l. The explosive compound 24DNT was detected at downgradient well location 6-2 at a concentration of 0.62 ug/l. The explosive compound HMX was detected at downgradient well location 6-6 at a concentration of 2.10 ug/l.

During the second round of groundwater sampling, the explosive compound RDX was detected at the sidegradient and downgradient monitoring well locations 6-1, 6-2, 6-3, 6-4, and 6-6 at respective concentrations of 2.62, 0.99, 10.7, 0.66, and 1.05 ug/l. The compound 13DNB was detected at sidegradient and downgradient monitoring well locations 6-4 and 6-5 at respective concentrations of 0.85 ug/l and 1.24 ug/l. The compound HMX was detected at downgradient monitoring well location 6-6 at a concentration of 1.31 ug/l. The compound Tetryl was detected at upgradient monitoring well location 6-7 at a concentration of 1.07 ug/l.

Volatile Organic Compounds

The analysis of the two rounds of groundwater sampling at Area 6 did not detect any volatile organic compounds.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 6 identified one BNA compound: B2EHP. During the first round of sampling, the compound was detected at the sidegradient well location 6-3 and the upgradient well 6-7 at respective concentrations of 30 and 500 ug/l.

During the second round of sampling, the upgradient well location 6-7 again showed a detection of B2EHP at a concentration of 500 ug/l.

The fact that B2EHP was not detected at any downgradient well locations suggests that it may be a post-sampling contaminant.

Unknown BNA compounds were detected in samples from four different monitoring wells at Area 6. Wells 6-3, 6-4, 6-5, and 6-7 had concentrations ranging from 10 to 200 ug/l. Detections occurred in both sampling rounds.

Inorganics

The results of the two rounds of groundwater sampling at Area 6 identified eleven inorganics which exceeded statistical background concentrations. A total of five of the eleven inorganics exceeded the MGS, MDWS, and/or MCL. Table 4-13 summarizes the inorganic parameters which were determined to be site-related detections and includes the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in this table. The parameters which

TABLE 4-13
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 6 GROUNDWATER RESULTS

METAL	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Antimony, total	6-7-2	5.11	6-7-2	--
Arsenic, dissolved	6-3-1	6.63	6-3-1	30.00
Arsenic, total	6-3-1, 6-3-2	7.35 - 15.4	6-3-1	30.00
Barium, dissolved	6-3-2, 6-5-2	305	6-5-2	--
Barium, total	*6-3-2	1450	*6-3-2	1000.00
Beryllium, dissolved	6-2-2	0.3	6-2-2	--
Beryllium, total	6-3-1, 6-3-2, 6-6-1, 6-7-1	1.91 - 4	6-3-2	--
Cadmium, total	*6-7-1	11.8	*6-7-1	--
Chromium, total	*6-1-1, *6-3-1, *6-4-1, *6-5-1, *6-7-1	51 - 188	*6-3-1	50.00
Copper, dissolved	6-1-2, 6-3-1, 6-7-1	4.18 - 6.22	6-3-1	1000.00
Copper, total	6-3-1, 6-3-2	110 - 140	6-3-1	1000.00
Lead, dissolved	6-4-2	9.2	6-4-2	50.00
Lead, total	*6-3-2, 6-7-1	26.4 - 59.7	*6-3-2	50.00
Nickel, dissolved	6-3-1, 6-4-1, 6-4-2, 6-5-2, 6-6-1, 6-7-1	12 - 82.5	6-4-1	200.00
Nickel, total	6-1-2, 6-3-1, 6-3-2, 6-6-1, *6-7-1	82.5 - 277	*6-7-1	200.00
Silver, dissolved	6-3-1	0.20	6-3-1	50.00
Silver, total	6-1-1, 6-3-2, 6-6-2, 6-7-2	0.21 - 4.9	6-7-2	50.00
Zinc, dissolved	6-1-1, 6-2-1, 6-3-1, 6-4-1, 6-5-1, 6-6-1, 6-7-1	308 - 1200	6-6-1	5000.00
Zinc, total	6-3-1, 6-4-1, 6-5-1	930 - 1400	6-3-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MSG, MDWS AND/OR MCL.

exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Total barium exceeded the MDWS of 1,000 ug/l in sidegradient sample 6-3-2 with a concentration of 1,450 ug/l.

Total cadmium exceeded the MCL of 5 ug/l and the MDWS of 10 ug/l in upgradient sample 6-7-1 with a detection of 11.8 ug/l.

Total chromium exceeded the MDWS of 50 ug/l in downgradient samples 6-1-1 and 6-4-1, and the upgradient sample 6-7-2 with respective concentrations of 72.1, 51.0, and 51.9 ug/l. Total chromium exceeded the MCL of 100 ug/l in the sidegradient and downgradient samples 6-3-1 and 6-5-1 with respective concentrations of 188 and 123 ug/l.

Total lead exceeded the MCL and MDWS of 50 ug/l in sidegradient sample 6-3-2 at a concentration of 59.7 ug/l.

Total nickel exceeded the MGS of 200 ug/l in the upgradient sample 6-7-1 with a detection of 277 ug/l. No standards for nickel exist under the MCL.

4.6.3 Summary

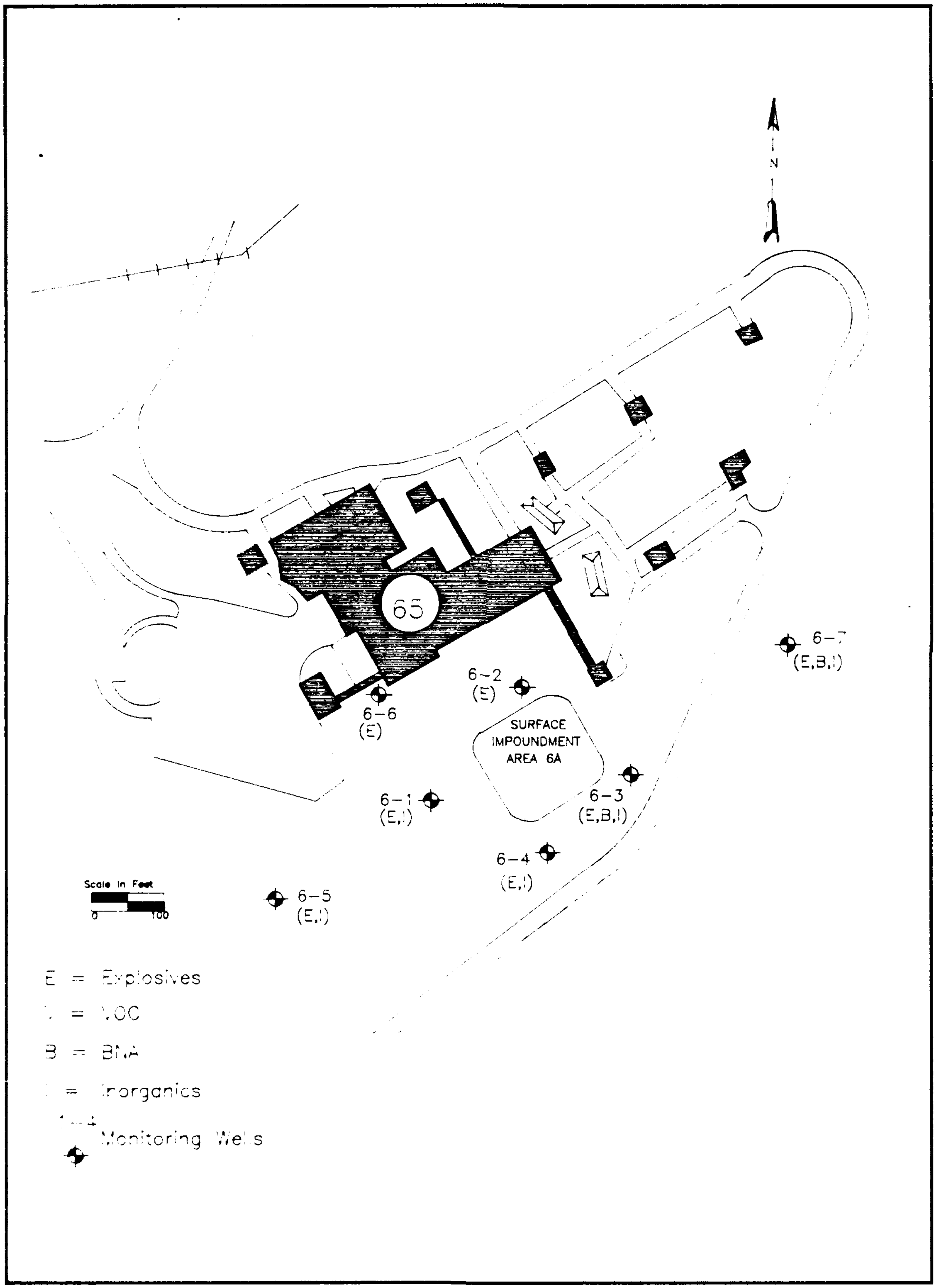
Potentially site-related detections occurred at all seven monitoring well locations within Area 6, including upgradient and downgradient locations. Figure 4-12 presents the Area 6 monitoring well locations and summarizes the distribution of site-related detections.

Explosive compounds were detected at moderate levels at all seven monitoring well locations at Area 6, including upgradient well 6-7. This data suggests the possibility of an upgradient source. The highest concentrations occurred adjacent to and downgradient of the surface impoundment. This indicates that the impoundment may be contributing low levels of explosive compounds to the groundwater, and that groundwater mounding may be causing radial flow from the impoundment, as evidenced by the presence of explosive compound RDX at well location 6-3. Results indicate that Area 10 may be contributing explosives to the groundwater upgradient of Area 6.

No VOCs are present in the groundwater at Area 6.

The detections of BNA phthalate compounds may be due to post-sampling contamination because they were not detected in any downgradient wells.

Inorganics analyses indicate that the surface impoundment at Area 6 may also be contributing some inorganic parameters to the groundwater. Elevated concentrations of barium, chromium, and lead were detected adjacent to and/or downgradient of the impoundment.



AREA6CO

FIGURE 4-12
AREA 6 DETECTION LOCATIONS

Elevated inorganic concentrations of cadmium and chromium were also detected at upgradient monitoring well location 6-7. This indicates the potential existence of an upgradient source or possibly elevated naturally occurring inorganics. The highest chromium levels occurred downgradient of the surface impoundment, however.

4.7 AREA 7 - INDUSTRIAL WASTEWATER LAGOONS AREA

4.7.1 Site Description and Field Investigation

4.7.1.1 Area 7A - IWTP Lagoons

This area, shown in Figure 4-13, contains six active lagoons (two sets of three lagoons). The west lagoons received IWTP sludge until 1989 when the sludge and water were removed. A leachate collection system and double-lined synthetic liner were installed. These lagoons are currently receiving the same IWTP sludge.

The east lagoons were retrofitted the same as the west lagoons, but were then backfilled with clean fill and capped. Three evaporation basins are currently being built to the south of these three lagoons. The basins will receive nonhazardous water from the water treatment plant clarifiers.

Based on analysis of the sludge, the six active lagoons do not meet RCRA criteria for EP toxicity wastes. However, since K046 waste from the 90-series buildings is discharged to the IWTP, these lagoons are defined as hazardous waste treatment facilities. In the past, the lagoon effluents were discharged to West Fire Prairie Creek under NPDES permit.

The two sets of lagoons were used alternately on an annual basis. In approximately 1985, the west lagoons were cleaned and the sludge removed and thereafter received nonhazardous mixture of materials. Hazardous constituents from the IWTP are lead, barium, and antimony. At the time of this RI, monitoring wells 7-1 through 7-10 were included as part of the lagoon groundwater monitoring network and were screened at a depth of 17 to 40 feet. Wells 7-1, 7-7, 7-8, 7-11, 7-12, and 7-13 monitored the groundwater on the downgradient side of the western set of lagoons. Well 7-9 monitored the groundwater on the downgradient side of the eastern set of lagoons. Wells 7-2 and 7-10 were sidegradient of the eastern lagoons. Analysis of the groundwater previously indicated that wells 7-2 and 7-7 contained elevated levels of the explosive HMX.

Three monitoring wells were installed at Area 7A in 1988. Figure 4-13 shows the locations. The three wells include one two-well cluster and one shallow single well. The two-well cluster is located at the northwestern corner of the site between monitoring wells 7-8 and 7-7. The deep well (7-12) in the cluster is

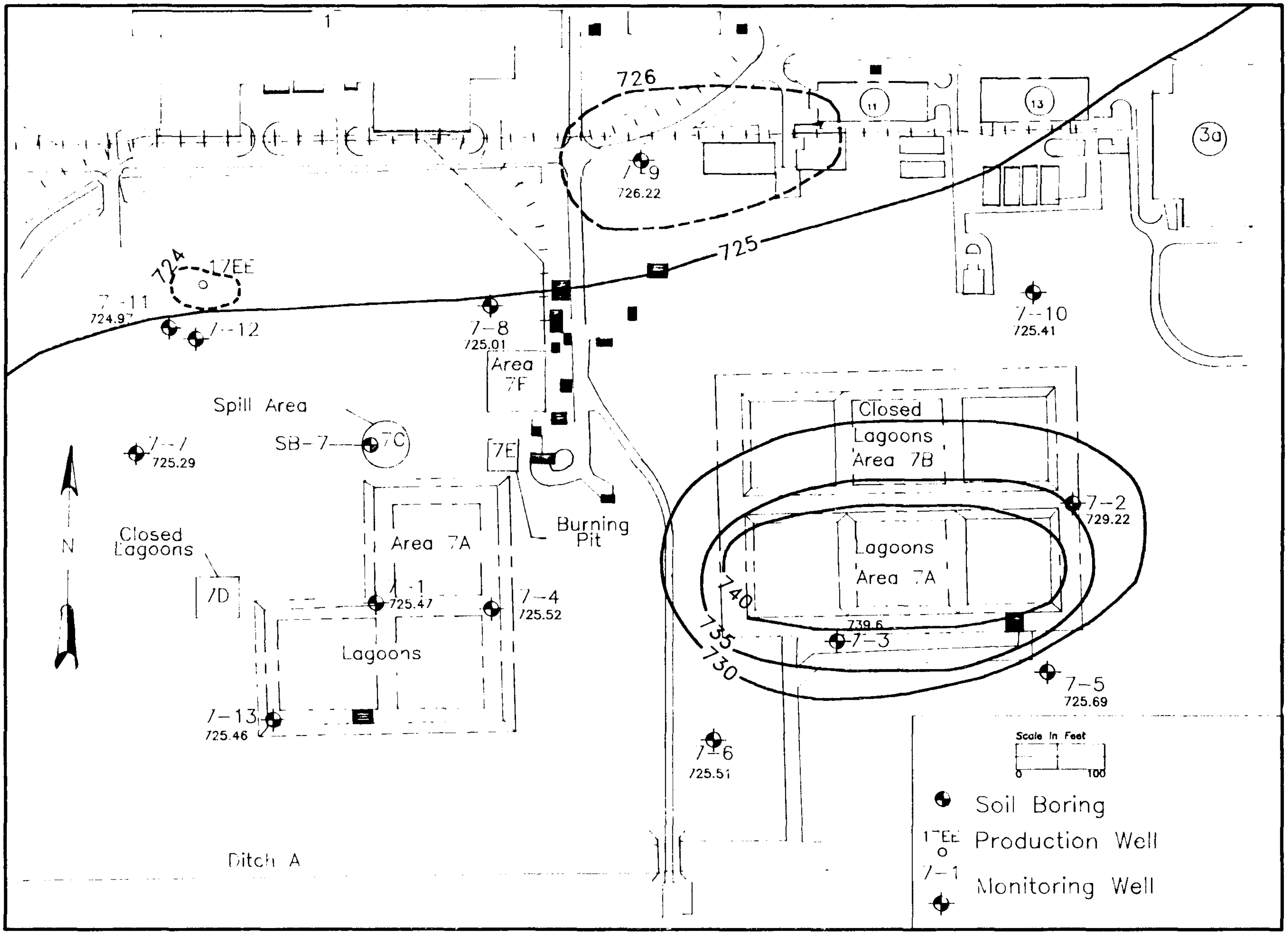


FIGURE 4-13
EA 7

approximately 83 feet deep and screened at the base of the alluvial valley. The shallow well in the cluster (7-11) is screened just below the water table at about 16 feet. The purpose of the two-well cluster is to monitor the groundwater downgradient from the three active western lagoons. This cluster also provides information regarding the vertical gradient between the upper and lower portions of the aquifer and the influence of production well 17-EE on the groundwater hydraulic system.

The single shallow well is located at the southwestern corner of the site. This well (7-13) is screened at the top of the water table at about 22 feet and monitors the groundwater adjacent to the IWTP lagoons. It also provides information regarding the groundwater mounding effect created by the infiltration from the lagoons. All wells were sampled twice. All samples were analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. The sampling events were separated by an interval of approximately three months. Monitoring wells 7-5 and 7-6 were the upgradient wells while the remaining wells were downgradient or mounding affected wells. Wells 7-5 and 7-6 were additionally analyzed for radiological parameters. Wells 7-1 through 7-6 were abandoned as part of the 1989 GWQAP and replaced with additional wells.

4.7.1.2 Area 7B - IWTP Lagoons

This site consists of three closed lagoons which once contained IWTP sludge (Figure 4-13). Precise details of the closure are unknown. This site was closed in 1952. The estimated area is 100,000 square feet, but the quantity of waste is unknown. Possible RCRA hazardous constituents are lead and mercury. Wells 7-9 and 7-10 are currently monitoring the shallow groundwater downgradient of the closed lagoons. Monitoring wells 7-2, 7-3, and 7-5 previously monitored the upgradient groundwater.

As part of the field investigation for Area 7, all the wells were each sampled twice, as described for Area 7A.

4.7.1.3 Area 7C - Spill Area

On 25 March 1983, a leak was detected in an underground line leading from an aboveground fuel oil storage tank to the demilitarization furnace. Figure 4-13 shows the location of the spill area. The released material was No. 1 fuel oil having a flash point of 125°F. It was estimated that 6,000 gallons of fuel oil had been released. Five wells were dug in the release area, and the collected fuel oil was pumped into drums. Analysis of samples from wells located 20 feet outside the known contaminated area did not indicate the presence of oil. Approximately 4,000 gallons of fuel oil were collected from the release area. This release was reported to the U.S. EPA and to MDNR. The spill area is currently being monitored by well 7-7, 7-11, and 7-12 and no detectable levels of organic compounds have been observed. However, residual soil contamination may exist.

At Area 7C, one soil boring (SB7-1) was drilled and sampled where the fuel oil spill occurred (Figure 4-13). This soil boring was drilled to a depth of approximately 10 feet and was to provide information regarding the vertical extent of soil contamination. Samples were collected at 1 to 2.5 feet, 3.5 to 5 feet, and 8.5 to 10 feet and were to be analyzed for oil and grease. Unfortunately, the samples to be analyzed were lost and, therefore, no analysis was performed.

4.7.1.4 Area 7D - Closed Lagoon

This area was an IWTP burning pit and lagoon. Waste oil and grease were disposed of in this lagoon and then burned. The estimated area of the lagoon is 20,000 square feet. The lagoon was closed in approximately 1953 and possible waste constituents included lead and mercury.

Currently, well 7-7 is monitoring the groundwater quality downgradient of the closed lagoon. The well was sampled twice, as described under Area 7A.

4.7.1.5 Area 7E - Explosives Burning Ground

This site, shown in Figure 4-13, was an explosives burning ground. All types of small arms ammunition up to 0.50 caliber were burned at this burning ground. Materials burned in these pits also included tracers and incendiary mixes, propellants, primers, and rounds from mercury crack tests. Burning in the pits was used starting in approximately 1955 and stopped when the Demilitarization Furnace was placed in operation in 1977. The estimated area is 40,000 square feet, but the quantity of waste is unknown. Possible RCRA hazardous constituents are lead, barium, mercury, and explosives.

Currently, the existing wells 7-11 and 7-12 are monitoring the downgradient groundwater, 7-7 and 7-8 are monitoring the sidegradient groundwater. Well 7-6 was monitoring the upgradient groundwater from the explosives burning grounds. Each of these wells was sampled twice and analyzed as described under Area 7A.

4.7.1.6 Area 7F - Container Cleanup Area

This site, shown in Figure 4-13, is designed for cleaning containers used in intraplant transporting of explosives and explosives components. The cleanup water is collected and chemically treated to render it nonreactive. The 6-foot by 4-foot steel tank is located in an underground concrete structure, and the treated water is discharged to the IWTP. The hazardous wastes are K044 and K046 and contain the hazardous constituents barium, lead, and antimony. Approximately 250 gallons per day of waste are generated.

Currently, well 7-8 is monitoring the groundwater quality downgradient of Area 7F. This well was sampled and analyzed twice for parameters described under Area 7A.

4.7.2 Site Investigation Results

The results of this site investigation at Area 7 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.7.3). All radiological, organic, and inorganic analytical data is presented in Table 4-14. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.7.2.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 7 identified three explosive compounds:

- 135TNB.
- HMX.
- RDX.

The first round of groundwater sampling at Area 7 detected the explosive compound RDX at downgradient well locations 7-7 and 7-11 at respective concentrations of 180 and 7.81 ug/l. The compound 135TNB was detected at downgradient well 7-9 at a concentration of 0.85 ug/l. HMX was detected at downgradient well 7-7 at a concentration of 28.0 ug/l.

The second round of groundwater sampling at Area 7 detected the explosive compound RDX at the downgradient well locations 7-7, 7-11, and 7-12 at respective concentrations of 770, 4.97, and 6.78 ug/l.

Volatile Organic Compounds

The results of two rounds of groundwater sampling at Area 7 identified seven VOCs:

- Trans-1,2-dichloroethene (T12DCE).
- 1,2-dichloroethane (12DCLE).
- Benzene.
- Methylene chloride.
- Toluene.

TABLE 4-14
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #7
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	7-1-1	7-1-2	7-2-1	7-2-2	7-3-1	7-3-2
DEPTH (FT)	37.5	37.5	35.5	35.5	37	37
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	70	ND	ND	ND
UNKNOWNS						
Hexanedioic Acid Ester	ND	ND	*10	ND	ND	ND
2-Ethyl-4-Pentenal [690]	ND	ND	ND	10	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	ND	ND	*10	ND	*20
C6-C9 Methyl Alkene/Alkane	ND	ND	ND	ND	ND	*10
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	<5.00	<5.00	9.01	10.4	<5.00	<5.00
Barium, dissolved	197	302	NA	37	71	75.3
Barium, total	239	249	268	72.3	88.4	78.2
Beryllium, total	0.2	0.2	0.26	<0.10	<0.10	<0.10
Copper, dissolved	<1.78	<1.78	7.29	12.1	7.07	8.68
Copper, total	8.04	7.72	31.2	11.1	11.1	13.3
Lead, dissolved	<2.50	<2.50	<2.50	<2.50	3.44	<2.50
Lead, total	<2.50	<2.50	5.66	<2.50	<2.50	<2.50
Nickel, dissolved	19.3	17.2	27.1	28.5	40.7	58
Nickel, total	47.9	75.2	32.7	49.8	30.7	128
Silver, dissolved	0.21	<0.19	<0.19	<0.19	<0.19	<0.19
Silver, total	2.02	0.32	<0.19	<0.19	<0.19	<0.19
Zinc, dissolved	930	19.2	320	106	580	87.9
Zinc, total	428	194	347	246	495	174
OTHERS	(ALL ND OR <CLR)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-14
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #7
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	7-4-1	7-4-2	7-5-1	7-5-2	7-6-1	7-6-2
DEPTH (FT)	27.5	27.5	30	30	25.5	25.5
VOLATILES						
1,2-Dichloroethane	ND	ND	ND	20	ND	ND
Methylene Chloride	ND	5	ND	ND	ND	ND
Trichloroethene	<0.71	<0.71	<0.71	7.8	<0.71	<0.71
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	ND	20	40	ND
UNKNOWNS						
C8-C11 Cyclo Alkane	ND	*10	ND	D	ND	ND
C6-C9 Cyclo Alkene/Alkane	ND	*10	ND	ND	ND	ND
2-Ethyl-4-Pentenal [762]	ND	*20	ND	ND	ND	30
Cyclopentanediol Ester	ND	ND	ND	*10	ND	ND
Iron Carbonyl	ND	ND	ND	ND	ND	*20
C8-C12 Alkene	ND	ND	ND	ND	ND	*10
2 2,4-Trimethyl-3-penten-1-01 [780]	ND	ND	ND	ND	ND	10
Hexanedioic Acid Ester	*10	ND	ND	ND	ND	ND
C9-C15 Organic Acid Ester	*10	ND	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	<5.00	8.07	<5.00	5.9	<5.00	11
Barium, dissolved	NA	199	NA	110	NA	345
Barium, total	210	201	145	239	NA	421
Beryllium, total	<0.10	<0.10	0.2	0.4	<0.10	0.2
Chromium, total	<36.1	<36.1	<36.1	<36.1	<36.1	67.3
Copper, dissolved	2.36	<1.78	<1.78	<1.78	2.47	<1.78
Copper, total	3.32	10.2	9.11	13.2	20.9	3.22
Lead, dissolved	<2.50	<2.50	<2.50	<2.50	9.5	<1.78
Lead total	<2.50	3.74	3.34	3.54	<2.50	<2.50
Nickel, dissolved	27.9	14.3	31.3	32.3	9.5	11.3
Nickel, total	41.5	33.6	33.9	43.5	13.9	65.2
Silver, dissolved	<0.19	0.21	<0.19	<0.19	<0.21	<0.19
Silver, total	<0.19	0.21	0.43	0.21	<0.19	<0.19
Zinc, dissolved	278	<17.20	880	25	355	88.8
Zinc, total	303	98.5	471	82.3	339	118
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCI/L)						
Alpha	NA	NA	NA	23+/-11	0+/-5	0+/-5
Beta	NA	NA	NA	34+/-5	4+/-3	17+/-4
U-234	NA	NA	NA	1.5+/-0.4	0+/-0.1	0.9+/-0.3
U-235	NA	NA	NA	0+/-0.1	0+/-0.1	0+/-0.1
U-238	NA	NA	NA	0.8+/-0.4	0+/-0.1	0.9+/-0.3
Total Uranium	NA	NA	NA	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-14
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #7
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	7-7-1	7-7-2	7-8-1	7-8-2	7-9-1	7-9-2
DEPTH (FT)	22.5	22.5	23	23	23	23
VOLATILES						
Vinyl Chloride	10.2	<1.79	<1.79	<1.79	<1.79	<1.79
Toluene	<1.57	<1.57	<1.57	<1.57	<1.57	<1.57
Trans 1,2-Dichloroethene	2.39	<1.79	<1.79	<1.79	<1.79	<1.79
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	90	ND	60	ND	90	ND
UNKNOWNS						
Hexanedioic Acid Ester	*10	ND	*10	ND	*10	ND
C6-C15 Organic Acid Ester	ND	ND	*10	ND	ND	ND
1-[4-(1-Hydroxy-1-Methyl Ethyl) Pehnyl] ethanone [854]	ND	ND	ND	ND	10	ND
Butoxyethoxy Ethanol	ND	ND	ND	ND	*10	ND
Benzene Acetic Acid Derivative	ND	ND	ND	ND	*20	ND
C6-C9 Cycloaklane	ND	*20	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
135-TNB	<0.56	<0.56	<0.56	<0.56	0.85	<0.56
HMX	28	<1.30	<1.30	<1.30	<1.30	<1.30
RDX	180	770	<0.63	<0.63	<0.63	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	6.63	<5.00	<5.00	<5.00	6	<5.00
Barium, dissolved	NA	83.5	52.7	200	NA	482
Barium, total	NA	400	NA	252	NA	573
Beryllium, total	<0.10	0.3	0.27	0.2	0.48	0.3
Chromium, total	<37.50	<37.50	<37.50	55.8	<37.50	<37.50
Copper, dissolved	3.11	3.54	3.32	<1.78	4.18	<1.78
Copper, total	30.7	13.2	13.8	4.29	37.1	10.6
Lead, dissolved	<2.50	<2.50	<2.50	3.54	<2.50	<2.50
Lead, total	9.2	11.7	6.77	5.36	12.4	4.25
Nickel, dissolved	13.7	<9.60	<9.5	<9.60	<9.60	<9.60
Nickel, total	56.4	77.8	15.3	20.8	27.5	50.8
Silver, dissolved	<0.19	<0.19	<0.2	<0.19	<0.19	<0.19
Zinc, dissolved	364	<17.20	373	74.2	312	37.4
Zinc, total	267	130	297	85.1	360	185
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-14
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #7
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	7-10-1 22.5	7-10-2 22.5	7-11-1 21	7-11-2 21	7-12-1 77.5	7-12-2 77.5
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	70	ND	50	ND	200	ND
UNKNOWNS						
2-ethyl-4-Pentenal [725]	ND	NS	10	ND	ND	ND
Carboxylic Acid Derivative	ND	*10	ND	ND	ND	ND
C6-C9 Cycloaklane	ND	*20	ND	ND	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	*20	ND	ND	ND	ND
Hexanedioic Acid Ester	ND	ND	*10	ND	*10	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	<0.63	<0.63	7.81	4.97	<0.63	6.75
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	<5.00	39.1	8.7	<5.00	<5.00	<5.00
Barium, dissolved	NA	139	NA	179	NA	416
Barium, total	NA	481	NA	341	NA	318
Beryllium, total	0.23	<0.10	0.61	0.4	0.11	0.2
Copper, dissolved	3.43	<1.78	3.22	<1.78	2.89	<1.78
Copper, total	15.2	8.04	41.4	15.4	14.9	<1.78
Lead, total	7.89	5.86	14.8	7.18	3.24	<2.50
Nickel, dissolved	<9.60	<9.60	<9.60	<9.60	13	12.6
Nickel, total	32.6	61	24.8	28.9	32.6	27.9
Selenium, dissolved	5.29	<5.00	7.4	<5.00	<5.00	<5.00
Selenium, total	5.19	<5.00	5.77	<5.00	<5.00	<5.00
Zinc, dissolved	346	<17.20	283	124	285	138
Zinc, total	320	106	285	87.7	247	134
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-14
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #7
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	7-13-1	7-13-2
DEPTH (FT)	27	27
VOLATILES		
Trichloroethene	0.8	ND
Benzene	0.9	ND
UNKNOWNS		
C15-C31 Unknown	20	ND
OTHERS	(ALL ND OR <CRL)	
BASE NEUTRAL & ACID EXTRACTABLES		
UNKNOWNS		
C6-C9 Cycloalkane	ND	*20
C8-C10 Methyl Alkene/Alkane	ND	*20
(Phenoxymethyl) Benzene [685]	ND	20
OTHERS	(ALL ND OR <CRL)	
EXPLOSIVE COMPOUNDS		
ALL	(ALL ND OR <CRL)	
INORGANICS		
Arsenic, total	<5.00	5.8
Barium, dissolved	NA	89.3
Barium, total	NA	143
Beryllium, total	0.34	0.2
Copper, dissolved	<1.78	<1.78
Copper, total	25.3	9
Lead, total	7.08	<2.50
Nickel, dissolved	<9.60	12.4
Nickel, total	26.4	42.4
Zinc, dissolved	257	<17.20
Zinc, total	300	157
OTHERS	(ALL ND OR <CRL)	

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

- TRCLE.
- Vinyl Chloride.

During round 1 of groundwater sampling, downgradient monitoring well 7-7 contained vinyl chloride and T12DCE at respective concentrations of 10.2 and 2.39 ug/l. Downgradient well 7-13 contained TRCLE and benzene at respective concentrations of 0.8 and 0.9 ug/l.

During round 2 of groundwater sampling, downgradient well 7-4 detected 5 ug/l of methylene chloride. The upgradient well 7-5 contained 12DCLE and TRCLE at respective concentrations of 20 and 7.8 ug/l, which exceeded the MCL of 5.00 ug/l for each compound.

One unknown VOC compound was detected in groundwater sample 7-13 during round 1 at a concentration of 20 ug/l. No other unknown VOC compounds were detected at Area 7.

Base Neutral and Acid Extractable Compounds

The BNA compound B2EHP was detected at the sidegradient and downgradient well locations 7-2, 7-7, 7-8, 7-9, 7-11, and 7-12 during the first round of groundwater sampling only at respective concentrations of 70, 90, 60, 90, 50, and 200 ug/l. Also during the first round of sampling the upgradient well 7-6 detected the same phthalate compound at 40 ug/l. During the second round of sampling the upgradient well 7-5 detected the same phthalate at a concentration of 20 ug/l.

Unknown BNA compounds were detected in samples from 12 different monitoring wells at Area 7. Wells 7-2 through 7-13 had concentrations ranging from 10 to 30 ug/l. Detections occurred in both sampling rounds.

Inorganics

The results of the two rounds of groundwater sampling at Area 7 identified nine inorganics which exceeded statistical background concentrations. One of the nine inorganics exceeded the criteria. Table 4-15 summarizes the inorganic parameter which was determined to be site-related and includes the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in this table. The parameter which exceeded the criteria is discussed in the following paragraph.

Total chromium exceeded the MDWS of 50 ug/l in the upgradient sample 7-6-2 and the downgradient sample 7-8-2 with respective concentrations of 67.3 and 55.8 ug/l.

TABLE 4-15
SUMMARY OF INORGANIC DETECTIONS
AREA 7 GROUNDWATER RESULTS
LCAAP

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Arsenic, total	7-2-1, 7-2-2, 7-4-2, 7-5-2, 7-6-2, 7-7-1, 7-9-1, *7-10-2, 7-11-1, 7-13-2	5.80 - 39.1	*7-10-2	30.00
Barium, dissolved	7-1-2, 7-6-2, 7-9-2, 7-12-2	482	7-9-2	--
Chromium, total	*7-6-2, *7-8-2	55.8 - 67.3	*7-6-2	50.00
Copper, dissolved	7-2-1, 7-2-2, 7-3-1, 7-3-2, 7-4-1, 7-6-1, 7-7-1, 7-7-2, 7-8-1, 7-9-1, 7-10-1, 7-11-1, 7-12-1	2.36 - 12.1	7-2-2	1000.00
Lead, dissolved	7-3-1, 7-6-1, 7-8-2	3.44 - 9.5	7-6-1	50.00
Nickel, dissolved	7-1-1, 7-1-2, 7-2-1, 7-2-2, 7-3-1, 7-3-2, 7-4-1, 7-4-2, 7-5-1, 7-5-2, 7-6-2, 7-7-1, 7-12-1, 7-12-2, 7-13-2	11.3 - 40.7	7-3-1	200.00
Nickel, total	7-1-2, 7-3-2, 7-6-2, 7-7-2	65.2 - 128	7-3-2	200.00
Selenium, dissolved	7-10-1, 7-11-1	5.29 - 7.4	7-11-1	10.00
Selenium, total	7-10-1, 7-11-1	5.19 - 5.77	7-11-1	10.00
Silver, dissolved	7-1-1, 7-4-2	0.21	7-1-1, 7-4-2	50.00
Silver, total	7-1-1, 7-1-2, 7-4-2, 7-5-1, 7-5-2	0.21 - 2.02	7-1-1	50.00
Zinc, dissolved	7-1-1, 7-2-1, 7-3-1, 7-5-1, 7-6-1, 7-7-1, 7-8-1, 7-9-1, 7-10-1, 7-11-1, 7-12-1	283 - 930	7-1-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXIST.

Radiation Parameters

The upgradient well 7-5, which was sampled once in August, 1988 had a high alpha activity (23 pCi/l) as well as high beta and uranium activities. However, this was somewhat anomalous since nearby well 7-6 had much lower activities in samples taken in both April and August 1988. In addition, Area 7 is not an area that is suspected of being contaminated with uranium. Further discussion of the radiological study is presented in Section 4.23.

4.7.3 Summary

Potentially site-related detections occurred at all 13 monitoring well locations within Area 7, including upgradient and downgradient well locations. Figure 4-14 presents the Area 7 monitoring well locations and summarizes the distribution of the detections.

Explosive compounds were detected at four monitoring well locations downgradient of the closed lagoon (Area 7B) and the active lagoons (Area 7A). This may indicate that the lagoons are a source of explosive contaminants. The highest concentrations of explosives were 180 and 770 ug/l of RDX at well location 7-7 during the first and second rounds of sampling, respectively.

Detectable concentrations of VOCs were observed at the downgradient wells 7-7 and 7-13, and at well locations 7-4 and 7-5, which are adjacent to closed and active lagoons. These detections indicate that there has probably been groundwater mounding around the lagoons and that the lagoons are probable sources of VOCs in groundwater.

The BNA compound B2EHP was detected at seven well locations during the first round of sampling and at one well location during the second round. It is apparent that this compound was not consistently identified between sampling rounds. B2EHP is commonly found as a laboratory or field contaminant and therefore, may not be reflective of actual groundwater chemistry at Area 7.

Inorganics were detected at elevated concentrations at each of the monitoring well locations at Area 7. Chromium exceeded the MDWS at well locations 7-6 and 7-8 during the second round of sampling. Well location 7-6 was upgradient of the lagoon source areas, and chromium detected in this well may indicate the presence of an unidentified source of inorganics upgradient of Area 7.

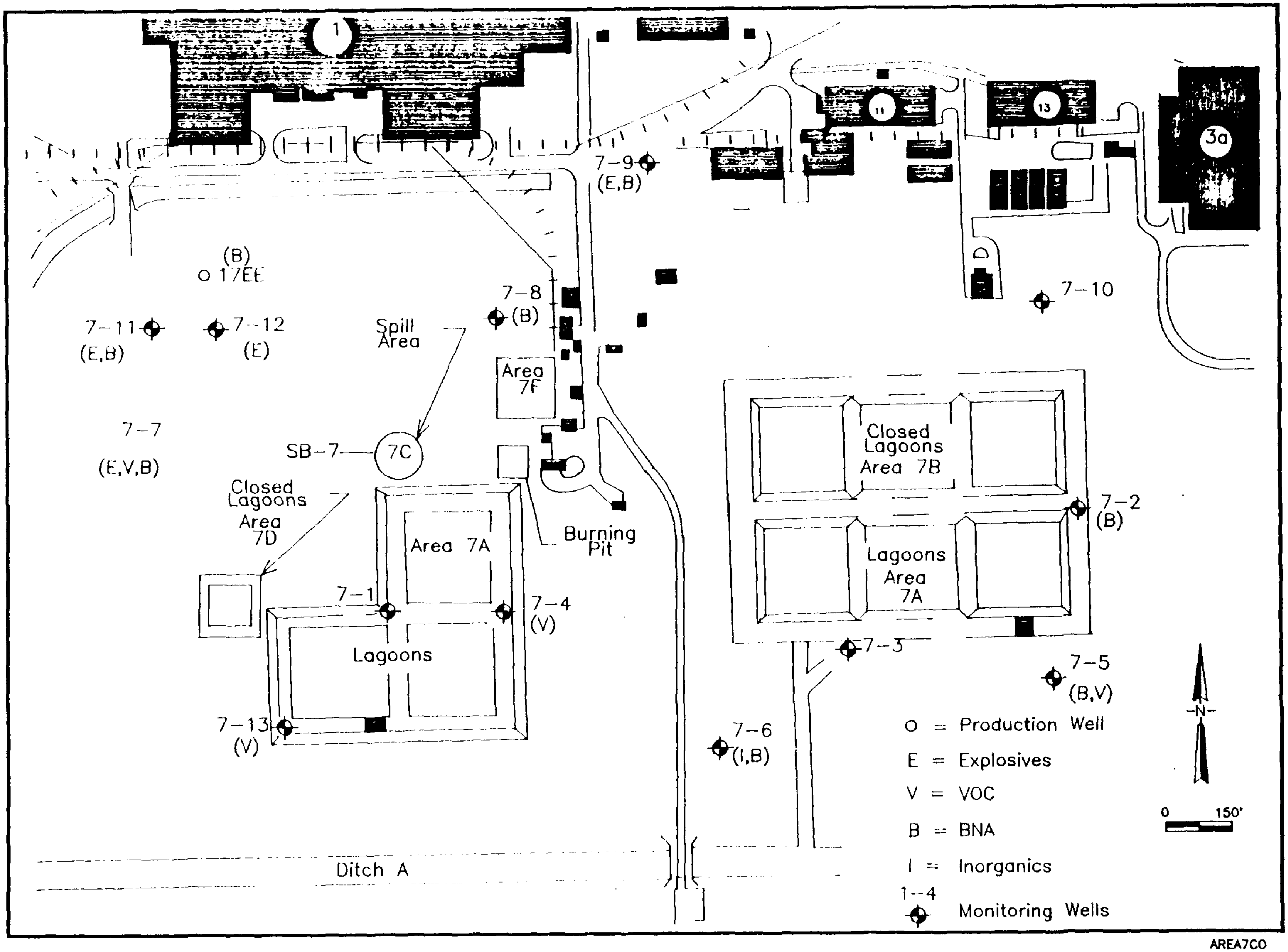


FIGURE 4-14
AREA 7 DETECTION LOCATIONS

4.8 AREA 8 - IWTP WASTE DISPOSAL AREA

4.8.1 Site Description and Field Investigation

4.8.1.1 Area 8A - Sludge Disposal Area

This site, shown in Figure 4-15, is an IWTP sludge disposal area. It was closed in 1979. The estimated area is 17,000 square feet, and the estimated quantity of waste is 30,000 cubic yards. The waste contains hazardous constituents lead, barium, and antimony. At the time of this RI, this area had a shallow groundwater monitoring network of five wells, 8-1 through 8-5. As part of the 1989 GWQAP, wells 8-1 and 8-3 were abandoned.

The field activities performed for Area 8A were the sampling and analysis of the five previously existing wells (8-1 through 8-5) to determine whether a release of hazardous waste constituents had occurred. Each well was sampled twice, and all samples were analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. The sampling events were separated by a three-month interval.

4.8.1.2 Area 8B - Sludge Disposal Area

This site, also shown in Figure 4-15, is an IWTP sludge disposal area. The area was opened in the mid-1970s and was closed in 1979. The estimated area is 17,000 square feet, and the estimated quantity of waste is 30,000 cubic yards. The waste contains hazardous constituents lead, barium, and antimony. At the time of this RI, monitoring wells 8-1 through 8-5 monitored this site.

As part of the Remedial Investigation, the five existing wells were sampled, as described in Area 8A, to determine whether a release of hazardous waste constituents had occurred.

4.8.1.3 Area 8C - Sludge Disposal Area

This site, also shown in Figure 4-15, is an IWTP sludge disposal area. The area was opened in the late 1960s and was closed in 1971. The estimated area is 40,000 square feet. The estimated quantity of waste is 30,000 cubic yards. Possible RCRA hazardous constituents are lead and mercury.

At Area 8C, two geophysical surveys were performed, and two downgradient monitoring wells, one upgradient well, and one soil boring were installed. Electromagnetics (EM-34) and GPR geophysical techniques were performed over the suspected disposal area. Figure 4-16 shows the locations where the geophysical surveys were conducted. These disposal areas contain heavy metals which are electrically conductive and can be detected by the EM-34 surveys. The geophysical techniques attempted to define the geometry of the old waste disposal area. This optimized well

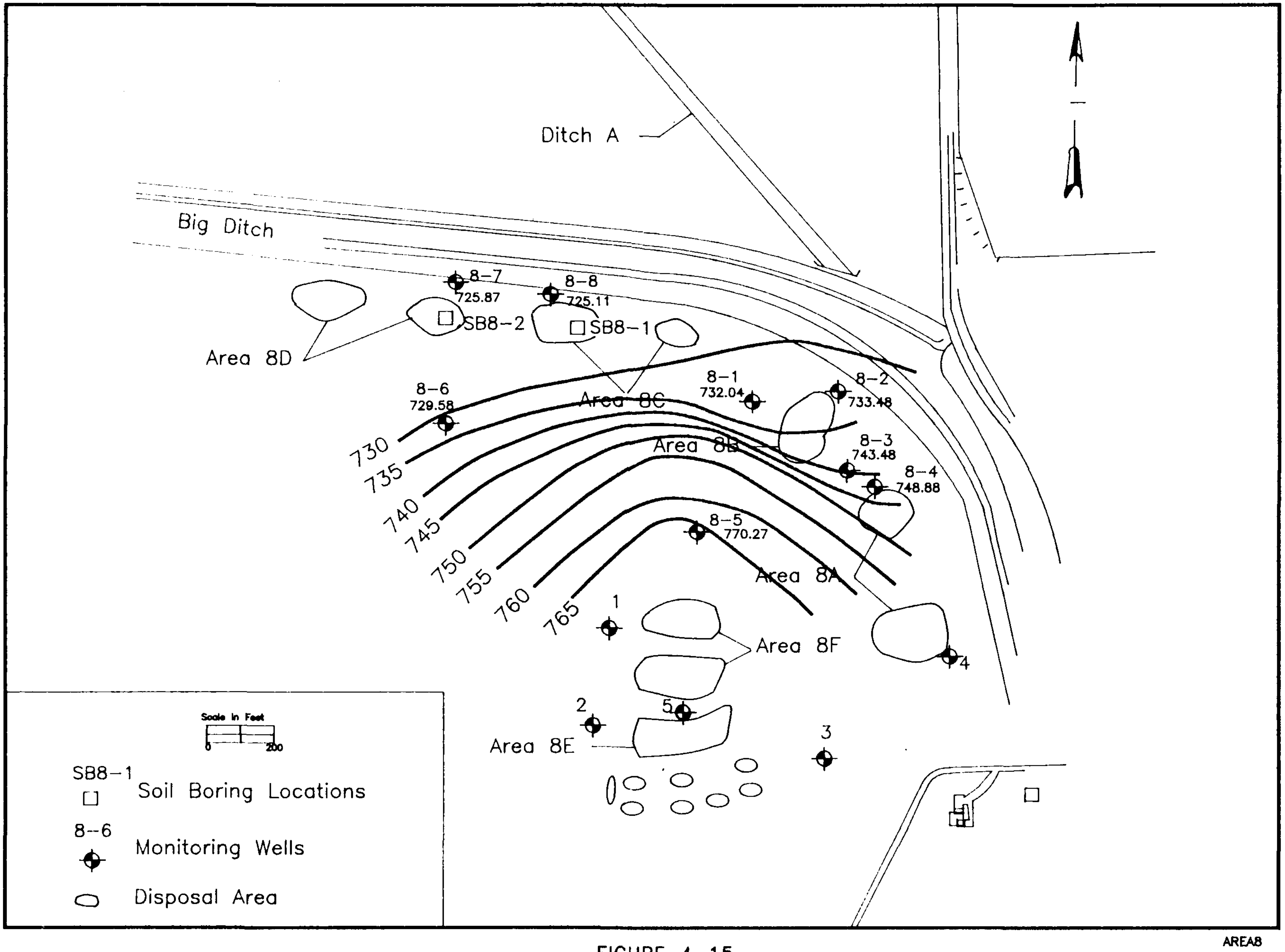


FIGURE 4-15
EA 8

placement and defined the extent of waste present in the area. The EM-34 survey required approximately 80 station readings at 50-foot grid spacing. The GPR complemented the EM-34 survey and was conducted over approximately 1,250 linear yards.

As part of the field investigation, one monitoring well was installed downgradient of the waste disposal area. The well (8-8) is screened just below the water table at approximately 33 feet. It was sampled twice, and was analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. In addition, this well was analyzed during the first round of sampling for radiation parameters. The sampling events were separated by a three-month interval.

One soil boring was drilled through the waste disposal area, which was located via geophysical methods. The boring (SB8-1) was drilled to the bottom of the waste disposal pit, which is approximately 10 feet deep. Three samples were collected from the boring at 1 to 1.5 feet, 3.5 to 5 feet, and 8.5 to 10 feet. These samples characterized the waste material and were analyzed for metals, explosives, and oil and grease.

4.8.1.4 Area 8D - Sludge Disposal Area

This site, also shown in Figure 4-15, is an IWTP sludge disposal area which was opened in the early to mid-1960s and closed in 1968. The estimated area is 40,000 square feet, and the estimated quantity of waste is 30,000 cubic yards. Possible RCRA hazardous constituents are lead and mercury.

The same geophysical surveys conducted at Area 8C were also carried out at Area 8D. Also, one downgradient (8-7) and one upgradient (8-6) monitoring well were installed at the area. Well 8-7 was screened below the water table at approximately 29 feet and monitoring well 8-6 was also screened below the water table at approximately 32 feet. The groundwater was analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. One soil boring (SB8-2) was drilled through the waste disposal area that had been located via geophysical methods. The soil boring was drilled to the bottom of the waste disposal pit, which was estimated to be at a depth of approximately 10 feet. Three soil samples were collected from the boring, at intervals of 1 to 2.5 feet, 3.5 to 5 feet, and 8.5 to 10 feet. These samples characterized the waste material. The soil samples were analyzed for inorganics, explosives, and oil and grease.

4.8.1.5 Area 8E - Oil and Grease Trenches

This was a disposal site for oil and grease from the IWTP. Hazardous waste K046 may be present due to the discharge of wastewater from primers manufacturing to the IWTP. This site has been closed in accordance with 40 CFR Part 265. There were eight pits (trenches), each approximately 15 feet wide by 50 feet long.

At the time of this RI, five shallow monitoring wells existed at Area 8E (wells 1 through 5). Previous sampling and analysis of the wells had not detected the release of hazardous waste constituents. These five wells were abandoned as part of the 1989 GWQAP. Many additional wells were subsequently installed at Area 8.

The field activities performed for Area 8E were two rounds of sampling and analysis of the existing five wells (1 through 5) to assess whether a release of hazardous waste constituents had occurred.

4.8.1.6 Area 8F - Sludge Disposal Area

This site is a currently operating solid waste disposal facility permitted by the MDNR. The approximate area is 18 acres. It is used for the disposal of sludge generated by the IWTP. Inorganic hazardous constituents contained in this sludge are lead, barium, and antimony. No data base exists for organic constituents. Groundwater at the site was previously monitored by the five wells described for Areas 8A, 8B and 8E.

The field activities performed for Area 8F were the sampling and analysis of the wells described above. The wells were sampled and analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives to assess whether a release of hazardous waste constituents had occurred.

The Area 8 monitoring wells have been designated as upgradeint, sidegradient, and downgradient according to their spacial relationship with the combined potential source locations. Well 8-6 is upgradient, wells 1, 2 and 4 are sidegradient, while the remaining wells are considered downgradient.

4.8.2 Site Investigation Results

The results of this site investigation at Area 8 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.8.3). All radiological, organic, and inorganic analytical data is presented in Table 4-16. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

TABLE 4-16
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #8
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	8-1-1	8-1-2	8-2-1	8-2-2	8-3-1	8-3-2
DEPTH (FT)	35	35	25	25	28	28
VOLATILES						
Trans 1,2-Dichloroethene	4	ND	ND	ND	ND	ND
Trichloroethene	0.9	ND	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
N-Nitrosodiphenylamine	10	ND	ND	ND	ND	ND
bis (2-Ethylhexyl) Phthalate	40	ND	20000	ND	ND	ND
UNKNOWNS						
2-(Phenylthio) Thiazole [679]	ND	ND	ND	ND	10	ND
Benzene Acetonitrile [518]	ND	ND	ND	ND	20	ND
C9-C14 Alkane Glycol	*200	ND	ND	ND	ND	ND
1-Flourodecane [980]	10	ND	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL ND OR <CRL)					
INORGANICS						
Antimony, dissolved	9.32	<3.00	<3.00	<3.00	17.5	<3.00
Antimony, total	7.61	<3.00	<3.00	<3.00	<3.00	<3.00
Arsenic, dissolved	<5.00	<5.00	<5.00	<5.00	8.59	<5.00
Arsenic, total	<5.00	11.4	<5.00	<5.00	9.21	14.1
Barium, dissolved	NA	396	NA	387	NA	300
Barium, total	NA	860	NA	483	NA	600
Beryllium, total	<0.10	2.52	0.55	0.2	4.1	1.31
Cadmium, total	<5.10	<5.10	<5.10	<5.10	12.9	<5.10
Chromium, dissolved	<37.50	<37.50	48.1	<37.50	<37.50	<37.50
Chromium, total	164	68.3	155	<37.50	363	<37.50
Copper, dissolved	2.89	<1.78	4.72	<1.78	3.75	<1.78
Copper, total	15.6	81	20.4	8.25	780	310
Lead, dissolved	<2.50	<2.50	<2.50	2.53	<2.50	2.53
Lead, total	<2.50	10.3	<2.50	2.63	14.5	23.6
Nickel, dissolved	46.5	48.4	497	13.3	35.9	28.8
Nickel, total	163	163	57	24	91	61.5
Silver, total	<0.19	0.32	<0.19	<0.19	<0.19	0.32
Zinc, dissolved	451	<17.20	438	412	295	<17.20
Zinc, total	210	267	258	27.7	1000	363
OTHERS	(ALL ND OR <CRL)					

CRL = CERTIFIED REPORTING LIMIT ND = NOT DETECTED NA = NOT ANALYZED

* DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-16
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #8
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	8-4-1 16	8-4-2 16	8-5-1 11	8-5-2 11	8-6-1 27	8-6-2 27
VOLATILES						
Trichloroethene	35	ND	ND	ND	ND	ND
Toluene	15	ND	ND	ND	ND	ND
Trans 1,2-Dichloroethene	94	ND	ND	ND	ND	ND
UNKNOWNS						
Tetrahydrofuran	*10	ND	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	40	ND	ND	ND	ND	ND
UNKNOWNS						
C6-C9 Cycloalkane	ND	*20	ND	ND	ND	*20
C8-C10 Methyl Alkene/Alkane	ND	*20	ND	ND	ND	*20
C6-C10 Methyl Alene/Alkane	ND	*20	ND	ND	ND	ND
Alkane	300	ND	ND	ND	ND	ND
Benzene Acid Ester [950]	10	ND	ND	ND	ND	ND
1-Methyl-2-Propyl-1-Pentanol [899]	10	ND	ND	ND	ND	ND
3-Bromodecane [916]	10	ND	ND	ND	ND	ND
(3,3-Dimethylbutyl) Oxirane [815]	10	ND	ND	ND	ND	ND
1-Chlorooctane [961]	10	ND	ND	ND	ND	ND
2-(Methylsileno)-ethanamine [948]	ND	ND	400	ND	ND	ND
Trimethyldecane	ND	ND	*10	ND	ND	ND
C13-Methyl Alkane	ND	ND	*40	ND	ND	ND
2,3,7-Trimethyldecane [978]	ND	ND	30	ND	ND	ND
C13-C36 Hydrocarbon	ND	ND	*40	ND	ND	ND
C13-C43 Hydrocarbon	ND	ND	*40	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	<5.00	<5.00	8.8	10.6	5.18	7.66
Barium, dissolved	NA	111	NA	85	NA	139
Barium, total	NA	387	NA	592	NA	397
Beryllium, total	<0.10	4.8	0.3	2.52	0.7	0.81
Chromium, dissolved	38.5	<37.50	<37.50	<37.50	<37.50	<37.50
Chromium, total	145	39.4	65.4	98.1	<37.50	<37.50
Copper, dissolved	<1.78	5.47	2.57	<1.78	<1.78	<1.78
Copper, total	<1.78	79	100	63	41.5	30.4
Lead, dissolved	<2.50	2.63	<2.50	4.35	<2.50	<2.50
Lead, total	<2.50	37.6	37.4	10.5	22.8	19.9
Nickel, dissolved	10.5	<9.60	<9.60	52.7	<9.60	<9.60
Nickel, total	17.1	106	50.8	160	29.9	48.2
Silver, total	<0.19	0.32	0.32	2.24	<0.19	0.32
Zinc, dissolved	283	39.4	232	<17.20	516	18
Zinc, total	101	560	213	290	592	228
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-16
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #8
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	8-7-1	8-7-2	8-8-1	8-8-2	MW-1-1	MW-1-2
DEPTH (FT)	34	34	38	38	25.5	25.5
VOLATILES						
Trans-1,2-Dichloroethene	<1.72	<1.72	<1.72	<1.72	4.1	<1.72
Trichloroethene	<0.71	<0.71	<0.71	<0.71	0.9	<0.71
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
N-Nitrosodiphenylamine	ND	ND	ND	ND	ND	10
UNKNOWNS						
C6-C9 Cycloalkane	ND	ND	ND	*20	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	ND	ND	*20	ND	ND
(Phenoxymethyl) Benzene [698]	ND	ND	ND	10	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	0.85	<0.63	0.91	<0.63	<0.63	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, total	<3.00	<3.00	<3.00	<3.00	<3.00	3.52
Arsenic, total	5.49	<5.00	5.9	<5.00	<5.00	<5.00
Barium, dissolved	NA	234	NA	165	NA	229
Barium, total	NA	286	NA	178	168	141
Beryllium, total	0.91	0.2	0.7	<0.10	0.81	0.2
Copper, dissolved	9.54	<1.78	3.64	<1.78	4.61	<1.78
Copper, total	49.9	8.68	31.8	5.47	33.9	10.8
Lead, dissolved	6.77	<2.50	2.53	<2.50	3.13	<2.50
Lead, total	15.7	<2.50	15	4.65	41.9	5.16
Nickel, dissolved	<9.60	14.2	23.4	<9.60	24.2	<9.60
Nickel, total	46.6	<9.60	66.1	15.3	35	<9.60
Zinc, dissolved	378	<17.20	416	41.6	507	<17.20
Zinc, total	449	21.4	398	73.7	547	35.5
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCI/L)						
Alpha	NA	NA	<7	NA	NA	0+/-5
Beta	NA	NA	<5	NA	NA	24+/-5
U-234	NA	NA	NA	NA	NA	1.3+/-0.3
U-235	NA	NA	NA	NA	NA	0.0+/-0.1
U-238	NA	NA	NA	NA	NA	0.9+/-0.3
Total Uranium	NA	NA	1.1	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

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TABLE 4-16
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #8
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	MW-2-1 26	MW-2-2 26	MW-3-1 25	MW-3-2 25	MW-4-1 25	MW-4-2 25
VOLATILES						
Toluene	<1.57	<1.57	<1.57	<1.57	15	<1.57
Trans-1,2-Dichloroethene	<1.72	<1.72	<1.72	<1.72	93	<1.72
Trichloroethene	<0.71	<0.71	<0.71	<0.71	34	<0.71
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	ND	ND	ND	30
UNKNOWNS						
(Phenoxymethyl) Benzene [741]	ND	ND	ND	20	ND	ND
(Phenoxymethyl Benzene [748]	ND	ND	ND	ND	ND	100
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	<5.00	<5.00	<5.00	12.8	<5.00	5.28
Barium, dissolved	NA	175	NA	200	NA	298
Barium, total	129	132	662	1470	277	449
Beryllium, total	<0.10	0.3	2.82	6	0.2	0.91
Cadmium, total	<5.10	<5.10	<5.10	14	<5.10	<5.10
Chromium, total	<37.50	<37.50	<37.50	51	<37.50	<37.50
Copper, dissolved	5.14	<1.78	<1.78	<1.78	<1.78	<1.78
Copper, total	8.57	16.9	20.4	100	11.4	26
Lead, dissolved	<2.50	<2.50	<2.50	<2.50	<2.50	2.83
Lead, total	15.6	12.1	9	90	12.6	12.8
Mercury, total	ND	ND	ND	ND	0.5	ND
Nickel, dissolved	<9.60	<9.60	37.6	<9.60	17.1	10.1
Nickel, total	44.5	15.6	53.1	193	12.4	33.1
Silver, dissolved	<0.19	<0.19	<0.19	12.8	<0.19	<0.19
Silver, total	<0.19	<0.19	<0.19	0.96	<0.19	0.32
Zinc, dissolved	860	17.6	1400	104	714	70.6
Zinc, total	439	67.5	496	650	437	98.3
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCI/L)						
Alpha	NA	6+/-6	NA	22+/-10	NA	33+/-15
Beta	NA	21+/-5	NA	96+/-8	NA	50+/-6
U-234	NA	1.7+/-0.3	NA	1.9+/-0.4	NA	1.5+/-0.2
U-235	NA	0.1+/-0.1	NA	0.0+/-0.1	NA	0.0+/-0.1
U-238	NA	1.3+/-0.3	NA	1.7+/-0.3	NA	1.2+/-0.2
Total Uranium	NA	NA	NA	NA	NA	NA

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TABLE 4-16
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #8
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	MW-5-1	MW-5-2
DEPTH (FT)	25	25
VOLATILES		
OTHERS	(ALL ND OR <CRL)	
BASE NEUTRAL & ACID EXTRACTABLES		
bis (2-Ethylhexyl) Phthalate	ND	40
UNKNOWNS		
1,1-[oxybis(2,1-ethanediyloxy)] Bisbutane [401]	ND	10
(Phenoxymethyl) Benzene [762]	ND	10
OTHERS	(ALL ND OR <CRL)	
EXPLOSIVE COMPOUNDS		
ALL	(ALL ND OR <CRL)	
INORGANICS		
Barium, dissolved	NA	303
Barium, total	213	230
Chromium, dissolved	65.4	<37.50
Copper, dissolved	2.79	<1.78
Copper, total	4.5	5.47
Lead, dissolved	<2.50	5.66
Lead, total	5.26	8.9
Nickel, dissolved	21.9	<9.60
Nickel, total	9.75	<9.60
Zinc, dissolved	770	35.6
Zinc, total	715	66.7
OTHERS	(ALL ND OR <CRL)	
RADIOLOGICAL (PCI/L)		
Alpha	NA	0+/-5
Beta	NA	29+/-6
U-234	NA	1.0+/-0.2
U-235	NA	0.0+/-0.1
U-238	NA	0.6+/-0.2
Total Uranium	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-16
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #8
SUMMARY OF ANALYTICAL DATA
SUBSURFACE SOIL SAMPLES (UG/G)

SITE ID DEPTH (FT)	SB8-1-1 1	SB8-1-2 3.5	SB8-1-3 8.5	SB8-2-1 1	SB8-2-2 3.5	SB8-2-3 8.5
VOLATILES						
ALL	(ALL NA)					
BASE NEUTRAL & ACID EXTRACTABLES						
ALL	(ALL NA)					
EXPLOSIVE COMPOUNDS						
26-DNT	<0.40	0.41	<0.40	<0.40	<0.40	<0.40
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	35.6	38.5	14.4	13.5	37.5	35.6
Barium, total	188	261	791	725	194	1250
Beryllium, total	0.36	0.42	0.31	0.48	0.46	0.49
Cadmium, total	<0.93	<0.93	<0.93	26.4	9.25	9.25
Copper, total	13.5	13.5	9.62	10.8	15.6	190
Lead, total	18.1	8.33	7.14	10.2	13.7	17.2
Mercury, total	<0.11	<0.12	<0.12	<0.12	<0.11	2.99
Nickel, total	35.1	30.8	16.8	29.9	40.1	30.3
Zinc, total	69.5	<60.2	<63.2	<61.7	<57.7	3010
OTHERS	(ALL ND OR <CRL)					
GENERAL TESTS						
Oil and Grease	ND	ND	ND	ND	ND	270

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

4.8.2.1 Geophysical Surveys

Electromagnetic Conductivity

The EM-34 terrain conductivity survey at Area 8 identified four areas which gave anomalous measurements, as shown in Figure 4-16. The most definitive area is located near the southwest corner of the survey, at coordinates 50N, 400W; 50N, 310W; 25S, 310W; and 25S, 400W. This area typically gave vertical dipole instrument readings of between 69 and 110 mmhos/m, with a maximum of approximately 300 mmhos/m. Horizontal dipole values also increased near these coordinates to a maximum of 56 mmhos/m. Horizontal dipole and vertical dipole background values at Area 8 ranged from 35 to 40 and 17 to 65 mmhos/m, respectively.

The three other anomalous areas gave only slightly elevated readings. The largest area is located near the north-central portion of the survey, at coordinates 300N, 50W; 300N, 250E; 200N, 250E; and 200N, 50E. Readings of 60 to 65 mmhos/m were obtained.

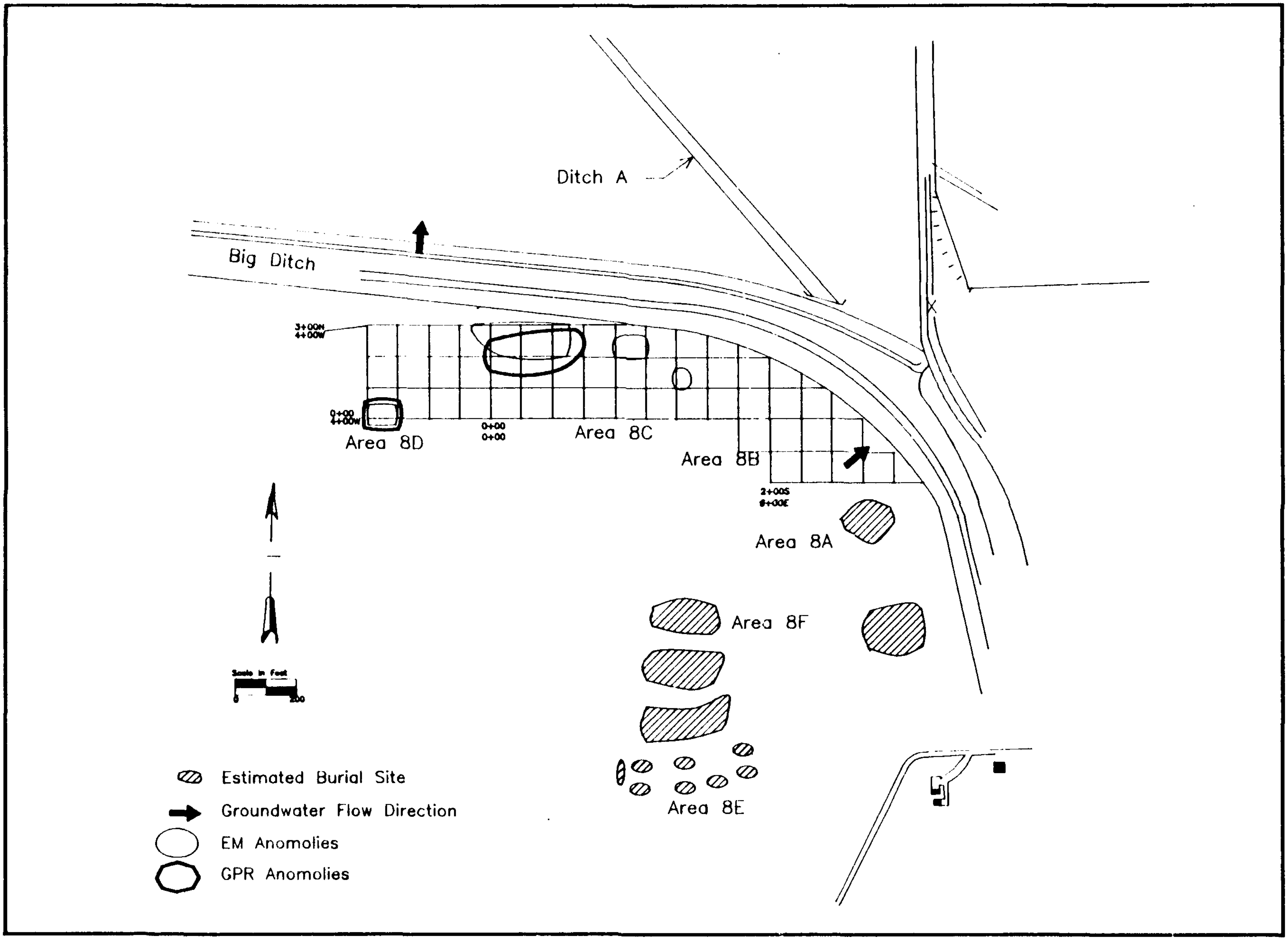
Coordinates 170N, 150W, near the northwest portion of the survey area, provided a single high vertical dipole value of 63 mmhos/m. Near the center of the survey area, coordinates 170N, 600E; 150N, 650E; 100N, 600E; and 150N, 630E recorded vertical dipole values of 60 to 61 mmhos/m with a low of 35 mmhos/m.

Ground-Penetrating Radar

A ground-penetrating radar survey was performed in conjunction with the EM-34 survey and several anomalous areas were noted. A definite anomaly coincided with the 300 plus mmhos/m zone on the EM survey in the southwest corner. Slightly positive results were obtained at various locations throughout Area 8, and can be delineated into three relatively independent zones. The first area can be approximated by coordinates 275N, 0W; 275N, 250E; 150N, 200E; and 150N, 0W. The reflective horizons were generally detected in the north-south direction. The northern limit of these horizons lies in a generally straight line along 275N, possibly indicating some excavation activities oriented east-west in this area.

The second area is somewhat smaller in extent. It is located in the north-central portion of the survey area, and is approximated by coordinates 250N, 400E; 260N, 500E; 200N, 500E; and 200N, 400E. Five consecutive north-south traverses detected reflective horizons in this area, possibly indicating disturbed soil.

The third area consists of widely scattered reflections approximated by coordinates 250N, 625E; 275N, 725E; 275N, 775E; 200N, 750E; and 200N, 625E. Several sharp anomalies and traverses (generally north-south) were detected within these limits and are



AREA8GR

FIGURE 4-16
LOCATION OF GEOPHYSICAL SURVEY
GRID AND COORDINATES OF AREA 8

a possible indication of disturbed soil. This location approximates an anomalous area identified with the EM-34 survey.

In addition to the three areas depicted above, several sharp anomalies were detected in the southeast portion of the area at scattered locations which could be attributed to near-surface debris or disturbed soil horizons.

4.8.2.2 Groundwater

Explosives

The results of the rounds of groundwater sampling at Area 8 identified one explosive compound: RDX. The compound was identified during the first round of sampling only. Downgradient wells 8-7 and 8-8 contained respective concentrations of 0.85 and 0.91 ug/l.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at Area 8 identified five VOCs:

- 111TCE.
- 11DCLE.
- Toluene.
- T12DCE.
- TRCLE.

All detections were during the first round only. Downgradient well 8-1 detected T12DCE and TRCLE at 4 and 0.9 ug/l, respectively. Downgradient well 8-2 detected 2 ug/l of 11DCLE. Downgradient well 8-4 detected TRCLE, toluene, and T12DCE at respective concentrations of 35, 15, and 10 ug/l. Upgradient well 1 detected 111TCE, T12DCE, and TRCLE at respective concentrations of 3, 4.1, and 0.90 ug/l. Sidegradient well 4 detected toluene, T12DCE, and TRCLE at respective concentrations of 15, 93, and 34 ug/l. The TRCLE MCL of 5 ug/l was exceeded.

The unknown VOC compound tetrahydrofuran was identified by library search methods in groundwater sample 8-4 at a concentration of 10 ug/l during round 1. No other unknown VOC compounds were detected at Area 8.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 8 identified two BNA compounds:

- NNDPA.
- B2EHP.

NNDPA was detected in both sample 8-1-1 and sample MW1-2 at a concentration of 10 ug/l.

B2EHP was detected in five samples during the investigation. One of the detections, 8-4-1, is considered a laboratory contaminant due to an elevated concentration (40 ug/l) found in the laboratory method blank. Detections were also found in investigative samples 8-1-1, 8-2-1, MW4-2, and MW5-2 at respective concentrations of 40, 20,000, 30, and 40 ug/l. The B2EHP concentration of 20,000 ug/l identified at well location 8-2-1 was one of the highest BNA detections of the investigation. This high concentration appears to be a real site-related detection.

Unknown BNA compounds were detected in samples from nine different monitoring wells at Area 8. Wells 3, 4, 5, 8-1, 8-3, 8-4, 8-5, 8-6, and 8-8 had concentrations ranging from 10 to 400 ug/l. Detections occurred in both sampling rounds.

Inorganics

The results of two rounds of groundwater sampling at Area 8 identified twelve metals which exceeded statistical background concentrations. A total of five of the eleven metals exceeded the MGS, MDWS, and/or MCL, and all were detected at downgradient monitoring well locations. Table 4-17 summarizes the inorganic parameters which were determined to be site-related detections and includes the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in this table. The parameters which exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Total barium exceeded the MDWS of 1,000 ug/l with a concentration of 1,470 ug/l in downgradient sample MW3-2.

Total cadmium exceeded the MCL of 5 ug/l and the MDWS of 10 ug/l in downgradient samples 8-3-1 and MW-3-2 with respective concentrations of 12.9 and 14.0 ug/l.

Dissolved chromium exceeded the MDWS for total chromium of 50 ug/l in downgradient sample MW5-1 with a detection of 65.4 ug/l. No detections of dissolved chromium at Area 8 exceeded the MCL for total chromium of 100 ug/l.

Total chromium exceeded the MDWS of 50 ug/l in downgradient samples 8-1-2, 8-5-1, 8-5-2, and MW-3-2 with respective concentrations of 68.3, 65.4, 98.1, and 51.0 ug/l. Total chromium exceeded the MCL of 100 ug/l in downgradient samples 8-1-1, 8-2-1, 8-3-1, and 8-4-1 with respective concentrations of 164, 155, 363, and 145 ug/l.

Total lead exceeded the MCL of 50 ug/l in downgradient sample MW-3-2 with a detection of 90.0 ug/l.

TABLE 4-17
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 8 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Antimony, dissolved	8-1-1, 8-3-1	9.32 - 17.5	8-3-1	--
Antimony, total	8-1-1, MW1-2	3.52 - 7.61	8-1-1	--
Arsenic, dissolved	8-3-1	8.59	8-3-1	30.00
Arsenic, total	8-1-2, 8-3-1, 8-3-2, 8-5-1, 8-5-2, 8-6-2, 8-7-1, 8-8-1, MW3-2, MW4-2	5.28 - 14.1	8-3-2	30.00
Barium, dissolved	8-1-2, 8-2-2, 8-3-2, MW4-2, MW5-2	298 - 396	8-1-2	--
Barium, total	8-1-2, *MW3-2	860 - 1470	*MW3-2	1000.00
Beryllium, total	8-1-2, 8-3-1, 8-3-2, 8-4-2, 8-5-2, 8-7-1, MW3-1, MW3-2, MW4-2	0.91 - 6	MW3-2	--
Cadmium, total	*8-3-1, *MW3-2	12.9 - 14	*MW3-2	5.00
Chromium, dissolved	8-2-1, 8-4-1, *MW5-1	38.5 - 65.4	MW5-1	50.00
Chromium, total	*8-1-1, *8-1-2, *8-2-1, *8-3-1, *8-4-1, 8-4-2, *8-5-1, *8-5-2, *MW3-2	51 - 363	*8-3-1	50.00
Copper, dissolved	8-1-1, 8-2-1, 8-3-1, 8-4-2, 8-5-1, 8-7-1, 8-8-1, MW1-1, MW2-1, MW5-1	2.57 - 9.54	8-7-1	1000.00
Copper, total	8-1-2, 8-3-1, 8-3-2, 8-4-2, 8-5-1, 8-5-2, 8-7-1, MW3-2	49.9 - 780	8-3-1	1000.00
Lead, dissolved	8-5-2, 8-7-1, MW1-1, MW5-2	3.13 - 6.77	8-7-1	50.00
Lead, total	8-4-2, 8-5-1, MW1-1, *MW3-2	37.4 - 90	MW3-2	50.00
Mercury, total	MW4-1	0.5	MW4-1	2.00
Nickel, dissolved	8-1-1, 8-1-2, *8-2-1, 8-2-2, 8-3-1, 8-3-2, 8-4-1, 8-5-2, 8-7-2, 8-8-1, MW1-1, MW3-1, MW4-1, MW4-2, MW5-1	10.1 - 497	*8-2-1	200.00
Nickel, total	8-1-1, 8-1-2, 8-3-1, 8-4-2, 8-5-2, 8-8-1, MW3-2	66.1 - 193	MW3-2	200.00
Silver, total	8-1-2, 8-3-2, 8-4-2, 8-5-1, 8-5-2, 8-6-2, MW3-2, MW4-2	0.32 - 2.24	8-5-2	50.00
Silver, dissolved	MW3-2	12.8	MW3-2	50.00
Zinc, dissolved	8-1-1, 8-2-1, 8-2-2, 8-3-1, 8-4-1, 8-6-1, 8-7-1, 8-8-1, MW1-1, MW2-1, MW3-1, MW4-1, MW5-1	283 - 1400	MW3-1	5000.00
Zinc, total	8-3-1	1000	8-3-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXIST.

Dissolved nickel exceeded the MGS of 200 ug/l in downgradient sample 8-2-1 with a detection of 497 ug/l. No standards for dissolved nickel exist under MDWS or MCL.

Radiation Parameters

Six groundwater samples were collected during round 2 at Area 8. Samples from monitoring wells MW-3 and MW-4 contained some of the highest alpha and beta activities of the investigation. Sample MW-3 contained a beta activity of 96 pCi/l. Sample MW-4 contained an alpha activity of 33 pCi/l.

Elevated uranium isotope levels were measured at wells MW-1 through MW-5. All radiological analytical results are discussed in Section 4.23.

4.8.2.3 Subsurface Soil

Explosives

The results of the soil boring program at Area 8 identified one explosive compound: 26DNT.

The compound was detected in boring SB8-1 at a depth of 3.5 feet and a concentration of 0.41 ug/g.

Oil and Grease

There was one detection of oil and grease from the Area 8 soil borings. Boring 8-2 detected 270 ug/g of oil and grease in the 8.5- to 10-foot sample.

Inorganics

The results of the soil boring program at Area 8 identified nine metals which exceeded statistical background concentrations. These detections are discussed in the following paragraphs.

Soil boring SB8-1 showed eight detections. Arsenic was detected at all three sample depths (1- to 2.5-foot, 3.5- to 5.0-foot, and 8.5- to 10-foot) at 35.6, 38.5, and 14.4 ug/g, respectively. Barium was detected in the middle and deep samples at 261 and 791 ug/g. Beryllium was detected in the middle sample at 0.42 ug/g. Lead was detected in the shallow sample at 18.1 ug/g. Nickel was detected in the shallow sample at 35.1 ug/g.

Soil boring SB8-2 showed 17 detections. Arsenic was detected at all three depths at 13.5, 37.5 and 35.6 ug/g. Barium was detected in the shallow and deep samples at 725 and 1250 ug/g. Beryllium was detected at 0.48, 0.46, and 0.49 ug/g. Cadmium was detected at 26.4, 9.25, and 9.25 ug/g. Copper was detected in the deep sample at 190 ug/g. Lead was detected in the middle and deep samples at 13.7 and 17.2 ug/g. Mercury was detected in the deep sample at 2.99 ug/g. Nickel was detected in the middle sample at 40.1 ug/g. Zinc was detected in the deep sample at 3010 ug/g.

4.8.3 Summary

Site-related detections of organic and/or inorganic parameters occurred at 11 of the 13 monitoring well locations within Area 8, including every downgradient well location. Figure 4-17 presents the Area 8 monitoring well locations and summarizes the distribution of detections.

Trace quantities of the explosive compound RDX were detected at two monitoring wells downgradient of the Area 8D sludge disposal pits. A soil boring sample collected from the pits also detected a trace quantity of the explosive compound 26DNT, which indicates that the pits are a potential source of explosive contaminants in the local groundwater.

Detectable concentrations of VOCs were observed at downgradient or sidegradient well locations 8-1, 8-2, 8-4, and 4 and at upgradient well location 1 during the first round of sampling. All three locations are adjacent to disposal pits. The positive detections at well 1 may be due to its close proximity to an Area 8F sludge disposal pit. These detections suggest that the Area 8 disposal pits are contributing VOCs to the groundwater. The detection of oil and grease in subsurface soil samples collected from the sludge disposal areas also indicates that the VOCs may be originating from the pits.

BNA compounds NNDPA and/or B2EHP were detected at five monitoring well locations, including one upgradient and four downgradient locations. The 20,000 ug/l of B2EHP detected at well location 8-2 during the first round of sampling is unusually high and suggests the possibility of an Area 8B disposal pit being a source of B2EHP. The compound was also detected in the laboratory method blank for sample 8-4-1. Numerous unknown BNA compounds were detected at nine well locations within the eastern portion of the area, with well 8-5 containing a high of 400 ug/l. These results implicate Areas 8A, 8B, 8C, 8E, and 8F as potential BNA source locations.

Inorganics which exceed statistical background concentrations were detected at seven downgradient monitoring well locations. None of the upgradient locations showed elevated levels of inorganic constituents. Barium, cadmium, chromium, lead, and nickel were detected at concentrations exceeding the MCL, MGS, and/or MDWS at locations downgradient of Areas 8A, 8B, and 8F, indicating that these areas are contributing inorganics to the local groundwater chemical results.

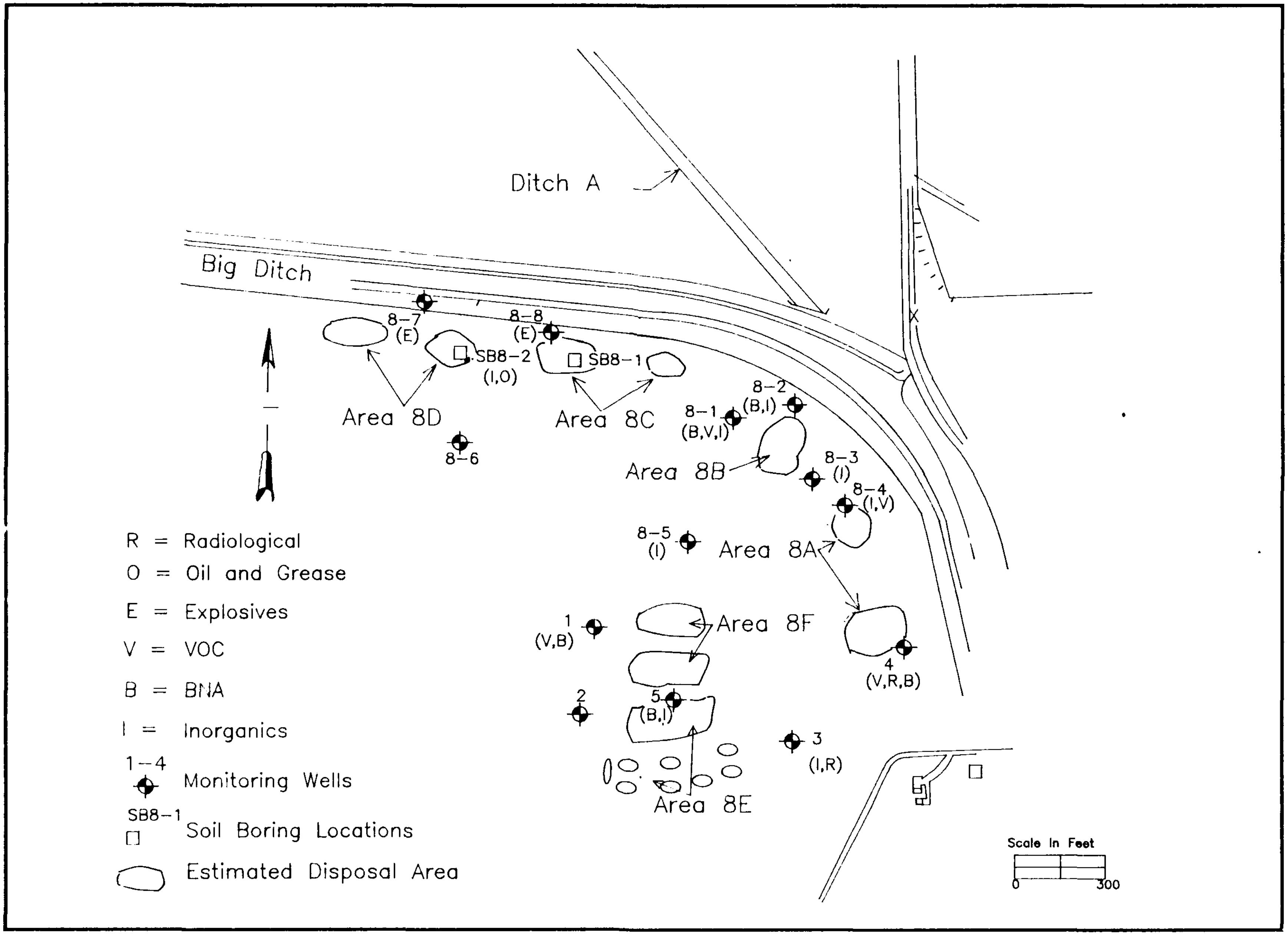


FIGURE 4-17
[illegible]A 8

Soil boring SB8-2, performed through the sludge pit at Area 8D, showed this area to be a contaminant source with detections of oil and grease and inorganics. Inorganics detections consisted of arsenic, beryllium, cadmium, copper, lead, mercury, and zinc. The two monitoring wells located downgradient of the sludge pit did not detect any of these constituents in the groundwater. Both wells are screened at the top of the water table.

4.9 AREA 9 - BUILDING 60 TREATMENT FACILITY

4.9.1 Site Description and Field Investigation

4.9.1.1 Area 9A-Percolation Sumps

Four sumps were located outside the Building 4 East Charging Wing (partially shown in Figure 4-18). These sumps collected tracer waste which may have contained the hazardous constituents lead and barium. The inlet pipes to the sumps were fitted with fabric filters to remove suspended solids. The efficiency of these filters is unknown. The sumps discharged through a storm sewer to nearby outflow areas. In 1982 all drains to the sumps were reportedly plugged or removed, and use of the sumps was discontinued.

As part of the remedial investigation, many sumps throughout the plant were inspected and sampled as discussed in Subsection 4.21. Sump outfall samples were collected in close proximity to the discharge from the sumps. Sump samples collected at each location were analyzed for metals, explosives, and oil and grease.

4.9.1.2 Area 9B - Mercury Waste Tank

This site, shown in Figure 4-18, contains the mercurous nitrate treatment and storage facility at Building 60. It includes five in-ground concrete tanks. The facility was originally used for cyanide treatment in the 1950s. Then, between approximately 1970 and 1982, it was used for treatment of mercurous nitrate, which was generated as a result of testing procedures for small arms cartridges. The facility has been inactivated, but the tanks presently contain water and sludge. These tanks are to be investigated and closed under the guidelines set forth in the Lake City Inter-Agency Agreement between the Army, EPA and State of Missouri.

Because of the past usage of these tanks involving hazardous substances, contamination of surrounding soils due to spills is a concern. In 1983, a flood occurred, which caused a release of wastewater contaminated with mercurous nitrate. Subsequent soil sampling performed by Langston Laboratories during November 1986 and March 1987 showed mercury contamination in the drainage ditch on the north, with levels generally in the range of 1 to 10 mg/kg. The soil samples were not tested for cyanide.

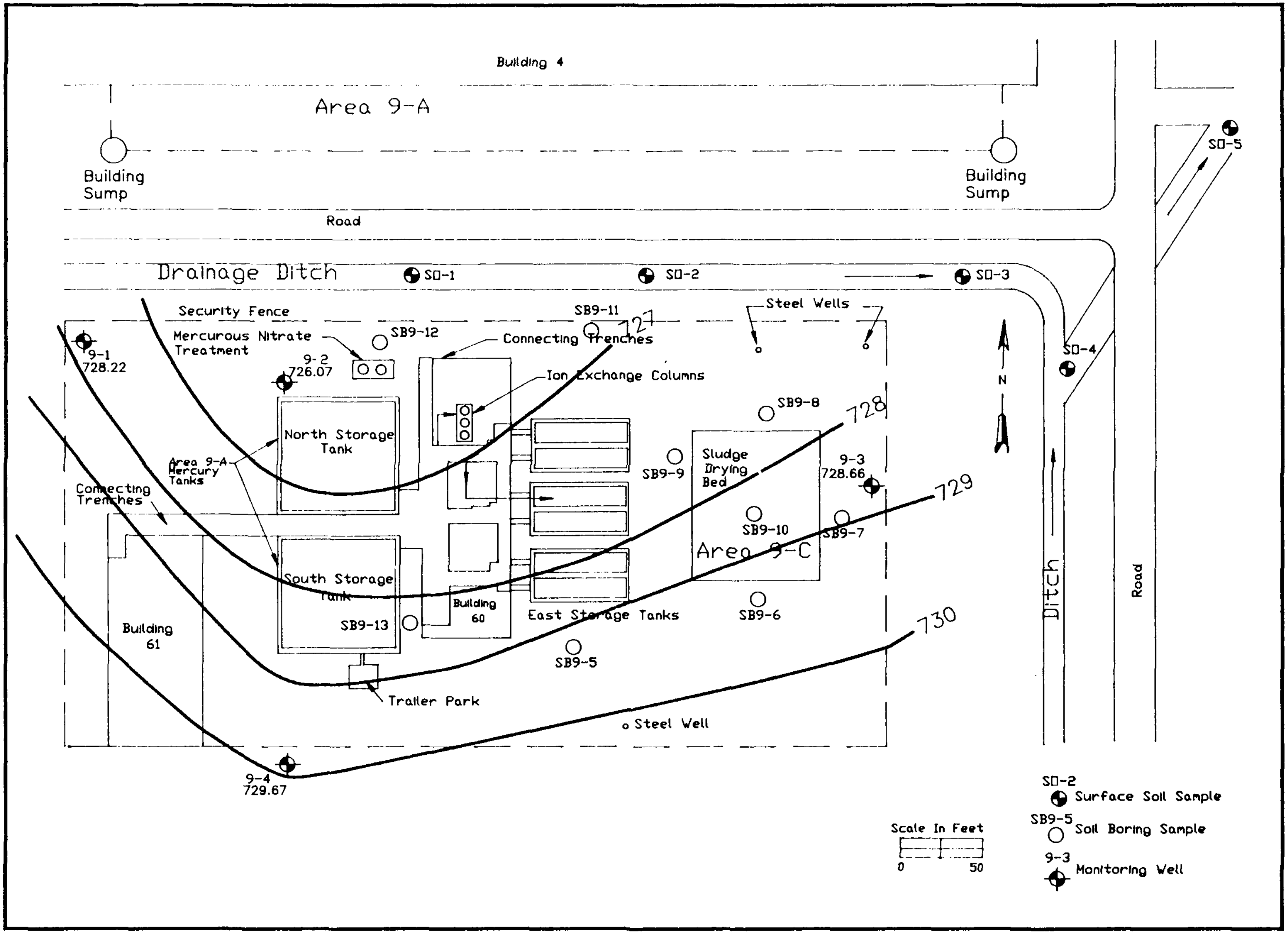


FIGURE 4-18
A 9

4.9.1.3 Area 9C - Sludge Drying Beds

This site, which is located east of Area 9B, was used for the drying of sludge produced by the treatment of zinc cyanide plating wastes. The treatment involved drying the sludge on gravel beds and destroying the cyanide by alkaline chlorination, producing zinc hydroxide as a residue. The area was opened in the late 1950s and operations ceased in the early 1960s. The estimated area is 10,000 square feet. The estimated quantity of waste is 5,000 cubic feet. The leaching beds are no longer used and are in the process of being investigated and closed under the guidelines set forth in the Lake City Inter-Agency Agreement.

4.9.2 Previous Investigations

The first set of samples was collected by Langston Laboratories in November 1986. These 18 surface soil samples were predominantly located within or adjacent to the security fence surrounding the Area 9 treatment facility, as shown in Figure 4-18. No samples were collected from the drainage ditch system. Mercury concentrations ranged from <0.02 to 9.6 mg/kg. The highest concentrations were found at sample locations adjacent to and north of the north storage tank in samples 21, 24, and 25. Table 4-18 summarizes the results of the mercury analyses.

The second set of samples, collected by Langston Laboratories in March 1987, was located both inside and outside of the fenced area and also within the drainage ditch system nearby, as shown in Figure 4-19. A total of 32 surface soil samples were analyzed, with mercury concentrations ranging from <0.02 to 28.5 mg/kg. The highest concentrations were found at two sample locations adjacent to the north storage tank (samples 1 and 21), and at numerous sample locations within the drainage ditch system downslope from the treatment facility. These elevated detections were observed in samples 24, 25, 27, 29, and 32. Table 4-19 summarizes the results of the second set of mercury analyses.

4.9.3 Current Field Investigation

4.9.3.1 Area 9B Mercury Waste Tank

In order to characterize the extent of potential mercury contamination at Area 9A, nine soil borings (providing eighteen subsurface soil samples) and five surface soil samples were performed and collected during this investigation. Subsurface soil samples were collected at 0.5 and 2.0 feet. Surface soil samples were collected in the drainage ditch north of the area. Sample locations are shown in Figure 4-18. By collecting these samples, previously collected data could be verified and the extent of contamination could be assessed. All soil samples were analyzed

TABLE 4-18
LAKE CITY ARMY AMMUNITIONS PLANT
MERCURY ANALYTICAL RESULTS
PREVIOUS INVESTIGATIONS
NOVEMBER 1986

SAMPLE IDENTIFICATION	RESULTS
# 9	0.03 mg/kg
#10	0.49 mg/kg
#11	0.036 mg/kg
#12	0.14 mg/kg
#13	<0.02 mg/kg
#14	0.039 mg/kg
#15	<0.02 mg/kg
#16	<0.02 mg/kg
#17	<0.02 mg/kg
#18	0.10 mg/kg
#19	0.05 mg/kg
#20	0.02 mg/kg
#21	9.6 mg/kg
#22	0.045 mg/kg
#23	<0.02 mg/kg
#24	1.18 mg/kg
#25	4.1 mg/kg
#26	0.04 mg/kg

SOURCE: LANGSTON LABORATORIES, 1986.

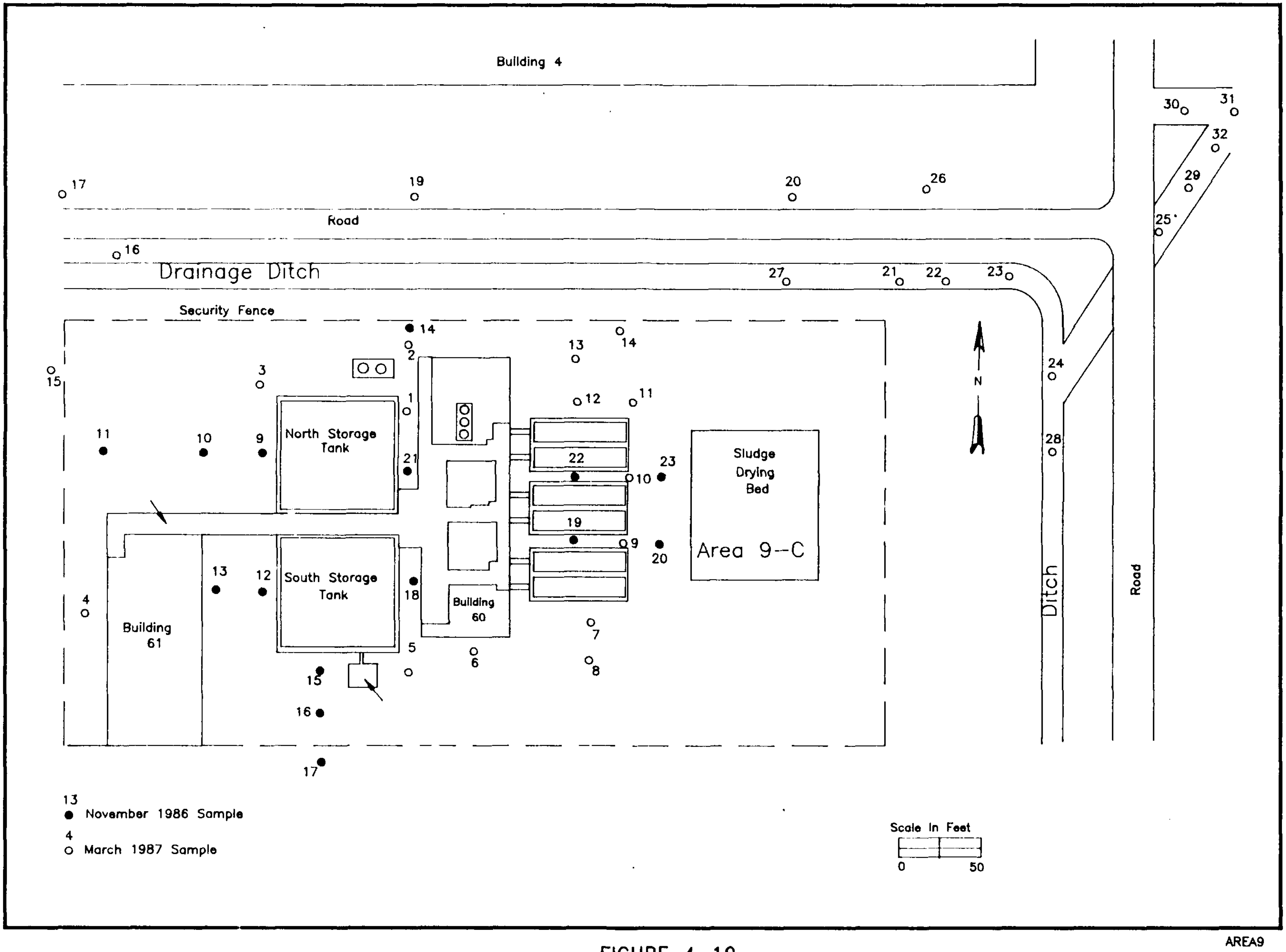


FIGURE 4-19
AREA 9 PREVIOUS SAMPLING LOCATIONS

TABLE 4-19
LAKE CITY ARMY AMMUNITIONS PLANT
MERCURY ANALYTICAL RESULTS
PREVIOUS INVESTIGATIONS
MARCH 1987

SAMPLE IDENTIFICATION	RESULTS
# 1	28.5 mg/kg
# 2	0.67 mg/kg
# 3	0.26 mg/kg
# 4	<0.02 mg/kg
# 5	<0.02 mg/kg
# 6	<0.02 mg/kg
# 7	<0.02 mg/kg
# 8	<0.02 mg/kg
# 9	0.17 mg/kg
#10	0.026 mg/kg
#11	0.076 mg/kg
#12	0.036 mg/kg
#13	<0.02 mg/kg
#14	<0.02 mg/kg
#15	<0.02 mg/kg
#16	0.30 mg/kg
#17	<0.02 mg/kg
#18	0.11 mg/kg
#19	0.037 mg/kg
#20	0.030 mg/kg
#21	7.9 mg/kg
#22	2.0 mg/kg
#23	0.94 mg/kg
#24	7.9 mg/kg
#25	11.5 mg/kg
#26	<0.02 mg/kg
#27	18.7 mg/kg
#28	<0.02 mg/kg
#29	4.13 mg/kg
#30	ND
#31	ND
#32	5.38 mg/kg

SOURCE: LANGSTON LABORATORIES, 1987.

for mercury, zinc, and cyanide. The five surface soil samples were additionally analyzed for VOCs, BNAs, inorganics, and explosives to provide a more detailed assessment of the migration pathway through the drainage ditch system.

The existing wells (9-1, 9-2, 9-3, and 9-4) were sampled twice. Monitoring shallow well 9-4 is upgradient of Area 9A, while wells 9-1 and 9-2 are downgradient of the tanks and 9-3 is sidegradient. All groundwater samples were analyzed for VOCs, BNAs, inorganics (total and dissolved), explosives, and cyanides. The two sampling events were separated by an interval of three months.

At Area 9 there are three existing steel wells which were not sampled because of the corroded condition of the metal pipes. The corroded pipes could have yielded unrepresentative groundwater chemical results.

4.9.3.2 Area 9C - Sludge Drying Beds

Four monitoring wells are presently located at Area 9. Monitoring well 9-4 is upgradient of the cyanide leaching bed, while well 9-3 is considered a sidegradient well and well 9-1 and 9-2 are far downgradient wells. In order to characterize the extent of potential zinc, mercury and cyanide contamination at Area 9C, eighteen subsurface soil samples and five surface soil samples were collected as described for Area 9B and shown in Figure 4-18 (the sampling description under Area 9B encompasses both Areas 9B and 9C). The existing steel-cased wells were located and their suitability for sampling was evaluated. They were not sampled since the corroded pipes could have yielded unrepresentative groundwater chemistry results.

4.9.4 Site Investigation Results

The results of this site investigation at Area 1 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.9.3). All organic and inorganic analytical data is presented in Table 4-20. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling. All soil boring samples were collected during round 1.

4.9.4.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 9 identified two explosive compounds:

TABLE 4-20
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #9
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	9-1-1 25.5	9-1-2 25.5	9-2-1 36.5	9-2-2 36.5	9-3-1 25	9-3-2 25
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis(2-Ethylhexyl) Phthalate	ND	1000	ND	ND	ND	ND
UNKNOWNS						
C6-C9 Cycloalkane	ND	*30	ND	ND	ND	*20
C8-C10 Methyl Alkene/Alkane	ND	*20	ND	*20	ND	*20
1-Methyl-2-Propyl Cyclohexane [851]	ND	10	ND	ND	ND	ND
Hexahydro-Methyl-2H-Azepin-2-one Ester	ND	*30	ND	ND	ND	ND
Bromacil	ND	*80	ND	*30	ND	*60
C13-C15 Alkyl Benzene	ND	10	ND	ND	ND	ND
Carboxylic Acid Derivative	ND	ND	ND	*10	ND	ND
C7-C8 Alcohol	ND	ND	ND	*20	ND	ND
1-Methyl-5-Nitro-1H-Imidazole [601]	ND	ND	ND	ND	ND	20
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
135-TNB	<0.56	<0.56	19	<0.56	22	<0.56
RDX	<0.63	<0.63	15	<0.63	<0.63	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	<5.00	<5.00	<5.00	5.28	<5.00	10.7
Barium, dissolved	81.2	114	40.7	54.5	97.2	131
Barium, total	125	133	156	126	123	473
Beryllium, total	<0.10	<0.10	0.4	<0.10	<0.10	0.2
Cyanide	<16	<16	<16	<16	<16	<16
Cadmium, total	<5.10	<5.10	6.44	<5.10	<5.10	<5.10
Copper, dissolved	<1.78	<1.78	<1.78	<1.78	<1.78	20.7
Copper, total	3.11	3.32	4.07	9.75	<1.78	7.93
Lead, total	<2.50	2.53	4.85	5.46	3.64	10.1
Nickel, dissolved	40.2	<9.60	<9.60	<9.60	51.1	11.5
Nickel, total	21.9	45.1	40	17.1	33.4	122
Silver, dissolved	<0.19	<0.19	8.2	<0.19	<0.19	<0.19
Silver, total	<0.19	<0.19	0.21	0.21	<0.19	0.21
Zinc, dissolved	1100	<17.20	1700	22.7	1100	161
Zinc, total	284	300	306	144	560	130
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-20
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #9
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	9-4-1	9-4-2
DEPTH (FT)	28	28
VOLATILES	(ALL ND OR <CRL)	
ALL		
BASE NEUTRAL & ACID EXTRACTABLES		
bis(2-Ethylhexyl) Phthalate	200	ND
UNKNOWNS		
C6-C9 Cycloalkane	ND	*20
C8-C10 Methyl Alkene/Alkane	ND	*20
C7-C10 Methyl Cyclohexane	ND	*10
1-Methyl-5-Nitro-H-Imiazole [586]	ND	30
Bromacil	ND	*80
OTHERS	(ALL ND OR <CRL)	
EXPLOSIVE COMPOUNDS		
ALL	(ALL ND OR <CRL)	
INORGANICS		
Barium, dissolved	49.1	73.8
Barium, total	136	106
Beryllium, total	0.3	<0.10
Cyanide	<16	<16
Copper, total	2.89	7.82
Lead, dissolved	3.94	<2.50
Lead, total	4.15	4.04
Nickel, dissolved	20.5	<9.60
Nickel, total	61.7	88
Zinc, dissolved	1100	32.8
Zinc, total	502	315
OTHERS	(ALL ND OR <CRL)	

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-20
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #9
SUMMARY OF ANALYTICAL DATA
SURFACE SOIL SAMPLES (UG/G)

SITE ID	SO9-1-1	SO9-2-1	SO9-3-1	S09-4-1	SO9-5-1
VOLATILES					
ALL	(ALL ND OR <CRL)				
BASE NEUTRAL & ACID EXTRACTABLES					
UNKNOWNS					
Hexanedioic Acid Ester	*9	*6	*10	*8	ND
OTHERS	(ALL ND OR <CRL)				
EXPLOSIVE COMPOUNDS					
ALL	(ALL ND OR <CRL)				
INORGANICS					
Arsenic, total	26.9	33.7	29.8	63	51
Barium, total	827	827	777	780	967
Beryllium, total	0 39	0.45	0.49	0 61	0.27
Cadmium total	15.9	170	34 3	106	55 5
Chromium total	<3.99	<3.99	<3.99	343	516
Copper total	96	83	50	1500	4800
Cyanide	ND	3	3	7	ND
Lead total	18.3	30.8	33.3	2900	4400
Mercury total	0.22	5 37	4.5	<0 10	4.27
Nickel, total	22 6	<17.6	22.3	22.9	31.4
Selenium total	<2 10	<2.10	<2.10	<2 10	7 2
Zinc total	634	508	321	844	2950
OTHERS	(ALL ND OR <CRL)				

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-20
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #9
SUMMARY OF ANALYTICAL DATA
SUBSURFACE SOIL SAMPLES (UG/G)

SITE ID	SB9-5-1	SB9-5-2	SB9-6-1	SB9-6-2	SB9-7-1	SB9-7-2
DEPTH (FT)	0.5	2	0.5	2	0.5	2
VOLATILES						
ALL	(ALL NA)					
BASE NEUTRAL & ACID EXTRACTABLES						
ALL	(ALL NA)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL NA)					
INORGANICS						
Mercury, total	(ALL <CRL)					
Cyanide	(ALL <CRL)					
Nickel, total	10.3	21.6	17.5	25.8	21.3	30.4
Zinc, total	(ALL <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED MD=MISSING DATA

DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-20
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #9
SUMMARY OF ANALYTICAL DATA
SUBSURFACE SOIL SAMPLES (UG/G)

SITE ID DEPTH (FT)	SB9-8-1 0.5	SB9-8-2 2	SB9-9-1 0.5	SB9-9-2 2	SB9-10-1 0.5	SB9-10-2 2
VOLATILES						
ALL	(ALL NA)					
BASE NEUTRAL & ACID EXTRACTABLES						
ALL	(ALL NA)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL NA)					
INORGANICS						
Mercury, total	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
Cyanide	<0.73	<0.73	<0.73	<0.73	<0.73	<0.73
Nickel, total	(ALL NA)					
Zinc, total	<78.9	128	128	<78.9	7800	272

RL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED MD=MISSING DATA

DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-20
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #9
SUMMARY OF ANALYTICAL DATA
SUBSURFACE SOIL SAMPLES (UG/G)

SITE ID	SB9-11-1	SB9-11-2	SB9-12-1	SB9-12-2	SB9-13-1	SB9-13-2
DEPTH (FT)	0.5	2	0.5	2	0.5	2
VOLATILES						
ALL	(ALL NA)					
BASE NEUTRAL & ACID EXTRACTABLES						
ALL	(ALL NA)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL NA)					
INORGANICS						
Mercury, total	<0.12	<0.12	0.64	<0.12	0.28	<0.12
Cyanide	<0.73	2.93	<0.73	<0.73	<0.73	<0.73
Nickel, total	(ALL NA)					
Zinc, total	<78.9	<78.9	<78.9	<78.9	206	<78.9

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED MD=MISSING DATA

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

- 135TNB.
- RDX.

These explosive compounds were detected only during the first round of groundwater sampling. At monitoring well location 9-2, 135TNB, and RDX were detected at respective concentrations of 19.0 and 15.0 ug/l. At well location 9-3, 135TNB was detected at a concentration of 22.0 ug/l.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at Area 9 did not identify any VOCs.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 9 identified one BNA compound: B2EHP. This compound was detected during the first round of groundwater sampling at well location 9-4 at a concentration of 200 ug/l and during the second round of sampling at well location 9-1 at a concentration of 1,000 ug/l.

Unknown BNA compounds were detected in samples from all four monitoring wells at Area 9. Wells 9-1 through 9-4 had concentrations ranging from 10 to 80 ug/l. All detections occurred during the second sampling round.

Inorganics

The results of the two rounds of groundwater sampling at Area 9 identified six inorganics which exceeded statistical background concentrations. Of those, total cadmium exceeded the MCL of 5 ug/l in sample 9-2-1 with a detection of 6.44 ug/l. Table 4-21 summarizes the inorganic parameters which were determined to exceed statistical background concentrations and includes the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in this table.

4.9.4.2 Subsurface Soil

Inorganics

The results of the soil boring program at Area 9 identified cyanide, mercury, and zinc at levels exceeding the statistical background concentrations. The soil boring samples showing these site-related detections are discussed in the following paragraphs.

Cyanide was detected in one sample at a concentration exceeding the CRL of 0.64 ug/g. Sample SB9-11-2 contained a concentration of 2.93 ug/g.

TABLE 4-21
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 9 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Arsenic, total	9-2-2, 9-3-2	5.28 - 10.7	9-3-2	--
Cadmium, total	*9-2-1	6.44	*9-2-1	5.00
Copper, dissolved	9-3-2	20.7	9-3-2	1000.00
Lead, dissolved	9-4-1	3.94	9-4-1	50.00
Nickel, dissolved	9-1-1, 9-3-1, 9-3-2, 9-4-1	20.5 - 122	9-3-2	200.00
Silver, dissolved	9-2-1	8.2	9-2-1	50.00
Silver, total	9-2-1, 9-2-2, 9-3-2	0.21	9-2-1, 9-2-2, 9-3-2	50.00
Zinc, dissolved	9-1-1, 9-2-1, 9-3-1, 9-4-1	1100 - 1700	9-2-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.

Mercury was detected in the shallow samples of soil borings SB9-12 and SB9-13. The 6-inch depth samples detected respective concentrations of 0.64 and 0.28 ug/g.

Zinc was detected in the 24-inch depth sample of SB9-8 at a concentration of 128 ug/g, the 6-inch depth sample of SB9-9 at a concentration of 128 ug/g, the 6-inch and 24-inch depth samples of SB9-10 at respective concentrations of 7,800 and 272 ug/g, and the 6-inch depth sample of SB9-13 at a concentration of 206 ug/g.

4.9.4.3 Surface Soil

Explosives

There were no explosive compounds detected in the five surface soil samples collected at Area 9.

Volatile Organic Compounds

There were no VOCs detected in the five surface soil samples collected at Area 9.

Base Neutral and Acid Extractable Compounds

There were no BNA compounds definitively identified in the five surface soil samples collected at Area 9. There were unknown BNA compounds detected in four of the five surface soil samples, however. Samples S09-1 through S09-4 had concentrations ranging from 6 to 10 ug/g.

Inorganics

The results of the WESTON surface soil sampling program at Area 9 identified 11 inorganic parameters which exceeded statistical background concentrations. All five samples contained elevated detections, with the highest concentrations usually detected in downgradient samples S09-4 and S09-5. The analytical results are discussed in the following paragraphs.

Arsenic was detected in all five samples at concentrations ranging from 26.9 to 63.0 ug/g, with highs of 63.0 and 51.0 ug/g in samples S09-4 and S09-5, respectively.

Barium was detected in all five samples at concentrations ranging from 777 to 967 ug/g. The highest level was detected in sample S09-5.

Beryllium was detected in samples S09-2, S09-3, and S09-4 at respective concentrations of 0.45, 0.49, and 0.61 ug/g.

Cadmium was detected in all five samples at concentrations ranging from 15.9 to 170 ug/g. Highs of 106 and 170 ug/g were detected in samples S09-4 and S09-2, respectively.

Chromium was detected in samples S09-4 and S09-5 at respective concentrations of 343 and 516 ug/g.

Copper was detected in all five samples, ranging from 50.0 to 4,800 ug/g. Samples S09-4 and S09-5 had the highest concentrations, with detections of 1,500 and 4,800 ug/g, respectively.

Cyanide was detected in samples S09-2, S09-3, and S09-4 at respective concentrations of 3, 3, and 7 ug/g.

Lead was detected in all five samples, ranging from 18.3 to 4,400 ug/g. Samples S09-4 and S09-5 had the highest concentrations, with respective detections of 2,900 and 4,400 ug/g.

Mercury was detected in four samples at concentrations ranging from 0.22 to 5.37 ug/g. The highest values were detected in samples S09-2, S09-3, and S09-5.

Selenium was detected in sample S09-5 at a concentration of 7 ug/g.

Zinc was detected in all five samples, ranging from 321 to 2,950 ug/g. The high value was detected in sample S09-5.

4.9.5 Summary

Potentially site-related organic and inorganic detections occurred at two of the monitoring wells at Area 9. The other two wells detected a BNA compound B2EHP which may not actually be present in the groundwater. Figure 4-20 presents the Area 9 monitoring well locations and soil boring locations, and summarizes the distribution of site-related detections.

Similar concentrations of explosive compounds were found at sidegradient well location 9-3 and downgradient well location 9-2 during the first round of groundwater sampling. No detections occurred during the second round. The presence of explosive compounds in the sidegradient well, coincident with the similar concentrations downgradient of Area 9, suggests the potential of an upgradient source.

No sources of VOC compounds are suspected to be present in Area 9. The two detections of B2EHP probably do not represent actual groundwater chemistry and may be post-sampling contaminants. The unknown BNA detections which occurred during the second round of sampling at concentrations ranging from 10 to 80 ug/l may indicate a potential BNA source within Area 9.

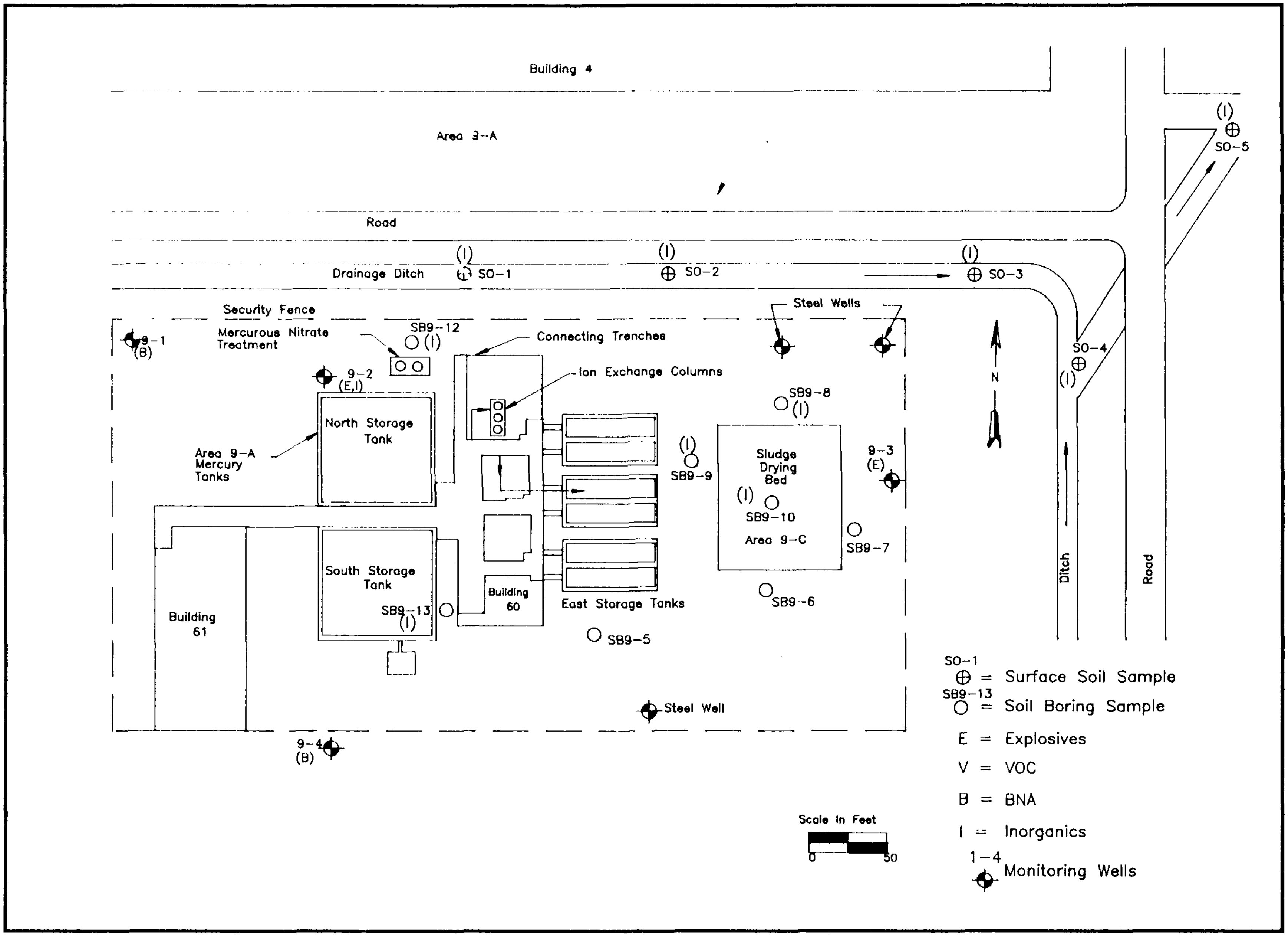


FIGURE 4-20
AREA 9 CTION LOCATION

While numerous site-related inorganic detections were found during the surface and subsurface soil investigation at Area 9, the results of the groundwater investigation do not indicate an impact of these inorganic soil contaminants on the local groundwater chemistry. Inorganic concentrations in the groundwater remain relatively consistent from upgradient to downgradient locations. The subsurface soil concentrations, while often exceeding background concentrations, indicate that the Area 9 soils have not caused groundwater quality to exceed regulatory limits, although the sludge drying bed of Area 9C did contain very high levels of zinc near the surface.

The surface soil samples collected from the nearby ditch system during this RI did contain some inorganic concentrations of concern, most often at downgradient locations. Relatively high concentrations of arsenic, cadmium, chromium, copper, cyanide, lead, mercury, selenium, and zinc were detected.

The surface soil sample results from all of the sampling programs show elevated inorganics concentrations throughout Area 9. The 1986 and 1987 mercury results, which indicated mercury contamination resulting from the 1983 flood episode, were verified during this RI. The mercury concentrations within the drainage ditch downgradient of Area 9 ranged from 0.22 to 18.7 ug/g. High concentrations of mercury were also found near the north storage tank.

4.10 AREA 10 - FIRING RANGE WASTE DUMP

4.10.1 Site Description and Field Investigation

4.10.1.1 Area 10A - Firing Range Waste Dump

This area, shown in Figure 4-21, is used for storing sand removed from ballistics firing ranges. Hazardous constituents are lead, barium, and antimony. Extensive sampling and analysis of the waste pile has been conducted, and, as a result, the material is not classified as a RCRA hazardous waste. The analyses have shown a decreasing lead content over time according to installation personnel. This dump area is heavily contaminated with all calibers and sizes of projectiles up to 30 millimeters, and signs are posted around the area warning of the possibility of unexploded ordnance. The area is approximately three acres and an estimated 89,000 cubic yards of sand is contained in the area. Six wells currently exist at Area 10A.

As part of the RI, four of the six existing monitoring wells, ranging in depth from 18 to 39 feet, were each sampled twice and analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. The two sampling events were separated by a three-month interval. WESTON was unable to sample the upgradient well 10-1 due to the damaged condition of the riser pipe. Monitoring

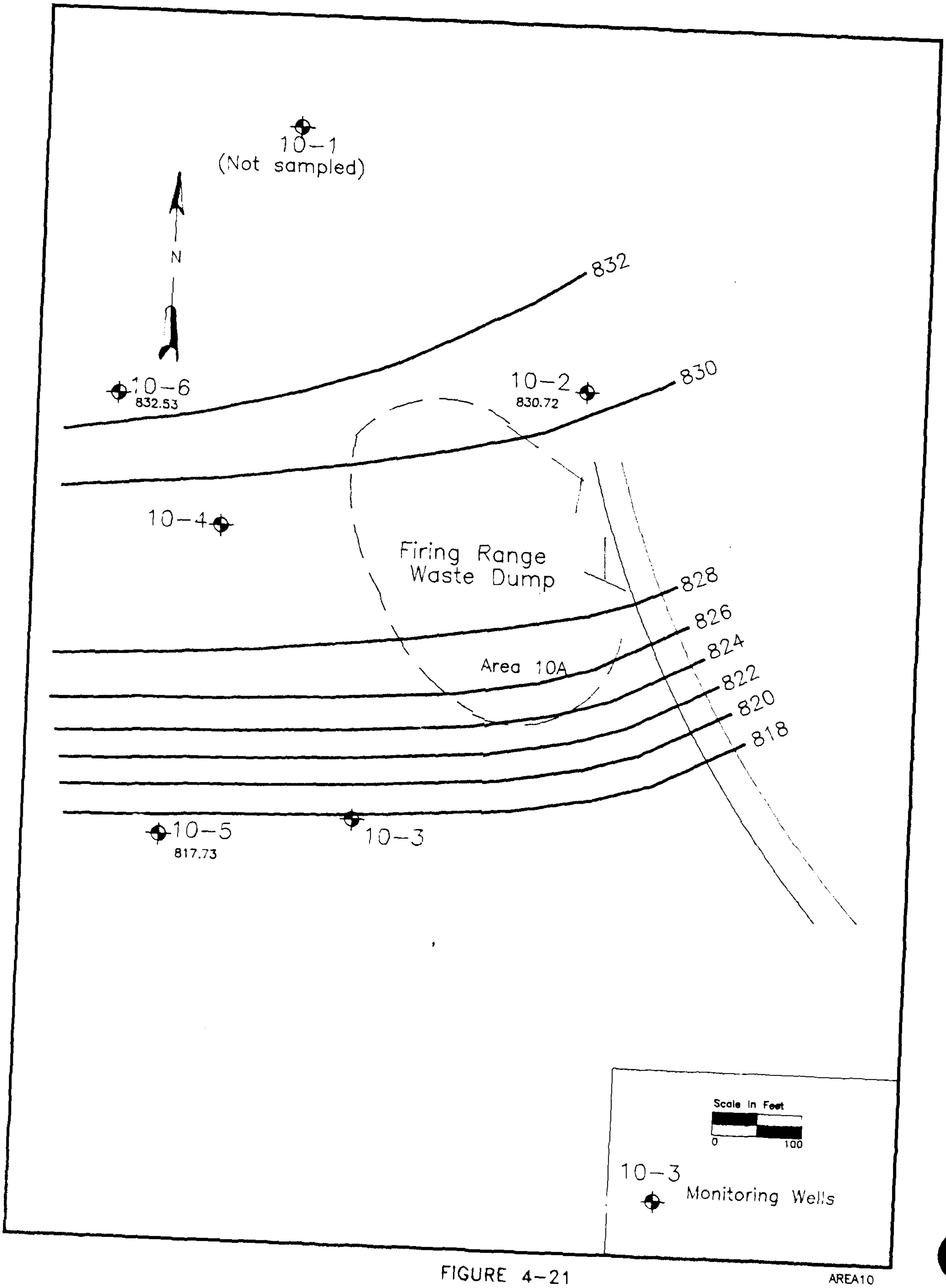


FIGURE 4-21
AREA 10

well 10-6 was nearly dry during both rounds of sampling. During round 1 only VOCs and BNAs were analyzed. During round 2 only VOCs were analyzed. Monitoring well 10-2, although upgradient of Area 10A, may be affected by runoff from this area and therefore is considered a sidegradient well. The remaining four monitoring wells are downgradient from Area 10A.

4.10.2 Site Investigation Results

The results of this site investigation at Area 10 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.10.3). All organic and inorganic analytical data is presented in Table 4-22. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.10.2.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 10 identified the explosive compound cyclonite (RDX). The compound RDX was identified during the first round of groundwater sampling only. RDX was detected at monitoring well locations 10-2, 10-3, 10-4, and 10-5 at respective concentrations of 4.58, 3.26, 2.01, and 1.33 ug/l.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at Area 10 did not detect any VOCs.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 10 identified two BNA compounds:

- DNOP.
- B2EHP.

All detections occurred during the first round of sampling. DNOP was detected at monitoring well location 10-6 at a concentration of 8 ug/l. B2EHP was detected at monitoring well locations 10-2 and 10-5 at respective concentrations of 10 and 700 ug/l.

Unknown BNA compounds were detected in samples from four monitoring wells at Area 10. Wells 10-2 through 10-5 had concentrations ranging from 10 to 300 ug/l. All detections occurred during the first round of sampling.

TABLE 4-22
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #10
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	10-2-1 29.5	10-2-2 29.5	10-3-1 20.5	10-3-2 20.5	10-4-1 31.5	10-4-2 31.5
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	10	ND	ND	ND	ND	ND
UNKNOWNS						
1,14-Tetradecanediol [995]	300	ND	100	ND	ND	ND
1-Flourodecane [981]	10	ND	ND	ND	ND	ND
C9-C14 Alkane Glycol	*10	ND	ND	ND	*20	ND
Dimethyl Cyclooctane	ND	ND	*10	ND	ND	ND
1,14-Tetradecanediol [967]	ND	ND	10	ND	ND	ND
Trichloroeicosyl Silane [946]	ND	ND	ND	ND	10	ND
1-Iodo-Tetradecaine [944]	ND	ND	ND	ND	10	ND
C9-C12 Hydrocarbon	ND	ND	ND	ND	*10	ND
Cycloheptatrienylium [931]	30	ND	10	ND	ND	ND
C8-C14 Cycloalkane	ND	ND	ND	ND	*10	ND
C13-C19 Methyl Alkane	ND	ND	ND	ND	*10	ND
C13-C15 Trimethyl Alkane	ND	ND	ND	ND	*20	ND
Benzenemethane sulfonamide [929]	ND	ND	ND	ND	10	ND
C11-C15 Trimethyl Alkane	ND	ND	ND	ND	40	ND
C17-C30 Organic Acid Derivative	ND	ND	ND	ND	*20	ND
C9-C13 Trimethyl Alkane	ND	ND	ND	ND	*40	ND
C13-Trimethyl Alkane	ND	ND	ND	ND	*90	ND
4,6-Dimethyl Undecane [966]	ND	ND	ND	ND	40	ND
C9-C11-Trimethyl Alkane	ND	ND	ND	ND	*90	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	4.58	<0.63	3.26	<0.63	2.01	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, dissolved	<3.00	<3.00	<3.00	<3.00	<3.00	5.11
Antimony, total	<3.00	<3.00	<3.00	11.5	<3.00	<3.00
Arsenic, total	<5.00	5.28	<5.00	<5.00	<5.00	21.3
Barium, dissolved	NA	244	NA	118	NA	239
Barium, total	NA	432	NA	327	NA	3030
Beryllium, total	0.3	<0.10	6.3	<0.10	2.41	5.6
Cadmium, total	<5.10	16.1	14	<5.10	6.44	80.6
Copper, dissolved	3.32	<1.78	4.5	4.29	4.5	<1.78
Copper, total	23.3	71	84	47.8	69	140
Lead, dissolved	<2.50	<2.50	<2.50	<2.50	3.44	<2.50
Lead, total	40.8	260	63	13.4	63	150
Nickel, dissolved	37.2	11	21	9.75	47.8	<9.60
Nickel, total	13.1	57.6	123	58.9	54.3	250
Silver, dissolved	0.2	<0.19	<0.19	<0.19	<0.19	<0.19
Silver, total	<0.19	0.21	<0.19	<0.19	<0.19	0.43
Zinc, dissolved	980	17	1200	61.7	1300	<17.20
Zinc, total	990	860	1400	261	1400	2400
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

** DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-22
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #10
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	10-5-1 31.5	10-5-2 31.5	10-6-1 15	10-6-2 15
VOLATILES				
ALL	(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES				
bis (2-Ethylhexyl) Phthalate	700	ND	ND	NA
UNKNOWNS				
Benzenedicarboxylie Acid Derivative	*20	ND	ND	NA
C10-C25 Ketone	*20	ND	ND	NA
Phenyl Pyridinone	*20	ND	ND	NA
1-(Hexyloxy)-5-Methyl-Hexane [945]	10	ND	ND	NA
3-Methyl-1-Napthalenol [962]	10	ND	ND	NA
6H,8H-Benzo [10, 11]	20	ND	ND	NA
2-Mercaptobenzothiazole [987]	20	ND	ND	NA
C9-C14-Alkane Glycol	*10	ND	ND	NA
1,1-Diphenyl-2-(2,4,6-Trinitrophenyl) Hydrozine	*10	ND	ND	NA
Methoxy-(Phenyl Ethenyl) Benzene	*30	ND	ND	NA
C9-C14 Alkane Glycol	*90	ND	ND	NA
OTHERS	(ALL ND OR <CRL)			NA
EXPLOSIVE COMPOUNDS				
RDX	1.33	<0.63	NA	NA
OTHERS	(ALL ND OR <CRL)		NA	NA
INORGANICS				
Barium, dissolved	NA	390	NA	NA
Barium, total	NA	170	NA	NA
Beryllium, dissolved	<0.1	0.3	NA	NA
Beryllium, total	8.1	0.5	NA	NA
Cadmium, total	32.2	12.9	NA	NA
Copper, dissolved	5.89	10.5	NA	NA
Copper, total	37.6	20.3	NA	NA
Lead, dissolved	<2.50	4.04	NA	NA
Lead, total	11.1	<2.50	NA	NA
Nickel, dissolved	43.3	50.7	NA	NA
Nickel, total	139	31.4	NA	NA
Silver, total	<0.19	0.53	NA	NA
Zinc, dissolved	1100	153	NA	NA
Zinc, total	910	176	NA	NA
OTHERS	(ALL ND OR <CRL)		NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

Inorganics

The results of the two rounds of groundwater sampling at Area 10 identified seven metals which exceeded statistical background concentrations. Four of the seven metals exceeded the MGS, MDWS and/or MCL. Table 4-23 summarizes the inorganic parameters which were determined to be site-related detections and includes the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard rae flagged with an asterisk in this table. The parameters which exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Total barium exceeded the MDWS of 1,000 ug/l in downgradient sample 10-4-2 with a concentration of 3,030 ug/l.

Total cadmium exceeded the MCL of 5 ug/l in sample 10-4-1 with a detection of 6.44 ug/l. Total cadmium exceeded the MDWS of 10 ug/l in samples 10-2-2, 10-3-1, 10-4-2, 10-5-1, and 10-5-2 with respective concentrations of 16.1, 14, 80.6, 32.2, and 12.9 ug/l.

Total lead exceeded the MCL and MDWS of 50 ug/l in samples 10-2-2, 10-3-1, 10-4-1 and 10-4-2 with respective concentrations of 260, 63.0, 63.0, and 150 ug/l.

Total nickel exceeded the MGS of 200 ug/l in sample 10-4-2 with a concentration of 250 ug/l.

4.10.3 Summary

Potentially site-related detections of organic and/or inorganic parameters occurred at all of the downgradient and sidegradient monitoring well locations at Area 10. Figure 4-22 presents the monitoring well locations and summarizes the distribution of site-related detections.

The explosive compound RDX was identified at consistent concentrations in all of the downgradient and sidegradient monitoring wells, indicating some release of RDX into the local groundwater from the firing range waste dump.

The Area 10 waste dump is probably not contributing any VOC compounds to the groundwater.

The waste dump may be a source of BNA groundwater contamination. This potential is based on the detection of numerous unknown BNA compounds during the second round of sampling. Although there was a relatively high detection of B2EHP at monitoring well location 10-5, the detection of this BNA compound may not reflect actual groundwater quality and may be the result of field contamination.

TABLE 4-23
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 10 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Antimony, dissolved	10-4-2	5.11	10-4-2	--
Antimony, total	10-3-2	11.5	10-3-2	--
Arsenic, total	10-2-2, 10-4-2	5.28 - 21.3	10-4-2	--
Barium, dissolved	10-5-2	390	10-5-2	1000.00
Barium, total	*10-4-2	3030	*10-4-2	1000.00
Beryllium, dissolved	10-5-2	0.3	10-5-2	--
Beryllium, total	10-3-1, 10-4-1, 10-4-2, 10-5-1	2.41 - 8.1	10-5-1	--
Cadmium, total	*10-2-2, *10-3-1, *10-4-1, *10-4-2, *10-5-1, *10-5-2	6.44 - 80.6	*10-4-2	5.00
Copper, dissolved	10-2-1, 10-3-1, 10-3-2, 10-4-1, 10-5-1, 10-5-2	3.32 - 10.5	10-5-2	1000.00
Copper, total	10-2-2, 10-3-1, 10-3-2, 10-4-1, 10-4-2	47.8 - 140	10-4-2	1000.00
Lead, dissolved	10-4-1, 10-5-2	3.44 - 4.04	10-5-2	50.00
Lead, total	10-2-1, *10-2-2, *10-3-1, *10-4-1, *10-4-2	40.8 - 260	*10-2-2	50.00
Nickel, dissolved	10-2-1, 10-2-2, 10-3-1, 10-3-2, 10-4-1, 10-5-1, 10-5-2	11 - 50.7	10-5-2	200.00
Nickel, total	10-3-1, *10-4-2, 10-5-1	123 - 250	*10-4-2	200.00
Silver, dissolved	10-2-1	0.2	10-2-1	50.00
Silver, total	10-2-2, 10-4-2, 10-5-2	0.21 - 0.53	10-5-2	50.00
Zinc, dissolved	10-2-1, 10-3-1, 10-4-1, 10-5-1	980 - 1300	10-4-1	5000.00
Zinc, total	10-2-1, 10-2-2, 10-3-1, 10-4-1, 10-4-2, 10-5-1	860 - 2400	10-4-2	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.

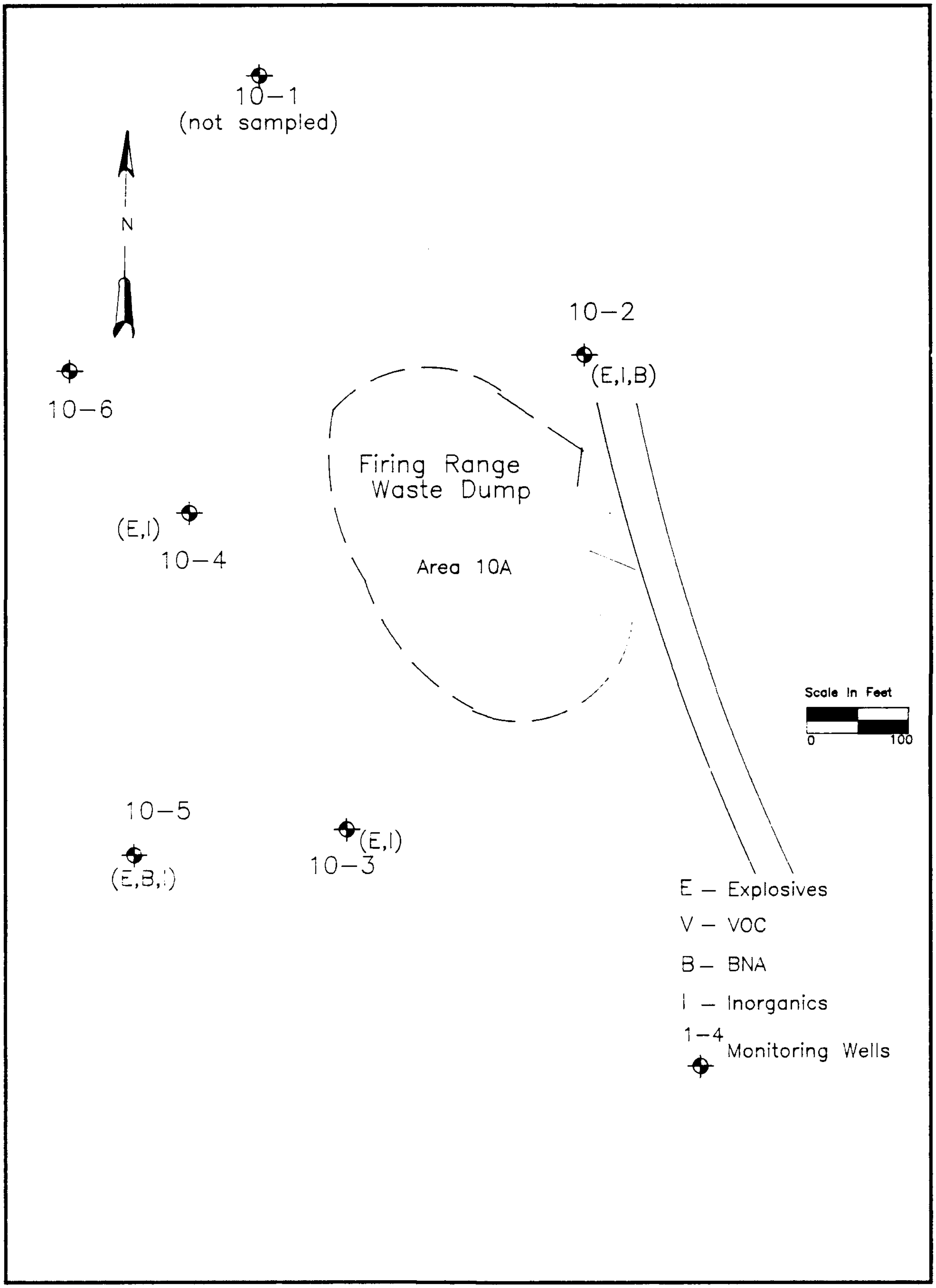


FIGURE 4-22
AREA 10 DETECTION LOCATIONS

Of the inorganics detected at elevated levels at Area 10, barium, cadmium, copper, lead, and nickel all appear to be originating at the waste dump.

4.11 AREA 11 - BURNING GROUNDS

4.11.1 Site Description and Field Investigation

4.11.1.1 Area 11A - Burning Grounds

This site, shown in Figure 4-23, is an active facility used for the open burning of propellants and waste pyrotechnic mixtures. Prior to 1985, burning was conducted on open ground. It now takes place on burning pans. The ash is packed in drums as hazardous waste and removed from the plant site. The area is 100 feet by 310 feet. The waste is a RCRA characteristic hazardous waste due to its EP toxicity (D005). Four monitoring wells currently exist at the site.

As part of the RI field work, the four existing monitoring wells, ranging in depth from 18 to 23 feet, were each sampled twice and analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. The two sampling events were separated by a three-month interval. Monitoring well 11-3 is designated as the upgradient well, while the remaining wells are downgradient wells.

4.11.2 Site Investigation Results

The results of this site investigation at Area 11 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.11.3). All organic and inorganic analytical data is presented in Table 4-24. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

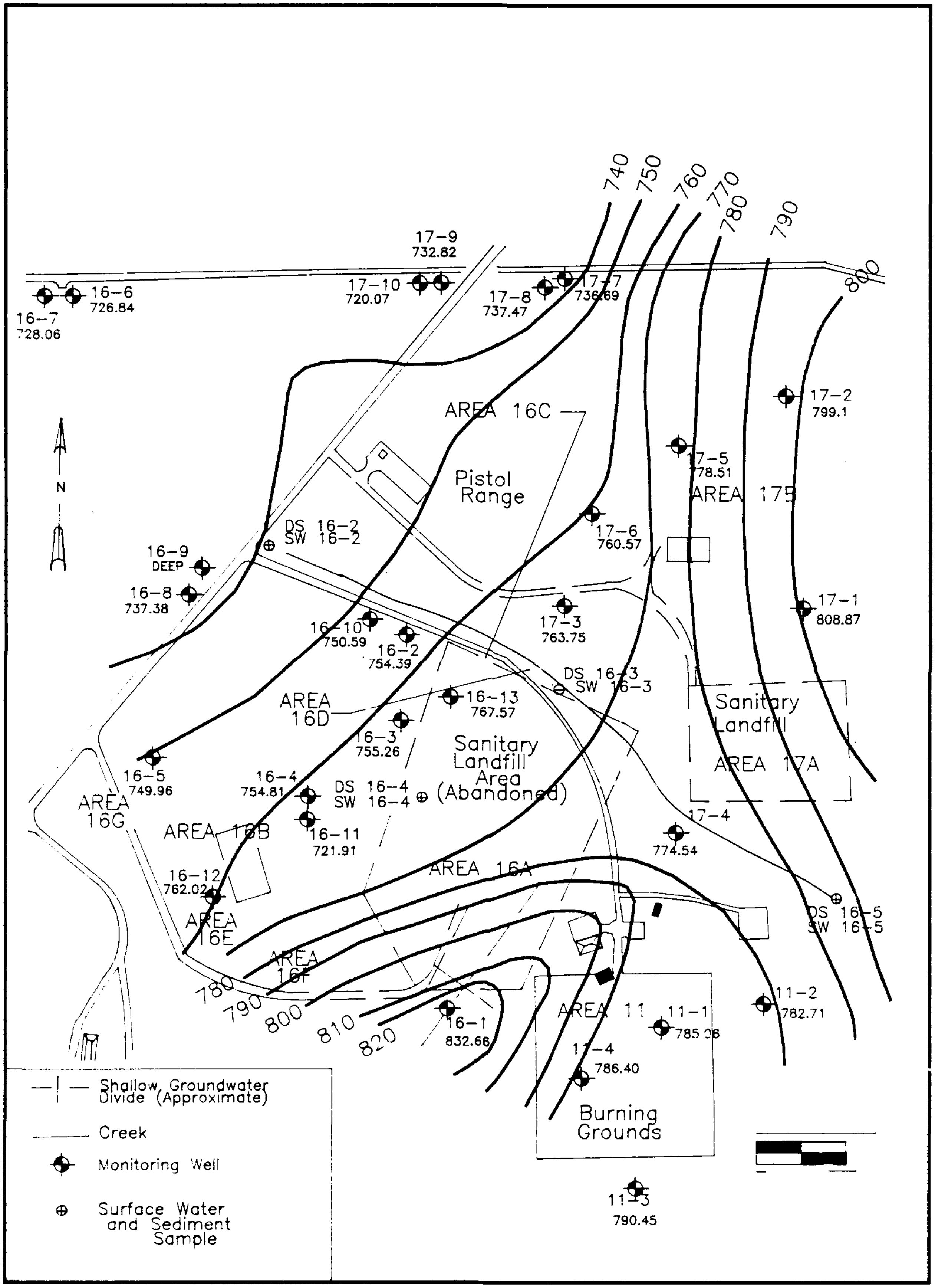
4.11.2.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 11 identified two explosive compounds:

- HMX.
- RDX.

The first round of groundwater results detected the explosive compound HMX in well location 11-2 at 5.28 ug/l and the explosive compound RDX in well locations 11-1, 11-2, and 11-4 at respective concentrations of 28.0, 16.0 and 1.74 ug/l.



AREA1167

FIGURE 4-23

AREAS 11/16/17

TABLE 4-24
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #11
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	11-1-1 20.5	11-1-2 20.5	11-2-1 26	11-2-2 26	11-3-1 25.5	11-3-2 25.5
VOLATILES						
Trans-1,2-Dichloroethene	<1.72	<1.72	<1.72	<1.72	2.3	<1.72
OTHERS			(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	ND	ND	50	ND
UNKNOWNS						
Bromacil	*6	ND	ND	ND	ND	ND
Pentanemide	ND	ND	*7	ND	ND	ND
C10-C15 Aromatic-1	ND	ND	*10	ND	ND	ND
C10-C15 Aromatic-2	ND	ND	*10	ND	ND	ND
(Iodomethyl) Benzene [744]	ND	50	ND	ND	ND	50
OTHERS			(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS						
HMX	<1.30	1.75	5.28	3.43	<1.30	<1.30
RDX	28	34	16	10.6	<0.63	<0.63
OTHERS			(ALL ND OR <CRL)			
INORGANICS						
Arsenic, total	<5.00	<5.00	6.63	<5.00	<5.00	<5.00
Barium, dissolved	65.4	92.2	101	201	NA	235
Barium, total	134	170	380	168	NA	360
Beryllium, total	0.6	0.2	1.51	<0.10	0.6	0.5
Cadmium, total	<5.10	<5.10	6.44	<5.10	<5.10	<5.10
Chromium, total	42.3	<37.50	<37.50	<37.50	<37.50	<37.50
Copper, dissolved	<1.78	6.32	<1.78	<1.78	<1.78	<1.78
Copper, total	5.36	17	11.8	13.2	22.2	30.2
Lead, dissolved	<2.5	<2.5	<2.5	<2.5	<2.5	5.56
Lead, total	2.73	<2.50	18.3	<2.50	<2.50	26.6
Nickel, dissolved	10.2	11.4	79.9	<9.60	19.1	<9.60
Nickel, total	35.8	53	81.5	9.85	31.8	51.7
Silver, total	<0.19	<0.19	0.32	<0.19	<0.19	<0.19
Zinc, dissolved	346	100	371	<17.20	910	<17.20
Zinc, total	259	369	403	80.1	970	220
OTHERS			(ALL ND OR <CRL)			

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

* DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-24
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #11
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	11-4-1	11-4-2
DEPTH (FT)	20.5	20.5
VOLATILES		
ALL	(ALL ND OR <CRL)	
BASE NEUTRAL & ACID EXTRACTABLES		
bis (2-Ethylhexyl) Phthalate	300	ND
UNKNOWNS		
4, 4-Dimethyl-2-Pentanol [928]	60	ND
C7-C13 Unknown Benzene Cmpd	ND	60
OTHERS	(ALL ND OR <CRL)	
EXPLOSIVE COMPOUNDS		
HMX	<1.30	2.16
RDX	1.74	50
OTHERS	(ALL ND OR <CRL)	
INORGANICS		
Barium, dissolved	90.2	167
Barium, total	164	195
Copper, total	<1.91	5.68
Nickel, dissolved	29.4	<9.60
Nickel, total	60.7	<9.60
Silver, total	0.31	<0.19
Zinc, dissolved	295	<17.20
Zinc, total	293	75.5
OTHERS	(ALL ND OR <CRL)	

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

[ ] DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

The second round of groundwater results detected HMX in wells 11-1, 11-2, and 11-4 at respective concentrations of 1.75, 3.43, and 2.16 ug/l. RDX was detected at well locations 11-1, 11-2, and 11-4 at respective concentrations 34.0, 10.6, and 50.0 ug/l.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at Area 11 identified one VOC: T12DCE. The compound was detected at upgradient well location 11-3 during the first round of sampling only, at a concentration of 2.3 ug/l.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 11 identified one BNA compound, B2EHP. The compound was detected during the first round of sampling only, at well locations 11-3 and 11-4 at respective concentrations of 50 and 300 ug/l. B2EHP is a common field contaminant.

Unknown BNA compounds were detected in samples from all four monitoring wells at Area 11. Concentrations ranged from 6 to 60 ug/l. Detections occurred during both rounds of sampling.

Inorganics

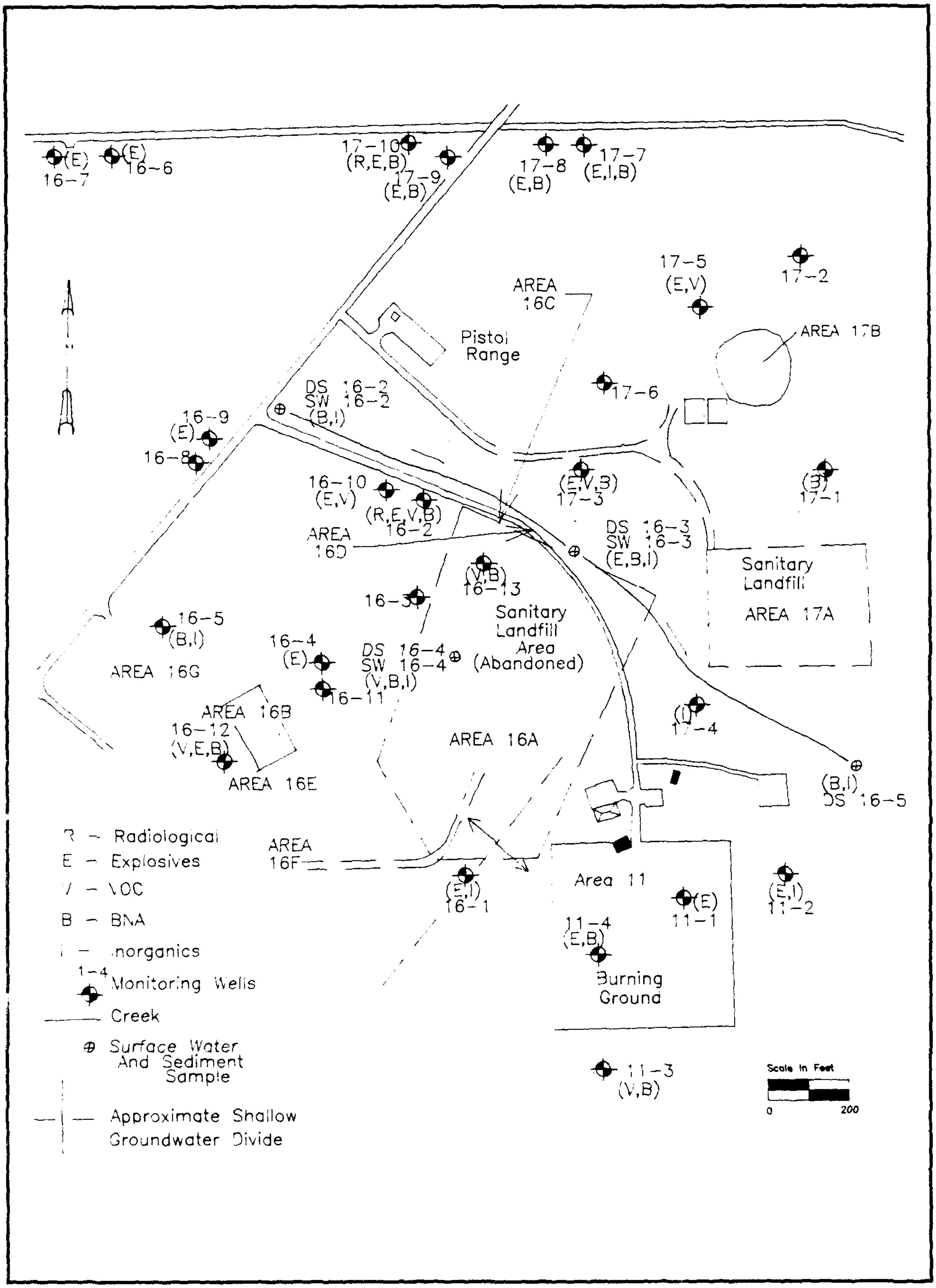
The results of the two rounds of groundwater sampling at Area 11 identified seven inorganics which exceeded statistical background concentrations, and one metal which exceeded the MGS, MDWS and/or MCL. Table 4-25 summarizes the inorganic parameters which were determined to be site-related detections and includes the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in Table 4-25.

Total cadmium exceeded the MCL of 5 ug/l in sample 11-2-1 with a detection of 6.44 ug/l.

4.11.3 Summary

Potentially site-related detections of organic and/or inorganic parameters occurred at the upgradient monitoring well location and all three downgradient monitoring well locations. Figure 4-24 presents the monitoring well locations and summarizes the distribution of elevated detections.

Explosive compounds RDX and HMX were detected at all three downgradient monitoring well locations, at relatively high concentrations. The lack of detections at the upgradient location indicates that the explosive burning grounds have contributed these explosive compounds to the groundwater.



AREA167C

FIGURE 4-24
AREA 11/16/17 DETECTION LOCATIONS

TABLE 4-25
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 11 GROUNDWATER RESULTS

METAL	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Arsenic, total	11-2-1	6.63	11-2-1	30.00
Beryllium, total	11-2-1	1.51	11-2-1	--
Cadmium, total	*11-2-1	6.44	*11-2-1	5.00
Chromium, total	11-1-1	42.3	11-1-1	50.00
Copper, dissolved	11-1-2	6.32	11-1-2	1000.00
Lead, dissolved	11-3-2	5.56	11-3-2	--
Lead, total	11-3-2	26.6	11-3-2	--
Nickel, dissolved	11-1-1, 11-1-2, 11-2-1, 11-3-1, 11-4-1	10.2 - 79.9	11-2-1	200.00
Nickel, total	11-2-1	81.5	11-2-1	200.00
Silver, total	11-2-1, 11-4-1	0.31 - 0.32	11-2-1	50.00
Zinc, dissolved	11-1-1, 11-2-1, 11-3-1, 11-4-1	295 - 910	11-3-1	5000.00
Zinc, total	11-3-1	970	11-3-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.

The single low detection of T12DCE at upgradient well location 11-3 during the first round of sampling does not appear indicative of any potential source areas of VOCs nearby.

Although there were two detections of B2EHP at Area 11, the detections may be field contamination and do not necessarily reflect actual groundwater chemistry.

The Area 11 burning grounds do not appear to have contributed inorganics to the local groundwater. Only cadmium exceeded an MCL, with a slightly elevated concentration of 6.44 ug/l in sample 11-2-1.

4.12 AREA 12 - LABORATORY WASTE LAGOON

4.12.1 Site Description and Field Investigation

4.12.1.1 Area 12A - Chemical Laboratory Waste Lagoon

This site, as shown in Figure 4-25, was a lagoon constructed in the early 1950s to contain waste from the chemical laboratory. It was closed in 1975. It collected RCRA hazardous constituents barium, chromium, lead, mercury, silver, antimony, and small quantities of laboratory chemicals. The estimated area of the lagoon is 2,500 square feet and approximate dimensions are 100 by 25 feet. The quantity of waste is estimated to be 5,000 gallons. This site has been listed on the NPL based on one groundwater monitoring analysis in Area 3 which showed silver concentrations above Missouri Drinking Water Standard levels (50 ug/l). Subsequent monitoring (including this RI) has not shown any detections of silver in the groundwater over 0.53 ug/l. The NPL lagoon is presently vegetated with grass and was previously monitored by three shallow groundwater monitoring wells (12-2, 12-3, and 12-4). Monitoring well 12-4 has previously detected TRCLE and 1,2-dichloroethene at 24 and 20 ug/L, respectively. The well is upgradient of the NPL lagoon; therefore, the lagoon is not considered to be a source of the volatile constituents. Production wells 17-AA and 17-CC (screened to a depth of 80 to 90 feet) have also been previously found to contain similar concentrations of TRCLE. A sewer line from Buildings 10 and 2 receives effluent from plant operations and may be a potential source of contamination if overflow or leaking occur.

To identify the source of TRCLE and other trace compounds in the volatiles fractions, a soil gas survey using field laboratory and gas chromatography techniques was conducted. The soil gas survey was performed south of the NPL lagoon and just south of the ditch. Approximately 43 probes were needed for an initial survey, with an additional 15 probes to further define any potential source. Figure 4-25 shows the location for the soil gas survey (dashed area). The soil gas samples were analyzed for TRCLE, vinyl chloride, and trans-1,2 dichloroethene.

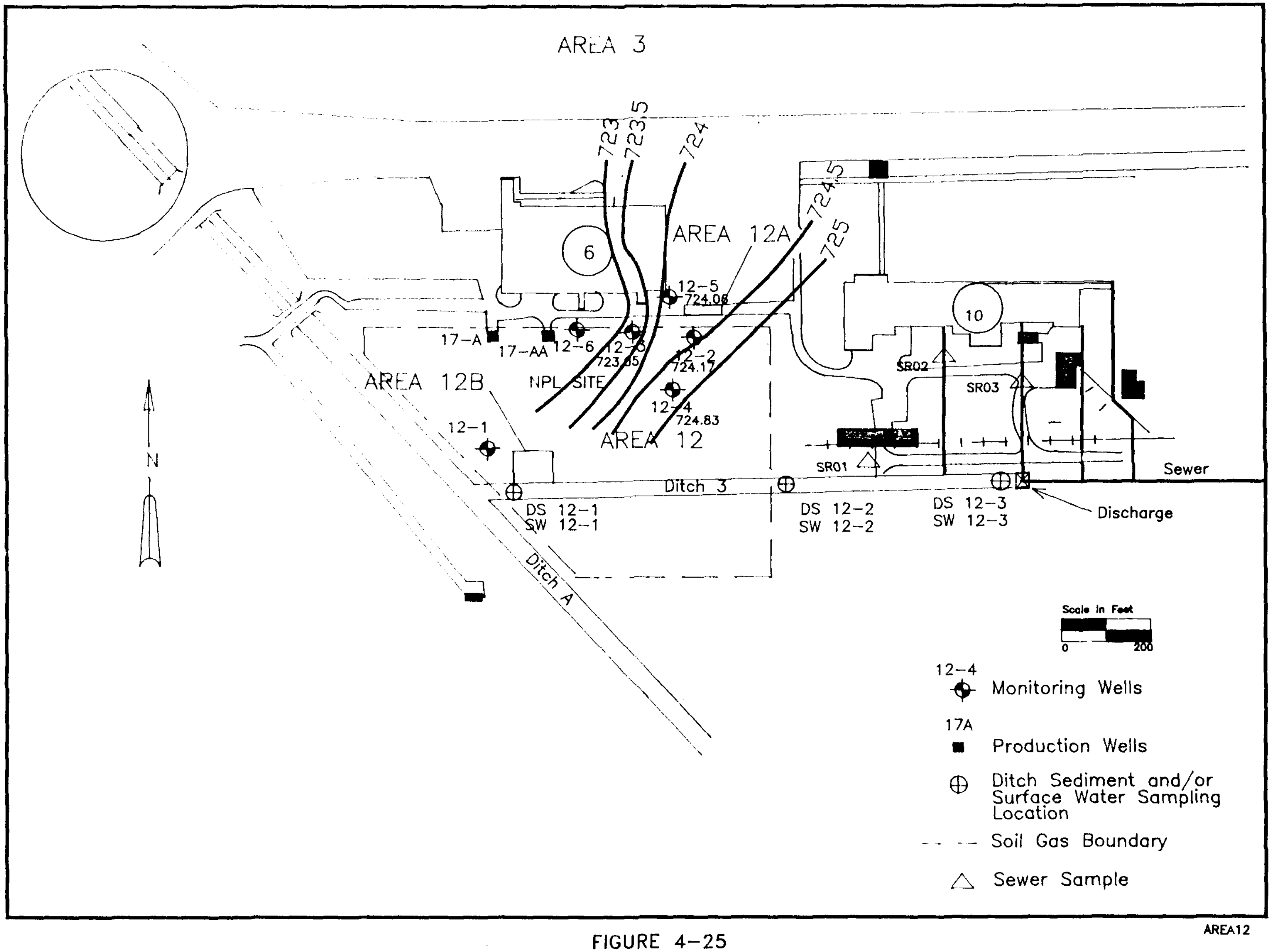


FIGURE 4-25
AREA 12

Two new monitoring wells were installed in this area. The first was a shallow well (12-5), screened just below the water table at about 24 feet and located downgradient of the NPL lagoon. Also, one deep well (12-6) was installed next to monitoring well 12-3. This provides information regarding vertical gradients in this area and drawdown data needed during the pump test (see Subsection 3.6.4). The deep well was installed on the top of bedrock, at approximately 86 feet.

The two new wells and three existing wells (12-2, 12-3, and 12-4) were each sampled twice. Well 12-1 was dry during both sampling rounds and consequently not sampled. In addition, production well 17-AA was sampled both rounds. All groundwater samples were analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. The metals analysis included silver, which is the parameter that qualified the site for the NPL.

The potential source of TRCLE contamination may be sewer lines south of Buildings 10 and 6. For this reason, three samples of the wastewater discharge from Building 10 (SR01, SR02, and SR03) and three samples each of surface water (SW12-1, SW12-2, and SW12-3) and sediment (DS12-1, DS12-2, and DS12-3) downgradient of the suspected area of overflow from the sewer line were analyzed. Figure 4-25 indicates the approximate locations of the wastewater discharge and the surface water and sediment samples. All of these samples were analyzed for VOCs.

4.12.1.2 Area 12B - Sludge Disposal Area

Area 12B was identified during the initial site visit. It is a small area about 20 feet by 20 feet. It is suspected that this area was used for IWTP sludge disposal. Four groundwater monitoring wells currently exist at Area 12. Three of these (12-2, 12-3, and 12-4) were discussed in the previous subsection. The fourth well (12-1) is directly downgradient of the 12B disposal area. Well 12-1 has never been sampled; its location appears to have been overlooked during previous sampling activities. An unbroken tape seal was still in place when this RI was conducted.

No field investigation activities were performed for Area 12B since well 12-1 was determined to be dry during both sampling events of this RI.

4.12.2 Site Investigation Results

The results of this site investigation at Area 12 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.12.3). All organic and inorganic analytical data is presented in Table

4-26. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.12.2.1 Soil Gas Survey

No compounds were detected during the soil gas survey at Area 12.

4.12.2.2 Groundwater

Explosives

The results of the two groundwater sampling at Area 12, identified four explosive compounds:

- 135TNB.
- HMX.
- RDX.
- Tetryl.

The first round of groundwater sampling identified the explosive compound RDX at monitoring well locations 12-2, 12-3, 12-4, 12-5, and 12-6 at respective concentrations of 61.0, 10.4, 6.64, 25.4, and 10.6 ug/l. The compound 135TNB was detected at monitoring well locations 12-2 and 12-5 at respective concentrations of 2.43 and 18.6 ug/l. HMX was detected at wells 12-2 and 12-5 at 4.91 and 6.33 ug/l, respectively. All wells are considered downgradient except well 12-4, which is located upgradient of Area 12A.

The second round of groundwater sampling at Area 12 detected the explosive compound Tetryl at monitoring well location 12-3 at a concentration of 1.31 ug/l.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at Area 12 did not identify any VOCs. Although, as discussed further in Section 4.20, production well 17-AA did detect TRDCE and TRCLE in the groundwater.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of monitoring well sampling at Area 12 identified one BNA compound: n-nitrosodiphenylamine (NNDPA). The compound was detected during the second round of sampling only, at well location 12-2 at a concentration of 10 ug/l. NNDPA is a common field contaminant.

Unknown BNA compounds were detected in samples from four different monitoring wells at Area 12. Wells 12-3 through 12-6 had concentrations ranging from 10 to 30 ug/l. All detections occurred during the second round of sampling.

TABLE 4-26
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #12
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	12-2-1	12-2-2	12-3-1	12-3-2	12-4-1	12-4-2
DEPTH (FT)	23	23	23	23	23	23
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
N-Nitrosodiphenylamine	ND	10	ND	ND	ND	ND
UNKNOWNS						
Cyclopentanediol Ester	ND	ND	ND	*30	ND	ND
C8-C10 Methyl Alkene	ND	ND	ND	*20	ND	ND
Unknown-1	ND	ND	ND	ND	ND	20
Unknown-2	ND	ND	ND	ND	ND	10
Ethyl Methyl Cyclohexane	ND	ND	ND	*10	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
135-TNB	2.43	<0.56	<0.56	<0.56	<0.56	<0.56
HMX	4.91	<1.30	<1.30	<1.30	<1.30	<1.30
RDX	61	<0.63	10.4	<0.63	6.64	<0.63
Tetryl	<0.66	<0.66	<0.66	1.31	<0.66	<0.66
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	<5.00	<5.00	<5.00	11.2	<5.00	<5.00
Barium, dissolved	NA	91	NA	136	NA	161
Barium, total	NA	112	NA	645	NA	317
Beryllium, total	0.34	<0.10	0.3	0.4	0.34	<0.10
Chromium, total	57.7	<37.50	49	<37.50	<37.50	<37.50
Copper, dissolved	2.47	3.54	2.04	<1.78	2.14	12.1
Copper, total	10.7	12.3	12.3	33.4	11.3	17.6
Lead, total	<2.50	<2.50	6.27	5.06	8.59	2.83
Nickel, dissolved	<9.60	<9.60	<9.60	<9.60	<9.60	26.1
Nickel, total	31.2	57.8	36.7	68.2	26.5	40.3
Silver, total	<0.19	<0.19	0.21	<0.19	<0.19	<0.19
Zinc, dissolved	281	103	241	<17.20	180	135
Zinc, total	271	154	263	246	285	207
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-26
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #12
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	12-5-1	12-5-2	12-6-1	12-6-2
DEPTH (FT)	29	29	29	29
VOLATILES				
ALL	(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES				
UNKNOWNS				
Cyclopentanediol Ester	ND	*10	ND	*10
C10 Methyl Alkene/Alkane	ND	*10	ND	*20
1 1-Dimethyl Cyclohexane [778]	ND	10	ND	ND
C8-C13 Alkyl Benzene	ND	*20	ND	ND
C6-C8 Dimethyl Alcohol	ND	ND	ND	*10
OTHERS	(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS				
135-TNB	18.6	<0.56	<0.56	<0.56
HMX	6.33	<1.30	<1.30	<1.30
RDX	25.4	<0.63	10.6	<0.63
OTHERS	(ALL ND OR <CRL)			
INORGANICS				
Arsenic, total	7.04	<5.00	5.28	16.3
Barium, dissolved	NA	153	NA	580
Barium, total	NA	512	NA	1020
Beryllium, dissolved	0.13	<0.10	0.13	<0.10
Beryllium, total	0.58	<0.10	0.34	0.81
Chromium, dissolved	3800	730	127	<37.50
Chromium, total	3800	710	126	<37.50
Copper, dissolved	2.79	<1.78	2.36	<1.78
Copper, total	18.4	24.3	9.86	51.6
Lead, total	10	2.93	6.37	5.36
Nickel, dissolved	12.8	<9.60	<9.60	55.4
Nickel, total	21.2	46.8	<9.60	39.9
Silver, total	<0.19	<0.19	<0.19	0.53
Zinc, dissolved	285	35.9	262	186
Zinc, total	317	201	294	185
OTHERS	(ALL ND OR <CRL)			

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

Production well sample 17-AA contained B2EHP and twenty-two different unknown BNA compounds at concentrations ranging from 10 to 500 ug/l. Ten of the twenty-two unknowns contain a 99% certainty of being present. The other twelve represent the best library match. Table 4-39 presents the analytical results for Production well 17-AA.

Inorganics

The results of the two rounds of groundwater sampling at Area 12 identified eight inorganics which exceeded statistical background concentrations and three metals which exceeded the MGS, MDWS and/or MCL. Table 4-27 summarizes the inorganic parameters which were determined to be site-related detections and includes the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in this table. The parameters which exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Total barium exceeded the MDWS of 1,000 ug/l in downgradient sample 12-6-2 with a concentration of 1,020 ug/l.

Dissolved chromium exceeded both the MDWS of 50 ug/l and the MCL of 100.00 ug/l in samples 12-5-1, 12-5-2, and 12-6-1 with respective concentrations of 3,800, 730, and 127 ug/l.

Total chromium exceeded the MDWS of 50 ug/l in sample 12-2-1 with a detection of 57.7 ug/l. Total chromium exceeded the MCL of 100 ug/l in samples 12-5-1, 12-5-2, and 12-6-1 with respective concentrations of 3,800, 710, and 126 ug/l.

4.12.2.3 Surface Water and Ditch Sediment

Volatile Organic Compounds

No VOCs were identified from the three surface water and ditch sediment samples collected from Area 12.

4.12.2.4 Wastewater Discharge

Volatile Organic Compounds

No VOCs were definitively identified from the three wastewater discharge samples collected at Area 12. Sample SR01-01 contained six different unknown VOC compounds at estimated concentrations ranging from 40 to 400 ug/l. A detailed discussion of the plant-wide sump and wastewater discharge samples is presented in Section 4.21 and analytical results are presented in Table 4-42.

TABLE 4-27
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 12 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Arsenic, total	12-3-2, 12-5-1, 12-6-1, 12-6-2	5.28 - 16.3	12-6-2	30.00
Barium, dissolved	12-6-2	580	12-6-2	1000.00
Barium, total	*12-6-2	1020	*12-6-2	1000.00
Beryllium, dissolved	12-5-1, 12-6-1	0.13	12-5-1, 12-6-1	--
Chromium, dissolved	*12-5-1, *12-5-2, *12-6-1	127 - 3800	*12-5-1	50.00
Chromium, total	*12-2-1, 12-3-1, *12-5-1, *12-5-2, *12-6-1	49 - 3800	*12-5-1	50.00
Copper, dissolved	12-2-1, 12-2-2, 12-3-1, 12-4-1, 12-4-2, 12-5-1, 12-6-1	2.04 - 12.1	12-4-2	1000.00
Copper, total	12-6-2	51.6	12-6-2	1000.00
Nickel, dissolved	12-4-2, 12-5-1, 12-6-2	12.8 - 55.4	12-6-2	200.00
Nickel, total	12-3-2	68.2	12-3-2	200.00
Silver, total	12-3-1, 12-6-2	0.21 - 0.53	12-6-2	50.00
Zinc, dissolved	12-2-1, 12-5-1	281 - 285	12-5-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.

4.12.3 Summary

Detections of organic and/or inorganic parameters were identified at all five of the sampled wells within Area 12, including the upgradient well. The vast majority of detections were found in the downgradient monitoring wells. Figure 4-26 presents the monitoring well locations and summarizes the distribution of elevated detections.

Although explosive compounds were identified in all five monitoring wells, upgradient location 12-4 showed the lowest concentrations and the downgradient wells showed the highest concentrations. This trend indicates that a source of explosive compounds is located within Area 12.

Area 12 does not appear to be contributing any VOC or BNA compounds upgradient of the monitoring wells. There were no VOCs identified in the monitoring well samples and the one detection of a definitive BNA compound probably does not reflect actual groundwater conditions. NNDPA is a common post-sampling contaminant, and it was detected only once during the investigation at Area 12. Production well 17-AA did contain VOCs, however, and the ramifications of this data is discussed in Section 4.20.

The lack of any VOC detections from the three surface water, the three ditch sediments or the three wastewater samples collected at Area 12 indicates that no VOC or BNA compounds have been recently introduced to the storm sewer or ditch system.

Elevated levels of inorganics at downgradient monitoring well locations indicate that Area 12 may be contributing inorganics to the groundwater. This is especially evident due to elevated concentrations of arsenic and chromium.

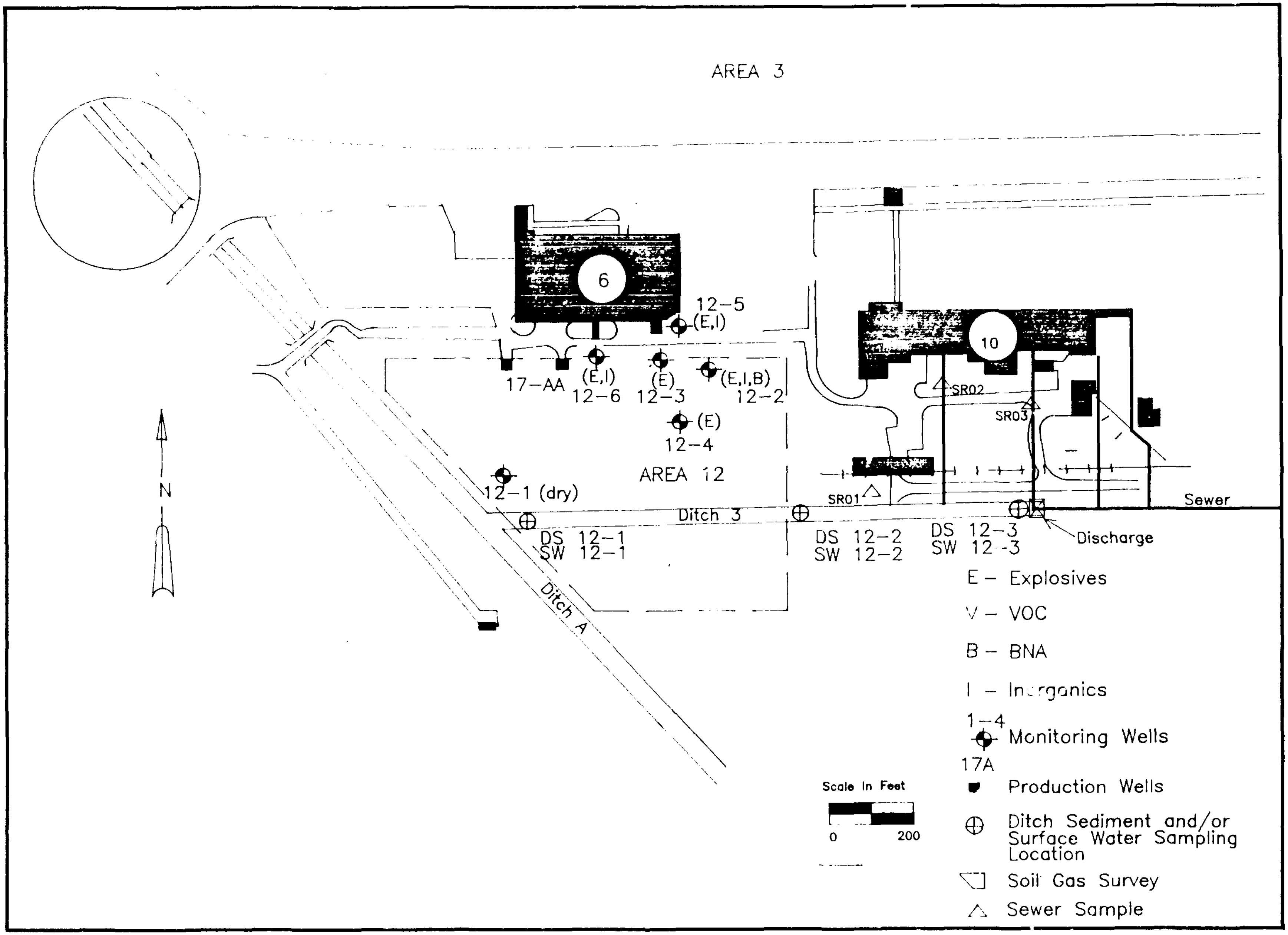
4.13 AREA 13 - BUILDING 35 DRAINAGE AREA

4.13.1 Site Description and Field Investigation

4.13.1.1 Area 13A - Open Waste Drainage Area

Area 13A, shown in Figure 4-27, was an open drainage area for metal parts manufacturing waste from Building 35. Open drainage was discontinued in 1971. The quantity of waste discharged is unknown. The RCRA hazardous constituent introduced into this area was chromium (sodium dichromate). At the present time, the open drainage area is a grass field with a small ditch running adjacent to it. Drainage from Building 35 ran into this ditch. No investigation had previously been conducted at Area 13.

To determine the potential extent of contamination, three surface water (SW13-1, 13-2, and 13-4) and four sediment (DS13-1 to 13-4) samples were collected from the drainage ditch. The first set of



AREA12CO

FIGURE 4-26
AREA 12 DETECTION LOCATIONS

surface water/sediment samples were collected just downstream of sump discharge pipe and located north of Building 35. The second set of samples were taken just downstream of the pipe that discharges wastewater from the west side of Building 35. The remaining two sets of samples were taken further downstream. All surface water and sediment samples were analyzed for VOCs, BNAs, inorganics, and explosives. Surface water sample SW13-3 was not collected because the drainage ditch was dry.

Three surface soil samples (SO13-1 to 13-3) were collected from the open waste drainage area, as shown in Figure 4-27. These soil samples were analyzed for VOCs, BNAs, inorganics, and explosives.

4.13.1.2 Area 13B - Primer Waste Treatment Tanks

The primer waste treatment tanks are designed to collect and treat primer waste generated in the primers mix area and in the primers manufacturing wing of Building 35. The tanks are located in the underground concrete structures shown in Figure 4-27. Buildings 90A and 90C service the primer mix area and Building 90B and 90D service the primer manufacturing process. The treatment tanks are constructed from steel having dimensions of 8 feet by 4 feet by 4 feet. Buildings 90A, 90B, and 90C contain three treatment tanks, and Building 90D contains six treatment tanks. The wastes are chemically treated to render them non-reactive and are then discharged to the IWTP. The hazardous wastes generated are K044 and K046, containing the hazardous constituents lead, barium, and antimony. The total waste generated during a normal one-shift period is estimated to be 11,730 gallons per day and is estimated to increase to 36,740 gallons per day under maximum production schedules.

Since the treatment tanks are protected by secondary containment, no field investigation activities were performed for Area 13B.

4.13.2 Site Investigation Results

The results of this site investigation at Area 13 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.13.4). All organic and inorganic analytical data is presented in Table 4-28. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

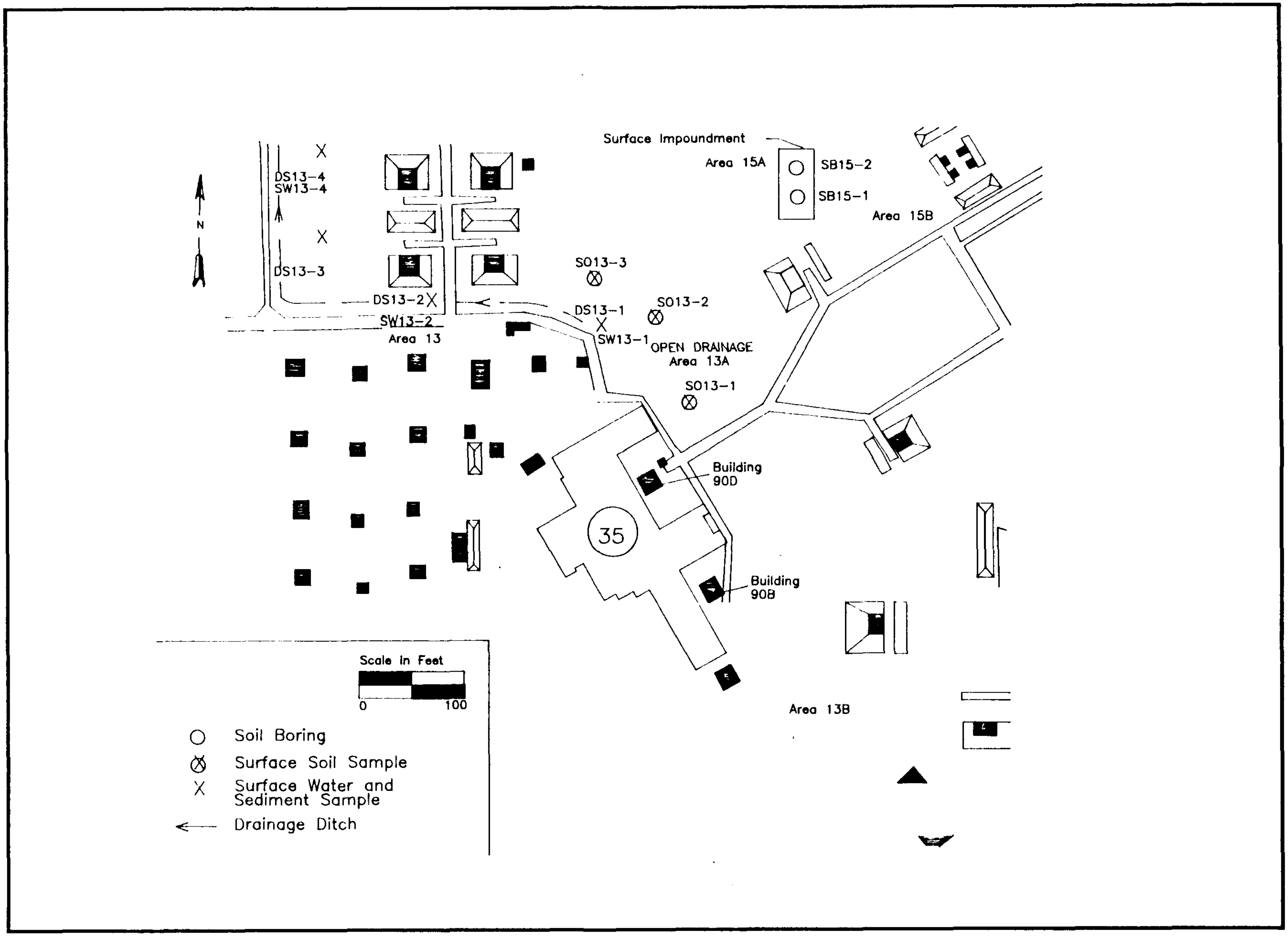


FIGURE 4-27
AREA 13/15

TABLE 4-28
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #13
SUMMARY OF ANALYTICAL DATA
DITCH SURFACE WATER SAMPLES (UG/L)

SITE ID	SW13-1-1	SW13-2-1	SW13-4-1
VOLATILES			
ALL	(ALL ND OR <CRL)		
BASE NEUTRAL & ACID EXTRACTABLES			
bis (2-Ethylhexyl) Phthalate	60	50	40
OTHERS	(ALL ND OR <CRL)		
EXPLOSIVE COMPOUNDS			
135-TNB	0.64	<0.56	<0.56
OTHERS	(ALL ND OR <CRL)		
INORGANICS			
Antimony, total	15.5	<3.00	<3.00
Chromium, total	<37.50	<37.50	38.5
Copper, total	40.8	78	180
Lead, total	12.4	13.7	12.7
Nickel, total	17.8	21.9	19.8
Zinc, total	293	346	321
OTHERS	(ALL ND OR <CRL)		

CRL = CERTIFIED REPORTING LIMIT ND = NOT DETECTED NA = NOT ANALYZED

DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-28
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #13
SUMMARY OF ANALYTICAL DATA
DITCH SEDIMENT SAMPLES (UG/G)

SITE ID	DS13-1-1	DS13-2-1	DS13-3-1	DS13-4-1
VOLATILES				
ALL	(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES				
Anthracene	ND	0.8	ND	ND
Chrysene	1	ND	0.8	ND
Fluoranthene	2	3	1	ND
Phenanthrene	1	3	ND	ND
Pyrene	1	ND	0.9	ND
UNKNOWNS				
Sulfur	*2	ND	ND	ND
1, 4-Dimethyl-Cyclooctane [945]	ND	1	ND	ND
Hexadecanoic Acid [971]	ND	1	ND	ND
Bicyclo Alkene/Alkane	ND	1	ND	ND
Cyclic Hydrocarbon, C10-C19	ND	ND	ND	*1
OTHERS	(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS				
ALL	(ALL ND OR <CRL)			
INORGANICS				
Arsenic, total	10.6	25	21.2	6.73
Barium, total	397	933	740	703
Cadmium, total	10.6	11.9	14.5	11.9
Chromium, total	<2.50	150	90.7	1000
Copper, total	9.4	150	200	790
Lead, total	210	52	39.5	170
Mercury, total	0.81	<0.10	<0.10	<0.10
Nickel, total	8.62	20.9	19.4	35.5
Zinc, total	149	180	271	475
OTHERS	(ALL ND OR <CRL)			

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-28
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #13
SUMMARY OF ANALYTICAL DATA
SURFACE SOIL SAMPLES (UG/G)

SITE ID	S013-1-1	SO13-2-1	S013-3-1
VOLATILES			
ALL	(ALL ND OR <CRL)		
BASE NEUTRAL & ACID EXTRACTABLES			
ALL	(ALL ND OR <CRL)		
EXPLOSIVE COMPOUNDS			
ALL	(ALL ND OR <CRL)		
INORGANICS			
Arsenic, total	24	24	30.8
Barium, total	499	749	720
Beryllium, total	0.36	<0.33	<0.33
Chromium, total	115	<3.99	<3.99
Copper, total	8.08	8.08	7.52
Lead, total	15.8	<4.78	20.3
Nickel, total	12.3	11.9	11.5
OTHERS	(ALL ND OR <CRL)		

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

4.13.2.1 Surface Water

Explosives

One explosive compound was identified during the surface water investigation at Area 13: 135TNB. The compound was detected in sample SW13-1 at a concentration of 0.64 ug/l.

Volatile Organic Compounds

No VOCs were identified in the three surface water samples collected at Area 13.

Base Neutral and Acid Extractable Compounds

The results of the surface water sampling at Area 13 identified one BNA compound: B2EHP.

The compound was detected at sample locations SW13-1, SW13-2, and SW13-4 at respective concentrations of 60, 50, and 40 ug/l.

Inorganics

The results of the surface water sampling at Area 13 identified five inorganics which exceeded the background concentrations. No criteria were exceeded.

Antimony was detected in sample SW13-1 at a concentration of 15.5 ug/l. Chromium was detected in sample SW13-4 at a concentration of 38.5 ug/l. Copper was detected at elevated concentrations in sample SW13-1 at 40.8 ug/l, in sample SW13-2 at 78 ug/l, and in sample SW13-4 at 180 ug/l. Lead was detected at elevated concentrations in all three samples at concentrations ranging from 12.40 to 13.70 ug/l. Nickel was detected at elevated concentrations in all three samples at concentrations ranging from 17.80 to 21.90 ug/l.

4.13.2.2 Ditch Sediment

Explosives

There were no explosive compounds identified from the four ditch sediment samples collected at Area 13.

Volatile Organic Compounds

There were no VOCs identified from the four ditch sediment samples collected at Area 13.

Base Neutral and Acid Extractable Compounds

A total of five BNA compounds were identified from the ditch sediment samples collected at Area 13:

- Anthracene.
- Chrysene.
- Fluorene.
- Phenanthrene.
- Pyrene.

Sample DS13-1 detected chrysene, fluorene, phenanthrene, and pyrene at respective concentrations of 1.19, 1.94, 1.07, and 1.46 ug/g. Sample DS13-2 detected anthracene, fluorene, and phenanthrene at respective concentrations of 0.78, 3.17, and 2.62 ug/g. Sample DS13-3 detected chrysene, fluorene, and pyrene at respective concentrations of 0.77, 1.14, and 0.91 ug/g. None of the compounds were detected in sample DS3-4.

Unknown BNA compounds were detected in three of the four Area 13 ditch sediment samples. Sample DS13-1 had one detection of 2 ug/g. Sample DS13-2 had three detections at 1 ug/g each. Sample DS13-4 had one detection at 1 ug/g.

Inorganics

The results of the ditch sediment sampling at Area 13 identified nine inorganics which exceeded statistical background concentrations. None of the detections exceeded the criteria. The nine inorganics are discussed in the following paragraphs.

Arsenic was detected at elevated concentrations in all four samples, ranging in concentration from 6.73 to 25.0 ug/g.

Barium was detected at elevated concentrations in all four samples, ranging in concentration from 397 to 933 ug/g.

Cadmium was detected at elevated concentrations in all four samples, ranging in concentration from 10.6 to 14.5 ug/g.

Chromium was detected at elevated concentrations in samples DS13-2, DS13-3, and DS13-4 at respective concentrations of 150, 90.7, and 1,000 ug/g.

Copper was detected at elevated concentrations in samples DS13-2, DS13-3, and DS13-4 at respective concentrations of 150, 200, and 790 ug/g.

Lead was detected at elevated concentrations in all four samples, ranging in concentration from 39.5 to 210 ug/g.

Mercury was detected in sample DS13-1 at a concentration of 0.81 ug/g.

Nickel was detected at a slightly elevated concentration of 35.5 ug/g in sample DS13-4.

Zinc was detected at elevated concentrations in all four samples with concentrations ranging from 149 to 475 ug/g.

4.13.2.3 Surface Soil

Explosives

There were no explosive compounds identified from the four surface soil samples collected at Area 13.

Volatile Organic Compounds

There were no VOCs identified from the three surface water and ditch sediment samples collected from Area 13.

Base Neutral and Acid Extractable Compounds

There were no BNA compounds identified from the three surface soil samples collected at Area 13.

Inorganics

The results of the surface soil sampling at Area 13 identified four inorganics which exceeded statistical background concentrations. The four inorganics are discussed in the following paragraphs.

Arsenic was detected at elevated concentrations in all three surface soil samples, ranging in concentration from 24.0 to 30.8 ug/g.

Barium was detected at elevated concentrations in all three surface soil samples, ranging in concentration from 499 to 749 ug/g.

Chromium was detected in sample S013-1 only, at a concentration of 115 ug/g.

Lead was detected in samples S013-1 and S013-3 at respective concentrations of 15.8 and 20.3 ug/g.

4.13.4 Summary

Potentially site-related detections were identified at all of the sample locations within Area 13, as shown in Figure 4-28. A trace quantity of the explosive compound 135TNB was detected in ditch surface water sample 13-1. No other explosives were identified further downgradient at Area 13. No VOCs were detected at Area 13.

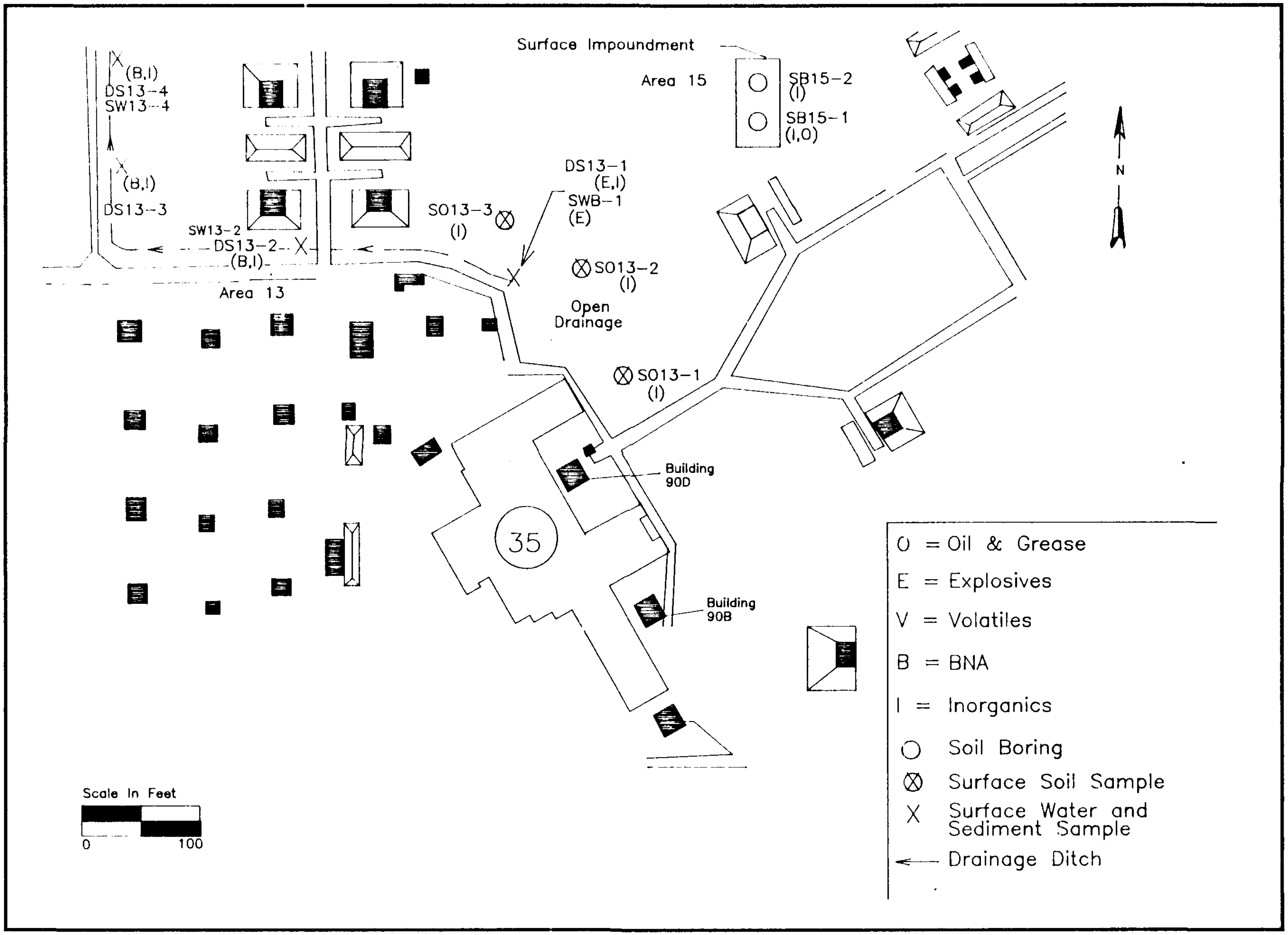


FIGURE 4-28
AREA 13/15 DETECTION LOCATIONS

BNAs were present at three of the four ditch sediment sampling locations at relatively low concentrations. This indicates a previous release of BNA contamination to the Area 13 ditch system. No BNAs were detected in surface soil samples collected away from the ditch.

Inorganic concentrations exceeded background levels in all of the samples collected at Area 13. Local waste handling practices appear to have impacted much of the soil and consequently surface water within the area. None of the surface water concentrations exceeded criteria or standards. However, of the four ditch sediment locations, DS13-4 shows the most elevated inorganic concentrations, specifically chromium, copper, and zinc. This may be due to the continual migration of the heavy metals downslope within the ditch.

4.14 AREA 14 - FUEL TANK, BURNING GROUND AND SLUDGE DISPOSAL AREA

4.14.1 Site Description and Field Investigation

4.14.1.1 Area 14A - Burning Ground

From 1951 through 1967, the plant fire department burned wooden ammunition boxes in the area east of the railroad classification yard and northwest of Building 78, the Oil Unloading Pump Building (Figure 4-29). This was generally done when a considerable number of ammunition boxes had been accumulated.

No field investigation activities were performed for Area 14A during this phase of work. The ammunition boxes should have contained only trace quantities of explosives.

4.14.1.2 Area 14B - Sludge Disposal Area

Area 14B, shown in Figure 4-29, is an IWTP sludge disposal area. It was closed in 1965 and occupies an estimated area of 30,000 square feet. The depth is estimated at 10 to 12 ft. The estimated quantity of waste is a maximum of 13,000 cu. yd. sPossible RCRA hazardous constituents are lead and mercury. Also within this area are four above-ground tanks used for storing fuel oil.

Currently, Area 14B consists of an open grass field with four large above-ground tanks located north of the disposal area. Ditch B runs along the northern edge of the study area. Previously, no investigation had been conducted at Area 14B. The northeastern tank is to be removed, and at that time, an assessment of the potential release of fuel will be addressed by the Olin Corporation as part of their ongoing plant management responsibility.

At Area 14B, only an approximate location of the sludge disposal area is known; therefore, electromagnetic and ground-penetrating radar were used to determine the geometry of the disposal area.

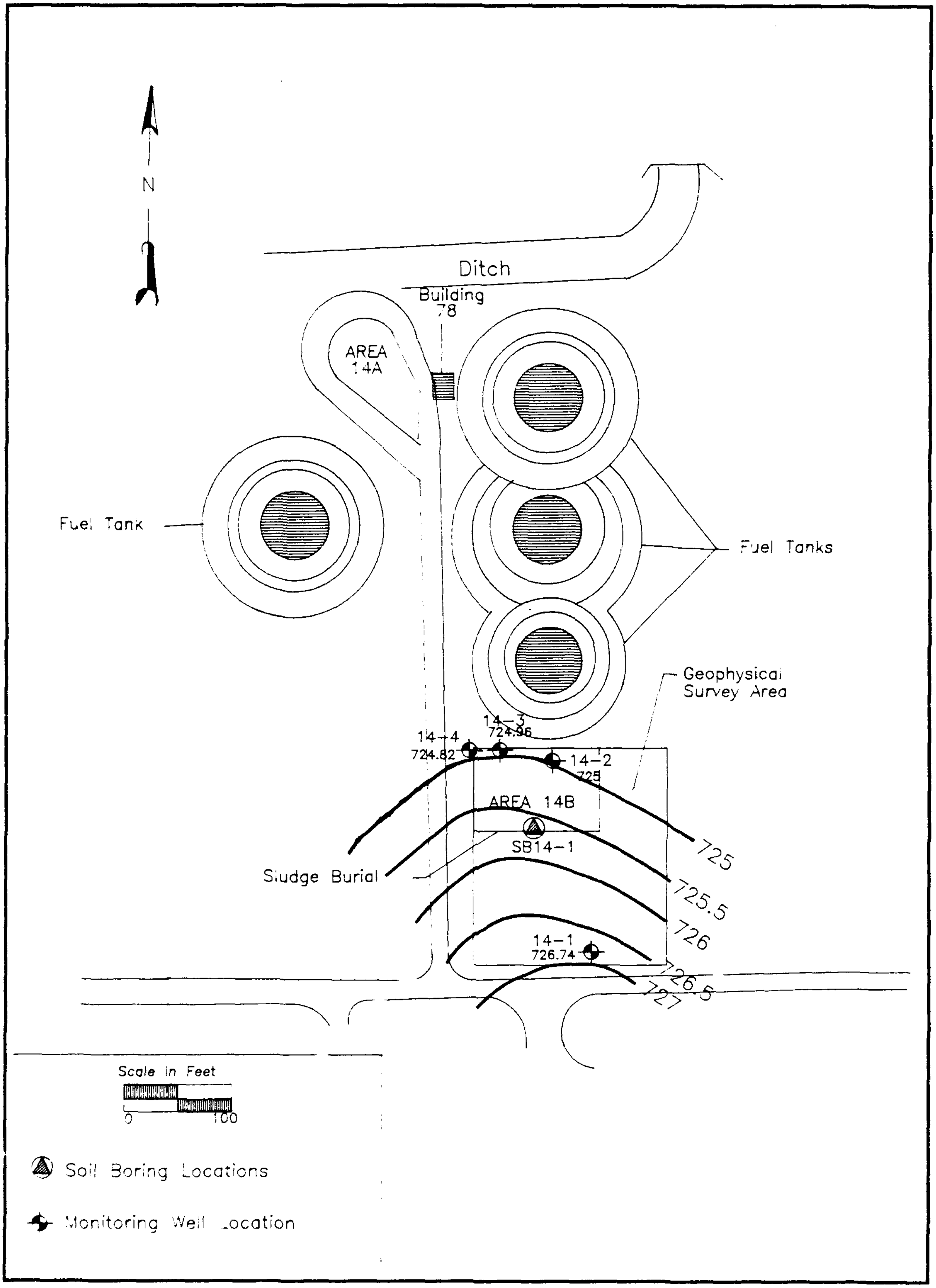


FIGURE 4-29
AREA 14

Figure 4-30 shows the designated area where the geophysical surveys were conducted. The EM-34 survey required 64 stations at 25-foot spacings, plus an additional 25 stations at 10-foot spacings in order to refine the survey. The GPR survey was carried out over 800 linear yards. The monitoring well locations were determined based on the results of the geophysical surveys.

Two shallow wells and one two-well cluster were installed in Area 14B. Figure 4-29 shows the locations for each of the monitoring wells. The first single shallow well (14-1) is located upgradient of the sludge disposal area at the southeastern corner of the site and installed to a depth of 35 ft. The two-well cluster and the remaining single shallow well (14-2) were located downgradient of the disposal area and monitor the potential migration of contaminants. At the two-well cluster, the deep well (14-4) was screened at 78.5 feet at the base of the aquifer, and the shallow well (14-3) was screened straddling the water table from 10 to 20 feet deep. Shallow well 14-2 was screened below the water table from 13 to 23 feet. This well cluster will provide data concerning the vertical gradients. Each monitoring well was sampled twice. All groundwater samples were analyzed for VOCs, BNAs, inorganics, and explosives. In addition, well 14-4 was analyzed for radiation parameters during the first round of groundwater sampling. The two sampling events were separated by a three-month interval.

One soil boring was drilled within the sludge disposal area. The location of soil boring 14-1 is shown in Figure 4-29. It was drilled to a depth of 10 feet to characterize the chemistry of the residual soil. Three samples (SB14-1-1 to 14-1-3, were collected at a depth of 1 to 2.5 ft., 6 to 7.5 ft., and 8.5 to 10 ft. The soil samples were analyzed for inorganics (mercury, nickel, zinc), explosives, and oil and grease.

4.14.2 Site Investigation Results

The results of this site investigation at Area 14 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.14.3). All organic and inorganic analytical data is presented in Table 4-29. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling. All soil boring samples were collected during round 1 and the last number of each sample designation refers to its relative depth.

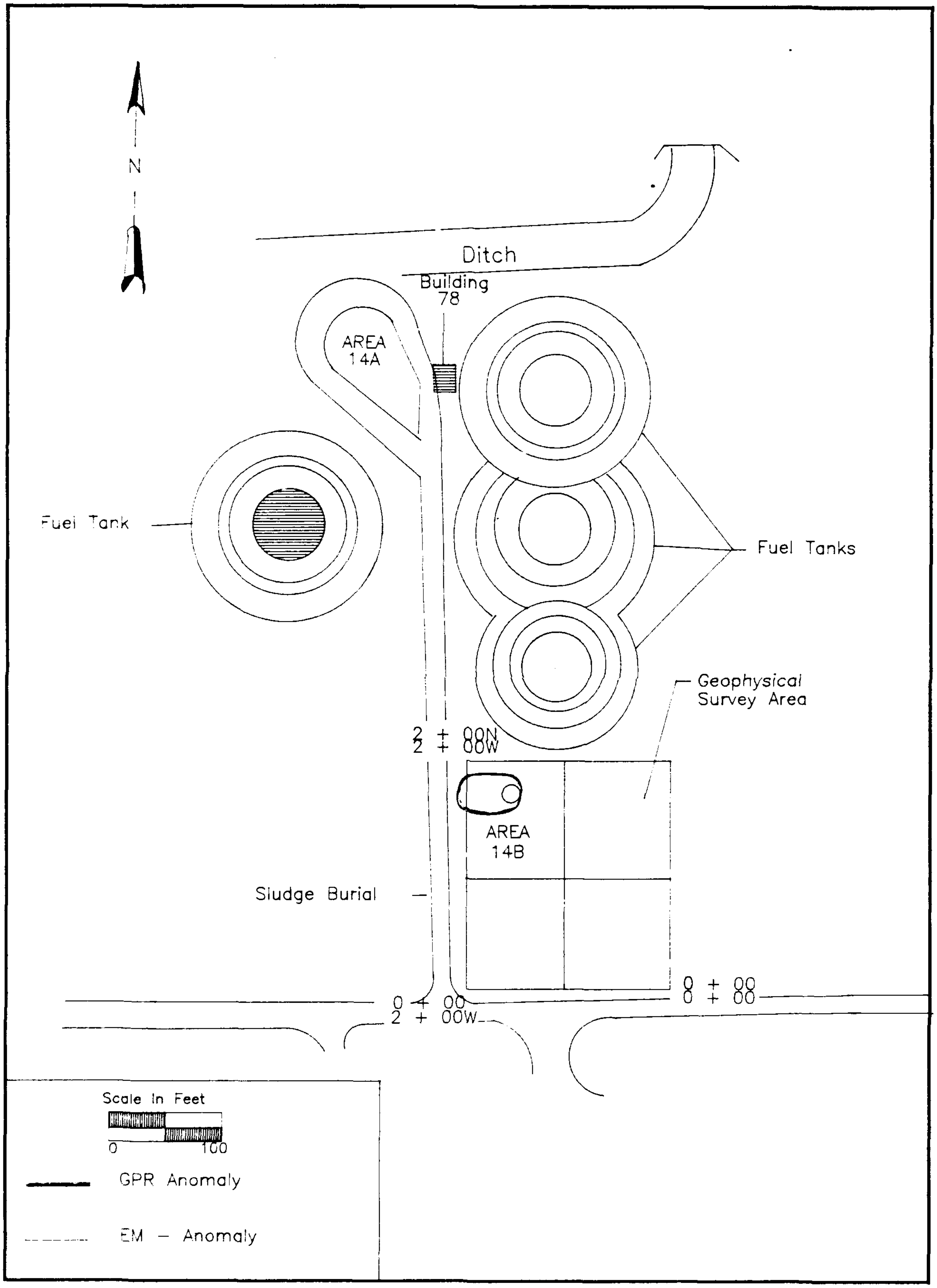


FIGURE 4–30
LOCATION OF GEOPHYSICAL SURVEY
GRID AND COORDINATES OF AREA 14

TABLE 4-29
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #14
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	14-1-1	14-1-2	14-2-1	14-2-2	14-3-1	14-3-2
DEPTH (FT)	23	23	18	18	15	15
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	50	ND	90	ND	80	ND
UNKNOWNS						
Hexanedioic Acid Ester	ND	ND	*50	ND	*50	ND
C4-C7 Organic Acid Ester	ND	ND	ND	ND	*10	ND
C7-C12 Methyl Alkene	*10	ND	ND	ND	ND	ND
Iron Carbonyl	ND	ND	ND	ND	ND	*10
Cyclopentanediol Ester	ND	ND	ND	ND	ND	*10
1,1,2,2-Tetrachloroethane	ND	ND	ND	*20	ND	ND
C6-C9 Cycloalkane	ND	ND	ND	*30	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	ND	ND	*20	ND	ND
C7-C10 Methyl Cyclohexane	ND	ND	ND	*10	ND	ND
C6-C7 Methyl Alcohol	ND	ND	ND	*10	ND	ND
C12-C28 Hydrocarbon	ND	ND	ND	*20	ND	ND
(Methylethyl) phenyl-ethanone	ND	ND	ND	*10	ND	ND
C7-C13 Alkyl Benzene	ND	ND	ND	*20	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, total	<5.00	<5.00	21.5	6.94	<5.00	<5.00
Barium, dissolved	NA	419	NA	538	NA	251
Barium, total	NA	333	NA	558	NA	227
Beryllium, total	0.29	<0.10	0.74	<0.10	0.2	0.2
Cadmium, total	27.1	<5.10	<5.10	9.67	<5.10	<5.10
Chromium, total	<37.50	<37.50	162	<37.50	57.7	<37.50
Copper, dissolved	3.22	<1.78	3.43	<1.78	2.68	<1.78
Copper, total	27	7.07	28.1	9.86	16.4	7.29
Lead, total	9.61	<2.50	10.8	4.15	5.36	2.83
Nickel, dissolved	24.9	33.7	38.4	42.7	22	<9.60
Nickel, total	48	40.9	101	49.1	42.4	28.5
Selenium, total	24.2	<5.00	<5.00	<5.00	<5.00	<5.00
Zinc, dissolved	321	63	526	37.3	211	17.4
Zinc, total	256	35.5	564	199	403	150
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-29
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #14
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	14-4-1	14-4-2
DEPTH (FT)	73.5	73.5
VOLATILES		
ALL	(ALL ND OR <CRL)	
BASE NEUTRAL & ACID EXTRACTABLES		
bis (2-Ethylhexyl) Phthalate	100	ND
UNKNOWNS		
Hexanedioic Acid Ester	*60	ND
Propylhdrazone Acetaldehyde [899]	*10	ND
C6-C9 Alkane/Alkene	ND	*20
C8-C10 Methyl Alkane/Alkene	ND	*20
EXPLOSIVE COMPOUNDS		
RDX	<0.63	9.38
OTHERS	(ALL ND OR <CRL)	
INORGANICS		
Arsenic, total	7.04	<5.00
Barium, dissolved	NA	322
Barium, total	NA	311
Beryllium, dissolved	0.17	<0.10
Beryllium, total	1.24	<0.10
Chromium, total	160	<37.50
Copper, dissolved	2.47	5.68
Copper, total	22.5	3.86
Lead, total	15.6	2.73
Nickel, dissolved	<9.60	10.3
Nickel, total	41.6	17.1
Zinc, dissolved	878	53.1
Zinc, total	457	116
OTHERS	(ALL ND OR <CRL)	
RADIOLOGICAL (PCI/L)		
Alpha	7+/-5	0+/-5
Beta	15+/-5	13+/-4
U-234	NA	0.5+/-0.3
U-235	NA	0+/-0.1
U-238	NA	0.7+/-0.3
Total Uranium	0.9	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-29
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #14
SUMMARY OF ANALYTICAL DATA
SUBSURFACE SOIL SAMPLES (UG/G)

SITE ID	SB14-1-1	SB14-1-2	SB14-1-3
DEPTH (FT)	1	6	8.5
EXPLOSIVE COMPOUNDS			
ALL	(ALL <CRL)		
INORGANICS			
Arsenic, total	34.6	180	130
Barium, total	534	972	949
Beryllium, total	0.36	0.36	<0.33
Cadmium, total	<0.70	7.93	7.93
Copper, total	11	11.6	9.96
Lead, total	11.5	13.7	10.4
Nickel, total	12.8	24.1	19.7
OTHERS	(ALL ND OR <CRL)		
GENERAL TESTS			
Oil and Grease	93	18	ND

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

4.14.2.1 Geophysical Surveys

Electromagnetic Conductivity

An EM-34 electromagnetic conductivity survey was conducted near the Area 14 above-ground fuel storage tanks. The survey area covered an approximately 200 x 200 feet area directly south of the above ground tanks. Vertical and horizontal dipole terrain conductivity surveys were completed using a 10-meter coil separation.

Background values in the vertical dipole mode ranged from 20 mmhos/m to approximately 40 mmhos/m. Higher than background readings were detected along the western and southern perimeter and can be attributed to the all-metal barbed wire fence surrounding the area. However, one area of higher readings stands apart from the fence. In the vicinity of coordinates 175N, 150W and 175N, 100W, twenty five feet away from the influence of the fence, readings of 56 and 84 mmhos/m were recorded.

In the case of the horizontal dipole readings, background values ranged from approximately 21 to 40 mmhos/m. Once again, higher readings recorded around the perimeter can be attributed to the barbed wire fence. However, readings of 54 and 50 mmhos/m were recorded at coordinates 175N, 150W and 175N, 100W, respectively. This location is concurrent with the vertical dipole measurements for that location. No other anomalies were encountered within the study area. The location of the magnetic anomalies coincides with the approximate location of the sludge disposal location of Area 14B.

Ground-Penetrating Radar

A ground-penetrating radar survey was conducted in conjunction with the EM-34 survey. Disturbed strata or reflective soils were detected in the northwest corner of the study area, and, like the EM-34 results, coincide with the location of the sludge disposal portion of Area 14B. The area can be approximated to the coordinates 180N, 200W; 175N, 130W; 145N, 130W and 130N; 200W. This area is approximately 70 x 50 feet lying in the northwest corner of the study area. North-south and east-west oriented traverses were conducted over the entire area and no other anomalies were detected.

4.14.2.2 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 14, identified the explosive compound cyclonite (RDX). This compound was identified only during the second round of groundwater sampling, at well location 14-4 at a concentration of 9.38 ug/l.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at area 14 did not identify any VOCs.

Base Neutral and Acid Extractable Compounds

B2EHP was identified during the first round of sampling in all four groundwater samples collected from Area 14. The laboratory method blank associated with samples 14-2-1, 14-3-1, and 14-4-1 also identified B2EHP. Because the concentrations in the investigative samples are less than ten times the concentrations in the blanks, it is assumed that the compound is not present in the groundwater at these three well locations. Since B2EHP is a common field contaminant, its detection in sample 14-1-1 is probably not representative of actual groundwater quality.

Unknown BNA compounds were detected in samples from all four monitoring wells at Area 14. Concentrations ranged from 10 to 60 ug/l. Detections occurred in both rounds of sampling.

Inorganics

The results of the two rounds of groundwater sampling at Area 14 identified nine inorganics which exceeded statistical background concentrations and three inorganics which exceeded the MGS, MDWS, and/or MCL. Table 4-30 summarizes the inorganic parameters which were determined to be statistically above background concentrations and includes the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in Table 4-30. The parameters which exceeded the MGS, MDWS and/or MCL are discussed in the following paragraphs.

Total cadmium exceeded the MCL of 5 ug/l in downgradient sample 14-2-2 with a detection of 9.67 ug/l. Total cadmium exceeded the MDWS of 10 ug/l in upgradient sample 14-1-1 with a detection of 27.1 ug/l.

Total chromium exceeded the MDWS of 50 ug/l in downgradient sample 14-3-1 with a detection of 57.7 ug/l. Total chromium exceeded the MCL of 100 ug/l in downgradient samples 14-2-1 and 14-4-1 with respective concentrations of 162 and 160 ug/l.

Total selenium exceeded the MDWS of 10 ug/l in upgradient sample 14-1-1 with a detection of 24.2 ug/l. No selenium was detected exceeding the MCL of 50 ug/l at Area 14.

TABLE 4-30
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 14 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	STANDARD (MGS, MDWS, or MCL) (ug/l)
Arsenic, total	14-2-1, 14-2-2, 14-4-1	6.94 - 21.5	14-2-1	--
Barium, dissolved	14-1-2, 14-2-2, 14-4-2	322 - 538	14-2-2	--
Beryllium, dissolved	14-4-1	0.17	14-4-1	--
Beryllium, total	14-4-1	1.24	14-4-1	--
Cadmium, total	*14-1-1, *14-2-2	9.67 - 27.1	*14-1-1	5.00
Chromium, total	*14-2-1, *14-3-1, *14-4-1	57.7 - 162	*14-2-1	50.00
Copper, dissolved	14-1-1, 14-2-1, 14-3-1, 14-4-1, 14-4-2	2.47 - 5.68	14-4-2	1000.00
Nickel, dissolved	14-1-1, 14-1-2, 14-2-1, 14-2-2, 14-3-1, 14-4-2	10.3 - 42.7	14-2-2	200.00
Nickel, total	14-2-1	101	14-2-1	200.00
Selenium, total	*14-1-1	24.2	*14-1-1	10.00
Zinc, dissolved	14-1-1, 14-2-1, 14-4-1	321 - 878	14-4-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.

Radiation Parameters

Two samples were taken from well 14-4. The results are in the normal range of groundwater activity. A further discussion of the plantside radiological results are presented in Section 4.23.

4.14.2.3 Subsurface Soil

Explosives

There were no detections of explosive compounds in the three soil boring samples collected at Area 14.

Oil and Grease

The soil boring at Area 14 detected oil and grease in the two uppermost samples. The 1 to 2.5-foot sample showed 93.2 ug/g of oil and grease. The 6 to 7.5-foot sample showed 17.9 ug/g of oil and grease.

Inorganics

The soil boring at Area 14 identified four inorganics which exceeded statistical background concentrations.

Arsenic exceeded the statistical concentrations in all three samples. The 1 to 2.5-foot sample detected a concentration of 34.6 ug/g. The 6 to 7.5-foot sample detected a concentration of 180 ug/g. The 8.5 to 10-foot sample detected a concentration of 130 ug/g.

Barium exceeded the statistical concentration in all three samples, with detections ranging from 534 to 972 ug/g.

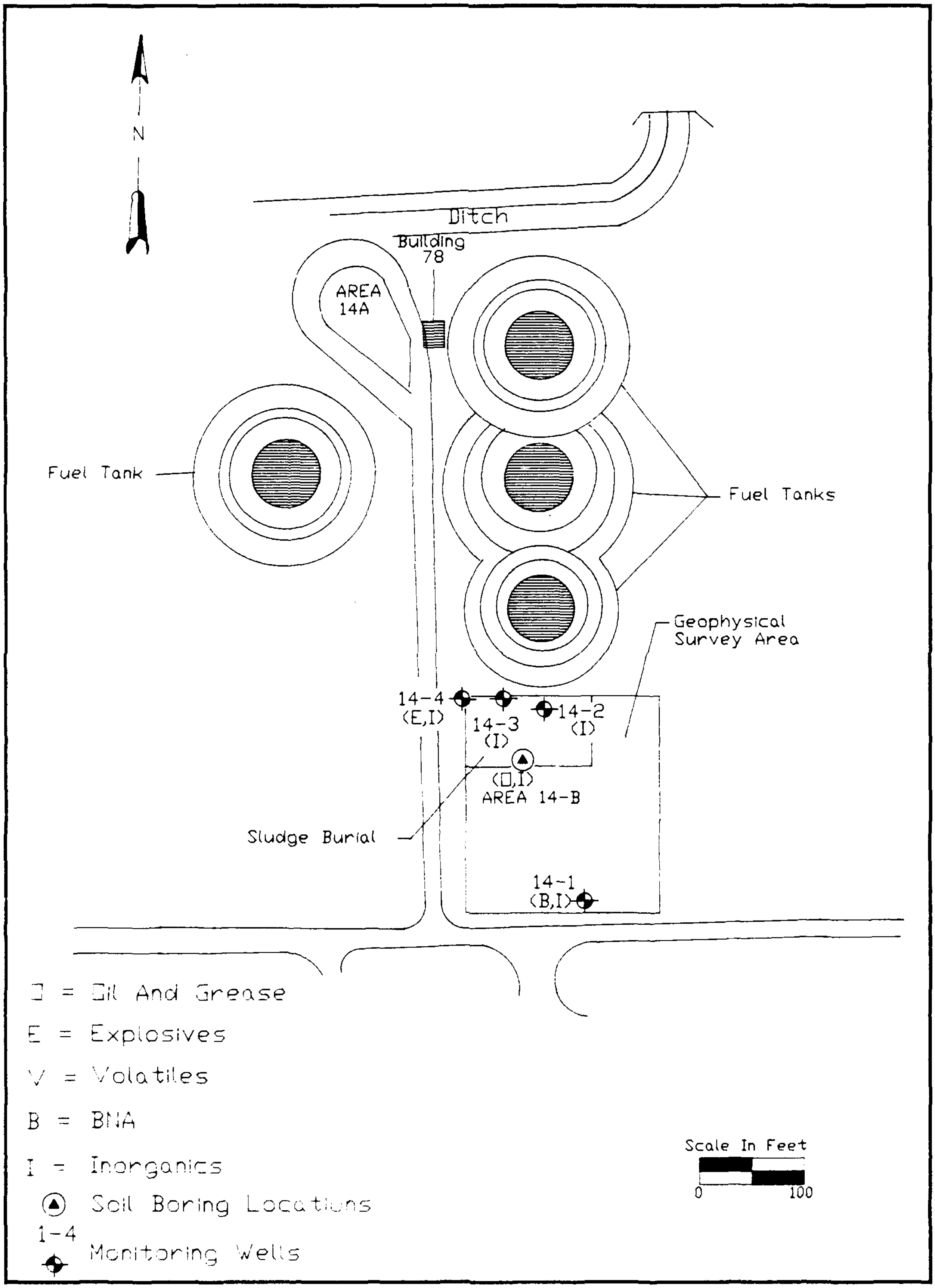
Cadmium exceeded statistical concentrations in the lower two samples with identical detections of 7.93 ug/g.

Lead narrowly exceeded statistical background levels in the 6 to 7.5-foot sample with a detection of 13.7 ug/g.

4.14.3 Summary

Site-related detections of organic and inorganic parameters were identified at all four monitoring well locations and the soil boring location within Area 14. Figure 4-31 presents the sampling locations and summarizes the distribution of elevated detections.

One explosive compound (RDX) was identified in the groundwater at Area 14, during the second round of sampling at monitoring well location 14-4. Well 14-4 is immediately downgradient of the sludge disposal location of Area 14B, which may be the source of this single detection. The analytical results of the soil boring sample



AREA14CO

FIGURE 4-31
AREA 14 DETECTION LOCATIONS

did not identify any explosive compounds. Another possible source may be the Building 3 sump and storm sewer system.

Some unknown BNA compounds were detected in the groundwater at very low concentrations; however, neither VOC nor BNA compounds have impacted groundwater or soil chemistry at Area 14.

Inorganics exceeded statistical background concentrations at each sampling location within Area 14. Additionally, some monitoring wells contained concentrations exceeding MGS, MDWS, and/or MCL values. Cadmium and selenium were identified at elevated concentrations at upgradient well location 14-1, which suggests an upgradient source. Other inorganics (arsenic and chromium) show increased concentrations in the groundwater downgradient of Area 14B, which indicates that the sludge burial area is contributing some inorganic contamination to the groundwater.

Oil and grease were identified in soil boring samples at the sludge burial location down to a depth of 7.5 feet.

Arsenic, barium, cadmium, and lead were identified at the soil boring location at statistically above background concentrations. The high arsenic concentration at the sludge burial location may correspond directly with detections in groundwater downgradient of Area 14B.

Radiation activity in Area 14 groundwater was within normal ranges.

4.15 <u>AREA 15 - TEMPORARY SURFACE IMPOUNDMENT</u>

4.15.1 <u>Site Description and Field Investigation</u>

4.15.1.1 Area 15A - Temporary Surface Impoundment

Area 15A, shown in Figure 4-27, is an approximately 50- by 50-foot surface impoundment designed to temporarily hold wastes from Buildings 35, 90C, and 90D during lift station pump repairs. The impoundment was constructed in the 1970s. Its use was discontinued prior to 1980.

The estimated area is 900 square feet and the quantity of waste is minimal. Wastes were K044 and K046. Hazardous constituents are lead, barium, and antimony.

Area 15A is overgrown with tall grass and weeds. The side embankments of the impoundment are still evident.

At Area 15A, two soil borings were drilled to 5 feet within the impoundment. Four subsurface soil samples, two from each boring, were collected and analyzed. The soil samples were composited between 0 to 2.5 feet and from 2.5 to 5.0 feet. These samples were taken to characterize the potential soil contamination present at the temporary surface impoundment. Because no cover material was placed over the impoundment, the 0 to 2.5-foot soil sample has the highest potential for contamination. The 2.5- to 5.0-foot sample was taken to identify whether vertical migration of contaminants had occurred. Figure 4-27 shows the locations of each soil boring. The soils were analyzed for inorganics, explosives, and oil and grease. No monitoring wells currently exist at Area 15.

4.15.1.2 Area 15B - Lift Station

This site is a concrete lift station used to transfer wastes generated in Building 35 and the 90 series buildings to the IWTP. The listed hazardous waste, K046 from the 90 series buildings, is pumped through this station. Hazardous constituents are lead, barium, and antimony.

No field investigation activities were conducted at Area 15B. Future investigations may be conducted if the findings produced during this work phase or information from other sources indicate such a need.

4.15.2 Site Investigation Results

The results of the site investigation at Area 15 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.15.3). All organic and inorganic analytical data is presented in Table 4-31. The sample designations refer to area number first, followed by sample number. Both soil boring samples were collected during round 1 and the last number of each sample designation refers to its relative depth.

4.15.2.1 Subsurface Soil

Explosives

No explosive compounds were identified in the four soil boring samples collected at Area 15.

Oil and Grease

There was one detection of oil and grease in the four soil samples collected at Area 15. Boring SB15-1 detected 129 ug/g of oil and grease in the 0- to 2.5-foot sample.

Inorganics

The results of the four soil boring samples identified at Area 15 identified seven inorganics which exceeded statistical background

TABLE 4-31
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #15
SUMMARY OF ANALYTICAL DATA
SUBSURFACE SOIL SAMPLES (UG/G)

SITE ID	SB15-1-1	SB15-1-2	SB15-2-1	SB15-2-2
DEPTH (FT)	2.5	5	2.5	5
VOLATILES				
ALL	(ALL NA)			
BASE NEUTRAL & ACID EXTRACTABLES				
ALL	(ALL NA)			
EXPLOSIVE COMPOUNDS				
ALL	(ALL ND OR <CRL)			
INORGANICS				
Antimony, total	140	<25.30	<25.30	<25.30
Arsenic, total	34.2	29.8	15.5	25
Barium, total	9840	5310	1740	625
Beryllium, total	0.35	0.38	<0.33	0.42
Cadmium, total	7.93	9.25	6.44	7.93
Copper, total	110	<3.82	43.7	14.5
Lead, total	2200	500	230	27.8
Nickel, total	17.5	21	20.2	21.7
Zinc, total	97.3	85.8	<52.00	<52.00
OTHERS	(ALL ND OR <CRL)			
GENERAL TESTS				
Oil and Grease	130	ND	ND	ND

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

concentrations. The detections are discussed in the following paragraphs.

Antimony was detected in the 0- to 2.5-foot sample of soil boring SB15-1 at a concentration of 140 ug/g.

Arsenic was detected in all four samples, at concentrations ranging from 15.5 to 34.2 ug/g.

Beryllium was detected in the 2.5 to 5.0-foot sample of soil boring SB15-2 at a concentration of 0.42 ug/g.

Cadmium was detected in all four samples at concentrations ranging from 6.44 to 9.25 ug/g.

Lead was detected in the 0 to 2.5-foot sample of SB15-1 at a high concentration of 2200 ug/g. The 2.5- to 5.0-foot sample detected 500 ug/g of lead. The 0 to 2.5-foot sample of SB15-2 detected 23.0 ug/g of lead and the 2.5 to 5-foot sample detected 27.8 ug/g.

Copper showed one detection, 58.0 ug/g in the 0 to 2.5-foot sample of soil boring SB15-1.

Barium was detected in the 0 to 2.5 and 2.5 to 5-foot samples of SB15-1 at respective concentrations of 9840 and 5310 ug/g. In samples SB15-2 at the 0 to 2.5 and 2.5 to 5-foot intervals, barium was detected at 1740 and 625 ug/g, respectively.

4.15.3 Summary

Potentially site-related detections of oil and grease and inorganic parameters were identified in the soil borings performed at Area 15A. Figure 4-28 presents the sampling locations and summarizes the distribution of elevated detections.

Analytical results indicate that the past storage of wastes at the Area 15A surface impoundment has impacted the soil chemistry with elevated levels of inorganics and some oil and grease. Oil and grease were identified near the surface at one soil boring location. Elevated inorganic parameters consisted of antimony, arsenic, and lead, which were found at concentrations ranging from 34.2 to 2100 ug/g. These inorganics have the potential to infiltrate to the water table and impact groundwater quality.

4.16 AREA 16 - ABANDONED LANDFILL

4.16.1 Site Description and Field Investigation

4.16.1.1 Area 16A - Abandoned Landfill

Area 16A is an abandoned sanitary landfill that accepted IWTP fly ash from the demilitarization operations in Buildings 13 and 97, grease and oil, scrap wood, paper, flooring from production buildings, industrial material contaminated with explosives, and solvents (Figure 4-23). Land disposal at this site began approximately in 1952, as observed from the EPIC aerial photographs. The site was approved for use as a scrap wood and paper landfill by the Missouri Geologic Survey in 1970 and official operation began in 1971. For the first several years, the landfill received only demolition type waste, but subsequently received industrial type waste. Land disposal methods included the excavation of trenches and then filling them with waste. Landfill operation at the site ended in approximately 1979. The estimated area is 390,000 square feet, and the quantity of waste is unknown. Possible RCRA hazardous constituents include lead, mercury, and barium. Depleted uranium waste may have also been disposed in the landfill.

Currently, the abandoned landfill is well-vegetated, but erosion has occurred at several areas. Several leachate seeps have been identified at the landfill. Of these, an active seep was sampled along with four leachate sediment locations. Analytical results from the leachate waste samples had previously indicated detectable levels of VOCs, BNAs, and explosives. The leachate sediment samples previously indicated detectable levels of explosives.

In order to delineate the boundaries of the landfill (Area 16A) and trench (Area 16B), an electromagnetic terrain conductivity survey was used. The EM-34 survey was carried out over the southern portion of the site at a 50-foot grid spacing. Also, three traverses were continued north toward the road at a 50-foot grid spacing in order to determine whether waste may have been disposed within this area. Historical photos show that this area was disturbed in the early 1960s, but do not indicate that waste was landfilled. Figure 4-32 shows the abandoned landfill where the EM-34 survey was conducted. This entire area required approximately 310 recording stations and covered approximately 12.5 acres. GPR was not used since the depth of radar penetration into the landfill was not expected to be more than a few feet due to the nature of the waste materials.

Five monitoring wells existed around the landfill prior to the initiation of this study. Of these, well 16-2 previously detected concentrations of 21,000 ppb of 1,2-dichloroethene and 2,200 ppb of trichloroethene. Five deep monitoring wells and three shallow monitoring wells were installed during this RI. Figure 4-23 shows the locations of the monitoring well network. The deep wells were drilled to bedrock at depths ranging from 31 to 89 feet (well 16-12 was screened within the shale bedrock unit to a depth of 31 feet). The shallow wells were drilled to the upper aquifer at depths between 18 and 29 feet deep. Deep well 16-10 was clustered next to existing well 16-2, and deep well 16-11 was clustered next to 16-4. These two-well clusters monitor the groundwater at the water table and the base of the aquifer immediately downgradient of the landfill. They also provide information regarding the vertical gradients. Two single wells were installed downgradient of the abandoned trench and landfill. These wells monitor the upper portion of the aquifer and assess whether potential contaminants are migrating from the trench. Well 16-12 is screened about six feet below the water table and well 16-13 is screened at the water table surface. Two-well clusters were also installed further downgradient from the trench and landfill. One of the two-well clusters was located along the road west of the landfill (16-8 and 16-9). The remaining two-well cluster was located along Ditch B west of the landfill (16-6 and 16-7). Both clusters provide groundwater chemistry data for the upper and lower portions of the outwash sand and gravel aquifer so the extent of groundwater contamination can be assessed and any potential for off base migration of groundwater contamination can be examined. The wells also provide information regarding the vertical gradients. All monitoring wells in Area 16, except 16-1, were sampled twice. The groundwater samples were analyzed for VOCs, BNAs, inorganics (total and dissolved), and explosives. Well 16-1 is located upgradient of Area 16A. A groundwater sample for 16-1 was analyzed for the listed parameters during the first round of sampling, but contained an insufficient volume of water to be sampled during round two. The two sampling events were separated by a three-month interval. Radiological parameters were analyzed in well 16-2 during round two. Table B-2 in Appendix B describes the screened intervals for all sampled monitoring wells within Area 16.

Also at this area, four surface water and four sediment samples were collected, as shown in Figure 4-23. The surface water was analyzed for VOCs, BNAs, inorganics, and explosives. Radiological parameters (gross alpha activity, gross beta activity, and U-234, U-235, and U-238 activities) were also measured. Samples SW16-4 and DS16-4 were taken approximately where the active seep was first visible, just below the landfill. Three other sets of surface water/sediment samples were collected from a small creek that flows between Areas 16 and 17. Samples SW16-5 and DS16-5 were collected from the upstream portion northeast of the burning grounds and samples SW16-3 and DS16-3 were collected due north of the abandoned sanitary landfill. Samples SW16-2 and DS16-2 were collected from the creek as it flows to the northwest downgradient of the landfill area. The 16-5 location is actually situated within Area 17.

4.16.1.2 Area 16B - Abandoned Trench

Located southwest of the landfill is a closed trench that was probably filled with the same type of wastes accepted by the landfill. The trench was active during the mid-1950s. It has been designated as Area 16B.

A radiological survey was conducted at the abandoned trench located at Area 16B. The survey was performed through the use of a Geiger-Mueller radiation meter, which is able to detect alpha and/or beta radiation. There was an expected potential for low-level radiation at the abandoned trench due to disposal of depleted uranium.

4.16.1.3 Area 16C - Waste Burial

A variety of wastes were buried in Area 16C, including fluorescent tubes, oil, grease, bleach cans, and paint cans. Burial occurred along both sides of the road leading to the burning grounds. This operation was discontinued in 1970.

Monitoring well 16-2 was previously the only well to monitor the shallow groundwater downgradient from this area. This well had previously detected 21,000 ppb of 1,2-dichloroethene and 2,200 ppb of TRCLE.

The development of the field investigation for Area 16A included Area 16C. As discussed in Subsection 4.16.1, a deep monitoring well was clustered next to existing well 16-2. This well (16-10) monitors the water quality at the base of the unconsolidated unit and provides information regarding the vertical gradients through the saturated unit. Also, the two-well cluster installed along the road directly northwest of the landfill (16-8 and 16-9) monitors the potential extent of groundwater contamination for both the upper and lower portions of the saturated unit.

4.16.1.4 Area 16D - Paint and Solvent Waste Storage Facility

A paint and solvent storage facility was previously operated at this site. Olin Corporation prepared closure plans for the facility in 1986 (simultaneous with the waste oil and solvent storage facility closure plan). Surficial soil samples from each facility were analyzed at that time. The paint and solvent storage facility soils were reported to be contaminated by cadmium, chromium, lead, nickel, lead chromate, acetone, dibutyl phthalate, isobutyl alcohol, and toluene. Ethyl acetate, 2-butanone (MEK), and naphtha were also detected. Recommendations of the closure plan were to remove and properly dispose contaminated soils at a licensed hazardous waste disposal facility and to resample and reanalyze remaining soils within the storage facility to determine whether additional removal and disposal is necessary. The removal action has been suspended, and the site is being studied in conjunction with the abandoned landfill (Area 16A).

The development of the field investigation for Area 16A included Area 16D. To monitor the potential groundwater contamination from Area 16D, the deep well 16-10 was clustered next to existing well 16-2 to monitor the downgradient deep portion of the aquifer, and the two-well cluster (16-8 and 16-9) was installed downgradient of the landfill. Also, surface water and sediment samples (which are also discussed in Subsection 4.17.1) were collected along the creek that is adjacent to Area 16D. As noted for Area 16A, two rounds of groundwater sampling were conducted, separated by a three-month interval. The surface water and sediment samples were collected during round one. All groundwater sediment and surface water samples were analyzed for VOCs, BNA, inorganics, and explosives.

4.16.1.5 Area 16E - Solvent and Oil Waste Tanks

This site contained aboveground tanks for storing waste solvents and waste recyclable oil. One tank was used for solvents and four tanks were used for oil. The hazardous waste in this area was D001. Hazardous constituents were TRCLE and 111TCE. The area is 40 feet by 75 feet. These tanks were removed from this site in 1983. Olin prepared closure plans for this facility in 1986, but the implementation of closure has been suspended, and the site is being studied in conjunction with the abandoned landfill (Area 16A).

The development of the field investigation for the Area 16A abandoned landfill included the solvent and oil waste tanks in Area 16E. As discussed in Subsection 4.16.1, the purpose of monitoring well 16-12 downgradient of the abandoned trench is to assess the potential groundwater contamination from the Area 16B trench and also from the Area 16E solvent and oil waste tanks.

4.16.1.6 Area 16F - Old Firing Range

A firing range existed south of Buckner Road, off the old landfill access road. The range was present in the 1952, 1957, and 1963 EPIC photographs. The 1969 photograph showed that the range had been removed. The firing range was observed to have World War II vintage small arms casings distributed in surficial soils about the range and lead bullets within the backstop. A natural clay hill, apparently utilized as a backstop, was observed.

No field investigations were conducted in Area 16F during this phase of work. Future investigations may be conducted if the findings during this work phase or information from other sources indicate such a need.

4.16.1.7 Area 16G - Burning Ground

An explosives burning ground covered approximately 16,000 square feet. The burning operations conducted here were the same as the operations conducted on the present demolition burning grounds at

Area 11. It was closed in the mid-1950s. The quantity of waste is unknown. Possible RCRA hazardous constituents are lead and barium. No field investigation activities were performed for this area.

4.16.2 Site Investigation Results

The results of this site investigation at Area 16 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.16.3). All radiological, organic and inorganic analytical data is presented in Table 4-32. The sample designations refer to area number first, followed by well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.16.2.1 Geophysical Survey

Electromagnetic Conductivity

The results of the EM-34 terrain conductivity survey at Area 16A and 16B past disposal areas showed several areas of interest with detected higher than normal conductivity readings. Background terrain conductivity values in the vertical dipole averaged between 20 and 45 mmhos/m throughout the study area. Five major areas and several smaller anomalies contained readings significantly above background to warrant discussion. The areas are labeled I through V for the purpose of discussion and are shown in Figure 4-32.

Area I, roughly 150 by 100 feet and surrounding a strong negative reading (>300 mmhos/m), is defined approximately by coordinates 350S, 350W; 400S, 200W and 475S, 325W. Negative readings occur when the instrument detects a very high reading above the scale of the instrument. In effect the instrument is overwhelmed by significant magnetic properties within its sensing zone and the needle records negative. This area is east of the gravel access road approximately 550 feet from the entrance gate. It coincides with the former trenched area.

Area II, a slightly larger area yielding readings from 50 mmhos/m to a high value of 309 mmhos/m, is contained roughly within the coordinates 500S, 50E; 550S, 125E; 675S, 75E; 675S, 100W; 625S, 175W; and 600S, 0W. This area is roughly 300 feet further up the road from Area I. The area is approximately 200 by 150 feet.

Area III, roughly 150 by 150 feet, yielding conductivity values between 25 to greater than 300 mmhos/m, is approximately bounded by the coordinates 350S, 200E; 475S, 150E; 475S, 275E; and 400S, 325E.

Area IV is roughly the same size as Area III, and yielded conductivity values ranging from 55 to greater than 300 mmhos/m. This area is roughly defined by coordinates 475S, 275E; 475S, 375E;

TABLE 4-32
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #16
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	16-1-1	16-2-1	16-2-2	16-3-1	16-3-2	16-4-1
DEPTH (FT)	23.5	19	19	19	19	27.5
VOLATILES						
1,1,1-Trichloroethane	ND	40	30	ND	ND	ND
1,1,2-Trichloroethane	ND	10	10	ND	ND	ND
1,1-Dichloroethane	<1.92	58	110	<1.92	<1.92	<1.92
1,2-Dichloroethane	ND	8	10	ND	ND	ND
1,1-Dichloroethene	ND	ND	60	ND	ND	ND
Benzene	<0.67	57	<0.67	<0.67	<0.67	<0.67
Carbon-Tetrachloride	ND	5	ND	ND	ND	ND
Ethylbenzene	ND	5	11	ND	ND	ND
Tetrachloroethene	ND	100	250	ND	ND	ND
Toluene	<1.57	5	<1.57	<1.57	<1.57	<1.57
Trans-1,2-Dichloroethene	<1.72	21000	<1.72	<1.72	<1.72	<1.72
Trichloroethene	<0.71	1700	<0.71	<0.71	<0.71	<0.71
UNKNOWNS						
C6-Cycloalkane	ND	ND	*30	ND	ND	ND
Ethanedioic Acid Ester [938]	ND	ND	20	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
1,2-Dichlorobenzene	ND	10	ND	ND	ND	ND
bis (2-Ethylhexyl) Phthalate	ND	ND	10	ND	ND	ND
UNKNOWNS						
1,14-Tetradecanediol [953]	ND	10	ND	ND	ND	ND
2-(2,6-Dimethyl(heptyl) Cyclobutanone [511]	ND	10	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
135-TNB	1.37	<0.56	<0.56	<0.56	<0.56	<0.56
HMX	7.4	<1.30	<1.30	<1.30	<1.30	<1.30
RDX	150	1.67	<0.63	<0.63	<0.63	1.84
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, dissolved	<5.00	<5.00	<5.00	<5.00	<5.00	6.63
Arsenic, total	21	<5.00	<5.00	<5.00	<5.00	9.01
Barium, dissolved	81.7	NA	301	173	172	NA
Barium, total	326	NA	224	163	153	NA
Beryllium, total	3.3	0.2	0.2	<0.10	<0.10	0.4
Cadmium, dissolved	6.44	<5.10	<5.10	<5.10	<5.10	<5.10
Chromium, total	58.7	<37.50	<37.50	<37.50	<37.50	<37.50
Copper, dissolved	<1.78	6.65	<1.78	<1.78	10.3	4.29
Copper, total	23.2	6.22	8.25	4.39	7.82	8.47
Lead, dissolved	<2.50	<2.50	5.66	2.53	<2.50	<2.50
Lead, total	45	4.75	16.2	<2.50	<2.50	5.06
Nickel, dissolved	65	30.4	<9.60	<9.60	17.5	<9.60
Nickel, total	146	25.2	<9.60	10.3	<9.60	59.5
Silver, total	0.32	<0.19	0.32	6.28	<0.19	<0.19
Zinc, dissolved	112	1500	56.3	700	131	800
Zinc, total	462	820	30.1	157	32.8	1100
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCI/L)						
Alpha	NA	NA	12+/-9	NA	NA	NA
Beta	NA	NA	46+/-6	NA	NA	NA
U-234	NA	NA	1.6+/-0.3	NA	NA	NA
U-235	NA	NA	0+/-0.1	NA	NA	NA
U-238	NA	NA	1.5+/-0.3	NA	NA	NA
Total Uranium	NA	NA	NA	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-32
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #16
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	16-4-2	16-5-1	16-5-2	16-6-1	16-6-2	16-7-1
DEPTH (FT)	27.5	19	19	84	84	24
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
Bis-2-Ethylhexphthalate	ND	ND	336	ND	ND	ND
UNKNOWNS						
1,13-Tetradecadiene [995]	ND	200	ND	ND	ND	ND
C9-C14 Alkane Glycol	ND	ND	ND	*10	ND	ND
C6-C8 Butoxy Alcohol	ND	ND	ND	*10	ND	ND
1,14-Tetradecanediol [995]	ND	ND	ND	ND	ND	70
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	<0.63	<0.63	<0.63	5.11	27	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, dissolved	<3.00	44.1	<3.00	<3.00	<3.00	<3.00
Arsenic, dissolved	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Arsenic, total	<5.00	<5.00	<5.00	<5.00	<5.00	8.28
Barium, dissolved	361	123	346	NA	370	NA
Barium, total	273	149	228	NA	264	NA
Beryllium, total	<0.10	1.41	<0.10	<0.10	<0.10	3.12
Chromium, total	<37.50	58.7	<37.50	<37.50	<37.50	<37.50
Copper, dissolved	3.97	8.04	<1.78	4.18	<1.78	<1.78
Copper, total	4.61	18.6	<1.78	14.6	13.9	20.7
Lead, dissolved	<2.50	2.83	<2.50	<2.50	<2.50	<2.50
Lead, total	<2.50	9.5	<2.50	11.6	<2.50	3.94
Nickel, dissolved	<9.60	<9.60	<9.60	76.6	<9.60	15.6
Nickel, total	<9.60	41.1	30.3	23.6	<9.60	46.9
Silver, dissolved	<0.19	0.21	<0.19	<0.19	<0.19	0.21
Zinc, dissolved	<17.20	1500	<17.20	1100	70.4	980
Zinc, total	24.4	2200	141	1100	86.4	970
OTHERS	(ALL ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-32
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #16
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	16-7-2	16-8-1	16-8-2	16-9-1	16-9-2	16-10-1
DEPTH (FT)	24	17	17	43	43	57.5
VOLATILES						
Tetrachloroethene	ND	ND	ND	ND	ND	20
OTHERS			(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES						
UNKNOWNS						
C6-C9 Cycloalkane	ND	ND	*20	ND	*20	ND
C8-C10 Methyl Alkene/Alkane	ND	ND	*20	ND	*10	ND
C10-Organic Acid Derivative	ND	ND	ND	ND	ND	*10
N-Methyl-N-(1-Oxododecyl)Glycine [996]	ND	ND	ND	ND	ND	40
C9-C14 Alkane Glycol	ND	ND	ND	ND	ND	*30
OTHERS			(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS						
13-DNB	0.73	<0.61	<0.61	<0.61	<0.61	<0.61
NB	<1.13	<1.13	<1.13	<1.13	<1.13	1.45
RDX	<0.63	<0.63	<0.63	1.26	<0.63	2.71
OTHERS			(ALL ND OR <CRL)			
INORGANICS						
Arsenic, dissolved	5.28	<5.00	<5.00	<5.00	<5.00	5.49
Arsenic, total	5.49	<5.00	6	<5.00	<5.00	<5.00
Barium, dissolved	402	NA	119	NA	NA	65.8
Barium, total	333	NA	247	NA	118	NA
Beryllium, total	<0.10	0.81	0.4	0.2	<0.10	<0.10
Copper, dissolved	<1.78	4.39	<1.78	9.22	<1.78	6.97
Copper, total	6.86	19.7	15.1	10.5	5.89	17.6
Lead, total	<2.50	5.26	7.38	3.64	<2.50	2.83
Nickel, dissolved	9.9	<9.60	23.2	<9.60	<9.60	16.6
Nickel, total	81.1	41.6	38.3	18	12.4	9.85
Silver, total	0.21	<0.19	0.53	<0.19	0.21	<0.19
Zinc, dissolved	82.8	1200	45.1	960	<17.20	1200
Zinc, total	182	1000	154	970	97.9	890
OTHERS			(ALL ND OR <CRL)			

CRL = CERTIFIED REPORTING LIMIT ND = NOT DETECTED NA = NOT ANALYZED

* NOTES A GREATER THAN 90% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-32
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #16
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	16-10-2 57.5	16-11-1 56	16-11-2 56	16-12-1 25	16-12-2 25	16-13-1 24.5	16-13-2 24.5
VOLATILES							
Benzene	6.57	ND	ND	ND	ND	ND	ND
Trans-1, 2-Dichloroethene	<1.72	<1.72	<1.72	1.8	<1.72	2.7	<1.72
Vinyl Chloride	<3.86	<3.86	<3.86	<3.86	<3.86	5.1	<3.86
Trichloroethene	14.6	ND	13.6	ND	ND	ND	ND
Tetrachloroethane	ND	ND	10	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)						
BASE NEUTRAL & ACID EXTRACTABLES							
Dimethyl-Phthalate	ND	ND	ND	ND	ND	5	ND
UNKNOWNS							
C9-C14 Alkane Glycol	ND	ND	ND	ND	*10	ND	ND
C6-C9 Cycloalkane	ND	ND	ND	ND	ND	ND	*20
C8-C10 Methyl Alkene/Alkane	ND	ND	ND	ND	ND	ND	*10
C6-C14 Ketone	ND	ND	ND	ND	ND	ND	*20
Methyl Benzamide Ester	ND	ND	ND	ND	ND	ND	*10
Alkyl Benzene	ND	ND	ND	ND	ND	ND	*20
1,1,2,2-Tetrachloethane	ND	ND	*90	ND	ND	ND	ND
C14-C44 Hydrocarbon	ND	ND	*30	ND	ND	ND	ND
C15-C44 Trimethylalkane	ND	ND	*20	ND	ND	ND	ND
(Phenylene) bis-ethanone Ester	ND	ND	*40	ND	ND	ND	ND
Methylethyl Ethanone Derivative	ND	ND	*50	ND	ND	ND	ND
C17-C19 Cyclohexyl Alkane	ND	ND	*10	ND	ND	ND	ND
Benzenedicarboxylic Acid Ester	ND	ND	*10	ND	ND	ND	ND
Methylethyl Ethanone Derivative	ND	ND	*30	ND	ND	ND	ND
C6-C36 Hydrocarbon	ND	ND	*50	ND	ND	ND	ND
C13-C21 Hydrocarbon	ND	ND	*30	ND	ND	ND	ND
Phthalate	ND	ND	*20	ND	ND	ND	ND
6-propyl-Tridecane [752]	ND	ND	20	ND	ND	ND	ND
Hexatriacontane [760]	ND	ND	20	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)						
EXPLOSIVE COMPOUNDS							
ALL	(ALL ND OR <CRL)						
INORGANICS							
Arsenic, dissolved	<5.00	<5.00	5.69	<5.00	<5.00	<5.00	<5.00
Arsenic, total	<5.00	14.3	6.73	<5.00	<5.00	<5.00	<5.00
Barium, dissolved	65.8	NA	NA	NA	581	NA	597
Barium, total	NA	NA	340	NA	885	NA	548
Beryllium, total	<0.10	<0.10	1.51	3.12	1.51	0.3	<0.10
Copper, dissolved	<1.78	<1.78	<1.78	3	<1.78	3	<1.78
Copper, total	9.65	14.6	37.2	51.8	61	5.68	8.9
Lead, dissolved	<2.50	<2.50	<2.50	<2.50	5.36	<2.50	3.64
Lead, total	<2.50	<2.50	[illegible]	2.73	2.63	<2.50	<2.50
Nickel, dissolved	<9.60	<9.60	<9.60	22.5	<9.60	<9.60	<9.60
Nickel, total	<9.60	26	74.6	52	123	<9.60	13.7
Silver, total	<0.19	0.53	<0.19	<0.19	<0.19	<0.19	<0.19
Zinc, dissolved	<17.20	<17.20	<17.20	1500	<17.20	630	41.3
Zinc, total	63.7	27.9	209	170	261	1200	116
OTHERS	(ALL ND OR <CRL)						

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-32
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #16
SUMMARY OF ANALYTICAL DATA
DITCH SURFACE WATER SAMPLES (UG/L)

SITE ID	SW16-2-1	SW16-3-1	SW16-4-1
VOLATILES			
1 1-Dichloroethane	ND	ND	30
Benzene	<0.67	<0.67	2.5
Chloroethane	ND	ND	40
Ethylbenzene	ND	ND	10
Methylene Chloride	ND	ND	40
Toluene	<1.57	<1.57	120
Trans-1,2-Dichloroethene	5	<1 72	17
Trichloroethene	2	<0.71	13
UNKNOWNS			
Acetone	ND	ND	*5000
4-Methyl-2-Pentanone	ND	ND	*400
C5-Ketone	ND	ND	*50
2-Hexanone	ND	ND	*50
C5-C6 Alkane	ND	ND	*10
C7-Ketone	ND	ND	*50
2-Methoxyethanamone [858]	ND	ND	*20
C8-C10 Methyl Ketone	ND	ND	*400
552+C6-C13 Oxygenated Hydrocarbon	ND	ND	*30
2,4-Dimethyl-1-Decene [944]	ND	ND	30
C5-Alcohol	ND	ND	*20
OTHERS	(ALL ND OR <CRL)		
BASE NEUTRAL & ACID EXTRACTABLES			
Phenol	ND	ND	2000
bis (2-Ethylhexyl) Phthalate	40	40	ND
UNKNOWNS			
2-Methyl-1Nitro Propane [967]	ND	ND	2000
C6-C8 Organic Acid Ester	ND	ND	*1000
C6-C9 Organic Acid Ester	ND	ND	*3000
Cyclohexane Carboxylic Acid Derivative	ND	ND	*1000
Dimethyl Cycloketone	ND	ND	*50000
C6-C8 Organic Acid Derivative	ND	ND	*20000
5-Methyl-1-Heptene [953]	ND	ND	7000
5-Methyl-1-Heptene [956]	ND	ND	6000
C6-C10 Propanol	ND	ND	*3000
C6-C10 Organic Acid Ester	ND	ND	*2000
C6-C7 Organic Acid Ester	ND	ND	*1000
OTHERS	(ALL ND OR <CRL)		
EXPLOSIVE COMPOUNDS			
135-TNB	<0.56	6.08	<0.56
OTHERS	(ALL ND OR <CRL)		
INORGANICS			
Beryllium, total	<0.10	<0.10	2.21
Copper, total	12.8	25.6	500
Lead, total	<2.50	6 88	140
Nickel, total	22.6	19.8	150
Silver, total	<0 19	<0 19	0.53
Zinc, total	312	339	2400
OTHERS	(ALL ND OR <CRL)		

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* DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-32
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #16
SUMMARY OF ANALYTICAL DATA
DITCH SEDIMENT SAMPLES (UG/G)

SITE ID	DS16-2-1	DS16-3-1	DS16-4-1	DS16-5-1
VOLATILES				
ALL	(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES				
Acenaphthene	ND	0.7	ND	ND
Anthracene	ND	1	ND	ND
Benzo (a) Anthracene	ND	3	3	ND
Benzo (a) Pyrene	ND	2	2	ND
Benzo (k) Fluoranthene	ND	ND	3	ND
Chrysene	ND	4	4	ND
Di-n-Butylphthalate	0.6	2	ND	ND
Fluoranthene	4	90	ND	ND
Fluorene	ND	0.6	ND	ND
Indeno (1,2,3-cd) Pyrene	ND	2	ND	ND
Napthalene	ND	ND	ND	10
Phenanthrene	ND	4	ND	ND
Pyrene	ND	5	ND	ND
UNKNOWNS				
Organic Acid Ester-1	ND	ND	*6	ND
Organic Acid Ester-2	ND	ND	*5	ND
C6-C7 Organic Acid Ester	ND	ND	*1	ND
C9-C10 Organic Acid Ester	ND	ND	*2	ND
C6-C12 Cyclo Amine	ND	ND	*2	ND
Benzoic Acid Ester	ND	*1	*1	ND
C5-C6 Organic Acid Ester	ND	ND	*5	ND
Indeno[1,2,3-CD] Pyrene [951]	ND	ND	1	ND
9H-Fluorene	ND	ND	*1	ND
Indeno[1,2,3-CD] Pyrene [960]	ND	ND	2	ND
C6-C8 Organic Acid Ester	ND	ND	*2	ND
Penanthrene	ND	ND	*5	ND
4H-Cyclo Penta[DEF] Phenanthrene	ND	ND	*1	ND
Pyrene [965]	ND	ND	5	ND
Pyrene [964]	ND	ND	5	ND
Hexanedioic Acid Ester	*6	*1	ND	ND
Unknown C5-C8	ND	ND	ND	10
Unknown	ND	ND	ND	2
OTHERS	(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS				
ALL	(ALL ND OR <CRL)			
INORGANICS				
Arsenic, total	26.9	47.1	25	<5.70
Barium, total	954	741	889	160
Beryllium, total	<0.33	0.44	<0.33	<0.33
Cadmium, total	10.6	33	<0.70	2.64
Chromium, total	<2.50	<2.50	<2.50	18.6
Copper, total	22	380	9.07	14.9
Lead, total	35.1	520	10.6	12.6
Nickel, total	20.2	16.7	14.4	17.7
Zinc, total	77.5	107	<52.00	<52.00
OTHERS	(ALL ND OR <CRL)			

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 90% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

600S, 400E; and 600S, 300E. Both areas III and IV lie in the south-central portion of the study area.

Area V, the largest area, encompasses approximately a 400 by 250 feet area and yielded values for terrain conductivity of 50 to 82 mmhos/m. The area can be described approximately by the coordinates 350S, 475E; 425S, 490E; 375S, 625E; 275S, 775E; 75S, 775E; 0, 760E; 0, 675E; 50S, 650E; 125S, 550E; and 275S, 550E. This area is located primarily over the abandoned sanitary landfill.

In addition to the five areas described above, five small point anomalies were noted. Two of the point anomalies possessed values significantly lower than background (10 to 12 mmhos/m) while the other three showed values higher than background, ranging from a low of 55 to greater than 300 mmhos/m. These five smaller areas are within a close proximity to Area V, the largest area, and can be considered anomalies caused by the abandoned landfill.

A horizontal dipole terrain conductivity survey was completed. Typical horizontal background terrain conductivity values for the study area ranged from 20 to 45 mmhos/m.

Three areas produced greater than background values. The first two areas described below coincide with the GPR anomalies shown in Figure 4-32. The first and smallest is located coincident with Area I and is approximated by coordinates 375S, 350W; 400S, 375W; 475S, 350W; and 400S, 275W. The area is approximately 100 by 100 feet in size. Terrain conductivity values within this area range from 53 to 61 mmhos/m.

The second area, approximately 300 by 200 feet, yielded terrain conductivity values ranging from 50 to a high of 75 mmhos/m. It is located in the south-central portion of the survey area and is approximated by coordinates 400S, 50E; 550S, 125W; 650S, 50W; 700S, 50W; 650S, 50E; 575S, 50E; and 475S, 125E.

The last and largest area comprised most of the south-central and southeast portions of the survey area, including Areas III and IV. It yielded terrain conductivity values between 50 and 145 mmhos/m. No ground-penetrating radar traverses were conducted in this area due to the high vegetation and uneven surface.

4.16.2.2 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 16 identified five explosive compounds:

- 13DNB.
- 135TNB.

- HMX.
- Nitrobenzene (NB).
- RDX.

The first round of groundwater sampling identified RDX at monitoring well locations 16-1, 16-2, 16-4, 16-6, 16-9, and 16-10 at respective concentrations of 150, 1.67, 1.84, 5.11, 1.26, and 2.71 ug/l. The explosive compounds 135TND and HMX were detected in well 16-1 at respective concentrations of 1.37 and 7.40 ug/l. The compound NB was detected at monitoring location 16-10 at a concentration of 1.45 ug/l.

The second round of groundwater sampling at Area 16 identified the explosive compound RDX at well location 16-6, at a concentration of 27.0 ug/l. The compound 13DNB was detected at monitoring well location 16-7 at a concentration of 0.73 ug/l.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at Area 16 identified 13 VOCs, seven of which exceeded MCLs:

- 111TCE.
- 1,1,2-trichloroethane (112TCE).
- 11DCE.
- 11DCLE.
- 12DCLE.
- Benzene.
- Carbon tetrachloride.
- Ethylbenzene.
- TCLEE.
- Toluene.
- T12DCE.
- TRCLE.
- Vinyl chloride.

The VOCs which exceeded MCLs during the first round are 11DCE, 12DCLE, benzene, carbon tetrachloride, TRCLE, T12DCE, and TCLEE. Downgradient well 16-2 detected 11 of the 13 VOCs; 111TCE at 40 ug/l, 112TCE at 10 ug/l, 11DCE at 58 ug/l, 12DCLE at 8 ug/l, benzene at 57 ug/l, carbon tetrachloride at 5 ug/l, ethylbenzene at 5 ug/l, TCLEE at 100 ug/l, toluene at 5.0 ug/l, T12DCE at 21,000 ug/l, and TRCLE at 1,700 ug/l. Downgradient well 16-10 detected TCLEE at 20 ug/l. Downgradient well 16-12 detected T12DCE at 1.8 ug/l. Downgradient well 16-13 detected T12DCE at 2.7 ug/l and vinyl chloride at 5.1 ug/l.

During the second round of sampling the VOCs which exceeded MCLs were 11DCE, TRCLE, and benzene. Downgradient well 16-2 detected 6 of the 13 VOCs; 111TCE at 30 ug/l, 112TCE at 10 ug/l, 11DCE at 60 ug/l, 11DCLE at 110 ug/l, ethylbenzene at 11 ug/l, and TRCLE at 250 ug/l. Downgradient well 16-10 detected benzene at 6.57 ug/l and

TRCLE at 10 ug/l. Downgradient well 16-11 detected TRCLE at 10 ug/l.

Two unknown VOC compounds were detected in the round 2 sample from monitoring well 16-2. Concentrations were 20 and 30 ug/l. No other unknown VOCs were identified.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 16 identified four BNA compounds:

- 1,2-dichlorobenzene.
- DNOP.
- Dimethyl phthalate.
- B2EHP.

During the first round of sampling, 1,2-dichlorobenzene was detected at downgradient well location 16-2 at a concentration of 10 ug/l. DNOP was detected at downgradient well locations 16-2, 16-12, and 16-13, all at a concentration of 2 ug/l. Dimethyl phthalate was detected at well location 16-13 at a concentration of 5.28 ug/l.

During the second round of sampling, B2EHP was detected at well locations 16-2 and 16-5 at respective concentrations of 10 and 300 ug/l.

Phthalate compounds are common field contaminants, and the inconsistent detections suggest that they may not be present in the groundwater at Area 16.

Unknown BNA compounds were detected in samples from ten different monitoring wells at Area 16. Wells 16-2 and 16-5 through 16-13 had concentrations ranging from 10 to 200 ug/l. Detections occurred in both rounds of sampling.

Inorganics

The results of the two rounds of groundwater sampling at Area 16 identified eleven inorganics which exceeded statistical background concentrations. Two of the eleven inorganics exceeded the MGS, MDWS and/or MCL. Wells which contained inorganics above a specified standard are flagged with an asterisk in Table 4-33. The parameters which exceeded the MGS, MDWS, and/or MCL are discussed in the following paragraphs.

Dissolved cadmium exceeded the MCL of 5 ug/l in well 16-1-1 with a detection of 6.44 ug/l. This well is upgradient of Area 16 but downgradient of Area 11.

TABLE 4-33
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 16 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Antimony, dissolved	16-5-1	44.1	16-5-1	--
Arsenic, dissolved	16-4-1, 16-7-1, 16-10-1, 16-11-2	5.28 - 6.63	16-4-1	30.00
Arsenic, total	16-1-1, 16-4-1, 16-7-1, 16-7-2, 16-8-2, 16-11-1, 16-11-2	5.49 - 21	16-1-1	30.00
Barium, dissolved	16-2-2, 16-4-2, 16-5-2, 16-6-2, 16 7-2, 16-12-2, 16-13-2	301 -597	16-13-2	--
Barium, total	16-12-2	885	16-12-2	5000.00
Beryllium, total	16-1-1, 16-5-1, 16-7-1, 16-11-2, 16-12-1, 16-12-2	1.41 - 3.3	16-1-1	--
Cadmium, dissolved	*16-1-1	6.44	*16-1-1	5.00
Chromium, total	*16-1-1, *16-5-1	58.7	*16-5-1, *16-1-1	50.00
Copper, dissolved	16-2-1, 16-3-2, 16-4-1, 16-4-2, 16-5-1, 16-6-1, 16-8-1, 16-9-1, 16-10-1, 16-12-1, 16-13-1	3 - 10.3	16-3-2	1000.00
Copper, total	16-12-1, 16-12-2	51.8 - 61	16-12-1	1000.00
Lead, dissolved	16-2-2, 16-12-2	5.36 - 5.66	16-2-2	50.00
Lead, total	16-1-1	45	16-1-1	50.00
Nickel, dissolved	16-1-1, 16-2-1, 16-3-2, 16-6-1 16-7-1, 16-7-2, 16-8-2, 16-10-1, 16-12-1	9.9 - 76.6	16-6-1	200.00
Nickel, total	16-1-1, 16-7-1, 16-11-2, 16-12-2	74.6 - 146	16-1-1	200.00
Silver, dissolved	16-5-1, 16-7-1	0.21	16-5-1, 16-7-1	50.00
Silver, total	16-1-1, 16-2-2, 16-3-1, 16-7-2 16-8-2, 16-9-2, 16-11-1	0.21 - 6.28	16-3-1	50.00
Zinc, dissolved	16-2-1, 16-3-1, 16-4-1, 16-5-1, 16-6-1, 16-7-1, 16-8-1, 16-9-1, 16-10-1, 16-12-1, 16-13-1	630 - 1500	16-2-1, 16-5-1, 16-12-1	5000.00
Zinc, total	16-4-1, 16-5-1, 16-6-1, 16-7-1, 16-8-1, 16-9-1, 16-10-1, 6-13-1	890 - 2200	16-5-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXIST.

Total chromium exceeded the MDWS of 50 ug/l in wells 16-1-1 and 16-5-1. Both samples detected total chromium at 58.7 ug/l. The MCL of 100 ug/l was not exceeded.

Radiation Parameters

Well 16-2 had the highest uranium activity of any well sampled at LCAAP during the RI. In addition, the alpha and beta activities were high. This well is immediately downgradient of a suspected uranium disposal area (Area 16A, Abandoned Landfill). Section 4.23 contains further discussions of the radiological results.

4.16.2.3 Surface Water

Explosives

The results of the surface water investigation at Area 16 identified one explosive compound: 135TNB. The compound was detected at sample location SW16-3 at a concentration of 6.08 ug/l.

Volatile Organic Compounds

The results of the surface water sampling at Area 16 identified seven VOCs from the leachate seep sample (SW16-4) at the following concentrations:

- 11DCLE, 30 ug/l.
- Benzene, 2.5 ug/l.
- Chloromethane, 40 ug/l.
- Ethylbenzene, 10 ug/l.
- Toluene, 120 ug/l.
- T12DCE, 17 ug/l.
- TRCLE, 13 ug/l.

The leachate seep sample also contained many unknown VOC compounds at very high concentrations. Eleven different detections were identified at concentrations ranging from 10 to 5,000 ug/l.

Downgradient creek sample SW16-2 identifed T12DCE and TRCLE at 5 and 2 ug/l, respectively.

Base Neutral and Acid Extractable Compounds

The results of the surface water sampling at Area 16 identified one BNA compound which is considered to be a site-related contaminant: phenol. The compound was detected in sample SW16-4 at a concentration of 2,000 ug/l. No other BNA compounds were identified other than B2EHP, a common field contaminant. B2EHP was detected at sample locations SW16-2 and SW16-3 at respective concentrations of 40 and 40 ug/l.

Numerous unknown BNA detections occurred in the leachate seep sample. Eleven different detections were identified at concentrations ranging from 1,000 to 50,000 ug/l.

Inorganics

The results of the surface water sampling at Area 16 identified six inorganics at concentrations exceeding background concentrations. One of the six inorganics (lead) also exceeded the MDWS and MCL value.

Lead exceeded the MDWS and MCL of 50 ug/l in the leachate seep sample 16-4 with a detection of 140 ug/l. The leachate seep contained other elevated inorganic concentrations, such as copper at 500 ug/l, nickel at 150 ug/l, silver at 0.53 ug/l, zinc at 2400 ug/l, and beryllium at 2.21 ug/l.

Creek sample locations 16-2 and 16-3 showed slightly elevated concentrations of copper, with respective concentrations of 12.8 and 25.6 ug/l. Nickel was detected at respective concentrations of 22.6 and 19.8 ug/L. Sample location 16-3 detected lead at a concentration of 6.88 ug/L.

4.16.2.4 Ditch Sediment

Explosives

There were no explosive compounds identified in the four sediment samples collected from Area 16.

Volatile Organic Compounds

There were no VOCs identified in the four sediment samples collected from Area 16.

Base Neutral and Acid Extractable Compounds

The results of the ditch sediment sampling at Area 16 identified 13 BNA compounds:

- Acenaphthene.
- Anthracene.
- Benzo(a)anthracene.
- Benzo(a)pyrene.
- Benzo(b)fluoranthene.
- Benzo(k)fluoranthene.
- Chrysene.
- Di-n-butylphthalate.
- Fluoranthene.
- Fluorene.
- Indeno(1,2,3-cd)pyrene.
- Naphthalene.

- Phenanthrene.
- Pyrene.

Creek sample location 16-2 detected DNOP and fluoranthene at respective concentrations of 0.6 and 4 ug/g.

Creek sample location 16-3 detected acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, di-n-butylphthalate, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene at consistently low concentrations ranging from 0.6 to 5 ug/g. Fluoranthene was detected at an elevated concentration of 90 ug/g.

Leachate sample location 16-4 detected benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthane, and chrysene at concentrations ranging from 2 to 4 ug/g.
Upgradient creek sample location 16-5 detected naphthalene at a concentration of 10 ug/g.

At least one unknown VOC detection was identified in each of the four sediment samples. Sample 16-4 had 15 detections ranging from 1 to 6 ug/g. Sample 16-2 had one detection of 6 ug/g. Sample 16-3 had two detections at 1 ug/g each. Sample 16-5 had one detection at 10 ug/g.

Inorganics

The results of the ditch sediment sampling at Area 16 identified seven inorganics at concentrations exceeding statistical background values. These elevated detections are discussed in the following paragraphs.

Arsenic was detected in samples 16-2, 16-3, and 16-4 at relatively high concentrations of 26.9, 47.1, and 25 ug/g, respectively.

Barium was detected in samples 16-2, 16-3, and 16-4 at respective concentrations of 954, 741, and 889 ug/g.

Cadmium was detected at elevated concentrations in samples 16-2, 16-3, and 16-5 at respective concentrations of 10.6, 33, and 2.64 ug/g.

Chromium was detected at sample location 16-5 at a concentration of 18.6 ug/g.

Copper was detected at sample locations 16-2 and 16-3 at respective concentrations of 22.0 and 380 ug/g.

Lead was detected at sample locations 16-2 and 16-3 at respective concentrations of 35.1 and 520 ug/g.

Beryllium was detected at sample location 16-3 at a concentration of 0.44 ug/g.

4.16.3 Summary

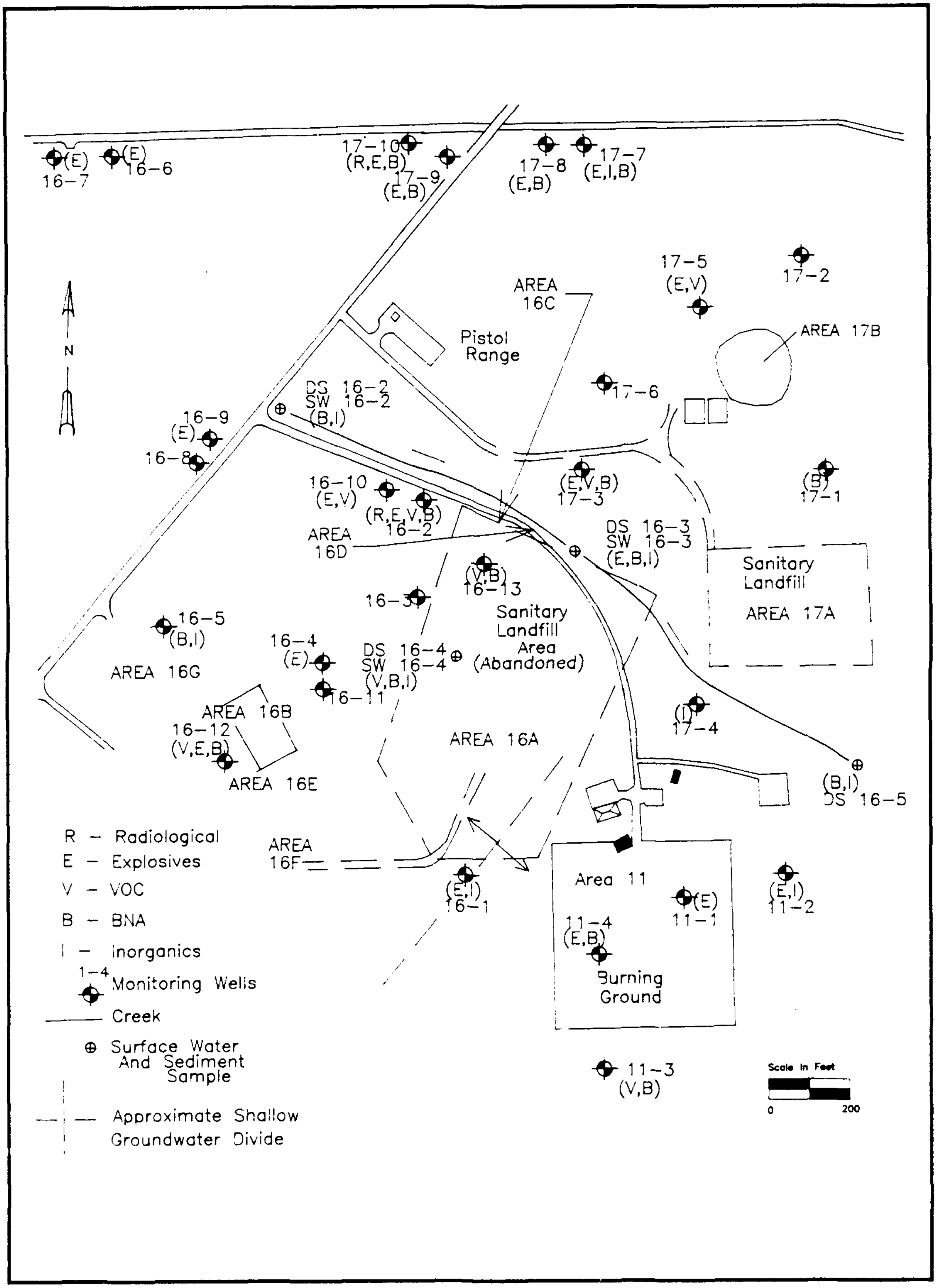
Potentially site-related detections of organic and/or inorganic parameters were identified at ten monitoring well locations across Area 16, including explosive, VOC, BNA, inorganic, and radiological parameters. Surface water and/or sediment samples also identified various parameters at elevated concentrations. Figure 4-24 (repeated on the following page) presents the monitoring well and surface water/sediment sample locations at Area 16 and summarizes the distribution of site-related detections.

Explosive compounds were identified at seven monitoring well locations and one surface water location at Area 16. RDX was most prevalent, with six monitoring wells containing it at concentrations ranging from 1.26 to 150 ug/l. Well location 16-1 contained the 150 ug/l concentration, which suggests that there is a source of explosive compounds southeast of Area 16. Well 16-1 is located upgradient of the landfill area and near a groundwater divide as shown in Figure 3-14; therefore, another source between Area 11 and monitoring well 16-1 may be present. All other well locations are considered downgradient of Area 16 and/or Area 17. The explosive detections downgradient and sidegradient of Area 16 indicate the presence of a source north-northeast of Area 16.

VOCs were detected at five monitoring well locations and the leachate seep location within Area 16. Three source areas may be contributing to these detections. Area 16A (abandoned landfill) certainly contains VOCs in the unsaturated and saturated zones, based on the results of the active leachate seep analysis. The leachate originating from the abandoned landfill contained eight known VOCs and numerous unknown VOCs with a high concentration of more than 5,000 ug/l. Area 16B (abandoned trench) may be the source of VOCs at well 16-12. Area 16C seems to be a likely source of VOCs at well locations 16-2 and 16-10.

The inconsistent detection of BNA compounds again makes it difficult to interpret the data. The high phenol and unknown BNA concentrations in the leachate seep verifies its origin at Area 16A. The detection of 1,2-dichlorobenzene at well location 16-2 indicates Area 16C may be a source of BNAs. If the phthalate compounds are actual detections, the high concentration of B2EHP at well location 16-5 may be from a BNA source at Area 16B. Numerous unknown BNA compounds were detected across the site, with the highest concentrations found in well 16-5.

BNAs are present in the Area 16 creek sediment, as evidenced by the wide variety of detections found in all three samples. The



AREA167C

FIGURE 4-24 (REPEATED)
AREA 11/16/17 DETECTION LOCATIONS

presence of naphthalene at upgradient sediment sample location 16-5 indicates a prior release of contaminants into the creek from some location upgradient of Area 16.

Inorganic parameters exceeded background values at every monitoring well location and every surface water/sediment location at Area 16. The results of the groundwater sampling show only chromium and cadmium exceeding criteria values. Dissolved barium exceeded background values at six downgradient well locations while total barium exceeded background values at only one downgradient well location. Of the surface water samples, only lead exceeds an MCL value, at the leachate seep location. This location also showed high zinc, nickel, and copper concentrations. Of the sediment samples, location 16-3 had the highest concentrations of arsenic, cadmium, copper, and lead. High arsenic concentrations were also detected at sediment sample locations 16-2 and 16-4.

The presence of high chromium levels at well location 16-1 is difficult to understand because of its upgradient location and the groundwater divide location. The high chromium level at well location 16-5 may be due to Area 16B (abandoned trench).

The elevated values of radioactivity at well location 16-2 indicate that Area 16C may contain some buried uranium.

4.17 AREA 17

4.17.1 Site Description and Field Investigation

4.17.1.1 Area 17A - Sanitary Landfill

The sanitary landfill, operating under permits from the MDNR, is used for the disposal of construction debris and normal sanitary solid waste (Figure 4-23). No hazardous waste is placed here. However, drums with trace amounts of ball powder explosives were seen being buried in the landfill by personnel employed by EA Engineering, Science, and Technology, Inc., as reported in the final draft of their Preliminary Assessment/Site Investigation, dated January 1989. Drums were constructed of cardboard and were approximately 20 gallons in size.

As part of the RI field work, five of the six existing wells were each sampled twice and analyzed for VOCs, BNAs, inorganics, and explosives. Due to the very small water volume in well 17-6, the only analysis possible was VOCs during round one. The well remained dry after it was purged during round two. The screened intervals of all sampled monitoring wells at Area 17 are given in Table B-2 of Appendix B.

4.17.1.2 Area 17B - Solvent Pits

This area contains three disposal pits. Two pits were used for the disposal of IWTP grease and oil, waste solvents, and waste oils. They were opened in the 1960s and closed in 1979. The estimated area is 25,000 square feet, and the estimated quantity is 10,000 cubic yards. Possible RCRA hazardous constituents are lead, mercury, carbon tetrachloride, and trichloroethene.

A third pit at this area was used for the disposal of demolition wastes and 55-gallon drums containing waste solvents and paints. It was opened in 1977 and closed in 1979. The estimated area is 15,000 square feet. The estimated quantity of waste is 600 gallons. Possible RCRA hazardous constituents are TRCLE, 111TCE, chromium, and lead.

Currently, the solvent pits are heavily vegetated, and the area surrounding the old pits is being landfilled with solid waste to the east, northeast, and south of the pits. Four wells located around the solvent pits monitor the upper portion of the aquifer. Monitoring wells 17-5 and 17-6 have previously detected elevated concentrations of VOCs. Well 17-5 is located directly downgradient of the solvent pits. Well 17-6 is essentially sidegradient of the pits.

Monitoring well 17-1 is sidegradient of the landfill and upgradient of the solvent pits.

At Area 17B, ground-penetrating radar and electromagnetics was used in order to determine the geometry of the pits. The surveys were conducted over the area where the pits were suspected to exist. Forty-five EM-34 stations were established; the GPR survey covered approximately 1300 linear yards. Figure 4-32 shows the designated area where the geophysical surveys were conducted.

Two two-well clusters were installed in Area 17B. Figure 4-23 shows the monitoring well locations for Area 17B. Each well cluster consists of a shallow water table well screened at about 20 feet and a deep well screened to the base of the aquifer. The first two-well cluster (17-7 and 17-8) is located north of the pits and along the property boundary. This cluster was installed to determine whether any contaminants are migrating off base at shallow or deep horizons. It also is used to determine the vertical gradients so that the potential for any downward migration of contaminants can be assessed. The second two-well cluster (17-9 and 17-10) is also located along the boundary of the base, but northwest of the solvent pits. This well cluster was installed to assess whether groundwater contamination exists at shallow or deep horizons of the aquifer and determine if contaminants are migrating off base. This cluster also provides information regarding the vertical gradient of the aquifer and assesses the potential for downward migration of contaminants. All wells were sampled twice.

All but one of the groundwater samples were analyzed for VOCs, BNAs, inorganics, and explosives. Well 17-1 was almost dry during round 2 and consequently was sampled for VOCs and BNAs only. The sampling events were separated by a three-month interval. Samples 17-9 and 17-10 were also analyzed for radiological parameters during both rounds. Radiological parameters included gross alpha activity, gross beta activity, and U-234, U-235, and U-238 activities.

4.17.2 Site Investigation Results

The results of this site investigation at Area 17 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.17.3). All radiological, organic and inorganic analytical data is presented in Table 4-34. The sample designations refer to area number first, followed by a well number or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.17.2.1 Geophysical Surveys

Anomalous results were detected in Area 17 with both the EM-34 and GPR surveys. Figure 4-32 presents the survey locations and detections.

Electromagnetic Conductivity

The EM-34 survey was conducted for both the vertical and horizontal dipoles. Vertical measurements with a 10-meter coil separation yield an effective sensing depth of penetration of approximately 15 meters with a small contribution from surface materials. Horizontal measurements with a 10-meter coil separation yield an effective sensing depth of 7.5 meters with a large contribution from surface material. The results for both the vertical and horizontal modes were generally coincident with each other. The approximate extent of the anomalous readings are located near the north-central portion of the survey area and are approximated by the following coordinates: 150E, 0S; 300E, 0S; 300E, 100S; 250E, 150S; and 100E, 100S.

Background vertical dipole measurements were between 35 and 45 mmhos/m. Vertical dipole measurements ranged from 48 to 72 mmhos/m, up to a maximum of greater than 300 mmhos/m. Vertical dipole anomalies defined an oblong area between coordinates 175E, 50S and 250E, 50S.

Background horizontal dipole measurements were between 44 and 49 mmhos/m. Horizontal dipole measurements recorded anomalous values of 50 to 70 mmhos/m at location 200E, 100S.

TABLE 4-34
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #17
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	17-1-1	17-1-2	17-2-1	17-2-2	17-3-1	17-3-2	17-4-1
DEPTH (FT)	44	44	32	32	15	15	19
VOLATILES							
Toluene	<1.57	MD	<1.57	<1.57	15	<1.57	<1.57
Trichloroethene	<0.71	MD	<0.71	<0.71	4.1	30	<0.71
ALL	(ALL ND OR <CRL)						
BASE NEUTRAL & ACID EXTRACTABLES							
bis (2-Ethylhexyl) Phthalate	200	MD	ND	ND	20	ND	ND
UNKNOWNS							
C7-C8 Alcohol	ND	*10	ND	ND	ND	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	*10	ND	ND	ND	ND	ND
Benzamide Derivative	ND	*10	ND	ND	ND	ND	ND
(Phenoxymethyl)Benzene[695]	ND	10	ND	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)						
EXPLOSIVE COMPOUNDS							
26-DNT	<0.55		<0.55	<0.55	<0.55	0.66	<0.55
OTHERS	(ALL ND OR <CRL)						
INORGANICS							
Antimony, dissolved	<3.00	NA	<3.00	<3.00	<3.00	3.98	<3.00
Antimony, total	<3.00	NA	<3.00	<3.00	<3.00	3.98	<3.00
Barium, dissolved	NA	NA	NA	222	NA	115	NA
Barium, total	NA	NA	NA	180	NA	204	NA
Beryllium, total	0.91	NA	1.51	0.2	0.7	0.5	0.2
Copper, dissolved	3.64	NA	3.11	<1.78	3.32	<1.78	4.18
Copper, total	13.3	NA	31.8	7.82	10.9	10.7	4.82
Lead, dissolved	<2.50	NA	2.83	<2.50	3.03	<2.50	<2.50
Lead, total	37	NA	17.7	2.73	9.2	2.73	6.77
Nickel, dissolved	<9.60	NA	22.8	<9.60	14.2	<9.60	<9.60
Nickel, total	28	NA	37	18.7	31.9	<9.60	16.6
Silver, dissolved	<0.19	NA	<0.19	<0.19	<0.19	0.21	<0.19
Zinc, dissolved	800	NA	798	33.8	439	70.2	570
Zinc, total	946	NA	467	66.3	780	147	635
OTHERS	(ALL ND OR <CRL)						

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED MD=MISSING DATA

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-34
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #17
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	17-4-2	17-5-1	17-5-2	17-6-1	17-6-2	17-7-1	17-7-2	17-8-1
DEPTH (FT)	19	19	19			12	12	80.5
VOLATILES								
1, 1, 1-Trichloroethane	ND	2000	2000	ND	NA	ND	ND	ND
1, 1, 2-Trichloroethane	ND	200	100	ND	NA	ND	ND	ND
1, 2-Dichloropropane	ND	ND	ND	ND	NA	ND	ND	ND
Benzene	<0.67	<0.67	14	ND	NA	<0.67	<0.67	<0.67
Chloroform	ND	100	80	ND	NA	ND	ND	ND
Ethylbenzene	ND	200	60	ND	NA	ND	ND	ND
Methylene Chloride	ND	300	ND	ND	NA	ND	ND	ND
Tetrachloroethene	ND	300	300	ND	NA	ND	ND	ND
Toluene	<1.57	21000	<1.57	ND	NA	<1.57	<1.57	<1.57
Trans-1, 2-Dichloroethene	<1.72	320000	<1.72	ND	NA	<1.72	<1.72	<1.72
Trichloroethene	<0.71	4300	<0.71	ND	NA	<0.71	<0.71	<0.71
UNKNOWNS								
152+C7 Alkane	ND	*200	*200	ND	NA	ND	ND	ND
4-Methyl-2-Pentanone	ND	*4000	*1000	ND	NA	ND	ND	ND
C6 Oxygenated Hydrocarbon	ND	*200	*80	ND	NA	ND	ND	ND
C7 Ketone	ND	*80	*70	ND	NA	ND	ND	ND
Total Xylenes	ND	*2000	*800	ND	NA	ND	ND	ND
OTHERS	(ALL ND OR <CRL)							
BASE NEUTRAL & ACID EXTRACTABLES								
bis (2-Ethylhexyl) Phthalate	ND	ND	ND	NA	NA	300	ND	60
UNKNOWNS								
C-11-C13 Methyl Alkane	*10	ND	ND	NA	NA	ND	ND	ND
C11-C13 Cycloalkane	*50	ND	ND	NA	NA	ND	ND	ND
C10-C13 Methyl Alkane	*30	ND	ND	NA	NA	ND	ND	ND
C10-C12 Hydrocarbon	*20	ND	ND	NA	NA	ND	ND	ND
C8 Alkye Benzene	*200	ND	ND	NA	NA	ND	ND	ND
C5-C8 Dimethyl Alkenediol	ND	ND	*10	NA	NA	ND	ND	ND
C4-C10 Unknown	ND	ND	*40	NA	NA	ND	ND	ND
C6-C7 Organic Acid Derivatives	ND	ND	*40	NA	NA	ND	ND	ND
Etheimethyl Benzene	ND	*10	*30	NA	NA	ND	ND	ND
Benzoic Acid	ND	ND	*20	NA	NA	ND	ND	ND
C5-C7 Organic Acid Derivative	ND	ND	*10	NA	NA	ND	ND	ND
C8 Organic Acid	ND	ND	*10	NA	NA	ND	ND	ND
2,6-Dimethyl-3-Octene[751]	ND	ND	ND	NA	NA	ND.	20	ND
C10 Alkene/Alkane	ND	ND	ND	NA	NA	ND	*20	ND
C11-C12 Methyl Decane	ND	ND	ND	NA	NA	*30	ND	ND
Heptanoic Acid Anhydride	ND	ND	ND	NA	NA	*20	ND	ND
Dimethyl Benzene	ND	*300	ND	NA	NA	ND	ND	ND
3-5-Dimethyl-3-Hexanol [910]	ND	100	ND	NA	NA	ND	ND	ND
C3-C7 Organic Acid Derivative	ND	*30	ND	NA	NA	ND	ND	ND
C8-C9 Organic Acid Derivative	ND	*40	ND	NA	NA	ND	ND	ND
C8-C9 Organic Acid Derivative-2	ND	*10	ND	NA	NA	ND	ND	ND
2-Ethoxy-1,2-Diphenyl Ethanone [898]	ND	20	ND	NA	NA	ND	ND	ND
Trimethyl Benzene	ND	*50	ND	NA	NA	ND	ND	ND
C8-C10 Alkene/Alkane	ND	ND	ND	NA	NA	*10	ND	ND
OTHERS	(ALL ND <CRL)							
EXPLOSIVE COMPOUNDS								
135-TNB	<0.56	<0.56	0.74	NA	NA	<0.56	<0.56	<0.56
HMX	<1.30	2.58	<1.30	NA	NA	<1.30	<1.30	<1.30
RDX	<0.63	5.14	1.84	NA	NA	<0.63	1.26	<0.63
Tetryl	<0.66	0.98	<0.66	NA	NA	<0.66	<0.66	<0.66
OTHERS	(ALL ND OR <CRL)							
INORGANICS								
Antimony, dissolved	3.98	<3.00	<3.00	NA	NA	<3.00	<3.00	<3.00
Arsenic, dissolved	<5.00	9.52	8.39	NA	NA	<5.00	<5.00	<5.00
Arsenic, total	12.2	9.32	11.6	NA	NA	<5.00	18.8	<5.00
Barium, dissolved	130	NA	518	NA	NA	NA	120	NA
Barium, total	1210	NA	425	NA	NA	NA	1070	NA
Beryllium, total	3.6	<0.10	0.2	NA	NA	0.91	1.91	2.11
Cadmium, total	11.8	<5.10	<5.10	NA	NA	<5.10	<5.10	<5.10
Chromium, total	67.3	<37.50	<37.50	NA	NA	<37.50	40.4	<37.50
Copper, dissolved	6.86	2.79	<1.78	NA	NA	2.89	<1.78	4.61
Copper, total	110	4.82	4.82	NA	NA	22.6	110	27.4
Lead, total	74	2.63	<2.50	NA	NA	12.2	32.1	7.79
Nickel, dissolved	<9.60	38.8	18.7	NA	NA	<9.60	13.8	<9.60
Nickel, total	205	44	20.9	NA	NA	34.5	110	37.3
Silver, dissolved	<0.19	1.81	<0.19	NA	NA	<0.19	<0.19	<0.19
Silver, total	0.53	1.28	<0.19	NA	NA	<0.19	1.06	<0.19
Zinc, dissolved	26.2	519	19.9	NA	NA	397	147	518
Zinc, total	452	565	34.5	NA	NA	609	374	870
OTHERS	(ALL ND OR <CRL)							

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED MD=MISSING DATA

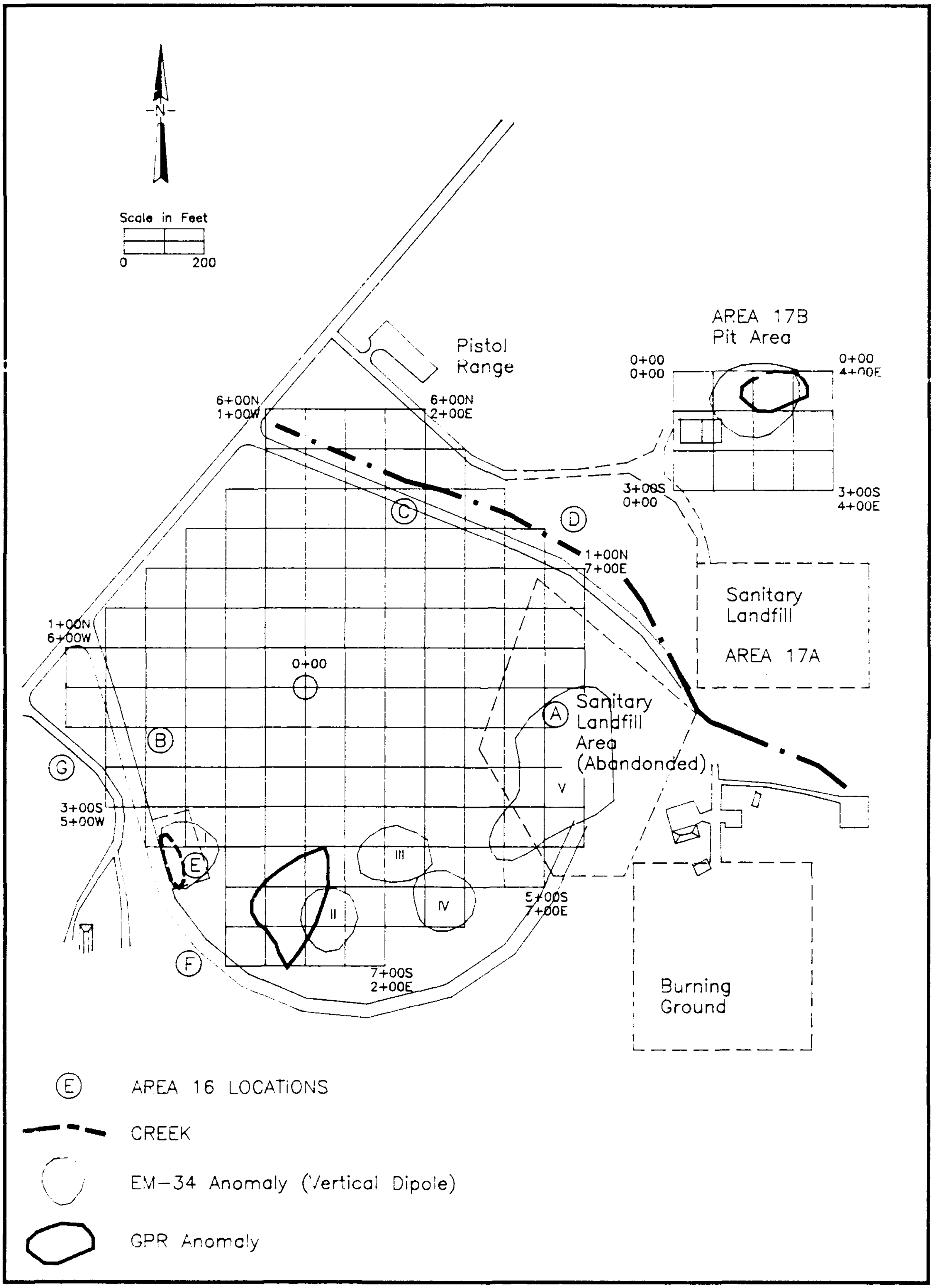
**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-34
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #17
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	17-8-2	17-9-1	17-9-2	17-10-1	17-10-2
DEPTH (FT)	80.5	15	15	22	22
VOLATILES					
ALL			(ALL ND OR <CRL)		
BASE NEUTRAL & ACID EXTRACTABLES					
bis (2-Ethylhexyl) Phthalate	ND	40	ND	20	ND
UNKNOWNS					
C7-C10 Cyclohexane	ND	ND	ND	ND	*10
Methyl Ethanone Derivative	ND	ND	ND	ND	*10
Phthalate Ester	ND	ND	*1	ND	ND
Cyclopentanediol Ester	*20	ND	ND	ND	ND
C10-Methyl Ester	*20	ND	ND	ND	ND
Methyl Propyl Cyclohexane	*10	ND	ND	ND	ND
Heptanoic Acid Anhydride [922]	ND	100	ND	ND	ND
2,7-Dimethyl-1-Octanol [915]	ND	20	ND	ND	ND
C6-Bromoalkane	ND	*10	ND	ND	ND
C9-C12 Alkyl Benzene	ND	*10	ND	ND	ND
C10 Alkyl Alkane	ND	*100	ND	ND	ND
OTHERS			(ALL ND OR <CRL)		
EXPLOSIVE COMPOUNDS					
RDX	0.64	2	0.96	13.2	29
OTHERS			(ALL ND OR <CRL)		
INORGANICS					
Arsenic, total	5.18	<5.00	<5.00	<5.00	<5.00
Barium, dissolved	142	NA	121	NA	373
Barium, total	442	NA	306	NA	332
Beryllium, total	0.6	1.61	0.3	0.3	0.2
Copper, dissolved	6	7.07	5.25	<1.78	<1.78
Copper, total	34.5	46.4	29.3	21.8	9.11
Lead, dissolved	<2.50	2.73	<2.50	<2.50	<2.50
Lead, total	<2.50	14.7	<2.50	15.1	3.13
Nickel, dissolved	<9.60	<9.60	42.1	<9.60	16
Nickel, total	55.7	32.6	33.2	23.1	85.5
Silver, total	0.32	<0.19	<0.19	<0.19	<0.19
Zinc, dissolved	84.8	473	122	556	21.3
Zinc, total	422	556	195	813	174
OTHERS			(ALL ND OR <CRL)		
RADIOLOGICAL (PCI/L)					
Alpha	NA	<5	12+/-10	<11	17+/-10
Beta	NA	<7	54+/-6	56+/-12	79+/-7
U-234	NA	NA	0.6+/-0.3	NA	0.9+/-0.3
U-235	NA	NA	0+/-0.1	NA	0+/-0.1
U-238	NA	NA	0.7+/-0.3	NA	0.7+/-0.3
Total Uranium	NA	0.5	NA	<0.2	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*



area

FIGURE 4-32
LOCATION OF GEOPHYSICAL SURVEY
GRID AND COORDINATES OF AREA 11/16/17

Ground-Penetrating Radar

Ground-penetrating radar traverses were performed in conjunction with the EM-34 survey and the resulting data coincided with the EM-34 results. Disturbed or reflective materials were encountered within coordinates 250E, 0S; 300E, 0S; 300E, 110S; 225E, 100S; 175E, 100S; 175E, 50S; and 225E, 0S. This area corresponds to the detected area during the EM-34 survey in approximate location and size. The detected area can be further divided by a line approximately 25 feet wide oriented northward from 235E, 0S to 235E, 100S. This effectively bisects the area into two relatively equal portions of disturbed soil.

4.17.2.2 Groundwater

Explosives

The results of the two groundwater sampling at Area 17 identified six explosive compounds:

- 135TNB.
- 24DNT.
- 26DNT.
- HMX.
- RDX.
- Tetryl.

During the first round of groundwater sampling RDX was detected at wells 17-5, 17-9 and 17-10 at respective concentrations of 5.14, 2.00, and 13.2 ug/l. Well 17-5 also detected HMX and Tetryl at respective concentrations of 2.58 and 0.98 ug/l.

During the second round of groundwater sampling, RDX was detected at wells 17-5, 17-7, 17-8, 17-9, and 17-10 at respective concentrations of 1.84, 1.26, 0.64, 0.96, and 29.0 ug/l. The explosive compound 135TNB was detected at well 17-5 at a concentration of 0.74 ug/l. The compound 24DNT was detected at well 17-9 at a concentration of 0.60 ug/l. The compound 26DNT was detected at well 17-3 at a concentration of 0.66 ug/l.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at Area 17 identified eleven VOCs, seven of which exceeded MCLs:

- 111TCE.
- 112TCE.
- 1,2-dichloropropane.
- Benzene.
- Chloroform.
- Ethylbenzene.
- Methylene chloride.

- TCLEE.
- Toluene.
- T12DCE.
- TRCLE.

During the first round of groundwater results, downgradient well 17-3 detected toluene and TRCLE at respective concentrations of 15 and 4.1 ug/l. During round 2 well 17-3 detected TRCLE at 30 ug/l. Well 17-5 detected 10 VOCs during round 1 and six VOCs during round 2. The detections are summarized below:

Compound	17-5-1	17-5-2	MCL
1,1,1-trichloroethane	2,000 ug/l	2,700 ug/l	200.00 ug/l
1,1,2-trichloroethane	200 ug/l	100 ug/l	----
1,2-dichloropropane	4 ug/l	----	5.00 ug/l
Benzene	----	14 ug/l	5.00 ug/l
Chloroform	100 ug/l	80 ug/l	----
Ethylbenzene	200 ug/l	60 ug/l	700.00 ug/l
Methylene chloride	300 ug/l	----	----
Tetrachloroethane	300 ug/l	300 ug/l	5.00 ug/l
Toluene	21,000 ug/l	----	2,000.00 ug/l
Trans-1,2-dichloroethene	320,000 ug/l	----	70.00 ug/l
Trichloroethene	4,300 ug/l	----	5.00 ug/l

Unknown VOC compounds were detected in well 17-5 samples at concentrations ranging from 70 to 4,000 ug/l. Detections occurred during both rounds of sampling.

Base Neutral and Acid Extractable Compounds

No BNA compounds were detected in samples from Area 17 other than B2EHP, a common field contaminant. The compound was detected in six samples during round 1 of sampling, including upgradient well location 17-1, at concentrations ranging from 20 to 300 ug/l.

Unknown BNA compounds were detected in samples from six different monitoring wells at Area 17. Wells 17-1, 17-5, 17-7, 17-8, 17-9, and 17-10 had concentrations ranging from 10 to 300 ug/l. Detections occurred in both rounds of sampling.

Inorganics

The results of the two rounds of groundwater sampling at Area 17 identified eleven inorganics which exceeded statistical background concentrations. Five of the eleven inorganics exceeded the MGS, MDWS, and/or MCL. Table 4-35 summarizes the inorganic parameters which were determined to be potentially site-related detections and the monitoring well samples in which they were identified. Wells which contained inorganics above a specified standard are flagged with an asterisk in this table.

Total barium exceeded the MDWS of 1,000 ug/l in upgradient sample 17-4-2 and downgradient sample 17-7-2 with respective concentrations of 1,210 and 1,070 ug/l.

TABLE 4-35
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 17 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Antimony, dissolved	17-3-2, 17-4-2	3.98	17-3-2, 17-4-2	--
Antimony, total	17-3-2	3.98	17-3-2	--
Arsenic, dissolved	17-5-1, 17-5-2	8.39 - 9.52	17-5-1	30.00
Arsenic, total	17-4-2, 17-5-1, 17-5-2, 17-7-2, 17-8-2	5.18 - 16.8	17-7-2	30.00
Barium, dissolved	17-5-2, 17-10-2	373 - 518	17-5-2	--
Barium, total	*17-4-2, *17-7-2	1070 - 1210	*17-4-2	1000.00
Beryllium, total	17-1-1, 17-2-1, 17-4-2, 17-7-1, 17-7-2, 17-8-1, 17-9-1	0.91 - 3.6	17-4-2	--
Cadmium, total	*17-4-2	11.8	*17-4-2	--
Chromium, total	*17-4-2, 17-7-2	40.4 - 67.3	*17-4-2	50.00
Copper, dissolved	17-1-1, 17-2-1, 17-3-1, 17-4-1, 17-4-2, 17-5-1, 17-7-1, 17-8-1, 17-8-2, 17-9-1, 17-9-2	2.79 - 7.07	17-9-1	1000.00
Copper, total	17-4-2, 17-9-1	46.4 - 110	17-4-2	1000.00
Lead, dissolved	17-3-1	3.03	17-3-1	50.00
Lead, total	17-1-1, *17-4-2, 17-7-2	32.1 - 74	*17-4-2	50.00
Nickel, dissolved	17-2-1, 17-3-1, 17-5-1, 17-5-2, 17-7-2, 17-9-2, 17-10-2	13.8 - 42.1	17-9-2	200.00
Nickel, total	*17-4-2, 17-7-2, 17-10-2	85.5 - 205	*17-4-2	200.00
Silver, dissolved	17-3-2, 17-5-1	0.21 - 1.81	17-5-1	50.00
Silver, total	17-4-2, 17-5-1, 17-7-2, 17-8-2	0.32 - 1.28	17-5-1	50.00
Zinc, dissolved	17-1-1, 17-2-1, 17-3-1, 17-4-1, 17-5-1, 17-7-1, 17-8-1, 17-9-1, 17-10-1	397 - 800	17-1-1	5000.00
Zinc, total	17-1-1, 17-8-1	870 - 946	17-1-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXIST.

Total cadmium exceeded the MCL of 5 ug/l and the MDWS of 10 ug/l in upgradient sample 17-4-2 with a detection of 11.8 ug/l.

Total chromium exceeded the MDWS of 50 ug/l in upgradient sample 17-4-2 with a concentration of 67.3 ug/l.

Total lead exceeded the MCL and MDWS of 50 ug/l in sample 17-4-2 with a detection of 74.0 ug/l.

Total nickel exceeded the MGS of 200 ug/l in upgradient sample 17-4-2 with a concentration of 205 ug/l.

Radiation Parameters

Monitoring wells 17-9 and 17-10 were sampled and analyzed for radiological activity during both rounds. Well 17-10 had very high beta activities in both samples. The August beta activity was one of the highest of any well sampled (79 pCi/l). The sample from well 17-9 had high beta activities in round 2 but not in round 1. An unknown radioactive source may be located within Area 17 since the suspected source location within Area 16 is sidegradient of wells 17-9 and 17-10; however, LCAAP does not have any record of radioactive disposal sites there. Section 4.23 contains further discussions of the radiological results.

4.17.3 Summary

Site-related detections occurred at six of the ten monitoring well locations within Area 17, including shallow and deep wells. All detections were at downgradient well locations. Figure 4-24 (repeated in Section 4.16.3) presents the monitoring well locations and summarizes the distribution of the detections.

Numerous explosive compounds were detected. The most significant was RDX, which was found at five well locations downgradient of Area 17B (solvent pits). The highest concentration of RDX was at well location 17-10, which is screened at the water table. This distribution of elevated detections indicates that Area 17B is contributing explosive compounds to the groundwater, and that wells as far downgradient as 16-6 and 16-7 are contaminated from the Area 17B solvent pits.

VOCs were detected at monitoring well locations 17-3 and 17-5. The relatively small concentrations found at well 17-3 may be originating from a local unknown source, since the well may not be downgradient of the solvent pits. The elevated VOC concentrations at well location 17-5 do show, however, that the solvent pits are contaminating the groundwater. Data indicates the likelihood of free product solvents in the groundwater. T12DCE was detected at approximately 50 percent its solubility concentration. Unlike the explosive compounds, no VOCs appear to have migrated as far as well location 17-9 or 16-7. One possible explanation may be that the explosives were introduced into the groundwater prior to the VOCs and the VOCs have not yet migrated to well locations 17-9 or 16-7.

BNA compounds appear to be impacting groundwater quality at Area 17. Numerous unknown BNA compounds were detected. The detections of B2EHP area-wide are probably due to field contamination.

Area 17 does not appear to be contributing inorganics to the local groundwater. The only monitoring wells exceeding standards were well locations 17-4 and 17-7 during round 2. Well 17-4 is located somewhat sidegradient of Area 11, which is a likely source of inorganics in the groundwater. The well 17-7 barium detection only slightly exceeded the MDWS.

The results of the radioactivity analysis of groundwater at well locations 17-9 and 17-10 suggests the presence of a radioactive material within Area 17. Elevated alpha and beta activities in these samples were identified during both rounds of sampling. These wells are not located downgradient of the suspected source area at Area 16C, but are downgradient of Area 17. Further radioactive analysis may be required since there are no records of uranium disposal at Area 17.

4.18 AREA 18

4.18.1 Site Description and Field Investigation

4.18.1.1 Area 18A - Waste Burning and Burial Pits

This site (Figure 4-33) contained six pits used for the disposal and burning of IWTP waste grease and oil, waste oil, waste solvents, and combustible plant trash. The estimated area is 28,000 square feet. The quantity of waste is unknown. Possible RCRA hazardous constituents are lead, mercury, carbon tetrachloride, and TRCLE. An EPIC photograph from 1952 indicated that one impoundment existed within Area 18, and that this impoundment was removed prior to the EPIC photos of 1957. Photos from 1957 indicate that two other impoundments existed during that time. These impoundments were absent in the photos from 1969.

Previously, six wells were installed to monitor any potential release of contaminated groundwater from Area 18A. These wells included 18-1 to 18-6. Deep well 18-7 was installed to the top of bedrock and clustered next to 18-3 to assess the potential for downward migration of contaminants. Table B-2 in Appendix B presents the screen depths of the Area 18 monitoring wells.

Each of these wells was sampled twice as part of the RI field work to assess whether a release of hazardous constituents to the groundwater had occurred. The samples were analyzed for VOCs, BNAs, inorganics, and explosives. The two sampling events were separated by an interval of approximately three months.

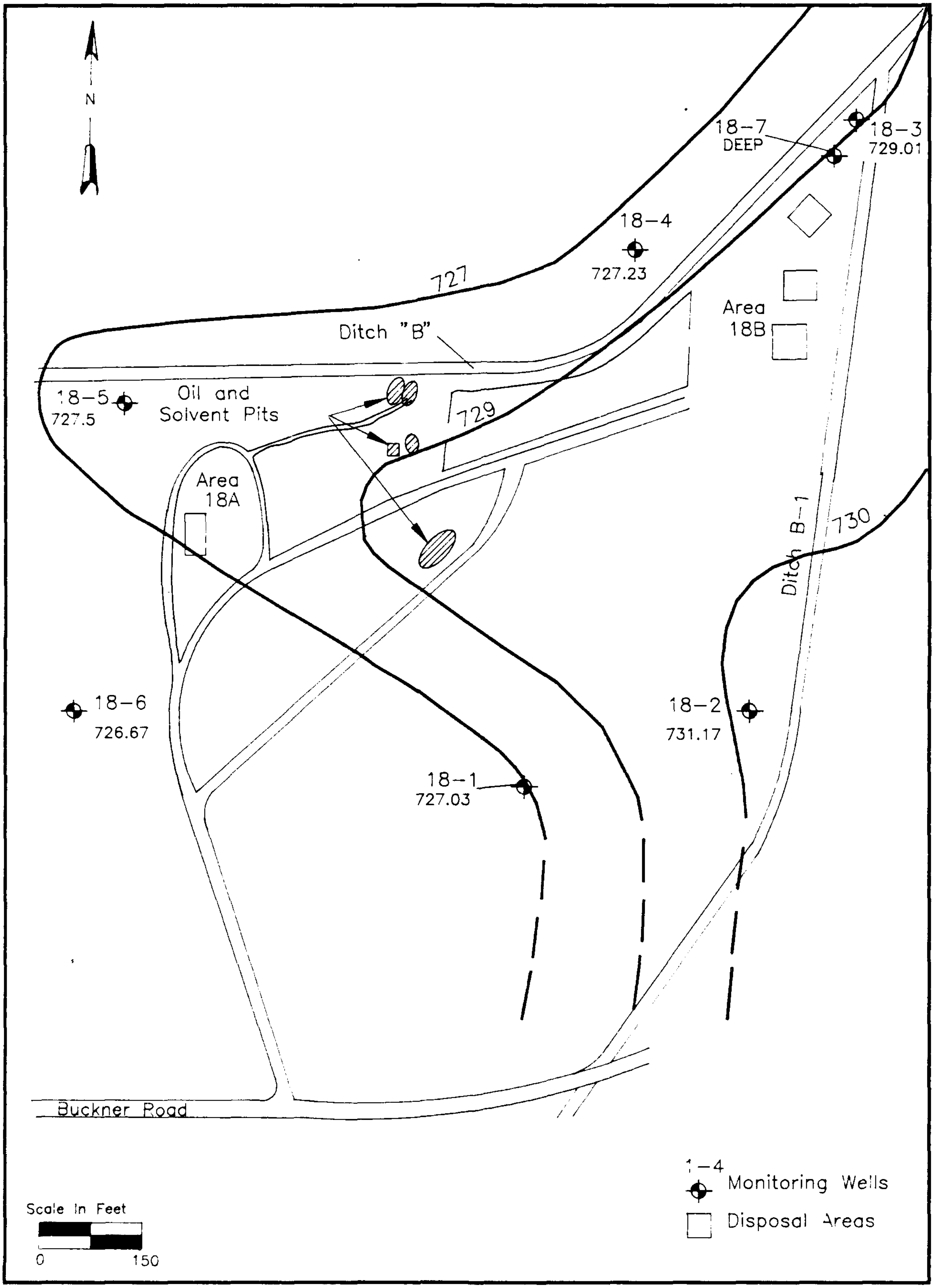


FIGURE 4-33
AREA 18

Radiological parameters (gross alpha activity, gross beta activity, and U-234, U-235, and U-238) were analyzed in wells 18-1, 18-4, 18-5, and 18-6 during round 1.

4.18.1.2 Area 18B - Waste Burning and Burial Pits

This site contains pits used for the burning of IWTP waste grease and oil, solvents, oils, and combustible plant trash. It was closed in 1970. The estimated area is 18,000 square feet. The quantity of waste is unknown. Possible RCRA hazardous wastes are trichloroethene, lead, and mercury.

The seven wells that are part of the monitoring network for Area 18A also apply to Area 18B, and were sampled as described in Subsection 4.18.1.

4.18.2 Site Investigation Results

The results of this site investigation at Area 18 are discussed below on an area-wide basis. The presentation of data is organized according to sampling media and contaminant type. Potentially site-related detections are discussed in relation to particular source areas in the area summary (Subsection 4.18.3). All radiological, organic and inorganic analytical data is presented in Table 4-36. The sample designations refer to area number first, followed by the well or sample number, followed by a 1 or 2, which refers to the round of sampling.

4.18.2.1 Groundwater

Explosives

The results of the two rounds of groundwater sampling at Area 18 identified two explosive compounds:

- HMX.
- RDX.

During the first round of groundwater sampling, the compound HMX was detected at well 18-7 at a concentration of 1.70 ug/l. The compound RDX was detected at monitoring well locations 18-1, 18-5, and 18-6 at respective concentrations of 1.60, 1.18, and 4.70 ug/l.

During the second round of groundwater sampling, the explosive compound RDX was detected at well location 18-7 at 4.15 ug/l.

Volatile Organic Compounds

The results of the two rounds of groundwater sampling at Area 18 identified one VOC: 1,1-dichloroethene (11DCE). The compound was detected during round 2 of sampling, in well 18-4 at a concentration of 15 ug/l. The 11DCE MCL of 7.00 ug/l was exceeded.

TABLE 4-36
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #18
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	18-1-1	18-1-2	18-2-1	18-2-2	18-3-1	18-3-2
DEPTH (FT)	18	18	19	19	18	18
VOLATILES						
ALL	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
UNKNOWNS						
C6-C9 Cycloalkane	ND	*20	ND	*10	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	*10	ND	*10	ND	ND
3-Ethyl-1-Octene[882]	ND	ND	ND	ND	ND	20
2,2,4-Trimethyl-3-Penten-1 -01[872]	ND	ND	ND	ND	ND	10
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	1.6	<0.63	<0.63	<0.63	<0.63	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, dissolved	8.59	7.97	<5.00	<5.00	<5.00	<5.00
Arsenic, total	14	5.28	<5.00	<5.00	7.56	<5.00
Barium, dissolved	NA	210	NA	124	NA	253
Barium, total	NA	570	NA	209	NA	284
Beryllium, total	0.81	<0.10	0.3	<0.10	0.2	<0.10
Copper, dissolved	2.89	<1.78	3.43	<1.78	4.82	2.68
Copper, total	10.6	5.68	21.5	15.4	15.9	13.8
Lead, dissolved	<2.50	<2.50	4.04	<2.50	2.63	<2.50
Lead, total	6.27	5.56	9.81	<2.50	9.3	<2.50
Nickel, dissolved	9.6	<9.60	<9.60	<9.60	10.2	10.4
Nickel, total	21	34	31.8	18.6	15.6	31
Silver, dissolved	<0.19	<0.19	<0.19	0.85	<0.19	<0.19
Silver, total	<0.19	2.02	<0.19	0.21	<0.19	<0.19
Zinc, dissolved	582	<17.20	<17.20	35.3	750	51.6
Zinc, total	664	182	560	108	533	102
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCI/L)						
Alpha	<5	NA	NA	NA	NA	NA
Beta	<7	NA	NA	NA	NA	NA
U-234	NA	NA	NA	NA	NA	NA
U-235	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA
Total Uranium	0.6	NA	NA	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-36
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #18
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	18-4-1 19	18-4-2 19	18-5-1 18	18-5-2 18	18-6-1 18	18-6-2 18
VOLATILES						
1,1-Dichloroethene	<1.92	15	<1.92	<1.92	<1.92	<1.92
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
Chrysene	ND	ND	ND	ND	ND	70
UNKNOWNS						
C6-C9 Methyl Alkene/Alkane	ND	ND	ND	*10	ND	ND
2-Ethyl-4-Heptenal[669]	ND	ND	ND	ND	ND	20
C8-C10 Methyl Alkene/Alkane	ND	*10	ND	ND	ND	*10
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
RDX	<0.63	<0.63	1.18	<0.63	4.7	<0.63
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Barium, dissolved	NA	296	NA	108	NA	256
Barium, total	NA	182	NA	121	NA	225
Beryllium, total	0.2	<0.10	0.5	<0.10	<0.10	<0.10
Copper, dissolved	4.61	<1.78	3.32	10.3	<1.78	<1.78
Copper, total	12	11.1	5.47	6.22	3.75	5.57
Lead, dissolved	<2.50	<2.50	3.13	<2.50	<2.50	<2.50
Lead, total	6.47	<2.50	2.83	<2.50	3.13	<2.50
Nickel, dissolved	41.5	<9.60	41.2	11.2	16.5	<9.60
Nickel, total	13.4	<9.60	10	18.1	12.7	15.4
Silver, dissolved	<0.19	0.53	<0.19	<0.19	<0.19	<0.19
Zinc, dissolved	765	23.9	668	108	547	25
Zinc, total	644	26.8	674	109	632	100
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCI/L)						
Alpha	<4	NA	<2	NA	<2	NA
Beta	<5	NA	<3	NA	<3	NA
U-234	NA	NA	NA	NA	NA	NA
U-235	NA	NA	NA	NA	NA	NA
U-238	NA	NA	NA	NA	NA	NA
Total Uranium	<0.2	NA	<0.2	NA	<0.2	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-36
LAKE CITY ARMY AMMUNITIONS PLANT
AREA #18
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	18-7-1	18-7-2
DEPTH (FT)	88.5	88.5
VOLATILES		
ALL	(ALL ND OR <CRL)	
BASE NEUTRAL & ACID EXTRACTABLES		
bis (2-Ethylhexy) Phthalate	20	400
UNKNOWNS		
C4-C8 Organic Acid Derivative	ND	*10
C6-C9 Cycloalkane	ND	*10
C8-C10 Methyl Alkene/Alkane	ND	*10
OTHERS	(ALL ND OR <CRL)	
EXPLOSIVE COMPOUNDS		
HMX	1.7	<1.30
RDX	<0.63	4.15
OTHERS	(ALL ND OR <CRL)	
INORGANICS		
Barium, dissolved	NA	541
Barium, total	NA	462
Copper, total	13.2	<1.78
Lead, total	6.47	<2.50
Nickel, dissolved	<9.60	15
Nickel, total	<9.60	64.6
Zinc, dissolved	783	44.1
Zinc, total	587	237
OTHERS	(ALL ND OR <CRL)	

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

Base Neutral and Acid Extractable Compounds

The results of the two rounds of groundwater sampling at Area 18 identified two BNAs:

- Chrysene.
- B2EHP.

During round 1, B2EHP was detected at well location 18-7 at a concentration of 20 ug/l.

During round 2, B2EHP was detected at well location 18-7 at a concentration of 360 ug/l, and chrysene was detected at well location 18-6 at a concentration of 70 ug/l.

Unknown BNA compounds were detected in samples from all seven monitoring wells at Area 18. Concentrations ranged from 10 to 20 ug/l. All detections occurred during the second round of sampling.

Inorganics

The results of the two rounds of groundwater sampling at Area 18 identified seven inorganics which exceeded statistical background concentrations. None of the detections exceeded the MGS, MDWS, or MCL. Table 4-37 summarizes the inorganic parameters which were determined to be potentially site-related detections and the monitoring well samples in which they were identified.

Radiation Parameters

The results of the two rounds of groundwater sampling at Area 18 did not identify any radioactivity above normal levels.

4.18.3 Summary

Potentially site-related detections occurred at five of the seven monitoring well locations within Area 18. Figure 4-34 presents the monitoring well locations and summarizes the distribution of the detections.

Explosive compounds were detected at relatively low concentrations at four well locations during round 1 and at one well location during round 2. Concentrations ranged from 1.18 to 4.70 ug/l. Given the directions of shallow and deep groundwater flow across Area 18, the likely sources of the groundwater contamination are Area 11, Area 16, Area 17, and/or Area 18. Similar compounds were identified in the groundwater at all four areas, specifically, HMX and RDX.

The detection of 11DCE at well location 18-4 indicates that Area 18B (waste burning and burial pits) has contributed some VOC

TABLE 4-37
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
AREA 18 GROUNDWATER RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Arsenic, dissolved	18-1-1, 18-1-2	7.97 - 8.59	18-1-1	30.00
Arsenic, total	18-1-1, 18-1-2, 18-3-1	5.28 - 14	18-1-1	30.00
Barium, dissolved	18-4-2, 18-6-2, 18-7-2	296 - 541	18-7-2	--
Copper, dissolved	18-1-1, 18-2-1, 18-3-1, 18-3-2, 18-4-1, 18-5-1, 18-5-2	2.68 - 10.3	18-5-2	1000.00
Lead, dissolved	18-2-1, 18-5-1	3.13 - 4.04	18-2-1	50.00
Nickel, dissolved	18-3-1, 18-3-2, 18-4-1, 18-5-1, 18-5-2, 18-6-1, 18-7-2	10.2 - 41.5	18-4-1	200.00
Nickel, total	18-7-2	64.6	18-7-2	200.00
Silver, dissolved	18-2-2, 18-4-2	0.53 - 0.85	18-2-2	50.00
Silver, total	18-1-2, 18-2-2	0.21 - 2.02	18-1-2	50.00
Zinc, dissolved	18-1-1, 18-3-1, 18-4-1, 18-5-1 18-6-1, 18-7-1	547 - 783	18-7-1	5000.00

NOTE: -- NO STANDARDS EXIST

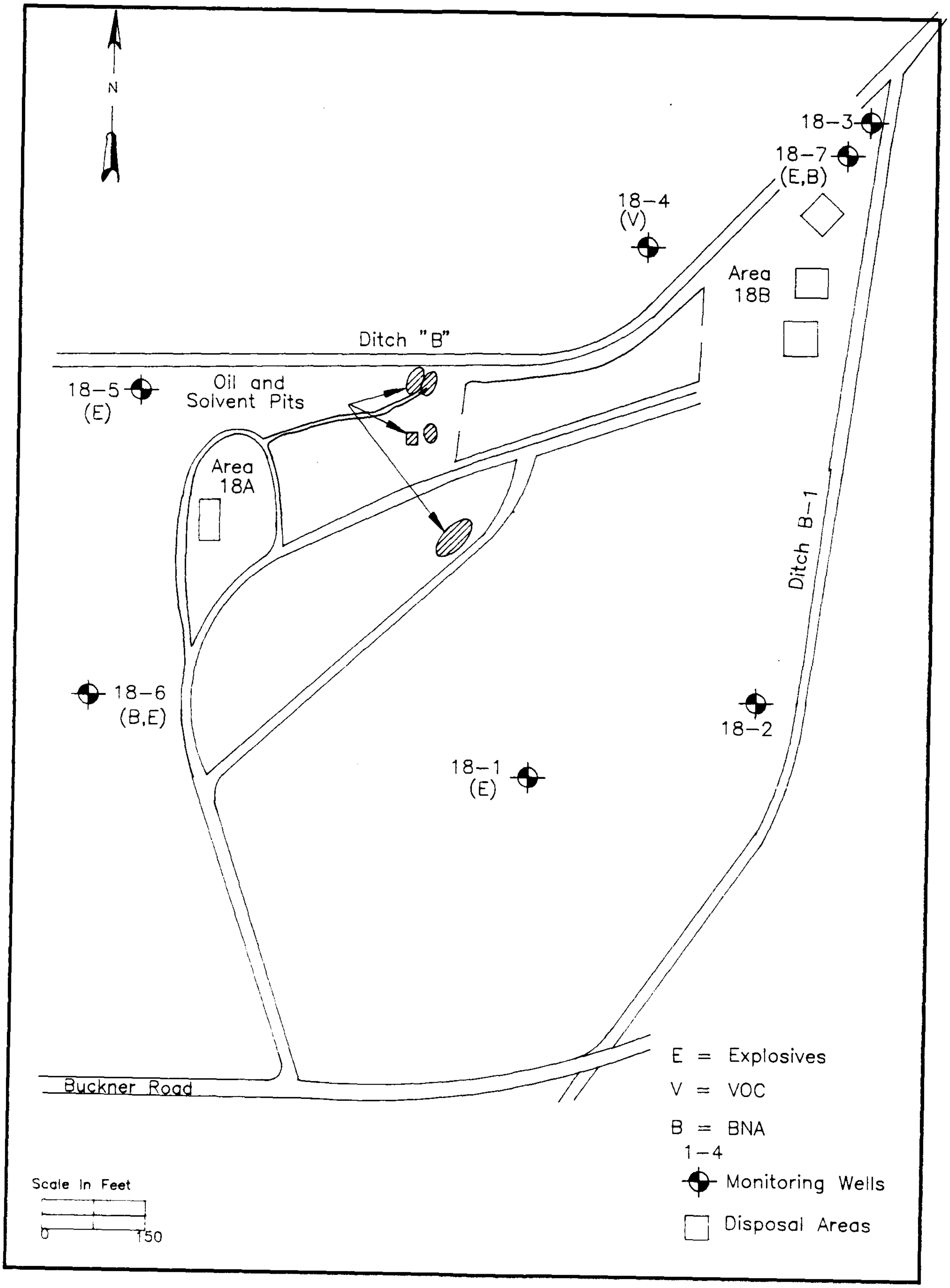


FIGURE 4-34
AREA 18 DETECTION LOCATIONS

contamination to the groundwater, since well 18-4 is directly downgradient of that area. No other VOCs were detected.

Two BNA compounds were detected in Area 18 groundwater: chrysene at well location 18-6 during round 2, and B2EHP at well location 18-7 during both rounds of sampling. The presence of chrysene in the groundwater at well location 18-6 may be due to an unknown source. The detection of B2EHP at well location 18-7 during both rounds may indicate that the results do reflect the groundwater quality at the location, which is sidegradient and upgradient of Area 18B.

Inorganic concentrations in the Area 18 groundwater appear to be normal; sample analysis did not reveal any concentrations exceeding standards.

Radiological activity in the groundwater at Area 18 is within the normal range.

4.19 PLANT-WIDE DITCH AND POND SAMPLES

4.19.1 Field Investigation

Seven surface water samples and eleven ditch sediment samples were collected from Ditch A, Ditch B, the Big Ditch, and an on-site pond. All surface water and sediment samples were analyzed for VOCs, BNAs, explosives, and inorganics. Figure 4-35 shows the surface water and sediment sampling locations. Surface water samples SW10, SW12, SW13, and SW18 were not collected because of dry conditions.

4.19.1.1 Ditch A

Two surface water (SW) and three ditch sediment (DS) samples were collected from Ditch A. Samples SW-09 and DS-09 were collected to assess the chemistry of the water and sediment just upstream of the point that Ditch A leaves the base. Samples DS-10, DS-11, and SW-11 assess the surface water and sediment quality downstream from potential contamination sources.

4.19.1.2 Ditch B

Two surface water and four ditch sediment samples were collected from Ditch B. Sample DS-12 was collected at the point where a small tributary discharges into Ditch B. Samples DS-13, DS-14, and SW-14 were collected downstream from potential contaminant sources. Samples DS-15 and SW-15 were collected to determine the water and sediment quality at the point that Ditch B leaves the site.

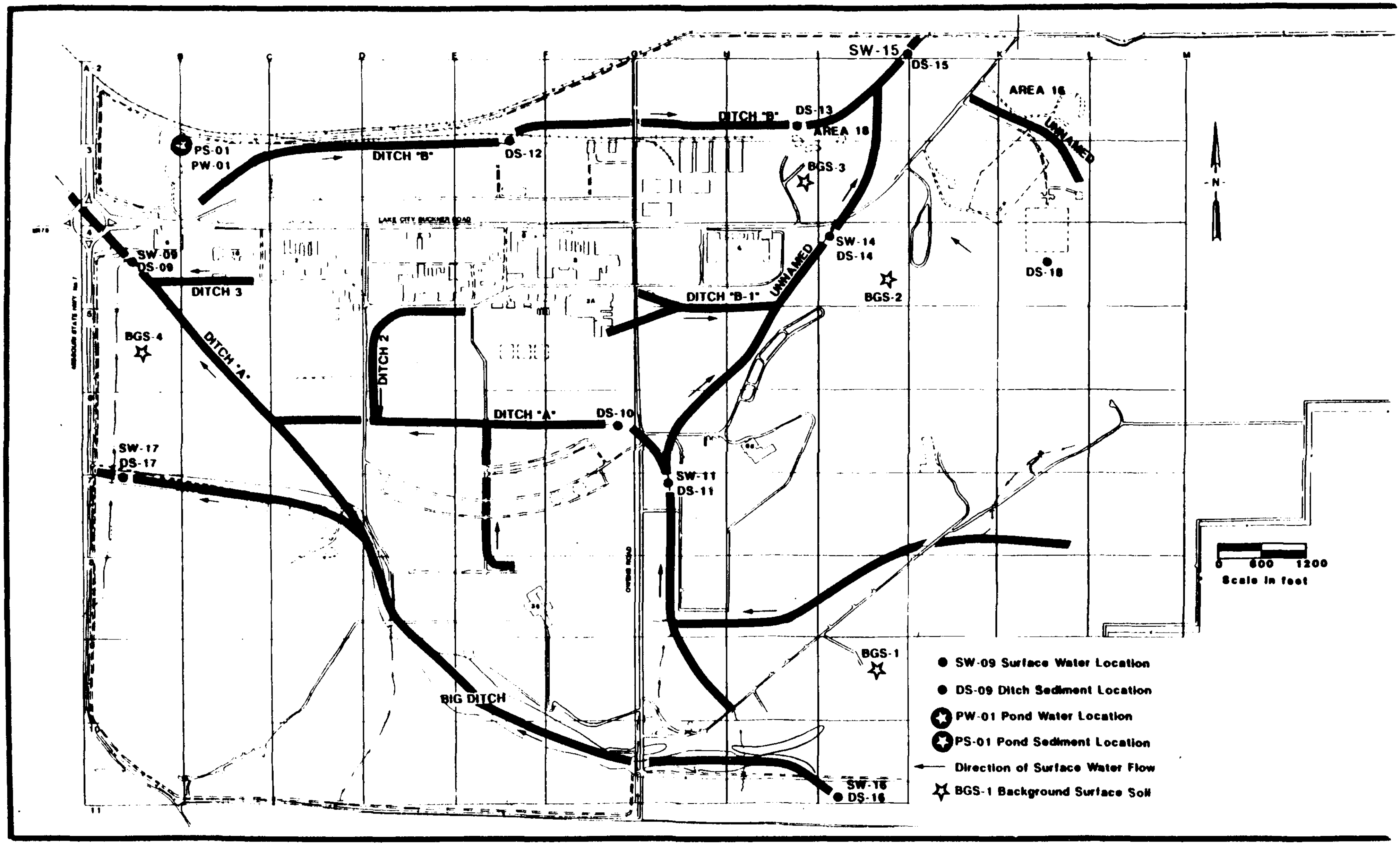


FIGURE 4-35

PLANT-WIDE SURFACE WATER AND SEDIMENT SAMPLES

4.19.1.3 Big Ditch

Two surface water and two sediment samples were collected from the Big Ditch. Samples SW-16 and DS-16 were collected and analyzed to determine the chemistry of the water and sediment entering the base. Samples SW-17 and DS-17 assess the chemistry of the water and sediment as it leaves the base.

Because of a lack of existing background surface water quality data from the Lake City area, surface water sample SW-16 was used for comparison against all other surface water quality results. Only three inorganic parameters were detected in sample SW-16: copper at a concentration of 4.93 ug/l, nickel at a concentration of 12.0 ug/l, and zinc at a concentration of 404 ug/l. Any surface water inorganic detections which exceeded these concentrations have been termed "elevated," and their analytical results have been presented in Subsection 4.19.2.

4.19.1.4 Unnamed Ditch

One sediment sample was collected from a small unnamed ditch located between Areas 16 and 17. Sample DS-18 was collected and analyzed to assess the chemistry of the sediment entering Areas 16 and 17. Downstream from the unnamed ditch, surface water and sediment samples were collected as part of Area 16 investigation. Refer to Sections 4.16.2.3 and 4.16.2.4 for results.

4.19.1.5 Pond

One pond water sample and one pond sediment sample (PW-01 and PS-01) were collected to determine the water and sediment chemistry in the pond located at the northern boundary of the base where cows previously grazed and watered. The pond is a groundwater recharge zone. A surface water staff gauge was placed in the pond to measure the water level elevation of the pond. The hydraulic connection was determined and the downward direction of groundwater out of the pond was established by comparing the pond elevation to the groundwater elevations.

4.19.2 <u>Ditch and Pond Analytical Results</u>

Results of the ditch and pond sample analysis are presented in Table 4-38.

4.19.2.1 Ditch A

Explosives

Two explosive compounds were identified during the Ditch A sampling program:

TABLE 4-38
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
DITCH SURFACE WATER SAMPLES (UG/L)

SITE ID	SW-09-1	SW-11-1	SW-14-1	SW-15-1	SW-16-1	SW-17-1
VOLATILES						
Benzene	<0.64	<0.64	<0.64	<0.64	<0.64	1.5
Trichloroethene	<0.14	<0.14	<0.14	<0.14	<0.14	1.6
OTHERS	(All ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	ND	10	ND	ND
OTHERS	(All ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
HMX	<1.30	1.37	<1.30	<1.30	<1.30	<1.30
OTHERS	(All ND OR <CRL)					
INORGANICS						
Antimony, total	<3.00	<3.00	<3.00	4.89	<3.00	<3.00
Arsenic, total	<5.00	<5.00	<5.00	10.4	<5.00	<5.00
Barium, total	94.6	104	84.2	242	NA	134
Beryllium, total	<0.10	<0.10	<0.10	0.4	<0.10	<0.10
Copper, total	21.5	6.65	13	100	4.93	6.22
Lead, total	<2.50	<2.50	<2.50	11.9	<2.50	<2.50
Nickel, total	<9.60	19.5	18.4	16.8	12	12.1
Selenium, total	<5.00	<5.00	<5.00	7.12	<5.00	<5.00
Silver, total	0.21	<0.19	<0.19	<0.19	<0.19	<0.19
Zinc, total	720	509	620	491	404	450
OTHERS	(All ND OR <CRL)					

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-38
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
DITCH SEDIMENT SAMPLES (UG/G)

SITE ID	DS-09-1	DS-10-1	DS-11-1	DS-12-1	DS-13-1	DS-14-1
VOLATILES						
ALL			(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES						
Benzo (a) Anthracene	ND	ND	ND	0.8	ND	ND
Benzo (a) Pyrene	ND	ND	ND	0.4	ND	ND
Benzo (b) Fluoranthene	ND	ND	ND	0.7	ND	ND
Benzo (k) Fluoranthene	ND	ND	ND	0.7	ND	ND
Chrysene	ND	ND	ND	2	ND	ND
Di-n-Butylphthalate	0.9	ND	ND	[illegible]	ND	ND
Fluoranthene	ND	ND	ND	5	ND	ND
Indeno (1, 2, 3-cd) Pyrene	ND	ND	ND	0.4	ND	ND
Napthalene	ND	ND	ND	0.7	ND	ND
Phenanthrene	ND	ND	ND	3	ND	ND
Pyrene	ND	ND	ND	4	ND	ND
UNKNOWNS						
C12-C13 Methyl Alkane	ND	ND	ND	ND	*1	ND
Unknown	ND	ND	ND	ND	*1	ND
Sulfur-1	*1	ND	*4	ND	ND	*5
Sulfur-2	*3	ND	ND	ND	ND	ND
Sulfur-3	*30	ND	ND	ND	ND	ND
3-[(Methylsulphanyl)oxy]-2-Butanone [775]	1	ND	ND	ND	ND	ND
Trichloroeicosyl-silane [915]	ND	ND	2	ND	ND	ND
Trichloroeicosyl-silane [955]	ND	ND	ND	ND	ND	2
C11-C13 Hydrocarbon	ND	ND	ND	ND	ND	*1
C10-C17 Hydrocarbon	ND	ND	ND	*1	ND	ND
C13-C36 Hydrocarbon	ND	ND	ND	*1	ND	ND
OTHERS			(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS						
24-DNT	4.2	<0.42	<0.42	<0.42	<0.42	<0.42
OTHERS			(ALL ND OR <CRL)			
INORGANICS						
Arsenic, total	<5.70	<5.70	<5 [illegible]	27.2	<5.70	<5.70
Barium, total	148	248	164	361	253	146
Beryllium, total	<0.33	0.4	<0.33	0.71	<0.33	<0.33
Cadmium, total	<0.70	<0.70	<0.70	2.05	<0.70	<0.70
Chromium, total	11.1	19.6	16.1	23.3	18.2	22.5
Copper, total	7.9	8.99	17.2	28.5	19.1	49.5
Lead, total	8.92	6.63	26.1	37.2	14.5	31.2
Nickel, total	19.9	28.3	16	19.2	14.4	14.2
Zinc, total	<52.00	<52.00	<52.00	166	95.3	81
OTHERS			(ALL ND OR <CRL)			

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-38
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
DITCH SEDIMENT SAMPLES (UG/G)

SITE ID	DS-15-1	DS-16-1	DS-17-1	DS-18-1
VOLATILES				
ALL	(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES				
UNKNOWNS				
C13-C15 Hydrocarbon	*1	ND	ND	ND
C13-C16 Hydrocarbon	ND	ND	*1	ND
OTHERS	(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS				
ALL	(ALL ND OR <CRL)			
INORGANICS				
Arsenic, total	7.8	25	7.25	<5.70
Barium, total	162	560	117	227
Beryllium, total	<0.33	0.74	0.36	0.4
Cadmium, total	1.9	2.92	<0.70	2.08
Chromium, total	14.2	19.6	21.2	15.9
Copper, total	46.3	13.1	13.3	7.86
Lead, total	14.8	30.4	7.55	16
Mercury, total	0.26	<0.10	<0.10	<0.10
Nickel, total	13	74.1	21.2	29.2
Zinc, total	109	110	<52.00	<52.00
OTHERS	(ALL ND OR <CRL)			

CRL=*CERTIFIED REPORTING LIMIT ND*=*NOT DETECTED NA*=*NOT ANALYZED*

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-38
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
SURFACE WATER SAMPLES (UG/L)

SITE ID	PW01-1
VOLATILES	
ALL	(ALL ND OR <CRL)
BASE NEUTRAL & ACID EXTRACTABLES	
ALL	(ALL ND OR <CRL)
EXPLOSIVE COMPOUNDS	
ALL	(ALL ND OR <CRL)
INORGANICS	
Antimony, total	70.8
Arsenic, total	5.28
Copper, total	72
Zinc, total	357
OTHERS	(ALL ND OR <CRL)

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-38
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
POND SEDIMENT (UG/G)

SITE ID	PS01-1
VOLATILES	
ALL	(ALL ND OR <CRL)
BASE NEUTRAL & ACID EXTRACTABLES	
Acenaphthene	7
Anthracene	9
Benzo (a) Anthracene	20
Benzo (k) Fluoranthene	2
Chrysene	20
Dibenzo (a,h) Anthracene	0.5
Fluoranthene	30
Fluorene	6
Indeno (1, 2, 3-cd) Pyrene	5
Napthalene	3
Phenanthrene	30
UNKNOWNS	
Benzoflouranthene	*1
Dihydroflouranthene	*1
OTHERS	(ALL ND OR <CRL)
EXPLOSIVE COMPOUNDS	
ALL	(ALL ND OR <CRL)
INORGANICS	
Barium, total	35.8
Chromium, total	10.9
Copper, total	680
Lead, total	80
OTHERS	(ALL ND OR <CRL)

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

- HMX.
- 24DNT.

HMX was detected in surface water sample SW-11 at a concentration of 1.37 ug/l. The compound 24DNT was detected in ditch sediment sample DS-09 at a concentration of 4.20 ug/g.

Volatile Organic Compounds

There were no VOCs identified during the Ditch A sampling program.

Base Neutral and Acid Extractable Compounds

There were no BNA compounds definitively identified during the Ditch A sampling program other than di-n-butyl phthalate, which is a common laboratory contaminant. This compound was detected in sample DS-09 at a concentration of 0.9 ug/g.

Unknown BNA compounds were detected in two of the three Ditch A sediment samples. Sample DS-09 had four detections ranging from 1 to 30 ug/g. Sample DS-11 had two detections at 2 and 4 ug/g.

Inorganics

Sediment samples taken from Ditch A identified two inorganics which exceeded the background concentrations. Sample DS-09 did not contain any elevated detection of inorganics. Sample DS-10 detected chromium at a concentration of 19.6 ug/g. Sample DS-11 detected chromium at 16.1 ug/g and lead at 26.1 ug/g.

The two surface water samples taken from Ditch A identified four metals which exceed background concentrations. Sample SW-09 detected copper, silver, and zinc at respective concentrations of 21.5, 0.21, and 720 ug/l. Sample SW-11 detected copper, nickel, and zinc at respective concentrations of 6.65, 19.5, and 509 ug/l. No detections exceeded MCL values.

4.19.2.2 Ditch B

Explosives

There were no explosive compounds identified during the Ditch B sampling program.

Volatile Organic Compounds

There were no VOCs identified during the Ditch B sampling program.

Base Neutral and Acid Extractable Compounds

The results of the Ditch B sampling program identified 10 BNA compounds. All detections occurred in ditch sediment sample DS-12.

Surface water samples SW-13 and SW-15 detected B2EHP, which is a common field contaminant. Ditch sediment sample DS-12 detected the following concentrations:

Benzo(a)anthracene	0.8	ug/g
Benzo(a)pyrene	0.4	ug/g
Benzo(b)fluoranthene	0.7	ug/g
Benzo(k)flouranthene	0.7	ug/g
Chrysene	2	ug/g
Fluorene	5	ug/g
Indeno(1,2,3-c,d)pyrene	0.4	ug/g
Naphthalene	0.7	ug/g
Phenanthrene	3	ug/g
Pyrene	4	ug/g

Unknown BNA compounds were detected in each of the Ditch B sediment samples. Sample DS-12 had two detections at 1 ug/g each. Sample DS-13 had two detections at 1 ug/g each. Sample DS-14 had three detections ranging from 1 to 5 ug/g. Sample DS-15 had one detection of 1 ug/g.

Inorganics

Sediment samples taken from Ditch B identified nine inorganics which exceeded background concentrations. These inorganics are discussed below.

Arsenic was detected in sediment samples DS-12 and DS-15 at respective concentrations of 27.2 and 7.80 ug/g. Barium was detected in samples DS-12 and DS-14 at concentrations of 361 and 253 ug/g. Beryllium was detected in sample DS-12 at a concentration of 0.71 ug/g. Cadmium was detected in samples DS-12 and DS-15 at respective concentrations of 2.05 and 1.90 ug/g. Chromium was detected in samples DS-12, DS-13, DS-14, and DS-15 at concentrations ranging from 14.2 to 23.3 ug/g. Total copper was detected in samples DS-12, DS-14, and DS-15 at respective concentrations of 28.5, 49.5, and 46.3 ug/g. Total lead was detected in samples DS-12, DS-13, DS-14, and DS-15 at respective concentrations of 37.2, 14.5, 31.2, and 14.8 ug/g. Mercury was detected in sample DS-15 at a concentration of 0.26 ug/g. Zinc was detected in sample DS-12 at a concentration of 166 ug/g.

The two surface water samples taken from Ditch B identified seven inorganic parameters which exceeded background concentrations. Sample SW-14 detected copper, nickel, and zinc at respective concentrations of 13.0, 18.4, and 620 ug/l. Sample SW-15 detected antimony at 4.89 ug/l, arsenic at 10.4 ug/l, beryllium at 0.4 ug/l, copper at 100 ug/l, lead at 11.9 ug/l, nickel at 16.8 ug/l, selenium at 7.12, and zinc at 491 ug/l.

4.19.2.3 Big Ditch

Explosives

There were no explosive compounds identified during the Big Ditch sampling program.

Volatile Organic Compounds

The results of the Big Ditch sampling program identified two VOCs:

- Benzene.
- TRCLE.

Both compounds were detected in surface water sample SW-17, where the Big Ditch leaves the plant. Benzene was detected at 1.5 ug/l and TRCLE was detected at 1.6 ug/l.

Base Neutral and Acid Extractable Compounds

There were no BNA compounds identified during the Big Ditch sampling program.

Inorganics

Sediment samples taken from the Big Ditch identified seven inorganics which exceeded the background concentrations. Those inorganics which exceeded the background concentrations are discussed below.

Arsenic was detected in samples DS-16 and DS-17 at respective concentrations of 25.0 and 7.25 ug/g. Barium was detected in sample DS-16 at a concentration of 560 ug/g. Beryllium was detected in sample DS-16 at a concentration of 0.74 ug/g. Cadmium was detected in DS-16 at 2.92 ug/g. Chromium was detected in both samples at respective concentrations of 19.6 and 21.2 ug/g. Lead was detected in sample DS-16 at a concentration of 30.4 ug/g. Nickel was detected in sample DS-16 at a concentration of 74.1 ug/g.

Surface water sample SW-16, taken from the Big Ditch as it enters the south end of the LCAAP, was used to establish a baseline for background inorganics concentrations in the local surface water. Only three inorganic parameters were identified at detectable levels. Total copper, total nickel, and total zinc were detected at respective concentrations of 4.93, 12.0, and 404 ug/l. Sample SW-17 was collected as the downgradient sample, located at the northwest corner of LCAAP as the Big Ditch exits the site. Analytical results were very similar to those of SW-16, with total copper, total nickel, and total zinc detected at respective concentrations of 6.22, 12.1, and 450 ug/l. None of the inorganics exceeded MCL values.

4.19.2.4 Unnamed Ditch

There were no explosive, VOC, or definitive BNA compounds identified from the Unnamed Ditch sediment sample although one unknown BNA compound was detected at an estimated concentration of 1 ug/l.

Downstream from the unnamed ditch, surface water and sediment samples were collected as part of Area 16 investigation. Refer to Sections 4.16.2.3 and 4.16.2.4 for results.

Inorganics

The sediment sample DS-18 taken from the Unnamed Ditch identified three inorganics which exceeded statistical background concentrations. These three inorganics are discussed below.

Cadmium was detected at a concentration of 2.08 ug/g. Chromium was detected at a concentration of 15.9 ug/g. Lead was detected at a concentration of 16.0 ug/g.

4.19.2.5 Pond

Explosives

There were no explosive compounds detected in either the pond surface water or sediment sample.

Volatile Organic Compounds

There were no VOCs detected in either the pond surface water or sediment sample.

Base Neutral and Acid Extractable Compounds

No BNAs were detected in the pond surface water sample. A total of ten BNA compounds were definitively identified in pond sediment sample PS-01. Pond sediment sample PS-01 detected the following concentrations:

Anthracene	9 ug/g
Benzo(a)anthracene	20 ug/g
Benzo(k)fluoranthene	2 ug/g
Chrysene	20 ug/g
Dibenzo(a,h)anthracene	0.5 ug/g
Fluoranthene	30 ug/g
Fluorene	6 ug/g
Indeno(1,2,3-cd)pyrene	5 ug/g
Naphthalene	3 ug/g
Phenanthrene	30 ug/g

The pond sediment sample also detected two unknown BNA compounds at 1 ug/g each.

Inorganics

The sediment sample PS-01 collected from the pond identified two inorganics which exceeded statistical background concentrations. Copper was detected at a concentration of 680 ug/g. Lead was detected at a concentration of 80.0 ug/g.

The pond water sample PW-01 identified three inorganic parameters at concentrations exceeding background values. Antimony, arsenic, and copper were detected at respective concentrations of 70.8, 5.28, and 72.0 ug/l. No detections exceeded MCL values.

4.19.3 Summary

The results of the plant-wide surface water and sediment sampling program identified a few locations with potentially site-related organic detections, and numerous locations with potentially site-related inorganic detections. None of the detections exceeded MCL values.

Surface Water

Explosive compounds were detected at one surface water location (SW-11) and one sediment location (DS-09). The two detections were 1.37 ug/l of HMX and 4.20 ug/g of 24DNT, respectively. Explosive compounds may be transported off-site during periods of significant stream flow from Ditch A, the location of sediment sample DS-09. The source locations for the SW-11 detection are likely to be located within Areas 2, 4, or 5. The source location for the DS-09 detection may be near Ditch A north of Ditch 3, since none of the sump investigation samples collected from either Ditch 3 or Ditch 4 at that junction detected any explosive compounds.

VOCs were identified in just one surface water sample. Benzene and TRCLE were detected in sample SW-17 at respective concentrations of 1.50 and 1.60 ug/l. Since this sample was collected from the Big Ditch just upstream from its exit location from the LCAAP, it must be assumed that these contaminants are reaching the site boundary. Area 8 disposal pits may be the potential source since TRCLE was detected in two groundwater samples there.

The BNA compound B2EHP was detected in Ditch B surface water samples SW-13 and SW-15. Although this compound is a common field contaminant, the fact that it was not detected in any other surface water samples indicates that it may be an actual contaminant within Ditch B. If so, it would be exiting the site just downstream of the SW-15 location. Potential source areas could be located anywhere along the ditch across the northern length of the site. No BNA compounds were identified in the laboratory blank samples.

A total of 10 BNA compound were identified in the pond sediment, at concentrations ranging from 0.5 to 30 ug/g. The source of the contamination is unknown.

Inorganic concentrations in the ditch and pond surface water samples were relatively consistent with the background levels. Ditch B had slightly elevated concentrations of antimony, arsenic, lead, and selenium, but none of the detections approached MCL values.

Sediments

Inorganic concentrations in the ditch and pond sediment samples were more varied. Lead concentrations ranged from undetectable to 80 ug/g, with the highest value detected in the pond sediment. No significant increasing trends were identified from upgradient to downgradient locations, indicating that there is no off-site migration of elevated inorganics levels in sediment.

4.20 PRODUCTION WELL SAMPLING

Seven production wells were each sampled twice during the investigation. Figure 3-28 presents the production well locations at the LCAAP. All samples were analyzed for explosive compounds, VOCs, BNAs, and inorganics (total and dissolved). Additionally, radioactive parameters in each well were analyzed during the second round of sampling. Sampling protocol is discussed in Subsection 2.1.5.4.

4.20.1 Production Well Analytical Results

The results of the production well sampling and analysis program are discussed on a plant-wide basis and any site-related detection at a production well will be related to a particular upgradient source area described in the summary subsections. Table 4-39 presents the analytical results.

Explosives

No explosive compounds were detected during the two rounds of production well sampling and analysis.

Volatile Organic Compounds

The results of the two rounds of production well sampling identified four VOCs, all of which were detected during the first round of sampling:

- Benzene.
- T12DCE.
- TRCLE.
- Vinyl chloride.

TABLE 4-39
LAKE CITY ARMY AMMUNITIONS PLANT
PRODUCTION WELLS
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	17AA-1	17AA-2	17BB-1	17BB-2	17DD-1	17DD-2
VOLATILES						
Trans-1,2-Dichloroethene	2.2	<1.72	<1.72	<1.72	<1.72	<1.72
Trichloroethene	26	<0.71	<0.71	<0.71	<0.71	<0.71
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	200	ND	ND	ND	ND	ND
UNKNOWNS						
3-Methoxy-ethanamine [905]	ND	ND	ND	ND	ND	20
C6-C9 Cycloalkane	ND	*10	ND	*8	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	*20	ND	ND	ND	*20
2,2,4-Trimethyl-3-Penten-1-ol [934]	ND	ND	ND	ND	ND	ND
C9-C16 propyl benzene	*100	ND	ND	ND	ND	ND
2,7-Dimethyl-1-Octanol [946]	40	ND	ND	ND	ND	ND
Bramohexane	*200	ND	ND	ND	ND	ND
2-(2,6-Dimethylheptyl) Cyclo butanone [958]	500	ND	ND	ND	ND	ND
C9-C12 Organic Acid Ester	*60	ND	ND	ND	ND	ND
Heptanoic Acid Anhydride [946]	500	ND	ND	ND	ND	ND
2,2,4-Trimethyl Pentanol [886]	30	ND	ND	ND	ND	ND
2,2-Dimethyl-1-Octonol [900]	100	ND	ND	ND	ND	ND
C18-C39 Unknown	300	ND	ND	ND	ND	ND
Benzothiazole Derivative	*20	ND	ND	ND	ND	ND
Heptanoic Acid Anhydride [949]	40	ND	ND	ND	ND	ND
1,3,5-Triphenyl-2, 4-Hexadien-1-one [901]	30	ND	ND	ND	ND	ND
N-Phenyl No. pthalenamine	*20	ND	ND	ND	ND	ND
3,5,5-Trimethyl-1-Hexanol [949]	80	ND	ND	ND	ND	ND
5,6-Decanedione [955]	50	ND	ND	ND	ND	ND
2,7-Dimethyl-1-Octanol [940]	100	ND	ND	ND	ND	ND
C6-C12 Alcohol	*30	ND	ND	ND	ND	ND
Hexanedioic Acid Ester	*50	ND	ND	ND	ND	ND
2,7-Dimethyl-1-Octanol [907]	200	ND	ND	ND	ND	ND
C6-Bromoalkane	*100	ND	ND	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, dissolved	<5.00	<5.00	6.11	<5.00	7.25	5.8
Arsenic, total	5.8	6.63	5.69	6.63	7.97	8.8
Barium, dissolved	NA	600	NA	66.3	NA	636
Barium, total	NA	655	NA	651	NA	608
Beryllium, total	<0.10	<0.10	<0.10	<0.10	0.15	<0.10
Copper, dissolved	28.9	<1.78	4.07	2.68	2.25	3.97
Copper, total	<1.78	5.04	10.6	<1.78	<1.78	4.07
Lead, dissolved	<2.50	3.54	<2.50	<2.50	<2.50	<2.50
Nickel, dissolved	10.4	<9.60	<9.60	<9.60	23.4	12
Nickel, total	<9.60	<9.60	<9.60	23.5	11.3	<9.60
Silver, dissolved	<0.19	<0.19	<0.19	<0.19	<0.19	0.64
Zinc, dissolved	183	46.5	193	90.2	175	19
Zinc, total	<17.20	55.1	<17.20	51.3	<17.20	117
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCI/L)						
Alpha	NA	10+/-6	NA	0+/-5	NA	0+/-5
Beta	NA	8+/-4	NA	9+/-4	NA	16+/-4
U-234	NA	0.2+/-0.1	NA	0.2+/-0.1	NA	0.2+/-0.1
U-235	NA	0+/-0.1	NA	0+/-0.1	NA	0+/-0.1
U-238	NA	0.3+/-0.2	NA	0.4+/-0.2	NA	0.2+/-0.1
Total Uranium	NA	NA	NA	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-39
LAKE CITY ARMY AMMUNITIONS PLANT
PRODUCTION WELLS
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	17EE-1	17EE-2	17FF-1	17FF-2	17JJ-1	17JJ-2
VOLATILES						
Benzene	<0.67	<0.67	1.4	<0.67	<0.67	<0.67
Trans-1, 2-Dichloroethene	<1.72	<1.72	<1.72	<1.72	<1.72	<1.72
Trichloroethene	<0.71	<0.71	3	<0.71	1.2	<0.71
Vinyl Chloride	<3.86	<3.86	350	<3.86	<3.86	<3.86
OTHERS	(ALL ND OR <CRL)					
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	10	ND	ND	ND	ND	ND
UNKNOWNS						
C6-C9 Alkene/Alkane	ND	*20	ND	ND	ND	ND
Hexene	ND	*10	ND	ND	ND	ND
C8-C10 Methyl Alkene/Alkane	ND	*20	ND	ND	ND	*10
C9-C10 Methyl Cyclohexane	ND	*10	ND	ND	ND	ND
C4-C8 Organic Acid derivative	ND	ND	ND	*10	ND	*20
C6-C9 Cycloalkane	ND	ND	ND	*30	ND	*20
C6-C7 Methyl Alcohol	ND	ND	ND	*20	ND	ND
1-Methoxy-2-(Methoxymethoxy) ethane [887]	ND	ND	20	ND	ND	ND
OTHERS	(ALL ND OR <CRL)					
EXPLOSIVE COMPOUNDS						
ALL	(ALL ND OR <CRL)					
INORGANICS						
Arsenic, dissolved	5.9	<5.00	10.6	5.49	<5.00	<5.00
Arsenic, total	6.11	7.35	11.2	9.63	<5.00	<5.00
Barium, dissolved	NA	313	NA	472	NA	563
Barium, total	NA	391	NA	577	NA	640
Beryllium, total	0.15	<0.10	<0.10	<0.10	<0.10	<0.10
Copper, dissolved	3	<1.78	2.89	<1.78	2.68	7.61
Copper, total	<1.78	3.22	<1.78	22.8	15.2	20.9
Lead, total	<2.50	<2.50	<2.50	3.34	<2.50	<2.50
Nickel, dissolved	23	<9.60	17.9	<9.60	15.4	<9.60
Nickel, total	10.2	<9.60	11.3	24.6	16.4	57.6
Silver, dissolved	<0.19	<0.19	<0.19	<0.19	<0.19	0.21
Zinc, dissolved	175	31.8	162	27.1	314	29.5
Zinc, total	<17.20	204	<17.20	369	<17.20	135
OTHERS	(ALL ND OR <CRL)					
RADIOLOGICAL (PCI/L)						
Alpha	NA	0+/-5	NA	0+/-5	NA	0+/-5
Beta	NA	14+/-4	NA	12+/-4	NA	17+/-5
U-234	NA	0.9+/-0.3	NA	0.4+/-0.2	NA	0+/-0.1
U-235	NA	0+/-0.1	NA	0+/-0.1	NA	0+/-0.1
U-238	NA	0+/-0.1	NA	0.5+/-0.2	NA	0.1+/-0.1
Total Uranium	NA	NA	NA	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-39
LAKE CITY ARMY AMMUNITIONS PLANT
PRODUCTION WELLS
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	17KK-1	17KK-2
VOLATILES		
ALL	(ALL ND OR <CRL)	
BASE NEUTRAL & ACID EXTRACTABLES		
UNKNOWNS		
C6-C7 Methyl Alcohol	ND	*20
C6-C9 Cyclo Alkane	ND	*20
Hexene	ND	*10
C8-C10 Methyl Alkene/Alkane	ND	*30
C9-C10 Methyl Propyl Cyclohexane	ND	*10
OTHERS	(ALL ND OR <CRL)	
EXPLOSIVE COMPOUNDS		
ALL	(ALL ND OR <CRL)	
INORGANICS		
Barium, dissolved	NA	113
Barium, total	NA	121
Beryllium, dissolved	0.13	<0.10
Copper, dissolved	3.43	4.07
Copper, total	12.1	5.25
Nickel, total	<9.60	19.1
Silver, dissolved	<0.19	0.74
Silver, total	0.21	<0.19
Zinc, dissolved	189	49.4
Zinc, total	<17.20	246
OTHERS	(ALL ND OR <CRL)	
RADIOLOGICAL (PCI/L)		
Alpha	NA	0+/-5
Beta	NA	17+/-4
U-234	NA	0.3+/-0.3
U-235	NA	0+/-0.2
U-238	NA	0+/-0.4
Total Uranium	NA	NA

CRL=CERTIFIED REPORTING LIMIT; ND=NOT DETECTED; NA=NA ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

During round 1, well 17-AA detected T12DCE and TRCLE at respective concentrations of 2.2 and 26 ug/l. Well 17-FF detected benzene, TRCLE, and vinyl chloride at respective concentrations of 1.4, 3.0 and 350 ug/l. Well 17-JJ detected TRCLE at 1.2 ug/l.

Base Neutral and Acid Extractable Compounds

The results of the two rounds of production well sampling identified one definitive BNA compound, B2EHP. The compound was detected during round 1 only, at well locations 17-AA and 17-EE at respective concentrations of 200 and 10 ug/l.

Numerous unknown BNA compounds were detected during the two rounds of sampling. At least one compound was detected in each of the seven production wells. Well 17-AA contained the most compounds at the highest concentrations. At least 22 different unknown BNA compounds were detected at concentrations ranging from 10 to 500 ug/l. Well 17-BB contained one unknown compound at 8 ug/l. Wells 17-DD, 17-EE, and 17-JJ contained unknowns ranging from 10 to 20 ug/l. Wells 17-FF and 17-KK contained unknowns ranging from 10 to 30 ug/l.

Inorganics

The results of the two rounds of groundwater sampling of seven production wells identified eight inorganics which exceeded statistical background concentrations. No inorganics identified exceeded the MGS, MDWS, and/or MCL. Table 4-40 summarizes the inorganic parameters which exceeded statistical background concentrations.

Radiological Parameters

All radiological activities were in the normal range for groundwater.

4.20.2 Summary

Potentially site-related detections of organic and/or inorganic parameters occurred at all seven sampled production well locations. Two of the well locations had VOC concentrations exceeding MCL values. No explosive compounds were identified during the two rounds of production well sampling.

All VOCs were detected during round 1. Trichloroethene exceeded the MCL of 5 ug/l at well location 17-AA with a detection of 26 ug/l. Vinyl chloride exceeded the MCL of 2 ug/l at well location 17-FF with a detection of 353 ug/l. The source of TRCLE at well location 17-AA is probably within Area 12, since the 17-AA capture zone attracts groundwater primarily from that area. The fact that no VOCs were detected at the Area 12 monitoring wells suggests that

TABLE 4-40
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
PRODUCTION WELL RESULTS

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION	MOST STRINGENT STANDARD (MGS, MDWS, or MCL) (ug/l)
Arsenic, dissolved	17EE-1, 17FF-1, 17FF-2, 17BB-1, 17DD-1, 17DD-2	5.49 - 10.6	17FF-1	30.00
Arsenic, total	17EE-1, 17EE-2, 17FF-1, 17FF-2, 17AA-1, 17AA-2, 17BB-1, 17BB-2 17DD-1, 17DD-2	5.69 - 11.2	17FF-1	30.00
Barium, dissolved	17AA-1, 17DD-2, 17EE-2, 17FF-2, 17JJ-2	313 - 636	17DD-2	--
Beryllium, dissolved	17KK-1	0.13	17KK-1	--
Copper, dissolved	17AA-1, 17BB-1, 17BB-2, 17DD-1, 17DD-2, 17EE-1, 17FF-1, 17JJ-1, 17JJ-2, 17KK-1, 17KK-2	2.25 - 28.9	17AA-1	1000.00
Lead, dissolved	17AA-2	3.54	17AA-2	50.00
Nickel, dissolved	17AA-1, 17DD-1, 17DD-2, 17EE-1 17FF-1, 17JJ-1	10.4 - 23.4	17DD-1	200.00
Silver, dissolved	17DD2, 17JJ-2, 17KK-2	0.21 - 0.74	17KK-2	50.00
Silver, total	17KK-1	0.21	17KK-1	50.00
Zinc, dissolved	17JJ-1	314	17JJ-1	5000.00

NOTE: * INDICATES CONCENTRATION GREATER THAN MGS, MDWS AND/OR MCL.
-- NO STANDARDS EXISTS.

the source may be located either between well 17-AA and the nearest monitoring well, or to the north, west, or south of well 17-AA.

The source of the vinyl chloride at well location 17-FF is probably within Area 18, especially the waste burning and burial pits at Area 18-B. However, the only nearby detection of vinyl chloride occurred at monitoring well location 16-13, which is downgradient of the abandoned landfill. This suggests that Area 16-A may also be the vinyl chloride source. Another explanation of the vinyl chloride at well 17-FF is the presence of TCLEE, TRCLLE, and 11DCLE at numerous upgradient locations in Areas 16, 17, and 18. Those contaminants could have degraded to produce some of the vinyl chloride.

The BNA compound B2EHP was detected at production well locations 17-AA and 17-EE at respective concentrations of 200 and 10 ug/l during round 1 only. This fact, in conjunction with the fact that B2EHP is a common field and laboratory contaminant suggests that it is not actually present in the groundwater at these two locations. The elevated concentrations of numerous unknown BNA compounds in well sample 17-AA suggest there is some site-related groundwater contamination of BNAs.

Eight inorganic parameters were detected at concentrations slightly exceeding statistical background values at various production well locations. None of the detections exceeded MGS, MDWS, or MCL values.

No elevated radiological activity was found at any of the seven production well locations.

4.21 SUMP AND SUMP OUTFLOW SAMPLING

4.21.1 Site Descriptions and Field Investigation

In many small buildings throughout the explosive area and outside the charging wings of the major buildings, small volumes of water containing various amounts of inorganics and explosive materials were discharged to sumps. The wastes discharged into the sumps were generated by miscellaneous housekeeping activities. The sumps collected wastes from ventilation systems, charging wings, and primer storage areas. Because of stringent safety rules governing the handling and accumulation of explosives in these areas, the discharges were limited to minor quantities. The typical sumps were provided with filter bags to collect the insoluble wastes, and the filtered water was discharged to the storm sewer or ditch system. In 1982, all floor drains and sinks leading to these sumps were reportedly plugged or removed to eliminate the discharge of housekeeping wastes. However, during this investigation, many of the sumps were actively receiving wastewater from various buildings, and the filter bags are no longer maintained. During the investigation, 35 sumps were visually inspected. The bottom sediments from eight sumps were sampled and analyzed. Of the eight locations sampled, three were observed to be actively receiving wastewater discharge. Additionally, many sumps contained large volumes of settled, oily sludge.

Because of the past and present condition of these sumps, and current discharge of wastewater into the unregulated storm sewer and ditch systems, a total of 34 samples were collected as part of the sump and sump outflow investigation. Samples were collected from the bottom of those sumps which receive or received wastewater from the source areas. Additional samples were collected at discharges near storm sewer outlets and in drainage ditch locations downgradient and upgradient of these discharges. The samples were analyzed for inorganics, oil and grease, and explosives. Site descriptions and field investigation summaries have been grouped according to common discharge and/or drainage locations. Figure 4-36 presents the sump sampling locations and the delineations which place them into their respective discharge or drainage groups. Table 4-41 summarizes the investigative sample designations and locations.

4.21.1.1 Group A

Group A consists of the sumps which service Buildings 1 and 2, and the storm sewer and drainage systems that receive the wastewater. Site reconnaissance indicates there are seven sumps that receive or have received wastewater from the charging wings of Building 1. As part of this investigation, sample SP31 was collected from the bottom of the sump located along the west-facing wall nearest the northwest corner of the eastern-most charging wing of Building 1. The sump is about 8 feet deep and contained 1 to 2 feet of oily sediment underlying about 3 feet of water. All seven sumps are designed to overflow into the storm sewer system which eventually discharges into Ditch 3.

Building 2 contains 12 sumps which receive or received wastewater from charging wings. As part of this investigation, two of these sumps were sampled during the field investigation. Sample SP32 was collected from the bottom of the sump located the farthest south along the eastern-most charging wing. Sample SP33 was collected from the bottom of the sump located at the southwestern corner of the western-most charging wing. Both sumps were about 8 feet deep with 3 feet of water overlying 3 feet of oily sediment. The latter sump was receiving flow from Building 2, and discharging through its overflow pipe apparently towards a nearby manhole.

Five samples were taken from Ditch A and Ditch 3 in order to characterize the effects of the sump discharge. Samples SP01, SP02, and SP03 were taken in Ditch 3 downgradient of the storm sewer discharge from Buildings 1 and 2. Samples SP04 and SP05 were taken in Ditch A immediately upgradient and downgradient of the

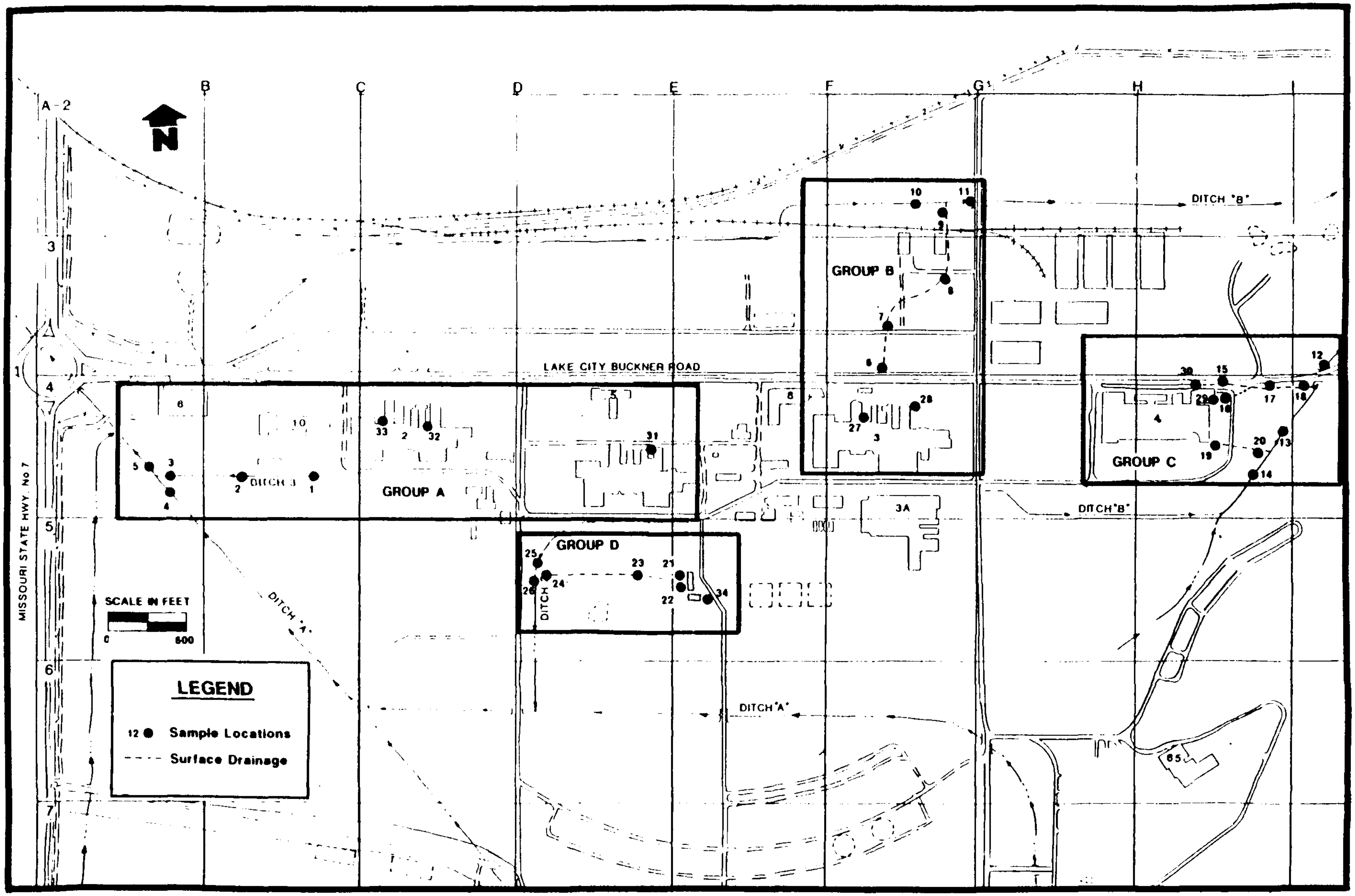


FIGURE 4-36

SUMP AND SUMP OUTFLOW SAMPLING LOCATIONS

TABLE 4-41
SUMP AND SUMP OUTFLOW SAMPLE DESIGNATIONS AND LOCATIONS

SAMPLE	GROUP	LOCATION DESCRIPTION
SP-01	A	Ditch 3, downgradient of discharge - closest, standing water
SP-02	A	Ditch 3, downgradient of discharge - midway, standing water
SP-03	A	Ditch 3, downgrade of discharge - farthest
SP-04	A	Ditch A, upgradient of Ditch 3, flowing water
SP-05	A	Ditch A, downgradient of Ditch 3, flowing water
SP-06	B	Drainage ditch from Building 3 - closest, standing water
SP-07	B	Drainage ditch from Building 3 - standing water
SP-08	B	Drainage ditch from Building 3 - dry
SP-09	B	Drainage ditch from Building 3 - farthest, dry
SP-10	B	Ditch B, upgradient of Building 3 drainage, dry
PS-11	B	Ditch B, downgradient of Building 3 drainage, dry
SP-12	C	Ditch B-1, downgradient of Building 4 discharge, standing water
SP-13	C	Ditch B-1, downgradient of Building 4 discharge, flowing water
SP-14	C	Ditch B-1, upgradient of all Building 4 discharge, flowing water
SP-15	C	Drainage ditch at discharge of Building 4 sump, standing water
SP-16	C	Drainage ditch at discharge of Building 4 sump, slow flow
SP-17	C	Drainage ditch downgradient of sump sample 29 discharge - closer, dry
SP-18	C	Drainage ditch downgradient of sump sample 29 discharge - farther, dry
SP-19	C	Drainage ditch at discharge of Building 4 sump, standing water
SP-20	C	Drainage ditch downgradient of southern sumps discharge, dry
SP-21	D	Discharge point from Building 97A sump (1 of 2), dry
SP-22	D	Discharge point from Building 98A sump (2 of 2), dry
SP-23	D	Drainage ditch downgradient of SP01 and SP02 -closer, dry
SP-24	D	Drainage ditch downgradient of SP01 and SP02 -farther, dry
SP-25	D	Ditch 2, upgradient of junction with SP23 & SP24 ditch, dry
SP-26	D	Ditch 2, downgradient of junction with SP23 & SP24 ditch, dry
SP-27	B	Sump, Building 3, possibly leaking, flow in
SP-28	B	Sump, Building 3, no flow
SP-29	C	Sump, Building 4, no flow
SP-30	C	Sump, Building 4, no flow
SP-31	A	Sump, Building 1, no flow
SP-32	A	Sump, Building 2, no flow, but water out overflow pipe
SP-33	A	Sump, Building 2 active flow in/out
SP-34	D	Sump, Building 97, recently constructed, active flow
SR-01	A	Manhole due south of laundry facility
SR-02	A	Manhole west of water tower south of Building 10
SR-03	A	Manhole due south of Building 10, northeast of the laundry facility

A0039

junction with Ditch 3. All five locations contained flowing or standing water.

4.21.1.2 Group B

Group B consists of the four sumps which receive or have received wastewater from the charging wings of Building 3, and the storm sewer and drainage systems through which the wastewater eventually flows. As part of this investigation, a total of eight samples were collected from the Group B area. Two of the samples were taken directly from the sumps. Sample SP27 was collected from the bottom of the southwestern-most sump near the western-most charging wing. The sump is approximately 5 feet deep and contained about 1.5 feet of soft black sediment underlying about 6 inches of clear water. The sump contained two inlets, one of which was discharging a small volume of clear water at the time of sampling. This inlet pipe appeared to come from the charging wing. No water was flowing out of the sump during the sampling, which may indicate that the sump bottom or discharge lines are leaking.

Sample SP28 was collected from the bottom of the eastern-most sump which services the eastern charging wing. This sump is approximately 7 feet deep and contained about 1 foot of black sediment underlying 2 to 3 feet of oily water at the time of sampling. The inlet pipe contained a disconnected filter bag. The sump is of the standard design having an overflow pipe leading to the storm sewer system. No water was flowing in or out of the sump during sampling.

Six additional samples were collected within the ditch drainage system which accepts wastewater from in the Building 3 sumps. Samples SP06, SP07, SP08, and SP09 were taken starting at the sewer system discharge location northwest of the Building 3 parking lot. Samples were collected progressively farther downgradient of that point in order to characterize any potential extent of contaminant migration. Samples SP10 and SP11 were collected in Ditch B immediately upgradient and downgradient of the junction with the initial drainage pathway. Sample locations SP06 and SP07 contained standing water while the remaining ditch locations were dry at the time of sampling.

4.21.1.3 Group C

Group C consists of nine sumps that receive wastewater from Building 4, plus the storm sewer and drainage systems through which the wastewater eventually flows. Of the nine building sumps, five appear to service the charging wing and four service the main building along its southern perimeter. A total of 11 Group C samples were collected as part of this investigation.

Sample SP29 was collected from the bottom of the eastern-most sump which appears to service the eastern-most charging wing. The sump is approximately 5 feet deep and contained about 1 foot of water over gray-black and brown sediment at the time of sampling. No water was flowing in or out of the sump. This sump is designed to discharge through an overflow pipe directly into the roadside ditch which runs along the south side of Lake City-Buckner Road.

Sample SP30 was collected from the bottom of the west-center sump located along the north side of the eastern-most charging wing. The sump is approximately 6 feet deep and contained about 1 foot of sediment underlying 1 foot of water at the time of sampling. This sump, along with the three others aligned near it, discharges to the sewer system that runs along the south side of the Lake City-Buckner Road. No water was flowing in any of these sumps.

The remaining nine Group C samples were collected in various ditches associated with the Building 4 sumps. Samples SP15, SP16, and SP19 were collected at the discharge points where the wastewater enters the drainage ditch systems. Samples SP17 and SP18 were taken in the ditch downgradient of the discharge of sump 29. Sample SP20 was taken in the ditch downgradient of the discharge from the southern sumps, and samples SP12, SP13, and SP14 were taken in Ditch B-1 downgradient and upgradient of its junction with all Building 4 wastewater discharge points.

4.21.1.4 Group D

Group D consists of approximately four sumps that may or may not have received wastewater from Buildings 94, 97, and 97A, plus the ditch system through which any overflow wastewater would eventually migrate. As part of this investigation, a total of seven Group D samples, consisting of one sump sample and six ditch samples, were collected as part of this investigation.

Sample SP34 was collected from the bottom of the sump located at the eastern end of Building 97. This sump was approximately 10 feet deep, with about 0.5 feet of black oily sediment underlying about 3.5 feet of water. This sump was newer than most of the others and was actively receiving wastewater from the building and discharging it through an overflow pipe to destinations unknown (towards the north). Samples SP21 and SP22 were collected at the discharge points of two drain pipes which lead from the Building 97A sump to the north. This sump is sand-filled and apparently not in use. A more recent pump station is apparently in operation for Buildings 97 and 97A. Samples SP23 and SP24 were taken in the drainage ditch progressively downgradient of these discharge points. Samples SP25 and SP26 were taken in Ditch 2 immediately upgradient and downgradient, respectively, of the junction with the Building 97 and 97A drainage ditch. All of these sample locations were dry at the time of sampling. No soil staining or other signs of contamination were evident.

TABLE 4-42
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
SUMP OUTFLOW SAMPLES

GROUP A

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION
Barium, total	SP-32, SP-33	287 - 379	SP-33
Cadmium, total	SP-02, SP-32, SP-33	7.99 - 11.9	SP-33
Chromium, total	SP-01, SP-02, SP-03, SP-05, SP-32, SP-33	14.9 - 89.8	SP-32
Copper, total	SP-01, SP-02, SP-03, SP-04, SP-05, SP-31, SP-32, SP-33	38.2 - 2900	SP-33
Lead, total	SP-01, SP-02, SP-03, SP-05, SP-31, SP-32, SP-33	14.7 - 370	SP-32
Mercury, total	SP-02, SP-04, SP-05, SP-32, SP-33	0.44 - 4.20	SP-33
Zinc, total	SP-02, SP-03, SP-04, SP-05, SP-31, SP-32, SP-33	136 - 8300	SP-33

GROUP B

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION
Barium, total	SP-07, SP-08, SP-09, SP-10, SP-11, SP-27, SP-28, SP-06	274 - 8090	SP-06
Beryllium, total	SP-08, SP-10	0.40 - 0.42	SP-08
Cadmium, total	SP-06, SP-27, SP-28	4.71 - 17.9	SP-27
Chromium, total	SP-06, SP-07, SP-08, SP-11, SP-27, SP-28	14.9 - 98.6	SP-27
Copper, total	SP-06, SP-07, SP-27, SP-28	230 - 14000	SP-27
Lead, total	SP-06, SP-07, SP-08, SP-09, SP-27, SP-28	13.9 - 990	SP-27
Mercury, total	SP-06, SP-28	0.57 - 7.01	SP-28
Nickel	SP-27	51.0	SP-27
Silver, total	SP-06, SP-07, SP-27	6.33 - 46	SP-06
Zinc, total	SP-06, SP-07, SP-08, SP-09, SP-27, SP-28	129 - 11000	SP-27

TABLE 4-42 (Cont.)
LAKE CITY ARMY AMMUNITIONS PLANT
SUMMARY OF INORGANIC DETECTIONS
SUMP OUTFLOW SAMPLES

GROUP C

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION
Barium, total	SP-20, SP-29, SP-30	316 - 2610	SP-29
Beryllium, total	SP-12	0.41	SP-12
Cadmium, total	SP-16, SP-19, SP-20, SP-29, SP-30	1.52 - 9.03	SP-30
Chromium, total	SP-12, SP-13, SP-14, SP-15, SP-16, SP-18, SP-19, SP-20, SP-29, SP-30	14.0 - 2500	SP-19
Copper, total	SP-12, SP-13, SP-14, SP-15, SP-16, SP-17, SP-18, SP-19, SP-20, SP-29, SP-30	24.3 - 10000	SP-19
Lead, total	SP-13, SP-15, SP-16, SP-17, SP-18, SP-19, SP-20, SP-29, SP-30	14.3 - 13000	SP-19
Mercury, total	SP-15, SP-17, SP-18, SP-19, SP-29, SP-30	0.55 - 19.0	SP-15
Silver, total	SP-29, SP-30	1.65 - 4.51	SP-30
Zinc, total	SP-14, SP-15, SP-16, SP-17, SP-18, SP-19, SP-20, SP-29, SP-30	138 - 2900	SP-19

GROUP D

INORGANIC	SAMPLE NUMBERS WITH SIGNIFICANT DETECTIONS	RANGE OF CONCENTRATIONS (ug/l)	SAMPLE NUMBER OF HIGHEST CONCENTRATION
Antimony	SP-21	58.6	SP-21
Barium, total	SP-21, SP-22, SP-23, SP-24, SP-34	334 - 4270	SP-34
Cadmium, total	SP-21, SP-22, SP-23, SP-24, SP-25, SP-26, SP-34	2.06 - 23.0	SP-22
Chromium, total	SP-21, SP-23, SP-24, SP-25, SP-26, SP-34	16.0 - 25.4	SP-23
Copper, total	SP-21, SP-22, SP-23, SP-24, SP-25, SP-26, SP-34	43.1 - 420	SP-23
Lead, total	SP-22, SP-23, SP-24, SP-25, SP-26, SP-34	51.0 - 1900	SP-23
Mercury, total	SP-21, SP-22, SP-23	0.60 - 0.95	SP-22
Zinc, total	SP-21, SP-22, SP-23, SP-24, SP-34	121 - 342	SP-23

TABLE 4-43
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
SUMP AND SEWER SAMPLES (UG/G)

SITE ID	SP-01-1	SP-02-1	SP-03-1	SP-04-1	SP-05-1	SP-06-1
VOLATILES						
ALL	(ALL NA)					
BASE NEUTRAL & ACID EXTRACTABLES						
ALL	(ALL NA)					
EXPLOSIVE COMPOUNDS						
24-DNT	<0.42	<0.42	<0.42	<0.42	<0.42	0.59
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Barium, total	142	52.3	143	112	147	8090
Cadmium, total	<0.70	7.99	<0.70	<0.70	<0.70	4.71
Chromium, total	18.8	32	14.9	11.7	20.9	43.8
Copper, total	38.2	260	41.4	59.8	84	1100
Lead, total	20	62.9	14.7	9.09	16.9	360
Mercury, total	<0.10	2.45	<0.10	0.44	2.17	0.57
Nickel, total	14	8.44	13.2	12.5	9.38	8.83
Silver, total	<0.65	<0.65	<0.65	<0.65	<0.65	46
Zinc, total	71.3	341	160	136	203	641
OTHERS	(ALL ND OR <CRL)					
GENERAL TESTS						
Oil and grease	ND	710	230	170	670	2100

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CER NTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-43
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
SUMP AND SEWER SAMPLES (UG/G)

SITE ID	SP-07-1	SP-08-1	SP-09-1	SP-10-1	SP-11-1	SP-12-1
VOLATILES						
ALL	(ALL NA)					
BASE NEUTRAL & ACID EXTRACTABLES						
ALL	(ALL NA)					
EXPLOSIVE COMPOUNDS						
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Barium, total	3850	529	394	274	292	161
Beryllium, total	<0.33	0.42	<0.33	0.4	0.36	0.41
Chromium, total	16.1	14.9	10	13.2	15.5	20.4
Copper, total	230	17.6	13.7	15.3	15.1	26.7
Lead, total	17.2	13.9	13.9	12.8	<4.78	<4.78
Nickel, total	11.7	15.9	22.9	14.2	15.6	20.7
Silver, total	6.33	<0.65	<0.65	<0.65	<0.65	<0.65
Zinc, total	420	129	140	93.2	94.2	77.8
OTHERS	(ALL ND OR <CRL)					
GENERAL TESTS						
Oil and grease	16	100	97	ND	220	120

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

TABLE 4-43
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
SUMP AND SEWER SAMPLES (UG/G)

SITE ID	SP-13-1	SP-14-1	SP-15-1	SP-16-1	SP-17-1	SP-18-1
VOLATILES						
ALL	(ALL NA)					
BASE NEUTRAL & ACID EXTRACTABLES						
ALL	(ALL NA)					
EXPLOSIVE COMPOUNDS						
24-DNT	<0.42	<0.42	0.77	<0.42	<0.42	<0.42
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Barium, total	157	160	144	120	163	149
Beryllium, total	<0.33	<0.33	<0.33	<0.33	<0.33	0.34
Cadmium, total	<0.70	<0.70	<0.70	1.52	<0.70	<0.70
Chromium, total	15.1	15.6	14	35.3	11.9	16.8
Copper, total	44.6	24.3	260	1000	58.5	110
Lead, total	19.7	8.83	14.3	180	24.7	15.6
Mercury, total	<0.10	<0.10	19	<0.10	6.3	2.14
Nickel, total	13.8	15.3	14.1	10.8	20.4	16
Zinc, total	109	138	558	940	264	218
OTHERS	(ALL ND OR <CRL)					
GENERAL TESTS						
Oil and grease	300	220	3900	1700	ND	210

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-43
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
SUMP AND SEWER SAMPLES (UG/G)

SITE ID	SP-19-1	SP-20-1	SP-21-1	SP-22-1	SP-23-1	SP-24-1
VOLATILES						
ALL	(ALL NA)					
BASE NEUTRAL & ACID EXTRACTABLES						
ALL	(ALL NA)					
EXPLOSIVE COMPOUNDS						
24-DNT	<0.42	<0.42	0.63	2.3	<0 42	<0.42
26-DNT	<0 40	<0.40	<0 40	<0.40	0.99	<0.40
HMX	<1.27	<1.27	<1.27	<1.27	3.1	<1.27
RDX	<0.98	<0.98	1.1	<0.98	2.4	<0.98
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Antimony, total	<25.30	<25.30	58.6	<25.30	<25.30	<25.30
Barium, total	130	316	2730	4140	2530	334
Beryllium, total	<0.33	0.37	<0.33	<0.33	<0.33	<0.33
Cadmium, total	6.38	2.4	11.1	23	18	6.98
Chromium, total	2500	57.7	18.1	12.2	25.4	17 5
Copper, total	10000	390	250	280	420	110
Lead, total	13000	300	<4.78	1300	1900	350
Mercury, total	0.55	<0.10	0.88	0.95	0.6	<0 10
Nickel, total	14.7	26.2	15.1	14.8	16	21.9
Zinc, total	2900	696	275	339	342	121
OTHERS	(ALL ND OR <CRL)					
GENERAL TESTS						
Oil and grease	27000	1300	200	570	800	ND

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-43
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
SUMP AND SEWER SAMPLES (UG/G)

SITE ID	SP-25-1	SP-26-1	SP-27-1	SP-28-1	SP-29-1	SP-30-1
VOLATILES						
ALL	(ALL NA)					
BASE NEUTRAL & ACID EXTRACTABLES						
ALL	(ALL NA)					
EXPLOSIVE COMPOUNDS						
135-TNB	<2.09	<2.09	<2.09	36	<2.09	<2.09
24-DNT	<0.42	<0.42	<0.42	930	63	0.67
26-DNT	<0.40	<0.40	<0.40	16	<0.40	<0.40
OTHERS	(ALL ND OR <CRL)					
INORGANICS						
Barium, total	216	234	1250	1290	2610	2280
Beryllium, total	0.38	<0.33	<0.33	<0.33	<0.33	<0.33
Cadmium, total	2.54	2.06	17.9	9.79	7.55	9.03
Chromium, total	18.3	16	98.6	31.2	31.2	101
Copper, total	47.6	43.1	14000	680	1000	1500
Lead, total	73	51	990	350	5100	1800
Mercury, total	<0.10	<0.10	<0.10	7.01	1.65	0.72
Nickel, total	20	17.5	51	14.5	11.3	22.1
Silver, total	<0.65	<0.65	10.6	<0.65	1.65	4.51
Zinc, total	102	92.5	11000	2000	523	2000
OTHERS	(ALL ND OR <CRL)					
GENERAL TESTS						
Oil and grease	98	ND	9100	4600	12000	18000

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-43
LAKE CITY ARMY AMMUNITIONS PLANT
PLANT WIDE
SUMMARY OF ANALYTICAL DATA
SUMP AND SEWER SAMPLES (UG/G)

SITE ID	SP-31-1	SP-32-1	SP-33-1	SP-34-1	SR01-1	SR02-1	SR03-1
VOLATILES							
ALL	NA	NA	NA	NA	ND	ND	ND
BASE NEUTRAL & ACID EXTRACTABLES							
ALL	(ALL NA)						
EXPLOSIVE COMPOUNDS							
NB	2.9	<0.42	<0.42	<0.42	NA	NA	NA
OTHERS	(ALL ND OR <CRL)				NA	NA	NA
INORGANICS							
Barium, total	138	287	379	4270	NA	NA	NA
Cadmium, total	<0.70	10.9	11.9	3.26	NA	NA	NA
Chromium, total	8.79	89.8	42.3	19.1	NA	NA	NA
Copper, total	150	1300	2900	380	NA	NA	NA
Lead, total	41.1	370	210	950	NA	NA	NA
Mercury, total	<0.10	1.5	4.2	<0.10	NA	NA	NA
Nickel, total	14.7	18.7	14.1	11.9	NA	NA	NA
Zinc, total	195	7300	8300	160	NA	NA	NA
OTHERS	(ALL ND OR <CRL)				NA	NA	NA
GENERAL TESTS							
Oil and grease	18000	4900	4900	2000	NA	NA	NA

CRL=CERTIFIED REPORTING LIMIT. ND=NOT DETECTED. NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH*

4.21.2 Sump and Sump Outflow Analytical Results

This section discusses the analytical data and presents significant findings and interpretations. Table 4-42 summarizes the inorganic parameters which exceeded statistical background concentrations. Table 4-43 presents all of the sump and sump outflow analytical results. In general, contaminant concentrations were highest in samples collected from the sumps themselves, while concentrations within the ditches decreased proportionally with sample distance from the discharge location.

4.21.2.1 Group A

Inorganics

Table 4-42 summarizes the significant detection of inorganic parameters from the sump and sump outflow sampling program.

The sump samples SP-32 and SP-33, which were taken from Building 2 sumps, contained the highest concentrations of all of the inorganics within the Group A analytical results. This includes elevated detections of barium, cadmium, chromium, copper, lead, mercury, and zinc. The concentrations detected at building 2 sumps are higher than those detected at building 1 sump.

Of the five samples collected from Ditch A and Ditch 3, sample SP-02 had consistently higher detections, showing high concentrations of cadmium, chromium, copper, lead, mercury, and zinc. As shown in Figure 4-36, sample SP-02 is the middle sample of the three Ditch 3 samples. An explanation for the higher detections at SP-02 is that the sample was collected closer to the sump outfall. Sample SP-01 was collected along the edge of the ditch and could not be collected in the center of the ditch where the sump outfall occurs and where higher concentrations of inorganics may occur.

The effects of the discharge of Ditch 3 sediment into Ditch A is clearly shown by comparing the results of sample SP-04 (upgradient of the junction) and sample SP-05 (downgradient of the junction). All five of the inorganics identified from these samples at elevated concentrations are found at higher levels in the downgradient sample.

The SP-33 sump had water actively flowing in and out toward a nearby manhole at the time of sampling.

Explosives

Explosive compound analytical results of the Group A samples were all non-detected except for 2.90 ug/g of nitrobenzene, found in SP31, the Building 1 sump.

Oil and Grease

Elevated values of oil and grease were found in the three Building 1 and 2 sump samples, with 18,300, 4,880, and 4,920 ug/g detected in SP31, SP32, and SP33 respectively. Ditch samples SP02, SP03, SP04, and SP05 showed oil and grease values of 705, 233, 172 and 667 ug/g, respectively.

Volatile Organic Compounds

No definitive VOCs were identified in the three sewer samples, but six different unknown VOCs were detected at estimated concentrations ranging from 40 to 400 ug/l in sample SR01-01.

4.21.2.2 Group B

Inorganics

Table 4-42 summarizes the elevated detections of inorganic parameters from the sump and sump outflow sampling program. The sump samples SP-27 and SP-28, which were taken from the Building 3 sumps, detected the highest concentrations of all but two of the inorganics within the Group B analytical results. This includes elevated detections of cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc. The SP-27 sump had water slowly flowing in but not flowing out the overflow drain.

The six ditch samples collected within the Building 3 storm sewer drainage ditch clearly show decreasing contaminant concentrations proportional to distance from the sump/storm sewer outfall. All of the highest elevated detections occurred in sample SP-06 except beryllium, which was sporadically detected in trace quantities. Sample SP-06 detected highs of barium, cadmium, chromium, copper, lead, mercury, silver, and zinc. Sample SP-06 detected 8090 ug/g of barium, the highest concentration found at LCAAP.

The effects of the sump discharge are negligible near sample SP-08 and downgradient from there. No change occurs in inorganic concentrations between samples SP-10 and SP-11, which were collected in Ditch B upgradient and downgradient, respectively, of its junction with the Group B drainage ditch.

Explosives

The only explosives detections in the Group B samples are from samples SP06 and SP28. Sample SP06 detected 0.59 ug/g of 24DNT. Sample SP28 detected 930 ug/g of 24DNT, 36.0 ug/g of 135TNB, and 16.0 ug/g of 26DNT.

Oil and Grease

Elevated values of oil and grease were found in all Group B samples except the upgradient location of SP10. The building sump samples SP27 and SP28 had oil and grease concentrations of 9070 and 4640 ug/g, respectively. The downgradient ditch samples SP06, SP07, SP08, SP09 and SP11 had values of 2090, 15.7, 104, 97.0, and 218 ug/g, respectively.

4.21.2.3 Group C

Inorganics

Table 4-42 summarizes the elevated detections of inorganic parameters from the sump and sump outflow sampling program.

Sump samples SP-29 and SP-30, which were taken from the Building 4 sumps, detected relatively high concentrations of barium, cadmium, chromium, copper, lead, mercury, silver, and zinc. Sample SP-29 had the highest barium concentration of the Group C samples. Sample SP-30 had the highest cadmium concentration of the Group C samples. The highest levels of chromium, copper, lead, mercury, silver, and zinc were uncharacteristically found in ditch samples.

Most of the highest inorganic detections in Group C occurred in sample SP-19, which was collected at the outfall of the southern sump/sewer system at Building 4. The exceptions to this are beryllium, which was sporadically detected in trace quantities, and mercury, which had an elevated detection of 19.0 ug/g in sample SP-15.

Ditch sample SP-20 was collected downgradient of sample SP-19, and shows a large decrease in parameter concentrations.

Sample SP-16, which was taken at another sump outfall, also showed relatively high detections, especially of chromium, copper, lead, and zinc.

Samples SP-17 and SP-18 characteristically showed decreasing concentrations of many inorganics identified in sample SP-15, especially mercury and zinc.

Relatively low concentrations of inorganics were detected in sample SP-12, SP-13, and SP-14, all of which were collected from Ditch B-1.

Explosives

One explosive compound was identified from the Group C samples. Samples SP15, SP29, and SP30 detected 24DNT at respective concentrations of 0.77, 63.0, and 0.67 ug/g.

Oil and Grease

Elevated concentrations of oil and grease were found in both sump samples and eight of nine ditch samples, including the upgradient ditch location. The building sumps contained two of the higher values: 11,700 ug/g in SP29 and 17,500 ug/g in SP30. The ditch samples contained the following concentrations: SP12, 118 ug/g; SP13, 304 ug/g; SP14, 216 ug/g; SP15, 3880 ug/g; SP16, 1670 ug/g; SP18, 214 ug/g; SP19, 27,200 ug/g; and SP20, 1270 ug/g. These results indicate that the southern Building 4 drainage system has released the most oil and grease into the ditch system.

4.21.2.4 Group D

Inorganics

Table 4-42 summarizes the significant detections of inorganic parameters from the sump and sump outflow sampling program.

The sump sample SP-34, collected from the Building 97 sump, exceeded statistical background concentrations of barium, cadmium, chromium, copper, lead, and zinc. Compared to inorganics concentrations from other sumps sampled during the investigations, detections in the Building 97 sump were relatively low. The most significant values were 950 ug/g of lead and 4270 ug/g of barium.

Of the six ditch samples, only those collected from the shallow drainage pathway leading from the former Building 97A sump outfall detected relatively high inorganics concentrations. Neither of the two Ditch 2 samples (SP-25 and SP-26) contained significant concentrations. Sample SP-21 had the sole detection of antimony, with an exceptionally high value of 58.6 ug/g. Samples SP-22 and SP-23 contained the highest concentrations of the remaining significant detections from Group D, especially barium, cadmium, and lead. Trace quantities of mercury were also detected in samples SP-21, SP-22, and SP-23. The downgradient ditch sample SP-24 showed predictably lower values of most inorganics.

Explosives

Explosive compound analytical results for the Group D samples showed low detections of various compounds. Sump sample SP34 was negative for all explosives analyzed, as were the two Ditch 2 samples. Ditch samples SP21 and SP22 had 0.63 and 2.3 ug/g of 24DNT, respectively. Samples SP21 and SP23 had 1.10 and 2.40 ug/g of RDX, respectively. Sample SP23 had 3.10 ug/g of HMX and 0.99 ug/g of 26DNT.

Oil and Grease

Elevated oil and grease concentrations were detected in the sump sample and four of the six ditch samples. SP34 had a high concentration of 2020 ug/g. Discharge locations SP21 and SP22 had values of 204 and 571 ug/g, respectively. Samples SP23 and SP25 has values of 804 and 97.8 ug/g, respectively. The oil and grease detected from SP25, which is upgradient of Building 97A discharge within Ditch 2, suggests the presence of another source upgradient of that location. This source is probably the Building 1 storm sewer system which originates along the south side of the building.

4.21.3 Summary

A total of 34 sump and sump outflow samples, and 3 sewer samples were collected and analyzed. Figure 4-36 shows the sampling locations and the four groups into which the samples are categorized. Table 4-41 describes the sample designations and locations.

The sump and sump outflow samples were analyzed for explosives, inorganics, and oil and grease. The sewer samples were analyzed for VOCs. All samples were collected during round 1. No VOCs were detected in the three sewer samples, which were collected at Area 12. There were many detections of elevated explosive, inorganic, and oil and grease concentrations in the sump and sump outflow samples.

The highest occurrence of significant detections was in the sumps, which commonly contained a few feet of clear water overlying a bottom layer of oily black sediment. Most of the sumps are designed to overflow into various storm sewers on-site, all of which eventually discharge into the plant-wide drainage ditch system. A total of 26 of the 34 samples were collected from the ditch system. Most of the highest concentrations of contaminants detected from the ditch samples (sump outflow samples) occurred nearest the discharge locations. Concentrations characteristically decline with increasing sample distance downgradient from the discharge locations.

All eight of the sampled sumps contained oil and grease, at concentrations ranging from 2,020 to 18,300 ug/g. Twenty-one of the 26 ditch samples also contained oil and grease, at concentrations ranging from 15.7 to 27,200 ug/g.

Four of the eight sumps contained explosive compounds, with total concentrations ranging from 0.67 to 930 ug/g. Sump sample SP-28 contained the highest level of explosive compounds (24-DNT). Five of the 26 ditch samples contained explosive compounds, with total concentrations ranging from 0.59 to 6.49 ug/g.

Inorganics analytical results often show a direct relationship between the magnitude of concentrations found in the sumps and the magnitude of concentrations found in each associated ditch sample. For instance, Group A sumps contained a high barium concentration of 379 ug/g while Group A ditch samples contained a high barium concentration of 147 ug/g. Group B sumps contained a high barium concentration of 1,290 ug/g while Group B ditch samples contained a high barium concentration of 8,090 ug/g.

Many of the sumps associated with miscellaneous building wastes were not sampled during this investigation, and this data gap may explain why some concentrations found in ditch samples are higher than those found in their associated sump samples.

4.22 BACKGROUND SAMPLES

As described in the introduction to this section, groundwater, surface water, and surface soil samples were collected at upgradient, or "clean" locations, in order to formulate background inorganic values for various matrices across the site. This subsection describes the sample designations and locations, and summarizes the inorganic analytical results of the various background samples collected during the RI. Appendix F presents the calculations used to formulate statistical background inorganic values of on-site soil and groundwater. Table 4-44 presents the analytical results for all of the background samples.

4.22.1 Background Surface Soil Samples

Four background surface soil samples were collected at four separate locations, as shown in Figure 4-35. The samples were analyzed for VOCs, BNAs, explosives, and inorganics. Three of the background samples were taken from the alluvial plain, and one was from the uplands. Samples were collected during round 1. No VOCs, BNAs, or explosive compounds were definitively identified in the background soils although some unknown BNAs were detected. Inorganics detected in BGS-2 and which were determined to be above statistical background concentrations included nickel and zinc at 36.7 and 126 ug/g, respectively. Sample BGS-3 detected barium, beryllium, chromium, copper, and lead at respective concentrations of 256, 0.45, 13.5, 22.6, and 14.9 ug/g.

Unknown BNA compounds were detected in three of the four background soil samples. Sample BGS-1 had one detection of 1 ug/g. Sample BGS-2 had three detections between 2 and 3 ug/g. Sample BGS-4 had one detection of 1 ug/g.

4.22.2 Background Surface Water Sample

Surface water sample SW-16 was collected from the Big Ditch as it enters the base at the south end of the property, as shown in Figure 4-34. The sample was analyzed for VOCs, BNAs, explosives, and inorganics. No VOCs, BNAs, or explosive compounds were detected and the inorganics were below criteria.

TABLE 4-44
LAKE CITY ARMY AMMUNITIONS PLANT
BACKGROUND SAMPLES
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID DEPTH (FT)	1-4-1 23.5	1-4-2 23.5	1-5-2 13	4-6-1 37.5	4-6-2 37.5	8-6-1 27
VOLATILES						
OTHERS			(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES						
bis (2-Ethylhexyl) Phthalate	ND	ND	20	ND	10	ND
OTHERS			(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS						
ALL			(ALL ND OR <CRL)			
INORGANICS						
Antimony, dissolved	<3.00	<3.00	<3.00	<3.00	4.66	<3.00
Antimony, total	<3.00	<3.00	<3.00	<3.00	11.4	<3.00
Arsenic, total	<5.00	<5.00	17.1	<5.00	<5.00	5.18
Barium, dissolved	NA	112	320	NA	156	NA
Barium, total	NA	135	1470	NA	131	NA
Beryllium, total	2.92	0.50	0.55	0.2	0.2	0.7
Cadmium, total	<5.10	<5.10	24.7	<5.10	33.3	<5.10
Chromium, total	<37.50	<37.50	49	<37.50	34.4	<37.50
Copper, dissolved	<1.78	<1.78	<1.78	5.04	<1.78	<1.78
Copper, total	71	10.9	200	14.1	3.86	41.5
Lead, dissolved	3.13	<2.50	<2.50	<2.50	<2.50	<2.50
Lead, total	57	8.39	45	3.54	<2.50	22.8
Mercury, dissolved	0.2	ND	ND	ND	ND	ND
Nickel, dissolved	14.2	<9.60	<9.60	16.7	<9.60	<9.60
Nickel, total	79.3	<9.60	346	14.4	9.8	29.9
Selenium, dissolved	7.4	<5.00	<5.00	<5.00	<5.00	<5.00
Selenium, total	<5.00	5.58	<5.00	<5.00	<5.00	<5.00
Silver, total	<0.19	0.21	0.53	<0.19	<0.19	<0.19
Zinc, dissolved	444	33.3	20.9	269	30.4	516
Zinc, total	744	62	1100	1100	703	592
OTHERS			(ALL ND OR <CRL)			

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

**DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT ALL OTHER UNKNOWNS SHOWN PRESENT THE BEST LIBRARY MATCH*

TABLE 4-44
LAKE CITY ARMY AMMUNITIONS PLANT
BACKGROUND SAMPLES
SUMMARY OF ANALYTICAL DATA
GROUNDWATER SAMPLES (UG/L)

SITE ID	8-6-2	11-3-1	11-3-2	17-1-1
DEPTH (FT)	27	25.5	25.5	44
VOLATILES				
Trans-1, 2-Dichloroethene	<1.72	2.3	<1.72	<1.72
OTHERS		(ALL ND OR <CRL)		
BASE NEUTRAL & ACID EXTRACTABLES				
bis (2-Ethylhexyl) Phthalate	ND	50	ND	200
OTHERS		(ALL ND OR <CRL)		
EXPLOSIVE COMPOUNDS				
RDX	<0.63	<0.63	<0.63	<0.63
OTHERS		(ALL ND OR <CRL)		
INORGANICS				
Antimony, total	<3.00	<3.00	<3.00	<3.00
Arsenic, total	7.66	<5.00	<5.00	<5.00
Barium, dissolved	139	NA	235	NA
Barium, total	397	NA	360	NA
Beryllium, total	0.81	0.6	0.5	0.91
Cadmium, total	<5.10	<5.10	<5.10	<5.10
Copper, dissolved	<1.78	<1.78	<1.78	3.64
Copper, total	30.4	22.2	30.2	13.3
Lead, dissolved	<2.50	<2.50	5.56	<2.50
Lead, total	19.9	<2.50	26.6	37
Nickel, dissolved	<9.60	19.1	<9.60	<9.60
Nickel, total	48.2	31.8	51.7	28
Silver, total	0.32	<0.19	<0.19	<0.19
Zinc, dissolved	18	910	<17.20	800
Zinc, total	228	970	220	946
OTHERS		(ALL ND OR <CRL)	(ALL ND OR <CRL)	

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

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TABLE 4-44
LAKE CITY ARMY AMMUNITIONS PLANT
BACKGROUND SAMPLES
SUMMARY OF ANALYTICAL DATA
SURFACE SOIL SAMPLES (UG/G)

SITE ID	BGS-1-1	BGS-2-1	BGS-3-1	BGS-4-1
VOLATILES				
ALL	(ALL ND OR <CRL)			
BASE NEUTRAL & ACID EXTRACTABLES				
UNKNOWNS				
2,4 6-Trimethyl Octane [874]	1	ND	ND	ND
C11-C13 Hydrocarbon-1	ND	*3	ND	ND
C11-C13 Hydrocarbon-2	ND	*2	ND	ND
C8-C12 Methyl Alkane	ND	*2	ND	ND
2-Bromooctane [885]	ND	ND	ND	1
OTHERS	(ALL ND OR <CRL)			
EXPLOSIVE COMPOUNDS				
ALL	(ALL ND OR <CRL)			
INORGANICS				
Barium, total	189	147	256	202
Beryllium, total	0.28	0.28	0.45	0.31
Chromium, total	13	13.1	13.5	12.9
Copper, total	11.3	12.9	22.6	15.1
Lead, total	7.82	6.3	14.9	10.5
Nickel, total	22.3	36.7	19.7	20.3
Zinc, total	67.1	126	98.5	84.6
OTHERS	(ALL ND OR <CRL)			

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

*DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS SHOWN REPRESENT THE BEST LIBRARY MATCH

TABLE 4-44
LAKE CITY ARMY AMMUNITIONS PLANT
BACKGROUND SAMPLES
SUMMARY OF ANALYTICAL DATA
DITCH SURFACE WATER SAMPLES (UG/L)

SITE ID	SW-16-1
VOLATILES	
ALL	(ALL ND OR <CRL)
BASE NEUTRAL & ACID EXTRACTABLES	
ALL	(ALL ND OR <CRL)
EXPLOSIVE COMPOUNDS	
ALL	(ALL ND OR <CRL)
INORGANICS	
Copper, total	4.93
Nickel, total	12
Zinc, total	404
OTHERS	(ALL ND OR <CRL)

CRL=CERTIFIED REPORTING LIMIT ND=NOT DETECTED NA=NOT ANALYZED

DENOTES A GREATER THAN 99% CERTAINTY THAT THE COMPOUND(S) IS PRESENT. ALL OTHER UNKNOWNS REPRESENT THE BEST LIBRARY MATCH

4.22.3 Background Groundwater Samples

Six monitoring well locations were used to determine the statistical background concentrations of inorganics in groundwater. These consisted of well locations 1-4, 1-5, 4-6, 8-6, 11-3, and 17-1, all of which are located upgradient or sidegradient of suspected contaminant source areas. The samples were analyzed for VOCs, BNAs, explosives, and inorganics.

4.23 RADIOLOGICAL INVESTIGATION

As part of the remedial investigation, a total of 38 samples were collected for radiological analysis, specifically, total alpha, total beta, and uranium radioactivity. Each sample has been discussed within the subsection for its particular study area. All of the samples were collected from monitoring wells and production wells.

4.23.1 Normal Groundwater Radioactivity

According to national averages, the normal range of uranium in groundwater is approximately 0.1 to 10 pCi/l. The average value for beta activity in drinking water in the U.S. is 3 pCi/l (Hem, 1985). The average alpha activity in domestic drinking water is 0.4 pCi/l. The alpha activity can go well above 1,000 pCi/l when radon is present.

There is little data in the Kansas City, Missouri region because most municipalities use surface water supplies. In the center of the state, where deep wells are used as a drinking water source, alpha activities are generally less than 15 pCi/l. However, some wells exceeded this level; for example, a particular well recorded an alpha activity of 40 pCi/l (Burgess, 1988). Available information regarding normal beta activity for the State of Missouri indicates 20 to 30 pCi/l is in the range of normal activity (Marikos, 1988).

4.23.2 Summary of Results

The analytical results are presented in Table 4-45.

In general, all of the readings are within the normal range of radiation activities found in groundwater. However, several of the alpha and beta activities are at the high end of that range for Missouri groundwater and are also above the government standards of 15 pCi/l for alpha and 50 pCi/l for beta. Three (16-2, 17-9, 17-10) of the six wells which contained the highest activities are near a suspected uranium disposal areas (Area 16 and 17).

The highest activities measured during this study are: total uranium activity of 3.6 pCi/l (3, Area 8), total alpha activity of 33 pCi/l (4, Area 8) and total beta activity of 96 pCi/l (3). Five

TABLE 4-45

RADIOLOGICAL SAMPLES
ANALYTICAL RESULTS (pCi/1)

Area	Round[1]	Well No.	Alpha	Beta	U-234	U-235	U-238	Total
1	1	1-10	<7	<9				0.6
3	1	3-2	0±5	0±5	0±0.1	0±0.1	0±0.1	
	1	3-3	0±5	0±5	0±0.1	0±0.1	0±0.1	
	1	3-4	0±5	0±5	0±0.1	0±0.1	0±0.1	
	1	3-5	0±5	0±5	0.1±0.1	0±0.1	0±0.1	
	1	3-7	0±5	4±3	0.1±0.1	0±0.1	0.1±0.1	
	2	3-7	0±5	9±4	0.2±0.1	0±0.1	0.1±0.1	
	1	3-8	0±5	9±4	0±0.1	0±0.1	0±0.1	
	2	3-8	0±5	22±5	0.7±0.2	0	0.8±0.2	
4	1	4-2	<6	<7				1.5
5	2	5-2	0±5	15±4	0.9±0/2	0±0.1	0.6±0.2	
7	2	7-5	23±11	34±5	1.5±0.4	0±0.1	0.8±0.4	
	1	7-6	0±5	4±3	0±0.1	0±0.1	0±0.1	
	2	7-6	0±5	17±4	0.9±0.3	0±0.1	0.9±0.3	
8	1	8-8	<7	<5				1.1
	2	1	0±5	24±5	1.3±0.3	0.0±0.1	0.9±0.3	
	2	2	6±6	21±5	1.7±0.3	0.1±0.1	1.3±0.3	
	2	3	22±10	96±8	1.9±0.4	0.0±0.1	1.7±0.3	
	2	4	33±15	50±6	1.5±0.2	0.0±0.1	1.2±0.2	
	2	5	0±5	29±6	1.0±0.2	0.0±0.1	0.6±0.2	
14	1	14-4	7±5	15±5				0.9
	2	14-4	0±5	13±4	0.5±0.3	0±0.1	0.7±0.3	
16	2	16-2	12±9	46±6	1.6±0.3	0±0.1	1.5±0.3	
17	1	17-9	<5	<7				0.5
	2	17-9	12±10	54±6	0.6±0.3	0±0.1	0.7±0.3	
	1	17-10	<11	56±12				<0.2
	2	17-10	17±10	79±7	0.9±0.3	0±0.1	0.7±0.3	
18	1	18-1	<5	<7				0.6
	1	18-4	<4	<5				<0.2
	1	18-5	<2	<3				<0.2
	1	18-6	<2	<3				<0.2
PW	2	17-AA	10±6	8±4	0.2±0.1	0.0±0.1	0.3±0.2	
	2	17-JJ	0±5	17±5	0±0.1	0±0.1	0.1±0.1	
	2	17-KK	0±5	17±4	0.3±0.3	0±0.2	0±0.4	
	2	17-BB	0±5	9±4	0.2±0.1	0±0.1	0.4±0.2	
	2	17-DD	0±5	16±4	0.2±0.1	0±0.1	0.2±0.1	
	2	17-EE	0±5	14±4	0.9±0.3	0.0±0.1	0.0±0.1	
	2	17-FF	0±5	12±4	0.4±0.2	0.0±0.1	0.5±0.2	

Note: 1. 1 denotes sample taken by WESTON in April 1988
2 denotes sample taken by WESTON in August 1988.

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samples exceeded the action limit of 50 pCi/l for beta activity (17-10 twice, 3, 4 and 17-9).

There was a significant difference between the measured activities in the samples collected in April and the samples collected in August. Six wells sampled in April were resampled in August. All but one had higher activities during the August sampling event. The higher activity in the August samples may be the result of higher solids content in the groundwater samples. The laboratory that analyzed the water samples noted more residue after the water was evaporated in the August samples (Eberline, 1988). It has been found that a higher dissolved solids content results in a higher beta activity (NAS, 1977).

4.23.3 Summary

Based on the elevated radiological activities of U-238 in the areas that were suspected uranium disposal sites, it is possible that uranium has been released to the groundwater. The activity in wells 16-2, 17-9, and 17-10 are potentially caused by the burial of radioactive wastes.

The elevated alpha and beta measurements at Area 8 are difficult to explain, since no disposal of radioactive material has reportedly occurred there or at any upgradient location. Monitoring wells 3 and 4 are scheduled to be abandoned due to their uncertain well construction. This construction may have caused a related high level of solids in the groundwater samples and this may be an explanation for the elevated alpha and beta levels.

5.0 BASELINE RISK ASSESSMENT

This Baseline Risk Assessment has been prepared by Clement Associates, Inc., 9300 Lee Highway, Fairfax, Virginia 22031, under subcontract to Roy F. Weston (Weston) and is part of Weston's Remedial Investigation (RI) report prepared for the United States Army Toxic and Hazardous Materials Agency (USATHAMA).

5.1 INTRODUCTION

This baseline assessment addresses the potential human health and environmental impacts associated with the Lake City Army Ammunition Plant (LCAAP) located northeast of Independence, Missouri, under the no-action alternative--that is, in the absence of remedial (corrective) action. Evaluation of the no-action alternative is required under Section 300.430 (d)(4) of the National Contingency Plan. A baseline assessment is conducted to aid in the determination of whether remedial actions (or in certain cases further sampling) should be undertaken. It should be noted that remedial actions include institutional controls that can be established to preclude use of a resource in an area where such use is extremely unlikely.

This assessment follows EPA guidance for risk assessment in general (EPA 1986a,b,c,) and for Superfund sites in particular (EPA 1988,1989a,b) and is based mainly on data discussed in earlier sections of this report. It should be noted, however, that the RI sampling plan was not designed to exhaustively characterize chemical contamination in all study areas of LCAAP. Only limited surface water/sediment and soil sampling was conducted in certain study areas to begin to evaluate potential source areas and contaminants from these study areas.

The assessment is organized as follows:

- Section 5.2 Identification of Chemicals of Potential Concern. Chemicals present in different media sampled during the RI at reportable levels[1] are identified based on the contamination assessment in Section 4 of this report, and chemicals that are considered to be related to past activities at the site are identified for evaluation in the baseline risk assessment.

The next three sections, 5.3, 5.4, and 5.5, constitute the components of the human health risk assessment.

- Section 5.3 Human Exposure Assessment. Mechanisms and pathways of contaminant migration are discussed, and the pathways through which human populations are potentially exposed to site contaminants are characterized under current and future land use patterns. In addition, for complete exposure pathways to be quantitatively evaluated, concentrations of chemicals in environmental media at potential exposure points are derived using available RI data. Estimated intakes of potentially exposed populations are derived using conservative assumptions regarding exposure, duration, route, frequency, and adsorption of chemicals.

- Section 5.4 Human Toxicity Assessment. Chemicals of potential concern in pathways to be qualitatively and quantitatively evaluated are characterized with respect to their toxic effects on humans, and available critical toxicity values are identified.

- Section 5.5 Human Risk Characterization. Quantitative estimates of risk are developed by combining the estimated intakes of potentially exposed populations with health effects criteria.

In the last three sections, 5.6, 5.7, and 5.8, the environmental assessment, uncertainties of the risk assessment, and summary and conclusions of the risk assessment are presented.

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[1] Reportable levels are defined as concentrations which are above USATHAMA certified reporting levels (CRL), or in the absence of CRLs, above the USATHAMA standard reporting levels (SRLs), which are equivalent to EPA Contract Laboratory Program (CLP) contract-required quantitation limits (CRQLs).

- Section 5.6 Environmental Assessment. In this section, the risk to non-human biota that may come in contact with site-related chemicals is evaluated. Potential receptors are identified, relevant toxicity data are summarized, and exposure is assessed. These components are then combined to evaluate the potential impacts of the site on biota.

- Section 5.7 Uncertainties in the Baseline Risk Assessment. The uncertainties and limitations of this risk assessment are discussed.

- Section 5.8 Summary and Conclusions. The main features and conclusions of the risk assessment, as well as any additional data needed to more completely assess potential exposures and risks from the site, are presented.

5.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

The extent of contamination in each area of concern at the LCAAP site as determined by the RI has been presented and fully evaluated in previous sections of this report, and therefore will not be repeated in this Section. Summary data, however, are presented for the chemicals detected in different media for each study area and chemicals of potential concern are selected. Chemicals of potential concern are defined as those chemicals detected that are considered likely to have been introduced because of activities at the site (i.e., those chemicals that could not definitely be associated with sampling or laboratory artifacts or that were detected at above naturally occurring background levels). These chemicals have been identified by the remedial investigation team (i.e., Roy F. Weston, Inc.) in Section 4 of this report, and the reader should refer to this section for full details of this selection process.

Chemicals of potential concern are identified below for groundwater (Section 5.2.1), soils (Section 5.2.2), and surface water and sediments (Section 5.2.3). For each medium and study area data are summarized by presenting the frequency of detection and the ranges of detected values in site and in background samples.

5.2.1 Groundwater

There are three hydrostratigraphic units at the site. These were defined in earlier sections of the RI as follows:

(1) The silty clay unit, which is unsaturated in several areas across the site, ranges in thickness from 5 to 44 feet, and lies between an unsaturated fill layer (existing primarily in developed portions of the site) and the alluvial sand layer;

(2) The alluvial sand unit, which is as much as 80-feet thick in the lowland areas, pinches out in the upland areas, and lies between the silty clay and weathered bedrock; and

(3) The weathered bedrock unit, which is approximately 100 feet below the surface in the lowland areas and outcrops in the upland areas.

These hydrostratigraphic units are all hydrologically connected with a vertical gradient of flow from the silty clay hydrostratigraphic unit to the alluvial sand hydrostratigraphic unit and a significant vertical gradient between the weathered bedrock and the alluvial sand units (see Section 3). The silty clay and weathered bedrock basically act as upper and lower partial confining layers, respectively, for the alluvial sand aquifer, which is the primary water-producing aquifer at the site. Eighteen monitoring wells (in Areas 1, 2, 4, 5, 8, 10, 11, and 17) are installed in the silty clay confining layer. The alluvial sand aquifer was investigated in study areas 3, 7, 9, 12, 14, and 18 using monitoring wells installed in shallow and deep portions of the aquifer. The on-site production wells are also installed in the deep portion of the alluvial sand aquifer. Finally, six monitoring wells are screened in the weathered bedrock confining layer in study Areas 6 and 16.

In order to characterize the quality of groundwater in the 3 hydrostratigraphic units across the site and within each of 16 study areas on-site, production wells currently used at LCAAP, as well as existing and newly installed monitoring wells, were sampled. Groundwater samples were not collected from areas which were not thought to be potential sources of groundwater contamination based on historic information (see Section 4). Twelve residential wells located directly off-site (just north of the northern boundary of the LCAAP near Areas 14, 16, 17, 18, and 22) were also sampled.

Sampling results for chemicals detected in monitoring wells and production wells were presented in Section 4 of this report. During sampling for this RI, groundwater samples were collected twice from each well over a three-month period. As discussed in Section 4, concentrations of chemicals detected during these two sampling periods generally showed no discernable trends in chemical levels between Round 1 and Round 2. Therefore, the data from these two time periods were combined for the purposes of this assessment.

Groundwater samples were analyzed for the presence of volatile, semi-volatile, explosive, and inorganic (total and dissolved) chemicals. Certain groundwater samples collected from monitoring wells in Areas 3, 5, 8, 14, 16, and 17, as well as some samples from the production wells, were analyzed for radionuclides. Area 9 groundwater samples were analyzed for cyanide. Section 4 identified all of the organics detected in sampled groundwater to be potentially site related.

Groundwater samples collected from monitoring wells located on-site but upgradient of all potential sources were used as background for comparison with on-site inorganic groundwater concentrations in monitoring and production wells. As discussed in Section 4, normal groundwater radioactivity measures for the State of Missouri were used for radioactivity background comparisons. Based on an evaluation discussed in Section 4, the concentrations of certain inorganic chemicals and radionuclides were not elevated above concentrations found in background groundwater samples. These inorganic chemicals were therefore not identified as chemicals of potential concern for this assessment. All radionuclides were selected as chemicals of potential concern at the request of EPA due to the burial of radioactive wastes on site.

In the following sections, groundwater results for the chemicals of potential concern in the production wells, monitoring wells, and the residential wells are summarized. Monitoring well data were grouped in two different ways in order to evaluate groundwater contamination. First, as discussed in detail in Section 3.6.4 and 3.6.5, the results of a pumping test conducted during the RI on production well 17AA, indicated that, except for groundwater located beneath areas 3, 8, 16 and 17, the capture zones of the nine production wells intercept nearly all groundwater beneath LCAAP. It should be noted that day-to-day pumping conditions at LCAAP may differ from those used during the pump test; therefore, the area of LCAAP located within the capture zones of the production wells may vary. For this assessment, in order to evaluate the quality of groundwater potentially captured by the production wells in the future (assuming no water treatment systems are in place), data from all monitoring wells within the capture zones of the production wells (as defined by the groundwater capture zone analysis performed during this RI) will be grouped together.

Concerning the second grouping of monitoring well data, as discussed in detail in Section 4.1 through 4.18, groundwater samples were collected directly upgradient, sidegradient, and downgradient of certain suspected source locations in each study area. For the purposes of this assessment, in order to evaluate chemical concentrations in groundwater at each of these areas, sampling results only from monitoring wells installed downgradient from suspected sources in each area were used. One exception to this was that sidegradient well 6-4 was grouped with other downgradient wells for Area 6 because of groundwater mounding caused by the surface impoundment.

5.2.1.1 Groundwater in On-Site Production Wells

As discussed in Section 3.6.5, LCAAP pumps as much as 1.4 million gallons of water per day from the deeper portions of the alluvial sand aquifer using the production wells primarily located in the northwestern quadrant of LCAAP (Figure 4-35). The plant pumps nine production wells in an alternating fashion to supply water for the plant. Each of these wells is pumped at least once per week. Other production wells exist on-site but are not in use, due primarily to mechanical problems or limited production rates. Before distribution, all water pumped from the production wells is treated using three aeration cells, a chlorination treatment process, and a flocculation process for eliminating heavy metals, according to LCAAP personnel. In addition, air stripping units are currently installed on two of the more contaminated production wells (17AA and 17FF) to pretreat water before it is sent to the water treatment plant. These air stripping units are currently not functional. Monitoring results collected during 1987 and 1988 LCAAP sampling of treated production well water were analyzed to identify chemicals of potential concern for treated water currently used at LCAAP. In addition, sampling results from seven of the above-mentioned nine production wells sampled during the RI (17AA, 17BB, 17DD, 17EE, 17FF, 17JJ and 17KK), each of which were sampled during the RI twice over a 3-month period, were used to represent groundwater quality from production wells (i.e., untreated water) under current use patterns, assuming no water treatment system is in place.

Treated Production Well Water: Bromodichloromethane, bromoform, chloroform, dibromochloromethane, total trihalomethanes, 1,1,1-trichloroethane, trichloroethene, and 1,2-dichloroethene (total) were identified as organic chemicals of potential concern for the treated production well water, as presented in Table 5-1. Trichloroethene and 1,2-dichloroethene (total) were the only organic chemicals detected in the treated production groundwater that also were detected in untreated production well groundwater, as well as in the monitoring wells. Chloroform was not detected in the untreated production well groundwater, but was detected in groundwater samples from Area 17. 1,1,1-Trichloroethane was not detected in the untreated production well groundwater, but was detected in groundwater samples from Areas 5, 16, and 17. It should be noted that several trihalomethane compounds including bromodichloromethane, bromoform, and dibromochloromethane were not detected in untreated production well groundwater or in the monitoring wells. These trihalomethanes are common substitution products of water treatment processes that use chlorine (40FR-59588, December 24, 1975, and Faust, S.D. and O.M. Ally 1983). Therefore, the presence of the trihalomethane compounds including chloroform in treated water is probably due to the chlorination treatment process employed by the LCAAP facility. In addition, none of the explosive organic chemicals that were detected in monitoring wells at various locations across the site were detected in the sampled production wells.

Treated production well water was analyzed for gross alpha activity, gross beta activity, and radium (Ra-226 and Ra-228). No site-specific information on the background concentrations of any of these parameters was available. Comparison of gross alspha and gross beta activity levels with normal Missouri state activity levels indicated that gross alpha activity and gross beta activity did not exceed these levels of <15 pCi/l and 20 to 30 pCi/l,

TABLE 5-1

SUMMARY OF CHEMICALS DETECTED IN TREATED PRODUCTION WELL GROUNDWATER AT LCAAP (a) LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (b)	Detection Limit (c)	Range of Detected On-site Concentrations
Radiological Parameter (pCi/L):			
* Alpha	1/2	2	8
* Beta	2/2	--	3 - 10
* Ra226 and Ra228	1/1	--	3
Organics:			
* Bromodichloromethane	5/6	5	1.1 - 8
* Bromoform	3/6	0.2 - 5	2.8 - 5
* Chloroform	5/6	5	1.1 - 3.4
* Dibromochloromethane	5/6	5	2.9 - 9
* 1,2-Dichloroethene (total)	12/25	0.2 - 5	0.5 - 9.7
* 1,1,1-Trichloroethane	1/25	0.2	1.5
* Trichloroethene	17/25	0.2 - 5	0.6 - 2.7
* Trihalomethanes (total)	1/1		16.7
Inorganics:			
Arsenic (total)	3/6	1	0.6 - 0.9
Barium (total)	3/6	200	70 - 300
Copper (total)	1/6	10	12
* Mercury (total)	1/6	0.2 - 1	0.7
Selenium (total)	1/6	0.2 - 1	0.8
* Silver (total)	1/5	20	8
* Thallium (total)	1/2	5	75
Zinc (total)	2/5	10	31 - 52

(a) Water Treatment Plant Outflow Chemical Sampling performed by LCAAP during the years 1987 and 1988.

(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.

(c) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).

* = Selected as a chemical of potential concern.

respectively. However, the alpha and beta radionuclide parameters were selected as chemicals of potential concern at the request of EPA. No site specific or Missouri state information on the background concentrations of Ra-226 or Ra-228 were available, therefore Ra-226 and Ra-228 were also retained as chemicals of potential concern. Concentrations of radiological parameters in production wells are presented in Table 5-1.

Mercury, silver, and thallium were identified as inorganic chemicals of potential concern based on their presence in treated production well groundwater at above background concentrations. Of these inorganics, silver was the only inorganic chemical that also was selected as a chemical of potential concern in untreated production well groundwater. Thallium was not detected in any other samples taken during the RI. Although arsenic, barium, copper, selenium, and zinc were detected in the treated water at levels above the detection limit, these chemicals were not considered to be elevated above background, and therefore were not identified as inorganic chemicals of potential concern. Concentrations of inorganic chemicals in production wells are shown in Table 5-1.

<u>Untreated Production Well Water</u>. Benzene, bis(2-ethylhexyl)phthalate, trichloroethene, trans-1,2-dichloroethene, and vinyl chloride were identified as chemicals of potential concern for the production wells, as presented in Table 5-2. As discussed in subsequent sections, these organic chemicals also were detected in monitoring wells installed in several areas across the site. None of the explosive organic chemicals that were detected in monitoring wells at various locations across the site were detected in the sampled production wells.

Seven production well samples were analyzed for gross alpha activity, gross beta activity, and uranium radioactivity, because of suspected uranium disposal at the LCAAP site. U-235 was the only radionuclide that was not detected (quantitation limits ranged from 0.1 to 0.2 pCi/L). No site specific information on the background concentrations of any of these radionuclide

TABLE 5-2

SUMMARY OF CHEMICALS DETECTED IN UNTREATED GROUNDWATER FROM PRODUCTION WELLS AT LCAAP (a) LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (b)	Detection Limit (c)	Range of Detected On-site Concentrations
Radiological Parameter (pCi/L):			
* Alpha	1/7	5	10
* Beta	7/7	--	8 - 17
* U-234	6/7	0.1	0.2 - 0.9
* U-238	5/7	0.1 - 0.4	0.1 - 0.5
Organics:			
* Benzene	1/14	0.7	1.4
* trans-1,2-Dichloroethene	1/14	1.7	2.2
* bis(2-Ethylhexyl)phthalate	2/14	10	10 - 200
* Trichloroethene	3/14	0.7	1.2 - 26
* Vinyl Chloride	1/14	3.9	350
Inorganics:			
* Arsenic (dissolved)	6/14	5	5.5 - 10.6
* Arsenic (total)	10/14	5	5.7 - 11.2
* Barium (dissolved)	7/7	25	66.3 - 636
Barium (total)	7/7	25	121 - 655
* Beryllium (dissolved)	1/14	0.1	0.1
Beryllium (total)	2/14	0.1	0.2
* Copper (dissolved)	11/14	1.8	2.3 - 28.9
Copper (total)	9/14	1.8	3.2 - 22.8
* Lead (dissolved)	1/14	2.5	3.5
Lead (total)	1/14	2.5	3.3
* Nickel (dissolved)	6/14	9.6	10.4 - 23.4
Nickel (total)	8/14	9.6	10.2 - 57.6
* Silver (dissolved)	3/14	0.2	0.2 - 0.7
* Silver (total)	1/14	0.2	0.2
* Zinc (dissolved)	14/14	17.2	19 - 314
Zinc (total)	7/14	17.2	51.3 - 369

(a) Samples 17AA-1, 17AA-2, 17BB-1, 17BB-2, 17DD-1, 17DD-2, 17EE-1, 17EE-2, 17FF-1, 17FF-2, 17JJ-1, 17JJ-2, 17KK-1, and 17KK-2.

(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.

(c) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).

* = Selected as a chemical of potential concern.

parameters was available. Although neither uranium radioactivity levels exceeded the normal range of uranium in groundwater (0.1 to 10 pCi/l) (Hem 1985), or gross alpha activity and gross beta activity levels exceeded the normal Missouri state activity levels of < 15 pCi/l and 20 to 30 pCi/l, respectively, these radionuclide parameters were selected as chemicals of potential concern at the request of EPA. Concentrations of radiological parameters in production wells are presented in Table 5-2.

Arsenic, barium, beryllium, copper, lead, nickel, silver, and zinc were identified as inorganic chemicals of potential concern based on their presence at above-background concentrations in either filtered (dissolved) or unfiltered (total) samples. It will be noted, however, that in some instances higher concentrations were measured in filtered samples than unfiltered (i.e., total concentrations were lower than dissolved, a situation that is theoretically impossible since the total measurement includes the dissolved fraction of the chemical plus any chemical that is adsorbed to any particulate matter in the sample). Concentrations of inorganic chemicals in production wells are also shown in Table 5-2.

5.2.1.2 Groundwater in Monitoring Wells in Areas Within the Capture Zones of Production Wells

As discussed in detail in Sections 3.6.4 and 3.6.5, the results of a pumping test conducted during the RI on seven of the nine production wells currently used by LCAAP indicated that, with the exception of groundwater located beneath areas 3, 8, 16, and 17, the capture zones of the nine production wells intercept nearly all groundwater beneath LCAAP. Therefore, data from all monitoring wells within the capture zones of the production wells have been grouped together in order to assess the quality of groundwater in the entire capture zone. This includes wells installed in the three hydrostratigraphic units at the site based on the assumption that these three units are interconnected hydraulically.

Summary results for identified chemicals of potential concern from the 82 monitoring wells in this capture zone (areas 1, 2, 4, 5, 6, 7, 9, 10, 11, 12, 14, and 18) are discussed below and presented in Table 5-3.

Nine volatile organics, 3 semi-volatile organics, and 7 explosive byproduct compounds were detected in monitoring wells in these areas. However, the majority of these chemicals were detected very infrequently (in less than 2% of the samples). The organic chemicals selected as chemicals of potential concern are presented in Table 5-3.

As discussed in Section 4.24, certain monitoring well samples in the study areas of concern were analyzed for gross alpha activity, gross beta activity, and uranium radioactivity. U-235 was the only radionuclide that was not detected (quantitation limits ranged from 0.1 to 0.4 pCi/l). Uranium radioactivity levels (U-234 and U-238) were within the normal range of uranium activity in groundwater of 0.1 to 10 pCi/l (Hem 1985), but were selected as chemicals of potential concern at the request of EPA. Gross alpha activity and gross beta activity exceeded normal state activity levels of <15 pCi/l and 20 to 30 pCi/l, respectively; therefore, the alpha and beta radionuclide parameters were selected as chemicals of potential concern.

All of the inorganics detected in production wells (antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc) were identified as inorganic chemicals of potential concern for groundwater potentially reaching the production wells, because these inorganics were present at above background levels in at least one study area included in this evaluation (see Table 5-3).

5.2.1.3 Groundwater in Monitoring Wells Downgradient of Each Study Area

Each of the 16 sampled study areas contains one or more suspected sources of contamination (e.g., wastewater lagoons, oil and grease pits). As discussed in detail in Sections 4.1 through 4.18, groundwater samples were collected

TABLE 5-3

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER POTENTIALLY REACHING PRODUCTION WELLS UNDER CURRENT USE CONDITIONS (a) LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (b)	Detection Limit (c)	Range of Detected On-site Concentrations
Radiological Parameter (pCi/L):			
* Alpha	2/12	2 - 7	7 - 23
* Beta	6/12	3 - 9	4 - 34
* Total Uranium	4/7	0.2	0.6 - 1.5
* U-234	4/5	0.1	0.5 - 1.5
* U-238	4/5	0.1	0.6 - 0.9
Organics:			
* Benzene	2/164	0.7	0.9
* Chrysene (Carcinogenic PAH)	1/163	10	70
* 1,3-DNB	3/163	0.6	0.9 - 1.7
* 2,4-DNT	1/163	0.6	0.6
* 2,6-DNT	2/163	0.6	0.7 - 0.8
* 1,1-Dichloroethane	3/164	5	10 - 20
* 1,2-Dichloroethane	1/164	5	20
* 1,1-Dichloroethene	2/164	5	4.6 - 15
* trans-1,2-Dichloroethene	7/164	1.7	2.3 - 362
* bis(2-Ethylhexyl)phthalate	36/163	10	10 - 1000
* HMX	11/163	1.3	1.3 - 28
* Methylene Chloride	2/164	10	5
* N-nitrosodiphenylamine	1/163	10	10
* RDX	58/162	0.6	0.7 - 770
* 1,3,5-TNB	8/163	0.6	0.6 - 22
* Tetryl	3/163	0.7	1.1 - 3.5
* 1,1,1-Trichloroethane	3/164	5	7
* Trichloroethene	4/164	0.7	0.8 - 42
* Vinyl Chloride	2/164	3.9	10 - 10.2
Inorganics:			
* Antimony (dissolved)	3/157	3	3.4 - 5.1
* Antimony (total)	12/157	3	4.1 - 77.2
* Arsenic (dissolved)	14/157	5	5.2 - 34.7
* Arsenic (total)	45/157	5	5.3 - 110
* Barium (dissolved)	102/102	25	26.5 - 580
* Barium (total)	105/105	25	31.4 - 3,030
* Beryllium (dissolved)	5/157	0.1	0.1 - 0.3
* Beryllium (total)	106/157	0.1	0.1 - 12
* Cadmium (dissolved)	1/157	5.1	10.7
* Cadmium (total)	30/157	5.1	6.4 - 130
* Chromium (dissolved)	5/157	37.5	4.3 - 3,800
* Chromium (total)	32/157	37.5	34.4 - 3,800
* Copper (dissolved)	62/157	1.8	2 - 90
* Copper (total)	145/157	1.8	2.5 - 250
* Lead (dissolved)	21/157	2.5	2.5 - 22
* Lead (total)	104/157	2.5	2.5 - 260
* Mercury (dissolved)	5/157	0.2	0.2 - 0.2
* Nickel (dissolved)	86/157	9.6	9.5 - 116
* Nickel (total)	147/157	9.6	9.8 - 472
* Selenium (dissolved)	2/157	5	5.3 - 7.4
* Selenium (total)	7/157	5	5.2 - 24.2
* Silver (dissolved)	13/157	0.2	0.2 - 14
* Silver (total)	43/157	0.2	0.2 - 8.2
* Zinc (dissolved)	135/157	17.2	17 - 2,600
* Zinc (total)	156/157	17.2	23.7 - 2,400

(a) Samples 1-1 through 1-10, 1-7A, 2-1 through 2-8, 4-1 through 4-6, 5-1 through 5-7, 6-1 through 6-7, 7-1 through 7-13, 9-1 through 9-4, 10-1 through 10-6, 11-1 through 11-4, 12-2 through 12-6, 14-1 through 14-4, and 18-1 through 18-7.

(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.

(c) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).

* = Selected as a chemical of potential concern.

from monitoring wells located directly upgradient and downgradient of certain suspected source locations in a study area. In order to characterize chemical concentrations in groundwater at each of these areas for the purposes of this baseline risk assessment, sampling results from monitoring wells installed downgradient from suspected sources of contamination were grouped in each area. Wells designated as side-gradient were not grouped with the downgradient wells with the exception of well 6-4 in Area 6 which was considered downgradient due to groundwater mounding around the surface impoundment. As discussed in Section 4, chemicals detected directly upgradient of various source areas were sometimes measured at concentrations higher than or similar to downgradient results. In such cases, the contaminants may have originated from other upgradient sources.

Groundwater Downgradient of Sources in Area 1: Area 1 is located on the northern bank of Big Ditch, in the southernmost portion of LCAAP property (see Figures 1-2 and 4-1). Several, currently closed, surface impoundments were used in the past to store wastewater sludges from the manufacturing and processing of explosive materials in Area 1.

Sampling results from five downgradient monitoring wells (1-2, 1-3, 1-6, 1-8 and 1-9) were used to assess groundwater quality in Area 1. Bis(2-ethylhexyl)phthalate and RDX were identified as organic chemicals of potential concern for groundwater in Area 1, as shown in Table 5-4. Antimony, arsenic, beryllium, cadmium, copper, lead, mercury, nickel, silver, and zinc were identified as inorganic chemicals of potential concern for Area 1. Table 5-4 also presents concentrations of inorganic chemicals of potential concern for Area 1.

Groundwater Downgradient of Sources in Area 2: Area 2 is located in the southern portion of the RI study area and borders Area 1 to the north (see Figures 1-2 and 4-3). One inactive and two other surface impoundments currently being closed were used to store wastewater sludges from the manufacturing and processing of explosive materials and wastewater treatment

TABLE 5-4

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER DOWNGRADIENT OF SOURCE AREAS LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 1 (c)			
Organics:			
* bis(2-Ethylhexyl)phthalate	3/10	10	20 - 70
* RDX	2/10	0.6	1.4 - 1.9
Inorganics:			
* Antimony (total)	1/10	3	77.2
* Arsenic (dissolved)	5/10	5	13.1 - 34.7
* Arsenic (total)	7/10	5	7.3 - 110
* Barium (dissolved)	6/6	25	139 - 400
Barium (total)	6/6	25	206 - 302
* Beryllium (total)	5/10	0.1	0.1 - 1.1
* Cadmium (total)	1/10	5.1	11.8
* Copper (dissolved)	7/10	1.8	2.6 - 5
* Copper (total)	9/10	1.8	8.5 - 52
* Lead (dissolved)	1/10	2.5	4.5
* Lead (total)	6/10	2.5	2.7 - 41.6
* Mercury (dissolved)	2/10	0.2	0.2
* Nickel (dissolved)	4/10	9.6	9.8 - 13.6
* Nickel (total)	9/10	9.6	10.3 - 226
* Silver (total)	4/10	0.2	0.2 - 7.8
* Zinc (dissolved)	8/10	17.2	25.4 - 452
Zinc (total)	10/10	17.2	58.2 - 1,200
Area 2 (d)			
Organics:			
* 2,6-DNT	1/12	0.6	0.7
* bis(2-Ethylhexyl)phthalate	4/12	10	60 - 500
* RDX	2/12	0.6	0.7 - 4.7
Inorganics:			
* Arsenic (total)	3/10	5	7.9 - 9
Barium (dissolved)	7/7	25	26.5 - 169
Barium (total)	8/8	25	147 - 595
* Beryllium (total)	6/10	0.1	0.2 - 1.4
* Cadmium (dissolved)	1/10	5.1	10.7
* Cadmium (total)	4/10	5.1	7.5 - 130
* Chromium (total)	1/10	37.5	51.9
* Copper (dissolved)	2/10	1.8	4.1 - 4.1
* Copper (total)	10/10	1.8	5.9 - 87
* Lead (dissolved)	2/10	2.5	3.9
Lead (total)	8/10	2.5	3.2 - 12
* Nickel (dissolved)	7/10	9.6	10.7 - 42.7
* Nickel (total)	8/10	9.6	14.1 - 82.7
* Selenium (total)	1/10	5	10.8
* Silver (total)	6/10	0.2	0.2 - 1.6
* Zinc (dissolved)	10/10	17.2	22 - 1,200
* Zinc (total)	10/10	17.2	119 - 880
Area 3 (e)			
Radiological Parameter (pCi/L):			
* Beta	2/4	5	9 - 22
* U-234	2/4	0.1	0.1 - 0.7
* U-238	1/4	0.1	0.8
Organics:			
* 2,4-DNT	1/8	0.6	0.6
* 1,1-Dichloroethene	1/8	5	11
* bis(2-Ethylhexyl)phthalate	1/8	10	40
* HMX	2/8	1.3	1.7 - 3
* RDX	4/8	0.6	0.7 - 120

TABLE 5-4 (Continued)

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER DOWNGRADIENT OF SOURCE AREAS LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 3 (e) (Continued)			
Inorganics:			
* Arsenic (dissolved)	1/8	5	14.7
* Arsenic (total)	3/8	5	8.6 - 15.1
* Barium (dissolved)	4/4	25	81.4 - 469
* Barium (total)	4/4	25	179 - 1,180
* Beryllium (dissolved)	3/8	0.1	0.1 - 1.6
* Beryllium (total)	5/8	0.1	0.2 - 1.3
* Chromium (dissolved)	1/8	37.5	255
* Chromium (total)	3/8	37.5	88.5 - 189
* Copper (dissolved)	6/8	1.8	5.7 - 41.3
* Copper (total)	8/8	1.8	3.1 - 49.6
* Lead (dissolved)	1/8	2.5	28.1
* Lead (total)	5/8	2.5	3 - 29.8
* Nickel (dissolved)	4/8	9.6	15 - 131
* Nickel (total)	8/8	9.6	26.6 - 95.4
* Silver (dissolved)	1/8	0.2	0.2
* Silver (total)	3/8	0.2	0.2
Zinc (dissolved)	8/8	17.2	18.8 - 262
Zinc (total)	8/8	17.2	98.7 - 585
Area 4 (f)			
Organics:			
* bis(2-Ethylhexyl)phthalate	1/4	10	10
* HMX	1/4	1.3	3.2
* RDX	1/4	0.6	2.3
* 1,3,5-TNB	1/4	0.6	11.7
Inorganics:			
* Antimony (total)	1/4	3	11.4
* Arsenic (total)	1/4	5	5.3
Barium (dissolved)	3/3	25	83.1 - 122
Barium (total)	3/3	25	190 - 303
Beryllium (total)	4/4	0.1	0.4 - 8.3
* Cadmium (total)	2/4	5.1	6.4 - 7.5
* Chromium (total)	1/4	37.5	335
* Copper (dissolved)	1/4	1.8	4
* Copper (total)	4/4	1.8	12 - 48.3
Lead (total)	4/4	2.5	3.4 - 15.3
* Nickel (dissolved)	1/4	9.6	15.1
* Nickel (total)	4/4	9.6	21.1 - 285
* Silver (dissolved)	1/4	0.2	14
* Zinc (dissolved)	4/4	17.2	36 - 1,200
Zinc (total)	4/4	17.2	101 - 740
Area 5 (g)			
Radiological Parameter (pCi/L):			
* Beta	1/1	--	15
* U-234	1/1	--	0.9
* U-238	1/1	--	0.6
Organics:			
* 1,1-Dichloroethane	2/8	5	10 - 20
* 1,1-Dichloroethene	1/8	5	4.6
* trans-1,2-Dichloroethene	3/8	1.7	4 - 362
* bis(2-Ethylhexyl)phthalate	2/8	10	20 - 40
* RDX	6/8	0.6	0.7 - 8.1
* 1,1,1-Trichloroethane	2/8	5	7
* Trichloroethene	1/8	0.7	42
* Vinyl Chloride	1/8	3.9	10

TABLE 5-4 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 5 (g) (continued)			
Inorganics:			
* Antimony (total)	2/8	3	10.6 - 15.9
* Arsenic (dissolved)	2/8	5	6.2 - 7.1
Arsenic (total)	1/8	5	11.5
* Barium (dissolved)	5/5	25	121 - 307
Barium (total)	5/5	25	75.4 - 325
* Beryllium (total)	5/8	0.1	0.2 - 7.6
* Cadmium (total)	2/8	5.1	8.6 - 20.4
* Chromium (total)	2/8	37.5	46.2 - 119
* Copper (dissolved)	1/8	1.8	90
* Copper (total)	6/8	1.8	4.5 - 250
* Lead (dissolved)	1/8	2.5	5
Lead (total)	6/8	2.5	3.1 - 17.4
* Nickel (dissolved)	5/8	9.6	11.5 - 97.4
* Nickel (total)	8/8	9.6	17.8 - 346
* Silver (total)	2/8	0.2	0.2
* Zinc (dissolved)	6/8	17.2	31.9 - 910
* Zinc (total)	8/8	17.2	86.5 - 1,000
Area 6 (h)			
Organics:			
* 1,3-DNB	1/8	0.6	0.9
* 2,4-DNT	1/8	0.6	0.6
* HMX	2/8	1.3	1.3 - 2.1
* RDX	7/8	0.6	0.7 - 14
Inorganics:			
Barium (dissolved)	7/7	25	125 - 418
Barium (total)	7/7	25	190 - 441
* Beryllium (dissolved)	1/8	0.1	0.3
* Beryllium (total)	6/8	0.1	0.2 - 1.9
* Chromium (total)	2/8	37.5	51 - 72.1
* Copper (dissolved)	1/8	1.8	4.2
Copper (total)	7/8	1.8	3.8 - 15
* Lead (dissolved)	1/8	2.5	9.2
Lead (total)	2/8	2.5	2.5 - 17.3
* Nickel (dissolved)	3/8	9.6	39.5 - 82.5
* Nickel (total)	8/8	9.6	10 - 95.5
* Silver (total)	2/8	0.2	0.2 - 0.3
* Zinc (dissolved)	7/8	17.2	39.7 - 1,200
* Zinc (total)	8/8	17.2	23.7 - 960
Area 7 (i)			
Organics:			
* Benzene	1/18	0.7	0.9
* trans-1,2-Dichloroethene	1/18	1.7	2.4
* bis(2-Ethylhexyl)phthalate	5/18	10	50 - 200
* HMX	1/18	1.3	28
* Methylene Chloride	1/18	10	5
* RDX	5/18	0.6	5 - 770
* 1,3,5-TNB	1/18	0.6	0.9
* Trichloroethene	1/18	0.7	0.8
* Vinyl Chloride	1/18	3.9	10.2
Inorganics:			
* Arsenic (total)	5/18	5	5.8 - 8.7
* Barium (dissolved)	12/12	25	52.7 - 482
Barium (total)	12/12	25	78.2 - 573
Beryllium (total)	13/18	0.1	0.1 - 0.6
* Chromium (total)	1/18	37.5	55.8
* Copper (dissolved)	9/18	1.8	2.4 - 8.7
Copper (total)	17/18	1.8	3.3 - 41.4
* Lead (dissolved)	2/18	2.5	3.4 - 3.5
Lead (total)	11/18	2.5	3.2 - 14.8

TABLE 5-4 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 7 (i) (Continued)			
Inorganics:			
* Nickel (dissolved)	10/18	9.6	12.4 - 58
* Nickel (total)	18/18	9.6	15.3 - 128
* Selenium (dissolved)	1/18	5	7.4
* Selenium (total)	1/18	5	5.8
* Silver (dissolved)	2/18	0.2	0.2
* Silver (total)	3/18	0.2	0.2 - 2
* Zinc (dissolved)	15/18	17.2	19.2 - 930
Zinc (total)	18/18	17.2	85.1 - 495
Area 8 (j)			
Radiological Parameter (pCi/L):			
* Alpha	1/3	5 - 7	22
* Beta	2/3	5	29 - 96
* Total Uranium	1/1	--	1.1
* U-234	2/2	--	1 - 1.9
* U-238	2/2	--	0.6 - 1.7
Organics:			
* trans-1,2-Dichloroethene	2/18	1.7	4 - 94
* bis(2-Ethylhexyl)phthalate	4/18	10	40 - 20,000
* N-nitrosodiphenylamine	1/18	10	10
* RDX	2/18	0.6	0.9
* Toluene	1/18	5	15
* Trichloroethene	2/18	0.7	0.9 - 35
Inorganics:			
* Antimony (dissolved)	2/18	3	9.3 - 17.5
* Antimony (total)	1/18	3	7.6
* Arsenic (dissolved)	1/18	5	8.6
* Arsenic (total)	8/18	5	5.5 - 14.1
* Barium (dissolved)	9/9	25	85 - 396
* Barium (total)	11/11	25	178 - 1,470
* Beryllium (total)	13/18	0.1	0.2 - 6
* Cadmium (total)	2/18	5.1	12.9 - 14
* Chromium (dissolved)	3/18	37.5	38.5 - 65.4
* Chromium (total)	9/18	37.5	39.4 - 363
* Copper (dissolved)	8/18	1.8	2.6 - 9.5
* Copper (total)	17/18	1.8	4.5 - 780
* Lead (dissolved)	7/18	2.5	2.5 - 6.8
* Lead (total)	14/18	2.5	2.6 - 90
* Nickel (dissolved)	12/18	9.6	10.5 - 497
* Nickel (total)	16/18	9.6	9.8 - 193
* Silver (dissolved)	1/18	0.2	12.8
* Silver (total)	6/18	0.2	0.3 - 2.2
* Zinc (dissolved)	14/18	17.2	35.6 - 1,400
* Zinc (total)	18/18	17.2	21.4 - 1,000
Area 9 (k)			
Organics:			
* bis(2-Ethylhexyl)phthalate	1/4	10	1,000
* RDX	1/4	0.6	15
* 1,3,5-TNB	1/4	0.6	19
Inorganics:			
* Arsenic (total)	1/4	5	5.3
Barium (dissolved)	4/4	25	40.7 - 114
Barium (total)	4/4	25	125 - 156
Beryllium (total)	1/4	0.1	0.4
* Cadmium (total)	1/4	5.1	6.4
Copper (total)	4/4	1.8	3.1 - 9.8
Lead (total)	3/4	2.5	2.5 - 5.5

TABLE 5-4 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 9 (k) (continued)			
Inorganics:			
* Nickel (dissolved)	1/4	9.6	21.9
Nickel (total)	4/4	9.6	17.1 - 45.1
* Silver (dissolved)	1/4	0.2	0.2
* Silver (total)	2/4	0.2	0.2 - 8.2
* Zinc (dissolved)	3/4	17.2	22.7 - 306
* Zinc (total)	4/4	17.2	144 - 1,700
Area 10 (l)			
Organics:			
* bis(2-Ethylhexyl)phthalate	1/7	10	700
* RDX	3/6	0.6	1.3 - 3.3
Inorganics:			
* Antimony (dissolved)	1/6	3	5.1
* Antimony (total)	1/6	3	11.5
* Arsenic (total)	1/6	5	21.3
Barium (dissolved)	3/3	25	118 - 390
* Barium (total)	3/3	25	170 - 3,030
* Beryllium (dissolved)	1/6	0.1	0.3
* Beryllium (total)	5/6	0.1	0.5 - 8.1
* Cadmium (total)	5/6	5.1	6.4 - 80.6
Chromium (dissolved)	1/6	37.5	4.3
Chromium (total)	1/6	37.5	47.8
* Copper (dissolved)	4/6	1.8	4.5 - 10.5
* Copper (total)	5/6	1.8	20.3 - 140
* Lead (dissolved)	2/6	2.5	3.4 - 4
* Lead (total)	5/6	2.5	11.1 - 150
* Nickel (dissolved)	5/6	9.6	9.8 - 50.7
* Nickel (total)	6/6	9.6	31.4 - 250
* Silver (total)	2/6	0.2	0.4 - 0.5
* Zinc (dissolved)	5/6	17.2	61.7 - 1,300
* Zinc (total)	6/6	17.2	176 - 2,400
Area 11 (m)			
Organics:			
* bis(2-Ethylhexyl)phthalate	1/6	10	300
* HMX	4/6	1.3	1.8 - 5.3
* RDX	6/6	0.6	1.7 - 50
Inorganics:			
* Arsenic (total)	1/6	5	6.6
Barium (dissolved)	6/6	25	65.4 - 168
Barium (total)	6/6	25	134 - 380
* Beryllium (total)	3/6	0.1	0.2 - 1.5
* Cadmium (total)	1/6	5.1	6.4
* Chromium (total)	1/6	37.5	42.3
* Copper (dissolved)	1/6	1.8	6.3
Copper (total)	5/6	1.8	5.4 - 17
Lead (total)	2/6	2.5	2.7 - 18.3
* Nickel (dissolved)	4/6	9.6	10.2 - 79.9
* Nickel (total)	5/6	9.6	9.9 - 81.5
* Silver (total)	2/6	0.2	0.3 - 0.3
* Zinc (dissolved)	4/6	17.2	100 - 371
Zinc (total)	6/6	17.2	75.5 - 403
Area 12 (n)			
Organics:			
* HMX	2/8	1.3	4.9 - 6.3
* N-nitrosodiphenylamine	1/8	10	10
* RDX	4/8	0.6	10.4 - 61
* 1,3,5-TNB	2/8	0.6	2.4 - 18.6
* Tetryl	1/8	0.7	1.3

TABLE 5-4 (Continued)

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER DOWNGRADIENT OF SOURCE AREAS LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 12 (n) (continued)			
Inorganics:			
* Arsenic (total)	4/8	5	5.3 - 16.3
* Barium (dissolved)	4/4	25	91 - 580
* Barium (total)	4/4	25	112 - 1,020
* Beryllium (dissolved)	2/8	0.1	0.1
Beryllium (total)	6/8	0.1	0.3 - 0.8
* Chromium (dissolved)	3/8	37.5	127 - 3,800
* Chromium (total)	5/8	37.5	49 - 3,800
* Copper (dissolved)	5/8	1.8	2 - 3.5
* Copper (total)	8/8	1.8	9.9 - 51.6
Lead (total)	6/8	2.5	2.9 - 10
* Nickel (dissolved)	2/8	9.6	12.8 - 55.4
* Nickel (total)	7/8	9.6	21.2 - 68.2
* Silver (total)	2/8	0.2	0.2 - 0.5
* Zinc (dissolved)	7/8	17.2	35.9 - 285
Zinc (total)	8/8	17.2	.154 - 317
Area 14 (o)			
Radiological Parameter (pCi/L):			
* Alpha	1/2	5	7
* Beta	2/2	--	13 - 15
* Total Uranium	1/1	--	0.9
* U-234	1/1	--	0.5
* U-238	1/1	--	0.7
Organics:			
* bis(2-Ethylhexyl)phthalate	3/6	10	80 - 100
* RDX	1/6	0.6	9.4
Inorganics:			
* Arsenic (total)	3/6	5	6.9 - 21.5
* Barium (dissolved)	3/3	25	251 - 538
Barium (total)	3/3	25	227 - 558
* Beryllium (dissolved)	1/6	0.1	0.2
* Beryllium (total)	4/6	0.1	0.2 - 1.2
* Cadmium (total)	1/6	5.1	9.7
* Chromium (total)	3/6	37.5	57.7 - 162
* Copper (dissolved)	4/6	1.8	2.5 - 5.7
Copper (total)	6/6	1.8	3.9 - 28.1
Lead (total)	6/6	2.5	2.7 - 15.6
* Nickel (dissolved)	4/6	9.6	10.3 - 42.7
* Nickel (total)	6/6	9.6	17.1 - 101
* Zinc (dissolved)	6/6	17.2	17.4 - 878
Zinc (total)	6/6	17.2	116 - 564
Area 16 (p)			
Radiological Parameter (pCi/L):			
* Alpha	1/1	--	12
* Beta	1/1	--	46
* U-234	1/1	--	1.6
* U-238	1/1	--	1.5
Organics:			
* Benzene	2/24	0.7	6.7 - 57
* Carbon Tetrachloride	1/24	5	5
* 1,3-DNB	1/24	0.6	0.7
* 1,2-Dichlorobenzene	1/24	10	10
* 1,1-Dichloroethane	2/24	5	58 - 110
* 1,2-Dichloroethane	2/24	5	8 - 10
* 1,1-Dichloroethene	1/24	5	10
* trans-1,2-Dichloroethene	3/24	1.7	1.8 - 21,000
* Dimethylphthalate	1/24	20	5

TABLE 5-4 (Continued)

SUMMARY OF CHEMICALS DETECTED IN GROUNDWATER DOWNGRADIENT OF SOURCE AREAS LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 16 (p) (continued)			
Organics:			
* Ethylbenzene	2/24	5	5 - 11
* bis(2-Ethylhexyl)phthalate	2/24	10	10 - 336
* Nitrobenzene	1/24	1.1	1.5
* RDX	6/24	0.6	1.3 - 27
* 1,1,2,2-Tetrachloroethane	1/24	5	10
* Tetrachloroethene	3/24	5	20 - 250
* Toluene	1/24	5	5
* 1,1,1-Trichloroethane	2/24	5	30 - 40
* 1,1,2-Trichloroethane	2/24	5	10
* Trichloroethene	3/24	0.7	13.6 - 1,700
* Vinyl Chloride	1/24	3.9	5.1
Inorganics:			
* Antimony (dissolved)	1/24	3	44.1
* Arsenic (dissolved)	4/24	5	5.3 - 6.6
* Arsenic (total)	6/24	5	5.5 - 14.3
* Barium (dissolved)	13/13	25	65.8 - 597
* Barium (total)	13/13	25	118 - 885
* Beryllium (total)	12/24	0.1	0.2 - 3.1
* Chromium (total)	1/24	37.5	58.7
* Copper (dissolved)	11/24	1.8	3 - 10.3
* Copper (total)	23/24	1.8	4.4 - 61
* Lead (dissolved)	5/24	2.5	2.5 - 5.7
Lead (total)	13/24	2.5	2.6 - 16.2
* Nickel (dissolved)	8/24	9.6	9.9 - 76.6
* Nickel (total)	18/24	9.6	9.9 - 123
* Silver (dissolved)	2/24	0.2	0.2
* Silver (total)	6/24	0.2	0.2 - 6.3
* Zinc (dissolved)	17/24	17.2	41.3 - 1,500
* Zinc (total)	24/24	17.2	24.4 - 2,200
Area 17 (q)			
Radiological Parameter (pCi/L):			
* Alpha	2/4	5 - 11	12 - 17
* Beta	3/4	7	54 - 79
* Total Uranium	1/2	0.2	0.5
* U-234	2/2	--	0.6 - 0.9
* U-238	2/2	--	0.7
Organics:			
* Benzene	1/15	0.7	14
* Chloroform	2/15	5	80 - 100
* 2,6-DNT	1/14	0.6	0.7
* trans-1,2-Dichloroethene	1/15	1.7	320,000
* Ethylbenzene	2/15	5	60 - 200
* bis(2-Ethylhexyl)phthalate	5/14	10	20 - 300
* HMX	1/14	1.3	2.6
* Methylene Chloride	1/15	10	300
* RDX	8/14	0.6	0.6 - 29
* 1,3,5-TNB	1/14	0.6	0.7
* Tetrachloroethene	2/15	5	300
* Tetryl	1/14	0.7	1
* Toluene	2/15	5	15 - 21,000
* 1,1,1-Trichloroethane	2/15	5	2,000
* 1,1,2-Trichloroethane	2/15	5	100 - 200
* Trichloroethene	3/15	0.7	4.1 - 4,300

TABLE 5-4 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 17 (q) (continued)			
Inorganics:			
* Antimony (dissolved)	1/14	3	4
* Antimony (total)	1/14	3	4
* Arsenic (dissolved)	2/14	5	8.4 - 9.5
* Arsenic (total)	4/14	5	5.2 - 16.8
* Barium (dissolved)	7/7	25	115 - 518
* Barium (total)	7/7	25	180 - 1,070
* Beryllium (total)	13/14	0.1	0.2 - 2.1
Chromium (total)	1/14	37.5	40.4
* Copper (dissolved)	8/14	1.8	2.8 - 7.1
* Copper (total)	14/14	1.8	4.8 - 110
* Lead (dissolved)	3/14	2.5	2.7 - 3
* Lead (total)	11/14	2.5	2.6 - 32.1
* Nickel (dissolved)	7/14	9.6	13.8 - 42.1
* Nickel (total)	13/14	9.6	18.7 - 110
* Silver (dissolved)	2/14	0.2	0.2 - 1.8
* Silver (total)	3/14	0.2	0.3 - 1.3
* Zinc (dissolved)	14/14	17.2	19.9 - 798
* Zinc (total)	14/14	17.2	34.5 - 870
Area 18 (r)			
Organics:			
* 1,1-Dichloroethene	1/10	5	15
* bis(2-Ethylhexyl)phthalate	2/10	10	20 - 400
* HMX	1/10	1.3	1.7
* Chrysene (Carcinogenic PAH)	1/10	10	70
* RDX	3/10	0.6	1.2 - 4.7
Inorganics:			
Arsenic (total)	1/10	5	7.6
* Barium (dissolved)	5/5	25	108 - 541
Barium (total)	5/5	25	121 - 462
Beryllium (total)	3/10	0.1	0.2 - 0.5
* Copper (dissolved)	5/10	1.8	2.7 - 10.3
Copper (total)	9/10	1.8	3.8 - 15.9
* Lead (dissolved)	2/10	2.5	2.6 - 3.1
Lead (total)	5/10	2.5	2.8 - 9.3
* Nickel (dissolved)	7/10	9.6	10.2 - 41.5
* Nickel (total)	8/10	9.6	10 - 64.6
* Silver (dissolved)	1/10	0.2	0.5
* Zinc (dissolved)	10/10	17.2	23.9 - 783
Zinc (total)	10/10	17.2	26.8 - 674

(a) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.

(b) Detection limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).

(c) Samples 1-2-1, 1-2-2, 1-3-1, 1-3-2, 1-6-1, 1-6-2, 1-8-1, 1-8-2, 1-9-1, and 1-9-2.

(d) Samples 2-1-1, 2-1-2, 2-2-1, 2-2-2, 2-5-1, 2-5-2, 2-6-1, 2-6-2, 2-7-1, 2-7-2, 2-8-1, and 2-8-2.

(e) Samples 3-1-1, 3-1-2, 3-2-1, 3-2-2, 3-5-1, 3-5-2, 3-8-1, and 3-8-2.

(f) Samples 4-1-1, 4-1-2, 4-4-1, and 4-4-2.

(g) Samples 5-1-1, 5-1-2, 5-2-1, 5-2-2, 5-5-1, 5-5-2, 5-7-1, and 5-7-2.

(h) Samples 6-1-1, 6-1-2, 6-2-1, 6-2-2, 6-4-1, 6-4-2, 6-6-1, and 6-6-2.

(i) Samples 7-1-1, 7-1-2, 7-3-1, 7-3-2, 7-4-1, 7-4-2, 7-7-1, 7-7-2, 7-8-1, 7-8-2, 7-9-1, 7-9-2, 7-11-1, 7-11-2, 7-12-1, 7-12-2, 7-13-1, and 7-13-2.

(j) Samples 8-1-1, 8-1-2, 8-2-1, 8-2-2, 8-3-1, 8-3-2, 8-4-1, 8-4-2, 8-5-1, 8-5-2, 8-7-1, 8-7-2, 8-8-1, 8-8-2, MW-3-1, MW-3-2, MW-5-1, and MW-5-2.

(k) Samples 9-1-1, 9-1-2, 9-2-1, and 9-2-2.

TABLE 5-4 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

(l) Samples 10-3-1, 10-3-2, 10-4-1, 10-4-2, 10-5-1, 10-5-2, 10-6-1, and 10-6-2.
(m) Samples 11-1-1, 11-1-2, 11-2-1, 11-2-2, 11-4-1, and 11-4-2.
(n) Samples 12-2-1, 12-2-2, 12-3-1, 12-3-2, 12-5-1, 12-5-2, 12-6-1, and 12-6-2.
(o) Samples 14-2-1, 14-2-2, 14-3-1, 14-3-2, 14-4-1, and 14-4-2.
(p) Samples 16-2-1, 16-2-2, 16-3-1, 16-3-2, 16-4-1, 16-4-2, 16-5-1, 16-5-2, 16-6-1, 16-6-2, 16-7-1, 16-7-2, 16-8-1, 16-8-2, 16-9-1, 16-9-2, 16-10-1, 16-10-2, 16-11-1, 16-11-2, 16-12-1, 16-12-2, 16-13-1, and 16-13-2.
(q) Samples 17-2-1, 17-2-2, 17-3-1, 17-3-2, 17-5-1, 17-5-2, 17-6-1, 17-7-1, 17-7-2, 17-8-1, 17-8-2, 17-9-1, 17-9-2, 17-10-1, and 17-10-2.
(r) Samples 18-3-1, 18-3-2, 18-4-1, 18-4-2, 18-5-1, 18-5-2, 18-6-1, 18-6-2, 18-7-1, and 18-7-2.

* = Selected as a chemical of potential concern.

sludges from the manufacturing, formulation, and loading of lead-based initiating compounds in Area 2. The two surface impoundments currently being closed were operated under RCRA interim status.

Sampling results from six monitoring wells (2-1, 2-2, 2-5, 2-6, 2-7 and 2-8) were used to assess downgradient groundwater quality in Area 2. Bis(2-ethylhexyl)phthalate, RDX, and 2,6-DNT were detected and identified as chemicals of potential concern for groundwater for Area 2. Inorganics identified as chemicals of potential concern for Area 2 were arsenic, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. Barium was detected in downgradient samples but was not considered to be elevated above background, and therefore was not identified as a chemical of potential concern for Area 2. Concentrations of organic and inorganic chemicals of potential concern in Area 2 are shown in Table 5-4.

<u>Groundwater Downgradient of Sources in Area 3</u>: Area 3 is located in the far northwestern corner of the study area at the intersection of Lake City Buckner Road and Missouri State Highway No. 7 (see Figures 1-2 and 4-5). An inactive sludge burial site and two inactive sand pits in this area were used to dispose of waste material. The sludge burial site was used to dispose of industrial wastewater treatment plant sludge that potentially contained lead and mercury. The sand pits were used to dispose of demolition waste material, and reported received wastes of unknown type from a nuclear weapons manufacturer. Wastes that were potentially disposed in the sand pits includes radioactive wastes and heavy metal RCRA hazardous waste constituents chromium, lead, and mercury.

Sampling results from four monitoring wells (3-1, 3-2, 3-5, and 3-8) were used to assess downgradient groundwater quality in Area 3. 1,1-Dichloroethene, bis(2-ethylhexyl)phthalate, RDX, 2,4-DNT, and HMX were detected and identified as organic chemicals of potential concern for groundwater for Area 3. The highest concentration of 2,4-DNT (0.6 ug/L) was detected in Area 3. (2,4-DNT was also detected at this concentration in Area 6.) Four groundwater samples from Area 3 were analyzed for gross alpha activity, gross beta activity, and uranium radioactivity. Gross alpha activity and U-235 were not detected in these samples. Although uranium radioactivity levels did not exceed the normal range of uranium in groundwater (0.1 to 10 pCi/l) (Hem 1985), the detected radionuclides (U-234 and U-238) were selected as chemicals of potential concern at the request of EPA. Although gross beta activity did not exceed the normal Missouri state beta activity of 20 to 30 pCi/l, the beta radionuclide parameter was retained for evaluation at the request of EPA.

Inorganics identified as chemicals of potential concern for Area 3 are arsenic, barium, beryllium, chromium, copper, lead, nickel, silver and zinc. Concentrations of radiological, organic, and inorganic chemicals of potential concern in Area 3 are shown in Table 5-4.

Groundwater Downgradient of Sources in Area 4: Area 4 is located in the southern portion of the study area and borders Area 2 to the south and Area 5 to the north (see Figures 1-2 and 4-7). Four inactive surface storage impoundments were used to store wastewater sludges from the manufacturing and processing of explosive materials and wastewater treatment sludges from the manufacturing, formulation, and loading of lead-based initiating compounds in Area 4 and were closed under a RCRA closure plan. Potential heavy metal RCRA hazardous constituents disposed in the these impoundments includes lead and antimony.

Sampling results from two monitoring wells (4-1 and 4-4) were used to assess downgradient groundwater quality in Area 4. Bis(2-ethylhexyl)phthalate, 1,3,5-TNB, HMX, and RDX were detected and identified as organic chemicals of potential concern for groundwater for Area 4. Inorganics identified as chemicals of potential concern for Area 4 are antimony, arsenic, cadmium, chromium, copper, nickel, silver, and zinc. Barium, beryllium, and lead also were detected in downgradient samples, but were within background and therefore were not selected as chemicals of potential concern. Concentrations of chemicals of potential concern in Area 4 are shown in Table 5-4.

Groundwater Downgradient of Sources in Area 5: Area 5 is located in the southern portion of the study area and borders Area 4 to the south (see Figures 1-2 and 4-9). One inactive surface impoundment and another currently being closed were used to store wastewater sludges from the manufacturing and processing of explosive materials and wastewater treatment sludges from the manufacturing, formulation, and loading of lead-based initiating compounds in Area 5. Potential heavy metal RCRA hazardous constituents disposed in the these impoundments and lagoons includes antimony, barium, and lead.

Sampling results from four monitoring wells (5-1, 5-2, 5-5, and 5-7) were used to assess downgradient potential groundwater contamination in Area 5. 1,1,1-Trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, trans-1,2-dichloroethene, trichloroethene, vinyl chloride, bis(2-ethylhexyl)phthalate, and RDX were identified as organic chemicals of potential concern for groundwater for Area 5. As discussed in Section 4, one groundwater sample from Area 5 was analyzed for gross alpha activity, gross beta activity and uranium radioactivity. Gross alpha activity and U-235 were not detected. Although the uranium radioactivity levels did not exceed the normal range of uranium in groundwater (0.1 to 10 pCi/l) (Hem 1985) and gross beta activity did not exceed the normal Missouri state beta activity of 20 to 30 pCi/l, the radionuclides U-234 and U-238 and gross beta activity were selected as chemicals of potential concern at the request of EPA.

Inorganic chemicals that were identified as chemicals of potential concern are antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, silver, and zinc. Concentrations of radiological, organic, and inorganic chemicals of potential concern in Area 5 are presented in Table 5-4.

Groundwater Downgradient of Sources in Area 6: Area 6 is located near the center of the study area and is northeast of Area 5 (see Figures 1-2 and 4-11). The surface impoundment currently being closed in Area 6 was used to store neutralized wastes from the packing of 20-mm cannon shells. The wastes stored in the impoundment may also have contained the heavy metal RCRA hazardous constituent barium.

Sampling results from four monitoring wells (6-1, 6-2, 6-4, and 6-6) were used to assess downgradient groundwater quality in Area 6. 2,4-DNT, 1,3-DNB, HMX, and RDX were detected and selected as organic chemicals of potential concern for Area 6 groundwater. The highest concentrations of all the downgradient areas of 1,3-DNB (0.9 ug/L) and 2,4-DNT (0.6 ug/L) were found in Area 6. (2,4-DNT was also detected at this concentration in Area 3.)

Inorganic chemicals identified as chemicals of potential concern were beryllium, chromium, copper, lead, nickel, silver, and zinc. Arsenic and barium were detected in downgradient samples but were within background, and therefore were not selected as chemicals of potential concern for Area 6 groundwater. Table 5-4 presents concentrations of organic and inorganic chemicals of potential concern in Area 6 groundwater.

Groundwater Downgradient of Sources in Area 7: Area 7 is located near the center of the study area and borders Area 19 to the north and Area 21 to the northeast (see Figures 1-2 and 4-13). This area has:

- three active lagoons which have been retrofitted to meet RCRA requirements and which receive treated IWTP wastewater (lagoon discharges to West Fire Prairie Creek are permitted under NPDES);
- three new lagoons which are being built to handle non-hazardous waste;
- three lagoons which have received IWTP wastewater in the past but are currently being closed;
- a spill area from a release in 1983 from an above-ground fuel oil storage tank;
- an inactive lagoon with no waste information;
- an inactive explosives burning ground; and
- a currently used container cleaning area.

Possible RCRA hazardous constituents in these source areas in Area 7 are lead, mercury, barium, antimony, and explosives.

Sampling results from nine monitoring wells (7-1, 7-3, 7-4, 7-7, 7-8, 7-9, 7-11, 7-12 and 7-13) were used to evaluate groundwater quality in this area. Benzene, bis(2-ethylhexyl)phthalate, trans-1,2-dichloroethene, methylene chloride, trichloroethene, vinyl chloride, HMX, RDX, and 1,3,5-TNB were detected in groundwater sampled in Area 7 and selected as chemicals of potential concern. Of all the areas sampled, the highest concentrations of HMX (28 ug/L) and RDX (770 ug/L) were detected in groundwater in this area.

Inorganic chemicals identified as chemicals of potential concern for Area 7 are arsenic, barium, chromium, copper, lead, nickel, selenium, silver, and zinc. Although antimony and mercury were reportedly disposed in Area 7, these chemicals were not present at above detection limits in groundwater in Area 7. Beryllium was detected in downgradient samples but was within background, and therefore was not selected as a chemical of potential concern for Area 7. Concentrations of organic and inorganic chemicals of potential concern in Area 7 are presented in Table 5-4.

Groundwater Downgradient in Area 8: Area 8 is located in the southwestern corner of the study area and is bordered by the Big Ditch to the north (see Figures 1-2 and 4-15). Several sludge disposal areas (4 inactive and 1 active) located in Area 8 were and are used to dispose of industrial wastewater treatment plant sludges that may have contained the heavy metal RCRA hazardous constituents antimony, barium, lead, and mercury. Several inactive and recently closed oil and grease trenches also are present in Area 8. These trenches were used to dispose of spent oil and grease, as well as wastewater treatment sludges from the manufacturing and processing of explosives, and are currently undergoing closure under RCRA.

Sampling results from nine monitoring wells (8-1, 8-2, 8-3, 8-4, 8-5, 8-7, 8-8, MW-3, and MW-5) were used to assess downgradient chemical concentrations in groundwater in Area 8. Organic chemicals of potential concern identified in Area 8 groundwater were trans-1,2-dichloroethene, trichloroethene, toluene, n-nitrosodiphenylamine, bis(2-ethylhexyl)phthalate, and RDX. The highest concentrations of bis(2-ethylhexyl)phthalate (20,000 ug/L) and n-nitrosodiphenylamine (10 ug/L) were detected in this area. (N-nitrosodiphenylamine was also detected at this concentration in Area 12.)

Three groundwater samples from Area 8 were analyzed for gross alpha activity, gross beta activity and uranium radioactivity. Although uranium radioactivity did not exceed the normal range of uranium in groundwater (0.1 to 10 pCi/l) (Hem 1985), uranium radionuclides (total uranium, U-234, and U-238) were selected as chemicals of potential concern at the request of EPA. The level of gross alpha and gross beta activity exceeded the normal Missouri state activity levels of <15 pCi/l and 20 to 30 pCi/l, therefore these parameters were selected as chemicals of potential concern.

Inorganic chemicals that were considered to be chemicals of potential concern for Area 8 are antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, silver, and zinc. Although mercury was reportedly disposed of in Area 8, mercury was not present at or above detection limits in groundwater in Area 8. Concentrations of radiological, organic, and inorganic chemicals of potential concern in groundwater in Area 8 are shown in Table 5-4.

<u>Groundwater Downgradient of Sources in Area 9</u>: Area 9 is located on the southern side of Buckner Road and borders Area 18 to the north (see Figures 1-2 and 4-18). Inactive percolation sumps in Area 9 were used to collect tracer wastes that may contain the heavy metal RCRA hazardous constituents lead and barium. Five in-ground concrete storage tanks (inactive) are also located in Area 9. These tanks were once used to store cyanide waste, and then they were used to store mercurous nitrate substances. In addition, the site also contains inactive sludge drying beds which were once used to treat zinc cyanide.

Sampling results from two monitoring wells (9-1 and 9-2) were used to assess downgradient groundwater in Area 9. Bis(2-ethylhexyl)phthalate, RDX, and 1,3,5-TNB were identified as organic chemicals of potential concern for groundwater for Area 9. The highest concentration of all the downgradient areas of 1,3,5-TNB (19 ug/L) was detected in groundwater in this area. Based on the disposal practices in Area 9, there does not appear to be a defined source of explosive compounds. The presence of RDX and 1,3,5-TNB may be due to some upgradient source, as discussed in Section 4.9.

Inorganic chemicals identified as chemicals of potential concern for Area 9 are arsenic, cadmium, nickel, silver, and zinc. Although barium, beryllium, copper, and lead were detected in downgradient samples, these chemicals were not considered to be elevated above background concentrations, and therefore were not selected as chemicals of potential concern. Although cyanide and mercury were stored in Area 9, these compounds were not present at above detection limits in groundwater of this area. Concentrations of chemicals of potential concern in Area 9 groundwater are presented in Table 5-4.

Groundwater Downgradient of Sources in Area 10: Area 10 is located in the eastern portion of the study area, due east of Area 6 (see Figures 1-2 and 4-20). Area 10 contains an active storage area for sand removed from ballistics firing ranges and may contain heavy metal RCRA hazardous constituents antimony, barium, and lead.

Sampling results from four monitoring wells (10-3, 10-4, 10-5, and 10-6) were used to assess downgradient chemical concentrations in groundwater in Area 10. RDX and bis(2-ethylhexyl)phthalate were identified as organic chemicals of potential concern for groundwater for Area 10. Based on the disposal history of Area 10 and the fact that organic compounds were detected in upgradient wells, it appears that the presence of organic compounds may be due to some upgradient source, as discussed in Section 4.10.

Inorganic chemicals identified as chemicals of potential concern for Area 10 are antimony, arsenic, barium, beryllium, cadmium, copper, lead, nickel, silver, and zinc. Chromium was detected in downgradient samples but was not elevated above background levels; therefore, chromium was not selected as a chemical of potential concern. Concentrations of organic and inorganic chemicals of potential concern in Area 10 are presented in Table 5-4.

<u>Groundwater Downgradient in Area 11</u>: Area 11 is located in the northeastern portion of the study area and borders Areas 16 and 17 to the north (see Figures 2-1 and 4-22). Area 11 contains a burning grounds used for open burning of propellants and pyrotechnic mixtures. The waste from the burning grounds (i.e., ash) is considered a RCRA hazardous waste based on the levels of barium present.

Sampling results from three monitoring wells (11-1, 11-2 and 11-4) were used to assess downgradient chemical concentrations in groundwater in Area 11. Two explosive organic chemicals, RDX and HMX, and bis(2-ethylhexyl)phthalate were identified as a chemicals of potential concern for groundwater for Area 11. Inorganic chemicals identified as chemicals of potential concern for Area 11 were arsenic, beryllium, cadmium, chromium, copper, nickel, silver, and zinc. Barium and lead were detected in downgradient samples; however, these chemicals were not considered to be elevated above background concentrations, and therefore they were not identified as chemicals of potential concern for Area 11. Table 5-4 presents the concentrations of organic and inorganic chemicals of potential concern in Area 11 groundwater.

<u>Groundwater Downgradient of Sources in Area 12</u>: Area 12 is located near the intersection of Missouri State Highway No.7 and Lake City Buckner Road in the far northwestern corner of the RI study area, just south of Area 3 (see Figures 1-2 and 4-24). A closed chemical laboratory waste lagoon listed as an NPL site is located in Area 12. The chemical waste lagoon accepted heavy metal RCRA hazardous constituents including antimony, barium, chromium, lead, mercury, and silver, as well as small quantities of laboratory organic wastes.

In addition, a sludge disposal area located in Area 12 accepted industrial wastewater treatment plant sludge.

Sampling results from four monitoring wells (12-2, 12-3, 12-5 and 12-6) were used to assess groundwater quality in Area 12. Four explosive/byproduct organic compounds (1,3,5-TNB, HMX, RDX and tetryl) and n-nitrosodiphenylamine were detected and identified as chemicals of potential concern for groundwater for Area 12. The highest concentrations of n-nitrosodiphenylamine (10 ug/LO and tetryl (1.3 ug/L) were detected in Area 12. (N-nitrosodiphenylamine was also detected at this concentration in Area 8.)

Inorganic chemicals identified as chemicals of potential concern for Area 12 were arsenic, barium, beryllium, chromium, copper, nickel, silver, and zinc. Although lead was detected in downgradient samples, it was not considered to be elevated above background concentrations; therefore, lead was not selected as a chemical of potential concern. Although antimony and mercury were reportedly disposed in the chemical waste lagoon, these chemicals were not present above detection limits in groundwater. Concentrations of chemicals of potential concern in Area 12 groundwater are presented in Table 5-4.

Groundwater Downgradient of Sources in Area 14: Area 14 is located in the northern portion of the study area on the north side of Lake City Buckner Road (see Figures 1-2 and 4-28). A inactive sludge disposal area located in Area 14 accepted industrial wastewater treatment plant sludge that may have contained the heavy metal RCRA hazardous constituents lead and mercury. In addition, there are four aboveground storage tanks in Area 14 that currently store fuel oil.

Sampling results from three monitoring wells (14-2, 14-3 and 14-4) were used to assess potential contamination of groundwater in Area 14. RDX and bis(2-ethylhexyl)phthalate were identified as organic chemicals of potential concern for groundwater for Area 14. As discussed in Section 4.24, 2 groundwater samples from Area 14 were analyzed for gross alpha activity, gross beta activity, and uranium radioactivity. U-235 was the only radionuclide that was not detected. Although uranium radioactivity levels did not exceed the normal range of uranium in groundwater (0.1 to 10 pCi/l) (Hem 1985); U-234, U-238, and total uranium were selected as chemicals of potential concern at the request of EPA. Although gross alpha activity and gross beta activity did not exceed the normal Missouri state activity levels of < 15 pCi/l and 20 to 30 pCi/l, respectively, the alpha and beta radionuclide parameters were selected as chemicals of potential concern at the request of EPA.

Inorganic chemicals identified as chemicals of potential concern for Area 14 were arsenic, barium, beryllium, cadmium, chromium, copper, nickel, and zinc. Although mercury was reportedly disposed in the sludge area, mercury was not present at above detection limits in groundwater in Area 14. Lead was detected in downgradient samples, however, lead was not considered to be elevated above background concentrations, and therefore was not selected as a chemical of potential concern. Table 5-4 presents concentrations of radiological, organic and inorganic chemicals of potential concern in Area 14 groundwater.

Groundwater Downgradient of Sources in Area 16: Area 16 is located in the northeastern corner of the study area, west of Area 17 (see Figures 1-2 and 4-22). Between 1970 and 1980, an abandoned landfill and trench in Area 16 accepted industrial wastewater treatment plant sludge, grease and oil, construction debris, explosive waste, and solvents. Possible heavy metal RCRA hazardous constituents accepted at the landfill during its operation includes barium, lead, and mercury. Several wastes including oil and grease, bleach cans, and paint cans were disposed at an inactive burial site located in Area 16. Several storage tanks in Area 16, which have been removed, were once used to store paint wastes, solvent wastes, and waste oil. Soil samples collected in the vicinity of certain tanks reportedly contained heavy metal RCRA hazardous constituents such as cadmium, chromium, lead, and nickel, as well as several volatile and semi-volatile organic compounds. A firing range and a demolition burning grounds is located in Area 16. The firing range contains ammunition wastes including lead bullets and lead casings. The waste material at the demolition burning grounds and soils may contain the heavy metal RCRA hazardous constituents lead and barium.

Sampling results from twelve monitoring wells (16-2, 16-3, 16-4, 16-5, 16-6, 16-7, 16-8, 16-9, 16-10, 16-11, 16-12 and 16-13) were used to assess downgradient chemical concentrations in groundwater in Area 16. Benzene, carbon tetrachloride, 1,3-DNB, 1,2-dichlorobenzene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, trans-1,2-dichloroethene, dimethylphthalate, ethylbenzene, bis(2-ethylhexyl)phthalate, nitrobenzene, RDX, 1,1,2,2-tetrachloroethane, tetrachloroethene, toluene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethene, and vinyl chloride were detected in groundwater sampled in Area 16 and were selected as chemicals of potential concern. Overall the types of chemicals detected in Areas 16 and 17 appeared to be similar. Of all the groundwater sampled, the highest concentrations of 1,1-dichloroethane (110 ug/L) and benzene (57 ug/L) were collected from Area 16. Of all the areas in which groundwater samples were collected, 1,2-dichloroethane, nitrobenzene, dimethylphthalate, carbon tetrachloride, 1,1,2,2-tetrachloroethane and 1,2-dichlorobenzene were detected only in Area 16. Most of the organic chemicals detected in Area 16 were found at well 16-2. Well 16-2 is located slightly downgradient from the abandoned sanitary landfill.

As discussed in Section 4, one groundwater sample from Area 16 was analyzed for alpha, beta, and uranium radioactivity, because Area 16 was a suspected uranium disposal site. U-235 was the only radionuclide that was not detected. Although uranium radioactivity levels did not exceed the normal range of uranium in groundwater (0.1 to 10 pCi/l) (Hem 1985), the radionuclides U-234 and U-238 were selected as chemicals of potential concern at the request of EPA. Gross alpha activity which did not exceed the normal Missouri state activity levels of < 15 pCi/l was also selected as a chemical of potential concern at the request of EPA. Gross beta activity exceeded the Missouri state activity level of 20 to 30 pCi/l, and was therefore selected as a chemical of potential concern.

Inorganic chemicals selected as chemicals of potential concern for Area 16 were antimony, arsenic, barium, beryllium, chromium, copper, lead, nickel, silver, and zinc. Concentrations of radiological, organic, and inorganic chemicals of potential concern in Area 16 groundwater are presented in Table 5-4.

<u>Groundwater Downgradient of Sources in Area 17</u>: Area 17 is located in the northeastern corner of the study area, east of Area 16 (see Figures 1-2 and 4-22). Lake City Buckner Road passes through the northwestern corner of Area 17. A sanitary landfill located in Area 17 accepts construction debris and normal sanitary solid wastes. According to the MDNR landfill permit, no hazardous waste can be dumped at this landfill. However, as stated previously in this report (Section 4.17) certain explosive compounds were reportedly disposed at this landfill. Three inactive disposal solvent pits located in Area 17 were used for disposing industrial wastewater treatment plant sludge, spent grease and waste oil, and waste solvents. Possible RCRA hazardous constituents disposed in these pits include 1,1,1-trichloroethane, trichloroethene, chromium, and lead.

Sampling results from eight monitoring wells (17-2, 17-3, 17-5, 17-6, 17-7, 17-8, 17-9 and 17-10) were used to assess Area 17 groundwater. Benzene, chloroform, 2,6-DNT, trans-1,2-dichloroethene, ethylbenzene, HMX, methylene chloride, RDX, 1,3,5-TNB, tetrachloroethene, tetryl, toluene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethene, and bis(2-ethylhexyl)phthalate were the organic chemicals detected and identified as chemicals of potential concern for groundwater in Area 17. As previously stated, the types of chemicals detected in Areas 16 and 17 appeared to be similar. Of all the downgradient areas sampled, the highest concentrations of 1,1,1-trichloroethane (2,000 ug/L), 1,1,2-trichloroethane (200 ug/L), chloroform (100 ug/L), 2,6-DNT (0.7 ug/L), methylene chloride (300 ug/L), ethylbenzene (200 ug/L), trichloroethene (4,300 ug/L), tetrachloroethene (300 ug/L), toluene (21,000 ug/L), and trans-1,2-dichloroethene (320,000 ug/L) were detected in Area 17 groundwater samples. With the exception of toluene and trichloroethene which were also detected in well 17-3, all of the volatile organic chemicals detected in Area 17 were found at well 17-5. Well 17-5 is located slightly downgradient (within 20 feet) of a solvent disposal pit.

As discussed in Section 4.24, 4 groundwater samples from Area 17 were analyzed for gross alpha activity, gross beta activity, and uranium radioactivity, because Area 17 was a suspected uranium disposal site. U-235 was the only radionuclide that was not detected. Although uranium radioactivity levels did not exceed the normal range of uranium in groundwater (0.1 to 10 pCi/l) (Hem 1985), the radionuclides U-234 and U-238 were selected as chemicals of potential concern at the request of EPA. Gross alpha and gross beta activity did exceed the normal Missouri state activity levels of <15 pCi/l and 20 to 30 pCi/l, respectively; therefore, the alpha and beta radionuclide parameters were selected as chemicals of potential concern.

Inorganic chemicals selected as chemicals of potential concern for Area 17 were antimony, arsenic, barium, beryllium, copper, lead, nickel, silver, and zinc. Although chromium was detected in downgradient samples, it was not considered to be elevated above background concentrations, and therefore was not selected as a chemical of potential concern. Concentrations of radiological, organic, and inorganic chemicals of potential concern in groundwater in Area 17 are presented in Table 5-4.

<u>Groundwater Downgradient of Sources in Area 18</u>: Area 18 is located in the northeastern corner of the study area, north of Lake City Buckner Road, and west of Area 16 (see Figures 2-1 and 4-32). Numerous closed waste burning/waste burial pits are located in Area 18. These pits were used for burning industrial wastewater treatment plant grease and oil, waste oil, waste solvents, and solid waste. The incineration ash was then disposed in these

pits. Potential RCRA hazardous constituents disposed in these pits include carbon tetrachloride, tetrachloroethene, lead, and mercury.

Sampling results from five monitoring wells (18-3, 18-4, 18-5, 18-6 and 18-7) were used to assess groundwater quality in Area 18. 1,1-Dichloroethene, bis(2-ethylhexyl)phthalate, chrysene (a carcinogenic PAH), RDX, and HMX were detected and identified as organic chemicals of potential concern for groundwater in Area 18. The highest concentration of 1,1-dichloroethene (15 ug/L) was detected in Area 18. Of all the groundwater samples, chrysene was only detected once. As discussed in Section 4.18, Areas 11, 16, and 17 may be potential sources of explosive compounds detected in groundwater in Area 18.

Inorganic chemicals identified as chemicals of potential concern for Area 18 are barium, copper, lead, nickel, silver, and zinc. Although arsenic and beryllium were detected in downgradient samples, these chemicals were not considered to be elevated above background concentrations, and therefore were not selected as chemicals of potential concern. Although mercury was reportedly disposed in Area 18, mercury was not detected in groundwater in Area 18. Table 5-4 presents concentrations of chemicals of potential concern in Area 18 groundwater.

5.2.1.4 Groundwater in the Off-site Residential Wells

5.2.1.4.1 Groundwater in the Off-Site Residential Wells Located North of LCAAP

The 12 off-site residential wells sampled during the RI are located just north of the northern boundary of the LCAAP near Areas 14, 16, 17, 18, and 22. Carbon tetrachloride, 1,2-dichlorobenzene, 1,4-dichlorobenzene, HMX, RDX, toluene, and trichloroethene were detected and identified as organic chemicals of potential concern for groundwater from these off-site residential wells. Chemicals measured in perimeter Areas 16 and 17 can potentially migrate beyond property boundaries since these areas lie outside production well capture zones. All of the organics detected in the off-site residential wells located along the northern LCAAP boundary were detected in at least one of the on-site wells in these areas with the exception of 1,4-dichlorobenzene. (Carbon tetrachloride in Area 16; 1,2-dichlorobenzene in Area 16; HMX in Areas 17 and 18; RDX in Areas 14, 16, 17, and 18; toluene in Areas 16 and 17; and trichloroethene in Areas 16 and 17). HMX and RDX were found in nine and three, respectively, of the 12 off-site wells. Toluene was detected at a trace level (1 ug/l) in the off-site well located just north of Area 17. It should be noted that toluene is a common laboratory contaminant (although since blank data are not available to determine this, this chemical will be assumed to be site-related). Finally, carbon tetrachloride (1.1 ug/l), 1,2-dichlorobenzene (12.4 ug/l), 1,4-dichlorobenzene (2.2 ug/l) and trichloroethene (1.2 ug/l) were detected at low levels in the Ure residential well located north of Area 22.

Inorganic chemicals identified as chemicals of potential concern for groundwater from the off-site residential wells are barium, chromium, copper, lead, mercury, nickel and zinc. Both barium and zinc were detected in 11 of the 12 off-site wells, while copper and mercury were found in eight and nine wells, respectively. Lead was detected in two off-site wells, while chromium and nickel were only found in the off-site well located just north of Area 17. It should be noted that no representative background samples were collected for these residential wells; therefore, it is not known whether the concentrations of these inorganics are elevated above background. To be conservative, all inorganics detected in the off-site residential wells that also were present in on-site monitoring wells at above background concentrations were selected as chemicals of potential concern. Table 5-5 presents concentrations of chemicals of potential concern in the residential wells.

TABLE 5-5

CHEMICALS OF POTENTIAL CONCERN IN OFF-POST RESIDENTIAL WELLS AT LCAAP LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Range of Detected Concentrations
Danner		
HMX	1/2	4.1
Barium	2/2	49.7 - 54.5
Copper	2/2	15.8 - 42.8
Mercury	1/2	0.4
Zinc	1/2	45
Fergeson		
Barium	1/1	58.1
Copper	1/1	13.1
Lead	1/1	4
Mercury	1/1	0.4
Zinc	1/1	578
Hedrickj-A		
HMX	1/3	8.5
RDX	1/3	3.4
Barium	3/3	77.7 - 167
Copper	3/3	11.6 - 26.3
Mercury	1/3	0.4
Zinc	3/3	52.9 - 165
Hedrickj-B		
HMX	1/2	7
Barium	2/2	69.1 - 77.7
Copper	1/2	7.9
Mercury	1/2	0.5
Zinc	2/2	29.4 - 31.9
Hedrickv		
HMX	1/2	5
Barium	2/2	56.1 - 68.3
Copper	1/2	9.6
Zinc	1/2	331
Lirely		
HMX	1/3	4.6
Barium	3/3	72.6 - 89.3
Copper	1/3	6.6
Mercury	1/3	0.4
Zinc	1/3	20.5
Pennington		
HMX	1/2	5.5
Barium	2/2	62.2 - 91.2
Mercury	1/2	0.4
Zinc	1/2	28.7
Tcarlton		
Barium	1/1	80.1
Lead	1/1	2.3

TABLE 5-5 (Continued)

CHEMICALS OF POTENTIAL CONCERN IN OFF-POST RESIDENTIAL WELLS AT LCAAP LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Range of Detected Concentrations
Turley		
HMX	1/3	5.9
RDX	1/3	2.8
Barium	3/3	48 - 69
Copper	3/3	11.5 - 15.8
Mercury	1/3	0.4
Zinc	3/3	30.9 - 174
Ure		
Carbon tetrachloride	1/2	1.1
1,2-Dichlorobenzene	1/2	12.4
1,4-Dichlorobenzene	1/2	2.2
HMX	1/2	7.1
RDX	1/2	2.8
Trichloroethene	1/2	1.2
Barium	2/2	43.5 - 45
Mercury	1/2	0.4
Zinc	2/2	23.6 - 37.6
Carlton		
HMX	1/3	6.2
Barium	3/3	83.1 - 119
Mercury	2/3	0.4
Zinc	1/3	75.2
Well Located Just North of Area 17 (b)		
Toluene	1/1	1
Chromium	1/1	91
Copper	1/1	37
Nickel	1/1	20
Zinc	1/1	310

(a) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.
(b) Sample RW-01.

5.2.1.4.2 Groundwater in the Off-Site Residential Wells Located West of LCAAP

Off-site residential potable wells are located approximately one mile off the western property line. These off-site residential wells are downgradient of Areas 3 and 8. Monitoring well data in Area 3 (perimeter wells 3-1, 3-5, and 3-8) and Area 8 (all wells were used because of the hydrogeology of Area 8) will be used to represent concentrations presented in groundwater alonga the LCAAP boundary to the west.

Trans-1,2-Dichloroethene, bis(2-ethylhexyl)phthalate, HMX, n-nitrosodiphenylamine, RDX, toluene, and trichloroethene were selected as organic chemicals of potential concern for these off-site residential wells. The highest concentration of bis(2-ethylhexyl)phthalate (20,000 ug/L) was detected in Area 8.

Nine monitoring wells were analyzed for gross alpha activity, gross beta activity, and uranium radioactivity. Although uranium radioactivity did not exceed the normal range of uranium in groundwater (0.1 to 10 pCi/l) (Hem 1985), uranium radionuclides (total uranium; U-234, and U-238) were selected as chemicals of potential concern at the request of EPA. The level of gross alpha and gross beta activity exceeded the normal Missouri state activity levels of <15 pCi/l and 20 to 30 pCi/l, therefore these parameters were selected as chemicals of potential concern.

All inorganic chemicals detected (antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc) were selected as chemicals of potential concern. Concentrations or radiological, organic, and inorganic chemicals of potential concern detected in groundwater at the western boundary of LCAAP are shown in Table 5-6.

TABLE 5-6

SUMMARY OF CHEMICALS DETECTED AT THE WESTERN BOUNDARY OF LCAAP (a)
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (b)	Detection Limit (c)	Range of Detected On-site Concentrations
Radiological Parameter (pCi/L):			
* Alpha	3/9	5 - 7	6 - 33
* Beta	7/9	5	9 - 96
* Total Uranium	1/1	--	1.1
* U-234	7/8	0.1	0.1 - 1.9
* U-235	1/8	0.1	0.1
* U-238	6/8	0.1	0.6 - 1.7
Organics:			
* trans-1,2-Dichloroethene	4/32	1.7	4 - 94
* bis(2-Ethylhexyl)phthalate	5/32	10	30 - 20,000
* HMX	2/32	1.3	1.7 - 3
* N-nitrosodiphenylamine	2/32	10	10
* RDX	5/32	0.6	0.9 - 120
* Toluene	2/32	5	15
* Trichloroethene	4/38	0.7	0.9 - 35
Inorganics:			
* Antimony (dissolved)	2/32	3	9.3 - 17.5
* Antimony (total)	2/32	3	3.5 - 7.6
* Arsenic (dissolved)	2/32	5	8.6 - 14.7
* Arsenic (total)	13/32	5	5.2 - 15.1
* Barium (dissolved)	16/16	25	81.4 - 469
* Barium (total)	21/21	25	129 - 1,470
* Beryllium (dissolved)	2/32	0.1	0.1 - 1.6
* Beryllium (total)	24/32	0.1	0.2 - 6
* Cadmium (total)	2/32	5.1	12.9 - 14
* Chromium (dissolved)	4/32	37.5	38.5 - 255
* Chromium (total)	11/32	37.5	39.4 - 363
* Copper (dissolved)	14/32	1.8	2.6 - 41.3
* Copper (total)	31/32	1.8	3.1 - 780
* Lead (dissolved)	10/32	2.5	2.5 - 28.1
* Lead (total)	26/32	2.5	2.6 - 90
* Mercury (total)	1/32	0.2	0.5
* Nickel (dissolved)	18/32	9.6	10.1 - 497
* Nickel (total)	29/32	9.6	9.8 - 193
* Silver (dissolved)	2/32	0.2	0.2 - 12.8
* Silver (total)	10/32	0.2	0.2 - 2.2
* Zinc (dissolved)	27/32	17.2	17.6 - 1,400
* Zinc (total)	32/32	17.2	21.4 - 1,000

(a) Western boundary samples 3-1, 3-5, 3-8, MW-1 through MW-5, and 8-1 through 8-8 were used to estimate potential exposure point concentrations for off-site residents 0.5-1 mile west/northwest of the site western perimeter (see Sections 4.3 and 4.8 for discussion of individual well data).

(b) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.

(c) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).

* = Selected as a chemical of potential concern.

5.2.2 Soil

As discussed in Section 4, soil sampling was performed in certain study areas to preliminarily assess the extent of soil contamination at the LCAAP site. Subsurface soil boring samples were collected in Areas 8, 9, 14, and 15, and surface samples were collected in Areas 9 and 13 at the LCAAP site. Soil samples were collected to characterize potential contamination in the waste disposal areas at each location and were analyzed for the types of wastes disposed. For this assessment, soil monitoring data were grouped by study area and by depth (i.e., surface and subsurface). Background soil samples were collected from areas of the site that are not considered to be influenced by waste site-related contamination and analyzed for volatiles, semi-volatiles, explosives, and inorganics. Concentrations of chemicals of potential concern identified in soils in the areas sampled are presented in Table 5-7.

Soil in Area 8: Six subsurface soil boring samples were collected from Area 8 at two sludge disposal locations and analyzed for explosives, inorganics, and oil and grease. These sludge disposal areas were used for the disposal of industrial wastewater treatment plant sludges that may have contained the heavy metal RCRA hazardous constituents lead and mercury. 2,6-DNT was the only explosive compound detected in the samples and was selected as a chemical of potential concern. Oil and grease was selected as a chemical of potential concern. Arsenic, barium, beryllium, cadmium, copper, lead, mercury, nickel, and zinc were identified as inorganic chemicals of potential concern. Table 5-7 presents concentrations of chemicals of potential concern in Area 8 subsurface soil.

Soil in Area 9: Eighteen subsurface soil boring samples collected at depths ranging from 6 to 24 inches and 5 surface soil samples were collected from the percolation sump area, mercury waste tank area, and sludge drying beds. The surface soil samples were analyzed for volatiles, semi-volatiles, explosives, inorganics and cyanide and the subsurface soil samples were

TABLE 5-7

SUMMARY OF CHEMICALS DETECTED IN
SOIL AT LCAAP
LAKE CITY, MISSOURI

(Concentrations reported in ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 8 - Subsurface (c)			
Organics:			
* 2,6-DNT	1/6	0.4	0.4
* Oil and Grease	1/6	50	270
Inorganics:			
* Arsenic	6/6	5.7	13.5 - 38.5
* Barium	6/6	40	188 - 1,250
* Beryllium	6/6	0.3	0.3 - 0.5
* Cadmium	3/6	0.7	9.3 - 26.4
* Copper	6/6	3.8	9.6 - 190
* Lead	6/6	4.8	7.1 - 18.1
* Mercury	1/6	0.1	3
* Nickel	6/6	4.8	16.8 - 40.1
* Zinc	2/6	52	69.5 - 3,010
Area 9 - Surface (d)			
Inorganics:			
* Arsenic	5/5	5.7	26.9 - 63
* Barium	5/5	40	777 - 967
* Beryllium	5/5	0.3	0.3 - 0.6
* Cadmium	5/5	0.7	15.9 - 170
* Chromium	2/5	2.5	343 - 516
* Copper	5/5	3.8	50 - 4,800
* Cyanide	3/5	0.7	3 - 7
* Lead	5/5	4.8	18.3 - 4,400
* Mercury	4/5	0.1	0.2 - 5.4
Nickel	3/5	4.8	22.3 - 31.4
* Selenium	1/5	2.1	7.2
* Zinc	5/5	52	321 - 2,950
Area 9 - Subsurface (e)			
Inorganics:			
* Cyanide	1/18	0.7	2.9
* Mercury	2/18	0.1	0.3 - 0.6
Nickel	6/6	4.8	10.3 - 30.4
* Zinc	5/18	52	128 - 7,800
Area 13 - Surface (f)			
Inorganics:			
* Arsenic	3/3	5.7	24 - 30.8
* Barium	3/3	40	499 - 749
Beryllium	1/3	0.3	0.4
* Chromium	1/3	2.5	115
Copper	3/3	3.8	7.5 - 8.1
* Lead	2/3	4.8	15.8 - 20.3
Nickel	3/3	4.8	11.5 - 12.3
Area 14 - Subsurface (g)			
Organics:			
* Oil and Grease	2/3	50	18 - 93
Inorganics:			
* Arsenic	3/3	5.7	34.6 - 180
* Barium	3/3	40	534 - 972
Beryllium	2/3	0.3	0.4
* Cadmium	2/3	0.7	7.9
Copper	3/3	3.8	10 - 11.6
Lead	3/3	4.8	10.4 - 13.7
Nickel	3/3	4.8	12.8 - 24.1

TABLE 5-7 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
SOIL AT LCAAP
LAKE CITY, MISSOURI

(Concentrations reported in ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 15 - Subsurface (h)			
Organics:			
* Oil and Grease	1/4	50	130
Inorganics:			
* Antimony	1/4	25.3	140
* Arsenic	4/4	5.7	14.4 - 34.2
* Barium	4/4	40	625 - 9,840
* Beryllium	3/4	0.3	0.3 - 0.4
* Cadmium	4/4	0.7	6.4 - 9.3
* Copper	3/4	3.8	14.5 - 110
* Lead	4/4	4.8	27.8 - 2,200
Nickel	4/4	4.8	17.5 - 21.7
Zinc	2/4	52	85.8 - 97.3

(a) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.
(b) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).
(c) Samples SB8-1-1, SB8-1-2, SB8-1-3, SB8-2-1, SB8-2-2, and SB8-2-3.
(d) Samples SO9-1-1, SO9-2-1, SO9-3-1, SO9-4-1, and SO9-5-1.
(e) Samples SB9-5-1, SB9-5-2, SB9-6-1, SB9-6-2, SB9-7-1, SB9-7-2, SB9-8-1 SB9-8-2, SB9-9-1, SB9-9-2, SB9-10-1, SB9-10-2, SB9-11-1, SB9-11-2, SB9-12-1, SB9-12-2, SB9-13-1, and SB9-13-2.
(f) Samples SO13-1-1, SO13-2-1, and SO13-3-1.
(g) Samples SB14-1-1, SB14-1-2, and SB14-1-3.
(h) Samples SB15-1-1, SB15-1-2, SB15-2-1, and SB15-2-2.

* = Selected as a chemical of potential concern.

analyzed for mercury, nickel (6 samples only), zinc, and cyanide. As discussed in Section 4.9 and 5.2.1.3, percolation sumps were used to collect tracer wastes that may have contained the heavy metal RCRA hazardous constituents lead and barium. Five mercury waste underground storage tanks also are located in Area 9. These tanks were once used to store cyanide waste, and then were used to store mercurous nitrate substances. The sludge drying beds were used as a dewatering step in a zinc cyanide treatment process.

No explosive chemicals were detected in the surface or subsurface soils in this area as shown in Table 5-7. The inorganic chemicals identified as chemicals of potential concern for surface soil samples were arsenic, barium, beryllium, cadmium, chromium, copper, cyanide, lead, mercury, selenium, and zinc. In subsurface soils, cyanide, mercury, and zinc were identified as chemicals of potential concern. Although nickel was detected in surface and subsurface soil samples, it was not considered to be elevated above background concentrations, and therefore was not selected as a chemical of potential concern for either surface or subsurface soil. Table 5-7 presents concentrations of chemicals of potential concern for surface and subsurface soils in this area.

Soil in Area 13: As discussed in Section 4, three surface soil samples were collected in Area 13 in an open waste drainage area (no subsurface samples were collected). As discussed in Section 4.13 and 5.2.1.3, chromium waste materials from metal part manufacturing were allowed to drain from building 35 in Area 13. No VOCs, BNAs, or explosive chemicals were detected in the surface soils, as shown in Table 5-7. The inorganic chemicals identified as chemicals of potential concern for surface soil samples were arsenic, barium, chromium, and lead. Although beryllium, copper, and nickel were detected in surface soil samples, they were not considered to be elevated above background concentrations, and therefore these chemicals were not selected as chemicals of potential concern for Area 13 surface soil. Table

5-7 presents concentrations of chemicals of potential concern for Area 13 surface soils.

Soil in Area 14: As discussed in Section 4, three subsurface soil boring samples were collected in Area 14 in a sludge disposal area (no surface soil samples were collected). These subsurface samples were analyzed for explosives, inorganics, and oil and grease. As discussed in Section 4.14 and 5.2.1.3, this sludge disposal area accepted industrial wastewater treatment plant sludge that may have contained the heavy metal RCRA hazardous constituents lead and mercury. No explosive chemicals were detected in the subsurface soil sample, as shown in Table 5-7. The inorganic chemicals identified as chemicals of potential concern for the subsurface soil sample includes arsenic, barium and cadmium. Although beryllium, copper, lead, and nickel were detected in the subsurface soil sample, levels of these chemicals were not considered to be elevated above background concentrations, and therefore were not selected as chemicals of potential concern for Area 14 subsurface soil. However, lead was reportedly disposed in the sludge disposal areas. Although wastes containing mercury also were reportedly disposed in the sludge disposal area, mercury was not present at above detection limits in subsurface soil in Area 14. Oil and grease was selected as a chemical of potential concern in Area 14. Table 5-7 presents the concentrations of chemicals of potential concern for subsurface soil for Area 14.

Soil in Area 15: As discussed in Section 4.15, two subsurface soil boring samples were collected in Area 15 in a temporary surface impoundment at a depth of 2.5 feet (no surface soil samples were collected). These subsurface samples were analyzed for explosives, inorganics, and oil and grease. As discussed in Section 4.15 and 5.2.1.3, the temporary surface impoundment stored waste water sludges from the manufacturing and processing of explosive materials and wastewater treatment sludges from the manufacturing, formulation, and loading of lead-based initiating compounds in Area 15. The sludge waste may have contained the heavy metal RCRA hazardous constituents antimony, barium, and lead. No explosive chemicals were detected in the subsurface soil samples, as shown in Table 5-7. The inorganic chemicals identified as chemicals of potential concern for subsurface soil samples in Area 15 were antimony, arsenic, barium, beryllium, cadmium, copper, and lead. Although nickel and zinc were detected in subsurface soil samples, these chemicals were not considered to be elevated above background concentrations, and were not selected as chemicals of potential concern for Area 15. Oil and grease was selected as a chemical of potential concern in Area 15. Table 5-7 presents the concentrations of chemicals of potential concern for subsurface soil for Area 15.

5.2.3 Surface Water and Sediment

This section presents the surface water and sediment sampling data and selected chemicals of potential concern for the ditches, landfill leachate, and pond (Section 5.2.3.1) and for the sump and sump outflows (Section 5.2.3.2).

5.2.3.1 Ditch, Leachate, and Pond Surface Water and Sediments

Surface water and sediment samples were only collected in Areas 12, 13, and 16; from the plant-wide ditch system; and from the on-site pond located in the northwest portion of the site (see Figure 4-34). Therefore, the surface water and sediment investigation at LCAAP is considered preliminary. The surface water and sediment samples collected in the ditches, landfill leachate, and pond were analyzed for the presence of explosive, volatile, semi-volatile, and inorganic chemicals (unfiltered samples only). Samples SP-01 through SP-34 also were analyzed for oil and grease. Surface water/sediment samples collected from a stream just as it enters the plant property and upstream of any potential source areas were used for inorganic background comparison with on-site surface water samples. Sediment samples were compared with background soil samples. Concentrations of chemicals of potential concern identified for surface water and sediments are presented in Table 5-8 and are discussed by study area below.

TABLE 5-8

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER AND SEDIMENT AT LCAAP
LAKE CITY, MISSOURI

(Surface Water: ug/L, Sediment: ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 13 Drainage Ditch			
Surface Water (c)			
Organics:			
* bis(2-Ethylhexyl)phthalate	3/3	10	40 - 60
* 1,3,5-TNB	1/3	0.6	0.6
Inorganics:			
* Antimony	1/3	3	15.5
* Chromium	1/3	37.5	38.5
* Copper	3/3	1.8	40.8 - 180
* Lead	3/3	2.5	12.4 - 13.7
* Nickel	3/3	9.6	17.8 - 21.9
Zinc	3/3	17.2	293 - 346
Sediment (d)			
Organics:			
* Carcinogenic PAHs			
Chrysene	2/4	0.3	0.8 - 1
Total Carcinogenic PAHs	2/4	0.3	0.8 - 1
* Noncarcinogenic PAHs			
Anthracene	1/4	0.3	0.8
Fluoranthene	3/4	0.3	1 - 3
Phenanthrene	2/4	0.3	1 - 3
Pyrene	2/4	0.3	0.9 - 1
Total Noncarcinogenic PAHs	3/4	0.3	2.2 - 7
Inorganics:			
* Arsenic	4/4	5.7	6.7 - 25
* Barium	4/4	40	397 - 933
* Cadmium	4/4	0.7	10.6 - 14.5
* Chromium	3/4	2.5	90.7 - 1,000
* Copper	4/4	3.8	9.4 - 790
* Lead	4/4	4.8	39.5 - 210
* Mercury	1/4	0.1	0.8
* Nickel	4/4	4.8	8.6 - 35.5
* Zinc	4/4	52	149 - 475
Area 16 Leachate Seep			
Surface Water (e)			
Organics:			
* Benzene	1/1	0.6	2.5
* Chloroethane	1/1	10	40
* 1,1-Dichloroethane	1/1	5	30
* trans-1,2-Dichloroethene	1/1	1.7	17
* Ethylbenzene	1/1	5	10
* Methylene Chloride	1/1	5	40
* Phenol	1/1	10	2,000
* Toluene	1/1	5	120
* Trichloroethene	1/1	0.7	13
Inorganics:			
* Beryllium	1/1	0.1	2.2
* Copper	1/1	1.8	500
* Lead	1/1	2.5	140
* Nickel	1/1	9.6	150
* Silver	1/1	0.19	0.5
* Zinc	1/1	17.2	2,400

TABLE 5-8 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER AND SEDIMENT AT LCAAP
LAKE CITY, MISSOURI

(Surface Water: ug/L, Sediment: ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Area 16 Leachate Seep (continued)			
Sediment (f)			
Organics:			
* Carcinogenic PAHs			
Benzo(a)anthracene	1/1	0.3	3
Benzo(a)pyrene	1/1	0.3	2
Benzo(k)fluoranthene	1/1	0.3	3
Chrysene	1/1	0.3	4
Total Carcinogenic PAHs	1/1	0.3	12
Inorganics:			
* Arsenic	1/1	5.7	25
* Barium	1/1	40	889
Copper	1/1	3.8	9.1
Lead	1/1	4.8	10.6
Nickel	1/1	4.8	14.4
Area 16 Drainage Ditch			
Surface Water (g)			
Organics:			
* trans-1,2-Dichloroethene	1/2	1.7	5
* bis(2-Ethylhexyl)phthalate	2/2	10	40
* 1,3,5-TNB	1/2	0.6	6.1
* Trichloroethene	1/2	0.7	2
Inorganics:			
* Copper	2/2	1.8	12.8 - 25.6
* Lead	1/2	2.5	6.9
* Nickel	2/2	9.6	19.8 - 22.6
Zinc	2/2	17.2	312 - 339
Sediment (h)			
Organics:			
* Di-n-butylphthalate	2/3	0.3	0.6 - 2
* Carcinogenic PAHs			
Benzo(a)anthracene	1/3	0.3	3
Benzo(a)pyrene	1/3	0.3	2
Chrysene	1/3	0.3	4
Indeno(1,2,3-c,d)pyrene	1/3	0.3	2
Total Carcinogenic PAHs	1/3	0.3	11
* Noncarcinogenic PAHs			
Acenaphthene	1/3	0.3	0.7
Anthracene	1/3	0.3	1
Fluoranthene	2/3	0.3	4 - 90
Fluorene	1/3	0.3	0.6
Naphthalene	1/3	0.3	10
Phenanthrene	1/3	0.3	4
Pyrene	1/3	0.3	5
Total Noncarcinogenic PAHs	3/3	0.3	4.9 - 101.5
Inorganics:			
* Arsenic	2/3	5.7	26.9 - 47.1
* Barium	3/3	40	160 - 954
* Beryllium	1/3	0.3	0.4
* Cadmium	3/3	0.7	2.6 - 33
* Chromium	1/3	2.5	18.6
* Copper	3/3	3.8	14.9 - 380
* Lead	3/3	4.8	12.6 - 520
Nickel	3/3	4.8	16.7 - 20.2
Zinc	2/3	52	77.5 - 107

TABLE 5-8 (Continued)

SUMMARY OF CHEMICALS DETECTED IN SURFACE WATER AND SEDIMENT AT LCAAP LAKE CITY, MISSOURI

(Surface Water: ug/L, Sediment: ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Cattle Pond			
Surface Water (i)			
Inorganics:			
* Antimony	1/1	3	70.8
* Arsenic	1/1	5	5.3
* Copper	1/1	1.8	72
Zinc	1/1	17.2	357
Sediment (j)			
Organics:			
* Carcinogenic PAHs			
Dibenzo(a,h)anthracene	1/1	0.3	0.5
Benzo(a)anthracene	1/1	0.3	20
Benzo(k)fluoranthene	1/1	0.3	2
Chrysene	1/1	0.3	20
Indeno(1,2,3-c,d)pyrene	1/1	0.3	5
Total Carcinogenic PAHs	1/1	0.3	47.5
* Noncarcinogenic PAHs			
Acenaphthene	1/1	0.3	7
Anthracene	1/1	0.3	9
Fluoranthene	1/1	0.3	30
Fluorene	1/1	0.3	6
Naphthalene	1/1	0.3	3
Phenanthrene	1/1	0.3	30
Total Noncarcinogenic PAHs	1/1	0.3	85
Inorganics:			
Barium	1/1	40	35.8
Chromium	1/1	2.5	10.9
* Copper	1/1	3.8	680
* Lead	1/1	3.8	80
Ditch A			
Surface Water (k)			
Organics:			
* HMX	1/2	1.3	1.4
Inorganics:			
Barium	2/2	25	94.6 - 104
* Copper	2/2	1.8	6.7 - 21.5
* Nickel	1/2	9.6	19.5
* Silver	1/2	0.2	0.2
* Zinc	2/2	17.2	509 - 720
Sediment (l)			
Organics:			
* 2,4-DNT	1/5	0.4	4.2
* Di-n-butylphthalate	1/3	0.3	0.9
* Oil and Grease	2/2	50	170 - 670
Inorganics:			
Barium	5/5	40	112 - 248
Beryllium	1/5	0.3	0.4
* Chromium	5/5	2.5	11.1 - 20.9
* Copper	5/5	3.8	7.9 - 84
* Lead	5/5	4.8	6.6 - 26.1
* Mercury	2/5	0.1	0.4 - 2.2
Nickel	5/5	4.8	9.4 - 28.3
* Zinc	2/5	52	136 - 203

TABLE 5-8 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER AND SEDIMENT AT LCAAP
LAKE CITY, MISSOURI

(Surface Water: ug/L, Sediment: ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Ditch B			
Surface Water (m)			
Organics:			
* bis(2-Ethylhexyl)phthalate	1/2	10	10
Inorganics:			
* Antimony	1/2	3	4.9
* Arsenic	1/2	5	10.4
Barium	2/2	25	84.2 - 242
* Beryllium	1/2	0.1	0.4
* Copper	2/2	1.8	13 - 100
* Lead	1/2	2.5	11.9
* Nickel	2/2	9.6	16.8 - 18.4
* Selenium	1/2	5	7.1
* Zinc	2/2	17.2	491 - 620
Sediment (n)			
Organics:			
* Oil and Grease	4/5	50	120 - 300
* Carcinogenic PAHs			
Benzo(a)anthracene	1/4	0.3	0.8
Benzo(a)pyrene	1/4	0.3	0.4
Benzo(b)fluoranthene	1/4	0.3	0.7
Benzo(k)fluoranthene	1/4	0.3	0.7
Chrysene	2/4	0.3	2 - 49.5
Indeno(1,2,3-c,d)pyrene	1/4	0.3	0.4
Total Carcinogenic PAHs	2/4	0.3	5 - 50.3
* Noncarcinogenic PAHs			
Fluoranthene	1/4	0.3	5
Naphthalene	1/4	0.3	0.7
Phenanthrene	1/4	0.3	3
Pyrene	1/4	0.3	4
Total Noncarcinogenic PAHs	1/4	0.3	12.7
Inorganics:			
* Arsenic	2/9	5.7	7.8 - 27.2
* Barium	9/9	25	146 - 361
* Beryllium	4/9	0.3	0.4 - 0.7
* Cadmium	2/9	0.7	1.9 - 2
* Chromium	9/9	2.5	13.2 - 23.3
* Copper	8/9	3.8	15.1 - 46.3
* Lead	7/9	4.8	8.8 - 37.2
* Mercury	1/9	0.1	0.3
Nickel	9/9	4.8	13 - 20.7
* Zinc	9/9	52	77.8 - 166
Big Ditch			
Surface Water (o)			
Organics:			
* Benzene	1/1	0.6	1.5
* Trichloroethene	1/1	0.7	1.6
Inorganics:			
Barium	1/1	25	134
* Copper	1/1	1.8	6.2
Nickel	1/1	9.6	12.1
* Zinc	1/1	17.2	450

TABLE 5-8 (Continued)

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER AND SEDIMENT AT LCAAP
LAKE CITY, MISSOURI

(Surface Water: ug/L, Sediment: ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Big Ditch (continued)			
Sediment (p)			
Inorganics:			
* Arsenic	1/1	5.7	7.3
Barium	1/1	40	117
Beryllium	1/1	0.3	0.4
* Chromium	1/1	2.5	21.2
Copper	1/1	3.8	13.3
Lead	1/1	4.8	7.6
Nickel	1/1	4.8	21.2
Unnamed Ditch			
Sediment (q)			
Inorganics:			
Barium	1/1	40	227
Beryllium	1/1	0.3	0.4
* Cadmium	1/1	0.7	2.1
* Chromium	1/1	2.5	15.9
Copper	1/1	3.8	7.9
* Lead	1/1	4.8	16
Nickel	1/1	4.8	29.2
Ditch 2			
Sediment (r)			
Organics:			
* Oil and Grease	1/1	50	98
Inorganics:			
Barium	1/1	40	216
Beryllium	1/1	0.3	0.4
* Cadmium	1/1	0.7	2.5
* Chromium	1/1	2.5	18.3
* Copper	1/1	3.8	47.6
* Lead	1/1	4.8	73
Nickel	1/1	4.8	20
Zinc	1/1	52	102

(a) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.
(b) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).
(c) Samples SW13-1-1, SW13-2-1, and SW13-4-1.
(d) Samples DS13-1-1, DS13-2-1, DS13-3-1, DS13-4-1.
(e) Sample SW16-4-1.
(f) Sample DS16-4-1.
(g) Samples SW16-2-1 and SW16-3-1.
(h) Samples DS16-2-1, DS16-3-1, and DS16-5-1.
(i) Sample PW01-1.
(j) Sample PS01-1.
(k) Samples SW-09-1 and SW-11-1.
(l) Samples DS-09-1, DS-10-1, DS-11-1, SP-04-1, and SP-05-1.
(m) Samples SW-14-1 and SW-15-1.
(n) Samples DS-12-1, DS-13-1, DS-14-1, DS-15-1, SP-10-1, SP-11-1, SP-12-1, SP-13-1, and SP-14-1.
(o) Sample SW-17-1.
(p) Sample DS-17-1.
(q) Sample DS-18-1.
(r) Sample SP-25-1.

* = Selected as a chemical of potential concern.

Surface Water and Sediments in Area 12: As discussed in Section 4.12 and 5.2.1, a closed chemical laboratory waste lagoon that is listed as an NPL site is located in Area 12. The chemical waste lagoon accepted heavy metal RCRA hazardous constituents including antimony, barium, chromium, lead, mercury, and silver as well as small quantities of laboratory organic wastes. It is currently filled and vegetated. In addition, a sludge disposal area located in Area 12 accepted industrial wastewater treatment plant sludge material. Three surface water and three sediment samples were collected in this area from ditches and three samples of wastewater discharging from a process sewer also were sampled. The ditches and sewer were suspected of being sources of trichloroethene contamination in groundwater. Thus, they were analyzed only for VOC content. No VOCs were identified in either the ditch or wastewater discharge surface water/sediment samples in Area 12, therefore there are no chemicals of potential concern for this area.

Surface Water and Sediments in Area 13: As discussed in Section 4.13, Building 35, which is currently used for manufacturing metal parts, in the past released wastewater to a drainage ditch in Area 13. Three surface water samples (SW13-1, SW13-2, and SW13-4) and four sediment samples (DS13-1, DS13-2, DS13-3, and DS13-4) were collected from this drainage ditch in Area 13. For surface water samples, the explosive compound 1,3,5-TNB and bis(2-ethylhexyl)phthalate was identified as a chemical of potential concern. Antimony, chromium, copper, lead, and nickel were identified as inorganic chemicals of potential concern in surface water. Although zinc was detected in surface water samples, it was not considered to be elevated above background concentrations and was not selected as a chemical of potential concern.

For sediment samples, the organic chemicals detected and selected as chemicals of potential concern were carcinogenic PAHs (chrysene) and noncarcinogenic PAHs (anthracene, fluoranthene, phenanthrene, pyrene). All of the inorganic chemicals detected in sediment samples, including arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc were considered to be elevated above background, and therefore were identified as inorganic chemicals of potential concern. Table 5-8 presents concentrations of chemicals of potential concern in Area 13 for surface water and sediment samples.

Surface Water and Sediments in Area 16 Leachate Seep: As discussed in Section 4.16, a surface water (SW16-4) and a sediment sample (DS16-4) were collected from a leachate seep located at an abandoned landfill in Area 16. The abandoned landfill in Area 16 accepted industrial wastewater treatment plant sludge, grease and oil, construction debris, explosive waste, and solvents. Possible heavy metal RCRA hazardous constituents accepted at the landfill during its operation include barium, lead, and mercury.

Nine organic compounds (1,1-dichloroethane, trans-1,2-dichloroethene, benzene, chloroethane, ethylbenzene, methylene chloride, phenol, toluene, and trichloroethene) were detected in the surface water sample and were selected as chemicals of potential concern for surface water. All of the inorganic chemicals detected in the surface water sample (i.e., beryllium, copper, lead, nickel, silver, and zinc) were considered to be elevated above background, and therefore were identified as inorganic chemicals of potential concern for surface water.

For sediment, only carcinogenic PAHs (benzo[a]anthracene, benzo[a]pyrene, benzo[k]fluoranthene, chrysene) were detected and identified as organic chemicals of potential concern. Inorganic chemicals identified as chemicals of concern for sediments were arsenic and barium. Although copper, lead, and nickel were detected in the sediment sample, these chemicals were not considered to be elevated above background concentrations, and therefore were not selected as chemicals of potential concern. Table 5-8 presents concentrations of chemicals of potential concern in the Area 16 leachate seep surface water and sediment.

Surface Water and Sediments in Area 16 Drainage Ditch: As discussed in Section 4.16, two surface water samples (SW16-2 and SW16-3) and three sediment samples (DS16-2, DS16-3, and DS16-5) were collected from a drainage ditch that runs along side of the abandoned landfill in Area 16. As discussed above, the abandoned landfill in Area 16 accepted industrial wastewater treatment plant sludge, grease and oil, construction debris, explosive waste, and solvents. Possible heavy metal RCRA hazardous constituents accepted at the landfill during its operation include barium, lead, and mercury.

Trans-1,2-dichloroethene, bis(2-ethylhexyl)phthalate, 1,3,5-TNB, and trichloroethene were detected in surface water collected from the drainage ditch in Area 16 and selected as chemicals of potential concern. Copper, lead, and nickel were considered to be elevated above background, and therefore were identified as inorganic chemicals of potential concern for surface water. Zinc was not considered to be elevated above background, and therefore was not selected as a chemical of potential concern.

For sediment, organic chemicals identified as chemicals of potential concern were di-n-butylphthalate, carcinogenic PAHs (benzo[a]anthracene, benzo[a]pyrene, chrysene, ideno[1,2,3-c,d]pyrene), and noncarcinogenic PAHs (acenaphthene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, pyrene). Arsenic, barium, beryllium, cadmium, chromium, copper, and lead were identified as inorganic chemicals of potential concern. Although nickel and zinc were detected in sediment samples, these chemicals were not considered to be elevated above background concentrations and were not selected as chemicals of potential concern. Table 5-8 presents concentrations of chemicals of potential concern in the Area 16 drainage ditch for surface water and sediment samples.

<u>Surface Water and Sediments in the Pond</u>: As discussed in Section 4.19.1, the on-site pond was used for the purpose of watering the cattle that until recently were allowed to graze on-site. One surface water sample (PW01) and one sediment sample (PS01) were collected from this pond. No volatile, semi-volatile, or explosive chemicals were detected in the pond surface water. Antimony, arsenic, and copper were the only chemicals of potential concern

identified in pond surface water. Although zinc was detected in the pond surface water, it was not considered to be elevated above background concentrations and was not selected as a chemical of potential concern for surface water.

Carcinogenic PAHs (dibenzo[a,h]anthrancene, benzo[a]anthracene, benzo[k] fluoranthene, chrysene, indeno[1,2,3-c,d]pyrene) and noncarcinogenic PAHs (acenaphthene, anthracene, fluoranthene, fluorene, naphthalene, phenanthrene) were identified as organic chemicals of potential concern, while copper and lead were identified as inorganic chemicals of potential concern in pond sediment. Although barium and chromium were detected in the pond sediment, these chemicals were not considered to be elevated above background concentrations and were not selected as chemicals of potential concern for the pond sediment. Table 5-8 presents concentrations of chemicals of potential concern for pond surface water and pond sediments.

Surface Water and Sediments in Ditch A: As shown in Figure 4-34, Ditch A generally runs east and northeast through the middle of the LCAAP site. Two surface water samples (SW09 and SW11) and 5 sediment samples (SP04, SP05, DS09, DS10, and DS11) were collected along Ditch A. HMX was identified as a chemical of potential concern for surface water. Copper, nickel, silver, and zinc, were identified as chemicals of potential concern for surface water. Although barium was detected in Ditch A surface water, it was not considered to be elevated above background concentrations; therefore, barium was not selected as a chemical of potential concern for surface water.

2,4-DNT, di-n-butylphthalate, and oil and grease were selected as chemicals of potential concern for Ditch A sediment. Chromium, copper, lead, mercury, and zinc were identified as inorganic chemicals of potential concern for sediments collected from Ditch A. Although barium, beryllium, and nickel were detected in the Ditch A sediments, these chemicals were not considered to be elevated above background concentrations, and were not selected as chemicals of potential concern. Table 5-8 presents concentrations of chemicals of potential concern for Ditch A surface water and sediments.

Surface Water and Sediments in Ditch B: As shown in Figure 4-34, one major branch of Ditch B runs along the north side of Lake City Buckner Road and flows to the west and northwest. The other major branch of Ditch B flows northwest and runs through the northwestern portion of the LCAAP site. Two surface water samples (SW14 and SW15) and 9 sediment samples (SP10, SP11, SP12, SP13, SP14, DS12, DS13, DS14, and DS15) were collected along Ditch B. Bis(2-ethylhexyl)phthalate and all of the inorganics detected in surface water (i.e., antimony, arsenic, barium, beryllium, copper, lead, nickel, selenium, and zinc) with the exception of barium, were identified as chemicals of potential concern for surface water for Ditch B. Although barium was detected in Ditch B surface water, it was not considered to be elevated above background concentrations; therefore, barium was not selected as a chemical of potential concern for surface water.

Carcinogenic PAHs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, indeno[1,2,3-c,d]pyrene) and noncarcinogenic PAHs (fluoranthene, naphthalene, phenanthrene, pyrene) and oil and grease were identified as chemicals of potential concern for Ditch B sediments. Inorganic chemicals identified as chemicals of potential concern for Ditch B sediments were arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, and zinc. Although nickel was detected in sediments in Ditch B, it was not considered to be elevated above background concentrations, and therefore was not selected as a chemical of potential concern. Table 5-8 presents concentrations of chemicals of potential concern for Ditch B surface water and sediments.

Surface Water and Sediments in the Big Ditch: As shown in Figure 4-34, the Big Ditch is located along the southern border of the LCAAP site and generally flows west and northwest. One surface water sample (SW17) and one sediment sample (DS17) were collected along the Big Ditch. Benzene and tetrachloroethene were identified as chemicals of potential concern in surface water in the Big Ditch. Copper and zinc were selected as chemicals of potential concern in Big Ditch surface water. Although barium and nickel were detected in Big Ditch surface water, these chemicals were not considered to be elevated above background; therefore, barium and nickel were not selected as chemicals of potential concern.

Arsenic and chromium were identified as inorganic chemicals of potential concern for Big Ditch sediment. Although barium, beryllium, copper, lead, and nickel were detected in sediment in the Big Ditch, these inorganic chemicals were not considered to be elevated above background concentrations, and therefore were not selected as chemicals of potential concern. Table 5-8 presents concentrations of chemicals of potential concern for the Big Ditch surface water and sediments. No volatile, semi-volatile, or explosive chemicals were detected in the sediment sample collected in the Big Ditch.

Sediments in the Unnamed Ditch: As shown in Figure 4-34, the unnamed ditch is located in the northwestern portion of the LCAAP site and flows to the northeast where it eventually drains into Ditch B. One sediment sample (DS18) was collected in the unnamed ditch. No data were available for assessing the concentrations of chemicals in surface water from the unnamed ditch. No volatile, semi-volatile, or explosive chemicals were detected in the unnamed ditch sediment sample. Cadmium, chromium, and lead were identified as chemicals of potential concern for sediment in the unnamed ditch. Although barium, beryllium, copper, and nickel were detected in the sediment sample collected in the unnamed ditch, these chemicals were not considered to be elevated above background concentrations, and were not selected as chemicals of potential concern. Table 5-8 presents concentrations of chemicals of potential concern for the unnamed ditch sediments.

Sediments in Ditch 2: As shown in Figures 4-35 and 4-36, Ditch 2 generally runs west near building 1 and then south where it eventually drains into Ditch A. One sediment sample (SP-25-1) was collected in Ditch 2. No data were available for assessing the concentrations of chemicals in surface water in Ditch 2. Volatiles and semi-volatiles were not analyzed for in the Ditch 2 sediment sample and explosive chemicals were not detected. Oil and grease was selected as a chemical of potential concern. Cadmium, chromium, copper, and lead were identified as chemicals of potential concern for sediment in Ditch 2. Although barium, beryllium, nickel, and zinc were detected in the sediment sample collected in Ditch 2, these chemicals were not considered to be elevated above background concentrations, and were not selected as chemicals of potential concern. Table 5-8 presents concentrations of chemicals of potential concern for Ditch 2 sediments.

5.2.3.2 Sump and Sump Outflow Sediments

Many of the buildings across LCAAP have in the past and possibly still do discharge small quantities of heavy metals and explosive compounds to an estimated 34 sumps located across the site. As discussed in Section 4.21, the wastes discharged into the sumps were generated by housekeeping activities in the listed buildings. Sediment samples were collected from sumps and sump outflows near buildings 1, 2, 3, 4, 94, 97, and 97A (see Figure 4-36). No surface water samples were collected from these sumps, most of which are old and highly subject to leakage. The sediment samples collected from the sumps and sump outflows were analyzed for oil and grease, explosive compounds, and inorganics. Sediments from the sumps and sump outflows located across the site may be potential sources of contamination to the area wide ditch system. Background soil samples were used for inorganic background comparisons with sump and sump outflow sediment samples.

Sediments from Buildings 1 and 2 Sumps and from Sump Outflows: One sediment sample (SP-31) was collected from the sump that accepts wastewater from building 1. Oil and grease and the explosive compound nitrobenzene were identified as chemicals of potential concern. Copper and lead were considered to be elevated above background concentrations and were identified as chemicals of potential concern. Although barium, chromium, nickel, and zinc were detected in the sump for building 1, these chemicals were not considered to be elevated above background, and were not selected as chemicals of potential concern.

Two sediment samples (SP-32 and SP-33) were collected from the sump that receives wastewater from building 2. Oil and grease, barium, cadmium, chromium, copper, lead, mercury, and zinc were selected as chemicals of potential concern for the building 2 sump. Although nickel was detected in the building 2 sump, it was not considered to be elevated above background and was not considered to be a chemical of potential concern.

Three sediment samples (SP-01, SP-02, and SP-03) were collected from the sump outflows located downgradient of the storm sewer discharge from buildings 1 and 2. No explosive compounds were detected in either the sump or sump outflow sediment samples. Oil and grease was selected as a chemical of potential concern. Cadmium, chromium, copper, lead, mercury, and zinc were identified as chemicals of potential concern for the sump outflow sediment samples. Barium and nickel were not considered to be elevated above background and therefore were not selected as chemicals of potential concern. Table 5-9 presents concentrations of chemicals of potential concern for the buildings 1 and 2 sump and the sump outflow sediments.

<u>Sediments from Building 3 Sump and Sump Outflow</u>: Two sediment samples (SP-27 and SP-28) were collected from the sump that receives wastewater from building 3. Four sediment samples (SP-06, SP-07, SP-08, and SP-09) were collected from the sump outflows. 1,3,5-TNB, 2,4-DNT, 2,6-DNT, and oil and grease were detected, and thus were identified as chemicals of potential concern in the sump sediment samples. 2,4-DNT was the only explosive compound identified as a chemical of potential concern in the sump outflow sediment. Oil and grease was selected as a chemical of potential concern in sump outflow sediment. All of the inorganic compounds detected in the sediment samples (i.e., barium, beryllium [sump outflow only], cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc) with the exception of nickel in the sump

TABLE 5-9

SUMMARY OF CHEMICALS DETECTED IN SUMP AND SUMP OUTFLOW SEDIMENT SAMPLES FROM BUILDINGS 1 AND 2 AT LCAAP LAKE CITY, MISSOURI

(Concentrations reported in ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Sumps - Building 1 (c)			
Organics:			
* Nitrobenzene	1/1	0.4	2.9
* Oil and Grease	1/1	50	18,000
Inorganics:			
Barium	1/1	40	138
Chromium	1/1	2.5	8.8
* Copper	1/1	3.8	150
* Lead	1/1	4.8	41.1
Nickel	1/1	4.8	14.7
Zinc	1/1	52	195
Sumps - Building 2 (d)			
Organics:			
* Oil and Grease	2/2	50	4,900
Inorganics:			
* Barium	2/2	40	287 - 379
* Cadmium	2/2	0.7	10.9 - 11.9
* Chromium	2/2	2.5	42.3 - 89.8
* Copper	2/2	3.8	1,300 - 2,900
* Lead	2/2	4.8	210 - 370
* Mercury	2/2	0.1	1.5 - 4.2
Nickel	2/2	4.8	14.1 - 18.7
* Zinc	2/2	52	7,300 - 8,300
Sump Outflows (e)			
Organics:			
* Oil and Grease	2/3	50	230 - 710
Inorganics:			
Barium	3/3	40	52.3 - 143
* Cadmium	1/3	0.7	8
* Chromium	3/3	2.5	14.9 - 32
* Copper	3/3	3.8	38.2 - 260
* Lead	3/3	4.8	14.7 - 62.9
* Mercury	1/3	0.1	2.5
Nickel	3/3	4.8	8.4 - 14
* Zinc	3/3	52	71.3 - 341

(a) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.
(b) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).
(c) Sample SP-31-1.
(d) Samples SP-32-1 and SP-33-1.
(e) Samples SP-01-1, SP-02-1, and SP-03-1.

* = Selected as a chemical of potential concern.

outflow were considered to be elevated above background concentrations, and therefore were identified as chemicals of potential concern for both the sump and sump outflow sediment samples. Nickel concentrations in the sump outflow sediment samples were not considered to be elevated above background. Table 5-10 presents concentrations of chemicals of potential concern for the building 3 sump and sump outflow sediments.

Sediments from Building 4 Sump and Sump Outflow: Two sediment samples (SP-29 and SP-30) were collected from the sump that receives wastewater from building 4. Six sediment samples (SP-15, SP-16, SP-17, SP-18, SP-19, and SP-20) also were collected from the sump outflows. 2,4-DNT was the only explosive compound identified as a chemical of potential concern in the sump and sump outflow sediment. Oil and grease was selected as a chemical of potential concern in both the sump and sump outflow sediment. Barium, cadmium, chromium, copper, lead, mercury, silver [sump only], and zinc were considered to be elevated above background concentrations and therefore were identified as chemicals of potential concern. Nickel and beryllium (sump outflow only) were not considered to be elevated above background and therefore were not considered to be chemicals of potential concern. Table 5-11 presents concentrations of chemicals of potential concern for the building 4 sump and sump outflow sediments.

Sediments from Building 94, 97, and 97A Sump and Sump Outflow: One sediment sample (SP-34) was collected from the sump that receives wastewater from buildings 94, 97, and 97A. Five sediment samples (SP-21, SP-22, SP-23, SP-24, and SP-26) also were collected from the sump outflows. No explosive compounds were detected in the sump sediment sample. 2,4-DNT, 2,6-DNT, HMX, and RDX were identified as chemicals of potential concern for the sump outflow. Oil and grease was selected as a chemical of potential concern for both the sump and sump outflow sediment samples. All of the inorganic compounds detected in the sediment samples (i.e., antimony [sump outflow only], barium, cadmium, chromium, copper, lead, mercury [sump outflow only], and zinc) with the exception of nickel were considered to be elevated above

TABLE 5-10

SUMMARY OF CHEMICALS DETECTED IN SUMP AND SUMP OUTFLOW SEDIMENT SAMPLES FROM BUILDING 3 AT LCAAP
LAKE CITY, MISSOURI

(Concentrations reported in ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Sumps (c)			
Organics:			
* 2,4-DNT	1/2	0.4	930
* 2,6-DNT	1/2	0.4	16
* Oil and Grease	2/2	50	4,600 - 9,100
* 1,3,5-TNB	1/2	2.1	36
Inorganics:			
* Barium	2/2	40	1,250 - 1,290
* Cadmium	2/2	0.7	9.8 - 17.9
* Chromium	2/2	2.5	31.2 - 98.6
* Copper	2/2	3.8	680 - 14,000
* Lead	2/2	4.8	350 - 990
* Mercury	1/2	0.1	7
* Nickel	2/2	4.8	14.5 - 51
* Silver	1/2	0.7	10.6
* Zinc	2/2	52	2,000 - 11,000
Sump Outflows (d)			
Organics:			
* 2,4-DNT	1/4	0.4	0.6
* Oil and Grease	4/4	50	16 - 2,100
Inorganics:			
* Barium	4/4	40	394 - 8,090
* Beryllium	1/4	0.3	0.4
* Cadmium	1/4	0.7	4.7
* Chromium	4/4	2.5	10 - 43.8
* Copper	4/4	3.8	13.7 - 1,100
* Lead	4/4	4.8	13.9 - 360
* Mercury	1/4	0.1	0.6
Nickel	4/4	4.8	8.8 - 22.9
* Silver	2/4	0.7	6.3 - 46
* Zinc	4/4	52	129 - 641

(a) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.
(b) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).
(c) Samples SP-27-1 and SP-28-1.
(d) Samples SP-06-1, SP-07-1, SP-08-1 and SP-09-1.

* = Selected as a chemical of potential concern.

TABLE 5-11

SUMMARY OF CHEMICALS DETECTED IN SUMP AND
SUMP OUTFLOW SEDIMENT SAMPLES FROM BUILDING 4 AT LCAAP
LAKE CITY, MISSOURI

(Concentrations reported in ug/g)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Sumps (c)			
Organics:			
* 2,4-DNT	2/2	0.4	0.7 - 63
* Oil and Grease	2/2	50	12,000 - 18,000
Inorganics:			
* Barium	2/2	40	2,280 - 2,610
* Cadmium	2/2	0.7	7.6 - 9
* Chromium	2/2	2.5	31.2 - 101
* Copper	2/2	3.8	1,000 - 1,500
* Lead	2/2	4.8	1,000 - 5,100
* Mercury	2/2	0.1	0.7 - 1.7
Nickel	2/2	4.8	11.3 - 22.1
* Silver	2/2	0.7	1.7 - 4.5
* Zinc	2/2	52	523 - 2,000
Sump Outflows (d)			
Organics:			
* 2,4-DNT	1/6	0.4	0.8
* Oil and Grease	5/6	50	200 - 27,000
Inorganics:			
* Barium	6/6	40	120 - 316
Beryllium	2/6	0.3	0.3 - 0.4
* Cadmium	3/6	0.7	1.5 - 6.4
* Chromium	6/6	2.5	11.9 - 2,500
* Copper	6/6	3.8	58.5 - 10,000
* Lead	6/6	4.8	14.3 - 13,000
* Mercury	4/6	0.1	0.6 - 19
Nickel	6/6	4.8	10.8 - 26.2
* Zinc	6/6	52	218 - 2,900

(a) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.
(b) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).
(c) Samples SP-29-1 and SP-30-1.
(d) Samples SP-15-1, SP-16-1, SP-17-1, SP-18-1, SP-19-1, and SP-20-1.

* = Selected as a chemical of potential concern.

background concentrations and were identified as chemicals of potential concern for both the sump and sump outflow sediment samples. Nickel concentrations detected in the sump and sump outflow sediment samples were not considered to be elevated above background, therefore nickel was not considered a chemical of potential concern. Table 5-12 presents concentrations of chemicals of potential concern for the building 94/97/97A sump and sump outflow sediments.

5.2.4 Summary of Chemicals of Potential Concern

Chemicals of potential concern identified for groundwater in the production wells (treated and untreated water), the monitoring wells with groundwater potentially reaching the production wells, and the 16 study areas are shown in Table 5-13. Chemicals of potential concern identified for groundwater in the off-site residential wells are summarized in Table 5-14. As may be seen from these tables, bis(2-ethylhexyl)phthalate, RDX, and HMX were the organic chemicals of potential concern in the most study areas across the site. RDX and HMX were not detected in the production wells during the RI; however, they were detected in groundwater samples from wells within production well capture zones. Although bis(2-ethylhexyl)phthalate is a common laboratory contaminant, detected concentrations were elevated above blank levels and varied considerably in the different study areas. RDX concentrations in groundwater also fluctuated widely in the different study areas, being highest in Areas 3, 7, 11, and 12. The highest concentration of HMX was detected in Area 7.

Carbon tetrachloride (Area 16), chrysene (Area 18), chloroform (Area 17), 1,2-dichlorobenzene (Area 16), 1,2-dichloroethane (Area 16), dimethylphthalate (Area 16), nitrobenzene (Area 16), and 1,1,2,2-tetrachloroethane (Area 16) were detected in groundwater in only 1 study area, and in only 1 or 2 samples within the samples collected in these areas. Carbon tetrachloride, 1,2-dichloroethane, 1,2-dichlorobenzene, dimethylphthalate, nitrobenzene, and 1,1,2,2-tetrachloroethane were detected at very low concentrations (i.e., near

TABLE 5-12

SUMMARY OF CHEMICALS DETECTED IN SUMP AND SUMP OUTFLOW SEDIMENT SAMPLES FROM BUILDINGS 94, 97 AND 97A AT LCAAP LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Chemical	Frequency of Detection (a)	Detection Limit (b)	Range of Detected On-site Concentrations
Sumps (c)			
Organics:			
* Oil and Grease	1/1	50	2,000
Inorganics:			
* Barium	1/1	40	4,270
* Cadmium	1/1	0.7	3.3
* Chromium	1/1	2.5	19.1
* Copper	1/1	3.8	380
* Lead	1/1	4.8	950
Nickel	1/1	4.8	11.9
* Zinc	1/1	52	160
Sump Outflows (d)			
Organics:			
* 2,4-DNT	2/5	0.4	0.6 - 2.3
* 2,6-DNT	1/5	0.4	1
* HMX	1/5	1.3	3.1
* Oil and Grease	3/5	50	200 - 800
* RDX	2/5	1	1.1 - 2.4
Inorganics:			
* Antimony	1/5	25.3	58.6
* Barium	5/5	40	234 - 4,140
* Cadmium	5/5	0.7	2.1 - 23
* Chromium	5/5	2.5	12.2 - 25.4
* Copper	5/5	3.8	43.1 - 420
* Lead	4/5	4.8	51 - 1,900
* Mercury	3/5	0.1	0.6 - 1
Nickel	5/5	4.8	14.8 - 21.9
* Zinc	5/5	52	92.5 - 342

(a) The number of samples in which the contaminant was detected divided by the total number of samples analyzed.

(b) Detection Limit is either a USATHAMA Certified Reporting Limit (CRL) or a USATHAMA Standard Reporting Limit (SRL).

(c) Sample SP-34-1.

(d) Samples SP-21-1, SP-22-1, SP-23-1, SP-24-1, and SP-26-1.

* = Selected as a chemical of potential concern.

TABLE 5-13

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT LCAAP
LAKE CITY, MISSOURI

Chemical	Treated Prod. Wells	Untreated Prod. Wells	Monitoring Well/Prod. Well Capture Zone	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	Area 11	Area 12	Area 14	Area 16	Area 17	Area 18
Organics:																			
Benzene		X	X							X							X	X	
Bromodichloromethane	X																		
Bromoform	X																		
Carbon tetrachloride																	X		
Carcinogenic PAHs (chrysene)			X																X
Chloroform	X																	X	
1,3-DNB			X						X								X		
2,4-DNT			X			X			X										
2,6-DNT			X		X													X	
Dibromochloromethane	X																		
1,2-Dichlorobenzene																	X		
1,1-Dichloroethane			X					X									X		
1,2-Dichloroethane			X														X		
1,1-Dichloroethene			X			X		X									X		X
trans-1,2-Dichloroethene		X	X					X		X	X						X	X	
1,2-Dichloroethene (total)	X																		
Dimethylphthalate																	X		
Ethylbenzene																	X	X	
bis(2-Ethylhexyl)phthalate		X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X
HMX			X			X	X		X	X				X	X			X	X
Methylene chloride			X							X								X	
Nitrobenzene																	X		
N-nitrosodiphenylamine			X								X				X				
RDX			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1,3,5-TNB			X				X			X		X			X			X	
1,1,2,2-Tetrachloroethane																	X		
Tetrachloroethene																	X	X	
Tetryl			X												X			X	
Toluene											X						X	X	
1,1,1-Trichloroethane	X		X					X									X	X	
1,1,2-Trichloroethane																	X	X	
Trichloroethene	X	X	X					X		X	X						X	X	
Trihalomethanes (total)	X																		
Vinyl chloride		X	X					X		X							X		

TABLE 5-13 (Continued)

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER AT LCAAP
LAKE CITY, MISSOURI

Chemical	Treated Prod. Wells	Untreated Prod. Wells	Monitoring Well/Prod. Well Capture Zone	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	Area 11	Area 12	Area 14	Area 16	Area 17	Area 18
Inorganics:																			
Antimony			X	X			X	X			X		X				X	X	
Arsenic		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	
Barium		X	X	X		X		X		X	X		X		X	X	X	X	X
Beryllium		X	X	X	X	X		X	X		X		X	X	X	X	X	X	
Cadmium			X	X	X		X	X			X	X	X	X		X			
Chromium			X		X	X	X	X	X	X	X			X	X	X	X		
Copper		X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
Lead		X	X	X	X	X		X	X	X	X		X				X	X	X
Mercury	X		X	X															
Nickel		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Selenium			X		X					X									
Silver	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Thallium	X																		
Zinc		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Radiological Parameters:																			
Alpha Radioactivity	X	X	X								X					X	X	X	
Beta Radioactivity	X	X	X			X		X			X					X	X	X	
Radon-226 and 228	X																		
U-234		X	X			X		X			X					X	X	X	
U-238		X	X			X		X			X					X	X	X	
Total Uranium			X								X					X		X	

TABLE 5-14

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN GROUNDWATER FROM THE OFF-SITE RESIDENTIAL WELLS LOCATION NORTH OF THE NORTHERN LCAAP BOUNDARY LAKE CITY, MISSOURI

Chemical	Danner	Ferguson	Hedrickj-A	Hedrickj-B	Hedrickv	Lirely	Pennington	Tcarlton	Turley	Ure	Carlton	Area North of Area 17
Organics:												
Carbon tetrachloride										X		
1,2-Dichlorobenzene										X		
1,4-Dichlorobenzene										X		
HMX	X		X	X	X	X	X		X	X	X	
RDX			X						X	X		
Toluene												X
Trichloroethene										X		
Inorganics:												
Barium	X	X	X	X	X	X	X	X	X	X	X	
Chromium												X
Copper	X	X	X	X	X	X			X			X
Lead		X						X				
Mercury	X	X	X	X		X	X		X	X	X	
Nickel												X
Zinc	X	X	X	X	X	X	X		X	X	X	X

or below the CRL or SRL values). Benzene, trans-1,2-dichloroethene, bis(2-ethylhexyl)phthalate, trichloroethene, and vinyl chloride, the organic chemicals of potential concern in untreated production well groundwater, were also detected in monitoring well samples.

Finally, all of the organic chemicals (i.e., carbon tetrachloride, 1,2-dichlorobenzene, 1,4-dichlorobenzene, HMX, RDX, toluene, and trichloroethene) detected in the off-site residential wells north of LCAAP were detected in other groundwater samples on-site with the exception of 1,4-dichlorobenzene. Toluene detected at a low level (i.e., near the CRL or SRL) in the residential well just north of Area 17, was also detected in Area 17 groundwater at levels far above its respective CRL.

Although in general, concentrations of radiological parameters did not exceed normal Missouri state activity levels (site background samples were not analyzed for radiological parameters), all radiological parameters were selected as chemicals of potential concern at the request of EPA due to the burial of radioactive wastes on-site. Radium-226 and -228 was only analyzed for in treated production well water, and no background values were available. Only treated production wells, untreated production wells, and Areas 3, 5, 8, 14, 16, and 17 were analyzed for radiological parameters.

Gross alpha radioactivity was detected in treated production wells, untreated production wells, the production well capture zone, and Areas 8, 14, 16, and 17 at a maximum concentration of 23 pCi/L in production well capture zone water. Gross beta radioactivity was detected in treated production wells, untreated production wells, the production well capture zone, and Areas 3, 5, 8, 14, 16, and 17 at a maximum concentration of 96 pCi/L in Area 8. Uranium (total uranium, U-234, and U-238) were detected in untreated production wells, the production well capture zone, and Areas 3, 5, 8, 14, 16, and 17 at maximum concentrations of 1.9 pCi/L and 1.7 pCi/L, respectively, and at a maximum concentration of total uranium of 1.5 pCi/L in the production well capture zone.

Of the inorganic chemicals of potential concern in groundwater, arsenic, barium, beryllium, chromium, copper, lead, nickel, silver, and zinc were detected at concentrations above background levels in groundwater in most on-site study areas and in the production wells. Antimony and cadmium were of potential concern in seven and nine of the on-site study areas, respectively, and were elevated above background in the production wells. Mercury and selenium were found in only one and two, respectively, of these off-site wells.

Table 5-15 presents a summary of the chemicals of potential concern in surface and subsurface soil at LCAAP, based on the preliminary sampling conducted during the RI. As may be seen in this table, only 2,6-DNT and oil and grease are at levels of concern in soils. 2,6-DNT, detected in only one area (Area 8) and in only one subsurface soil sample from that area at a concentration near the CRL, was not of potential concern in groundwater in Area 8. 2,6-DNT was detected in only a few groundwater samples across the site (i.e., Areas 2 and 17) at concentrations near the CRL.

Mercury and zinc were found at relatively high concentrations in Area 9 (i.e., relative to levels in soil samples collected in Area 8, the only other study area with levels of mercury and zinc above background). Mercury was a chemical of potential concern in Area 1 and in treated production well water. Antimony was of potential concern only in Area 15 soils. Area 9 surface soils were the only soils containing detectable levels of selenium.

Organic and inorganic chemicals of potential concern in surface water and sediment samples generally varied depending on the study area as shown in Table 5-16; few chemicals were seen in all areas. Exceptions are copper and lead which were seen at above background levels in most ditches and surface water/sediment samples across the site. Several chemicals of potential concern (e.g., chloroethane, 1,1-dichloroethane, ethylbenzene, methylene chloride, phenol and toluene) were detected only in the surface water sample from the in Area 16 leachate seep. Several of these chemicals were also

TABLE 5-15

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE AND SUBSURFACE SOILS AT LCAAP
LAKE CITY, MISSOURI

	Surface Soil		Subsurface Soil			
Chemical	Area 9	Area 13	Area 8	Area 9	Area 14	Area 15
Organics:						
2,6-DNT			X			
Oil and Grease			X		X	X
Inorganics:						
Antimony						X
Arsenic	X	X	X		X	X
Barium	X	X	X		X	X
Beryllium	X		X			X
Cadmium	X		X		X	X
Chromium	X	X				
Copper	X		X			X
Cyanide	X			X		
Lead	X	X	X			X
Mercury	X		X	X		
Nickel			X			
Selenium	X					
Zinc	X		X	X		

TABLE 5-16

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER AND SEDIMENT AT LCAAP
LAKE CITY, MISSOURI

Chemical	SW	Sediment	SW	Sediment	SW	Sediment	SW	Sediment	SW	Sediment	SW	Sediment	SW	Sediment	Sediment	Sediment
	Area 13 Drainage Ditch		Area 16 Leachate Seep		Area 16 Drainage Ditch		Cattle Pond		Ditch A		Ditch B		Big Ditch		Unnamed Ditch	Ditch 2
Organics:																
Benzene			X										X			
Carcinogenic PAHs		X		X		X		X				X				
Chloroethane			X													
2,4-DNT										X						
1,1-Dichloroethane			X													
trans-1,2-Dichloroethene			X		X											
Di-n-butyl phthalate						X				X						
Ethylbenzene			X													
bis(2-Ethylhexyl)phthalate	X				X						X					
HMX									X							
Methylene chloride			X													
Noncarcinogenic PAHs		X				X		X				X				
Oil and Grease										X		X				X
Phenol			X													
1,3,5-TNB	X				X											
Toluene			X													
Trichloroethene			X		X								X			
Inorganics:																
Antimony	X						X				X					
Arsenic		X		X		X	X				X	X		X		
Barium		X		X		X						X				
Beryllium			X			X					X	X				
Cadmium		X				X						X			X	X
Chromium	X	X				X				X		X		X	X	X
Copper	X	X	X		X	X	X	X	X	X	X	X	X			X
Lead	X	X	X		X	X		X		X	X	X			X	X
Mercury		X								X		X				
Nickel	X	X	X		X				X		X					
Selenium											X					
Silver			X						X							
Zinc		X	X						X	X	X	X	X			

detected in groundwater samples in this and other study areas, although groundwater samples were relatively infrequent and groundwater concentrations generally low.

Table 5-17 presents a summary of the chemicals of potential concern identified in sump and sump outflow sediment samples at LCAAP, based on the preliminarysampling conducted during the RI. The explosive compound 2,4-DNT, oil and grease, and several inorganic chemicals including barium, cadmium, chromium, copper, lead, mercury, and zinc were often identified as chemicals of potential concern in sump and sump outflow sediment. No VOCs were detected in sump and sump outflow sediment samples, as shown in Table 5-17.

In summary, many of the same chemicals suspected of being disposed in potential source areas at the site were found in groundwater sampled from the production wells, groundwater collected from the monitoring wells installed across the site, surface and subsurface soil collected in various areas at the LCAAP site, surface water and sediment samples collected in different ditches across the site, and sump and sump outflow sediment samples. As shown in Table 5-13, 5-14, 5-15, 5-16 and 5-17, *explosive compounds* such as RDX and HMX and heavy metal compounds such as arsenic, beryllium, cadmium, chromium, copper, lead, nickel, silver, and zinc were identified as chemicals of potential concern in nearly all media sampled, and thus may be considered fairly widespread chemical contaminants at the LCAAP site. In general, volatile contaminants were identified as chemicals of potential concern in media that were collected near suspected solvent disposal source areas.

TABLE 5-17

SUMMARY OF CHEMICALS OF POTENTIAL CONCERN IN SUMP AND SUMP OUTFLOW SEDIMENT SAMPLES AT LCAAP LAKE CITY, MISSOURI

	Buildings 1 and 2			Building 3		Building 4		Buildings 94, 97 & 97A	
Chemical	Bldg. 1 Sumps	Bldg. 2 Sumps	Sump Outflows	Sumps	Sump Outflows	Sumps	Sump Outflows	Sumps	Sump Outflows
Organics:									
2,4-DNT				X	X	X	X		X
2,6-DNT				X					X
HMX									X
Nitrobenzene	X								
Oil and Grease	X	X	X	X	X	X	X	X	X
RDX									X
1,3,5-TNB				X					
Inorganics:									
Antimony									X
Barium		X		X	X	X	X	X	X
Beryllium					X				
Cadmium		X	X	X	X	X	X	X	X
Chromium		X	X	X	X	X	X	X	X
Copper	X	X	X	X	X	X	X	X	X
Lead	X	X	X	X	X	X	X	X	X
Mercury		X	X	X	X	X	X		X
Nickel				X					
Silver				X	X	X			
Zinc		X	X	X	X	X	X	X	X

5.3 EXPOSURE ASSESSMENT

This section addresses the potential pathways by which human populations may be exposed to chemicals of potential concern at, or originating from, the study areas at LCAAP and exposure is quantified. Both current and likely future land-use of the site and surrounding areas are considered when identifying potential exposure pathways. In addition, the mechanisms by which the chemicals of potential concern at the site may migrate in the environment are considered. Such an evaluation is an important step in identifying potential exposure pathways because chemical migration can result in the movement of a chemical from a source to a potentially exposed population.

Chemical migration pathways are discussed in Section 5.3.1, followed in Section 5.3.2 by a discussion of potential human exposure pathways. In Section 5.3.3, the chemical concentrations at the exposure points are calculated for each pathway selected for quantitative evaluation. Then the magnitude, frequency, and duration of exposure are estimated and exposures (intakes) are quantified.

5.3.1 Migration Pathways

The migration of chemicals, in and between environmental media, at LCAAP is influenced by the environmental characteristics of the site and surrounding area, the characteristics of source areas, and the physical/chemical characteristics of the chemicals. The site environmental and source area characteristics have previously been addressed in Sections 3 and 4 of this report and will only be briefly referred to in this section where relevant. The physical/chemical characteristics of the chemicals of potential concern are addressed below in Section 5.3.1.1 followed in Section 5.3.1.2 by a discussion of the mechanisms of migration and transformation of chemicals of potential concern at the site.

5.3.1.1 Physical and Chemical Properties of the Chemicals of Potential Concern

The chemicals of potential concern being evaluated in this assessment can be classified into general categories according to their similarity in chemical structure and/or physicochemical properties (i.e., factors that would influence mobility and transformation in the environment). The chemical categories and the chemicals of potential concern within each category are listed below:

- Benzenes and Alkylbenzenes: benzene, ethylbenzene, toluene.
- Chlorinated Aliphatics: bromoform, carbon tetrachloride, chloroethene, chloroform, dibromochloromethane, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethene (total), methylene chloride, 1,1,2,2-tetrachloroethane, tetrachloroethene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethene, vinyl chloride.
- Chlorinated Aromatics: chlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene.
- Nitroaromatics (Explosives/By-Products): 2,4-DNT, 2,6-DNT, 1,3-DNB, 1,3,5-TNB, nitrobenzene, RDX, HMX, tetryl.
- Low Molecular Weight PAHs: naphthalene, acenaphthene, fluorene, phenanthrene, anthracene.
- High Molecular Weight PAHs: benzo(a)anthracene, benzo(a)pyrene, bnzo(a)fluranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h) anthracene, indeno(1,2,3-c,d)pyrene, fluoranthene, pyrene.
- Nitrosamines: n-nitrosodiphenylamine.
- Phenolics: phenol.
- Phthalates: dimethylphthalate, di-n-butylphthalane, bis(2-ethylhexyl)phthalate.
- Inorganic chemicals: antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, mercury, silver, selenium, zinc.
- Radiological parameters: gross alpha activity, gross beta activity, uranium, radon.

The numerical values of the physicochemical properties of the organic chemicals of potential concern listed above that are germane to transport processes are summarized in Table 5-18. A similar table is not presented for metals and other inorganic chemicals, since their potential for migration is greatly dependent upon external factors seldom measured as part of a site investigation. These factors include several site-specific factors such as (1) the identity of other ions which enhance or limit mobility through competitive complex formation; (2) pH of the medium; (3) cation exchange capacity of the soil; (4) presence of humic materials, hydrous oxides, silicates and carbonate minerals; (5) oxidizing or reducing conditions, and (6) presence of microbes. Moreover, important physicochemical properties such as the solubility of inorganics depend upon the identity of the metal complex, which is rarely known. For these reasons, to the extent possible, the migration potential of metals will be evaluated and discussed by a comparison of unfiltered (total) and filtered (dissolved) groundwater sample results.

A brief discussion of the relevance of the parameters listed in Table 5-18 to the migration of the organic chemicals of potential concern in the environment follows.

The water solubility of a substance is a critical property affecting environmental fate; highly soluble chemicals can be leached from wastes and soils and are mobile in surface water and groundwater.

Volatilization of a compound from environmental media will depend on its vapor pressure, water solubility, and diffusion coefficient. For estimating releases from water to air, the Henry's Law constant, the partition coefficient which expresses the ratio of the chemical concentration between air and water at equilibrium, is more appropriate than vapor pressure alone and is frequently measured for volatile chemicals, the Henry's Law constant can be estimated for chemicals of low aqueous solubility (less than a few percent) by the ratio of vapor pressure and solubility at similar temperatures (Mackay and Shiu 1981). Compounds with Henry's law constants in the range of

TABLE 5-18

PHYSICAL-CHEMICAL PROPERTIES OF ORGANIC CHEMICALS OF POTENTIAL CONCERN
AT LAKE CITY, MISSOURI

Chemical Name	Molecular Weight (g/mol)	Solubility in Water 20-25 C (mg/l)	WSol Source	Vapor Pressure 20-25 C (mm Hg)	VP Source	Henry's Law Constant 20-25 C (atm-m3/mol)	HL Source	Koc (ml/g)	Koc Source	Log Kow	Kow Source
Alkylbenzenes											
Benzene	78.00	1.75E+03	(1)	9.52E+01	(12)	5.43E-03	(22)	8.30E+01	(23)	2.13	(25)
Ethylbenzene	106.17	1.53E+02	(2)	7.00E+00	(13)	7.90E-03	(22)	2.20E+02	(24)	3.15	(26)
Toluene	92.15	1.55E+03	(1)	2.81E+01	(14)	6.60E-03	(22)	3.00E+02	(7)	2.69	(2)
Chlorinated Aliphatics											
Bromoform	252.75	3.01E+03	(7)	5.00E+00	(7)	5.32E-04	(42)	1.16E+02	(7)	2.40	(7)
Bromodichloromethane	163.80	5.00E+01	(46)	5.94E+01	(47)	2.56E-01	(37)	1.07E+02	(23)	2.24	(48)
Carbon tetrachloride	154.00	7.58E+02	(1)	1.10E+02	(35)	2.30E-02	(22)	4.39E+02	(7)	2.73	(1)
Chloroethane	64.52	5.74E+03	(3)	1.00E+03	(3)	2.00E-03	(22)	1.50E+01	(7)	1.43	(27)
Chloroform	119.38	7.22E+03	(1)	1.51E+02	(15)	3.80E-03	(22)	4.40E+01	(7)	1.97	(26)
Dibromochloromethane	208.29	4.54E+03	(44)	7.60E+01	(8)	4.59E-03	(37)	1.07E+02	23)	2.24	(7)
1,1-Dichloroethane	98.96	5.50E+03	(4)	1.82E+02	(4)	5.70E-03	(22)	3.00E+01	(7)	1.79	(4)
1,2-Dichloroethane	98.76	7.99E+03	(1)	6.40E+01	(16)	1.10E-03	(22)	1.40E+01	(7)	1.45	(1)
1,1-Dichloroethene	96.94	2.25E+03	(5)	6.00E+02	(5)	1.54E-01	(22)	6.50E+01	(7)	2.13	(7)
trans-1,2-Dichloroethene	96.94	6.30E+03	(6)	3.24E+02	(6)	6.60E-03	(22)	5.90E+01	(7)	2.09	(7)
Methylene chloride	84.93	1.80E+04	(8)	3.62E+02	(7)	2.60E-03	(22)	8.80E+00	(7)	1.51	(25)
1,1,2,2-Tetrachloroethane	167.85	2.97E+03	(1)	5.00E+00	(43)	4.70E-04	(42)	1.18E+02	(7)	2.39	(1)
Tetrachloroethene	165.85	4.84E+02	(1)	1.78E+01	(17)	2.30E-02	(22)	3.64E+02	(7)	2.53	(1)
1,1,1-Trichloroethane	133.41	1.33E+03	(1)	1.23E+02	(18)	2.80E-02	(22)	1.52E+02	(7)	2.47	(1)
1,1,2-Trichlorethane	133.41	4.50E+03	(9)	3.00E+01	(9)	1.20E-03	(22)	5.60E+01	(7)	2.47	(9)
Trichloroethene	131.29	1.47E+03	(1)	5.79E+01	(19)	8.90E-03	(22)	1.26E+02	(7)	2.42	(1)
Vinyl chloride	62.50	2.67E+03	(10)	2.66E+03	(10)	6.90E-01	(22)	8.20E+00	(7)	1.38	(10)
Chlorinated Aromatics											
1,2-Dichlorobenzene	147.01	1.18E+02	(8)	1.47E+00	(45)	1.90E-03	(22)	1.70E+03	(7)	3.38	(2)
1,4-Dichlorobenzene	147.01	7.38E+01	(1)	1.18E+00	(7)	1.60E-03	(22)	1.70E+03	(7)	3.39	(2)
Nitrocyclics/Aromatics											
1,3-Dinitrobenzene	168.12	5.33E+02	(11)	1.31E-04	(11)	5.44E-08	(11)	3.63E+01	(11)	1.49	(11)
2,4-Dinitrotoluene	182.15	2.80E+02	(11)	2.17E-04	(11)	1.86E-07	(11)	2.51E+02	(11)	1.98	(25)
2,6-Dinitrotoluene	182.15	2.06E+02	(11)	5.67E-04	(11)	4.86E-07	(11)	7.76E+01	(11)	1.89	(11)
HMX	296.20	5.00E+00	(11)	3.33E-14	(11)	2.60E-15	(11)	3.47E+00	(11)	0.26	(11)
Nitrobenzene	123.11	2.09E+03	(1)	1.50E-01	(21)	1.31E-05	(7)	3.60E+01	(7)	1.83	(1)
RDX	222.15	6.00E+01	(11)	4.03E-09	(11)	1.96E-11	(11)	1.00E+02	(11)	0.87	(11)
Tetryl	287.17	8.00E+01	(11)	5.69E-09	(11)	2.69E-11	(11)	4.90E+01	(11)	1.65	(11)
1,3,5-Trinitrobenzene	213.12	3.85E+02	(11)	3.03E-06	(11)	2.21E-09	(11)	2.00E+01	(11)	1.18	(11)
Nitrosamines											
N-Nitrosodiphenylamine	198.20	3.51E+01	(1)	6.69E-04	(34)	5.00E-06	(34)	6.48E+02	(7)	3.13	(1)
Phenolics											
Phenol	94.11	9.30E+04	(28)	3.41E-01	(28)	3.97E-07	(35)	1.42E+01	(7)	1.48	(25)
Phthalates											
Bis(2-ethylhexyl) phthalate	391.00	4.00E-01	(29)	2.00E-07	(7)	4.40E-07	(36)	8.74E+04	(38)	5.11	(29)
Dimethylphthalate	194.18	2.12E+03	(29)	4.19E-03	(7)	5.05E-07	(37)	1.74E+01	(7)	1.56	(7)
Di-n-butyl phthalate	278.00	9.20E+00	(29)	1.00E-05	(7)	1.30E-06	(36)	1.39E+03	(38)	3.75	(29)
Low Molecular Weight PAHs											
Acenaphthene	154.00	3.93E+00	(30)	2.15E-03	(32)	2.40E-04	(22)	4.60E+03	(7)	3.92	(1)
Anthracene	178.08	7.30E-02	(30)	6.00E-06	(32)	5.90E-05	(22)	1.40E+04	(7)	4.54	(2)
Fluorene	166.08	1.98E+00	(30)	6.00E-04	(32)	8.40E-05	(22)	7.30E+03	(7)	4.18	(25)
Naphthalene	128.06	3.17E+01	(30)	7.80E-02	(32)	4.20E-04	(22)	9.40E+02	(7)	3.36	(25)
Phenanthrene	178.08	1.29E+00	(30)	1.20E-04	(32)	3.90E-05	(22)	1.40E+04	(7)	4.52	(25)
High Molecular Weight PAHs											
Benzo(a)anthracene	228.09	1.40E-02	(30)	2.10E-07	(32)	4.50E-06	(37)	1.38E+06	(23)	5.61	(25)
Benzo(a)pyrene	252.09	5.00E-05	(31)	5.60E-09	(33)	3.72E-05	(37)	5.50E+06	(7)	6.25	(39)
Benzo(b)fluoranthene	252.00	1.40E-02	(7)	5.00E-07	(7)	1.18E-05	(37)	5.50E+05	(7)	6.06	(39)
Benzo(k)fluoranthene	252.32	4.30E-03	(7)	5.10E-07	(7)	3.94E-05	(37)	5.50E+05	(7)	6.06	(39)
Chrysene	228.09	2.00E-03	(30)	6.40E-09	(33)	9.60E-07	(37)	2.00E+05	(7)	5.61	(40)
Dibenzo(a,h)anthracene	278.00	1.40E-02	(21)	1.00E-10	(7)	2.61E-09	(37)	3.30E+06	(7)	5.61	(40)
Fluoranthene	202.08	2.60E-01	(30)	9.20E-06	(32)	9.41E-06	(37)	3.80E+04	(7)	5.33	(40)
Indeno(1,2,3-cd)pyrene	276.00	5.30E-04	(7)	1.00E-10	(7)	6.85E-08	(37)	1.60E+06	(7)	6.50	(7)
Pyrene	202.08	1.35E-01	(30)	4.50E-06	(32)	8.86E-06	(37)	3.80E+04	(7)	5.18	(2)

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10^{-3} atm m^3/mole and larger can be expected to volatilize readily from water; those with values ranging from 10^{-3} to 10^{-5} atm m^3/mole are associated with significant, but lesser, volatilization, while compounds with values less than 10^{-5} atm m^3/mole volatilize from water only to a limited extent (Lyman et al. 1982).

The octanol-water partition coefficient (K_{ow}) is often used to estimate the extent to which a chemical will partition from water into lipophilic parts of organisms, for example into animal fat. The higher the K_{ow} value, the greater is a chemical's tendency to partition into fat. Similarly, the organic carbon partition coefficient (K_{oc}) reflects the propensity of a compound to adsorb to the organic carbon found in soil. The higher the K_{oc} value, the greater is a chemical's tendency to adsorb to soil organic carbon. In addition to organic carbon, sorption to soil is also a function of the surface area of the soil particle as well as the size, shape and surface area of the adsorbing molecule.

5.3.1.2 Mechanisms of Migration and Transformation at the LCAAP Site

In this section, information concerning site characteristics (discussed in Section 3), sampling data presented in Section 5.2, and the information on physicochemical properties given above in Section 5.3.3.1 are used to determine the potential mechanisms of migration and transformation that may occur at Lake City in each study area. Due to the preliminary nature of the investigation for several of the areas, all media were not sampled in all study areas. Therefore, sampling data are not always available to substantiate predictions of intermedia transfer, fate, and transport of the chemicals of potential concern at the site. This section will first address the potential for chemicals in sampled media to migrate into groundwater and the transport of chemicals within groundwater for each study area. Finally, the potential for sampled media (i.e., surface water, sediment and soil) to impact air in each study area will be addressed. Since the major focus of this RI has been groundwater, a brief summary of the hydrogeology of the site and hydrostatic units sampled is first presented below.

As previously discussed, three hydrostratographic units at the site (the silty clay, the alluvial sand aquifer, and the weathered bedrock unit) are hydrologically connected with a vertical gradient of flow from the silty clay hydrostatic unit to the alluvial sand hydrostratographic unit and a significant vertical gradient between the weathered bedrock and the alluvial sand units. The silty clay and weathered bedrock basically act as upper and lower confining layers, respectively, for the alluvial sand aquifer, which is the primary water-producing aquifer at the site, supplying LCAAP with as much as 1.4 million gallons of water per day. Eighteen monitoring wells (in Areas 1, 2, 4, 5, 8, 10, 11, and 17) are installed in the silty clay confining layer. As stated previously in this report (Section 4), the alluvial sand aquifer was investigated in study areas 3, 7, 9, 12, 14, and 18 using monitoring wells installed in shallow and deep portions of the aquifer. The on-site production wells are also installed in the deep portion of the alluvial sand aquifer. Finally, six monitoring wells are screened in the weathered bedrock confining layer in study Areas 6 and 16.

As discussed in detail in Section 3.6.1, groundwater in the silty clay hydrostratographic unit flows generally north and northwest along the contour of the bedrock and topography of the surface. The alluvial sand layer is more permeable than the silty clay layer, and thus the groundwater in the alluvial sand aquifer flows faster than water in the silty clay hydrostratographic unit. Groundwater in the upper (i.e., shallow) portions of the alluvial sand aquifer flows west, while the groundwater in the deeper portions flows west and southwest. Groundwater in the weathered bedrock unit, the deepest hydrostatic unit on-site, flows relatively slowly to the northwest along the elevation contours of the bedrock material. In general, horizontal flow of groundwater in all three hydrostratographic units in the upland areas is much faster than flow in the lowland areas because of the difference in the gradient of the bedrock.

As discussed in Section 3.6.4 and 3.6.5, groundwater in several investigated areas is within the production well capture zones. As discussed in these sections, chemicals measured in groundwater in monitoring wells from Areas 1, 2, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, and 18 should not migrate beyond property boundaries under current production well use based on hydrogeological investigations that considered past use of these wells (as discussed in Section 3). On the other hand, perimeter Areas 3, 8, 16, and 17 lie outside production well capture zones, and chemicals measured in groundwater at these locations can potentially migrate beyond property boundaries. Groundwater contaminants in Areas 16 and 17 are expected to primarily move off site north/northwest from the northern site boundary, whereas contaminants in Areas 3 and 8 are expected to move off site from the western boundary in a west/northwest direction. Based on these factors, the migration characteristics of areas along the perimeter of the site whose groundwater may move off-site are discussed separately from the migration characteristics of those central areas of the site affected by the production well activity.

Migration and Transformation Mechanisms in Areas Along the Perimeter of the Site (Areas 3 and 8, 16 and 17). Chemical fate and transport in the two sampled areas from which groundwater contaminants may migrate off-site from the western boundary (Areas 3 and 8) and the two sampled areas from which groundwater contaminants may migrate off-site from the northern border of LCAAP (Areas 16 and 17) are discussed below. No off-site data from locations downgradient of areas along the western boundary (Areas 3 and 8) were available to determine to what extent off-site migration has occurred. However, sampling data from 12 residential wells located downgradient of areas along the northern boundary (Areas 16 and 17) were available for use in assessing potential migration of chemicals from the site in that area.

Migration of Chemicals into and Within Groundwater Near the Western Site Boundary in Area 3. Several potential source areas are located in Area 3 including an inactive sludge burial site and two inactive sand pits. Industrial wastewater treatment plant sludge that potentially contained lead and mercury were disposed in the sludge burial site. Demolition waste material and wastes from a nuclear weapons manufacturer reportedly were disposed in the two inactive sand pits. The full extent of source contamination cannot be characterized at this time because no soil, surface water, sediment or leachate samples were collected during the RI in Area 3 (with the exception of one sediment/surface water sample collected in a pond, to be discussed later). However, a possible link between these source areas and groundwater contamination downgradient of these source areas was assessed in Section 4.3 based on an assessment of disposal history in Area 3, hydrogeology of the site, and analysis of chemicals found in monitoring wells installed upgradient and downgradient in Area 3. As discussed in Section 4.3, the sludge burial site (Area 3A) and the two inactive sand pits (Area 3B) may have contributed explosive compounds, bis(2-ethylhexyl)phthalate (Area 3A only), and to a certain extent inorganic compounds, to the contamination found in groundwater in Area 3. The source of 1,1-dichloroethene detected in groundwater in Area 3 is unknown.

As discussed in Section 4.19.1, the on-site pond was used for the purpose of watering cattle that until recently were allowed to graze on-site. The pond was sampled because it was suspected that groundwater was discharged to the pond. However, analysis of aquifer elevations around the pond area reveal that the pond recharges groundwater in this area. This pond was not used as a waste disposal area. One surface water and sediment sample were collected from the pond. No volatile, semi-volatile, or explosive chemicals were detected in the pond. The only chemicals of potential concern identified in the pond surface water and sediment that also were identified in groundwater in Area 3 included antimony, arsenic, and copper. However, these chemicals were detected at low concentrations in the pond and therefore the pond does not appear to be a source of concern relative to the other sources identified in Area 3 or a receptor of contamination from groundwater.

Of the chemicals detected in groundwater in Area 3, 1,1-dichloroethene, RDX, HMX, and 2,4-DNT have relatively low K_{oc} values and thus are very mobile in the subsurface environment and could migrate further downgradient beyond the property boundary of the LCAAP site. However, no off-site data from locations downgradient of Area 3 were available to determine to what extent actual off-site migration has occurred. The presence of 1,1-dichloroethene may be due to the microbial degradation of the commonly used solvents (e.g., tetrachloroethene and trichloroethene) which, however, were not detected in groundwater in this area, although at high concentrations in Areas 16 and 17. 1,1-Dichloroethene is also a by-product in the dehydrohalogenation of 1,1,1-trichloroethane, a chemical measured in other areas of the site (Dulling et al. 1975), and Vogel et al. 1987). Further transformation of this chemical leads to the formation of vinyl chloride which is highly mobile in groundwater. However, vinyl chloride was not detected in groundwater in this area. Nitro groups on aromatic compounds can be reduced by microbes to amino groups under anaerobic conditions, and 4-amino-2-nitrotoluene has been reported as a biotransformation product of 2,4-DNT (McCormick et al. 1976). Biodegradation of RDX has been observed under anaerobic conditions, but this degradation depends heavily upon the presence of other organic nutrients (Spanggord 1980). In the absence of such nutrients, RDX could be persistent in groundwater at LCAAP and the widespread occurrence of RDX at the site may be an indication that subsurface biodegradation is not readily occurring. While little information is available for HMX, the compound is structurally similar to RDX and thus similar requirements for biodegradation would be expected.

Bis(2-ethylhexyl)phthalate, the other organic chemical of potential concern in groundwater of this area, has a high K_{oc} value, therefore this chemical strongly absorbs to soil and surfaces in general and does not migrate readily to or in groundwater. The presence of bis(2-ethylhexyl)phthalate in this medium may be due to laboratory contamination since this compound, a component of many plastics, is a common laboratory artifact. However, since the levels of this chemical were much lower in blanks than in site samples, there is currently no evidence to support this hypothesis.

Inorganic chemicals typically migrate slowly in groundwater, relative to volatile and certain semi-volatile chemicals. However, the migration potential of the inorganic chemicals of potential concern in groundwater in this area may vary considerably due to organic material complexing agents. These organic compounds can increase the solubility and hence the mobility of these metals.

Migration of Chemicals into and within Groundwater Near the Western Site Boundary in Area 8. Several potential source areas are located in Area 8 including four inactive and one active sludge disposal areas and several oil and grease trenches. Industrial wastewater treatment plant sludge that potentially contained antimony, barium, lead, and mercury were disposed in the active sludge disposal area. Soil boring samples were only collected from two of the sludge disposal areas, therefore, at this time, the full extent of source contamination cannot be characterized in Area 8. Based on the chemicals of potential concern in the soil borings collected in Area 8D (see Figure 4-17 and Table 5-6) this area may be a potential source of inorganic contamination in groundwater. As shown in Table 5-6, elevated levels of arsenic, barium, lead, and zinc, as well as other inorganic chemicals, were found in subsurface soil collected in the sludge disposal areas. Elevated levels of these same inorganic chemicals also were found in groundwater in Area 8. In addition, as stated in Section 4.8, sources in Areas 8A, 8B, and 8F which were not sampled in the RI, also may be potential sources of inorganic contamination, and the disposal pits in Area 8 may be sources of organic contaminants found in downgradient groundwater. The high concentration of bis(2-ethylhexyl)phthalate detected in Area 8 groundwater may be the result of laboratory contamination or perhaps contamination from the sludge disposal areas in Area 8B.

Several organic chemicals of potential concern were measured in groundwater in this area including: chlorinated aliphatics (1,1-dichloroethane, trans-1,2-dichloroethene, trichloroethene), a nitrosamine (n-nitrosodiphenylamine), a phthalate (bis[2-ethylhexyl]phthalate) and a nitrocyclic compound (RDX). As mentioned previously, the chlorinated aliphatics and nitrocyclic compound are very mobile in groundwater and can migrate beyond property boundaries. However, no off-site data from locations downgradient of Area 8 were available to determine to what extent actual off-site migration has occurred. The presence of trichloroethene and trans-1,2-dichloroethene in groundwater in this area indicates that some biodegradation of trichloroethene may be occurring in this area. As mentioned earlier, microbial transformations of RDX may not be readily occurring at the site. N-nitrosodiphenylamine was measured in a groundwater sample collected in Area 8. Based on professional experience, this compound is most frequently an analytical artifact due to the difficulty in analyzing nitrogen compounds on a mass spectrometer.

Bis(2-ethylhexyl)phthalate was measured in Area 8 groundwater at a concentration 45 times greater than its aqueous solubility, which is shown on Table 5-16. This indicates that if indeed present, the phthalate is adsorbed to sediment collected during sampling. Most likely, the chemical is present as a result of laboratory contamination.

Metals (antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, silver, zinc) are the most abundant chemicals of potential concern in groundwater in Area 8 (see Table 5-4). A comparison of filtered and unfiltered groundwater samples appears to indicate that a significant portion of zinc is dissolved and thus mobile; very little copper, however, was measured in filtered samples versus unfiltered samples. It is difficult to predict the migration potential of the other metals in this area based on the data, and as noted above, no off-site data are available to help in this determination.

<u>Migration of Chemicals Into and Within Groundwater Near the Northern Site Boundary in Areas 16</u>. Several potential sources of groundwater contamination are located in Area 16 including: (1) an abandoned landfill and trench (used for disposal of IWTP sludge, oil and grease, construction debris, explosive waste, and solvents and possibly containing RCRA hazardous

constituents barium, lead, and mercury), (2) an inactive burial site (used for disposal of oil and grease, bleach cans, and paint cans), (3) several storage tanks (since removed, but used to store paint wastes, solvent wastes, and waste oil and potentially contaminating surrounding soils with RCRA hazardous constituents cadmium, chromium, lead, nickel, VOCs, and semivolatile organic chemicals), and (4) inactive firing range and demolition burning grounds (containing lead bullets, lead casings, and possible RCRA hazardous constituents lead and barium).

A possible link between source areas that were not characterized based on soil monitoring data collected during the RI and groundwater contamination downgradient of these source areas was assessed in Section 4.16 based on an assessment of disposal history in Area 16, hydrogeology of the site, and analysis of chemicals found in monitoring wells installed in Area 16. Disposal sites in Areas 16A, 16B, and 16C were identified as potential sources of VOC contamination in groundwater in Area 16. Disposal sites in Areas 16A, 16B, and 16C may have contributed to the concentrations of 1,2-dichlorobenzene and bis(2-ethylhexyl)phthalate found in groundwater, in these respected areas. Significant concentrations of several inorganic chemicals of potential concern identified in groundwater in nearly all of the Area 16 monitoring wells indicates possible contribution of several source areas in Area 16. As discussed in Section 4.16, based on a comparison of upgradient and downgradient groundwater data, a further upgradient source of explosive compound contamination may be present.

Of the potential sources outlined above in Area 16, only surface water/sediment samples were collected from a drainage ditch flowing between Areas 16 and 17 near the abandoned landfill (3 samples) and from a leachate seep taken just below the abandoned landfill (one sample). The drainage ditch was sampled to evaluate runoff from the landfill and from the area where the storage tanks were located.

Although PAHs were detected in the drainage ditch sediments they were not identified in groundwater in Area 16. Low molecular weight PAHs are fairly immobile in subsurface environments as observed from their K_{oc} values presented in Table 5-18. The absence of PAHs in groundwater also may be due to their initial low concentrations and further decreases through processes such as biodegradation. Of the low molecular weight PAH measured in sediment, naphthalene disappeared rapidly in agricultural soil during the first 60 days of a controlled study, while the estimated half-life for acenaphthene, flourene, and phenanthrene at 20°C were <10, 47 and <6 days, respectively (Coover and Sims 1987). The authors hypothesized that significant losses of acenaphthene, fluorene, phanthrene, and anthracene may have resulted from volatilization, and similar behavior would be expected in the case of naphthalene during periods when ditches are dry.

Many of the chemicals of potential concern identified in groundwater downgradient of Area 16 also were found in the landfill leachate seep (benzene, 1,1-dichloroethane, trichloroethene, trans-1,2-dichloroethene, ethylbenzene, beryllium, copper, lead, nickel, silver, zinc), in drainage ditch sediments (arsenic, beryllium, copper, lead), or in drainage ditch surface water (bis[2-ethylhexyl]phthalate, copper, lead, nickel), as presented in Table 5-7. The landfill in Area 16 is probably the primary source of these contaminants since these chemicals were detected in the landfill leachate seep and the drainage ditch which receives runoff from the landfill, as well as in groundwater downgradient of the landfill. Surface water and sediment areas, containing high concentrations of metals such as lead and copper, also may be acting to some degree as sources of these chemicals to groundwater in this area. The reason for the presence of phthalates in groundwater and surface water samples is unknown but considered possibly to be due to laboratory contamination.

Several chemicals detected in groundwater in Area 16 were not found in landfill leachate, surface water or sediment in this area. These chemicals are chlorinated aliphatics, (1,1,2-trichloroethane, 1,1-dichloroethene, 1,2-

dichloroethane, vinyl chloride), and nitrocyclic/ aromatics (RDX, 1,3-DNB, nitrobenzene). Several of the VOC chemicals are biodegradation products of various chemicals that were detected in sources sampled in Area 16. As discussed above and in Section 4.16, a further upgradient source of explosive compound contamination may be present. With the exception of the phthalate, the organic chemicals in groundwater in this area are very mobile in the subsurface environment, and can migrate with groundwater to property boundaries and beyond.

Chlorinated aliphatics such as tetrachloroethene, trichloroethene, and 1,2-dichloroethene (total) and benzene were measured at the highest concentrations in this area (up to 21,000 ug/L in the case of trans-1,2-dichloroethene) (see Table 5-4). These chemicals are very mobile in the subsurface environment, as can be observed from their K_{oc} values shown on Table 5-18. In addition, other chlorinated aliphatic compounds such as 1,1-dichloroethene, 1,2-dichloroethane, and vinyl chloride also were found in Area 16 groundwater. These chemicals, which are likely transformation by-products of trichloroethene and tetrachloroethene, are all very mobile as evidenced by their K_{oc} values and are likely to migrate off property boundaries in this area of the site. Other organic chemicals such as RDX, 1,3-DNB, and nitrobenzene also may migrate off-site but to a more limited extent than the chlorinated aliphatic compounds.

Of the organic chemicals detected in groundwater in Area 16, both trichloroethene and RDX were found in off-site residential wells located just north of the northern LCAAP boundary. Trichloroethene was detected in one of the off-site wells (Ure) at a concentration of 1.2 ug/l while RDX was detected in three of the off-site wells at concentrations up to 3.4 ug/l. Nitroaromatic compounds such as 1,3-DNB and nitrobenzene, and the nitrocyclic compound RDX also can undergo microbial transformations under anaerobic conditions as discussed earlier.

A comparison of results from unfiltered and filtered metal samples indicates that a significant portion of zinc is dissolved and thus able to migrate to property boundaries; however, it is difficult to determine if the other metals are also in a mobile form. Of the metals of potential concern in this area, zinc was present at the highest concentration in all of the wells in this area. Several inorganics were detected in off-site residential wells located just north of the LCAPP. However, since these inorganics occur naturally in groundwater and no background data were available to determine if concentrations in residential wells were elevated above background in the area, no connection between on-site and off-site groundwater in this area can be made based on inorganic data.

Gross beta activity also was measured above background concentrations, but the identity of the emitter is not known at this time.

Migration of Chemicals into and within Groundwater Near the Western Site Boundary in Area 17. Several potential source areas are located in Area 17 including three inactive disposal solvent pits and a sanitary landfill. According to the MDNR landfill permit, no hazardous waste can be dumped at this landfill. However, as state previously in this report (Section 4.17), certain explosive compounds were reportedly disposed at this landfill. The three inactive disposal solvent pits located in Area 17 were used for disposing industrial wastewater treatment plant sludge, spent grease and waste oil, and waste solvents. Possible RCRA hazardous constituents disposed in these pits include trichloroethene, 1,1,1-trichloroethane, tetrachloroethene, chromium, and lead. The full extent of current source strength cannot be characterized because no soil, surface water, sediment or leachate samples were collected in Area 17. However, based on an assessment of disposal history in Area 17, hydrogeology of the site, and analysis of chemicals found in upgradient and downgradient monitoring wells installed in this area (as discussed in Section 4.17), Area 17B (solvent pits) may be a potential source of explosive chemicals and VOCs in groundwater in Area 17. The solvent pits were not identified as significant potential sources of inorganic contamination based on a comparison of levels of inorganic chemicals in upgradient and downgradient wells. The sanitary landfill was not identified as a significant potential source of groundwater contamination based on the disposal history of the landfill and analysis of upgradient and downgradient wells (as discussed in Section 4.17). The presence of bis(2-ethylhexyl)phthalate was thought to be due to field contamination.

Chlorinated aliphatics (1,1,1-trichloroethane, 1,1,2-trichloroethane, chloroform, methylene chloride, tetrachloroethene, trichloroethene, trans-1,2-dichloroethene) were infrequently detected in this area, but were detected at high concentrations, particularly in Well 17-5 (up to 320,000 ug/L) (see Table 5-4). These chemicals are in all likelihood originating from the solvent pits located in this vicinity. Chlorinated aliphatics are very mobile in the subsurface environment and able to migrate beyond the northern property boundary given their low K_{oc} values. Of the chlorinated aliphatics of potential concern in Area 17 groundwater, only trichloroethene was detected in any of the residential wells located just beyond the northern boundary of the LCAAP. Trichloroethene was detected in one off-site well at a concentration of 1.2 ug/l. In addition, the presence of trans-1,2-dichloroethene in site groundwater may indicate that some microbial transformations of the higher chlorinated compounds may be occurring.

Alkyl aromatics (benzene, ethylbenzene, toluene), nitrocyclics/aromatics (HMX, RDX, 1,3,5-TNB, 2,6-DNT, tetryl), a phthalate (bis[2-ethylhexyl] phthalate) are also chemicals of potential concern in Area 17 groundwater. Of these chemicals, toluene was measured at the highest concentrations. With the exception of the phthalate, all of these organic chemicals are very mobile in the subsurface and will migrate further downgradient in groundwater beyond the LCAAP property boundaries. HMX, RDX, and toluene were each found in at least one of the off-site residential wells located just beyond the northern LCAAP boundary at concentrations up to 8.5 ug/l, 3.4 ug/l, and 1 ug/l, respectively. As discussed previously, bis(2-ethylhexyl)phthalate, if really present in groundwater, will not be mobile since it adsorbs strongly to soils and surfaces.

Metals of potential concern (antimony, arsenic, barium, beryllium, copper, lead, nickel, silver, zinc) and radiological parameters (alpha and beta particles) also were detected above background concentrations in this area. The presence of gross alpha particles could be attributed to naturally occurring uranium, but the identity of the beta particle emitter is not know at this time. A comparison of results from filtered and unfiltered metal samples appears to indicate that a significant portion of antimony, arsenic, and zinc are dissolved and thus able to migrate to property boundaries. Of the metals of potential concern, zinc was measured at the highest concentration in the majority of the wells in this area. It is difficult to determine if beryllium, chromium, copper, lead, nickel and silver are also migrating in the subsurface based on available data from filtered and unfiltered samples.

Off-site inorganic data from residential wells cannot be used to indicate migration from the site since these chemicals occur naturally in groundwater and no background data are available to determine if they are present in residential wells at above background concentrations.

Migration of Chemicals and Transformation Mechanisms in Areas In the Central Portion of the Site Within Production Well Capture Zones. Soil was sampled in Areas 9, 13, 14, and 15; sediment and surface water were sampled in Area 13, along the Big Ditch, Ditch A, Ditch B, and the unnamed ditch; and groundwater was sampled in all areas within the production well capture zones.

Potential sources that may affect groundwater quality in the production well capture zone under current pumping patterns are discussed in detail in Section 4 of this report and are summarized below by study area:

Area 1: An inactive surface impoundment used to store treated wastes from the manufacture and processing of explosives and possibly containing the RCRA hazardous constituent resorcinol.

Area 2: Two surface storage impoundments currently being closed and one inactive surface impoundment formerly used to store neutralized wastes from lead styphnate and tetrazene production and possibly containing the RCRA hazardous constituent lead. Also, an overflow area from the impoundments during a flood event.

Area 4: None currently, since all potential sources were closed under a RCRA closure plan.

Area 5: One surface impoundment currently being closed and one inactive surface impoundment formerly receiving neutralized wastes from one of the manufacturing and processing facilities. Also, an overflow area from the blockage treatment tanks in the manufacturing facility.

Area 6: One surface impoundment currently being closed and formerly used to store neutralized waste from the packing of 20-mm cannon shells and possibly containing the RCRA hazardous constituent BA.

Area 7: Three new lagoons which are being built to receive non-hazardous wastes; three active lagoons (retrofitted to meet RCRA requirements) receiving treated IWTP wastewater (lagoon discharge to West Fire Prairie Creek is permitted under NPDES); three lagoons currently being closed formerly receiving the same wastes; three inactive lagoons containing the same waste and having possible RCRA hazardous constituents lead and mercury; a spill area from a release in 1983 from an above-ground fuel oil storage tank; an inactive lagoon with no waste information; an inactive explosives burning ground used to burn small arms ammunition (≤ .50 caliber) and other items and containing possible RCRA hazardous constituents lead, barium, mercury, and explosives; a currently used container cleanup area where intraplant explosives transport containers are chemically treated (possible hazardous constituents barium, lead, and antimony).

Area 9: 4 inactive percolation sumps containing hazardous constituents lead and mercury; inactive sludge drying beds for zinc cyanide plating treatment wastes; and concrete waste tanks that once stored mercuric nitrate waste sludge.

Area 10: Current storage area for sand removed from ballistics firing ranges and containing RCRA hazardous constituents lead, barium, and antimony.

Area 11: An active burning ground for propellants and waste pyrotechnic mixtures.

Area 12: An inactive chemical laboratory waste lagoon containing RCRA hazardous constituent's barium, chromium, lead, mercury, silver, antimony, and other laboratory chemicals; an inactive IWTP sludge disposal area.

Area 13: An inactive open waste drainage area with RCRA hazardous constituent chromium.

Area 14: An inactive IWTP sludge disposal area with RCRA hazardous constituents lead and mercury; 4 above-ground storage tanks currently used to store fuel oil.

Area 15: An inactive surface impoundment used to temporarily hold manufacturing wastes and containing RCRA hazardous constituents lead, barium, and antimony; a concrete lift station used to transfer wastes to the IWTP from manufacturing facilities and containing possible hazardous constituents lead, barium, and antimony.

Area 18: Inactive pits used to dispose and burn IWTP waste grease and oil, waste solvents, and combustible plant trash and containing potential RCRA hazardous constituents lead, mercury, carbon tetrachloride and trichloroethylene.

A subset of the potential sources noted above were sampled in this RI and this data can be used in a preliminary assessment of the potential contribution of these sources to groundwater contaminants that may reach production wells. Five surface and thirteen subsurface soil samples were collected across Area 9 to evaluate the extent of contamination due to various sources, three surface soil samples were collected from the open waste drainage area in Area 13, three soil borings were collected in the sludge disposal area in Area 14, and four soil borings were collected within the surface impoundment located at Area 15. In addition, sediment and surface water samples collected in the ditch leading to the open waste drainage area in Area 13 and collected in Ditches A, B, and the unnamed ditch, as well as sediments collected from site-wide sumps, may be used to preliminarily evaluate potential groundwater contamination from these sources.

<u>Soil</u>: For areas within the capture zone of the production wells, surface soil samples were only collected in Areas 9 and 13, while subsurface soil borings were only collected in Areas 9, 14, and 15. Thus, the extent of soil contamination can only be assessed for a limited number of potential source areas. All of the chemicals of potential concern in surface and subsurface soil in these areas are inorganic compounds.

In Area 9, arsenic, cadmium, nickel, silver, and zinc were the only inorganic chemicals identified as chemicals of potential concern in groundwater that also were elevated above background concentrations in the surface soil. Although lead was detected at a fairly low level in groundwater in Area 9, lead was detected at high levels in surface soil (4,400 ug/g), this may indicate that lead may not be mobile in this environment. In subsurface soils in Area 9, the concentrations of mercury and zinc exceeded background concentrations. However, mercury was not present at above detection limits in groundwater in this area. The potential of inorganic chemicals of potential concern to leach into groundwater is generally low since inorganics typically bind tightly to soil particles. However, the leaching potential of inorganic chemicals of potential concern may vary considerably due to organic material complexing agents. These organic compounds can increase the solubility and hence the leaching and mobility characteristics of these metals. As discussed in section 4.9, based on comparison of upgradient and downgradient groundwater concentrations, it does not appear that the inorganic contamination in soil in Area 9 significantly impacts groundwater quality.

In Area 13, three surface soil samples were collected from the open waste drainage area. Concentrations of arsenic, barium, chromium, and lead exceeded background concentrations in Area 13 surface soil. The concentrations detected of these inorganics were low relative to other sampled areas where little impact was seen in groundwater. However, no groundwater samples were collected in Area 13, therefore the current impact of inorganic contamination on groundwater is unknown.

In Area 14, three subsurface soil samples were collected from the sludge burial site located in Area 14. Concentrations of arsenic, barium, and cadmium exceeded background concentrations in Area 14. The highest concentration of arsenic (180 ug/g) was detected in the sample collected from this sludge burial site. The level of arsenic and barium in groundwater downgradient of the sludge area did exceed background levels. Thus indicating that the current impact of the sludge burial site may be impacting groundwater in Area 14. It should be noted that the concentrations of cadmium did exceed background levels in both groundwater and soil samples, thus indicating that this chemical may be leaching from the sludge burial site. However, the level of cadmium in soil and groundwater was relatively low.

In Area 15, four soil borings were collected from a temporary surface impoundment. Concentrations of antimony, arsenic, barium, beryllium, cadmium, copper, and lead exceeded background concentrations in soil. In particular, high levels of barium and lead were found in the soil borings, indicating that these chemicals may have an impact on groundwater in Area 15. However, no groundwater samples were collected in Area 15, therefore the current impact of inorganic contamination, in subsurface soils in this area, on groundwater is unknown.

<u>Drainage Ditch Sediment and Surface Water</u>: Sediment and surface water samples were collected from the Area 13 drainage ditch, Area 16 drainage ditch and leachate seep, Ditch A, Ditch B, the Big Ditch, the unnamed ditch (sediment only), and Ditch 2 (sediment only). Relatively high levels of inorganics were found in the Area 13 drainage ditch and the Area 16 drainage ditch and leachate seep. Groundwater samples were not collected in Area 13, therefore the impact of sediment contamination on groundwater in that area cannot be evaluated at this time. In Ditch A, Ditch B, the Big Ditch, the unnamed ditch, and Ditch 2 moderate levels of metals were present in both sediments and surface water. Surface water runoff from the potential source areas located across the LCAAP site, water table leaching, and sump outflows may act as potential sources of surface water and sediment contamination.

Inorganic chemicals and semi-volatile organic chemicals (e.g., PAHs and phthalates) tend to partition to sediments. However, the behavior of inorganic chemicals of potential concern in surface water in aquatic systems varies due to organic complexing agents (e.g., fulvic and humic acids). These organic compounds can increase the solubility and hence mobility of these metals. The increased solubility of inorganic/organic chemical complexes may result in inorganics moving from sediments into surface water, thereby resulting in their downstream transport to off-site locations. However, the potential of chemicals of potential concern detected in Ditch A, Ditch B, the Big Ditch, the unnamed ditch, and Ditch 2 to significantly impact groundwater via infiltration appears to be relatively low given the moderate levels of inorganic chemicals detected in surface water and sediments.

Sumps and Sump Outflows: Sediment samples were collected from sumps and sump outflows near buildings 1, 2, 3, 4, 94, 97, and 97A. No surface water samples were collected from these sumps, most of which are old and highly subject to leakage and therefore did not contain liquid. Inorganic and explosive chemicals were the only chemicals selected as chemicals of potential concern in the sump and sump outflow sediments. Similar inorganic and explosive chemicals were detected in the sumps and sump outflows located across the site. Very high concentrations of barium, chromium, copper, lead, and zinc were found in sumps and sump outflows. Relatively high concentrations of 2,4-DNT also were found in sumps located outside of buildings 1, 2, 3, and 4. Generally, the inorganic chemicals of potential concern will tend to partition in sediments and thus remain in their current state. Significant concentrations of inorganic chemicals of potential concern detected in sump outflows reveals that the sumps may be contributing to contamination found in the LCAAP ditch system. As previously discussed, inorganic/organic complexes also may increase the solubility of inorganic chemicals of potential concern, and hence the mobility of these metals. The increased solubility of inorganic/organic chemical complexes may result in inorganics moving from sediments into surface water, thereby resulting in their downstream transport to off-site locations. 2,4-DNT is fairly soluble in water and has a relatively low K_{oc} value, therefore 2,4-DNT may partition from sediments into surface water and therefore be transported into the ditch system and further downstream to off-site locations. However, 2,4-DNT has been shown to undergo a photolysis reaction in surface water (Burlinson and Glover, as cited in Spanggord 1980). Given the very high levels of inorganics detected in the sumps and current condition of the sump casings, the infiltration of inorganics in the sumps into groundwater is likely.

Groundwater. In general, metals are the chemicals of potential concern which are most abundant in groundwater potentially reaching production wells under current pumping conditions (see Table 5-2). Zinc and nickel are present most frequently and at the highest concentrations. A comparison of filtered and unfiltered metal samples indicates that a significant portion of zinc is dissolved and thus mobile in the subsurface environment. The data are less clear with respect to the other metals of potential concern, however.

Other chemicals of potential concern in groundwater in central site areas are chlorinated aliphatics (1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethene (total), chloroethene, methylene chloride, trichloroethene, vinyl chloride, tetrachloroethene), nitrocyclic/aromatics (RDX, 2,6-DNT, HMX, 1,3,5-TNB, 1,3-DNB, tetryl), high molecular weight PAH (pyrene, chrysene), phthalates (bis[2-ethylhexyl] phthalate), and a nitrosamine (n-nitrosodiphenylamine). Chlorinated aliphatics are highly mobile in the subsurface, and will move readily with groundwater to production wells. There is some indication that subsurface transformations are occurring due to the presence of 1,1-dichloroethane, chloroethane, 1,1-dichloroethene, trans-1,2-dichloroethene, methylene chloride, and vinyl chloride, as observed in other areas of the site.

As discussed earlier, phthalates and high molecular weight PAH are not very mobile in the subsurface, and readily adsorb to soil organic carbon and surfaces in general. The measurement of these chemicals in groundwater may be due to laboratory contamination or adsorption onto suspended sediment inadvertently collected during sampling. This is further indicated by the fact that bis(2-ethylhexyl)phthalate was measured often at concentrations greater than its solubility in water. Chrysene was also measured in groundwater far above its aqueous solubility. These chemicals, even if actually present, are not likely to migrate with groundwater.

N-nitrosodiphenylamine was measured in a groundwater sample collected in Area 12. As mentioned earlier, this compound is most frequently an analytical artifact, and is not likely to be present at the site.

The nitroaromatic compounds measured in groundwater are very mobile in the subsurface environment, and subsurface transformations also can occur under certain conditions. These compounds were not measured in soil borings or sediments in this area. Many of these compounds were measured in sediments from sumps and sump outflows.

Although several of the chemicals of potential concern measured in groundwater are mobile in the subsurface and will migrate with groundwater, the central site areas are within the cone of influence of on-site production wells, and thus migration to property boundaries will not occur.

Migration into Air. No air sampling was undertaken during the RI and therefore this discussion will assess the potential for chemicals detected in soil, sediments, and surface water to migrate into air. As discussed previously, only a limited number of soil samples were collected from a large number of potential source areas, therefore this evaluation should be considered preliminary. Only inorganic compounds were detected in subsurface borings from Areas 8, 9, 14, and 15 (with the exception of low levels of 2,6-DNT found in Area 8 subsurface soil), and surface samples collected from Areas 9 and 13 (see Table 5-6). Inorganic compounds were the primary chemicals of concern in sediment collected from the Area 13 drainage ditch, Area 16 leachate sediments, the Area 16 drainage ditch, the cattle pond located in Area 3, Ditch A, Ditch B, the Big Ditch, and the unnamed ditch (see Table

5-7). Inorganic chemicals of potential concern also were found in surface water samples collected from the above mentioned sediment sample locations (see Table 5-7). Migration into air via the vapor phase is not an important transport mechanism for the inorganic chemicals detected in the above mentioned sampled areas since these chemicals are not volatile. The potential for inorganic soil contaminants to migrate into the air via resuspension of contaminated soils through wind erosion or mechanical distribution, while possible, is not considered significant since most of these areas are generally wet or moist, vegetated, and there are no ground disturbance activities taking place at the LCAAP site.

As indicated by their Henry's Law constants, volatile organic chemicals detected in surface water samples collected from the Area 16 drainage ditch and the Big Ditch are expected to volatilize readily. However, given the limited number of areas where volatiles were found in surface water at the LCAAP site, the relatively low concentrations found in surface water, and the dilution and air dispersion of volatilized compounds; the impact to air quality across the site is likely to be low. It should be noted that areas where volatilization may have been a problem at one time (e.g., the solvent pits located in Area 17) have been closed and covered. PAHs detected in sediments in the Area 13 and Area 16 drainage ditch, the Area 16 leachate seep, the cattle pond, Ditch B, and phthalates detected in the Area 16 drainage ditch surface water and sediments, and the Ditch B surface water may volatilize to a more limited extent. High molecular weight PAHs and phthalates also have moderate to high K_{oc} that indicates that these compounds will be more strongly sorbed onto sediments thus inhibiting volatilization. The detection of PAHs and phthalates in surface water also may be due to suspension of particulates that may settle out into sediments. Therefore, the potential impact of PAHs and phthalates on air is considered to be low given their low potential to volatilize into air and dilution and dispersion of volatilized chemicals. Explosive compounds were detected infrequently and/or at low levels in surface water and sediments at the LCAAP plant (see Table 5-7), therefore the impact of these chemicals on air is considered to be low.

5.3.2 Potential Exposure Pathways

An exposure pathway (the sequence of events leading to contact with a chemical) is defined by the following four elements:

(1) a source and mechanism of chemical release to the environment;

(2) an environmental transport medium for the released chemical;

(3) a point of potential exposure by the receptor with the medium (i.e., the "exposure point"); and

(4) a route of exposure.

An exposure pathway is considered "complete" only if all these elements are present. The first two elements of an exposure pathway, a source and transport of a chemical, have been addressed above and in previous sections of this report.

In this section, the last two elements of an exposure pathway are discussed; human populations potentially exposed to site contaminants both on and off site under current and future land-use conditions are discussed, and the routes through which they may be exposed are identified. The potential for these exposures to occur is discussed below and exposure pathways selected for evaluation in this assessment. In Section 5.3.2.1, potential exposures are discussed for current land use conditions. Additional pathways potentially resulting from possible future land use conditions are discussed in Section 5.3.2.2.

It should be noted that in most of the eighteen study areas, groundwater was the only medium sampled. For the most part, relatively few samples of surface water, sediment, and soils are available compared to the number of groundwater samples collected. Areas 13 and 16 are the only on-site areas specifically sampled for, and having detectable levels of, surface water/sediment contamination. Study areas 8, 9, 13, 14, and 15 are the only areas specifically sampled for, and having detectable levels of, soil contamination.

In addition, surface water/sediment samples were collected from the plant-wide ditch system and the on-site pond located in the northwest portion of the site. Therefore, the investigation of the soils and surface water/sediments at LCAAP is considered preliminary at this stage. The exposure pathway discussions are organized by medium, with groundwater-related pathways evaluated first, followed by soil-related and surface water/sediment-related pathways. Within each medium, worker exposures are evaluated first, followed by an evaluation of potential residential exposures.

5.3.2.1 Potential Exposure Pathways Under Current Land Use Conditions

5.3.2.1.1 Overview of Current Land-Use Patterns

As discussed in Sections 1.2 and 3.9 of this report, LCAAP is a 6.2-square mile site located in a predominantly agricultural area (crop cultivation). On-site, there are approximately 11 military personnel residences located in the southwestern portion of the site in an upland area. Most of the population within one-half mile of the site reside in the small town of Lake City, consisting of approximately 12 homes beginning across the street from the northern boundary of the site (see Figure 1.2). No residences are located directly on other boundaries of the site; however, there are scattered residences located at least one-half to one mile from the northwestern and southwestern boundaries of the site, and more than one mile west of the western site boundary.

LCAAP is currently used to manufacture small arms ammunition and to store and test the firing of ammunition. Specific processes and operations taking place at various study locations throughout the site have been discussed in detail by study area in Section 4 of this report and are briefly discussed below where appropriate. Until recently, unindustrialized, flat portions of the property were leased for crops and the grazing of cattle; however, the practice was stopped in 1988. An undeveloped area located on the northeastern portion of the LCAAP property is used for recreational hunting (numerous deer, rabbits, and turkeys are present on-site) and recreational fishing (a 10-12 acre lake is located in this undeveloped area). It should be noted that this undeveloped area was not included within the RI study since no industrial operations or disposal activities have or are intended to take place there. Individuals, primarily LCAAP employees, are allowed to hunt under permit in certain unindustrialized areas of the plant property on weekends during hunting season; however, some poaching probably also occurs (personal communication with LCAAP personnel).

As discussed in Sections 3.6 and 3.8 of this report, the alluvial sand aquifer supplies all drinking water and process water for the plant. Private wells are located off site in the town of Lake City, and nearby farms may also use the alluvial sand aquifer for drinking water and agricultural purposes. In addition, off-site wells may be installed in other water-bearing, but much less productive stratigraphic zones in the vicinity of the site (i.e., the silty-clay layer, primarily overlying the alluvial aquifer for most of the site and the weathered bedrock, which contains water primarily in the upland regions of the site). However, these zones are not considered good producers of water and serve primarily as partial confining layers for the alluvial sand aquifer.

5.3.2.1.2 Groundwater-Related Exposure Pathways Under Current Land Use Conditions.

As discussed in Section 3.6, production wells installed in the alluvial aquifer on-site supply all the drinking water for the on-site facilities and residences. Therefore, the potential exposures of current residents and on-site workers in any of the facilities via ingestion of groundwater obtained from these on-site production wells are complete pathways and will be quantitatively evaluated in three ways. First, current exposure via this pathway will be evaluated using treated water monitoring data provided by LCAAP. Since the treated production well water is an actual source of drinking water for both facility workers and on-site residents, this pathway will be evaluated for both populations. From 1987, personnel at LCAAP have been monitoring production well water for VOCs, semi-volatiles, metals, and explosives. Currently, all water pumped from the production wells is sent to an on-site treatment plant prior to distribution in the plant's drinking water system. This treatment includes an aeration cell to remove volatile organic chemicals, alum flocculation for the removal of heavy metals, and chlorination treatment.

Second, exposure via ingestion to chemicals in production well water will also be evaluated using concentrations of chemicals of potential concern identified in production well groundwater before treatment. This hypothetical exposure will be evaluated quantitatively for on-site residents and semi-quantitatively (by comparison to residents which will have greater exposure) for on-site workers. These pathways are not meant to estimate risks currently posed to residents or workers; rather, it will determine the need for continued treatment of production water.

Third, the results of the pumping test conducted during the RI (Sections 3.6.4 and 3.6.5) indicated that, with the exception of groundwater located at Areas 3, 8, 16, and 17, the capture zones of these nine production wells intercept nearly all groundwater flowing through the alluvial valley. Therefore, it may be possible, that under current use patterns, the on-site production wells may receive contamination from groundwater from almost every other study area. Moreover, as noted in Section 5.3.1.2, several chemicals of potential concern in groundwater of areas within the capture zones are highly mobile (e.g., chlorinated aliphatics) and may be easily transported to the production wells. Therefore, the hypothetical ingestion of production well water under current use conditions also will be evaluated using data from wells in the capture zone, as defined above. As above, this hypothetical exposure will be evaluated quantitatively for on-site residents and semi-quantitatively for on-site workers. Since pumping of the production wells may vary with time, it is not known whether data from these monitoring wells represent concentrations that may realistically reach the production wells. For example, several of the chemicals detected in these monitoring wells (e.g., the explosive chemicals) were not present at above detection limits in production wells sampled during the RI.

According to LCAAP personnel, employee showers are located in the major manufacturing facilities on-site. Employees using these showers could be exposed to groundwater contaminants via dermal absorption and inhalation of organic chemicals volatilizing from the water during showers; however, the use of on-site showers is voluntary, and few personnel are reported to use them. Although pathways related to contact with shower water by on-site workers are not considered likely to be significant, to be conservative, potential exposure to on-site workers via inhalation of VOCs while showering will be semi-quantitatively evaluated in this assessment. On-site residents would potentially use showers more regularly. In addition, since the treated production well water is an actual source for on-site residents, the inhalation exposure of on-site residents to VOCs while showering with this treated water will be quantitatively evaluated. Limited experimental data are available for quantifying exposures and risks associated with the dermal absorption of chemicals from dilute concentrations of contaminants (e.g., as found in household water supplies) as a result of short-duration exposures (i.e., showering, washing hands, etc.). In addition, short duration exposures to contaminants in rapidly moving water are expected to be limited. Thus, the quantitative evaluation of potential exposure of on-site residents during showering with treated production well water will focus on the inhalation of VOCs.

As noted above, under current water use patterns at LCAAP (i.e., with the production wells used), the only places where groundwater may migrate off site is from Areas 3, 8, 16, and 17. Off-site residential potable wells are located just beyond the northern property line of the facility and approximately one mile off the western property line. Residential well data from 12 off-site wells are available for the residential areas located along the boundary of the facility down gradient of areas 16 and 17. This data will be used to quantitatively evaluate exposures of off-site residents using these wells. As this water is an actual supply to these residents, the quantitative evaluation will include both ingestion of the groundwater as well as the inhalation of VOCs while showering with the groundwater. No data exists for off-site residential wells downgradient of Areas 3 and 8 (western boundary). Therefore, these exposures will be preliminarily evaluated using data from monitoring wells located in Areas 3 and 8. Monitoring well data in Areas 3 (perimeter wells) and 8 (all wells were used because of the hydrogeology of Area 8) will be used to represent concentrations present in groundwater along the LCAAP boundary to the west.

5.3.2.1.3 Surface Water/Sediment-Related Exposure Pathways Under Current Land Use Conditions.

As previously noted, area-specific surface water/sediment samples were collected only from Areas 12, 13, and 16. Potential surface water/sediment-related exposure pathways in these areas, as well as pathways related to contamination in the plant-wide ditches, sumps and sump overflows, and in the on-site pond, are discussed below. As will be noted in this section, for various reasons, no human exposures to surface waters or sediments are expected in any of these areas. However, some of these areas may be acting as contributing sources of groundwater contamination. This has been discussed to the extent possible in Section 5.3.1. In addition, exposures to these media will be addressed in the environmental assessment in Section 5.6.

An indirect pathway potentially exposing persons to site-related contamination from various surface water/sediments across the site involves the ingestion of venison from deer who may use ditch and seep water for drinking or who may eat plants from contaminated areas and turkeys which also may ingest ditch and seep water for drinking. If chemicals detected in these surface waters are accumulated in edible portions of the deer and turkey, individuals eating such meat may be exposed. As mentioned in Section 3.9 of the RI, bow hunting is allowed at LCAAP and, according to LCAAP personnel 8 deer were reportedly taken under permitted hunting in 1988. In addition, turkeys also were reportedly taken in areas surrounding LCAAP (personal communication with LCAAP personnel). However, the potential for significant exposure via these pathways are considered remote for the following reasons: (1) In general, only trace concentrations of chemicals that do not bioaccumulate were of concern in surface water samples from areas deer and turkey may use as drinking water sources; (2) there is a low likelihood of significant exposure by a particular hunter (who may not kill a deer or turkey every year); (3) several other more attractive areas for deer to drink and forage and turkeys to drink exist; and (4) some areas are unvegetated (Area 9) and therefore could not be used as foraging areas. Therefore, these exposure pathways are not considered significant pathways of exposure under current land use conditions.

Direct pathways by which individuals may be exposed to contaminated surface water/sediments in particular study areas are evaluated below.

<u>Surface Water/Sediments in Area 12</u>. As discussed in Section 4.12, Area 12 contains the currently active chemical laboratory, along with the inactive chemical laboratory waste lagoon and the inactive sludge disposal area. Surface water/sediment samples were collected in this area from ditches and wastewater discharge suspected of being sources of trichloroethene contamination in the groundwater. Thus, they were analyzed only for VOC content. Based on this sampling and analysis, no chemicals of potential concern were identified in either the ditch or wastewater discharge surface water/sediment samples; therefore, although the chemistry laboratory in Area 12 is currently active, these suspected sources in this area do not appear to present any potential for worker exposure.

<u>Surface Water/Sediments in Area 13</u>. Area 13 contains Building 35, which is currently used to manufacture metal parts. As discussed in Section 4.13, the ditch sampled during the RI received drainage from Building 35. According to observations by Weston personnel, no outdoor worker activities currently take place there. Workers in Area 13 are usually outside only when walking along the sidewalk from building to building. Therefore, workers in Area 13

are not expected to directly contact surface water/sediments in this area. Additionally, exposure via inhalation of dust from contaminated sediments during periods when the ditch is dry is not considered a pathway of concern, because the ditch is vegetated and is wet most of the time, particularly near the building. With respect to potential exposure of workers who may be exposed via inhalation of chemicals volatilizing from either the surface water or the sediments, the potential for significant exposure via this pathway is considered negligible given the low (i.e., close to the detection limit) concentrations of organic chemicals detected in the surface water/sediment samples collected.

Surface Water/Sediments in Area 16. The locations in Area 16 from which surface water/sediment samples were collected are a leachate seep at the inactive abandoned landfill and a small ditch alongside the landfill. According to LCAAP personnel, there are no ongoing worker activities at this remote, highly vegetated location.

Access to Area 16 by hunters is possible, but difficult. According to LCAAP personnel, frequent use of the area by hunters is not expected, given the much larger, natural area located northeast of Areas 16 and 17, where most hunting occurs. In addition, the size of the leachate seep and ditch area is very small compared with the size of the area that may be frequented by hunters. Therefore, any exposure through direct contact or inhalation by hunters with chemicals of potential concern in surface water/sediment samples at Area 16 is not expected to be a significant exposure pathway of concern, if it were to occur at all.

Surface Water/Sediments in the Plant-Wide Ditch System. In most sampling locations, the ditches are wet and water flows for the majority of the year. Small minnows have been observed in limited portions of the bigger ditches (e.g., in part of the Big Ditch in the southwestern part of the plant near Area 8) on-site; however, no bigger fish are expected to be present in these generally shallow, intermittent waters, and no fishing is known to occur. As discussed in Section 3.6, organic chemicals detected in the surface waters and sediments of these ditches may volatilize; however, the only individuals likely to be exposed on or near these ditches are persons occasionally mowing the grass and persons walking on bridges over certain parts of the bigger ditches. In addition, concentrations of volatile chemicals detected in the surface water/sediments of these ditches were low (i.e., near the detection limit); therefore, the exposure of these individuals via inhalation of volatiles is not considered to be a significant exposure pathway. There are no ongoing activities in or near the ditches; therefore, the potential for direct contact with chemicals of potential concern in the surface water/sediments of the ditches is considered negligible. Finally, inhalation of dust from these ditches is not a concern since the ditches are normally wet and there are no ongoing activities in the area.

<u>Sediment Samples From Sumps and Sump Overflows</u>. No surface water samples were collected from the sumps and sump overflow areas sampled during the RI. The primary concern for sediments in the sumps located across the site are their potential to be sources of ditch contamination since flow through the sumps generally discharges to the plant-wide ditch system. Sections 4.21 and 5.3.1.2 contains an qualitative evaluation of the potential migration of sump contaminants to surface water on-site. As indicated by the presence of chemicals of potential concern in the sump overflow samples (i.e., at points of discharge to ditches), contamination in the sumps may be reaching the ditch system. However, as noted above for the plant-wide ditches, there are currently no human exposure pathways of concern to contaminants in the ditches and at the sump outflow points. As discussed in Section 4, all floor drains and sinks leading to the sumps were plugged or removed in 1982. Although many of the sumps actively receive wastewater, the sumps are not maintained; therefore, there is no potential for individuals to directly contact chemicals of potential concern in the sumps themselves. In addition, the sumps themselves are located in manholes beneath the site. Therefore, no human exposures to sump sediments are expected under current land use conditions.

Surface Water/Sediment Samples in the On-Site Pond. According to Section 4.19.1, the on-site pond was installed for the purposes of watering the cattle that until recently were allowed to graze on-site. No current exposures (e.g., direct contact) with the inorganic chemicals detected in the one surface water sample or the inorganics and PAHs of concern in the one pond sediment sample are expected, since the pond is not currently in use. According to LCAAP personnel (personal communication), the pond is not stocked; therefore, no fishing takes place there. No other human recreational activities (i.e., picnicking) are known to occur in or near the pond (personal communication with LCAAP personnel). Based on this information, no human exposures to pond surface water/sediment contaminants are expected under current land use conditions.

5.3.2.1.4 Soil-Related Exposure Pathways Under Current Land Use Conditions

As previously noted, area-specific soil samples were collected only from Areas 8, 9, 13, 14, and 15. Potential soil-related exposure pathways in these areas are discussed below. As will be noted on reading this section, for various reasons no human exposures are expected to soils in any of these areas. However, some of these areas may be acting as contributing sources of groundwater contamination. This has been discussed to the extent possible in Section 5.3.1. In addition, exposures to these media will be addressed in the environmental assessment in Section 5.6. It should be noted that potential risk to on-site remediation workers (and exposure to on-site plant workers resulting from remediation activities) will not be evaluated in this assessment. This type of evaluation is not in the scope of a baseline risk assessment which evaluates the no-action alternative.

Surface and Subsurface Soils at Area 9. As discussed in Section 4.9, Area 9 holds the currently inactive Building 60 treatment facility, used in the past for the treatment of cyanide wastewaters and the treatment of mercurous nitrate wastes generated by testing procedures for small arms cartridges. This area contains several percolation sumps (Area 9A, included above in the discussion of sumps and sump overflows throughout the site, see Section 4.9.1.1) and five inground concrete storage tanks (that once contained mercurous nitrate sludges) (Area 9B, see Section 4.9.1.2). A fence surrounds the area of the mercury waste tanks and the area is closed off from general entry due to RCRA closure activities; therefore, there is no potential for direct contact with surface soil contaminants in this area under current land use conditions. A wastewater treatment plant maintenance station (Building 61) is located inside the fence; however, according to LCAAP personnel, this station is primarily used for storage, and only a few, if any, personnel visit the building and the surrounding areas for more than a short period once a week to pick up or store equipment. Therefore, although the potential for dust generation and direct contact with soils exists (although most of the area soils are covered by a layer of stones, portions are bare), exposures of workers to soil contaminants under current land use conditions in this inactive area are considered negligible and will not be further evaluated.

Surface Soils in Area 13. No subsurface soil samples were collected in Area 13. The surface soil samples collected in Area 13 were collected from the open waste drainage area that in the past received drainage from Building 35, which is currently used to manufacture metal parts. According to Weston personnel, this drainage area is located 25 to 40 feet away from the building in an area where no current ongoing outdoor activities take place, although the field is infrequently mowed. The potential for direct contact with chemicals of potential concern in this area by workers, therefore, is considered negligible. Inhalation of dust by workers in the vicinity of the field is not a pathway of concern since the field is well vegetated. Finally, only inorganic chemicals of potential concern were identified in the soils of this area; therefore, no volatiles would be emitted from this area.

Subsurface Soils in Areas 8, 14, and 15. Only subsurface soil samples were collected in Areas 8, 14, and 15. As discussed in Section 4.8, Area 8 is the Industrial Waste Treatment Plant (IWTP) waste disposal area and contains four inactive sludge disposal areas (areas 8A, 8B, 8C, 8D - see Sections

4.8.1.1, 4.8.1.2, 4.8.1.3, and 4.8.1.4), several oil and grease disposal trenches (Area 8E - see Section 4.8.1.5), and a currently operating IWTP solid waste disposal facility (Area 8F - see Section 4.8.1.6). As discussed in Section 4.14, Area 14 is the inactive fuel tank burning ground (area 14A, where no RI field investigation activities were conducted - see Section 4.14.1.1) and the sludge disposal area (area 14 B - see Section 4.14.1.2). As discussed in Section 4.15, Area 15 is a small inactive surface impoundment used in the past to temporarily hold wastes from Buildings 35, 90C, and 90D when certain repairs were taking place.

Areas 8, 14 and 15 are located in remote portions of the site, and no current activities that disturb the subsurface soils are known to take place. Therefore, there is no potential for exposure via pathways involving direct contact with soils or inhalation of airborne chemicals of potential concern originating from subsurface soils of these areas.

5.3.2.2 Future Land Use

5.3.2.2.1 Overview of Future Land-Use Patterns

Several items concerning possible future land use at LCAAP should be noted. LCAAP is not listed among the DOD installations that were recommended for closure in a 1988 report to the U.S. Congress. According to LCAAP personnel, there is a possibility that the plant may be expanded in the future to allow for the production of 35-mm ammunition on-site. This expansion could significantly increase the size of the industrialized portion of the property. Future construction activities in certain study areas are therefore conceivable, and construction workers in particular may be exposed to contamination in various media if building activities occur on or near study areas of potential concern. As noted by LCAAP personnel, no definite plans concerning this development, including locations of potential future development, have been decided, but such development could occur in the future.

LCAAP personnel expect that, for the most part, future land-use patterns of the areas studied at the site during the RI will not differ significantly from current use. In addition, most of the study areas have been inactive for a number of years and are expected to remain inactive indefinitely. The few additional exposure pathways potentially occurring under future land use conditions are discussed by media below.

5.3.2.2.2 Additional Groundwater-Related Exposure Pathways Under Future Land Use Conditions.

Groundwater at each study area constitutes a resource that could be used for potable water in the future. This scenario, however, is considered highly unlikely given other, more reasonable locations for future on-site well development. However, to evaluate groundwater as a resource in each of these source areas, the ingestion of water by future on-site residents from wells that in the future may be installed downgradient of each study area will be quantitatively evaluated using concentrations given in Table 5-4. Evaluation of the future potential exposure to on-site residents from ingestion of groundwater downgradient of each of the suspected source areas also will provide information concerning specific source areas that may be contributing significantly to groundwater contamination.

Although unlikely, if future production well use on-site were to significantly diminish from current use or cease completely in the future (i.e., if the plant were to shut down), then groundwater from beneath study areas at the site could potentially migrate off site. No information concerning flow patterns under these conditions or off-site hydrogeological characteristics is available. Therefore, the future exposure of residents downgradient from the site under the conditions of limited or no production well activity on-site can not be quantitatively evaluated in this assessment.

5.3.2.2.3 Additional Surface Water/Sediment-Related Exposure Pathways of Concern Under Future Land Use Conditions

Future surface water/sediment-related exposure pathways are not expected to significantly differ from those discussed under current land use patterns. Future development or disturbance of the ditch system or the sumps on-site is not expected, and land use patterns in Areas 13 and 16 are not expected to change. It should be noted that the potential future land development is not expected to significantly alter the surface water/sediment-related exposures of future on-site workers at the new buildings since ongoing worker activities would take place <u>inside</u> the new buildings; no significant ongoing outdoor worker activities are expected under hypothetical future land use conditions. Therefore, no additional pathways will be quantitatively evaluated for these media.

5.3.2.2.4 Additional Soil-Related Exposure Pathways Under Future Land Use Conditions

The only additional population potentially exposed under hypothetical future land use conditions are construction workers, who may directly contact contaminated soils or inhale dust generated during construction activities if plant expansion in various study areas is undertaken. Inhalation of volatiles from soils under future land use conditions is not considered important given the infrequent and low (i.e., near the detection limit) concentrations of organic chemicals detected in the soils of study areas sampled during the RI. Although unlikely, if future development takes place in the western undeveloped portions of the plant property, the subsurface soils in Area 8 may be disturbed. The limited data available in this preliminary study indicate contamination with at least one explosive (2,6-DNT at trace levels) and several inorganics. Although future development is considered less likely, soils in other study areas for which only limited data also are available, Area 14, and Area 15 also may be disturbed if future development takes place Based on discussions with LCAAP personnel, future development of Area 9, an area where more extensive soil sampling was undertaken (nine surface and nine subsurface soil samples from a 10,000-ft^2 area), is highly unlikely since the area is currently undergoing RCRA closure. Therefore, future exposures to contaminants in Area 9 is highly unlikely. These potential future exposure pathways will not be quantitatively evaluated at this time given (1) the generally preliminary nature of the soil sampling to date in these three areas, and (2) the low probability that future development will take place in these waste disposal areas. However, a qualitative assessment of available soil monitoring data will be conducted. It is recommended that these pathways of concern be evaluated quantitatively in the future once the contamination in surface and subsurface soils has been fully characterized.

It should be noted that the potential future land development is not expected to significantly alter the soil-related exposures of future on-site operating LCAAP personnel, since ongoing worker activities would take place inside the new buildings; once the expansion is complete, no significant ongoing outdoor worker activities are expected under hypothetical future land use conditions.

5.3.2.3 Exposure Pathways to be Quantitatively Evaluated

Based on the discussion above, the following human exposure pathways, summarized in Table 5-19, will be quantitatively evaluated in Section 5.5:

- ingestion of treated water from the LCAAP production wells by on-site workers and residents, and inhalation of VOCs while showering with treated water by on-site residents (using finished water data provided by LCAAP);
- hypothetical ingestion of groundwater from the production wells (before treatment) by on-site residents (using RI production well data) (inhalation exposure via showering and exposure to on-site workers will be semi-quantitatively evaluated);
- hypothetical ingestion of groundwater by on-site residents using groundwater data from wells in production well capture zone assuming no treatment of groundwater (all on-site areas except areas 3, 8, 16, 17) (inhalation exposure via showering and exposure to on-site workers will be semi-quantitatively evaluated);

TABLE 5-19

POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE EVALUATED QUANTITATIVELY
LAKE CITY, MISSOURI

Potentially Exposed Population	Potential Exposure Pathway	Likelihood of Exposure	Adequacy of Data to Support Exposure Estimates
On-site workers and residents (a)	Ingestion of treated water from production wells and inhalation exposures while showering	High, since water supply for all facility workers and on-site residents.	Treated water data provided by LCAAP will be used to evaluate current exposures.
	Ingestion of untreated water from production wells and inhalation exposures while showering	Low, since treatment plant currently removes volatiles and metals from groundwater.	Data from RI production well sampling are considered adequate for quantitative evaluation.
	Ingestion of untreated water from production well capture zone and inhalation exposures while showering	Low, since treatment plant currently removes volatiles and metals from groundwater and contaminants must migrate to production wells.	Data from RI monitoring well sampling are considered adequate for quantitatie evaluation.
Residents using sampled wells located off-site just north of the LCAAP boundary	Ingestion of groundwater from off-site residential wells and inhalation exposures while showering	High, since water supply for all off-site residents.	Data from the residential wells sampled are considered adequate for quantitative evaluations of these wells.
Residents located off-site downgradient of Area 3 and 8	Ingestion of groundwater located beyond the western property line of the LCAAP site and inhalation exposures while showering	Unknown. Residents located downgradient of Areas 3 and 8 are at least 1/2 mile away.	No off-site residential well data are available for off-site locations downgradient from Areas 3 and 8. On-site perimeter monitoring well data are considered adequate for a preliminary assessment of this exposure pathway, but will likely overestimate residential exposure point concentrations.
Future on-site workers and residents (a)	Ingestion of groundwater directly downgradient of sources in each study area and inhalation exposures while showering	Low, since it is unlikely that wells will be installed in these areas.	Data from monitoring wells directly downgradient of potential sources in each study area are considered adequate to quantitatively evaluate the potential degradation of groundwater quality in each study area and to assist in identifying source areas of particular concern.

(a) Since current ingestion of untreated water from production wells and production well capture zones and future ingestion of groundwater downgradient of sources in each study area are hypothetical exposure pathways, these pathways will only be evaluated for one population, on-site residents, (facility workers will be evaluated semi-quantitatively).

- ingestion and inhalation of VOCs while showering with groundwater by residents in off-site areas located along the northern border of the LCAAP using data from the residential wells sampled during the RI;

- ingestion of groundwater by residents located approximately 1 mile west of the LCAAP plant (using data collected at the perimeter of Area 3 and data from Area 8). This assessment will be preliminary since perimeter data is used in the absence of data from this off-site residential area (inhalation exposure via showering will be semi-quantitatively evaluated); and

- hypothetical ingestion of groundwater by on-site residents from wells that in the future may be installed downgradient of each study area (using data from monitoring wells located directly downgradient of each study area) (inhalation exposure via showering and exposure to on-site workers will be semi-quantitatively evaluated).

To quantitatively assess exposure via these pathways, the chronic daily intake (CDI) of each chemical of potential concern is estimated. CDIs are expressed as the amount of a substance taken into the body per unit body weight per unit time, or mg/kg-day. A CDI is averaged over a lifetime for carcinogens and over the exposure period for noncarcinogens. CDIs are estimated using concentrations of chemicals at exposure points together with other exposure parameters specifically describing the exposure pathway. The assumptions used in evaluating exposure to both on- and off-site residents via ingestion of groundwater are presented in Table 5-20 and are based on EPA (1989) where possible. In other instances, best professional judgement and site-specific information are used. The assumptions used in evaluating exposure to on-site workers via ingestion of groundwater are presented in Table 5-21.

Based on recent EPA guidance on risk assessment (EPA 1989), exposures are quantified by estimating the reasonable maximum exposure (RME) associated with the pathway of concern. The RME is intended to represent a possible upper bound exposure to a typical individual. It is derived by combining reasonable maximum exposure estimates with upper bound toxicity criteria. The RME for a given pathway is derived by combining the upper 95 percent confidence limit of

TABLE 5-20

ASSUMPTIONS USED TO CALCULATE GROUNDWATER EXPOSURES FOR CURRENT RESIDENTS AT LCAAP LAKE CITY, MISSOURI

Parameter	Reasonable Maximum Exposure Case
Exposure duration (a)	70 years
Exposure frequency	365 days/year
Ingestion rate (a)	2 l/day
Body weight (a)	70 kg

(a) EPA 1989a.

TABLE 5-21

ASSUMPTIONS USED TO CALCULATE GROUNDWATER EXPOSURES FOR WORKERS AT LCAAP LAKE CITY, MISSOURI

Parameter	Reasonable Maximum Exposure Case
Exposure duration (a)	20 years
Exposure frequency (b)	241 days/year
Ingestion rate	1 l/day
Body weight (c)	70 kg

(a) Based on site specific information provided by Roy F. Weston personnel.
(b) Assuming a 5-day work week, 9 holidays, and 10 vacation days.
(c) EPA 1989a.

the arithmetic mean concentration for each chemical with reasonable maximum values describing the extent, frequency, and duration of exposure (EPA 1989).

A statistical test developed by Land (1971, 1975) was used to estimate the upper 95 percent confidence interval of the arithmetic mean assuming a log-normal distribution. This approach was used because studies have shown that environmental contaminants tend to be log-normally distributed in nature (Dean 1981, Ott 1988). The 95 percent upper confidence on the arithmetic mean concentrations for the pathways which are being quantitatively evaluated are presented in Tables 5-22 through 5-28. The equation for calculating the 95th UCL on the arithmetic mean is presented below (Land 1971, 1975):

$$UL_{(95th)} = EXP\ [AM + (0.5\ x\ VAR) + \left(\frac{(STD\ x\ H_{(95th)})}{(N-1)^{1/2}}\right)]$$

where

UL - 95th UCL on the arithmetic mean;

EXP - the anti-natural log of the sum of the parameters within the brackets;

AM - the arithmetic mean of the natural log transformed data;

VAR - the varience of the natural log transformed data;

STD - the standard deviation of the natural log tranformed data;

H - tabular value which is based on the degrees of freedom and varience of the data for the 95th percentile of the H distribution (Land 1971, 1975); and

N - sample size.

Also presented in these tables is the maximum detected concentration for each chemical of potential concern. In certain instances, the calculated upper 95 percent confidence limit on the mean exceeds the maximum concentration detected for a particular chemical. This often happens when the variance of the data is large and the sample size is small. In these cases, the maximum

TABLE 5-22

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF TREATED GROUNDWATER BY ON-SITE WORKERS LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
Chemicals with Potential Carcinogenic Effects				
Organics:				
Bromodichloromethane	3.4	8	8	2.2E-05
Bromoform	2.3	1600	5	1.3E-05
Chloroform	2.5	3.8	3.4	9.2E-06
Dibromochloromethane	4.9	9.1	9	2.4E-05
Trichloroethene	1.1	2.6	2.7	7.0E-06
Radionuclides (pCi/L):				
Ra226 and Ra228	-- (d)	3	3	1.4E+04
Chemicals With Noncarcinogenic Effects				
Organics:				
Bromodichloromethane	3.4	8	8	7.5E-05
Bromoform	2.3	5	5	4.7E-05
Chloroform	2.5	3.8	3.4	3.2E-05
1,2-Dichloroethene (total)	2.3	14	9.7	9.1E-05
Dibromochloromethane	4.9	9.1	9	8.5E-05
1,1,1-Trichloroethane	0.2	0.2	1.5	1.9E-06
Trichloroethene	1.1	2.6	2.7	2.5E-05
Inorganics (a):				
Mercury	0.3	2.1	0.7	6.6E-06
Silver	8	-- (e)	8	7.5E-05
Thallium	39	-- (e)	75	7.1E-04
Radionuclides (pCi/L):				
Alpha	4.5	8	8	3.9E+04
Beta	6.5	10	10	4.8E+04

(a) Chemicals are grouped with respect to toxicity criteria because such classifications determine the way chronic daily intakes are calculated. See Sections 5.3.3 and 5.4 for further discussion and Table 5-29.

(b) Maximum detected concentration; used if the upper confidence limit exceeded the maximum or could not be calculated due to an insufficient number of samples. See text.

(c) Chronic daily intakes were calculated assuming that this chemical is noncarcinogenic.

(d) Arithmetic mean was not calculated since only one sample was available.

(e) There were not enough samples to calculate the upper 95th percent confidence limit on the arithmetic mean.

TABLE 5-23

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF TREATED GROUNDWATER BY ON-SITE RESIDENTS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b) (c)
Chemicals with Potential Carcinogenic Effects				
Organics:				
Bromodichloromethane	3.4	8	8	2.3E-04
Bromoform	2.3	1600	5	1.4E-04
Chloroform	2.5	3.8	3.4	9.7E-05
Dibromochloromethane	4.9	9.1	9	2.6E-04
Trichloroethene	1.1	2.6	2.7	7.4E-05
Radionuclides (pCi/L):				
Ra226 and Ra228	-- (d)	-- (e)	3	1.5E+05
Chemicals With Noncarcinogenic Effects				
Organics:				
Bromodichloromethane	3.4	8	8	2.3E-04
Bromoform	2.3	1600	5	1.4E-04
Chloroform	2.5	3.8	3.4	9.7E-05
1,2-Dichloroethene (total)	2.3	14	9.7	2.8E-04
Dibromochloromethane	4.9	9.1	9	2.6E-04
1,1,1-Trichloroethane	0.2	0.2	1.5	5.7E-06
Trichloroethene	1.1	2.6	2.7	7.4E-05
Inorganics (d):				
Mercury	0.3	2.1	0.7	2.0E-05
Silver	8	-- (e)	8	2.3E-04
Thallium	39	-- (e)	75	2.1E-03

(a) Chemicals are grouped with respect to toxicity criteria because such classifications determine the way chronic daily intakes are calculated. See Sections 5.3.3 and 5.4 for further discussion and Table 5-29.

(b) Maximum detected concentration; used if the upper confidence limit exceeded the maximum or could not be calculated due to an insufficient number of samples. See text.

(c) CDIs calculated only for chemicals with toxicity criteria.

(d) Total inorganics were used to estimate exposure and risk. In some cases, the dissolved concentration was used when the dissolved concentration exceeded total concentrations.

(e) There were not enough samples to calculate the upper 95th percent confidence limit on the arithmetic mean.

TABLE 5-24

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF UNTREATED GROUNDWATER FROM PRODUCTION WELLS BY CURRENT ON-SITE RESIDENTS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Toxicity Class/Chemical (a)	Concentration			RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	
Chemicals with Potential Carcinogenic Effects				
Organics:				
Benzene	0.4	0.5	1.4	1.4E-05
bis(2-Ethylhexyl)phthalate	19	24	200	6.9E-04
Trichloroethene	2.4	4	26	1.1E-04
Vinyl Chloride	27	29	350	8.3E-04
Inorganics:				
Arsenic (total)	6.1	8.6	11.2	2.5E-04
Beryllium (total)	0.1	0.1	0.2	2.9E-06
Radionuclides (pCi/L):				
U-234	0.3	1.2	0.9	4.6E+04
U-238	0.3	0.7	0.5	2.6E+04
Chemicals With Noncarcinogenic Effects				
Organics:				
trans-1,2-Dichloroethene	1	1.1	2.2	3.1E-05
bis(2-Ethylhexyl)phthalate	19	24	200	6.9E-04
Trichloroethene	2.4	4	26	1.1E-04
Inorganics(d):				
Arsenic	6.1	8.6	11.2	2.5E-04
Barium	520	1100	655	1.9E-02
Beryllium	0.1	0.1	0.1	2.9E-06
Nickel	14	24	57.6	6.9E-04
Silver	0.2	0.3	0.7	8.6E-06
Zinc	88	520	369	1.1E-02
Chemicals Without Toxicity Criteria (c)				
Inorganics:				
Copper (total)	7.4	27	22.8	
Lead (total)	1.4	3.3	1.6	

(a) Chemicals are grouped with respect to toxicity criteria because such classifications determine the way chronic daily intakes are calculated. See Sections 5.3.3 and 5.4 for further discussion and Table 5-29.

(b) Maximum detected concentration used to calculate the CDI if the upper confidence limit exceeded the maximum or could not be calculated due to an insufficient number of samples. See text.

(c) CDIs calculated only for chemicals with toxicity criteria.

(d) Total inorganics were used to estimate exposure and risk. In some cases, the dissolved concentration was used when the dissolved concentration exceeded total concentrations.

TABLE 5-25

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER FROM PRODUCTION WELL CAPTURE ZONE BY RESIDENTS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
Chemicals With Potential Carcinogenic Effects				
Organics:				
Benzene	0.3	0.3	0.9	8.6E-06
Chrysene (Carcinogenic PAH)	5.4	5.3	70	1.5E-04
2,4-DNT	0.3	0.3	0.6	8.6E-06
2,6-DNT	0.3	0.3	0.8	8.6E-06
1,1-Dichloroethane	2.8	2.8	20	8.0E-05
1,2-Dichloroethane	2.6	2.6	20	7.4E-05
1,1-Dichloroethene	2.6	2.6	15	7.4E-05
bis(2-Ethylhexyl)phthalate	41	27	1,000	7.7E-04
Methylene Chloride	5	-- (d)	5	1.4E-04
N-nitrosodiphenylamine	5	5.1	10	1.5E-04
RDX	8.8	3.9	770	1.1E-04
Trichloroethene	0.7	0.4	42	1.1E-05
Vinyl Chloride	2	2.1	10.2	6.0E-05
Inorganics:				
Arsenic (total)	6.5	6.1	110	1.7E-04
Beryllium (total)	0.9	1.1	12	3.1E-05
Radionuclides (pCi/L):				
U-234	0.8	1.5	1.5	7.7E+04
U-238	0.6	0.9	0.9	4.6E+04
Chemicals With Noncarcinogenic Effects				
Organics:				
1,3-DNB	0.3	0.3	1.7	8.6E-06
1,1-Dichloroethane	2.8	2.8	20	8.0E-05
1,1-Dichloroethene	2.6	2.6	15	7.4E-05
trans-1,2-Dichloroethene	3.4	1.3	362	3.7E-05
bis(2-Ethylhexyl)phthalate	41	27	1,000	7.7E-04
HMX	1	0.9	28	2.6E-05
Methylene Chloride	5	-- (d)	5	1.4E-04
RDX	8.8	3.9	770	1.1E-04
1,3,5-TNB	0.7	0.4	22	1.1E-05
1,1,1-Trichloroethane	2.6	2.6	7	7.4E-05
Trichloroethene	0.7	0.4	42	1.1E-05
Inorganics:				
Antimony (total)	2.5	2.2	77.2	6.3E-05
Arsenic (total)	6.5	6.1	110	1.7E-04
Barium (total)	370	400	3,030	1.1E-02
Beryllium (total)	0.9	1.1	12	3.1E-05
Cadmium (total)	5.9	5.1	130	1.5E-04
Chromium (total)	60	39	3,800	1.1E-03
Mercury (dissolved)	0.1	0.1	0.2	2.9E-06
Nickel (total)	61	71	472	2.0E-03
Selenium (total)	2.8	2.8	24.2	8.0E-05
Silver (total)	0.3	0.2	8.2	5.7E-06
Zinc (dissolved)	340	700	2,600	2.0E-02

TABLE 5-25 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER FROM PRODUCTION WELL CAPTURE ZONE BY RESIDENTS LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
Chemicals Without Toxicity Criteria (d)				
Organics:				
Tetryl	0.4	0.4	3.5	
Inorganics:				
Copper (total)	23	29	250	
Lead (total)	10	11	260	

(a) Chemicals are grouped with respect to toxicity criteria because such classifications determine the way chronic daily intakes are calculated. See Sections 5.3.3 and 5.4 for further discussion and Table 5-29.

(b) Maximum detected concentration; used if the upper confidence limit exceeded the maximum or could not be calculated due to an insufficient number of samples. See text.

(c) CDIs calculated only for chemicals with toxicity criteria.

(d) There were not enough samples to calculate the upper 95th percent confidence limit on the arithmetic mean.

TABLE 5-26

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER BY OFF-SITE RESIDENTS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Toxicity Class/Residential Well/Chemical (a)	Maximum Concentration	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)
Chemicals with Potential Carcinogenic Effects		
Hedrickj-A		
RDX	3.4	9.7E-05
Turley		
RDX	2.8	8.0E-05
Ure		
Carbon tetrachloride	1.1	3.1E-05
1,4-Dichlorobenzene	2.2	6.3E-05
RDX	2.8	8.0E-05
Trichloroethene	1.2	3.4E-05
Chemicals With Noncarcinogenic Effects		
Danner		
HMX	4.1	1.2E-04
Barium	54.5	1.6E-03
Mercury	0.4	1.1E-05
Zinc	45	1.3E-03
Fergeson		
Barium	58.1	1.7E-03
Mercury	0.4	1.1E-05
Zinc	578	1.7E-02
Hedrickj-A		
HMX	8.5	2.4E-04
RDX	3.4	9.7E-05
Barium	167	4.8E-03
Mercury	0.4	1.1E-05
Zinc	165	4.7E-03
Hedrickj-B		
HMX	7	2.0E-04
Barium	77.7	2.2E-03
Mercury	0.5	1.4E-05
Zinc	31.9	9.1E-04
Hedrickv		
HMX	5	1.4E-04
Barium	68.3	2.0E-03
Zinc	331	9.5E-03

TABLE 5-26 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER BY OFF-SITE RESIDENTS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Toxicity Class/Residential Well Chemical (a)	Maximum Concentration	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)
Lirely		
HMX	4.6	1.3E-04
Barium	89.3	2.6E-03
Mercury	0.4	1.1E-05
Zinc	20.5	5.9E-04
Pennington		
HMX	5.5	1.6E-04
Barium	91.2	2.6E-03
Mercury	0.4	1.1E-05
Zinc	28.7	8.2E-04
Tcarlton		
Barium	80.1	2.3E-03
Turley		
HMX	5.9	1.7E-04
RDX	2.8	8.0E-05
Barium	69	2.0E-03
Mercury	0.4	1.1E-05
Zinc	174	5.0E-03
Ure		
Carbon tetrachloride	1.1	3.1E-05
1,2-Dichlorobenzene	12.4	3.5E-04
1,4-Dichlorobenzene	2.2	6.3E-05
HMX	7.1	2.0E-04
RDX	2.8	8.0E-05
Trichloroethene	1.2	3.4E-05
Barium	45	1.3E-03
Mercury	0.4	1.1E-05
Zinc	37.6	1.1E-03
Carlton		
HMX	6.2	1.8E-04
Barium	119	3.4E-03
Mercury	0.4	1.1E-05
Zinc	75.2	2.1E-03
Well North of Area 17		
Toluene	1	2.9E-05
Chromium	91	2.6E-03
Nickel	20	5.7E-04
Zinc	310	8.9E-03

TABLE 5-26 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER BY OFF-SITE RESIDENTS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Toxicity Class/Residential Well Chemical (a)	Maximum Concentration	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)
Chemicals Without Toxicity Criteria (b)		
Danner		
Copper	42.8	1.2E-03
Fergeson		
Copper	13.1	3.7E-04
Lead	4	1.1E-04
Hedrickj-A		
Copper	26.3	7.5E-04
Hedrickj-B		
Copper	7.9	2.3E-04
Hedrickv		
Copper	9.6	2.7E-04
Lirely		
Copper	6.6	1.9E-04
Tcarlton		
Lead	2.3	6.6E-05
Turley		
Copper	15.8	4.5E-04
Well North of Area 17		
Copper	37	1.1E-03

(a) Chemicals are grouped with respect to toxicity criteria because such classifications determine the way chronic daily intakes are calculated. See Sections 5.3.3 and 5.4 for further discussion.

(b) Chronic daily intakes were calculated assuming that these chemicals are noncarcinogenic.

TABLE 5-27

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF SITE PERIMETER GROUNDWATER BY OFF-SITE RESIDENTS LOCATED WEST OF LCAAP LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
Chemicals With Potential Carcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	630	69	20,000	2.0E-03
N-nitrosodiphenylamine	5.3	5.6	10	1.6E-04
RDX	5.7	3	120	8.6E-05
Trichloroethene	2.2	1.2	35	3.4E-05
Inorganics:				
Arsenic (total)	5.4	6.9	15.1	2.0E-04
Beryllium (total)	1.1	3.1	6	8.9E-05
Radionuclides (pCi/L):				
U-234	1	1.9	1.9	9.7E+04
U-235	0.1	0.1	0.1	5.1E+03
U-238	0.8	1.7	1.7	8.7E+04
Chemicals With Noncarcinogenic Effects				
Organics:				
trans-1,2-Dichloroethene	6.8	4.6	94	1.3E-04
bis(2-Ethylhexyl)phthalate	630	69	20,000	2.0E-03
HMX	0.8	0.8	3	2.3E-05
RDX	5.7	3	120	8.6E-05
Toluene	3.3	3.6	15	1.0E-04
Trichloroethene	2.2	1.2	35	3.4E-05
Inorganics:				
Antimony (dissolved)	2.2	2.4	17.5	6.9E-05
Arsenic (total)	5.4	6.9	15.1	2.0E-04
Barium (total)	450	640	1470	1.8E-02
Beryllium (total)	1.1	3.1	6	8.9E-05
Cadmium (total)	3.2	3.5	14	1.0E-04
Chromium (total)	57	76	363	2.2E-03
Nickel (total)	58	100	193	2.9E-03
Mercury (total)	0.1	0.1	0.5	2.9E-06
Silver (total)	0.2	0.3	2.2	8.6E-06
Zinc (dissolved)	270	940	1,400	2.7E-02
Chemicals Without Toxicity Criteria				
Inorganics:				
Copper (dissolved)	4.2	5.8	41.3	
Copper (total)	63	120	780	
Lead (dissolved)	2.8	3	28.1	
Lead (total)	16	32	90	

(a) Chemicals are grouped with respect to toxicity criteria because such classifications determine the way chronic daily intakes are calculated. See Sections 5.3.3 and 5.4 for further discussion and Table 5-29.

(b) Maximum detected concentration; used if the upper confidence limit exceeded the maximum or could not be calculated due to an insufficient number of samples. See text.

(c) CDIs calculated only for chemicals with toxicity criteria.

(d) Total inorganics were used to estimate exposure and risk. In some cases, the dissolved concentration was used when the dissolved concentration exceeded total concentrations.

TABLE 5-28

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 1				
Chemicals With Potential Carcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	14	33	70	9.4E-04
RDX	0.6	1	1.9	2.9E-05
Inorganics:				
Arsenic (total)	32	310	110	3.1E-03
Beryllium (total)	0.4	3.1	1.1	3.1E-05
Chemicals With Noncarcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	14	33	70	9.4E-04
RDX	0.6	1	1.9	2.9E-05
Inorganics:				
Antimony (total)	9.1	21	77.2	6.0E-04
Arsenic (total)	32	310	110	3.1E-03
Barium (dissolved)	220	330	400	9.4E-03
Beryllium (total)	0.4	3.1	1.1	3.1E-05
Cadmium (total)	3.5	4.8	11.8	1.4E-04
Mercury (dissolved)	0.1	0.1	0.2	2.9E-06
Nickel (total)	44	120	226	3.4E-03
Silver (total)	0.9	3.1	7.8	8.9E-05
Zinc (total)	350	1,000	1,200	2.9E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	22	94	52	
Lead (total)	8.6	38	41.6	
AREA 2				
Chemicals With Potential Carcinogenic Effects				
Organics:				
2,6-DNT	0.3	0.4	0.7	1.1E-05
bis(2-Ethylhexyl)phthalate	92	500	500	1.4E-02
RDX	0.7	1	4.7	2.9E-05
Inorganics:				
Arsenic (total)	4.3	6.7	9	1.9E-04
Beryllium (total)	0.4	3.3	1.4	4.0E-05
Chemicals With Noncarcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	92	500	500	1.4E-02
RDX	0.7	1	4.7	2.9E-05

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF
GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 2 (continued)				
Chemicals With Noncarcinogenic Effects				
Inorganics:				
Arsenic (total)	4.3	6.7	9	1.9E-04
Beryllium (total)	0.4	1.4	1.4	4.0E-05
Cadmium (total)	23	190	130	3.7E-03
Chromium (total)	22	27	51.9	7.7E-04
Nickel (total)	35	110	82.7	2.4E-03
Selenium (total)	3.3	4.5	10.8	1.3E-04
Silver (total)	0.4	0.9	1.6	2.6E-05
Zinc (dissolved)	300	3,400	1,200	3.4E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	22	50	87	
Lead (dissolved)	1.8	25	3.9	
AREA 3				
Chemicals With Potential Carcinogenic Effects				
Organics:				
2,4-DNT	0.3	0.4	0.6	1.1E-05
1,1-Dichloroethene	3.6	5.5	11	1.6E-04
bis(2-Ethylhexyl)phthalate	9.4	18	40	5.1E-04
RDX	22	45000	120	3.4E-03
Inorganics:				
Arsenic (total)	6.3	15	15.1	4.3E-04
Beryllium (total)	0.4	5.6	1.3	3.7E-05
Radiological Parameters (pCi/L):				
U-234	0.2	0.7	0.7	3.6E+04
U-238	0.2	0.8	0.8	4.1E+04
Chemicals With Noncarcinogenic Effects				
Organics:				
1,1-Dichloroethene	3.6	5.5	11	1.6E-04
bis(2-Ethylhexyl)phthalate	9.4	18	40	5.1E-04
HMX	1.1	1.9	3	5.4E-05
RDX	22	45000	120	3.4E-03
Inorganics:				
Arsenic (total)	6.3	15	15.1	4.3E-04
Barium (total)	530	5,200	1,180	3.4E-02
Beryllium (total)	0.4	5.6	1.3	3.7E-05
Chromium (total)	64	250	189	5.4E-03
Nickel (dissolved)	27	170	131	3.7E-03
Silver (total)	0.1	0.2	0.2	5.7E-06

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF
GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 3 (continued)				
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	23	49.6	49.6	
Lead (total)	9.8	29.8	29.8	
AREA 4				
Chemicals With Potential Carcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	6.3	11	10	2.9E-04
RDX	0.8	38	2.3	6.6E-05
Inorganics:				
Arsenic (total)	3.2	5.9	5.3	1.5E-04
Chemicals With Noncarcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	6.3	11	10	2.9E-04
HMX	1.3	12	3.2	9.1E-05
RDX	0.8	38	2.3	6.6E-05
1,3,5-TNB	3.1	2800000	11.7	3.3E-04
Inorganics:				
Antimony (total)	4	210	11.4	3.3E-04
Arsenic (total)	3.2	5.9	5.3	1.5E-04
Cadmium (total)	4.8	21	7.5	2.1E-04
Chromium (total)	98	240000	335	9.6E-03
Nickel (total)	88	32000	285	8.1E-03
Silver (dissolved)	3.6	1.3E+11	14	4.0E-04
Zinc (dissolved)	770	87,000,000	1,200	3.4E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	24	48.3	48.3	
AREA 5				
Chemicals With Potential Carcinogenic Effects				
Organics:				
1,1-Dichloroethane	5.6	13	20	3.7E-04
bis(2-Ethylhexyl)phthalate	11	25	40	7.1E-04
RDX	3.4	35	8.1	2.3E-04
Trichloroethene	5.6	80	42	1.2E-03
Vinyl Chloride	2.9	4.9	10	1.4E-04

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 5 (continued)				
Chemicals With Potential Carcinogenic Effects				
Inorganics:				
Arsenic (total)	3.6	5.7	11.5	1.6E-04
Beryllium (total)	1.2	33	7.6	2.2E-04
Radiological Parameters (pCi/L):				
U-234	-- (f)	0.9	0.9	4.6E+04
U-238	-- (f)	0.6	0.6	3.1E+04
Chemicals With Noncarcinogenic Effects				
Organics:				
1,1-Dichloroethane	5.6	13	20	3.7E-04
trans-1,2-Dichloroethene	51	23000	362	1.0E-02
bis(2-Ethylhexyl)phthalate	11	25	40	7.1E-04
RDX	3.4	35	8.1	2.3E-04
1,1,1-Trichloroethane	3.6	5.5	7	1.6E-04
Trichloroethene	5.6	80	42	1.2E-03
Inorganics:				
Antimony (total)	4.4	16	15.9	4.5E-04
Arsenic (total)	3.6	5.7	11.5	1.6E-04
Barium (total)	220	690	325	9.3E-03
Beryllium (total)	1.2	33	7.6	2.2E-04
Cadmium (total)	5.5	12	20.4	3.4E-04
Chromium (total)	35	68	119	1.9E-03
Nickel (total)	81	290	346	8.3E-03
Silver (total)	0.1	0.2	0.2	5.7E-06
Zinc (total)	450	1,700	1,000	2.9E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	37	1600	250	
Lead (total)	6	22	17.4	
Radiological Parameters (pCi/L):				
Beta	-- (f)	15	15	7.7E+05
AREA 6				
Chemicals With Potential Carcinogenic Effects				
Organics:				
2,4-DNT	0.3	0.4	0.6	1.1E-05
RDX	3.1	18	14	4.0E-04
Inorganics:				
Beryllium (total)	0.4	2.8	1.9	5.4E-05

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Toxicity Class/Chemical (a)	Concentration			RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	
AREA 6 (continued)				
Chemicals With Noncarcinogenic Effects				
Organics:				
1,3-DNB	0.4	0.5	0.9	1.4E-05
HMX	0.9	1.4	2.1	4.0E-05
RDX	3.1	18	14	4.0E-04
Inorganics:				
Beryllium (total)	0.4	2.8	1.9	5.4E-05
Chromium (total)	29	50	72.1	1.4E-03
Nickel (total)	41	100	95.5	2.7E-03
Silver (total)	0.1	0.2	0.3	5.7E-06
Zinc (dissolved)	480	44,000	1,200	3.4E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	9	37	15	
Lead (total)	3.4	8.9	17.3	
AREA 7				
Chemicals With Potential Carcinogenic Effects				
Organics:				
Benzene	0.4	0.4	0.9	1.1E-05
bis(2-Ethylhexyl)phthalate	31	71	200	2.0E-03
Methylene Chloride	5	-- (e)	5	1.4E-04
RDX	54	400	770	1.1E-02
Trichloroethene	0.4	0.4	0.8	1.1E-05
Vinyl Chloride	2.4	2.7	10.2	7.7E-05
Inorganics:				
Arsenic (total)	3.8	4.7	8.7	1.3E-04
Chemicals With Noncarcinogenic Effects				
Organics:				
trans-1,2-Dichloroethene	0.9	1	2.4	2.9E-05
bis(2-Ethylhexyl)phthalate	31	71	200	2.0E-03
HMX	2.2	2	28	5.7E-05
Methylene Chloride	5	-- (e)	5	1.4E-04
RDX	54	400	770	1.1E-02
1,3,5-TNB	0.3	0.4	0.9	1.1E-05
Trichloroethene	0.4	0.4	0.8	1.1E-05

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF
GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Toxicity Class/Chemical (a)	Concentration: Arithmetic Mean	Concentration: Upper 95th Percent Confidence Limit on Arithmetic Mean	Concentration: Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 7 (continued)				
Chemicals With Noncarcinogenic Effects				
Inorganics:				
Arsenic (total)	3.8	4.7	8.7	1.3E-04
Barium (total)	260	390	573	1.1E-02
Chromium (total)	21	23	55.8	6.6E-04
Nickel (total)	44	56	128	1.6E-03
Selenium (dissolved)	2.8	3.1	7.4	8.9E-05
Silver (total)	0.2	0.3	2	8.6E-06
Zinc (dissolved)	230	1200	930	2.7E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	15	29	41.4	
Lead (total)	5.2	9.9	14.8	
AREA 8				
Chemicals With Potential Carcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	1,100	740	20,000	2.1E-02
N-nitrosodiphenylamine	5.3	5.6	10	1.6E-04
RDX	0.4	0.4	0.9	1.1E-05
Trichloroethene	2.3	1.8	35	5.1E-05
Inorganics:				
Arsenic (total)	5.7	8.5	14.1	2.4E-04
Beryllium (total)	1.5	14	6	1.7E-04
Radiological Parameters (pCi/L):				
U-234	-- (f)	1.9	1.9	9.7E+04
U-238	-- (f)	1.7	1.7	8.7E+04
Chemicals With Noncarcinogenic Effects				
Organics:				
trans-1,2-Dichloroethene	6.2	4.9	94	1.4E-04
bis(2-Ethylhexyl)phthalate	1,100	740	20,000	2.1E-02
RDX	0.4	0.4	0.9	1.1E-05
Toluene	3.2	3.7	15	1.1E-04
Trichloroethene	2.3	1.8	35	5.1E-05
Inorganics:				
Antimony (dissolved)	2.8	3.6	17.5	1.0E-04
Arsenic (total)	5.7	8.5	14.1	2.4E-04
Barium (total)	540	910	1,470	2.6E-02
Beryllium (total)	1.5	14	6	1.7E-04

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 8 (Continued)				
Chemicals With Noncarcinogenic Effects				
Cadmium (total)	3.8	4.6	14	1.3E-04
Chromium (total)	73	140	363	4.0E-03
Nickel (total)	71	200	193	5.5E-03
Silver (dissolved)	0.8	0.6	12.8	1.7E-05
Zinc (dissolved)	300	2,500	1,400	4.0E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	94	520	780	
Lead (total)	16	47	90	
Radiological Parameters (pCi/L):				
Alpha	9.3	22	22	1.1E+04
Beta	43	96	96	4.9E+06
Total Uranium	-- (f)	1.1	1.1	5.6E+04
AREA 9				
Chemicals With Potential Carcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	250	4.6E+13	1,000	2.9E-02
RDX	4	5800000	15	4.3E-04
Inorganics:				
Arsenic (total)	3.2	5.9	5.3	1.5E-04
Beryllium (total)	0.1	7.9	0.4	1.1E-05
Chemicals With Noncarcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	250	4.6E+13	1,000	2.9E-02
RDX	4	5800000	15	4.3E-04
1,3,5-TNB	5	63000000	19	5.4E-04
Inorganics:				
Arsenic (total)	3.2	5.9	5.3	1.5E-04
Cadmium (total)	3.5	9.5	6.4	1.8E-04
Nickel (total)	36	76	45.1	1.3E-03
Silver (total)	2.2	34000000	8.2	2.3E-04
Zinc (total)	810	83,000	1,700	4.9E-02

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 10				
Chemicals With Potential Carcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	100	7900	700	2.0E-02
RDX	1.3	10	3.3	9.4E-05
Inorganics:				
Arsenic (total)	5.6	23	21.3	6.1E-04
Beryllium (total)	3.8	10000	8.1	2.3E-04
Chemicals With Noncarcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	100	7900	700	2.0E-02
RDX	1.3	10	3.3	9.4E-05
Inorganics:				
Antimony (total)	3.2	9.7	11.5	2.8E-04
Arsenic (total)	5.6	23	21.3	6.1E-04
Barium (total)	1,200	2.1E+12	3,030	8.7E-02
Beryllium (total)	3.8	10000	8.1	2.3E-04
Cadmium (total)	25	400	80.6	2.3E-03
Nickel (total)	110	340	250	7.1E-03
Silver (total)	0.2	0.8	0.5	1.4E-05
Zinc (total)	1,100	8,900	2,400	6.9E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	59	46000	140	
Lead (total)	50	16000	150	
AREA 11				
Chemicals With Potential Carcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	54	5700	300	8.6E-03
RDX	23	440	50	1.4E-03
Inorganics:				
Arsenic (total)	3.2	4.7	6.6	1.3E-04
Beryllium (total)	0.4	25	1.5	4.3E-05

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 11 (Continued)				
Chemicals With Noncarcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	54	5700	300	8.6E-03
HMX	2.3	11	5.3	1.5E-04
RDX	23	440	50	1.4E-03
Inorganics:				
Arsenic (total)	3.2	4.7	6.6	1.3E-04
Beryllium (total)	0.4	25	1.5	4.3E-05
Cadmium (total)	3.2	4.7	6.4	1.3E-04
Chromium (total)	23	32	42.3	9.1E-04
Nickel (total)	41	420	81.5	2.3E-03
Silver (total)	0.2	0.4	0.3	8.6E-06
Zinc (total)	250	790	403	1.2E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	9	84	17	
AREA 12				
Chemicals With Potential Carcinogenic Effects				
Organics:				
N-nitrosodiphenylamine	5.6	6.7	10	1.9E-04
RDX	14	15000	61	1.7E-03
Inorganics:				
Arsenic (total)	6.2	14	16.3	4.0E-04
Beryllium (total)	0.4	1.7	0.8	2.3E-05
Chemicals With Noncarcinogenic Effects				
Organics:				
HMX	1.9	6.7	6.3	1.8E-04
RDX	14	15000	61	1.7E-03
1,3,5-TNB	2.8	36	18.6	5.3E-04

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 12 (continued)				
Chemicals With Noncarcinogenic Effects				
Inorganics:				
Arsenic (total)	6.2	14	16.3	4.0E-04
Barium (total)	570	28,000	1,020	2.9E-02
Beryllium (total)	0.4	1.7	0.8	2.3E-05
Chromium (total)	600	46,000	3,800	1.1E-01
Nickel (total)	38	100	68.2	1.9E-03
Silver (total)	0.2	0.3	0.5	8.6E-06
Zinc (total)	240	290	317	8.3E-03
Chemicals Without Toxicity Criteria (d)				
Organics:				
Tetryl	0.5	0.7	1.3	
Inorganics:				
Copper (total)	22	39	51.6	
AREA 14				
Chemicals With Potential Carcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	47	4900	100	2.9E-03
RDX	1.8	45	9.4	2.7E-04
Inorganics:				
Arsenic (total)	7.2	32	21.5	6.1E-04
Beryllium (total)	0.4	9.2	1.2	3.4E-05
Radiological Parameters (pCi/L):				
U-234	-- (f)	-- (e)	0.5	2.6E+04
U-238	-- (f)	-- (e)	0.7	3.6E+04
Chemicals With Noncarcinogenic Effects				
Organics:				
bis(2-Ethylhexyl)phthalate	47	4900	100	2.9E-03
RDX	1.8	45	9.4	2.7E-04
Inorganics:				
Arsenic (total)	7.2	32	21.5	6.1E-04
Barium (total)	370	3100	558	1.6E-02
Beryllium (total)	0.4	9.2	1.2	3.4E-05
Cadmium (total)	3.7	7	9.7	2.0E-04
Chromium (total)	73	570	162	4.6E-03
Nickel (total)	47	100	101	2.9E-03
Zinc (dissolved)	290	26000	878	2.5E-02

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 14 (continued)				
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	15	45	28.1	
Radiological Parameters (pCi/L):				
Alpha	4.7	7	7	3.6E+05
Beta	14	15	15	7.7E+05
Total Uranimum	-- (f)	0.9	0.9	4.6E+04
AREA 16				
Chemicals With Potential Carcinogenic Effects				
Organics:				
Benzene	3	1.9	57	5.4E-05
Carbon Tetrachloride	2.6	2.7	5	7.7E-05
1,1-Dichloroethane	9.3	9	110	2.6E-04
1,2-Dichloroethane	3	3.4	10	9.7E-05
1,1-Dichloroethene	2.8	3.1	10	8.9E-05
bis(2-Ethylhexyl)phthalate	19	14	336	4.0E-04
RDX	1.9	2.3	27	6.6E-05
1,1,2,2-Tetrachloroethane	2.8	3.1	10	8.9E-05
Tetrachloroethene	18	17	250	4.9E-04
1,1,2-Trichloroethane	3.1	3.5	10	1.0E-04
Trichloroethene	72	24	1,700	6.9E-04
Vinyl Chloride	2.1	2.2	5.1	6.3E-05
Inorganics:				
Arsenic (total)	4	4.8	14.3	1.4E-04
Beryllium (total)	0.6	1.6	3.1	4.6E-05
Radiological Parameters (pCi/L):				
U-234	-- (f)	1.6	1.6	8.2E+04
U-238	-- (f)	1.5	1.5	7.7E+04
Chemicals With Noncarcinogenic Effects				
Organics:				
Carbon Tetrachloride	2.6	2.7	5	7.7E-05
1,3-DNB	0.3	0.3	0.7	8.6E-06
1,2-Dichlorobenzene	5.2	5.5	10	1.6E-04
1,1-Dichloroethane	9.3	9	110	2.6E-04
trans-1,2-Dichloroethene	880	67	21,000	1.9E-03
Ethylbenzene	3	3.3	11	9.4E-05
bis(2-Ethylhexyl)phthalate	19	14	336	4.0E-04
Nitrobenzene	0.6	0.6	1.5	1.7E-05
RDX	1.9	2.3	27	6.6E-05
Tetrachloroethene	18	17	250	4.9E-04
Toluene	2.6	2.7	5	7.7E-05
1,1,1-Trichloroethane	5.2	5.7	40	1.6E-04
1,1,2-Trichloroethane	3.1	3.5	10	1.0E-04
Trichloroethene	72	24	1,700	6.9E-04

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 16 (continued)				
Chemicals With Noncarcinogenic Effects				
Inorganics:				
Antimony (dissolved)	3.3	3	44.1	8.6E-05
Arsenic (total)	4	4.8	14.3	1.4E-04
Barium (dissolved)	280	500	597	1.4E-02
Beryllium (total)	0.6	1.6	3.1	4.6E-05
Chromium (total)	20	22	58.7	6.3E-04
Nickel (total)	32	59	123	1.7E-03
Silver (total)	0.4	0.4	6.3	1.1E-05
Zinc (total)	500	1,500	2,200	4.3E-02
Chemicals Without Toxicity Criteria (d)				
Organics:				
Dimethylphthalate	5	5	5	
Inorganics:				
Copper (total)	16	25	61	
Lead (total)	3.8	5.5	16.2	
Radiological Parameters (pCi/L):				
Beta	-- (f)	46	46	2.4E+06
AREA 17				
Chemicals With Potential Carcinogenic Effects				
Organics:				
Benzene	1.2	1.4	14	4.0E-05
Chloroform	14	26	100	7.4E-04
2,6-DNT	0.3	0.3	0.7	8.6E-06
bis(2-Ethylhexyl)phthalate	35	82	300	2.3E-03
Methylene Chloride	25	25	300	7.1E-04
RDX	4	17	29	4.9E-04
Tetrachloroethene	42	120	300	3.4E-03
1,1,2-Trichloroethane	22	45	200	1.3E-03
Trichloroethene	290	1,600	4,300	4.6E-02
Inorganics:				
Arsenic (total)	4.9	7.3	16.8	2.1E-04
Beryllium (total)	0.8	2.1	2.1	6.0E-05
Radiological Parameters (pCi/L):				
U-234	0.8	0.9	0.9	4.6E+04
U-238	0.7	0.7	0.7	3.6E+04

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

Toxicity Class/Chemical (a)	Concentration			RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	
AREA 17 (Continued)				
Chemicals With Noncarcinogenic Effects				
Organics:				
Chloroform	14	26	100	7.4E-04
trans-1,2-Dichloroethene	21,000	280,000	320,000	8.0E+00
Ethylbenzene	19	32	200	9.1E-04
bis(2-Ethylhexyl)phthalate	35	82	300	2.3E-03
HMX	0.8	0.9	2.6	2.6E-05
Methylene Chloride	25	25	300	7.1E-04
RDX	4	17	29	4.9E-04
1,3,5-TNB	0.3	0.4	0.7	1.1E-05
Tetrachloroethene	42	120	300	3.4E-03
Toluene	1,400	2,100	21,000	6.0E-02
1,1,1-Trichloroethane	270	2,800	2,000	5.7E-02
1,1,2-Trichloroethane	22	45	200	1.3E-03
Trichloroethene	290	1,600	4,300	4.6E-02
Inorganics:				
Antimony (total)	1.7	1.9	4	5.4E-05
Arsenic (total)	4.9	7.3	16.8	2.1E-04
Barium (total)	420	810	1,070	2.3E-02
Beryllium (total)	0.8	2.1	2.1	6.0E-05
Nickel (total)	41	70	110	2.0E-03
Silver (total)	0.3	0.5	1.3	1.4E-05
Zinc (total)	430	1100	870	2.5E-02
Chemicals Without Toxicity Criteria (d)				
Organics:				
Tetryl	0.4	0.4	1	
Inorganics:				
Copper (total)	27	53	110	
Lead (total)	8.8	23	32.1	
Radiological Parameters (pCi/L):				
Alpha	9.3	17	17	8.7E+05
Beta	43	79	79	4.0E+06
Total Uranium	0.3	0.5	0.5	2.6E+04
AREA 18				
Chemicals With Potential Carcinogenic Effects				
Organics:				
Chrysene (Carcinogenic PAH)	11	19	70	5.4E-04
1,1-Dichloroethene	3.8	5.5	15	1.6E-04
bis(2-Ethylhexyl)phthalate	46	160	400	4.6E-03
RDX	1.2	3.7	4.7	1.1E-04

TABLE 5-28 (Continued)

EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INGESTION OF GROUNDWATER DOWNGRADIENT OF SOURCE AREAS
LAKE CITY, MISSOURI

(Concentrations reported in ug/L)

	Concentration			
Toxicity Class/Chemical (a)	Arithmetic Mean	Upper 95th Percent Confidence Limit on Arithmetic Mean	Maximum	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (b)(c)
AREA 18 (Continued)				
Chemicals With Noncarcinogenic Effects				
Organics:				
1,1-Dichloroethene	3.8	5.5	15	1.6E-04
bis(2-Ethylhexyl)phthalate	46	160	400	4.6E-03
HMX	0.8	0.9	1.7	2.6E-05
RDX	1.2	3.7	4.7	1.1E-04
Inorganics:				
Barium (dissolved)	290	780	541	1.5E-02
Nickel (total)	19	37	64.6	1.1E-03
Silver (dissolved)	0.1	0.2	0.5	5.7E-06
Zinc (dissolved)	380	4800	783	2.2E-02
Chemicals Without Toxicity Criteria (d)				
Inorganics:				
Copper (total)	8.8	23	15.9	4.5E-04
Lead (total)	3.4	7	9.3	2.0E-04

(a) Chemicals are grouped with respect to toxicity criteria because such classifications determine the way chronic daily intakes are calculated. See Sections 5.3.3 and 5.4 for further discussion and Table 5-29.

(b) Maximum detected concentration used to calculate the CDI if the upper confidence limit exceeded the maximum or could not be calculated due to an insufficient number of samples. See text.

(c) CDIs calculated only for chemicals with toxicity criteria.

(d) Total inorganics were used to estimate exposure and risk. In some cases, the dissolved concentration was used when the dissolved concentration exceeded total concentrations.

(e) There were not enough samples to calculate the upper 95th percent confidence limit on the arithmetic mean.

(f) Arithmetic mean was not calculated since only one sample was available.

detected concentration of the chemical was used to calculate the RME exposure instead of the 95 percent upper confidence limit on the mean, as recommended in EPA (1989). The maximum detected concentrations were used for the ingestion of groundwater from off-site residential wells pathway since too few samples were available to calculate the standard deviation required to calculate the 95 percent upper confidence interval. In a few instances when the sample size was high (e.g., >100 samples), the estimated 95th upper confidence limit on the arithmetic mean was below the calculated arithmetic mean of the sample data set. This can occur because the calculation of the 95th upper confidence limit on the arithmetic mean is based on log-normal statistics as described above (i.e., the 95th upper confidence limit on the arithmetic mean is derived from the geometric mean and geometric standard deviation). As recommended in EPA (1989) guidance, the 95th upper confidence limit on the arithmetic mean was used in estimating exposure.

To calculate the arithmetic mean for a medium in which a chemical was positively detected in at least one sample, non-detects were included in the mean by using one-half of each sample-specific detection limit. This arbitrarily selected value (one-half) is commonly assigned to non-detects when averaging data for risk assessment purposes, since the actual value can be between zero and a value just below the detection limit (Vollmerhausen and Turnham 1988). Due to the fact that there are varying chemical- and sample-specific detection limits, even within one medium, samples in which a chemical was not detected were compared to the maximum detected concentration for that chemical to determine if the nondetects would be included in calculating the arithmetic mean. If the detection limit (for a nondetect sample) was two or more times higher than the maximum detected concentration in that medium, the sample was not included in the arithmetic mean calculation for that chemical. This was done to prevent the mean from being artificially biased upwards by high detection limits. [There is some uncertainty associated with this since high detection limits may result in a chemical not being observed when it was actually present (i.e., false negatives).] These high nondetects were, however, included in the determination of frequencies of detection, shown in

Section 5.2, in order to provide a more accurate count of samples collected and analyzed for that compound.

For all of the groundwater pathways that will be evaluated below it was assumed that chemical concentrations will remain constant over the duration of the exposure period. However, it is not known at this time whether concentrations of certain chemicals of potential concern identified in groundwater will increase or decrease over time. Certain organic chemicals that are currently found in groundwater may degrade by various processes and thereby decrease in concentration. However, it should be noted that chemical transformations also may take place in groundwater, which may yield increased levels of chemical by-products with time. For example, concentrations of tetrachloroethene and trichloroethene may decrease in concentration due in part to microbial degradation pathways in groundwater. 1,1-Dichloroethene is a product of this degradation pathway. Further transformation of 1,1-dichloroethene may yield the very persistent and mobile compound, vinyl chloride. Therefore, the concentrations of vinyl chloride may actually increase due to transformation of other chlorinated aliphatic compounds. This is of potential concern since vinyl chloride is a chemical which exhibits carcinogenic effects and has a high potency.

Leaching from source areas also is important in predicting chemical concentrations in groundwater over time. As discussed in Section 4 and Section 5.2, contaminated soil, surface water, and sediments within the study areas may be acting as potential sources of groundwater contamination. However, given the limited data available to assess the extent of soil and sediment contamination at the site, the impact on groundwater of future leaching from identified source areas cannot be evaluated at this time. It is expected that many of these source areas will continue to contribute contamination to groundwater at the site. However, given the history of many of the source areas and the rate of groundwater flow in the alluvial sand aquifer, it is believed that the concentrations of certain chemicals (e.g., trichloroethene, 1,2-dichloroethene [total]) of potential concern currently detected in groundwater will not increase in the future and will probably decrease due to degradation, dilution, and decreases in the release from potential source areas. Overall, however, the trend in concentrations of chemicals of potential concern in groundwater over time is uncertain, and therefore the estimated risks presented in this assessment must be interpreted with this in mind.

Estimating Exposure for the Groundwater Ingestion Pathway. For the RME case of the ingestion pathways, residents were assumed to ingest 2 liters of groundwater per day for 365 days a year over a lifetime of 70 years. This latter assumption (70 years) was chosen as an RME estimate for a rural area where populations are more stable. For the RME case, on-site workers were assumed to ingest 1 liter of groundwater per day for a maximum of 241 days per year (assuming a 5-day work week, 9 holidays and 10 vacation days) over a 20 year period (based on personal communication with Weston personnel). Workers and residents were assumed to weigh an average of 70 kg over a lifetime. For each inorganic chemical of potential concern, the higher of the filtered and unfiltered concentration was considered the exposure point concentration. CDIs were calculated using the parameters presented in Tables 5-20 and 5-21 and the equation presented below and presented in Tables 5-22 through 5-28:

$$CDI = \frac{(C_w)(WI)(E)(YR)}{(BW)(DY)(YL)}$$

where

CDI = chronic daily intake (mg/kg-day);

C_w = chemical concentration in water (mg/liter);

WI = amount of water ingested (liters/day);

E = number of exposure days (days/year);

YR = duration of exposure (years);

BW = average body weight (kg);

DY = days/year (365 days/year); and

YL = period over which risk is being estimated (i.e., a lifetime of 70 years for carcinogens, or the duration of exposure (YR) for noncarcinogens) (years).

Estimating Exposure for the Inhalation Pathway. VOCs dissolved in household water supplies can be released into the indoor air as a result of activities such as showering, bathing and dishwashing. Of particular concern to human health is the potential for elevated exposures to occur in the confined space of a shower. The shower model developed by Foster and Chrostowski (1987), was used to assess the possible inhalation exposures to volatile chemicals from groundwater which is being used for showering by both on- and off-site residents (i.e., treated production well water and off-site residential wells). In the shower model, inhalation exposures are modeled by estimating the rate of chemical release into the air (generation rate), the buildup (shower on) and decay (shower off) of volatile chemicals in shower room air, and the quantity of airborne volatile chemicals inhaled while the shower is both on and off.

Estimation of the rate of volatile chemical release into the air is based upon Liss and Slater's adaptation of the two-layer film model of gas-liquid mass transfer. The two-film boundary theory provides the basis for estimating the overall mass transfer coefficient (K_L) for each volatile chemical of interest according to the following equation:

$$K_L = (1/k_1 + RT/Hk_g)^{-1} \qquad (1)$$

where:

K_L = overall mass transfer coefficient (cm/hr),

H = Henry's Law Constant (atm-m^3/mol-K)

RT = 2.4×10^{-2} atm-m^3/mole (gas constant of 8.2×10^{-5} atm-m^3/mol-K times absolute temperature of 293 K),

kg = gas-film mass transfer coefficient (cm/hr), and

k_1 = liquid-film mass transfer coefficient (cm/hr).

Equation 1 describes the mass transfer rate of a compound at an air-water interface where diffusion may be limited by both liquid- and gas-phase resistances.

The chemical-specific resistances to mass transport for both the liquid and gas phases were calculated from empirical expressions suggested by Liss and Slater (1974). Typical values of k_l (20 cm/hr) and k_g (3,000 cm/hr), which have been measured for CO_2 and H_2O, respectively, were used to estimate chemical-specific values for these parameters:

$$k_l = 20*[44/MW]^{1/2} \quad (2)$$

$$k_g = 3000*[18/MW]^{1/2} \quad (3)$$

where:

k_l = liquid-phase mass transfer coefficient (cm/hr);
k_g = gas-phase mass transfer coefficient (cm/hr); and
MW = molecular weight of the chemical.

The mass transfer coefficient, K_L, is adjusted to the shower water temperature, T_s, according to a semi-empirical equation developed to estimate the effect of temperature on oxygen mass-transfer rate:

$$K_{aL} = K_L(T_1 m_s/T_s m_1)^{-0.5} \quad (4)$$

where:

K_{aL} = adjusted overall mass transfer coefficient (cm/hr);
T_1 = calibration water temperature of K_L (K);
T_s = shower water temperature (K);
m_1 = water viscosity at T_1 (cp); and
m_s = water viscosity at T_s (cp).

The concentration leaving the shower droplet, C_{wd}, is obtained from an integrated rate equation based on a mass-balance approach:

$$C_{wd} = C_{w0}(1\text{-}\exp[-K_{aL}t_s/60d]) \qquad (5)$$

where:

C_{wd} = concentration leaving shower droplet after time t_s (ug/l);

C_{w0} = shower water concentration (ug/l);

d = shower droplet diameter (mm); and

t_s = shower droplet drop time (sec).

The term $K_{aL}/60d$ combines both the rate transfer and the available interfacial area across which volatilization can occur. The value 1/60d equals the specific interfacial area, 6/d, for a spherical shower droplet of diameter d multiplied by conversion factors (hr/3,600 sec and 10 mm/cm).

The volatile chemical generation rate in the shower room, S, can then be calculated by the equation:

$$S = C_{wd}(Fr)/SV \qquad (6)$$

where:

S = indoor volatile chemical generation rate (ug/m^3-min);

FR = shower water flow rate (l/min); and

SV = shower room air volume (m^3).

A simple one-box indoor air pollution model was used to estimate volatile chemical air concentrations in the shower room. This model can be expressed as a differential equation describing the rate of change of the indoor pollutant concentration with time:

$$dC_a/dt = RC_a + S \tag{7}$$

where:

C_a = indoor volatile chemical air concentration ($\mu g/m^3$); and

R = air exchange rate (min^{-1}).

When equation 7 is integrated, the time-dependent indoor concentration can be estimated as follows:

$$C_a(t) = (S/R)(1 - \exp[-Rt]) \text{ for } t \leq D_s \tag{8}$$

and

$$C_a(t) = (S/R(\exp[RDs] -1)\exp(-Rt) \text{ for } t > D_s \tag{9}$$

where:

$C_a(t)$ = indoor air volatile chemical concentration at time t (mg/m^3);

D_s = shower duration (min); and

t = time (min).

The average air concentration was estimated by calculating the arithmetic mean of the estimated air concentration for each minute over the duration of the exposure period.

The inhalation exposure per shower can then be calculated according to the equation:

$$E_{inh} = \left[\frac{Vr}{(BW)\ (10^6)}\right]\int_0^{D_t} C_a(t)\,dt \tag{10}$$

where:

E_{inh} = inhalation exposure per shower (mg/kg/shower);

VR = ventilation rate (l/min);

BW = body weight (kg); and

D_t = total duration in shower room (min).

This equation can be solved as:

$$E_{inh} = [(Vr)(S)/[(BW)(R)(10^6)]] \; [D_s - 1/R + \exp(-RD_s)/R] \qquad (11)$$

for the duration of the shower, and as:

$$E_{inh} = [(Vr)(S)/[(BW)(R)(10^6)] \times [D_s + \exp(-RD_t)/R - \exp[R(D_s - D_t)]/R] \qquad (12)$$

for both the duration of the shower and the duration in the room after the shower is turned off. The inhalation exposure per shower is then adjusted using the exposure frequencies and exposure durations presented in Table 5-28a to calculate chronic daily intakes.

All of the input parameters to the shower model are summarized in Table 5-28b. The resulting air concentrations and the chronic daily intakes estimated using the shower model for treated production well water and off-site residential well water are presented in Tables 5-28c to 5-28d, respectively and were calculated using the equation below:

$$CDI = \frac{(C_a)(IR)(ET)(E)(YR)}{(BW)(DY)(YL)} \qquad (13)$$

where

CDI = chronic daily intake (mg/kg-day);

C_a = chemical concentration in air (mg/m^3);

IR = inhalation rate (m^3/minute);

ET = exposure time (minutes/day);

Table 5-28a

ASSUMPTIONS USED TO CALCULATE INHALATION EXPOSURES FOR ON-SITE AND OFF-SITE RESIDENTS AT LCAAP LAKE CITY, MISSOURI

Parameter	RME Case
Inhalation Rate (m3/min) (a)	0.021
Exposure Time (min/day) (b)	20
Exposure Frequency (days/year)	365
Exposure Duration (years) (c)	70
Body Weight (kg) (d)	70
Lifetime (years) (e)	70

(a) EPA (1989a) upperbound adult resting ventilation rate.
(b) Based on EPA (1989a) 90th percentile showering duration (12 minutes) plus an assumed additional 8 minutes in the showering room.
(c) Based on EPA (1989a) values for maximum plausible durations for residents in the same place.
(d) Based on EPA (1989a) standard assumptions for average adult body weight.
(e) Based on EPA (1989a) standard assumption for a lifetime.

TABLE 5-28b

INPUT PARAMETERS TO THE SHOWER MODEL

Parameter	Value
Shower Water Temperature	318 K
Water Viscosity at Shower Temperature	0.596 cp
Shower Droplet Drop Time	2 sec
Shower Droplet Diameter	1 mm
Shower Water Flow Rate	10 liter/min
Air Exchange Rate in Shower Room	0.00833 min^{-1}
Ventilation Rate	13.89 liter/min
Body Weight	70 kg
Shower Duration	12 min
Duration in Shower Room After Shower Stops	8 min

TABLE 5-28c

ESTIMATED EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INHALATION WHILE SHOWERING WITH TREATED GROUNDWATER BY ON-SITE RESIDENTS
LAKE CITY, MISSOURI

Toxicity Class/Chemical (a)	Upper 95 Percent Confidence Limit Concentration (ug/L)	Estimated Air Concentrations From Showering (mg/m3)	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Chemicals with Potential Carcinogenic Effects			
Bromoform	5.0 (b)	1.46E-02	8.7E-05
Chloroform	3.4 (b)	1.77E-02	1.1E-04
Trichloroethene	2.6	1.34E-02	8.0E-05
Chemicals with Noncarcinogenic Effects			
1,1,1-Trichloroethane	0.2	1.04E-03	6.2E-06
Chemicals without Toxicity Criteria (c)			
Bromodichloromethane	8.0 (b)	3.87E-02	2.3E-04
Dibromochloromethane	9.0 (b)	3.79E-02	2.3E-04
1,2-Dichloroethene (total)	9.7 (b)	5.57E-02	3.3E-04

a) Chemicals are grouped with respect to toxicity category because such classifications determine the way chronic daily intakes are calculated. See Sections 5.3.3 and 5.4 for further discussion.
(b) Maximum detected concentration; used if the upper confidence limit exceeded the maximum or could not be calculated due to an insufficient number of samples. See text.
(c) Chronic daily intakes were calculated assuming that these chemicals are noncarcinogenic.

TABLE 5-28d

ESTIMATED EXPOSURE POINT CONCENTRATIONS AND CHRONIC DAILY INTAKES FOR INHALATION WHILE SHOWERING WITH GROUNDWATER BY OFF-SITE RESIDENTS (a)
LAKE CITY, MISSOURI

Toxicity Class/Chemical (b)	Maximum Concentration (ug/L)	Estimated Air Concentrations From Showering (mg/m3)	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day)
Chemicals with Potential Carcinogenic Effects			
Ure			
Carbon tetrachloride	1.1	5.40E-03	3.2E-05
Trichloroethane	1.2	6.19E-03	3.7E-05
Chemicals with Noncarcinogenic Effects			
Ure			
1,2-Dichlorobenzene	12.4	5.67E-02	3.4E-04
1,4-Dichlorobenzene	2.2	9.89E-03	5.9E-05
Well North of Area 17			
Toluene	1.0	5.85E-03	3.5E-05

(a) The Ure well and the well north of Area 17 were the only off-post residential wells which were found to contain VOCs. Therefore, these are the only residents evaluated for inhalation exposure while showering.

(b) Chemicals are grouped with respect to toxicity category because such classifications determine the way chronic daily intakes are calculated. See Sections 5.3.3 and 5.4 for further discussion.

E = number of exposure days (days/year);

YR = duration of exposure (years);

BW = average body weight (kg);

DY = days/year (365 days/year); and

YL = period over which risk is being estimated (70 years).

5.4 TOXICITY ASSESSMENT

The general methodology for the classification of health effects and the development of health effects criteria is described in this section in 5.4.1 in order to provide the analytical framework for the characterization of human health impacts in Section 5.5. Finally, in 5.4.2, brief summaries of the mammalian toxicity of those chemicals that will be evaluated qualitatively and quantitatively in this assessment together with the health effects criteria developed for the chemicals that will be used in the quantitative risk assessment are given. The numerical values of the health effects criteria are presented in Table 5-29 for those chemicals to be evaluated quantitatively. Inhalation health effects criteria are not presented since no inhalation exposure pathways were complete under either current or future land use conditions.

5.4.1 Health Effects Classification and Criteria Development

For risk assessment purposes, individual pollutants are separated into two categories of chemical toxicity depending on whether they exhibit noncarcinogenic or carcinogenic effects. This distinction relates to the currently held scientific opinion that the mechanism of action for each category is different. EPA has adopted, for the purpose of assessing risks associated with potential carcinogens, the scientific position that a small number of molecular events can cause changes in a single cell or a small number of cells that can lead to tumor formation. This is described as a no-threshold mechanism, since there is essentially no level of exposure (i.e., a threshold) to a carcinogen which will not result in some finite possibility of causing the disease. In the case of chemicals exhibiting noncarcinogenic effects, however, it is believed that organisms have protective mechanisms that must be overcome before the toxic endpoint is manifested. For example, if a large number of cells performs the same or similar functions, it would be necessary for significant damage or depletion of these cells to occur before an effect could be seen. This threshold view holds that a range of exposures

TABLE 5-29

HEALTH EFFECTS CRITERIA FOR CHEMICALS OF CONCERN
LAKE CITY, MISSOURI

Potential Carcinogens

Chemical (a)	Slope Factor (SF) (mg/kg-day)-1	Weight of Evidence (b)	Type of Cancer	SF Basis (c)	SF Source (d)
ORAL ROUTE:					
Organics:					
Benzene	2.90E-02	A	Blood	Inhalation	IRIS
Bromodichloromethane	1.30E-01	B2	Liver	Gavage	HEAST
Bromoform	7.90E-03	B2	GI	Gavage	HEAST
Carbon Tetrachloride	1.30E-01	B2	Liver	Gavage	IRIS
Carcinogenic PAHs (Benzo[a]pyrene)	1.15E+01 *	B2	Forestomach	Gavage	(e)
Chloroform	6.10E-03	B2	Kidney	Water	IRIS
1,3-DNB	--	--	--	--	--
2,4-DNT	6.80E-01 (f)	B2	Liver/Mammary Gland	Diet	HEAST
2,6-DNT	6.80E-01 (f)	B2	Liver/Mammary Gland	Diet	HEAST
Dibromochloromethane	8.40E-02	B2	Liver	Gavage	HEAST
1,2-Dichlorobenzene	--	--	--	--	--
1,4-Dichlorobenzene	2.40E-02	B2	Liver	Gavage	HEAST
1,1-Dichloroethane	9.10E-02	B2	Hemangiosarcoma	Gavage	HEAST
1,2-Dichloroethane	9.10E-02	B2	Circulatory	Gavage	IRIS
1,1-Dichloroethene	6.00E-01	C	Adrenal	Gavage	IRIS
cis-1,2-Dichloroethene	--	--	--	--	--
trans-1,2-Dichloroethene	--	--	--	--	--
Dimethylphthalate	--	--	--	--	--
1,3-Dinitrobenzene	--	--	--	--	--
Di-n-butylphthalate	--	--	--	--	--
Ethylbenzene	--	--	--	--	--
bis(2-Ethylhexyl)phthalate	1.40E-02	B2	Liver	Diet	IRIS
HMX	--	--	--	--	--
Methylene chloride	7.50E-03	B2	Liver	Inh. & Water	IRIS
Nitrobenzene	--	--	--	--	--
N-nitrosodiphenylamine	4.90E-03	B2	Urinary/Bladder	Diet	IRIS
Noncarcinogenic PAHs (Naphthalene)	--	--	--	--	--
Phenol	--	--	--	--	--
RDX	1.10E-01	C	Liver	Diet	HEAST
1,1,2,2-Tetrachloroethane	2.00E-01	C	Liver	Gavage	IRIS
Tetrachloroethene	5.10E-02	B2	Liver	Gavage	HEAST
Toluene	--	--	--	--	--
1,1,1-Trichloroethane	--	--	--	--	--
1,1,2-Trichloroethane	5.70E-02	C	Liver	Gavage	IRIS
Trichloroethene	1.10E-02	B2	Liver	Gavage	HEAST
1,3,5-Trinitrobenzene	--	--	--	--	--
Vinyl Chloride	2.30E+00	A	Lung	Ingestion	HEAST
Inorganics:					
Antimony	--	--	--	--	--
Arsenic	2.00E+00	A	Skin	Water	(g)
Barium	--	--	--	--	--
Beryllium	4.30E+00	B2	General	Water	IRIS
Cadmium	--	--	--	--	--
Chromium (III)	--	--	--	--	--
Chromium (VI)	--	--	--	--	--
Copper	--	--	--	--	--
Cyanide	--	--	--	--	--
Mercury (mercuric)	--	--	--	--	--
Nickel	--	--	--	--	--
Selenium	--	--	--	--	--
Silver	--	--	--	--	--
Thallium	--	--	--	--	--
Zinc	--	--	--	--	--
Radiological Parameters:					
Ra226	1.20E-10	A	--	--	HEAST
Ra228	1.00E-10	A	--	--	HEAST
U-234	1.40E-10	A	--	--	HEAST
U-235	1.30E-10	A	--	--	HEAST
U-238	1.30E-10	A	--	--	HEAST
INHALATION ROUTE:					
Organics:					
Bromodichloromethane	--	B2	--	--	IRIS
Bromoform	3.9E-03	B2	--	--	IRIS
Chloroform	8.1E-01	B2	Liver	--	IRIS
Carbon tetrachloride	1.3E-01	B2	Liver	--	IRIS
Dibromochloromethane	--	C	--	--	IRIS
1,2-Dichloroethene	--	--	--	--	--
1,2-Dichlorobenzene	--	D	--	--	IRIS
1,4-Dichlorobenzene	--	B2	--	--	IRIS
1,1,1-Trichloroethane	--	--	--	--	--
Trichloroethene	1.7E-02	B2	Lung	--	HEAST
Toluene	--	--	--	--	--

TABLE 5-29 (Continued)

HEALTH EFFECTS CRITERIA FOR CHEMICALS OF CONCERN
LAKE CITY, MISSOURI

Noncarcinogens

Chemical (a)	Reference Dose (RfD) (mg/kg-day)	Uncertainty Factor (h)	Target Organ (i)	RfD Basis (c)	RfD Source (d)
ORAL ROUTE:					
Organics:					
Benzene	--	--	--	--	--
Bromodichloromethane	2E-02	1,000	Renal	Gavage	IRIS
Bromoform	2E-02	1,000	Liver	Gavage	IRIS
Carbon Tetrachloride	7E-04	1,000	Liver	Gavage	IRIS
Carcinogenic PAHs (Benzo[a]pyrene)	--	--	--	--	--
Chloroform	1E-02	1,000	Liver	Food	IRIS
1,3-DNB	--	--	--	--	--
2,4-DNT	--	--	--	--	--
2,6-DNT	--	--	--	--	--
Dibromochloromethane	2E-02	1,000	Liver	Gavage	IRIS
1,2-Dichlorobenzene	9E-02	1,000	Liver	Gavage	IRIS
1,4-Dichlorobenzene	1E-01	1,000	Liver	Gavage	HA
1,1-Dichloroethane	1E-01	1,000	Kidney	Inhalation	HEAST
1,2-Dichloroethane	--	--	--	--	--
1,1-Dichloroethene	9E-03	1,000	Liver	Water	IRIS
cis-1,2-Dichloroethene	1E-02	1,000	Liver	Water	HA
trans-1,2-Dichloroethene	2E-02	1,000	Blood	Water	IRIS
Dimethylphthalate	--	--	--	--	--
1,3-Dinitrobenzene	1E-04	3,000	Spleen	Water	IRIS
Di-n-butylphthalate	1E-01	1,000	Mortality	Diet	IRIS
Ethylbenzene	1E-01	1,000	Liver, Kidney	Gavage	IRIS
bis(2-Ethylhexyl)phthalate	2E-02	1,000	Liver	Diet	IRIS
HMX	5E-02	1,000	Liver	Food	IRIS
Methylene chloride	6E-02	100	Liver	Water	IRIS
Nitrobenzene	5E-04	10,000	Adrenal Liver, & Kidney Lesions	Inhalation	IRIS
N-nitrosodiphenylamine					
Noncarcinogenic PAHs (Naphthalene)	4E-03 *	10,000	Ocular & Internal Lesions	Diet	HEAST
Phenol	6E-01	100	Fetal Weight	Gavage	IRIS
RDX	3E-03	100	Prostate Inflam.	Diet	IRIS
1,1,2,2-Tetrachloroethane	--	--	--	--	--
Tetrachloroethene	1E-02	1,000	Liver	Gavage	IRIS
Toluene	3E-01	100	CNS	Gavage	IRIS
1,1,1-Trichloroethane	9E-02 *	1,000	Liver	Inhalation	IRIS
1,1,2-Trichloroethane	4E-03	1,000	Blood Chemistry	Water	IRIS
Trichloroethene	7.35E-03 *	1,000	Liver	Inhalation	HA
1,3,5-Trinitrobenzene	5E-05	10,000	Spleen	Water	IRIS
Vinyl chloride	--	--	--	--	--
Inorganics:					
Antimony	4E-04	1,000	Blood Chemistry	Water	IRIS
Arsenic	1E-03 *	1	Skin	Water	HEAST
Barium	5E-02	100	Blood	Water	IRIS
Beryllium	5E-03	100	Blood, skin	Water	IRIS
Cadmium	1E-03 (j) 5E-04 (water)	10	Renal	NA	IRIS
Chromium (III)	1E+00	1,000	Liver	Diet	IRIS
Chromium (VI)	5E-03	500	Liver, Kidney	Water	IRIS
Copper	--	--	--	--	--
Cyanide	2E-02	500	Weight, Thyroid	Diet	IRIS
Mercury (mercuric)	3E-04	1,000	Kidney	Diet	HEAST
Nickel	2E-02	300	Organ Weight	Diet	IRIS
Selenium	3E-03	15	Skin	Food	HEAST
Silver	3E-03	2	Argyria	Drug	IRIS
Thallium	7E-05	3,000	Blood Chemistry	Gavage	HEAST
Zinc	2E-01	10	Blood	Drug	HEAST
Radiological Parameters:					
Ra226	--	--	--	--	--
Ra228	--	--	--	--	--
U-234	--	--	--	--	--
U-235	--	--	--	--	--
U-238	--	--	--	--	--
INHALATION ROUTE:					
Organics:					
Bromodichloromethane	--	--	--	--	--
Bromoform	--	--	--	--	--
Chloroform	--	--	--	--	--
Carbon tetrachloride	--	--	--	--	--
Dibromochloromethane	--	--	--	--	--
1,2-Dichloroethene	--	--	--	--	--
1,2-Dichlorobenzene	4E-02	1000	Weight gain	--	HEAST
1,4-Dichlorobenzene	2E-01	100	Liver and kidney	--	HEAST
1,1,1-Trichloroethane	3E-01	1000	Liver	--	HEAST
Trichloroethene	--	--	--	--	--
Toluene	5.7E-01	100	CNS	--	HEAST

TABLE 5-29 (Continued)

HEALTH EFFECTS CRITERIA FOR ORAL EXPOSURE TO CHEMICALS OF CONCERN
LAKE CITY, MISSOURI

Footnotes

(a) Toxicity criteria are not available for chloroethane, copper, dimethylphthalate, lead, tetryl, oil and grease, total uranium, gross alpha activity and gross beta activity.

(b) EPA weight of evidence classification scheme for carcinogens:

A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies;
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data; and
D = Not classified.

(c) Route of exposure in toxicity study upon which toxicity criterion is based.

(d) IRIS = the chemical files of EPA's Integrated Risk Information System (as of 5/1/90); HEAST = Health Effects Assessment Summary Tables (10/1/89); and HA = Health Advisory (Office of Drinking Water, 3/31/87).

(e) Health Effects Assessment for Benzo(a)pyrene. 1984. Environmental Criteria and Assessment Office. Cincinnati, Ohio. September 1984. EPA 540/1-86/022.

(f) The slope factor for 2,4-DNT and 2,6-DNT is based on the same mixture.

(g) EPA 1988. Special Report on Ingested Inorganic Arsenic. Skin Cancer; Nutritional Essentiality. Risk Assessment Forum, Washington, D.C. EPA/625/3-87-013F. July 1988

(h) Safety factors used to develop reference doses are the products of uncertainty and modifying factors. Uncertainty factors consist of multiples of 10, with each factor representing a specific area of uncertainty in the data available. The standard uncertainty factors include:

- a 10-fold factor to account for the variation in sensitivity among the members of the human population;
- a 10-fold factor to account for the uncertainty in extrapolating animal data to the case of humans;
- a 10-fold factor to account for the uncertainty in extrapolating from less-than-chronic NOAELs to chronic NOAELS; and
- a 10-fold factor to account for the uncertainty in extrapolating from LOAELs to NOAELs.

Modifying factors are applied at the discretion of the reviewer to cover other uncertainties in the data.

(i) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(j) In accordance with EPA guidance, the cadmium RfD for food is used for food (i.e., fish) and other nonaqueous materials (i.e., soil).

* = Pending review by EPA.
-- = No information available.

from just above zero to some finite value can be tolerated by the organism without appreciable risk of causing the disease (EPA 1985a).

Generally, this section discusses only those health effects criteria (i.e., RfDs, slope factors) which have been approved by EPA. Toxicity criteria are not available for chloroethane, copper, dimethylphthalate, lead, tetryl, oil and grease, total uranium, gross alpha activity, and gross beta activity.

5.4.1.1 Health Effects Criteria for Noncarcinogens

Health criteria for chemicals exhibiting noncarcinogenic effects are generally developed using risk reference doses (RfDs) developed by the USEPA RfD Work Group, or RfDs obtained from Health Effects Assessments (HEAs). The RfD, expressed in units of mg/kg/day, is an estimate of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. These RfDs are usually derived either from human studies involving workplace exposures or from animal studies, and are adjusted using uncertainty factors. The RfD provides a benchmark to which chemical intakes by other routes (e.g., via exposure to contaminated environmental media) may be compared.

5.4.1.2 Health Effects Criteria for Potential Carcinogens

Slope factors, developed by EPA's Carcinogen Assessment Group (CAG) for potentially carcinogenic chemicals and expressed in units of $(mg/kg/day)^{-1}$, are derived from the results of human epidemiological studies or chronic animal bioassays. The animal studies must usually be conducted using relatively high doses in order to detect possible adverse effects. Since humans are expected to be exposed at lower doses than those used in the animal studies, the data are adjusted by using mathematical models. The data from animal studies are typically fitted to the linearized multistage model to obtain a dose-response curve. The 95th percentile upper confidence limit slope of the dose-response curve is subjected to various adjustments and an interspecies scaling factor is applied to derive the slope factor for humans. Thus, the actual risks associated with exposure to a potential carcinogen quantitatively evaluated based on animal data are not likely to exceed the risks estimated using these slope factors, but they may be much lower. Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves on an ad hoc basis. These models provide rough, but plausible, estimates of the upper limits on lifetime risk. Slope factors based on human epidemiological data are also derived using very conservative assumptions and, as such, they too are unlikely to underestimate risks. Therefore, while the actual risks associated with exposures to potential carcinogens are unlikely to be higher than the risks calculated using a slope factor, they could be considerably lower.

EPA assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as either Group A, Group B1, Group B2, Group C, Group D, or Group E. Group A chemicals (human carcinogens) are agents for which there is sufficient evidence to support the causal association between exposure to the agents in humans and cancer. Groups B1 and B2 chemicals (probable human carcinogens) are agents for which there is limited (B1) or inadequate (B2) evidence of carcinogenicity from human studies but for which there is sufficient evidence of carcinogenicity from animal studies. Group C chemicals (possible human carcinogens) are agents for which there is limited evidence of carcinogenicity in animals, and Group D chemicals (not classified as to human carcinogenicity) are agents with inadequate human and animal evidence of carcinogenicity or for which no data are available. Group E chemicals (evidence of non-carcinogenicity in humans) are agents for which there is no evidence of carcinogenicity in adequate human or animal studies.

5.4.2 Toxicity Summaries

Brief descriptions of the human and animal toxicity of the chemicals that will be evaluated in this assessment (that is those chemicals that are associated forms (EPA 1984). Approximately 95% of soluble inorganic arsenic administered to rats is absorbed from the gastrointestinal tract (Coulson et al. 1935, Ray-Bettley and O'Shea 1975). Approximately 70%-80% of arsenic deposited in the respiratory tract of humans has been shown to be absorbed (Holland et al. 1959). Dermal absorption is not significant (EPA 1984). Acute exposure of humans to metallic arsenic has been associated with gastrointestinal effects, hemolysis, and neuropathy (EPA 1984). Chronic exposure of humans to this metal can produce toxic effects on both the peripheral and central nervous systems, keratosis, hyperpigmentation, precancerous dermal lesions, and cardiovascular damage (EPA 1984, Tseng 1977). Arsenic is embryotoxic, fetotoxic, and teratogenic in several animal species (EPA 1984). Arsenic is a known human carcinogen. Epidemiological studies of workers in smelters and in plants manufacturing arsenical pesticides have shown that inhalation of arsenic is strongly associated with lung cancer and perhaps with hepatic angiosarcoma (EPA 1984). Ingestion of arsenic has been linked to a form of skin cancer and more recently to bladder, liver, and lung cancer (Tseng 1977, Tseng et al. 1968, Chen et al. 1986).

EPA has classified arsenic in Group A—Human Carcinogen—and has developed inhalation (EPA 1990) and oral (EPA 1988) slope factors of 50 $(mg/kg/day)^{-1}$ and 2.0 $(mg/kg/day)^{-1}$, respectively. The inhalation potency factor is the geometric mean value of potency factors derived from four occupational exposure studies on two different exposure populations (EPA 1984). The oral cancer potency factor was based on an epidemiological study in Taiwan which indicated an increased incidence of skin cancer in individuals exposed to arsenic in drinking water (Tseng 1977). A risk assessment for noncarcinogenic effects of arsenic is currently under review by EPA (1990). An oral reference dose (RfD) of $1x10^{-3}$ mg/kg/day was calculated for arsenic based on the same oral epidemiological study (Tseng 1977) which also showed greater incidence of keratosis and hyperpigmentation in humans (EPA 1989). An uncertainty factor of 1 was used to derive the oral RfD. This RfD is presently being reconsidered by the RfD workgroup.

5.4.2.3 Barium

Adverse effects in humans following oral exposure to soluble barium compounds include gastroenteritis, muscular paralysis, hypertension, ventricular fibrillation, and central nervous system damage (EPA 1984). Inhalation of barium sulfate or barium carbonate in occupationally exposed workers has been associated with baritosis, a benign pneumoconiosis (Goyer 1986). Experimental animals exposed chronically to barium in drinking water developed increased blood pressure (EPA 1984, Perry et al. 1983). Inhalation of barium carbonate dust by experimental animals has been associated with reduced sperm count, increased fetal mortality, atresia of the ovarian follicles, decreased body weight, and alterations in liver function (EPA 1984, Tarasenko et al. 1977).

EPA (1989a) derived an oral reference dose (RfD) based on a chronic rat study in which a lowest-observed-adverse-effect level (LOAEL) for increased blood pressure was observed (Perry et al. 1983). Using the LOAEL of 5.1 mg/kg/day and an uncertainty factor of 100, an oral RfD of 5×10^{-2} mg/kg/day was calculated. EPA (1989b) has also developed an inhalation RfD of 1.0×10^{-4} mg/kg/day for barium based on a study by Tarasenko et al. (1977). In this study rats were exposed to barium carbonate dust at airborne concentrations of up to 5.2 mg/m^3 for 4-6 months. Adverse effects noted at this concentration included decreased body weight, alterations in liver function, and increased fetal mortality. An uncertainty factor of 1,000 was used in developing the RfD.

5.4.2.4 Benzene

Benzene is readily absorbed following oral and inhalation exposure (EPA 1985). The toxic effects of benzene in humans and other animals following exposure by inhalation include central nervous system effects, hematological effects, and immune system depression. In humans, acute exposures to high concentrations of benzene vapors have been associated with dizziness, nausea, vomiting, headache, drowsiness, narcosis, coma, and death (NAS 1976). Chronic exposure to benzene vapors can produce reduced leukocyte, platelet, and red blood cell counts (EPA 1985). Benzene induced both solid tumors and leukemias in rats exposed by gavage (Maltoni et al. 1985). Many studies have also described a causal relationship between exposure to benzene by inhalation (either alone or in combination with other chemicals) and leukemia in humans (IARC 1982, Rinsky et al. 1981, Ott et al. 1978, Wong et al. 1983).

Applying EPA's criteria for evaluating the overall evidence of carcinogenicity to humans, benzene is classified in Group A (Human Carcinogen) based on adequate evidence of carcinogenicity from epidemiological studies. EPA (1990) derived both an oral and an inhalation cancer potency factor for benzene of $2.9\text{x}10^{-2}$ $(\text{mg/kg/day})^{-1}$. This value was based on several studies in which increased incidences of nonlymphocytic leukemia were observed in humans occupationally exposed to benzene principally by inhalation (Rinsky et al. 1981, Ott et al. 1978, Wong et al. 1983). EPA (1990) is currently reviewing both oral and inhalation RfDs for benzene, for which the status is pending.

5.4.2.5 Beryllium

Beryllium is not readily absorbed by any route of exposure. Occupational exposure to beryllium results in bone, liver and kidney depositions (EPA 1986). In humans, acute respiratory effects due to beryllium exposure include rhinitis, pharyngitis, tracheobronchitis, and acute pneumonitis. Dermal exposure to soluble beryllium compounds can cause contact dermatitis, ulceration and granulomas (Hammond and Beliles 1980). Ocular effects include conjunctivitis and corneal ulceration from splash burns. The most common clinical symptom caused by chronic beryllium exposure is granulomatous lung inflammation (IARC 1980, EPA 1986). Chronic skin lesions sometimes appear after a long latent period in conjunction with the pulmonary effects. Systemic effects from beryllium exposure may include right heart enlargement with accompanying cardiac failure, liver and spleen enlargement, cyanosis, digital clubbing, and kidney stone development (EPA 1986, Schroeder and Mitchner 1975). Beryllium has been shown to be carcinogenic in experimental animals resulting primarily in lung and/or bone tumors when given by injection, intratracheal administration, or inhalation (EPA 1986). Chronic oral administration to rats resulted in an increased occurrence of gross tumors of all sites combined (Schroeder and Mitchner 1975). Several epidemiological studies have suggested that occupational exposure to beryllium may result in an increased lung cancer risk although the data are inconclusive (EPA 1986, Wagoner et al. 1980).

Beryllium has been classified by EPA in Group B2--Probable Human Carcinogen based on increased incidences of lung cancer and osteosarcomas in animals (EPA 1989). EPA (1989) has calculated an inhalation cancer potency factor of 8.4 $(mg/kg/day)^{-1}$ based on the relative risk for lung cancer, estimated from an epidemiological study by Wagoner et al. (1980). EPA (1989) established an oral cancer potency factor of 4.3 $(mg/kg/day)^{-1}$ based on the induction of tumors (type and site unspecified) in rats chronically administered beryllium sulfate in their drinking water (Schroeder and Mitchner 1975). EPA (1989) has also developed an oral reference dose (RfD) for beryllium of 5.0×10^{-3} mg/kg/day based on a study by Schroeder and Mitchner (1975) in which rats exposed to 0.54 mg/kg/day beryllium sulfate (the highest dose tested) in drinking water for a lifetime did not exhibit adverse effects; an uncertainty factor of 100 was used to develop the RfD.

5.4.2.6 Bromodichloromethane

Bromodichloromethane, also known as dichlorobromomethane is readily absorbed following oral exposure (EPA 1984, NTP 1986). Compound-related cytomegaly and tubular cell hyperplasia of the kidney and fatty metamorphosis of the liver have been observed in rats following chronic gavage administration (NTP 1986). Some fetal anomalies were observed in the offspring of mice exposed to very high levels of bromodichloromethane during gestation (EPA 1984). This chemical tested positive for mutagenicity in the Salmonella/microsome assay and in the L5178Y mouse lymphoma test (NTP 1986). Mice chronically administered bromodichloromethane by gavage developed an increased incidence of liver tumors (NTP 1986).

EPA (1989) has classified bromodichloromethane as a B2 agent (probable human carcinogen) indicating there is sufficient evidence of carcinogenicity in animals but inadequate evidence in humans. EPA (1989) has established an oral cancer potency factor of 0.13 $(mg/kg/day)^{-1}$ based on an increased incidence of liver tumors in mice (NTP 1986). EPA (1990) has derived an oral reference dose (RfD) for bromodichloromethane of $2x10^{-2}$ mg/kg/day based on a chronic gavage study in which renal cytomegaly was observed in mice (NTP 1986). An uncertainty factor of 1,000 was applied to a LOAEL of 17.9 mg/kg/day to derived the RfD.

5.4.2.7 Bromoform

Bromoform is rapidly absorbed following oral administration, with gastrointestinal absorption estimated to be 60 to 90% complete (Mink et al. 1986). Low-level inhalation exposure of humans to bromoform results in irritation, lacrimation and reddening of the face (Sax and Lewis 1989). Bromoform, like other halogenated hydrocarbrons, can induce central nervous system depression following both oral and inhalation exposures (ATSDR 1989). In experimental animals the target organs appear to be the CNS, liver and kidney following acute exposure (Dykan 1962, 1964, Bowman et al. 1978). Subchronic oral administration of rats resulted in liver and thyroid effects characterized by fatty liver infiltration and vacuolization, and a reduction in the follicular size (Chu et al. 1982, NTP 1980). In animals, chronic exposure produced nonneoplastic liver lesions manifested as fatty change, active chronic inflammation, and necrosis (NTP 1988). Increased incidences of uncommon tumors of the large intestine have been induced by chronic oral bromoform exposure (NTP 1988).

Bromoform is classified in B2 (EPA 1989). EPA (1990) has derived an oral reference dose (RfD) of $2x10^{-2}$ mg/kg/day for bromoform based on a subchronic oral bioassay conducted in rats (NTP 1980). A no-observed-adverse effect level (NOAEL) of 25 mg/kg/day for hepatic lesions was identified, to which an uncertainty factor of 1,000 was applied to derive the RfD. EPA (1989) has calculated an oral cancer potency factor of 7.9×10^{-3} $(mg/kg/day)^{-1}$ based on the development of adenomatous polyps or adenocarcinomas in the large intestine of rats chronically administered bromoform by gavage (NTP 1988).

5.4.2.8 Cadmium

Gastrointestinal absorption of cadmium in humans ranges from 5-6% (EPA 1985a). Pulmonary absorption of cadmium in humans is reported to range from 10% to 50% (CDHS 1986). Cadmium bioaccumulates in humans, particularly in the kidney and liver (EPA 1985a,b). Chronic oral or inhalation exposure of humans to cadmium has been associated with renal dysfunction, itai-itai disease (bone damage), hypertension, anemia, endocrine alterations, and immunosuppression. Renal toxicity occurs in humans at a renal cortex concentration of cadmium of 200 µg/g (EPA 1985b). Epidemiological studies have demonstrated a strong association between inhalation exposure to cadmium and cancers of the lung, kidney, and prostate (EPA 1985b, Thun et al. 1985). In experimental animals, cadmium induces injection-site sarcomas and testicular tumors. When administered by inhalation, cadmium chloride is a potent pulmonary carcinogen in rats. Cadmium is a well-documented animal teratogen (EPA 1985b).

EPA (1989, 1990) classified cadmium as a Group B1 agent (Probable Human Carcinogen) by inhalation. This classification applies to agents for which there is limited evidence of carcinogenicity in humans from epidemiologic studies. EPA (1989, 1990) derived an inhalation cancer potency factor of 6.1 $(mg/kg/day)^{-1}$ for cadmium based on epidemiologic studies in which respiratory tract tumors were observed (Thun et al. 1985, EPA 1985b). Using renal toxicity as an endpoint, and a safety factor of 10, EPA (1989, 1990) has derived two separate oral reference doses (RfD). The RfD associated with oral exposure to drinking water is 5×10^{-4} mg/kg/day, and is based upon the lowest-observed-adverse-effect level (LOAEL) of 0.005 mg/kg in humans (EPA 1985a, Friberg et al. 1974). The RfD associated with exposure to cadmium in food or other nonaqueous oral exposures is 1x10^{-3} mg/kg/day.

5.4.2.9 Carbon Tetrachloride

Carbon tetrachloride (CCl_4) is readily absorbed following oral and inhalation exposure. About 60% of an oral dose was absorbed by 6 hours, and up to 86% was absorbed by 24 hours. Absorption from the lung has been estimated at about 30% (EPA 1984). CCl_4, like many other chlorinated hydrocarbons, acts as a central nervous system depressant (ACGIH 1986). The toxic effects of oral and inhalation exposure to CCl_4 in humans and animals include damage to the liver, kidney and lung, although the liver is the most sensitive tissue (EPA 1985, Bruckner et al 1986). In animals, acute oral administration produces fatty infiltration and histological alterations in the liver. High doses produce irreversible liver damage and necrosis while the effects observed following lower doses are largely reversible (EPA 1985). Humans occupationally exposed to 5-15 ppm of CCl_4 experience biochemical alterations, nausea, headaches and in more severe cases, liver dysfunction (jaundice, enlargement and fatty infiltration) (ACGIH 1986, EPA 1984). Animals chronically exposed to CCl_4 exhibit effects similar to those observed following acute exposure. Prenatal toxicity has been demonstrated in mammalian fetuses and neonates after inhalation exposure in pregnant rats (EPA 1984), although CCl_4 has not been shown to be teratogenic (EPA 1985). Carbon tetrachloride is a carcinogen in animals producing mainly hepatic neoplasms. Oral administration of 30 mg/kg/day or higher for 6 months has been found to produce an increased frequency of hepatomas, hepatocellular adenomas and hepatocellular carcinomas in mice, rats and hamsters (EPA 1985).

EPA (1989) has classified CCl_4 as a B2 agent (probable human carcinogen). The cancer potency factor for both oral and inhalation exposure is 1.3x10^{-1} (mg/kg/day)$^{-1}$. EPA (1989) established the cancer potency factor based on several gavage studies in which hepatocellular carcinomas and hepatomas were observed in rats, mice and hamsters (Della Porta et al. 1961, Edwards et al.

1942, NCI 1976a, 1976b, 1977). EPA (1989) has derived an oral reference dose (RfD) of $7x10^{-4}$ mg/kg/day based on a subchronic rat gavage study in which liver lesions were the most sensitive effect (Bruckner et al. 1986). A no observed adverse effect level (NOAEL) of 0.71 mg/kg/day and an uncertainty factor of 1,000 were used to derive the RfD.

5.4.2.10 Carcinogenic PAHs

PAHs occur in the environment as complex mixtures containing numerous PAHs of varying carcinogenic potencies. Only a few components of these mixtures have been adequately characterized, and only limited information is available on the relative potencies of different compounds.

PAH absorption following oral exposure is inferred from the demonstrated toxicity of PAHs following ingestion (EPA 1984a). PAH absorption following inhalation exposure is inferred from the demonstrated toxicity of PAHs following inhalation (EPA 1984a). PAHs are also absorbed following dermal exposure (Kao et al. 1985). It has been suggested that simultaneous exposure to carcinogenic PAHs such as benzo[a]pyrene and particulate matter can increase the effective dose of the compound (ATSDR 1987). Acute effects from direct contact with PAHs and related materials are limited primarily to phototoxicity; the primary effect is dermatitis (NIOSH 1977). PAHs have also been shown to cause cytotoxicity in rapidly proliferating cells throughout the body; the hematopoietic system, lymphoid system, and testes are frequent targets (Santodonato et al. 1981). Destruction of the sebaceous glands, hyperkeratosis, hyperplasia, and ulceration have been observed in mouse skin following dermal application of the carcinogenic PAHs (Santodonato et al. 1981). The carcinogenic PAHs have also been shown to have an immunosuppressive effect in animals (ATSDR 1987). Nonneoplastic lesions have been observed in animals exposed to the more potent carcinogenic PAHs but only after exposure to levels well above those required to elicit a carcinogenic response. Carcinogenic PAHs are believed to induce tumors both at the site of application and systemically. Neal and Rigdon (1967) reported that oral administration of 250 ppm benzo[a]pyrene for approximately 110 days led to forestomach tumors in mice. Thyssen et al. (1981) observed respiratory tract tumors in hamsters exposed to up to 9.5 mg/m^3 benzo[a]pyrene for up to 96 weeks.

Benzo[a]pyrene is representative of the carcinogenic PAHs and is classified by EPA in Group B2--Probable Human Carcinogen--based on sufficient evidence of carcinogenicity from animal studies and inadequate evidence from epidemiological studies (EPA 1984b, 1989). EPA (1984b) calculated an oral cancer potency factor of 11.5 (mg/kg/day)$^{-1}$ for carcinogenic PAHs (specifically benzo[a]pyrene) based on the study by Neal and Rigdon (1967).

5.4.2.11 Chloroethane

Chloroethane is primarily absorbed through the lungs, although some dermal absorption may occur. Absorption and excretion of chloroethane occurs rapidly via the lungs; it is not metabolized to a significant degree (Clayton and Clayton 1981). Severe acute inhalation of chloroethane by humans produces minor neurological effects that are manifested as stupor and lack of coordination, and in some incidences as cardiac arrhythmia produced by the potentiation of adrenalin (Clayton and Clayton 1981). Acute inhalation of chloroethane by animals has produced histological or pathological changes in the liver, brain, and lungs (Troshina 1964). Chronic exposure of animals to chloroethane produced kidney damage and fatty changes in the liver, and at high levels has upset cardiac rhythm (EPA 1985). Studies assessing the mutagenicity and carcinogenicity of chloroethane are currently being conducted (EPA 1985). No health based criteria numbers have been established by EPA.

5.4.2.12 Chloroform

Chloroform, a trihalomethane, is rapidly absorbed through the respiratory and gastrointestinal tracts in humans and experimental animals; dermal absorption from contact of the skin with liquid chloroform can also occur (EPA 1985). In humans, acute exposures to chloroform may result in depression of the central nervous system, hepatic and renal damage, and death caused by ventricular fibrillation following an acute ingested dose of 10 ml (EPA 1984). Acute exposure to chloroform may also cause irritation to the skin, eyes, and gastrointestinal tract (EPA 1984, 1985). In experimental animals, chronic exposure may lead to fatty cyst formation in the liver (Heywood et al. 1979), renal and cardiac effects, and central nervous system depression (EPA 1985). Chloroform has been reported to induce renal epithelial tumors in rats (Jorgenson et al. 1985) and hepatocellular carcinomas in mice (NCI 1976). Suggestive evidence from human epidemiological studies indicates that long-term exposure to chloroform and other trihalomethanes in contaminated water supplies may be associated with an increased incidence of bladder tumors (EPA 1985). Chloroform is embryotoxic in pregnant rats and has retarded fetal development and increased the incidences of fetal resorption, acadia (absence of tail), imperforate anus, missing ribs and delayed ossification of sternebrae (Schwetz et al. 1974).

Chloroform has been classified by EPA as a Group B2 Carcinogen (Probable Human Carcinogen) (EPA 1989). EPA (1989) developed an oral cancer potency factor for chloroform of 6.1×10^{-3} $(mg/kg/day)^{-1}$ based on a study in which kidney tumors were observed in rats exposed to chloroform in drinking water (Jorgenson et al. 1985). An inhalation cancer potency factor of 8.1×10^{-2} $(mg/kg/day)^{-1}$ has been developed by EPA (1989) based on an NCI (1976) bioassay in which liver tumors were observed in mice. EPA (1989) also derived an oral reference dose (RfD) of 0.01 mg/kg/day for chloroform based on a chronic bioassay in dogs in which liver effects were observed at 12.9 mg/kg/day (Heywood et al. 1979); an uncertainty factor of 1,000 was used to derive the RfD.

5.4.2.13 Chromium

Chromium exists in two states, as chromium (III) and as chromium (VI). Following oral exposure, absorption of chromium (III) is low while absorption of chromium (VI) is high (EPA 1987). Chromium is an essential micronutrient animals resulting primarily in lung and/or bone tumors when given by injection, intratracheal administration, or inhalation (EPA 1986). Chronic oral administration to rats resulted in an increased occurrence of gross tumors of all sites combined (Schroeder and Mitchner 1975). Several epidemiological studies have suggested that occupational exposure to beryllium may result in an increased lung cancer risk although the data are inconclusive (EPA 1986, Wagoner et al. 1980).

Beryllium has been classified by EPA in Group B2--Probable Human Carcinogen based on increased incidences of lung cancer and osteosarcomas in animals (EPA 1989). EPA (1989) has calculated an inhalation cancer potency factor of 8.4 $(mg/kg/day)^{-1}$ based on the relative risk for lung cancer, estimated from an epidemiological study by Wagoner et al. (1980). EPA (1989) established an oral cancer potency factor of 4.3 $(mg/kg/day)^{-1}$ based on the induction of tumors (type and site unspecified) in rats chronically administered beryllium sulfate in their drinking water (Schroeder and Mitchner 1975). EPA (1989) has also developed an oral reference dose (RfD) for beryllium of 5.0×10^{-3} mg/kg/day based on a study by Schroeder and Mitchner (1975) in which rats exposed to 0.54 mg/kg/day beryllium sulfate (the highest dose tested) in drinking water for a lifetime did not exhibit adverse effects; an uncertainty factor of 100 was used to develop the RfD.

5.4.2.6 Bromodichloromethane

Bromodichloromethane, also known as dichlorobromomethane is readily absorbed following oral exposure (EPA 1984, NTP 1986). Compound-related cytomegaly and tubular cell hyperplasia of the kidney and fatty metamorphosis of the liver have been observed in rats following chronic gavage administration (NTP 1986). Some fetal anomalies were observed in the offspring of mice exposed to very high levels of bromodichloromethane during gestation (EPA 1984). This chemical tested positive for mutagenicity in the Salmonella/microsome assay and in the L5178Y mouse lymphoma test (NTP 1986). Mice chronically and is not toxic in trace quantities (EPA 1980). High levels of soluble chromium (VI) and chromium (III) can produce kidney and liver damage following acute oral exposure; target organs affected by chronic oral exposure remain unidentified (EPA 1984). Chronic inhalation exposure may cause respiratory system damage (EPA 1984). Further, epidemiological studies of worker populations have clearly established that inhaled chromium (VI) is a human carcinogen; the respiratory passages and the lungs are the target organs (Mancuso 1975, EPA 1984). Inhalation of chromium (III) or ingestion of chromium (VI) or (III) has not been associated with carcinogenicity in humans or experimental animals (EPA 1984). Certain chromium salts have been shown to be teratogenic and embryotoxic in mice and hamsters following intravenous or intraperitoneal injection (EPA 1984).

EPA has classified inhaled chromium (VI) in Group A--Probable Human Carcinogen by the inhalation route (EPA 1990). Inhaled chromium (III) and ingested chromium (III) and (VI) have not been classified with respect to carcinogenicity (EPA 1990). EPA (1990) developed an inhalation slope factor of 41 $(mg/kg/day)^{-1}$ for chromium (VI) based on an increased incidence of lung cancer in workers exposed to chromium over a 6 year period, and followed for approximately 40 years (Mancuso 1975). EPA (1990) derived an oral reference dose (RfD) of 5.0×10^{-3} mg/kg/day for chromium (VI) based on a study by MacKenzie et al. (1958) in which no adverse effects were observed in rats exposed to 2.4 mg chromium (VI)/kg/day in drinking water for 1 year. A safety factor of 500 was used to derive the RfD. EPA (1990) developed an oral RfD of 1 mg/kg/day for chromium (III) based on a study in which rats were exposed to chromic oxide baked in bread; no effects due to chromic oxide treatment were observed at any dose level (Ivankovic and Preussman 1975). A safety factor of 1,000 was used to calculate the oral RfD.

5.4.2.14 Copper

Copper is an essential element. A daily copper intake of 2 mg is considered to be adequate for normal health and nutrition; the minimum daily requirement is 10 μg/kg (EPA 1985). In humans, absorption of copper following oral exposure is approximately 60% and is influenced by competition with other metals and the level of dietary protein and ascorbic acid in both humans and animals (EPA 1984). Copper is absorbed following inhalation exposures, although quantitative data on the extent of absorption are unavailable (EPA 1984). Adverse effects in humans resulting from acute exposure to copper at concentrations that exceed these recommended levels by ingestion include salivation, gastrointestinal irritation, nausea, vomiting, hemorrhagic gastritis, and diarrhea (ACGIH 1986). Dermal or ocular exposure of humans to copper salts can produce irritation (ACGIH 1986). Acute inhalation of dusts or mists of copper salts by humans may produce irritation of the mucous membranes and pharynx, ulceration of the nasal septum, and metal fume fever. The latter condition is characterized by chills, fever, headache, and muscle pain. Limited data are available on the chronic toxicity of copper; however, chronic over-exposure to copper by humans has been associated with anemia (ACGIH 1986) and local gastrointestinal irritation (EPA 1987). Results of several animal bioassays suggest that copper compounds are not carcinogenic by oral administration; however, some copper compounds can induce injection-site tumors in mice (EPA 1985).

EPA (1989) has reported the drinking water standard of 1.3 mg/liter as an oral reference dose (RfD) based on local gastrointestinal irritation (EPA 1987). Assuming a 70-kg adult ingests 2 liters of water per day, this concentration is equivalent to a dose of 3.7×10^{-2} mg/kg/day. However, EPA (1987) concluded toxicity data were inadequate for the calculation of a reference dose (RfD) for copper.

5.4.2.15 Cyanide

The toxicity of cyanides is strongly dependent on their chemical speciation. Free cyanides are readily absorbed from the gastrointestinal tract, lungs, and skin and, once absorbed, are rapidly distributed throughout the body (EPA 1985). The toxic effects in humans following acute oral exposure to free cyanides include hyperventilation, vomiting, unconsciousness, convulsions, vascular collapse and cyanosis, and death (EPA 1985). Inhalation of high concentrations of hydrogen cyanide (HCN) gas results in almost immediate collapse, respiratory arrest, and death within minutes (DiPalma 1971). Airborne hydrogen cyanide concentrations between 99 and 528 mg/m^3 are fatal within 30-60 minutes (NIOSH 1976). There is limited data on chronic exposures of cyanide in humans, although the following effects have been identified in chronic occupationally exposed workers in some epidemiologic studies: neurological dysfunction, lacrimation, abdominal pain, muscular weakness, and shortness of breath (NIOSH 1976). Cyanide appears to be less toxic to animals following chronic exposures than following acute exposures. In animals, chronic oral exposure has produced weight loss, thyroid effects and myelin degeneration (Howard and Hanzal 1955). Cyanide can cause teratogenic effects when subcutaneously administered to hamsters; this teratogenic effect has not been observed in other species although some reproductive toxicity has been noted (EPA 1985).

EPA (1989a, 1989b) calculated an oral reference dose (RfD) of 0.02 mg/kg/day for cyanide based on a chronic study by Howard and Hanzal (1955) in which rats were maintained on a diet fumigated with hydrogen cyanide and exhibited weight loss, thyroid effects and myelin degeneration. No observed adverse effects (NOAEL) were noted at the highest dose administered (10.8 mg/kg/day). A NOAEL of 10.8 mg/kg/day and a safety factor of 500 were used to derive the RfD (EPA 1989a).

5.4.2.16 Dibromochloromethane

Dibromochloromethane (DBCM) also known as chlorodibromomethane, is absorbed 60 to 90% in rats and mice following oral exposure (Mink et al. 1986). Human absorption data and animal absorption data through other routes is not available. Acute oral and inhalation exposure to high doses of DBCM can cause depression of the central nervous system, and injury to the liver and kidney (ATSDR 1989). In animals, acute effects on the central nervous system include ataxia, sedation, and labored breathing (Balster and Borzelleca 1982, Bowman et al. 1978, NTP 1985). Acute exposure (14 days) of mice to 125-250 mg/kg/day to DBCM resulted in a decrease in several indices of humoral and cell mediated immunity (Munson et al. 1982). Most studies of the toxicity of DBCM in rats and mice indicate that the liver is the target tissue. Although hepatic effects are not severe, they are characterized by increased vacuolization, fat accumulation, increased liver weight, and altered serum enzyme levels (Condie et al. 1983, Munson et al. 1982, NTP 1985). There also appear to be species and sex sensitivites for hepatic effects. Mice show a greater sensitivity to DBCM than rats, and males tend to be more sensitive than females (Condie et al. 1983, NTP 1985). These sensitivites may be related to differences in the metabolism of this compound by the respective species and sex. Renal effects characterized as tubular degeneration and mineralization have been reported following longer-term exposure regimens (NTP 1985). Studies of the reproductive effects of DBCM in animals indicate that oral exposure does not result in significant damage to male or female reproductive organs (NTP 1985). Likewise, animal studies of the developmental effects of oral exposure to DBCM do not result in fetotoxicity or teratogenicity (Ruddick et al. 1983).

EPA (1989) has classified DBCM as a B2 agent and has reported an oral cancer potency factor of 0.084 based on a chronic (102 week) study investigating hepatic effects in mice (NTP 1985). EPA (1990) derived an oral reference dose (RfD) of 0.02 mg/kg/day for DBCM (chlorodibromomethane) based on a chronic study which observed hepatic lesions. An uncertainty factor of 1,000 was used to develop the RfD.

5.4.2.17 1,2-Dichlorobenzene

1,2-Dichlorobenzene is readily absorbed through the lungs, skin, and gastrointestinal tract (EPA 1987). The principal toxic effects of this compound in humans and experimental animals from acute and longer-term exposure include central nervous system depression, blood dyscrasias, and lung, kidney, and liver damage (EPA 1985, NTP 1985). Chromosome breaks also have been observed in exposed humans (EPA 1987).

EPA (1989b) derived an inhalation RfD of 0.04 mg/kg/day for 1,2-dichlorobenzene based on a study in which decreased body weight gain was observed in rats administered 1,2-dichlorobenzene, 7 hours/day, 5 days/week for up to 7 months (Hollingsworth et al. 1958); an uncertainty factor of 1,000 was used to derive the RfD. EPA (1989a) also reported an oral reference dose for 1,2-dichlorobenzene of 9×10^{-2} mg/kg/day based on an NTP (1985) study in which liver effects were observed in rats exposed to 1,2-dichlorobenzene for 5 days/week for 13 weeks; an uncertainty factor of 1,000 was used to develop the RfD.

5.4.2.18 1,4-Dichlorobenzene

1,4-Dichlorobenzene is a solid used as an air deodorant and as an insecticide. EPA (1987) reports that 100% of an oral dose and 60% of an inhalation dose are absorbed when exposure persists for longer than one to three hours (Astrand 1975, Dallas et al. 1983). The principal toxic effects of this compound in humans and experimental animals from acute and longer-term exposure include central nervous system depression, blood dyscrasias, and lung, kidney, and liver damage (EPA 1985, Riley et al. 1980). In humans, pigmentation and allergic dermatitis have been reported after dermal contact (EPA 1987). Chromosome breaks also have been observed in exposed humans (EPA 1987). 1,4-Dichlorobenzene was found to cause renal adenocarcinomas in male rats and carcinomas and adenocarcinomas of the liver in female mice in a 103-week gavage study (NTP 1986).

EPA classified 1,4-dichlorobenzene in Group B2--Probable Human Carcinogen based on adequate evidence of carcinogenicity in animals (EPA 1989). An oral cancer potency factor of 2.4×10^{-2} $(\mathrm{mg/kg/day})^{-1}$ has been reported by EPA (1989) based on the development of liver tumors in mice (NTP 1986). EPA (1987) also derived an oral reference dose (RfD) for 1,4-dichlorobenzene of 0.1 mg/kg/day based on the NTP (1986) rat study in which a no-observed-adverse-effect level (NOAEL) of 150 mg/kg/day for renal lesions was identified. An uncertainty factor of 1,000 was used to derive the RfD. This RfD was used to develop a lifetime health advisory for 1,4-dichlorobenzene. EPA (1989) developed an inhalation RfD of 7.0×10^{-1} mg/m^3 based on the Riley et al. (1980) study in which rats exposed to 75 ppm (454.6 mg/m^3) for 76 weeks exhibited liver and kidney effects. An uncertainty factor of 100 was used to derive the RfD.

5.4.2.19 1,1-Dichloroethane

1,1-DCA is probably less toxic than the 1,2-isomer (EPA 1980). At one time, the compound was used as an anesthetic, but it induced cardiac arrhythmias and its use was discontinued. It is probable that human exposure to sufficiently high levels of 1,1-DCA would cause central nervous system depression and respiratory tract and skin irritation, since many of the chlorinated aliphatics cause these effects (Parker at al. 1979). However, no dose-response data concerning these effects are available. Renal damage was observed in cats exposed by inhalation in a subchronic study (Hofmann et al. 1971). Inhalation exposure of pregnant rats to high doses of 1,1-DCA (6,000 ppm) retarded fetal development (Schwetz et al. 1974). A carcinogenicity bioassay of 1,1-DCA was limited by poor survival of both treatment and control groups, and the physical conditions of the treated animals were markedly stressed. Dose-related marginal increases in mammary gland adenocarcinomas and in hemangiosarcomas were seen in female rats, and a statistically significant increase in endometrial stromal polyps was seen in female mice; however, these data were not interpreted as providing conclusive evidence for the carcinogenicity of 1,1-DCA because of the previously mentioned limitations of the bioassay (NCI 1978).

EPA (1989) has classified 1,1-DCA as a Group B2 agent (Probable Human Carcinogen) and reported an oral cancer potency factor of 9.1×10^{-2} (mg/kg/day)$^{-1}$. This potency factor is based on structure-activity relationship to the isomer 1,2-dichloroethane, a Group B2 carcinogen and on the increased incidence of hemangiosarcomas observed in rats administered 1,1-DCA via gavage (NCI 1978). EPA (1989) developed an oral and inhalation reference dose of 0.1 mg/kg/day based on adverse renal effects seen in cats following subchronic inhalation exposure (Hofmann et al. 1971). A safety factor of 1000 was used to develop the RfD.

5.4.2.20 1,2-Dichloroethane

Data on the toxicokinetics of 1,2-dichloroethane (1,2-DCA) in humans are limited, but data from animal studies suggest that the chemical is rapidly absorbed following oral and inhalation exposure and after dermal contact with the liquid form of the compound (EPA 1985). Effects of acute inhalation exposure in humans include irritation of mucous membranes in the respiratory tract and central nervous system depression (EPA 1985). Death may occur as a result of respiratory and circulatory failure. Pathological examinations typically show congestion, degeneration, necrosis, and hemorrhagic lesions of the respiratory and gastrointestinal tracts, liver, kidney, spleen, and lungs (EPA 1985). Adverse effects caused by less extreme exposures are generally associated with the gastrointestinal and nervous systems. Occupational exposures to 1,2-DCA vapors result in anorexia, nausea, vomiting, fatigue, nervousness, epigastric pain, irritation of the eyes and respiratory tract, and gastrointestinal, liver, and gallbladder disease (EPA 1984, 1985). Chronic inhalation studies in animals also have revealed toxic effects including degeneration of the liver (EPA 1985). Available data suggest that 1,2-DCA does not adversely affect reproductive or developmental processes in experimental animals except at maternally toxic levels (EPA 1985). In long-term oral bioassays sponsored by the National Cancer Institute (NCI 1978), increased incidences of squamous-cell carcinomas of the forestomach, mammary gland adenocarcinomas, and hemangiosarcomas have been observed in rats exposed to 1,2-DCA; pulmonary adenomas, mammary adenocarcinomas, and uterine endometrial tumors have been observed in mice exposed to this chemical.

EPA (1989) has classified 1,2-DCA in Group B2 (Probable Human Carcinogen) based on inadequate evidence of carcinogenicity from human studies and sufficient evidence of carcinogenicity from animal studies. EPA (1989) derived an oral and an inhalation cancer potency factor (q_1*) of 9.1×10^{-2} $(mg/kg/day)^{-1}$ for 1,2-DCA based on the incidences of hemangiosarcomas in Osborne-Mendel male rats observed in the NCI (1978) gavage study.

5.4.2.21 1,1-Dichloroethene

1,1-Dichloroethene (1,1-DCE) is rapidly absorbed after oral and inhalation exposures (EPA 1984, 1987). Humans acutely exposed to 1,1-DCE vapors exhibit central nervous system depression. In animals, the liver is the principal target of 1,1-DCE toxicity. Acute exposures result in liver damage which ranges from fatty infiltration to necrosis (EPA 1987). Workers chronically exposed to 1,1-DCE in combination with other vinyl compounds exhibit liver dysfunction, headaches, vision problems, weakness, fatigue and neurological sensory disturbances (EPA 1987). Chronic oral administration of 1,1-DCE to experimental animals results in both hepatic and renal toxicity (EPA 1984, Quast et al. 1983). Inhalation or oral exposure of rats and rabbits has produced fetotoxicity and minor skeletal abnormalities, but only at maternally toxic doses. 1,1-DCE vapors produced kidney tumors and leukemia in a single study of mice exposed by inhalation, but the results of other studies were equivocal or negative (EPA 1987, Maltoni et al. 1985).

EPA has classified 1,1-DCE as a Group C agent (Possible Human Carcinogen) and has developed inhalation and oral cancer potency factors of 1.2 $(mg/kg/day)^{-1}$ and 0.6 $(mg/kg/day)^{-1}$, respectively (EPA 1985, 1989). The inhalation potency factor was based on the increased incidence of renal adenocarcinomas in male mice exposed to 1,1-DCE via inhalation for 52 weeks and observed for a total of 121 weeks (Maltoni et al. 1985). The oral potency factor was derived by estimating an upper-limit value from negative bioassay data and assuming that a carcinogenic response occurs via ingestion, although there is no direct evidence that this is true. EPA (1989) developed an oral reference dose (RfD) of 9×10^{-3} mg/kg/day based on the occurrence of hepatic lesions in rats chronically exposed to 1,1-DCE in drinking water (Quast et al. 1983). A safety factor of 1000 was applied to the lowest-observed-adverse-effect level (LOAEL) of 9 mg/kg/day to derive the oral RfD.

5.4.2.22 trans- and cis-1,2-Dichloroethene

Both *trans*-1,2-Dichloroethene (1,2-DCE) and *cis*-1,2-DCE are expected to be absorbed by any route of exposure (EPA 1987). Information on the health effects of both *trans*-1,2-DCE and *cis*-1,2-DCE are limited. In humans, *trans*-1,2-DCE and *cis*-1,2-DCE are central nervous system depressants, and exposure to high concentrations can result in anesthetic effects (Irish 1963). Acute exposure to higher dose levels of the trans-isomer can cause narcosis and death in rats (Torkelson and Rowe 1981). In animals, *cis*-1,2-DCE also has narcotic effects at high doses. Inhalation exposure of rats to 200 ppm *trans*-1,2-DCE has been associated with pneumonic infiltration of the lungs and progressive fatty degeneration of the liver (Freundt et al. 1977). Exposure of rats to 200 ppm *trans*- or *cis*-1,2-DCE by inhalation has been observed to result in inhibition of the mixed function oxidase enzyme system; the cis-isomer was more potent (Freundt and Macholz 1978). Chronic oral exposure of rats to *trans*-1,2-DCE has resulted in increased serum alkaline phosphatase (Barnes et al. 1985). Rats chronically administered *cis*-1,2-DCE in their diet have exhibited hepatocellular swelling and fatty changes (Quast et al. 1983). *cis*-1,2-DCE was reported to induce mutations using a host-mediated assay and chromosomal aberrations in mouse bone marrow cells (Cerna and Kypenova 1977).

EPA (1990) has derived an oral reference dose (RfD) of 2×10^{-2} mg/kg/day for *trans*-1,2-DCE based on a 90-day drinking water study conducted in mice (Barnes et al. 1985). A no-observed-adverse-effect level (NOAEL) of 17 mg/kg/day for increased serum alkaline phosphatase and an uncertainty factor of 1,000 were used to derive the RfD. EPA (1987) has derived an oral RfD or 0.01 mg/kg/day based on results of a 2-year chronic toxicity/ oncogenicity study in which rats exhibited significant microscopic liver changes and minimal hepatocellular swelling and fatty changes (Quast et al. 1983). The RfD was calculated using a lowest-observed-effect level (LOAEL) of 10 mg/kg/day and an uncertainty factor of 1,000.

5.4.2.23 Dimethyl phthalate

Dimethyl phthalate is absorbed through the lungs and gut, and some skin absorption has been reported (ACGIH 1986). It is moderately toxic by ingestion and interperitoneal routes and very mildly toxic by inhalation (Sax and Lewis 1989). In humans, ingestion causes gastrointestinal irritation, coma, and occasionally hypotension (ACGIH 1986). The oral LD_{50} in rats is 6,800 mg/kg (Sax and Lewis 1989). It is a slight eye irritant (Sax and Lewis 1989). It has been shown to have mutagenic effects through an increase in chromosomal aberrations in hepatocytes (NTP/IRLG 1982). Dimethyl phthalate is also an experimental teratogen and has been shown to have adverse reproductive effects (Sax and Lewis 1989). No health-based criteria have been established by EPA.

5.4.2.24 1,3-DNB

Absorption of the dinitrobenzene (DNB) isomers (1,2-DNB, 1,3-DNB, and 1,4-DNB) have not been well characterized, however ready absorption through the skin is a major factor in its toxicity (ACGIH 1986). Occupational exposures to the DNB isomers have been associated with methemoglobinemia and respiratory tract irritation. Prolonged exposures of humans to dinitrobenzene may result in anemia, liver damage and cyanosis (Beard and Noe 1981). In animals, subchronic oral exposures have resulted in retarded growth, decreased hemoglobin concentrations, splenic enlargement and hemosiderin deposits. Testicular atrophy and decreased spermatogenesis have also been observed in male rats following oral exposures (Cody et al. 1981).

EPA 1988 has developed an oral reference dose (RfD) of 1.0×10^{-4} mg/kg/day for 1,3-DNB based on a subchronic drinking water study in rats. This study identified a lowest-observed-effect-level (LOEL) of 8 ppm for increased splenic weight and a no-observed-effect-level (NOAEL) of 3 ppm (0.40 mg/kg/day) (Cody et al. 1981). The RfD was calculated using the NOAEL and an uncertainty factor of 3000.

5.4.2.25 2,4 and 2,6 - Dinitrotoluene

Although five isomers of dinitrotoluene (DNT) exist, only two (2,4-and 2,6-) will be discussed. Dinitrotoluene is rapidly absorbed following inhalation, oral and dermal exposure. The blood, liver, and neuromuscular systems are the primary target organs for DNT toxicity in both humans and experimental animals. In humans, exposure symptoms include moderate cyanosis, anemia, dyspnea, dizziness, sleepiness, and methemoglobinemia (Hamblin 1963; von Oettingen 1941). Long term occupational exposures also have been correlated with an increase in ischemic heart disease (Levine et al. 1986). In rats, chronic exposure to pure 2,6-DNT and mixtures of 2,4- and 2,6-DNT in the diet have significantly increased the incidence of liver tumors (Ellis et al. 1979; Leonard et al. 1987).

EPA (1989) has classified 2,4- and 2,6-dinitrotoluene in Group B2 --Probable Human Carcinogen for oral and inhalation routes. Both isomers have an oral cancer potency factor of 0.68 $(mg/kg/day)^{-1}$ based on a 2-year study in which rats developed liver and mammary gland tumors when fed a mixture of 2,4- and 2,6- dinitrotoluene isomers (Ellis et al. 1979). The oral cancer potency factor for 2,4-DNT is pending by EPA (1990).

5.4.2.26 Di-n-butyl phthalate

Di-n-butyl phthalate is readily absorbed following oral and inhalation exposure (EPA 1980). Acute exposures of di-n-butyl phthalate aerosol in mice have produced irritation of the eyes and upper respiratory tract mucous membranes. Extreme exposures result in labored breathing, ataxia, paresis, convulsions and death from paralysis of the respiratory system (ACGIH 1986).

Workers chronically exposed to di-n-butyl phthalate in combination with other phthalate plasticizers have exhibited pain, numbness and spasms in the upper and lower extremities. Further evaluation revealed vestibular dysfunction and polyneuritis (ACGIH 1986). Reduced fetal weight, increased numbers of resorptions, and dose-related musculoskeletal abnormalities have been observed among fetuses from rats and mice exposed to very high doses of di-n-butyl phthalate during gestation (Shiota and Nishimura 1982).

EPA (1990) calculated an oral reference dose (RfD) for di-n-butyl phthalate based on a study by Smith (1953) in which male Sprague-Dawley rats were fed a diet containing dibutyl phthalate for a period of 1 year. One-half of all rats receiving the highest dibutyl phthalate concentration (1.25% of diet, or 600 mg/kg/day) died during the first week of exposure. The remaining animals survived the study with no apparent adverse effects. Using a NOAEL of 125 mg/kg/day (0.25% dibutyl phthalate in diet) and an uncertainty factor of 1,000, an oral reference dose (RfD) of 0.1 mg/kg/day was derived; a LOAEL of 600 mg/kg/day (1.25% dibutyl phthalate in diet) was observed in this study.

5.4.2.27 Ethylbenzene

Ethylbenzene is absorbed via inhalation and distributed throughout the body in rats; the highest levels were detected in the kidney, lung, adipose tissue, digestive tract, and liver (Chin et al. 1980). In humans, short-term inhalation exposure to 435 mg/m^3 ethylbenzene for 8 hours can result in sleepiness, fatigue, headache, and mild eye and respiratory irritation (Bardodej and Bardodejova 1970); eye irritation has also been observed in experimental animals exposed to ethylbenzene (EPA 1987). Increased weights and cloudy swelling were observed in the liver and kidney of rats exposed to ethylbenzene by gavage at a dose of 408 mg/kg/day for 182 days (Wolf et al. 1956). A single oral dose of ethylbenzene administered to male and female Wistar-derived rats was reported to have an LD$_{50}$ of 3,500 mg/kg body weight, with systemic effects occurring primarily in the liver and kidney (Wolf et al. 1956). Maternal toxicity was observed in rats exposed by inhalation to 4,348

mg/m^3 ethylbenzene for 6-7 hours/day during the first 19 days of gestation (Hardin et al. 1981).

EPA (1990) derived an oral reference dose of 0.1 mg/kg/day for ethylbenzene based on the chronic study by Wolf et al. (1956) in which no liver or kidney effects were observed in rats exposed to 136 mg/kg/day. An uncertainty factor of 1,000 was applied to the no-observed-effect-level to derive the reference dose.

5.4.2.28 bis(2-Ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate, also known as di-ethylhexyl phthalate (DEHP), is readily absorbed following oral or inhalation exposure (EPA 1980). Chronic exposure to relatively high concentrations of DEHP in the diet can cause retardation of growth and increased liver and kidney weights in laboratory animals (NTP 1982, EPA 1980, Carpenter et al. 1953). Reduced fetal weight and increased number of resorptions have been observed in rats exposed orally to DEHP (EPA 1980). DEHP is reported to be carcinogenic in rats and mice, causing increased incidences of hepatocellular carcinomas or neoplastic nodules following oral administration (NTP 1982).

DEHP has been classified in Group B2--Probable Human Carcinogen (EPA 1986, 1989). EPA (1989) calculated an oral cancer potency factor for DEHP of 1.4×10^{-2} $(mg/kg/day)^{-1}$ based on data from the NTP (1982) study. EPA has recommended an oral reference dose (RfD) for DEHP of 0.02 mg/kg/day based on a study by Carpenter et al. (1953) in which increased liver weight was observed in female guinea pigs exposed to 19 mg/kg bw/day in the diet for 1 year (EPA 1989); an uncertainty factor of 1,000 was used to develop the RfD.

5.4.2.29 HMX

HMX, or octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine, is poorly absorbed when administered orally and intravenously to rats and mice due to its low aqueous solubility (EPA 1988). No data were found in the available literature regarding pulmonary or dermal absorption. Although no adverse effects were reported in workers who had been potentially exposed to HMX at a munitions plant, acute oral doses of HMX administered to rats and mice have resulted in histologic liver changes, and CNS effects including ataxia and hyperkinesia. Animals receiving higher doses experienced convulsions (EPA 1988). Subchronic oral administration of HDX to rats caused transient weight loss and blood changes (e.g. reduced hemoglobin, hematocrit, and red blood cell counts) in all treated animals (DOD, 1985). At higher HDX levels, males exhibited liver necrosis and enlarged centrilobular cells while tubular kidney changes such as focal atrophy and dilation were seen in treated female rats (DOD 1985). These results suggest a sex difference in target organs of rats to HMX (DOD 1985). Microbial genetic toxicology assays suggest that HMX is not mutagenic, although only low concentrations of HMX were used in tests due to limited solubility (DOD 1977).

EPA (1990) has reported an oral reference dose (RfD) of 5×10^{-2} mg/kg/day based on a subchronic rat feeding study where administration of 150 mg/kg/day led to hepatic lesions (DOD 1985). The RfD was determined by applying an uncertainty factor of 1,000 to the no observed adverse effect level (NOAEL) of 50 mg/kg/day for males.

5.4.2.30 Lead

Absorption of lead from the gastrointestinal tract of adult humans is estimated at 8%-45%. In children, absorption from non-paint sources ranges from 30% to 50% (Hammond and Beliles 1980, EPA 1986). There are other interpretations of the data (Duggan 1983) that suggest this may be as high as 70%. For adult humans, the deposition rate of particulate airborne lead is 30%-50%, and essentially all of the lead deposited is absorbed. Lead is stored in the body in the kidney liver, and bone (EPA 1984). The major adverse effects in humans caused by lead include alterations in the hematopoietic and nervous systems. The toxic effects are generally related to the concentration of this metal in blood. Blood concentration levels of over 80 μg/dl in children and over 100 μg/dl in sensitive adults can cause severe, irreversible brain damage, encephalopathy, and possible death. The Centers for Disease Control (CDC 1985) have used the value of 25 μg/dl as an acceptable level of blood lead. Recent information (EPA 1988), however, indicates that physiological and/or biochemical effects can occur even at lower levels. These include enzyme inhibition (16 μg/dl), elevated erythrocyte protoporphyrin (15 μg/dl), interference with Vitamin D metabolism, cognitive dysfunction in infants (10 to 15 μg/dl), electrophysiological dysfunction (6 μg/dl), and reduced childhood growth (4 μg/dl). Decreased fertility, fetotoxic effects, and skeletal malformations have been observed in experimental animals exposed to lead (EPA 1984). Chronic oral ingestion of certain lead salts (lead acetate, lead phosphate, lead subacetate) has been associated in experimental animals with increased renal tumors. Doses of lead that induced kidney tumors were high and were beyond the lethal dose in humans (EPA 1985).

EPA classified certain lead salts in Group B2—Probable Human Carcinogen, although no cancer potency factor has been established (EPA 1989a). This category applies to those agents for which there is sufficient evidence of carcinogenicity in animals and inadequate evidence of carcinogenicity in humans. EPA (1988) has recently proposed a maximum contaminant level goal (MCLG) of zero for lead. EPA (1989a) has considered it inappropriate to develop a reference dose (RfD) for inorganic lead and lead compounds, since many of the health effects associated with lead intake occur essentially without a threshold. The new proposed MCLG is based on subtle effects of lead at low blood levels, the overall Agency goal of reducing lead exposures, and the probable carcinogenicity of lead at very high doses. Underlying this proposal was the assumption that blood lead levels in the range of 10-15 μg/dl are associated with serious effects. Additionally EPA noted that existing bodv burdens of lead were already in the range where adverse effects could result.

An alternative approach is also undergoing review by EPA to evaluate potential subchronic lead exposures to young children. This approach is based on a linear pharmacokinetic model used by EPA's Office of Air Quality Planning and Standards (OAQPS) for lead air quality standard setting (EPA 1989b). The model, based on work by Harley and Kneip (1985), takes into account the uptake, retention and excretion of lead. It is referred to as the "Integrated Uptake/Biokinetic Model", and it estimates blood lead levels.

5.4.2.31 Mercury

In humans, inorganic mercury is absorbed following inhalation and oral exposure, however only 7% to 15% of administered inorganic mercury is absorbed following oral exposure (EPA 1984, Rahola et al. 1971, Task Group on Metal Accumulation 1973). Organic mercury is almost completely absorbed from the gastrointestinal tract and is assumed to be well absorbed via inhalation in humans (EPA 1984). A primary target organ for inorganic compounds is the kidney. Acute and chronic exposures of humans to inorganic mercury compounds have been associated with anuria, polyuria, proteinuria, and renal lesions (Hammond and Beliles 1980). Chronic occupational exposure of workers to elemental mercury vapors (0.1 to 0.2 mg/m^3) has been associated with mental disturbances, tremors, and gingivitis (EPA 1984). Animals exposed to inorganic mercury for 12 weeks have exhibited proteinuria, nephrotic syndrome and renal disease (Druet et al. 1978). Rats chronically administered inorganic mercury (as mercuric acetate) in their diet have exhibited decreased body weights and significantly increased kidney weights (Fitzhugh et al. 1950). The central nervous system is a major target for organic mercury compounds. Adverse effects in humans, resulting from subchronic and chronic oral exposures to organic mercury compounds, have included destruction of cortical cerebral neurons, damage to Purkinje cells, and lesions of the cerebellum. Clinical symptoms following exposure to organic mercury compounds have included paresthesia, loss of sensation in extremities, ataxia, and hearing and visual impairment (WHO 1976). Embryotoxic and teratogenic effects, including malformations of the skeletal and genitourinary systems, have been observed in animals exposed orally to organic mercury (EPA 1984). Both organic and inorganic compounds are reported to be genotoxic in eukaryotic systems (Leonard et al. 1984).

EPA (1989) has reported an oral RfD for alkyl and inorganic mercury of 3×10^{-4} mg/kg/day based on studies investigating central nervous system effects in humans exposed to mercury (EPA 1980, 1984); an uncertainty factor of 10 was used to develop the RfD. EPA (1989) has also reported an oral reference dose of 3×10^{-4} mg/kg/day for inorganic mercury based on a chronic rat study in which kidney effects were observed (Fitzhugh et al. 1950). An uncertainty factor of 1,000 was used to derive the RfD.

5.4.2.32 Methylene chloride

Methylene chloride is absorbed following oral and inhalation exposure. The amount of airborne methylene chloride absorbed following inhalation exposure increases in direct proportion to its concentration in inspired air, the duration of exposure, and physical activity. Dermal absorption has not been accurately measured (EPA 1985a). Acute human exposure to methylene chloride may result in irritation of eyes, skin, and respiratory tract; central nervous system depression; elevated carboxyhemoglobin levels; and circulatory disorders that may be fatal (EPA 1980). Chronic exposure of animals can produce renal and hepatic toxicity (NCA 1982). Methylene chloride is mutagenic for *Salmonella typhimurium* and produces mitotic recombination in yeast (EPA 1989a). Several inhalation studies conducted in animals provide clear evidence of methylene chloride's carcinogenicity (NTP 1986). There is only suggestive evidence in experimental animals that hepatocellular carcinomas and neoplastic nodules arise from oral exposure (EPA 1985a,b).

EPA (1989a) classified methylene chloride in Group B2--Probable Human Carcinogen. It has been concluded by EPA (1985b) that the induction of distant site tumors from inhalation exposure and the borderline significance for induction of tumors in a drinking water study are an adequate basis for concluding that methylene chloride be considered a probable human carcinogen via ingestion as well as inhalation. EPA (1989a) derived an inhalation cancer potency factor of 1.4×10^{-2} $(mg/kg/day)^{-1}$ based on the results of a National Toxicology Program (NTP) inhalation bioassay conducted in rats and mice (NTP 1986). Mammary tumors were noted in rats, while lung and liver tumors were observed in mice. EPA (1989a) determined an oral cancer potency factor of 7.5×10^{-3} $(mg/kg/day)^{-1}$ based on the results of the NTP (1986) inhalation bioassay and on an ingestion bioassay conducted by the National Coffee Association (NCA 1983). In the NCA study, hepatocellular adenomas and/or carcinomas were observed in male mice. An oral reference dose (RfD) of 0.06 mg/kg/day has been developed by EPA (1989a) based on a 2-year rat drinking water bioassay (NCA 1982) that identified no-observed-effect levels (NOELs) of 5.85 and 6.47 mg/kg/day for male and female rats, respectively. Liver toxicity was observed at doses of 52.58 and 58.32 mg/kg/day for males and females, respectively. An uncertainty factor of 100 was used to derive the RfD. EPA (1989b) has established an inhalation RfD of 3 mg/m^3 based on a study by Nitschke et al. (1988) in which rats were exposed to 200 ppm (694.8 mg/m^3) for 2 years. A safety factor of 100 was used to derive the RfD. This RfD is currently undergoing verification by EPA (1989a).

5.4.2.33 Nickel

Nickel compounds can be absorbed following inhalation, ingestion, or dermal exposure. The amount absorbed depends on the dose administered and the chemical and physical form of the particular nickel compound (EPA 1986). Dermal exposure of humans to nickel produces allergic contact dermatitis (EPA 1986). Adverse effects associated with acute exposure in animals have included depressed weight gain, altered hematological parameters, and increased iron deposition in blood, heart, liver, and testes (EPA 1987). Chronic or subchronic exposure of experimental animals to nickel has been associated with reduced weight gain, degenerative lesions of the male reproductive tract, asthma, nasal septal perforations, rhinitis, sinusitis, hyperglycemia, decreased prolactin levels, decreased iodine uptake, and vasoconstriction of the coronary vessels (EPA 1986). Teratogenic and fetotoxic effects have been observed in the offspring of exposed animals (EPA 1986). Inhalation exposure of experimental animals to nickel carbonyl or nickel subsulfide induces pulmonary tumors (EPA 1986). Several nickel salts cause localized tumors when administered by subcutaneous injection or implantation. Epidemiological evidence indicates that inhalation of nickel refinery dust and nickel subsulfide is associated with cancers of the nasal cavity, lung, larynx, kidney, and prostate (EPA 1986).

Nickel refinery dust and nickel subsulfide are both categorized in Group A--Human Carcinogens (EPA 1990). These classifications are based on an increased incidence of lung and nasal tumors observed in workers occupationally exposed to nickel refinery dust (EPA 1986). These materials have inhalation cancer potency factors of 0.84 $(mg/kg/day)^{-1}$ and 1.7 $(mg/kg/day)^{-1}$, respectively (EPA 1990). Nickel carbonyl is categorized in Group B2--Probable Human Carcinogen; however, a potency factor has not been derived for nickel carbonyl (EPA 1990). EPA (1990) derived an oral reference dose (RfD) for nickel of $2x10^{-2}$ mg/kg/day based on a study by Ambrose et al. (1976) in which rats administered 5 mg/kg/day (NOAEL) nickel in the diet for 2 years did not experience decreased weight gain which was observed in animals administered 50 mg/kg/day (LOAEL). A safety factor of 300 was used to calculate the RfD.

5.4.2.34 Nitrobenzene

Nitrobenzene is absorbed by all possible routes, but absorption primarily occurs through the respiratory tract and skin (EPA 1980); approximately 80% of inhaled nitrobenzene is absorbed (EPA 1980). In humans long-term occupational exposure to nitrobenzene can result in cyanosis, methemoglobinemia, jaundice, anemia, sulfhemoglobinemia, and dark urine (EPA 1980). Short-term exposure to high levels of nitrobenzene can result in cyanosis, and if severe, the individual can go into a coma (Piotrowski 1967). Hematologic, adrenal, renal, and hepatic lesions have been reported in rats and mice exposed to nitrobenzene in air for 90 days (CIIT 1984). There is also limited evidence that exposure to nitrobenzene can result in changes in the tissues of the chorion and placenta in pregnant women (Dorigan and Hushon 1976); menstrual disturbances after chronic nitrobenzene exposure have also been reported (EPA 1980).

EPA (1989a) developed an inhalation RfD for nitrobenzene of $6x10^{-4}$ mg/kg/day based on a study in which hematological, adrenal, renal, and hepatic lesions were observed in mice following inhalation exposure to nitrobenzene (CIIT 1984) and using an uncertainty factor of 10,000. EPA (1989b) also developed an oral RfD for nitrobenzene of $5x10^{-4}$ mg/kg/day based on the CIIT study based on route-to-route extrapolation and using an uncertainty factor of 10,000 (EPA 1989b). EPA (1989b) is currently evaluating the carcinogenic potential of nitrobenzene.

5.4.2.35 N-nitrosodiphenylamine

N-Nitrosodiphenylamine (NDPA) is absorbed following ingestion. In rats NDPA can cross the placenta (EPA 1980). Its acute oral toxicity in rats is very low (Druckrey et al. 1967). In subchronic feeding studies conducted in rats, weight reduction was reported. Trace amounts of pigmentation were observed in hepatic Kupffer cells of male mice (NCI 1979). When NDPA was administered to rats late in pregnancy, neoplasms were induced in the offspring (EPA 1980). Significant increases in the incidence of urinary bladder carcinomas in male and female rats were reported. A dose related trend in fibromas of the subcutis and skin among male rats was also observed (NCI 1979).

NDPA by ingestion is categorized in Group B2--Probable Human Carcinogen. EPA (1989) has developed an oral cancer potency factor of $4.9x10^{-3}$ $(mg/kg/day)^{-1}$ for NDPA based on an increased incidence of bladder tumors in male and female rats (NCI 1979).

5.4.2.36 Noncarcinogenic PAHs

Polycyclic aromatic hydrocarbons (PAHs) occur in the environment as complex mixtures of which only a few components have been adequately characterized. Only limited information is available on the relative potencies of the "noncarcinogenic" PAHs. However, many have been shown to have some weak carcinogenic activity, or to act as promoters or cocarcinogens.

PAH absorption following oral and inhalation exposure is inferred from the demonstrated toxicity of PAHs following these routes of administration (EPA 1984). PAHs are also absorbed following dermal exposure (Kao et al. 1985). Acute effects from direct contact with PAHs and related materials are limited primarily to phototoxicity; the primary effect is dermatitis (NIOSH 1977). PAHs have also been shown to cause cytotoxicity in rapidly proliferating cells throughout the body; the hematopoietic system, lymphoid system, and testes are frequent targets (Santodonato et al. 1981). Some of the noncarcinogenic PAHs have been shown to cause systemic toxicity but these effects are generally seen at high doses (Santodonato et al. 1981). Slight morphological changes in the liver and kidney of rats have been reported following oral exposure to acenaphthene for 40 days (EPA 1984). Subchronic oral administration of naphthalene to rabbits and rats has resulted in cataract formation (Schmahl 1955).

EPA (1989) developed an oral reference dose of 0.4 mg/kg/day for naphthalene based on the development of ocular and systemic lesions in rats (Schmahl 1955, EPA 1986). An uncertainty factor of 100 was applied to the animal data in the development of the reference dose.

5.4.2.37 Phenol

Phenol is readily absorbed through the gut, by inhalation, and percutaneously (EPA 1980). Signs of acute phenol toxicity in humans and experimental animals are central nervous system depression, collapse, coma, cardiac arrest, and death. Acutely toxic doses can also cause extensive necrosis at the site of exposure (eyes, skin, oropharynx) (EPA 1980). In experimental animals subchronic oral and inhalation studies suggest that kidney, pulmonary, myocardial, and liver damage are associated with exposure, although many of these studies were poorly designed (EPA 1980, 1984). Oral administration of phenol to pregnant rats during gestational days 6 to 15 resulted in a significant reduction in fetal body weight (NTP 1983). Phenol exhibited tumor-promoting activity in the mouse skin painting system following initiation with 9,10-dimethyl-1,2-benzanthracene (DMBA) or benzo[a]pyrene (B[a]P), and it exhibited cutaneous carcinogenic activity in a sensitive mouse strain when applied at concentrations that produced repeated skin damage (EPA 1980).

EPA (1989) has established an oral reference dose (RfD) of 0.6 mg/kg/day for phenol based on reduced fetal body weight in rats (NTP 1983). A no-observed-adverse-effect level (NOAEL) of 60 mg/kg/day and a safety factor of 100 were used to derive RfD. EPA has not yet established an inhalation RfD (EPA 1989).

5.4.2.38 RDX

RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine; cyclonite) is completely absorbed following oral exposure (EPA 1988). No data are available regarding dermal absorption. Workers exposed to RDX via inhalation and gastrointestinal routes suffered CNS effects, including headaches, nausea, vomiting, amnesia, clonic/tonic convulsions, and unconsciousness (Gosselin 1984; Kaplan 1965). These symptoms paralleled those previously reported in animal studies (Sunderman et al 1944; Von Oettingen et al 1949). However, a cross-sectional epidemiological study in a munitions plant did not identify any abnormalities in employees attributable to RDX exposure (Hathaway 1977). In acute toxicity studies, dogs exposed intravenously to RDX experienced decreased blood pressure and erratic electroencephalographic patterns at low doses, central nervous system hyperactivity and nonlethal convulsions at higher doses, and convulsions and death at the highest dose levels (EPA 1988). In subchronic feeding studies, mice experienced increased liver weights. Anemia was seen in male mice and rats, and female rats experienced increased liver weights (EPA 1988). Chronic oral exposure to RDX in rats and mice produced CNS effects, increased mortality, weight loss, anemia, hepatoxicity, renal toxicity, testicular degeneration, and inflammation of the prostate (Levine et al. 1983; EPA 1988). Decreased fertility, developmental effects, and embryotoxicity were observed in rats that were fed RDX. In rabbits, RDX caused maternal toxicity, and there was suggestive evidence for teratogenic effects (EPA 1988). No conclusive evidence of carcinogenicity has been shown for RDX. RDX was not found to be carcinogenic in Fisher 344 rats (Levine et al. 1983) or Sprague-Dawley rats (Hart 1977) exposed to RDX in the diet for 2 years. However, Lish et al. (1984) reported a statistically significant increase in the combined incidence of hepatocellular carcinomas and adenomas in female B6C3F1 mice fed RDX in the diet for two years.

EPA (1989) has classified RDX in Group C -- Possible Human Carcinogen -- and has developed an oral cancer potency factor of 0.11 $(mg/kg/day)^{-1}$. The potency factor is based on the increased incidence of combined hepatocellular carcinomas and adenomas in female mice receiving RDX in the diet for two years (Lish et al. 1984). EPA (1989) has derived a reference dose (RfD) of 0.003 mg/kg/day based on a chronic study in which rats receiving RDX in the diet for 24 months at varying dosages experienced inflammation of the prostate (Levine et al. 1983). A lowest observed adverse effect level (LOAEL) of 1.5 mg/kg/day was identified. An uncertainty factor of 100 was used to derive the RfD.

5.4.2.39 Selenium

Results of studies with humans and experimental animals indicate that certain selenium compounds are readily absorbed from the gastrointestinal tract following oral exposure (EPA 1984). The pulmonary absorption of selenium following inhalation exposure has not been well studied, although there are reports suggesting that selenium is absorbed to some extent by this route (EPA 1984). Selenium is an essential element and therefore is nontoxic at doses necessary for normal health and nutrition. NAS (1980) reported that an adequate and safe selenium intake for an adult human ranges from 0.05 mg/day to 0.2 mg/day. However, exposure to selenium at levels that exceed these standards has been associated with adverse health effects. Such effects observed in experimental animals following subchronic or chronic oral exposure to various selenium compounds have included anemia, reduced growth, increased mortality, and lesions of the liver, heart, kidney, and spleen (EPA 1984). In humans, chronic oral exposure to selenium has been associated with alopecia, dermatitis, discoloration of the skin, loss of fingernails, muscular dysfunction, convulsions, paralysis, and increased incidences of dental caries (EPA 1984, Yang et al. 1983). Headaches and respiratory irritation have been noted in humans following acute inhalation exposure (EPA 1984); dermatitis and gastrointestinal disturbances have resulted from occupational exposure (Glover 1967). Studies with a variety of animals have suggested that selenium may be teratogenic; however, these studies are limited in that exposure levels are not well characterized (EPA 1984).

Oral and inhalation reference doses (RfD) of $3.0\text{x}10^{-3}$ mg/kg/day and $1.0\text{x}10^{-3}$ mg/kg/day, respectively, have been derived by EPA (1984, 1989). The oral RfD value was based on a study by Yang et al. (1983) in which humans exposed to selenium in the diet at doses of 3.2 mg/day developed loss of hair, loss of fingernails, dermatitis, and muscular dysfunction. By applying an uncertainty factor of 15 to the LOAEL of 3.2 mg/day, EPA (1989) determined the oral RfD value of $3\text{x}10^{-3}$ mg/kg/day. The oral RfD is currently under review by the oral RfD Work Group at EPA (1989). The inhalation RfD value was based on an occupational study by Glover (1967) in which workers exposed to airborne concentrations of selenium developed dermatitis and gastrointestinal disturbances. An uncertainty factor of 10 was used to determine the inhalation RfD (EPA 1989).

5.4.2.40 Silver

Silver in various forms is absorbed to a limited extent following oral and inhalation exposures (EPA 1985). The acute toxic effects in humans following oral exposure to silver include corrosive damage to the GI tract leading to shock, convulsions, and death. In animals, acute exposure has been shown to affect the central nervous system and to cause respiratory paralysis (Hill and Pillsbury 1939). The primary effect of silver in humans following chronic exposures is argyria, a permanent bluish-metallic discoloration of the skin and mucous membranes, which can be either localized or generalized. Silver also accumulates in the blood vessels and connective tissue (EPA 1985).

EPA (1990) derived an oral reference dose (RfD) of 3.0×10^{-3} mg/kg/day for silver based on the human case reports of Gaul and Staud (1935), Blumberg and Carey (1934), and East et al. (1980). In these studies, argyria was observed at an average dose of silver of 0.0052 mg/kg/day, to which an uncertainty factor of 2 was applied.

5.4.2.41 1,1,2,2-Tetrachloroethane

In humans, absorption of a single inhalation dose of 1,1,2,2,-tetrachloroethane vapor was reported to be 97%; absorption of this chemical from the gastrointestinal tract is inferred from studies in which an increased incidence of liver tumors was reported in mice exposed in the diet (EPA 1984). The effects associated with occupational exposure to 1,1,2,2-tetrachloroethane by inhalation or dermal routes are primarily neurological and include, tremors, headache, numbness, excessive perspiration, and anorexia (EPA 1984). In experimental animals, subchronic inhalation exposure to 1,1,2,2-tetrachloroethane is associated with liver effects, decreased hemoglobin content of red blood cells, decreased hematocrit, and fluctuations in white blood cell count (Schmidt et al. 1972, Navrotskiy et al. 1971, Horiuchi et al. 1962). 1,1,2,2-Tetrachloroethane is a liver carcinogen when administered orally to mice (NCI 1978).

EPA (1990) classified 1,1,2,2-tetrachloroethane in Group C--Possible Human Carcinogen based on increased incidence of hepatocellular carcinoma in mice. EPA (1990) developed an oral cancer potency factor of 0.2 (mg/kg/day)$^{-1}$ based on the study conducted by NCI (1978) in which a highly significant dose-related increase in the incidence of hepatocellular carcinomas was observed in both male and female mice. An inhalation cancer potency factor of 0.2 (mg/kg/day)$^{-1}$ was also calculated from these data (EPA 1990).

EPA (1987) has also derived an interim oral reference dose (RfD) of $4.6\text{x}10^{-4}$ mg/kg/day for 1,1,2,2-tetrachloroethane based on an inhalation study by Schmidt et al. (1972) in which rats were exposed to 1,1,2,2-tetrachloroethane vapor for 5 hours/day for 265 days. In this study decreased body weight, increased white blood cell count and increased hepatic fate content were observed. Using a LOAEL of 0.456 mg/kg/day and applying a safety factor of 1,000 the interim RfD was derived.

5.4.2.42 Tetrachloroethene

Tetrachloroethene is absorbed following inhalation (IARC 1979) and oral (EPA 1985a,b) exposure. Tetrachloroethene vapors and liquid also can be absorbed through the skin (EPA 1985a,b). The principal toxic effects of tetrachloroethyene in humans and animals following acute and longer-term exposures include central nervous system (CNS) depression and fatty infiltration of the liver and kidney with concomitant changes in serum enzyme activity levels indicative of tissue damage (EPA 1985a,b, Buben and O'Flaherty 1985). Humans exposed to doses of between 136 and 1,018 mg/m^3 for 5 weeks develop central nervous system effects, such as lassitude and signs of inebriation (Stewart et al. 1974). The offspring of female rats and mice exposed to high concentrations of tetrachloroethene for 7 hours daily on days 6-15 of gestation developed toxic effects, including a decrease in fetal body weight in mice and a small but significant increase in fetal resorption in rats (Schwetz et al. 1975). Mice also exhibited developmental effects, including subcutaneous edema and delayed ossification of skull bones and sternebrae

(Schwetz et al. 1975). In a National Cancer Institute bioassay (NCI 1977), increased incidences of hepatocellular carcinoma were observed in both sexes of B6C3F1 mice administered tetrachloroethene in corn oil by gavage for 78 weeks. Increased incidences of mononuclear cell leukemia and renal adenomas and carcinomas (combined) have also been observed in long term bioassays in which rats were exposed to tetrachloroethene by inhalation (NTP 1986).

EPA (1989) classifies tetrachloroethene as a Group B2 carcinogen (Probable Human Carcinogen). EPA (1989, 1985b) has derived an oral slope factor of 5.1×10^{-2} $(mg/kg/day)^{-1}$ based on liver tumors observed in the NCI (1977) gavage bioassay for mice. The inhalation cancer potency factor for tetrachloroethene of 3.3×10^{-3} $(mg/kg/day)^{-1}$ is based on an NTP (1986) bioassay in rats and mice in which leukemia and liver tumors were observed (EPA 1989). Both cancer potency factors are currently under review by EPA (1990). EPA (1989, 1990) also has derived an oral reference dose (RfD) of 1×10^{-2} mg/kg/day for tetrachloroethene based on a 6-week gavage study by Buben and O'Flaherty (1985). In this study, liver weight/body weight ratios were significantly increased in mice and rats treated with 71 mg/kg/day tetrachloroethene but not in animals treated with 14 mg/kg/day. Using a NOAEL of 14 mg/kg/day and applying an uncertainty factor of 1,000, the RfD was derived.

5.4.2.43 Tetryl

Tetryl is absorbed through oral, inhalation, and dermal routes. It is a skin and mucous membrane irritant, with the most common reaction being skin sensitization and dermatitis. Industrial exposure to tetryl has caused severe upper respiratory tract irritation with coughing and epistaxis, edema, headache, irritability, malaise, lassitude, sleeplessness, and conjunctivitis (Witkowski et al. 1942). Dermal exposure may stain the skin and hair yellow (Hamilton and Hardy 1974). Additionally, heavy airborne exposure to tetryl may cause liver damage (Hardy and Maloof 1950; Schwartz 1942). Acute exposure to tetryl in rabbits (via gavage) and dogs (subcutaneously) led to severe acute inflammation at the injection site, varying degrees of edema and hemorrhaging.

degeneration of muscle tissue, and toxic degeneration of the kidneys. Dog livers showed varying degrees of necrosis in the centers of the lobules and severe fatty degeneration of the liver cells. Rabbit livers showed almost no changes (Wells 1920). Tetryl appears to be a potent, direct-acting mutagen in three microbial mutagenicity test systems (*Neurospora crassa, Salmonella typhimurium, and Saccharomyces cerevisiae* D_4)even at low concentrations (Whong et al. 1980). EPA has not derived health-based criteria for tetryl.

5.4.2.44 Thallium

Thallium and its salts are readily and rapidly absorbed through the skin, lungs, and mucous membranes of the mouth and gastrointestinal tract. Percutaneous absorption has also been reported to occur through rubber gloves (Rumack 1986). Thallium is acutely toxic to humans regardless of the chemical form of the compound or route of administration. Hundreds of cases of thallotoxicosis due to ingestion of thallium-based pesticides have been reported (ACGIH 1986). Children poisoned by thallium ingestion have exhibited neurological abnormalities including mental retardation and psychoses (ACGIH 1986). The effects of thallium toxicity are similar in humans and animals. The most commonly noted response to thallium exposure is alopecia, but neurological and gastrointestinal findings are frequently found. Such effects include ataxia, lethargy, painful extremities, peripheral neuropathies, convulsions, endocrine disorders, psychoses, nausea, vomiting, and abdominal pains (Bank 1980). It has been noted that the degree and duration of exposure to thallium and its salts can influence the clinical picture of thallium intoxication. Subchronic feeding studies conducted with rats observed marked growth depression and a nearly complete loss of hair (EPA 1986, Clayton and Clayton 1981). Exposure to thallium salts during critical developmental stages in chicks and rats has been reported to be associated with the induction of adverse developmental outcomes (Karnofsky et al. 1950). Pre- and postnatally exposed rat pups have exhibited hydronephrosis, fetal weight reduction and growth retardation (Clayton and Clayton 1981, Gibson and Becker 1970). Thallium has also been shown to cross the placenta and, presumably, enter the fetal blood system (Clayton and Clayton 1981). Thallium has not been demonstrated to be carcinogenic in humans or experimental animals and may have some antitumor activity (Clayton and Clayton 1981).

EPA (1989) developed an oral reference dose (RfD) of 7×10^{-5} mg/kg/day for thallium in soluble salts based on a subchronic feeding study in which rats received 0.20 mg thallium/kg/day administered as thallium sulfate (MRI 1986, EPA 1986). Increased blood chemistry parameters (SGOT and serum LDH) and alopecia were observed. An uncertainty factor of 3,000 was used to calculate the RfD. EPA (1990) also derived oral RfDs for certain thallium salts (i.e., thallium acetate, thallium carbonate, thallium chloride, thallium nitrate, thallium selenite and thallium sulfate) of between $8\text{-}9 \times 10^{-5}$ mg/kg/day based on the same EPA (1986) 90-day subchronic rat study. The same endpoints of toxicity were observed and an uncertainty factor of 3,000 was used to derive the RfDs.

5.4.2.45 Toluene

Toluene is absorbed in humans following both inhalation and dermal exposure (EPA 1985). In humans, the primary acute effects of toluene vapor are central nervous system (CNS) depression and narcosis. These effects occur at concentrations of 200 ppm (754 mg/m^3) (von Oettingen et al. 1942a,b). In experimental animals, acute oral and inhalation exposures to toluene can result in central nervous system (CNS) depression and lesions of the lungs, liver, and kidneys (EPA 1987). The earliest observable sign of acute oral toxicity in animals is depression of the CNS, which becomes evident at approximately 2,000 mg/kg (Kimura et al. 1971). In humans, chronic exposure to toluene vapors at concentrations of approximately 200 and 800 ppm has been associated with CNS and peripheral nervous system effects, hepatomegaly, and hepatic and renal function changes (EPA 1987, Anderson et al. 1983). Toxic effects following prolonged exposure of experimental animals to toluene are similar to those seen following acute exposure (Hanninen et al. 1976, von Oettingen et al. 1942a). In rats, chronic exposure to toluene via inhalation results in CNS toxicity and a dose-related reduction in hematocrit values (CIIT 1980). There is some evidence in mice that oral exposure to greater than 0.3 ml/kg toluene during gestation results in embryotoxicity (Nawrot and Staples 1979). Inhalation exposure of up to 1,000 mg/m^3 by pregnant rats during gestation has been associated with significant increases in skeletal retardation (Hudak and Ungvary 1978).

EPA (1989a) has derived an oral risk reference dose (RfD) of 0.3 mg/kg/day for toluene based on a 24-month inhalation study in which rats were exposed to concentrations as high as 300 ppm (29 mg/kg/day) and hematological parameters were examined (CIIT 1980). No adverse effects were observed in any of the treated animals. Using a no-observed-adverse-effect level (NOAEL) of 29 mg/kg/day and an uncertainty factor of 100, the oral RfD was derived. EPA (1989b) reported an inhalation RfD for toluene of 2 mg/m^3 based on the development of adverse CNS effects in humans (Anderson et al. 1983). An uncertainty factor of 100 was used.

5.4.2.46 1,1,1-Trichloroethane

Like other chlorinated aliphatic hydrocarbons, 1,1,1-trichloroethane (1,1,1-TCA, methyl chloroform) is rapidly and completely absorbed following both oral and inhalation exposure. Pulmonary absorption is initially large and gradually decreases to a steady-state condition. Absorption through the skin is slow. 1,1,1-TCA distributes throughout the body and readily crosses the blood-brain barrier (EPA 1984). The most notable toxic effects of 1,1,1-TCA inhalation exposure in humans and animals are central nervous system depression, including anesthesia at very high concentrations, and impairment of coordination, equilibrium, and judgment at lower concentrations (350 ppm and above). In both humans and animals, cardiovascular effects, including premature ventricular contractions, decreased blood pressure, and sensitization to epinephrine-induced arrhythmia can result from acute exposure to high concentrations of 1,1,1-TCA vapor (EPA 1985). Fatty liver changes have been reported in guinea pigs following subchronic inhalation exposure

(Torkelson et al. 1958). NTP (1984) reported preliminary results of bioassays in rats and mice indicating that oral administration of 1,1,1-TCA increases the incidence of hepatocellular carcinomas in female mice but not for male rats. This study was inadequate to evaluate the carcinogenicity of 1,1,1-TCA in female rats and male mice.

EPA (1990) calculated an oral reference dose (RfD) for 1,1,1-trichloroethane based on an inhalation study by Torkelson et al. (1958) in which rats, rabbits, guinea pigs and monkeys were exposed to 1,1,1-TCA vapor. A no-observed-adverse-effect (NOAEL) of 500 ppm (2,730 mg/m^3, or 90 mg/kg/day) was identified from this study. Using the NOAEL of 90 mg/kg/day and an uncertainty factor of 1,000, a RfD of 9x10^{-2} mg/kg/day was derived. An inhalation RfD of 0.3 mg/kg/day for 1,1,1-TCA also has been determined by EPA (1989) based on this same study, in which hepatotoxicity was observed in guinea pigs. An uncertainty factor of 1,000 was used in calculating the RfD.

5.4.2.47 1,1,2-Trichloethane

1,1,2-Trichloroethane (1,1,2-TCA) is rapidly absorbed from oral, inhalation and dermal exposures (Torkelson and Rowe 1981, Arena 1979). In humans, acute oral and inhalation exposures to 1,1,2-TCA result in central nervous system (CNS) depression, equilibrium disturbances, vertigo, headaches, lassitude, hypotension, anesthesia and coma (Arena 1979). Acute oral and inhalation administration to animals produces liver and kidney damage, irritation to the eyes and nose, CNS depression, and death due to respiratory arrest (ACGIH 1986, Torkelson and Rowe 1981). In dogs the hepatotoxic effects include hepatocyte vacuolation, enzyme induction, fatty degeneration and necrosis (NRC 1977, Torkelson and Rowe 1981). The hepatoxicity and nephrotoxicity of 1,1,2-TCA has been found to be potentiated by pretreatment with certain halogenated organic compounds and solvents. Subchronic oral administration to mice produced alterations in clinical serum levels indicative of adverse liver effects (White et al. 1985, Sanders et al. 1985). Dermal exposures result in irritation and injury to the skin from defatation (Torkelson and Rowe 1981).

Evidence suggests that 1,1,2-TCA is embryo toxic to chicken eggs (Elovaara 1979). 1,1,2-TCA was found to be weakly mutagenic in S. Cerevisiae (Torkelson and Rowe 1981). Oral administration of 1,1,2-TCA has been associated with the induction of hepatocellular carcinomas and pheochromocytomas in mice but not in rats (NCI 1978, Weisburger 1977)

EPA has classified 1,1,2-TCA in group C (Possible Human Carcinogen). This category applies to agents for which there is limited evidence of carcinogenicty in animals. EPA (1989) has derived a cancer potency factor of 5.7×10^{-2} $(mg/kg/day)^{-1}$ for both oral and inhalation exposures based on an increased incidence of liver tumors in mice (NCI 1978). EPA (1989) has also established an oral reference dose (RfD) of 4.0×10^{-3} mg/kg/day for 1,1,2-TCA based upon clinical chemistry alterations in mice given 3.9 mg/kg/day in drinking water (White et al 1985, Sanders et al 1985). An uncertainty factor of 1,000 was used to calculate the RfD.

5.4.2.48 Trichloroethene

Absorption of trichloroethene (TCE) from the gastrointestinal tract is virtually complete. Absorption following inhalation exposure is proportional to concentration and duration of exposure (EPA 1985). TCE is a central nervous system depressant following acute and chronic exposures. In humans, single oral doses of 15 to 25 ml (21 to 35 grams) of TCE have resulted in vomiting and abdominal pain, followed by transient unconsciousness (Stephens 1945). High-level exposure can result in death due to respiratory and cardiac failure (EPA 1985). Hepatotoxicity has been reported in human and animal studies following acute exposure to TCE (EPA 1985). Nephrotoxicity has been observed in animals following acute exposure to TCE vapors (ACGIH 1986, Torkelson and Rowe 1981). Subacute inhalation exposures of mice have resulted in transient trichloroethene-induced increased liver weights (Kjellstrand et al. 1983). Industrial use of TCE is often associated with adverse dermatological effects including reddening and skin burns on contact with the liquid form, and dermatitis resulting from vapors. These effects are usually the result of contact with concentrated solvent, however, and no effects have been reported after exposure to TCE in dilute, aqueous solutions (EPA 1985). Trichloroethylene has caused significant increases in the incidence of hepatocellular carcinomas in mice (NCI 1976) and renal tubular-cell neoplasms in rats exposed by gavage (NTP 1983), and pulmonary adenocarcinomas in mice following inhalation exposure (Fukuda et al. 1983, Maltoni et al. 1986). Trichloroethene was mutagenic in *Salmonella typhimurium* and in *E. coli* (strain K-12), utilizing liver microsomes for activation (Greim et al. 1977).

EPA (1989) classified trichloroethene in Group B2--Probable Human Carcinogen based on inadequate evidence in humans and sufficient evidence of carcinogenicity from animals studies. An oral cancer potency factor of $1.1x10^{-2}$ $(mg/kg/day)^{-1}$ has been derived by EPA (1989) based on two gavage studies conducted in mice in which an increased incidence of liver tumors were observed (Maltoni et al. 1986, Fukuda et al. 1983). An inhalation cancer potency factor of $1.7x10^{-2}$ $(mg/kg/day)^{-1}$ has been derived for trichloroethene (EPA 1989) based on an increased incidence of lung tumors in mice (NCI 1976). EPA (1987) developed an oral reference dose (RfD) of $7.35x10^{-3}$ mg/kg/day based on a subchronic inhalation study in rats in which elevated liver weights were observed following exposure to 55 ppm, 5 days/week for 14 weeks (Kimmerle and Eben 1973). A safety factor of 1,000 was used to calculate the RfD. However, this RfD is currently under review by EPA.

5.4.2.49 1,3,5-TNB

Little information is available for 1,3,5-trinitrobenzene (TNB). Therefore, toxicity information is based on the structurally similar 1,3-dinitrobenzene (RTECS 1983). 1,3-dinitrobenzene is absorbed orally. In subchronic drinking water studies, rats experienced decreased hemoglobin concentrations, splenic weight gain and enlargement with hemosiderin deposits, decreased body weight gain in females, and testicular atrophy in males in the two highest dose levels (Cody et al. 1981). 1,3,5-TNB has been shown to be mutagenic in DNA repair assays (McGregor et al. 1980).

EPA (1989) has derived an oral reference dose (RfD) for 1,3,5-TNB of 5.00×10^{-5} mg/kg/day based on a subchronic study whereby rats experienced increased spleen weights when given 1,3-dinitrobenzene in drinking water (Cody et al. 1981). The RfD for 1,3,5-TNB was derived by analogy from 1,3-dinitrobenzene. A NOAEL of 0.4 mg/kg/day for 1,3-DNB (equivalent to 0.51 mg/kg/day 1,3,5-TNB) was identified from this study. An uncertainty factor of 10,000 was used to calculate the RfD for 1,3,5-TNB.

5.4.2.50 Vinyl chloride

Vinyl chloride is rapidly absorbed in rats following oral and inhalation exposure, while dermal absorption of vinyl chloride is minor (EPA 1985). At high inhalation exposure levels, workers have experienced dizziness, headaches, euphoria, and narcosis. In experimental animals, inhalation exposure to high levels of vinyl chloride can induce narcosis and death. Lower doses result in ataxia, narcosis, congestion and edema of the lungs, and hyperemia in the liver (EPA 1985). Chronic inhalation exposure of workers to vinyl chloride is associated with hepatotoxicity, central nervous system disturbances, pulmonary insufficiency, cardiovascular toxicity, gastrointestinal toxicity, and acro-osteolysis (EPA 1985). Experimental animals chronically exposed via inhalation or ingestion have exhibited effects involving the liver, spleen, kidneys, hematopoietic system, and skeletal system (EPA 1984). Feron et al. (1975) found that administration of vinyl chloride to rats by gavage resulted in hematologic, biochemical, and organ-weight effects at doses above 30 mg/kg/day. Evidence for an association between human exposure to vinyl chloride and birth defects or fetal loss is conflicting (EPA 1987). Human exposure to vinyl chloride has been associated with an increased incidence of hepatic angiosarcoma and brain, lung, and hemolymphopoietic cancers. In animal studies, chronic inhalation and ingestion of vinyl chloride at levels as low as 1.7 and 5 mg/kg/day have induced cancer in the liver and in other tissues of rats and mice (IARC 1979; Feron et al. 1981; Maltoni et al. 1980, 1981).

EPA (1989) has classified vinyl chloride in Group A (Human Carcinogen) based on adequate evidence of carcinogenicity from epidemiological studies. EPA (1989) reported an oral slope factor of 2.3 $(mg/kg/day)^{-1}$ for vinyl chloride based on the long-term ingestion study in rats in which lung tumors were observed (Feron et al. 1981). The inhalation slope factor for vinyl chloride is 2.95×10^{-1} $(mg/kg/day)^{-1}$ (EPA 1989) and is based on chronic inhalation studies conducted by Maltoni et al. (1980, 1981) in which liver tumors were observed in rats.

5.4.2.51 Zinc

Zinc is absorbed in humans following oral exposure; however, insufficient data are available to evaluate absorption following inhalation exposure (EPA 1984). Zinc is an essential trace element that is necessary for normal health and metabolism and therefore is nontoxic in trace quantities (Hammond and Beliles 1980). Exposure to zinc at concentrations that exceed recommended levels has, however, been associated with a variety of adverse effects. Chronic and subchronic inhalation exposure of humans to zinc has been associated with gastrointestinal disturbances, dermatitis, and metal fume fever, a condition characterized by fever, chills, coughing, dyspnea, and muscle pain (EPA 1984). Chronic oral exposure of humans to zinc may cause anemia and altered hematological parameters (Pories et al. 1967, Prasad et al. 1975). Reduced body weights have been observed in studies in which rats were administered zinc in the diet. There is no evidence that zinc is teratogenic or carcinogenic (EPA 1984).

EPA (1989) has derived an oral reference dose (RfD) of 2×10^{-1} mg/kg/day based on studies in which anemia and reduced blood copper were observed in humans exposed to oral zinc doses of 2.14 mg/kg/day (Pories et al. 1967, Prasad et al. 1975). A safety factor of 10 was used in developing the RfD.

5.5 RISK CHARACTERIZATION

In this section, the human health risks potentially associated with the LCAAP are evaluated. Potential risks under current land conditions are presented in Section 5.5.1 and those for hypothetical future land use conditions are presented in Section 5.5.2.

To quantitatively assess risks to future residents from ingestion of groundwater, the chronic daily intakes (CDIs) calculated in Section 5.3.2 are combined with the health effects criteria presented in Section 5.4. For potential carcinogens, excess lifetime cancer risks are obtained by multiplying the CDI for each chemical by its cancer slope factor. A risk level of 10^{-6} represents a probability of one in 1,000,000 that an individual could contract cancer due to exposure to the potential carcinogen. The upper bound lifetime excess cancer risks derived in this report can be compared to EPA's risk range for health protectiveness at Superfund sites. EPA recommends that the total cancer risk to individuals resulting from exposure at a Superfund site be reduced to zero where possible. EPA has implemented actions (e.g., remedial responses) under Superfund associated with total cancer risks ranging from 10^{-4} to 10^{-6} (EPA 1990).

Potential risks for noncarcinogens are presented as the ratio of the CDI to the reference dose (CDI:RfD) for each chemical. The sum of the ratios of all chemicals under consideration is called the hazard index. The hazard index is useful as a reference point for gauging the potential effects of environmental exposures to complex mixtures. In general, hazard indices which are less than one are not likely to be associated with any health risks, and are therefore less likely to be of regulatory concern than hazard indices greater than one. A conclusion should not be categorically drawn, however, that all hazard indices less than one are "acceptable" or that hazard indices greater than one are "unacceptable". This is a consequence of the perhaps one order of magnitude or greater uncertainty inherent in estimates of the RfD and CDI, in addition to the fact that the uncertainties associated with the individual terms in the hazard index calculation are additive.

In the absence of specific information on the toxicity of the mixture of chemicals to be assessed or on similar mixtures, EPA guidelines generally recommend assuming that the effects of different components on the mixtures are additive when affecting a particular organ or system. Synergistic or antagonistic interactions may be taken into account if there is specific information on particular combinations of chemicals (EPA 1986). Information on the toxic effects of the specific chemical mixtures at the AMSCS are not available. Accordingly, it is assumed in this assessment that the toxic effects of the chemical of potential concern are additive. Thus, lifetime excess cancer risks and the CDI:RfD ratios for individual chemicals are summed to indicate the potential risks associated with mixtures of potential carcinogens and noncarcinogens, respectively.

5.5.1 Current Land Use Exposure Pathways

As discussed in Section 5.3, the following current land use exposure pathways will be evaluated:

- ingestion of treated water from on-site production wells by on-site workers (inhalation exposures to VOCs while showering will also be semi-quantitatively evaluated);
- ingestion and inhalation of VOCs while showering with treated water from on-site production wells by on-site residents;
- ingestion of groundwater from production wells (assuming no treatment of the water) by on-site facility workers and residents (inhalation exposures to VOCs while showering will also be semi-quantitatively evaluated);
- ingestion of groundwater from production well capture zone (assuming no treatment of the water) by on-site facility workers and residents (inhalation exposures to VOCs while showering will also be semi-quantitatively evaluated);

- ingestion and inhalation of VOCs while showering with groundwater from the off-site residential wells located north of the LCAAP; and
- ingestion of groundwater from residential wells in western off-site areas downgradient of Areas 3 and 8 (using data from site perimeter since residential well data is not available) (inhalation exposures to VOCs while showering will also be semi-quantitatively evaluated).

5.5.1.1 Current Exposure to Treated Water from Production Wells by Workers (treated water data collected by LCAAP personnel)

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of treated production well water by workers are displayed in Table 5-30. This scenario represents the true current use of production well water at the LCAAP, since the CDIs and estimated risks are based on consumption of treated water. Bromodichloromethane, bromoform, chloroform, dibromochloromethane, trichloroethene, and Radium 226 and Radium 228 were the only suspected carcinogenic agents of the selected chemicals of potential concern. As shown in Table 5-30, upper bound excess lifetime cancer risks for the RME case for individual chemicals of concern ranged from $8x10^{-8}$ to $3x10^{-6}$ with a total excess cancer risk of $7x10^{-6}$. For noncarcinogenic risk, the CDI:RfD ratios for all the chemicals of potential concern for the RME case were all well below a value of one, with the exception of thallium. When thallium is excluded, the hazard index did not exceed a value of one. Thallium was the only noncarcinogenic chemical of potential concern detected in treated production well water that presented a significant risk estimate. The CDI:RfD ratio for thallium was 10 for the RME case. As discussed in Section 5.2.1.1, thallium was detected in one out of two samples at a concentration of 75 ug/L. It should be noted, that a very large safety factor of 3,000 has been incorporated into the RfD for thallium, because of the uncertainty surrounding the toxicity data used to estimate the noncarcinogenic toxicity of thallium. In addition, the data from treated production well water (collected by LCAAP personnel) were not collected as part of the RI and therefore, did not undergo the same QA/QC protocols used to evaluate the RI data. Although thallium is not a common laboratory contaminant, the one high

TABLE 5-30

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF OF TREATED GROUNDWATER BY ON-SITE WORKERS

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
Bromodichloromethane	2.2E-05	1.3E-01	B2	3E-06
Bromoform	1.3E-05	7.9E-03	B2	1E-07
Chloroform	9.2E-06	6.1E-03	B2	6E-08
Dibromochloromethane	2.4E-05	8.4E-02	B2	2E-06
Trichloroethene	7.0E-06	1.1E-02	B2	8E-08
Radiological Parameters:				
Ra226 and Ra228	1.4E+04 pCi	1.2E-10 (pCi)-1	A	2E-06
Total	--	--	--	7E-06

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
Bromodichloromethane	7.5E-05	2E-02	Renal	4E-03
Bromoform	4.7E-05	2E-02	Liver	2E-03
Chloroform	3.2E-05	1E-02	Liver	3E-03
Dibromochloromethane	8.5E-05	2E-02	Liver	4E-03
1,2-Dichloroethene (total)	9.1E-05	1E-02	Liver	9E-03
1,1,1-Trichloroethane	1.9E-06	9E-02	Liver	2E-05
Trichloroethene	2.5E-05	7.35E-03	Liver	3E-03
Inorganics:				
Mercury	6.6E-06	3E-04	Kidney	2E-02
Silver	7.5E-05	3E-03	Argyria	3E-02
Thallium	7.1E-04	7E-05	Blood Chemistry	1E+01
Hazard Index	--	--	--	>1 (1E+01)

(a) Presented originally in Table 5-22.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

detection might be a result of laboratory error (e.g., mislabelled units, drifting instrument response). Thallium is a rare inorganic, which is sometimes found to be associated with the use of pesticides in the environment. Thus, the high thallium detection might also be a result of pesticide use in the area around the time of sampling. As discussed in Section 5.2.1.1, thallium was not detected in any other groundwater samples collected for the RI, or in any other media. Therefore, the presence of thallium is probably not due to waste disposal practices at the LCAAP site. In order to determine if high thallium levels in the treated water actually occur and present the potential for adverse human health effects to occur, further sampling of the treated water is recommended.

The above risks were estimated for ingestion of water only. Other use of this water may result in additional risks. Volatile chemicals present in tap water may also be emitted into indoor air, for example as a result of showering, laundering, and dishwashing. Inhalation of these volatilized chemicals may be associated with exposures and risks as large as, and perhaps larger than, those associated with direct ingestion (Foster and Chrostowski 1987).

5.5.1.2 Current Exposure to Treated Water from Production Wells by Residents (treated water data collected by LCAAP)

CDIs and calculated carcinogenic risks associated with ingestion of treated production well water by on-site residents are displayed in Table 5-31. This scenario represents the true current use of production well water at the LCAAP, since the CDIs and estimated risks are based on consumption of treated water. Bromodichloromethane, bromoform, chloroform, dibromochloromethane, trichloroethene, and Radium 228 and Radium 228 were the only suspected carcinogenic agents of the selected chemicals of potential concern. As shown in Table 5-31, upperbound excess lifetime cancer risks for the RME case for individual chemicals of concern ranged from 6×10^{-7} to 3×10^{-5}. The total excess cancer risk was 7×10^{-5} for the RME case. Bromodichloromethane, dibromochloromethane, and Radium 226 and 228 comprised the majority of the

TABLE 5-31

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF OF TREATED GROUNDWATER BY ON-SITE RESIDENTS

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
Bromodichloromethane	2.3E-04	1.3E-01	B2	3E-05
Bromoform	1.4E-04	7.9E-03	B2	1E-06
Chloroform	9.7E-05	6.1E-03	B2	6E-07
Dibromochloromethane	2.6E-04	8.4E-02	B2	2E-05
Trichloroethene	7.4E-05	1.1E-02	B2	8E-07
Radiological Parameters:				
Ra226 and Ra228	1.5E+05 pCi	1.2E-10 (pCi)-1	A	2E-05
Total	--	--	-	7E-05

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
Bromodichloromethane	2.3E-04	2E-02	Renal	1E-02
Bromoform	1.4E-04	2E-02	Liver	7E-03
Chloroform	9.7E-05	1E-02	Liver	1E-02
Dibromochloromethane	2.6E-04	2E-02	Liver	1E-02
1,2-Dichloroethene (total)	2.8E-04	1E-02	Liver	3E-02
1,1,1-Trichloroethane	5.7E-06	9E-02	Liver	6E-05
Trichloroethene	7.4E-05	7.35E-03	Liver	1E-02
Inorganics:				
Mercury	2.0E-05	3E-04	Kidney	7E-02
Silver	2.3E-04	3E-03	Argyria	8E-02
Thallium	2.1E-03	7E-05	Blood Chemistry	3E+01
Hazard Index	--	--	--	>1 (3E+01)

(a) Presented originally in Table 5-23.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

risk. For noncarcinogenic risk the CDI:RfD ratios for all the chemicals of potential concern for the RME case were all well below a value of one, with the exception of thallium. When thallium is excluded, the hazard index did not exceed a value of one. As discussed in Section 5.5.1.1, thallium was the only non-carcinogenic chemical of potential concern detected in treated production well water that presented a significant risk estimate. The CDI:RfD ratio for thallium was 30 for RME case. It should be noted that a very large safety factor of 3,000 has been incorporated into the RfD for thallium, because of the uncertainty surrounding the toxicity data used to estimate the noncarcinogenic toxicity of thallium. As discussed in the previous section (5.5.1.1) one high detect of thallium recorded might be a result of a laboratory error or pesticide use in the area around the time of sampling, but it is not expected to be due to waste disposal practices at the LCAAP site.

CDIs and risks associated with the inhalation of VOCs by residents while showering with treated production well water are presented in Table 5-31a. As is the case with the ingestion pathway discussed above, this scenario represents the true current use of production well water at the LCAAP. Bromoform, chloroform, and trichloroethene, which were the three suspected carcinogenic VOCs detected, were associated with upperbound excess lifetime cancer risks for the RME case of $3\text{x}10^{-7}$, $9\text{x}10^{-6}$, and $1\text{x}10^{-6}$, respectively. The total excess cancer risk for inhalation while showering was $1\text{x}10^{-5}$. The total excess cancer risk associated with inhalation exposure was less than the total excess cancer risk associated with the ingestion of treated production well water ($7\text{x}10^{-5}$). The estimated CDI:RfD ratio for the RME case (1,1,1-trichloroethane was the only VOC with an inhalation RfD) was well below one at $2\text{x}10^{-5}$ and thus, did not contribute to the noncarcinogenic risk associated with use of untreated water.

TABLE 5-31a

POTENTIAL EXPOSURES AND RISKS TO ON-SITE RESIDENTS FROM INHALATION WHILE SHOWERING WITH TREATED GROUNDWATER

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Bromoform	8.7E-05	3.9E-03	B2	3E-07
Chloroform	1.1E-04	8.1E-02	B2	9E-06
Trichloroethene	8.0E-05	1.7E-02	B2	1E-06
Total	--	--	--	1E-05

Potential Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
1,1,1-Trichloroethane	6.2E-06	3.0E-01	Liver	2E-05

(a) Presented originally in Table 5-23a.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

5.5.1.3 Ingestion of Untreated Groundwater from Production Wells by On-Site Residents (data collected from production wells during the RI)

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of untreated production well groundwater by on-site residents are shown in Table 5-32. This scenario assumes that the production well water is not treated with the water treatment plant system that is currently in use, as described in Section 5.2.1.1. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $4x10^{-7}$ to $2x10^{-3}$, with a total excess cancer risk of $2x10^{-3}$. Vinyl chloride and arsenic comprised the majority of the risk. Vinyl chloride was only detected at production well 17FF at a concentration of 350 ug/L. Arsenic was detected at above background in 5 of the 7 production well locations sampled. For noncarcinogenic risk, the hazard index value was below a value of one. Based on available exposure assumptions, it should be noted that the potential risks of exposure would be approximately three times lower for on-site facility workers.

The above risks were estimated for ingestion of water only. Other use of this water may result in additional risks. Volatile chemicals present in tap water may also be emitted into indoor air, for example as a result of showering, laundering, and dishwashing. Inhalation of these volatilized chemicals may be associated with exposures and risks similar to those associated with direct ingestion (Foster and Chrostowski 1987).

5.5.1.4 Ingestion of Groundwater from Production Well Capture Zone by On-Site Residents (data collected from monitoring wells located within the capture zone of the production wells)

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater in the production well capture zone by on-site residents are shown in Table 5-33. As discussed in Section 5.2.1.2 and 5.3, data collected from monitoring wells located within the capture zone of the production wells were grouped together in order to assess the quality of

TABLE 5-32

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF UNTREATED GROUNDWATER FROM PRODUCTION WELLS BY CURRENT (ON-SITE) RESIDENTS

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
Benzene	1.4E-05	2.9E-02	A	4E-07
bis(2-Ethylhexyl)phthalate	6.9E-04	1.4E-02	B2	1E-05
Trichloroethene	1.1E-04	1.1E-02	B2	1E-06
Vinyl Chloride	8.3E-04	2.3E+00	A	2E-03
Inorganics:				
Arsenic	2.5E-04	2.0E+00	A	5E-04
Beryllium	2.9E-06	4.3E+00	B2	1E-05
Radiological Parameters:				
U-234	4.6E+04 pCi	1.4E-10 (pCi)-1	A	6E-06
U-238	2.6E+04 pCi	1.3E-10 (pCi)-1	A	3E-06
Total	--	--	--	2E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
trans-1,2-Dichloroethene	3.1E-05	2E-02	Blood	2E-03
bis(2-Ethylhexyl)phthalate	6.9E-04	2E-02	Liver	3E-02
Trichloroethene	1.1E-04	7.35E-03	Liver	2E-02
Inorganics:				
Arsenic	2.5E-04	1E-03	Skin	2E-01
Barium	1.9E-02	5E-02	Blood	4E-01
Beryllium	2.9E-06	5E-03	Blood, skin	6E-04
Nickel	6.9E-04	2E-02	Organ Weight	3E-02
Silver	8.6E-06	3E-03	Argyria	3E-03
Zinc	1.1E-02	2E-01	Blood	5E-02
Hazard Index	--	--	--	<1 (8E-01)

(a) Presented originally in Table 5-24. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

TABLE 5-33

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER FROM PRODUCTION WELL CAPTURE ZONE BY RESIDENTS

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
Benzene	8.6E-06	2.9E-02	A	2E-07
Carcinogenic PAHs (Chrysene)	1.5E-04	1.2E+01	B2	2E-03
2,4-DNT	8.6E-06	6.8E-01	B2	6E-06
2,6-DNT	8.6E-06	6.8E-01	B2	6E-06
1,1-Dichloroethane	8.0E-05	9.1E-02	B2	7E-06
1,2-Dichloroethane	7.4E-05	9.1E-02	B2	7E-06
1,1-Dichloroethene	7.4E-05	6.0E-01	C	4E-05
bis(2-Ethylhexyl)phthalate	7.7E-04	1.4E-02	B2	1E-05
Methylene chloride	1.4E-04	7.5E-03	B2	1E-06
N-nitrosodiphenylamine	1.5E-04	4.9E-03	B2	7E-07
RDX	1.1E-04	1.1E-01	C	1E-05
Trichloroethene	1.1E-05	1.1E-02	B2	1E-07
Vinyl Chloride	6.0E-05	2.3E+00	A	1E-04
Inorganics:				
Arsenic	1.7E-04	2.0E+00	A	3E-04
Beryllium	3.1E-05	4.3E+00	B2	1E-04
Radiological Parameters:				
U-234	7.7E+04 pCi	1.4E-10 (pCi)-1	A	1E-05
U-238	4.6E+04 pCi	1.3E-10 (pCi)-1	A	6E-06
Total	--	--	--	2E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
1,3-DNB	8.6E-06	1E-04	Spleen	9E-02
1,1-Dichloroethane	8.0E-05	1E-01	Kidney	8E-04
1,1-Dichloroethene	7.4E-05	9E-03	Liver	8E-03
trans-1,2-Dichloroethene	3.7E-05	2E-02	Blood	2E-03
bis(2-Ethylhexyl)phthalate	7.7E-04	2E-02	Liver	4E-02
HMX	2.6E-05	5E-02	Liver	5E-04
Methylene chloride	1.4E-04	6E-02	Liver	2E-03
RDX	1.1E-04	3E-03	Prostate Inflam.	4E-02
1,3,5-TNB	1.1E-05	5E-05	Spleen	2E-01
1,1,1-Trichloroethane	7.4E-05	9E-02	Liver	8E-04
Trichloroethene	1.1E-05	7.35E-03	Liver	2E-03
Inorganics:				
Antimony	6.3E-05	4E-04	Blood Chemistry	2E-01
Arsenic	1.7E-04	1E-03	Skin	2E-01
Barium	1.1E-02	5E-02	Blood	2E-01
Beryllium	3.1E-05	5E-03	Blood, skin	6E-03
Cadmium	1.5E-04	5E-04	Renal	3E-01
Chromium	1.1E-03	5E-03	Liver, Kidney	2E-01
Mercury	2.9E-06	3E-04	Kidney	1E-02
Nickel	2.0E-03	2E-02	Organ Weight	1E-01
Selenium	8.0E-05	3E-03	Skin	3E-02
Silver	5.7E-06	3E-03	Argyria	2E-03
Zinc	2.0E-02	2E-01	Blood	1E-01
Hazard Index	--	--	--	>1 (2E+00)

TABLE 5-33 (Continued)

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH INGESTION
OF GROUNDWATER FROM PRODUCTION WELL CAPTURE ZONE BY RESIDENTS

(a) Presented originally in Table 5-25. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
  A = Human Carcinogen, sufficient evidence from human epidemiological studies;
  B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
  B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
  C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
  D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

groundwater potentially captured by these production wells. In addition, this scenario assumes that the production well water is not treated by the water treatment plant system that is currently in use, as described in Section 5.2.1.1. Evaluation of this pathway was performed because generally higher concentrations of chemicals of potential concern were found in capture zone monitoring wells downgradient of potential sources than were found in the production wells. It is believed that evaluation of this pathway may present an upperbound estimate of concentrations and exposure (assuming no treatment of water). Most likely, concentrations of chemicals of potential concern in the production wells will be lower than concentrations found in the monitoring wells due to dilution and various biodegradation pathways.

Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $7x10^{-7}$ to $2x10^{-3}$, with a total risk of $2x10^{-3}$. Chrysene (a carcinogenic PAH) comprised the majority of the risk, while vinyl chloride, arsenic, and beryllium also contributed significantly to the risk. Chrysene was detected once in Area 18 at a concentration of 70 ug/L. Vinyl chloride was detected only in Areas 5, 7, and 16 groundwater. The highest concentrations of arsenic were detected in Area 1 groundwater at concentrations as high as 110 ug/L. The highest detected concentration of beryllium was 12 ug/L. For noncarcinogenic risk, the CDI:RfD ratios for all chemicals of potential concern were below a value of one. The hazard index was 2 for the RME case. Several inorganics and 1,3,5-TNB accounted for the majority of the noncarcinogenic risk.

Based on available exposure assumptions, it should be noted that the potential risks of ingestion exposure would be approximately three times lower for on-site facility workers.

The above risks were estimated for ingestion of water only. Other use of this water may result in additional risks. Volatile chemicals present in tap water may also be emitted into indoor air, for example as a result of showering, laundering, and dishwashing. Inhalation of these volatilized chemicals may be associated with exposures and risks similar to those associated with direct ingestion (Foster and Chrostowski 1987).

5.5.1.5 Ingestion of Groundwater from the Off-site Residential Wells Located North of the LCAAP

CDIs and estimated risks associated with ingestion of groundwater from the off-site residential wells located north of the LCAAP by current residents are displayed in Table 5-34. As discussed in Section 5.3.2.1.2, the maximum concentrations detected were used in the risk calculations to provide upperbound estimates of the potential risks associated with ingesting water from the off-site wells. Carbon tetrachloride, 1,4-dichlorobenzene, RDX, and trichloroethene were the only suspected carcinogenic agents in the off-site wells. RDX was detected in three wells (Hedrickj-A, Turley, and Ure) at maximum concentrations ranging from 2.8 to 3.4 ug/L. Carbon tetrachloride, 1,4-dichlorobenzene, and trichloroethene were detected in only one of the off-site wells (Ure) at maximum concentrations of 1.1 ug/L, 2.2 ug/L, and 1.2 ug/L, respectively. Upperbound excess lifetime cancer risks for the Hendrickj-A and Ure wells were $1x10^{-5}$ and for the Turley well was $9x10^{-6}$.

For noncarcinogenic risk, the CDI:RfD ratios for all chemicals of potential concern were below a value of one. In addition, the hazard indices for all off-site wells were below a value of one. Chromium in the well north of Area 17 had the largest noncarcinogenic risk with a CDI:RfD ratio of 0.5.

CDIs and estimated risks associated with the inhalation of VOCs while showering with groundwater from the off-site residential wells are presented in Table 5-34a. The Ure well ad the well north of Are 17 were the only two wells in which VOCs were detected. In addition, for the inhalation pathway, the Ure well was the sole well containing suspected carcinogenic VOCs (carbon tetrachloride and trichloroethene). The excess upperbound lifetime cancer risks associated with the inhalation of carbon tetrachloride and trichloroethene were $4x10^{-6}$ and $6x10^{-7}$, respectively. These risks are

TABLE 5-34

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER BY OFF-SITE RESIDENTS

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (b) (mg/kg-day)-1	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Hedrickj-A				
RDX	9.7E-05	1.1E-01	C	1E-05
Turley				
RDX	8.0E-05	1.1E-01	C	9E-06
Ure				
Carbon tetrachloride	3.1E-05	1.3E-01	B2	4E-06
1,4-Dichlorobenzene	6.3E-05	2.4E-02	B2	2E-06
RDX	8.0E-05	1.1E-01	C	9E-06
Trichloroethene	3.4E-05	1.1E-02	B2	4E-07
Total				1E-05

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD Ratio (f)
Danner				
HMX	1.2E-04	5.0E-02	Liver	2E-03
Barium	1.6E-03	5.0E-02	Blood	3E-02
Mercury	1.1E-05	3.0E-04	Kidney	4E-02
Zinc	1.3E-03	2.0E-01	Blood	6E-03
Hazard Index				<(8E-02)
Fergeson				
Barium	1.7E-03	5.0E-02	Blood	3E-02
Mercury	1.1E-05	3.0E-04	Kidney	4E-02
Zinc	1.7E-02	2.0E-01	Blood	8E-02
Hazard Index				<(2E-01)
Hedrickj-A				
HMX	2.4E-04	5.0E-02	Liver	5E-03
RDX	9.7E-05	3.0E-03	Prostate Inflam.	3E-02
Barium	4.8E-03	5.0E-02	Blood	1E-01
Mercury	1.1E-05	3.0E-04	Kidney	4E-02
Zinc	4.7E-03	2.0E-01	Blood	2E-02
Hazard Index				<(2E-01)

TABLE 5-34 (Continued)

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER BY OFF-SITE RESIDENTS

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD Ratio (f)
Hedrickj-B				
HMX	2.0E-04	5.0E-02	Liver	4E-03
Barium	2.2E-03	5.0E-02	Blood	4E-02
Mercury	1.4E-05	3.0E-04	Kidney	5E-02
Zinc	9.1E-04	2.0E-01	Blood	5E-03
Hazard Index				<(1E-01)
Hedrickv				
HMX	1.4E-04	5.0E-02	Liver	3E-03
Barium	2.0E-03	5.0E-02	Blood	4E-02
Zinc	9.5E-03	2.0E-01	Blood	5E-02
Hazard Index				<(9E-02)
Lirely				
HMX	1.3E-04	5.0E-02	Liver	3E-03
Barium	2.6E-03	5.0E-02	Blood	5E-02
Mercury	1.1E-05	3.0E-04	Kidney	4E-02
Zinc	5.9E-04	2.0E-01	Blood	3E-03
Hazard Index				<(9E-02)
Pennington				
HMX	1.6E-04	5.0E-02	Liver	3E-03
Barium	2.6E-03	5.0E-02	Blood	5E-02
Mercury	1.1E-05	3.0E-04	Kidney	4E-02
Zinc	8.2E-04	2.0E-01	Blood	4E-03
Hazard Index				<(1E-01)
Tcarlton				
Barium	2.3E-03	5.0E-02	Blood	5E-02
Hazard Index				<(5E-02)
Turley				
HMX	1.7E-04	5.0E-02	Liver	3E-03
RDX	8.0E-05	3.0E-03	Prostate Inflam.	3E-02
Barium	2.0E-03	5.0E-02	Blood	4E-02
Mercury	1.1E-05	3.0E-04	Kidney	4E-02
Zinc	5.0E-03	2.0E-01	Blood	2E-02
Hazard Index				<(1E-01)

TABLE 5-34 (Continued)

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER BY OFF-SITE RESIDENTS

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD Ratio (f)
Ure				
Carbon tetrachloride	3.1E-05	7.0E-04	Liver	4E-02
1,2-Dichlorobenzene	3.5E-04	9.0E-02	Liver	4E-03
1,4-Dichlorobenzene	6.3E-05	1.0E-01	Liver	6E-04
HMX	2.0E-04	5.0E-02	Liver	4E-03
RDX	8.0E-05	3.0E-03	Prostate Inflam.	3E-02
Trichloroethene	3.4E-05	7.3E-03	Liver	5E-03
Barium	1.3E-03	5.0E-02	Blood	3E-02
Mercury	1.1E-05	3.0E-04	Kidney	4E-02
Zinc	1.1E-03	2.0E-01	Blood	5E-03

Hazard Index				<(2E-01)
Carlton				
HMX	1.8E-04	5.0E-02	Liver	4E-03
Barium	3.4E-03	5.0E-02	Blood	7E-02
Mercury	1.1E-05	3.0E-04	Kidney	4E-02
Zinc	2.1E-03	2.0E-01	Blood	1E-02

Hazard Index				<(1E-01)
Well North of Area 17				
Toluene	2.9E-05	3.0E-01	CNS	1E-04
Chromium	2.6E-03	5.0E-03	Liver, Kidney	5E-01
Nickel	5.7E-04	2.0E-02	Organ Weight	3E-02
Zinc	8.9E-03	2.0E-01	Blood	4E-02

Hazard Index				<(6E-01)

(a) Presented originally in Table 5-26.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
    A = Human Carcinogen, sufficient evidence from human epidemiological studies;
    B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
    B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
    C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
    D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

TABLE 5-34a

POTENTIAL EXPOSURES AND RISKS TO OFF-SITE RESIDENTS FROM INHALATION WHILE SHOWERING WITH GROUNDWATER

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
URE				
Carbon tetrachloride	3.2E-05	1.3E-01	B2	4E-06
Trichloroethene	3.7E-05	1.7E-02	B2	6E-07
Total				5E-06

Potential Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
URE				
1,2-Dichlorobenzene	1.2E-04	4.0E-02	Body weight	3E-03
1,4-Dichlorobenzene	4.8E-05	2.0E-01	Liver, Kidney	2E-04
Hazard Index				<1 (3E-03)
Well North of Area 17				
Toluene	1.2E-04	5.7E-01	CNS	<1 (2E-04)

(a) Presented originally in Table 5-26a.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
   A = Human Carcinogen, sufficient evidence from human epidemiological studies;
   B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
   C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

approximately equal to the individual chemical risks associated with the ingestion pathway, presented in Table 5-34. For noncarcinogenic risk, the CDI:RfD ratios for the VOCs detected in both the Ure well (1,2-dichlorobenzene and 1,4-dichlorobenzene) and the well north of Area 17 (toluene) were all well below one. The hazard index for the Ure well was also well below one.

5.5.1.6 Ingestion of Groundwater from Site Perimeter Wells As a Preliminary Assessment of Exposure to Off-site Residents Located West of LCAAP

As discussed in Section 5.3.2.1, exposure to residents ingesting groundwater from residential wells located west of LCAAP were preliminarily evaluated. Residential wells downgradient from Areas 3 and 8 are located just beyond one mile from the western boundary of LCAAP. It is not known whether groundwater on-site near the western boundary of the facility will intercept residential wells located west of LCAAP. Even if the groundwater in these areas intercepts these residential wells, the concentrations of chemicals found on-site along the western boundary may decrease with time due to dilution and certain biodegradation pathways, as discussed in Section 5.3. However, it should be noted that chemical transformations may also take place in groundwater that may yield increased levels of chemical by-products with time. In any event, there is a great deal of uncertainty in quantitatively evaluating this pathway and thus the results of this assessment are preliminary and most likely present an upper-bound estimate of actual exposure if it were to occur.

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater from perimeter groundwater near off-site residential wells located west of LCAAP by current residents are displayed in Table 5-35. Upperbound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $8x10^{-7}$ to $4x10^{-4}$ with a total excess cancer risk of $8x10^{-4}$. Arsenic and beryllium comprised the majority of the carcinogenic risk for the RME case. For noncarcinogenic risk, all of the individual CDI:RfD ratios were less than one, however, the hazard index for

TABLE 5-35

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF SITE PERIMETER GROUNDWATER BY OFF-SITE RESIDENTS LOCATED WEST OF LCAAP

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
bis(2-Ethylhexyl)phthalate	2.0E-03	1.4E-02	B2	3E-05
N-nitrosodiphenylamine	1.6E-04	4.9E-03	B2	8E-07
RDX	8.6E-05	1.1E-01	C	9E-06
Trichloroethene	3.4E-05	1.1E-02	B2	4E-07
Inorganics:				
Arsenic	2.0E-04	2.0E+00	A	4E-04
Beryllium	8.9E-05	4.3E+00	B2	4E-04
Radiological Parameters:				
U-234	9.7E+04 pCi	1.4E-10 (pCi)-1	A	1E-05
U-235	5.1E+03 pCi	1.3E-10 (pCi)-1	A	7E-07
U-238	8.7E+04 pCi	1.3E-10 (pCi)-1	A	1E-05
Total	--	--	--	8E-04

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
trans-1,2-Dichloroethene	1.3E-04	2E-02	Blood	7E-03
bis(2-Ethylhexyl)phthalate	2.0E-03	2E-02	Liver	1E-01
HMX	2.3E-05	5E-02	Liver	5E-04
RDX	8.6E-05	3E-03	Prostate Inflam.	3E-02
Toluene	1.0E-04	3E-01	CNS	3E-04
Trichloroethene	3.4E-05	7.35E-03	Liver	5E-03
Inorganics:				
Antimony (g)	6.9E-05	4E-04	Blood Chmistry	2E-01
Arsenic	2.0E-04	1E-03	Skin	2E-01
Barium	1.8E-02	5E-02	Blood	4E-01
Beryllium	8.9E-05	5E-03	Blood, skin	2E-02
Cadmium	1.0E-04	5E-04	Renal	2E-01
Chromium	2.2E-03	5E-03	Liver, Kidney	4E-01
Mercury	2.9E-06	3E-04	Kidney	1E-02
Nickel	2.9E-03	2E-02	Organ Weight	1E-01
Silver	8.6E-06	3E-03	Argyria	3E-03
Zinc	2.7E-02	2E-01	Blood	1E-01
Hazard Index	--	--	--	>1 (2E+00)

(a) Presented originally in Table 5-27. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
  A = Human Carcinogen, sufficient evidence from human epidemiological studies;
  B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
  B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
  C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
  D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

the RME case was 2. Several inorganics and bis(2-ethylhexyl)phthalate comprised the majority of the risk.

The above risks were estimated for ingestion of water only. Other use of this water may result in additional risks. Volatile chemicals present in tap water may also be emitted into indoor air, for example as a result of showering, laundering, and dishwashing. Inhalation of these volatilized chemicals may be associated with exposures and risks similar to those associated with direct ingestion (Foster and Chrostowski 1987).

5.5.2 Future Land Use Exposure Pathways

As discussed in Section 5.3, ingestion of groundwater from future wells installed in all study areas directly downgradient of potential sources by on-site residents will be quantitatively evaluated for this assessment. These scenarios, however, are considered highly unlikely given other, more reasonable locations for future on-site well development. These scenarios were assessed for the following reasons: (1) evaluation of the potential degradation of the groundwater as a resource in each of these source areas; and (2) identification of specific sources of groundwater contamination.

The only additional population potentially exposed under hypothetical future land-use conditions are construction workers who may directly contact contaminated soils or inhale dust generated during construction activities if plant expansion in various study areas is undertaken. Although unlikely, if future development takes place, contaminated subsurface soils may be disturbed and these exposure pathways would then be pathways of concern. These potential future exposure pathways were not quantitatively evaluated at this time given (1) the generally preliminary nature of the soil sampling to date, and (2) the low probability that future development will take place in these waste disposal areas. However, these pathways will be qualitatively evaluated for areas where data are available (Areas 8, 9, 14 and 15).

The risks from groundwater exposures presented below were estimated for ingestion of water only by on-site residents. Based on available exposure assumptions, the potential risk to on-site workers would be three times lower than the risks presented below for on-site residents. Other use of this water may result in additional risks. Volatile chemicals present in tap water may also be emitted into indoor air, for example as a result of showering, laundering, and dishwashing. Inhalation of these volatilized chemicals may be associated with exposures and risks similar to those associated with direct contact ingestion (Foster and Chrostowski 1987).

5.5.2.1 Ingestion of Groundwater Directly Downgradient of Sources in Area 1 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 1 by future on-site residents are displayed in Table 5-36. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $3x10^{-6}$ to $6x10^{-3}$ with a total risk of $6x10^{-3}$. Arsenic comprised the majority of the risk for the RME case. For noncarcinogenic risk, the hazard index value for the RME case was 6. Antimony and arsenic were the only chemicals with CDI:RfD ratios of greater than one. The maximum concentration of arsenic of 110 ug/L was detected at well 1-3. As stated in Section 4.1, fairly high concentrations of arsenic were found in wells upgradient from potential sources. Antimony was only detected in one downgradient well (well 1-6) at a concentration of 77 ug/L.

5.5.2.2 Ingestion of Groundwater Directly Downgradient of Sources in Area 2 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 2 by future on-site residents are displayed in Table 5-37. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern

TABLE 5-36

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 1

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
bis(2-Ethylhexyl)phthalate	9.4E-04	1.4E-02	B2	1E-05
RDX	2.9E-05	1.1E-01	C	3E-06
Inorganics:				
Arsenic	3.1E-03	2.0E+00	A	6E-03
Beryllium	3.1E-05	4.3E+00	B2	1E-04
Total	--	--	--	6E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
bis(2-Ethylhexyl)phthalate	9.4E-04	2E-02	Liver	5E-02
RDX	2.9E-05	3E-03	Prostate Inflam.	1E-02
norganics:				
Antimony	6.0E-04	4E-04	Blood Chmistry	1E+00
Arsenic	3.1E-03	1E-03	Skin	3E+00
Barium	9.4E-03	5E-02	Blood	2E-01
Beryllium	3.1E-05	5E-03	Blood, skin	6E-03
Cadmium	1.4E-04	5E-04	Renal	3E-01
Mercury	2.9E-06	3E-04	Kidney	1E-02
Nickel	3.4E-03	2E-02	Organ Weight	2E-01
Silver	8.9E-05	3E-03	Argyria	3E-02
Zinc	2.9E-02	2E-01	Blood	1E-01
Hazard Index	--	--	--	>1 (6E+00)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
- A = Human Carcinogen, sufficient evidence from human epidemiological studies;
- B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
- B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
- C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
- D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

TABLE 5-37

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 2

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
2,6-DNT	1.1E-05	6.8E-01	B2	8E-06
bis(2-Ethylhexyl)phthalate	1.4E-02	1.4E-02	B2	2E-04
RDX	2.9E-05	1.1E-01	C	3E-06
Inorganics:				
Arsenic	1.9E-04	2.0E+00	A	4E-04
Beryllium	4.0E-05	4.3E+00	B2	2E-04
Total	--	--	--	8E-04

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
bis(2-Ethylhexyl)phthalate	1.4E-02	2E-02	Liver	7E-01
RDX	2.9E-05	3E-03	Prostate Inflam.	1E-02
Inorganics:				
Arsenic	1.9E-04	1E-03	Skin	2E-01
Beryllium	4.0E-05	5E-03	Blood, skin	8E-03
Cadmium	3.7E-03	5E-04	Renal	7E+00
Chromium	7.7E-04	5E-03	Liver, Kidney	2E-01
Nickel	2.4E-03	2E-02	Organ Weight	1E-01
Selenium	1.3E-04	3E-03	Skin	4E-02
Silver	2.6E-05	3E-03	Argyria	9E-03
Zinc	3.4E-02	2E-01	Blood	2E-01
Hazard Index	--	--	--	>1 (9E+00)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
  A = Human Carcinogen, sufficient evidence from human epidemiological studies;
  B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
  B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
  C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
  D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

ranged from $8x10^{-6}$ to $4x10^{-4}$ with a total excess cancer risk of $8x10^{-4}$. Bis(2-ethylhexyl)phthalate, arsenic, and beryllium comprised the majority of the risk. The maximum concentration of arsenic of 9 ug/L was detected at well 2-2 and the maximum concentration of beryllium was detected at well 2-7. As stated in Section 4.2, the surface impoundments located in Area 2 may be a suspected source of arsenic. The surface impoundment is a suspected source of phthalate contamination, as stated in Section 4. For noncarcinogenic risk, the hazard index for the RME case was 9. Cadmium was the only chemical with a CDI:RfD ratio greater than one. The maximum concentration of cadmium of 130 ug/L was detected at well 2-2. As stated in Section 4, the surface impoundments located in Area 2 may be the source of cadmium contamination.

5.5.2.3 Ingestion of Groundwater Directly Downgradient of Sources in Area 3 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 3 by future on-site residents are displayed in Table 5-38. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $8x10^{-6}$ to $9x10^{-4}$ with a total excess cancer risk of $2x10^{-3}$. Arsenic again comprised the majority of the risk. The maximum concentration of arsenic of 15.1 ug/L was detected at well 3-5. The burial pits or Area 12 located upgradient of Area 3 are suspected sources of arsenic. Beryllium and RDX also significantly contributed to the risks. As stated in Section 4.3, the burial sites may be potential sources of RDX contamination. The maximum concentration of beryllium of 1.6 ug/L was detected at well 3-5. For noncarcinogenic risk, the hazard index value for the RME case was 3. RDX and chromium were the only chemicals with a CDI:RfD ratio greater than one. The maximum concentration of RDX (120 ug/L) was detected at well 3-8 and the maximum concentration of chromium (255 ug/L) was detected at well 3-5.

TABLE 5-38

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 3

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
2,4-DNT	1.1E-05	6.8E-01	B2	8E-06
1,1-Dichloroethene	1.6E-04	6.0E-01	C	9E-05
bis(2-Ethylhexyl)phthalate	5.1E-04	1.4E-02	B2	7E-06
RDX	3.4E-03	1.1E-01	C	4E-04
Inorganics:				
Arsenic	4.3E-04	2.0E+00	A	9E-04
Beryllium	3.7E-05	4.3E+00	B2	2E-04
Radiological Parameters:				
U-234	3.6E+04 pCi	1.4E-10 (pCi)-1	A	5E-06
U-238	4.1E+04 pCi	1.3E-10 (pCi)-1	A	5E-06
Total	--	--	--	2E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
1,1-Dichloroethene	1.6E-04	9E-03	Liver	2E-02
bis(2-Ethylhexyl)phthalate	5.1E-04	2E-02	Liver	3E-02
HMX	5.4E-05	5E-02	Liver	1E-03
RDX	3.4E-03	3E-03	Prostate Inflam.	1E+00
Inorganics:				
Arsenic	4.3E-04	1E-03	Skin	4E-01
Barium	3.4E-02	5E-02	Blood	7E-01
Beryllium	3.7E-05	5E-03	Blood, skin	7E-03
Chromium	5.4E-03	5E-03	Liver, Kidney	1E+00
Nickel	3.7E-03	2E-02	Organ Weight	2E-01
Silver	5.7E-06	3E-03	Argyria	2E-03
Hazard Index	--	--	--	>1 (3E+00)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:
- A = Human Carcinogen, sufficient evidence from human epidemiological studies;
- B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
- B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
- C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
- D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

5.5.2.4 Ingestion of Groundwater Directly Downgradient of Sources in Area 4 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 4 by future on-site residents are displayed in Table 5-39. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $7x10^{-6}$ to $3x10^{-4}$ with a total excess cancer risk of $3x10^{-4}$. Arsenic comprised the majority of the risk. The maximum concentration of arsenic of 5.3 ug/L was detected at well 4-4. For noncarcinogenic risk, the hazard index value for the RME case was 10. 1,3,5-TNB and chromium were the only chemicals with a CDI:RfD ratio greater than one. The maximum concentration of 1,3,5-TNB of 11.7 ug/L was detected at well 4-1, which is downgradient of the surface storage impoundments in Area 4, thus indicating a potential source of explosives contamination. The maximum concentration of chromium of 335 ug/L was detected at well 4-4. As stated in Section 4.4, the four surface impoundments located in Area 4 may be potential sources of chromium contamination.

5.5.2.5 Ingestion of Groundwater Directly Downgradient of Sources in Area 5 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 5 by future on-site residents are displayed in Table 5-40. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $4x10^{-6}$ to $9x10^{-4}$ with a total excess cancer risk of $2x10^{-3}$. Arsenic, beryllium, and vinyl chloride comprised the majority of the risk.

The maximum concentrations of arsenic, beryllium, and vinyl chloride were detected at wells 5-1, 5-1, and 5-7, respectively. The surface impoundment located in Area 5B may be a potential source of arsenic and beryllium found in well 5-1. As stated in Section 4.5, the surface impoundment that received

TABLE 5-39

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE
INGESTION OF ON-SITE GROUNDWATER
DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 4

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
bis(2-Ethylhexyl)phthalate	2.9E-04	1.4E-02	B2	4E-06
RDX	6.6E-05	1.1E-01	C	7E-06
Inorganics:				
Arsenic	1.5E-04	2.0E+00	A	3E-04
Total	--	--	--	3E-04

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
bis(2-Ethylhexyl)phthalate	2.9E-04	2E-02	Liver	1E-02
HMX	9.1E-05	5E-02	Liver	2E-03
RDX	6.6E-05	3E-03	Prostate Inflam.	2E-02
1,3,5-TNB	3.3E-04	5E-05	Spleen	7E+00
Inorganics:				
Antimony	3.3E-04	4E-04	Blood Chmistry	8E-01
Arsenic	1.5E-04	1E-03	Skin	2E-01
Cadmium	2.1E-04	5E-04	Renal	4E-01
Chromium	9.6E-03	5E-03	Liver, Kidney	2E+00
Nickel	8.1E-03	2E-02	Organ Weight	4E-01
Silver	4.0E-04	3E-03	Argyria	1E-01
Zinc	3.4E-02	2E-01	Blood	2E-01
Hazard Index	--	--	--	>1 (1E+01)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

TABLE 5-40

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 5

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
1,1-Dichloroethane	3.7E-04	9.1E-02	B2	3E-05
1,1-Dichloroethene	9.1E-05	6.0E-01	C	5E-05
bis(2-Ethylhexyl)phthalate	7.1E-04	1.4E-02	B2	1E-05
RDX	2.3E-04	1.1E-01	C	3E-05
Trichloroethene	1.2E-03	1.1E-02	B2	1E-05
Vinyl Chloride	1.4E-04	2.3E+00	A	3E-04
Inorganics:				
Arsenic	1.6E-04	2.0E+00	A	3E-04
Beryllium	2.2E-04	4.3E+00	B2	9E-04
Radiological Parameters:				
U-234	4.6E+04 pCi	1.4E-10 (pCi)-1	A	6E-06
U-238	3.1E+04 pCi	1.3E-10 (pCi)-1	A	4E-06
Total	--	--	--	2E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
1,1-Dichloroethane	3.7E-04	1E-01	Kidney	4E-03
1,1-Dichloroethene	9.1E-05	9E-03	Liver	1E-02
trans-1,2-Dichloroethene	1.0E-02	2E-02	Blood	5E-01
bis(2-Ethylhexyl)phthalate	7.1E-04	2E-02	Liver	4E-02
RDX	2.3E-04	3E-03	Prostate Inflam.	8E-02
1,1,1-Trichloroethane	1.6E-04	9E-02	Liver	2E-03
Trichloroethene	1.2E-03	7.35E-03	Liver	2E-01
Inorganics:				
Antimony	4.5E-04	4E-04	Blood Chmistry	1E+00
Arsenic	1.6E-04	1E-03	Skin	2E-01
Barium	9.3E-03	5E-02	Blood	2E-01
Beryllium	2.2E-04	5E-03	Blood, skin	4E-02
Cadmium	3.4E-04	5E-04	Renal	7E-01
Chromium	1.9E-03	5E-03	Liver, Kidney	4E-01
Nickel	8.3E-03	2E-02	Organ Weight	4E-01
Silver	5.7E-06	3E-03	Argyria	2E-03
Zinc	2.9E-02	2E-01	Blood	1E-01
Hazard Index	--	--	--	>1 (4E+00)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:
- A = Human Carcinogen, sufficient evidence from human epidemiological studies;
- B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
- B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
- C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
- D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

waste from building 139 may be a potential source of VOCs (vinyl chloride) detected in well 5-7 in Area 5C. For noncarcinogenic risk, the hazard index value for the RME case was 4. Antimony was the only chemical with a CDI:RfD ratio greater than one. The concentrations of several other inorganic chemicals also contributed to the cumulative noncarcinogenic risk in Area 5, including arsenic, barium, cadmium, chromium, nickel, and zinc. The highest concentrations of many of the inorganic chemicals were detected downgradient of the surface impoundment in Area 5B, indicating that the impoundment is a potential source of inorganic contamination in groundwater in Area 5.

5.5.2.6 Ingestion of Groundwater Directly Downgradient of Sources in Area 6 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 6 by future on-site residents are displayed in Table 5-41. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $8x10^{-6}$ to $2x10^{-4}$ with a total excess lifetime cancer risk of $3x10^{-4}$. Beryllium comprised the majority of the risks. The maximum concentration of beryllium of 1.9 ug/L, was detected at well 6-6. For noncarcinogenic risk, the hazard index value for the RME case was less than one.

5.5.2.7 Ingestion of Groundwater Directly Downgradient of Sources in Area 7 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 7 by future on-site residents are displayed in Table 5-42. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $3x10^{-7}$ to $1x10^{-3}$ with a total excess lifetime cancer risk of $2x10^{-3}$. RDX, vinyl chloride, and arsenic comprised the majority of the risk for the RME case. The maximum concentration of RDX of 770 ug/L was

TABLE 5-41

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 6

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
2,4-DNT	1.1E-05	6.8E-01	B2	8E-06
RDX	4.0E-04	1.1E-01	C	4E-05
Inorganics:				
Beryllium	5.4E-05	4.3E+00	B2	2E-04
Total	--	--	--	3E-04

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
1,3-DNB	1.4E-05	1E-04	Spleen	1E-01
HMX	4.0E-05	5E-02	Liver	8E-04
RDX	4.0E-04	3E-03	Prostate Inflam.	1E-01
Inorganics:				
Beryllium	5.4E-05	5E-03	Blood, skin	1E-02
Chromium	1.4E-03	5E-03	Liver, Kidney	3E-01
Nickel	2.7E-03	2E-02	Organ Weight	1E-01
Silver	5.7E-06	3E-03	Argyria	2E-03
Zinc	3.4E-02	2E-01	Blood	2E-01
Hazard Index	--	--	--	<1 (9E-01)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:

A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

TABLE 5-42

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 7

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
Benzene	1.1E-05	2.9E-02	A	3E-07
bis(2-Ethylhexyl)phthalate	2.0E-03	1.4E-02	B2	3E-05
Methylene chloride	1.4E-04	7.5E-03	B2	1E-06
RDX	1.1E-02	1.1E-01	C	1E-03
Trichloroethene	1.1E-05	1.1E-02	B2	1E-07
Vinyl Chloride	7.7E-05	2.3E+00	A	2E-04
Inorganics:				
Arsenic	1.3E-04	2.0E+00	A	3E-04
Total	--	--	--	2E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
trans-1,2-Dichloroethene	2.9E-05	2E-02	Blood	1E-03
bis(2-Ethylhexyl)phthalate	2.0E-03	2E-02	Liver	1E-01
HMX	5.7E-05	5E-02	Liver	1E-03
Methylene chloride	1.4E-04	6E-02	Liver	2E-03
RDX	1.1E-02	3E-03	Prostate Inflam.	4E+00
Trichloroethene	1.1E-05	7.35E-03	Liver	2E-03
1,3,5-TNB	1.1E-05	5E-05	Spleen	2E-01
Inorganics:				
Arsenic	1.3E-04	1E-03	Skin	1E-01
Barium	1.1E-02	5E-02	Blood	2E-01
Chromium	6.6E-04	5E-03	Liver, Kidney	1E-01
Nickel	1.6E-03	2E-02	Organ Weight	8E-02
Selenium (g)	8.9E-05	3E-03	Skin	3E-02
Silver	8.6E-06	3E-03	Argyria	3E-03
Zinc (g)	2.7E-02	2E-01	Blood	1E-01
Hazard Index	--	--	--	>1 (5E+00)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:

A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

detected at well 7-7, which is downgradient of the closed lagoons and active lagoons in Areas 7A and 7D, thus indicating a potential source of explosives contamination. The maximum concentration of vinyl chloride of 10.2 ug/L was detected in well 7-7. The maximum concentration of arsenic of 8.7 ug/L was detected at well 7-11, which is slightly downgradient of the closed lagoons in Area 7B, thus indicating a potential source of arsenic contamination. For noncarcinogenic risk, the hazard index value for the RME case was 5. RDX was the only chemical with a CDI:RfD ratio greater than one.

5.5.2.8 Ingestion of Groundwater Directly Downgradient of Sources in Area 8 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 8 by future on-site residents are displayed in Table 5-43. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $8x10^{-7}$ to $7x10^{-4}$ with a total excess lifetime cancer risk of $2x10^{-3}$. Bis(2-ethylhexyl)phthalate, arsenic, and beryllium comprised the majority of the risk for the RME case. The maximum concentrations of arsenic (14.1 ug/L), beryllium (6 ug/L), and bis(2-ethylhexyl)phthalate (20,000 ug/L) were detected at wells 8-3, MW-3, and 8-2, respectively. Wells 8-2 and 8-3 are downgradient of the disposal pit areas (Areas 8A and 8B), thus indicating potential sources for these chemicals. Disposal pits located throughout the area may have contributed to the concentrations of inorganic contaminants detected in groundwater in Area 8. For noncarcinogenic risk, the hazard index value for the RME case was 4. Bis(2-ethylhexyl)phthalate was the only chemical with a CDI:RfD ratio greater than one.

5.5.2.9 Ingestion of Groundwater Directly Downgradient of Sources in Area 9 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 9 by future

TABLE 5-43

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 8

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
bis(2-Ethylhexyl)phthalate	2.1E-02	1.4E-02	B2	3E-04
N-nitrosodiphenylamine	1.6E-04	4.9E-03	B2	8E-07
RDX	1.1E-05	1.1E-01	C	1E-06
Trichloroethene	5.1E-05	1.1E-02	B2	6E-07
Inorganics:				
Arsenic	2.4E-04	2.0E+00	A	5E-04
Beryllium	1.7E-04	4.3E+00	B2	7E-04
Radiological Parameters:				
U-234	9.7E+04 pCi	1.4E-10 (pCi)-1	A	1E-05
U-238	8.7E+04 pCi	1.3E-10 (pCi)-1	A	1E-05
Total	--	--	--	2E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
trans-1,2-Dichloroethene	1.4E-04	2E-02	Blood	7E-03
bis(2-Ethylhexyl)phthalate	2.1E-02	2E-02	Liver	1E+00
RDX	1.1E-05	3E-03	Prostate Inflam.	4E-03
Toluene	1.1E-04	3E-01	CNS	4E-04
Trichloroethene	5.1E-05	7.35E-03	Liver	7E-03
Inorganics:				
Antimony	1.0E-04	4E-04	Blood Chemistry	3E-01
Arsenic	2.4E-04	1E-03	Skin	2E-01
Barium	2.6E-02	5E-02	Blood	5E-01
Beryllium	1.7E-04	5E-03	Blood, skin	3E-02
Cadmium	1.3E-04	5E-04	Renal	3E-01
Chromium	4.0E-03	5E-03	Liver, Kidney	8E-01
Nickel	5.5E-03	2E-02	Organ Weight	3E-01
Silver	1.7E-05	3E-03	Argyria	6E-03
Zinc	4.0E-02	2E-01	Blood	2E-01
Hazard Index	--	--	--	>1 (4E+00)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:

A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

on-site residents are displayed in Table 5-44. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $5x10^{-5}$ to $4x10^{-4}$ with a total excess lifetime cancer risk of . $8x10^{-4}$. Bis(2-ethylhexyl)phthalate and arsenic comprised the majority of the risk for the RME case. The maximum concentration of bis(2-ethylhexyl)phthalate (1,000 ug/L) was detected at well 9-1. As stated in Section 4.9, the detection of bis(2-ethylhexyl)phthalate was potentially due to post-sampling contamination. The maximum concentration of arsenic of 5.3 ug/L was detected at well 9-2. For noncarcinogenic risk, the hazard index value for the RME case was 10. 1,3,5-TNB and bis(2-ethylhexyl)phthalate were the only chemicals with a CDI:RfD ratio greater than one. The maximum concentration of 1,3,5-TNB of 19 ug/L was detected at well 9-2, which is downgradient of the mercurous nitrate tanks, thus indicating a potential source of explosives contamination.

5.5.2.10 Ingestion of Groundwater Directly Downgradient of Sources in Area 10 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 10 by future on-site residents are displayed in Table 5-45. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $1x10^{-5}$ to $1x10^{-3}$ with a total excess lifetime cnacer risk of $3x10^{-3}$. Arsenic and beryllium comprised the majority of the risk. The maximum concentrations of arsenic (21.3 ug/L) and beryllium (8.1 ug/L) were detected at wells 10-4 and 10-5, respectively. For noncarcinogenic risk, the hazard index value for the RME case was 9. The CDI:RfD ratios for bis(2-ethylhexyl)phthalate, barium, and cadmium exceeded a value of one. The maximum concentration of bis(2-ethylhexyl)phthalate (700 ug/L) was detected at well 10-5. As stated in Section 4.9, the detection of bis(2-ethylhexyl)phthalate was potentially due to field contamination, since this compound was not detected in the second round of sampling and its presence could not be attributed to site related activities. The maximum

TABLE 5-44

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 9

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
bis(2-Ethylhexyl)phthalate	2.9E-02	1.4E-02	B2	4E-04
RDX	4.3E-04	1.1E-01	C	5E-05
Inorganics:				
Arsenic	1.5E-04	2.0E+00	A	3E-04
Beryllium	1.1E-05	4.3E+00	B2	5E-05
Total	--	--	--	8E-04

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
bis(2-Ethylhexyl)phthalate	2.9E-02	2E-02	Liver	1E+00
RDX	4.3E-04	3E-03	Prostate Inflam.	1E-01
1,3,5-TNB	5.4E-04	5E-05	Spleen	1E+01
Inorganics:				
Arsenic	1.5E-04	1E-03	Skin	2E-01
Cadmium	1.8E-04	5E-04	Renal	4E-01
Nickel	1.3E-03	2E-02	Organ Weight	6E-02
Silver	2.3E-04	3E-03	Argyria	8E-02
Zinc	4.9E-02	2E-01	Blood	2E-01
Hazard Index	--	--	--	>1 (1E+01)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

TABLE 5-45

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 10

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
bis(2-Ethylhexyl)phthalate	2.0E-02	1.4E-02	B2	3E-04
RDX	9.4E-05	1.1E-01	C	1E-05
Inorganics:				
Arsenic	6.1E-04	2.0E+00	A	1E-03
Beryllium	2.3E-04	4.3E+00	B2	1E-03
Total	--	--	--	3E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
bis(2-Ethylhexyl)phthalate	2.0E-02	2E-02	Liver	1E+00
RDX	9.4E-05	3E-03	Prostate Inflam.	3E-02
Inorganics:				
Antimony	2.8E-04	4E-04	Blood Chmistry	7E-01
Arsenic	6.1E-04	1E-03	Skin	6E-01
Barium	8.7E-02	5E-02	Blood	2E+00
Beryllium	2.3E-04	5E-03	Blood, skin	5E-02
Cadmium	2.3E-03	5E-04	Renal	5E+00
Nickel	7.1E-03	2E-02	Organ Weight	4E-01
Silver	1.4E-05	3E-03	Argyria	5E-03
Zinc	6.9E-02	2E-01	Blood	3E-01
Hazard Index	--	--	--	>1 (9E+00)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

concentrations of barium (3,030 ug/L) and cadmium (32 ug/L) were detected at well 10-4.

5.5.2.11 Ingestion of Groundwater Directly Downgradient of Sources in Area 11 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 11 by future on-site residents are displayed in Table 5-46. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern were approximately 10^{-4} with a total excess lifetime cancer risk of $7x10^{-4}$. RDX, bis(2-ethylhexyl)phthalate, arsenic, and beryllium were the only potential carcinogenic compounds identified in Area 11. The maximum concentrations of RDX (50 ug/L) and bis(2-ethylhexyl) phthalate (300 ug/L) were detected at well 11-4. The maximum concentrations of arsenic (6.6 ug/L) and beryllium (1.5 ug/L) were detected at well 11-2. As stated in Section 4.9, the burning grounds area was a suspected source of explosive compound contamination in Area 11. However, the presence of bis(2-ethylhexyl)phthalate was probably due to field contamination, since this compound was not detected in groundwater during the second round of sampling, as stated in Section 4.11. For noncarcinogenic risk, the hazard index value for the RME case was 2. None of the chemical-specific CDI:RfD ratios exceeded a value of one.

5.5.2.12 Ingestion of Groundwater Directly Downgradient of Sources in Area 12 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 12 by future on-site residents are displayed in Table 5-47. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $9x10^{-7}$ to $8x10^{-4}$ with a total excess lifetime cancer risk of $1x10^{-3}$. RDX, arsenic, and beryllium comprised the majority of the carcinogenic risk for the RME case in Area 12. The maximum concentration of

TABLE 5-46

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 11

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
bis(2-Ethylhexyl)phthalate	8.6E-03	1.4E-02	B2	1E-04
RDX	1.4E-03	1.1E-01	C	2E-04
Inorganics:				
Arsenic	1.3E-04	2.0E+00	A	3E-04
Beryllium	4.3E-05	4.3E+00	B2	2E-04
Total	--	--	--	7E-04

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
bis(2-Ethylhexyl)phthalate	8.6E-03	2E-02	Liver	4E-01
HMX	1.5E-04	5E-02	Liver	3E-03
RDX	1.4E-03	3E-03	Prostate Inflam.	5E-01
Inorganics:				
Arsenic	1.3E-04	1E-03	Skin	1E-01
Beryllium	4.3E-05	5E-03	Blood, skin	9E-03
Cadmium	1.3E-04	5E-04	Renal	3E-01
Chromium	9.1E-04	5E-03	Liver, Kidney	2E-01
Nickel	2.3E-03	2E-02	Organ Weight	1E-01
Silver	8.6E-06	3E-03	Argyria	3E-03
Zinc	1.2E-02	2E-01	Blood	6E-02
Hazard Index	--	--	--	>1 (2E+00)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:

A = Human Carcinogen, sufficient evidence from human epidemiological studies;

B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;

B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and

C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.

D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

TABLE 5-47

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 12

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
N-nitrosodiphenylamine	1.9E-04	4.9E-03	B2	9E-07
RDX	1.7E-03	1.1E-01	C	2E-04
Inorganics:				
Arsenic	4.0E-04	2.0E+00	A	8E-04
Beryllium	2.3E-05	4.3E+00	B2	1E-04
Total	--	--	--	1E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
HMX	1.8E-04	5E-02	Liver	4E-03
RDX	1.7E-03	3E-03	Prostate Inflam.	6E-01
1,3,5-TNB	5.3E-04	5E-05	Spleen	1E+01
Inorganics:				
Arsenic	4.0E-04	1E-03	Skin	4E-01
Barium	2.9E-02	5E-02	Blood	6E-01
Beryllium	2.3E-05	5E-03	Blood, skin	5E-03
Chromium	1.1E-01	5E-03	Liver, Kidney	2E+01
Nickel	1.9E-03	2E-02	Organ Weight	1E-01
Silver	8.6E-06	3E-03	Argyria	3E-03
Zinc	8.3E-03	2E-01	Blood	4E-02
Hazard Index	--	--	--	>1 (3E+01)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

RDX (61 ug/L) was detected at well 12-2. The maximum concentrations of arsenic (16.3 ug/L) and beryllium (0.8 ug/L) were detected at well 12-6. For noncarcinogenic risk, the hazard index value for the RME case was 30. Only the CDI:RfD ratios for 1,3,5-TNB and chromium exceeded a value of one. The maximum concentrations of 1,3,5-TNB (18.6 ug/L) and chromium (3,500 ug/L) were detected at well 12-5. As stated in Section 4.9, there appears to be a source of explosive compound and inorganic contamination in Area 12.

5.5.2.13 Ingestion of Groundwater Directly Downgradient of Sources in Area 14 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 14 by future on-site residents are displayed in Table 5-48. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $5x10^{-6}$ to $1x10^{-3}$ with a total excess lifetime cancer risk of $1x10^{-3}$. Arsenic comprised the majority of the risk with a maximum concentration of 21.5 ug/L at well 14-2. For noncarcinogenic risk, the hazard index value for the RME case was 3. No chemical-specific CDI:RfD ratios exceeded a value of one. Chromium was primarily driving the noncarcinogenic risk. The maximum concentration of chromium (160 ug/L) was detected at well 14-4.

The sludge disposal area located in Area 14B may be a potential source of chromium contamination.

5.5.2.14 Ingestion of Groundwater Directly Downgradient of Sources in Area 16 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 16 by future on-site residents are displayed in Table 5-49. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $9x10^{-6}$ to $3x10^{-4}$ with a total excess lifetime cancer risk of

TABLE 5-48

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 14

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
bis(2-Ethylhexyl)phthalate	2.9E-03	1.4E-02	B2	4E-05
RDX	2.7E-04	1.1E-01	C	3E-05
Inorganics:				
Arsenic	6.1E-04	2.0E+00	A	1E-03
Beryllium	3.4E-05	4.3E+00	B2	1E-04
Radiological Parameters:				
U-234	2.6E+04 pCi	1.4E-10 (pCi)-1	A	4E-06
U-238	3.6E+04 pCi	1.3E-10 (pCi)-1	A	5E-06
Total	--	--	--	1E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
bis(2-Ethylhexyl)phthalate	2.9E-03	2E-02	Liver	1E-01
RDX	2.7E-04	3E-03	Prostate Inflam.	9E-02
Inorganics:				
Arsenic	6.1E-04	1E-03	Skin	6E-01
Barium	1.6E-02	5E-02	Blood	3E-01
Beryllium	3.4E-05	5E-03	Blood, skin	7E-03
Cadmium	2.0E-04	5E-04	Renal	4E-01
Chromium	4.6E-03	5E-03	Liver, Kidney	9E-01
Nickel	2.9E-03	2E-02	Organ Weight	1E-01
Zinc	2.5E-02	2E-01	Blood	1E-01
Hazard Index	--	--	--	>1 (3E+00)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:

A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

TABLE 5-49

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 16

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
Benzene	5.4E-05	2.9E-02	A	2E-06
Carbon tetrachloride	7.7E-05	1.3E-01	B2	1E-05
1,1-Dichloroethane	2.6E-04	9.1E-02	B2	2E-05
1,2-Dichloroethane	9.7E-05	9.1E-02	B2	9E-06
1,1-Dichloroethene	8.9E-05	6.0E-01	C	5E-05
bis(2-Ethylhexyl)phthalate	4.0E-04	1.4E-02	B2	6E-06
RDX	6.6E-05	1.1E-01	C	7E-06
1,1,2,2-Tetrachloroethane	8.9E-05	2.0E-01	C	2E-05
Tetrachloroethene	4.9E-04	5.1E-02	B2	2E-05
1,1,2-Trichloroethane	1.0E-04	5.7E-02	C	6E-06
Trichloroethene	6.9E-04	1.1E-02	B2	8E-06
Vinyl Chloride	6.3E-05	2.3E+00	A	1E-04
Inorganics:				
Arsenic	1.4E-04	2.0E+00	A	3E-04
Beryllium	4.6E-05	4.3E+00	B2	2E-04
Radiological Parameters:				
U-234	8.2E+04 pCi	1.4E-10 (pCi)-1	A	1E-05
U-238	7.7E+04 pCi	1.3E-10 (pCi)-1	A	1E-05
Total	--	--	--	8E-04

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
Carbon tetrachloride	7.7E-05	7E-04	Liver	1E-01
1,3-DNB	8.6E-06	1E-04	Spleen	9E-02
1,2-Dichlorobenzene	1.6E-04	9E-02	Liver	2E-03
1,1-Dichloroethane	2.6E-04	1E-01	Kidney	3E-03
1,1-Dichloroethene	8.9E-05	9E-03	Liver	1E-02
trans-1,2-Dichloroethene	1.9E-03	2E-02	Blood	1E-01
Ethylbenzene	9.4E-05	1E-01	Liver, Kidney	9E-04
bis(2-Ethylhexyl)phthalate	4.0E-04	2E-02	Liver	2E-02
Nitrobenzene	1.7E-05	5E-04	Adrenal, Liver & Kidney Lesions	3E-02
RDX	6.6E-05	3E-03	Prostate Inflam.	2E-02
Tetrachloroethene	4.9E-04	1E-02	Liver	5E-02
Toluene	7.7E-05	3E-01	CNS	3E-04
1,1,1-Trichloroethane	1.6E-04	9E-02	Liver	2E-03
1,1,2-Trichloroethane	1.0E-04	4E-03	Blood Chemistry	3E-02
Trichloroethene	6.9E-04	7.35E-03	Liver	9E-02
Inorganics:				
Antimony	8.6E-05	4E-04	Blood Chmistry	2E-01
Arsenic	1.4E-04	1E-03	Skin	1E-01
Barium	1.4E-02	5E-02	Blood	3E-01
Beryllium	4.6E-05	5E-03	Blood, skin	9E-03
Chromium	6.3E-04	5E-03	Liver, Kidney	1E-01
Nickel	1.7E-03	2E-02	Organ Weight	8E-02
Silver	1.1E-05	3E-03	Argyria	4E-03
Zinc	4.3E-02	2E-01	Blood	2E-01
azard Index	--	--	--	>1 (2E+00)

TABLE 5-49 (Continued)

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 16

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
  A = Human Carcinogen, sufficient evidence from human epidemiological studies;
  B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
  B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
  C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
  D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

$8x10^{-4}$. Vinyl chloride, arsenic, and beryllium comprised the majority of the risk. The abandoned landfill may be a potential source of vinyl chloride (detected only in well 16-13 at 5.1 ug/L) and arsenic contamination (the maximum concentration of arsenic of 14.3 ug/L was detected at well 16-11). The maximum concentration of beryllium of 3.1 ug/L was detected at well 16-12. For noncarcinogenic risk, the hazard index value for the RME case was 2. No chemical-specific CDI:RfD ratios exceeded a value of one.

5.5.2.15 Ingestion of Groundwater Directly Downgradient of Sources in Area 17 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 17 by future on-site residents are displayed in Table 5-50. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $5x10^{-6}$ to $5x10^{-4}$ with a total excess lifetime cancer risk of $2x10^{-3}$. Trichloroethene, arsenic, and beryllium comprised the majority of the risk. The solvent pits located in Area 17B were identified as the source areas for trichloroethene which was detected at a maximum concentration of 4,300 ug/L in well 17-5. The maximum concentrations of arsenic of 16.8 ug/L and beryllium of 2.1 ug/L detected in Area 17 groundwater were collected from wells 17-7 and 17-8, respectively. However, Area 17 is not a suspected source of inorganic contamination, as stated in Section 4.17.

For noncarcinogenic risk, the hazard index for the RME case was 400. Trans-1,2-dichloroethene and trichloroethene were the only chemicals with CDI:RfD ratios that exceeded a value of one. Trans-1,2-dichloroethene had a CDI:RfD ratio of 400, the highest ratio estimated for this site. Trans-1,2-dichloroethene was only detected in well 17-5 at a concentration of 320,000 ug/L. The solvent pits located in Area 17B were identified as the source areas for the VOCs detected in Area 17.

TABLE 5-50

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 17

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
Benzene	4.0E-05	2.9E-02	A	1E-06
Chloroform	7.4E-04	6.1E-03	B2	5E-06
2,6-DNT	8.6E-06	6.8E-01	B2	6E-06
bis(2-Ethylhexyl)phthalate	2.3E-03	1.4E-02	B2	3E-05
Methylene chloride	7.1E-04	7.5E-03	B2	5E-06
RDX	4.9E-04	1.1E-01	C	5E-05
Tetrachloroethene	3.4E-03	5.1E-02	B2	2E-04
1,1,2-Trichloroethane	1.3E-03	5.7E-02	C	7E-05
Trichloroethene	4.6E-02	1.1E-02	B2	5E-04
Inorganics:				
Arsenic	2.1E-04	2.0E+00	A	4E-04
Beryllium	6.0E-05	4.3E+00	B2	3E-04
Radiological Parameters:				
U-234	4.6E+04 pCi	1.4E-10 (pCi)-1	A	6E-06
U-238	3.6E+04 pCi	1.3E-10 (pCi)-1	A	5E-06
Total	--	--	--	2E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
Chloroform	7.4E-04	1E-02	Liver	7E-02
trans-1,2-Dichloroethene	8.0E+00	2E-02	Blood	4E+02
Ethylbenzene	9.1E-04	1E-01	Liver, Kidney	9E-03
bis(2-Ethylhexyl)phthalate	2.3E-03	2E-02	Liver	1E-01
HMX	2.6E-05	5E-02	Liver	5E-04
Methylene chloride	7.1E-04	6E-02	Liver	1E-02
RDX	4.9E-04	3E-03	Prostate Inflam.	2E-01
1,3,5-Trinitrobenzene	1.1E-05	5E-05	Spleen	2E-01
Tetrachloroethene	3.4E-03	1E-02	Liver	3E-01
Toluene	6.0E-02	3E-01	CNS	2E-01
1,1,1-Trichloroethane	5.7E-02	9E-02	Liver	6E-01
1,1,2-Trichloroethane	1.3E-03	4E-03	Blood Chemistry	3E-01
Trichloroethene	4.6E-02	7.35E-03	Liver	6E+00
Inorganics:				
Antimony	5.4E-05	4E-04	Blood Chmistry	1E-01
Arsenic	2.1E-04	1E-03	Skin	2E-01
Barium	2.3E-02	5E-02	Blood	5E-01
Beryllium	6.0E-05	5E-03	Blood, skin	1E-02
Nickel	2.0E-03	2E-02	Organ Weight	1E-01
Silver	1.4E-05	3E-03	Argyria	5E-03
Zinc	2.5E-02	2E-01	Blood	1E-01
Hazard Index	--	--	--	>1 (4E+02)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.
(b) Presented originally in Table 5-29.
(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.
(d) Calculated by multiplying the CDI by the slope factor.
(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.
(f) Calculated by dividing the CDI by the RfD.

5.5.2.16 Ingestion of Groundwater Directly Downgradient of Sources in Area 18 by Future On-Site Residents

CDIs and calculated carcinogenic and non-carcinogenic risks associated with ingestion of groundwater directly downgradient of sources in Area 18 by future on-site residents are displayed in Table 5-51. Upper bound excess lifetime cancer risks for the RME case for individual chemicals of potential concern ranged from $9x10^{-5}$ to $6x10^{-3}$ with a total excess lifetime cancer risk of $6x10^{-3}$. Chrysene, a carcinogenic PAH, was primarily driving the risk for the RME case. Chrysene was detected only at well 18-6 and this chemical's presence is due to an unknown source, as stated in Section 4.18. Well 18-6 is not downgradient of any of the Area 11, 16, 17 or 18 source areas. It should be noted that the slope factor used in the risk calculation for chrysene was based on the toxicity of benzo(a)pyrene, a highly potent PAH, since there is no available slope factor for chrysene. Therefore, the actual risks presented in Table 5-51 are most likely overestimates of actual risks. For noncarcinogenic risk, the hazard index for the RME case was less than one.

5.5.2.17 Direct Contact with Soil and Inhalation of Dust by Future Construction Workers

With respect to potential exposures and associated risks from chemicals in soils, if future development of study areas were to occur, the chemicals of potential concern in subsurface soils (as discussed in Section 5.2) include 2,6-DNT (in Area 8), oil and grease (in Areas 8, 14, and 15), and several inorganics, including mercury in Areas 8 and 9. Direct contact by workers with these soils may result in inadvertant ingestion of chemicals during activities such as smoking as well as absorption of chemicals through the skin. Ingestion may occur however, dermal absorption of inorganics in general will not occur with the exception of mercury, which is absorbed through the skin (mercury was found to be a chemical of concern in Areas 8 and 9 due to past waste disposal activities). Inhalation of dust contaminated with 2,6-DNT and with the inorganics of potential concern would also be a source of

TABLE 5-51

POTENTIAL EXPOSURES AND RISKS ASSOCIATED WITH FUTURE INGESTION OF ON-SITE GROUNDWATER DIRECTLY DOWNGRADIENT OF SOURCES IN AREA 18

Potential Carcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Slope Factor (mg/kg-day)-1 (b)	Weight of Evidence Class (c)	Excess Upper Bound Lifetime Cancer Risk (d)
Organics:				
Carcinogenic PAHs (Chrysene)	5.4E-04	1.2E+01	B2	6E-03
1,1-Dichloroethene	1.6E-04	6.0E-01	C	9E-05
bis(2-Ethylhexyl)phthalate	4.6E-03	1.4E-02	B2	6E-05
RDX	1.1E-04	1.1E-01	C	1E-05
Total	--	--	--	6E-03

Noncarcinogenic Effects

Chemical	RME Estimated Chronic Daily Intake (CDI) (mg/kg-day) (a)	Reference Dose (mg/kg-day) (b)	Target Organ (e)	CDI:RfD (f)
Organics:				
1,1-Dichloroethene	1.6E-04	9E-03	Liver	2E-02
bis(2-Ethylhexyl)phthalate	4.6E-03	2E-02	Liver	2E-01
HMX	2.6E-05	5E-02	Liver	5E-04
RDX	1.1E-04	3E-03	Prostate Inflam.	4E-02
Inorganics:				
Barium	1.5E-02	5E-02	Blood	3E-01
Nickel	1.1E-03	2E-02	Organ Weight	5E-02
Silver	5.7E-06	3E-03	Argyria	2E-03
Zinc	2.2E-02	2E-01	Blood	1E-01
Hazard Index	--	--	--	<1 (8E-01)

(a) Presented originally in Table 5-28. For metals, the higher concentration (from filtered or unfiltered analyses) was used. Concentration given is the total concentration (from unfiltered samples) unless otherwise noted.

(b) Presented originally in Table 5-29.

(c) EPA weight of evidence classification scheme for carcinogens:
A = Human Carcinogen, sufficient evidence from human epidemiological studies;
B1 = Probable Human Carcinogen, limited evidence from epidemiological studies and adequate evidence from animal studies;
B2 = Probable Human Carcinogen, inadequate evidence from epidemiological studies and adequate evidence from animal studies; and
C = Possible Human Carcinogen, limited evidence in animals in the absence of human data.
D = Not classified.

(d) Calculated by multiplying the CDI by the slope factor.

(e) A target organ is the organ most sensitive to a chemical's toxic effect. RfDs are based on toxic effects in the target organ. If an RfD was based on a study in which a target organ was not identified, the organ listed is one known to be affected by the particular chemical of concern.

(f) Calculated by dividing the CDI by the RfD.

exposure to construction workers and might be associated with significant risks. Thus, it is recommended that these pathways of concern be evaluated quantitatively in the future once contamination in surface and subsurface soils have been fully characterized.

5.6 ENVIRONMENTAL ASSESSMENT

This section assesses potential impacts to nonhuman receptors associated with the chemicals of potential concern at LCAAP. In this analysis, chemicals of potential concern identified for the human health risk assessment were used for the environmental assessment. The assessment is comprised of four major sections: identification of potential environmental receptors at the sites, quantification of exposure, toxicity assessment of the chemicals of concern, and risk assessment. The assessments of risk are limited primarily to the population (species) level because data on community and ecosystem level responses to environmental pollutants generally are lacking. However, where possible, the implications of population level impacts on the community or ecosystem are qualitatively discussed.

5.6.1 Potential Receptors

In this section the plant and animal species which occur at LCAAP are identified and indicator species or species groups are selected for further evaluation.

For the environmental assessment, LCAAP is divided into two distinct areas: (1) the manufacturing and storage facilities area and (2) the uplands area. The manufacturing and storage facilities area is located on the flood plain of West Fire Prairie Creek, has few trees, and is of very limited value to wildlife (USA/LCAAP 1988). The uplands area is dominated by woodlands and is excellent for wildlife habitat (USA/LCAAP 1988). In this section, the major species of plants and wildlife occurring in these areas are indicated. For convenience, only common name are used in this section (scientific names are given in Appendix B).

5.6.1.1 Terrestrial Receptors

LCAAP covers 1,582 hectares (ha) (3,907 acres), of which 464 ha (1,146 acres) are forested. The remaining area includes 132 ha (326 acres) of improved ground, 398 ha (983 acres) of semi-improved grounds, and 588 ha (1,452 acres) of unimproved grounds. LCAAP has a 5-year land management plan for the conservation of land and material resources (USATHAMA 1980).

Plants. The following are the principal tree species in the woodland areas of LCAAP: white ash, boxelder, eastern cottonwood, American elm, hackberry, bitternut hickory, black hickory, shagbark hickory, shellbark hickory, black locust, honey locust, silver maple, black oak, bur oak, red oak, white oak, osage orange, redbud, American sycamore, and black walnut. Blackberry briars, buckbrush, poison ivy, smooth sumac, and wild grapevine are also found within the woodlands. Common weed species include blackeyed susan, bull thistle, Carolina horse nettle, chickweed, cocklebur, common flannel mullein, dandelion, European glory bind weed, goldenrod, jimson weed, Pennsylvania smartweed, rippleseed plantain, and Virginia strawberry (USATHAMA 1980).

The improved grounds (i.e., areas adjacent to buildings in the manufacturing, explosives, and residential areas) at LCAAP are planted in Kentucky bluegrass. Kentucky fescue, sericea lespedeza, red clover, and Korean lespedeza are planted on 72 acres of firebreaks within timbered areas. Kentucky fescue and/or Korean lespedeza are planted on all of the grassy areas at LCAAP (USA/LCAAP 1988)

The principal trees used in landscaped areas are American elm, black walnut, cottonwood, jack pine, Norway maple, and pin oak. Major shrubs include blue spruce, Japanese yew, and Pfitzer junipers (USA/LCAAP 1988).

Mammals. Species of mammals that occur at LCAAP include coyote, white-tailed deer, gray fox, red fox, muskrat, opossum, cottontail rabbit, raccoon, striped skunk, and fox squirrels (USA/LCAAP 1988, USATHAMA 1980). Most of these species would likely spend the large majority of their time in the upland forested areas. Species such as the fox squirrel and cottontail rabbit may also be found in the manufacturing and storage areas where suitable food and cover exist.

The distribution of small acreages of uneven-aged timber at LCAAP is considered ideal habitat for white-tailed deer and fox squirrels. Approximately 189 white-tailed deer inhabit LCAAP, according to an aerial survey conducted in February, 1988 (Olin Corporation 1988). Deer health was reported as good and no habitat deficiencies were observed (Olin Corporation 1988). A sizeable concentration of deer occurs in the Big Ditch area (USA/LCAAP 1988a). Deer frequently use salt licks located along Area 16 seep areas. Bow-hunting is allowed at LCAAP, and eight deer were taken in 1988 (USA/LCAAP 1989a).

Birds. No complete list of bird species at LCAAP has been made (USA/LCAAP 1988). However, most of the resident species common to this area of Missouri have been observed at LCAAP (USA/LCAAP 1988). Bird species known to occur at LCAAP include: Canada geese, wood duck, bobwhite quail, wild turkey, woodcock, mourning dove, Cooper's hawk, red-shouldered hawk, red-tailed hawk, sharp-shinned hawk, kestrel, barn owl, screech owl, great horned owl, common flicker, downy woodpecker, red-bellied woodpecker, red-headed woodpecker, common raven, common crow, fish crow, blue jay, loggerhead shrike, eastern meadowlark, Carolina wren, American goldfinch, horned lark, tufted titmouse, and white-breasted nuthatch (USATHAMA 1980, USA/LCAAP 1988).

The upper part of Veteran's Lake (described in Section 5.6.1.2) is a prime nesting area for Canada geese and wood ducks. Their populations are 40 to 60 and 10 to 15, respectively. The other water bodies at LCAAP are of less importance to waterfowl (USA/LCAAP 1988). Waterfowl generally do not occur in the manufacturing and storage areas.

Wild turkey are the most important game species at LCAAP (USA/LCAAP 1988). This and other species of gamebirds are likely to spend the majority of their time in the upland forested areas of the site. The estimated population is 192 birds according to an aerial survey conducted in February, 1988 (Olin Corporation 1988).

In general, the variety of bird species occurring in the manufacturing and storage areas is expected to be low compared to the upland forested area. Common songbirds, such as blue jay, tufted titmouse, and Carolina wren (listed above), would be expected to occur in landscaped areas around the buildings. Flicker, woodpeckers, and screech owls may also occur.

5.6.1.2 Aquatic Receptors

No major rivers or streams are present at the site; however, there are numerous drainage ditches within the lowland areas of the plant. The largest of the drainage ditches are Ditch A, the Ditch B, Big Ditch, and the unnamed ditch. The larger ditches are generally wet and water flows the majority of the year. Water hardness values in Ditch A and Ditch B range from 160 to 408 mg/L $CaCO_3$ and show little variation between ditches (USA/LCAAP 1989b). No hardness values are available for the Big Ditch, although it is assumed to be similar (USA/LCAAP 1989b). According to Weston personnel, small fish have been observed in limited portions of the larger ditches on-site (e.g., in Big Ditch in the southwestern part of the site near Area 8). Frogs have also been observed in these ditches (USA/LCAAP 1989b). Large fish are not expected to occur in the shallow intermittent waters of these ditches, and fishing is not known to occur.

Ditch A (also known as West Fire Prairie Creek) flows northwest across the LCAAP property from the south-central boundary to the northwestern boundary (USATHAMA 1980). It flows into Little Blue River approximately 1/2 mile downstream (USA/LCAAP 1989b). Little Blue River is protected for use as a warmwater fishery by the State of Missouri. West Fire Prairie Creek is not classified by the State of Missouri (personal communication with Missouri Department of Water Pollution Control, April, 1989). Ditch B (also known as East Fire Prairie Creek) is an intermittent stream that flows northeast across LCAAP from Building 6 to the north-central boundary. East Fire Prairie Creek also is not classified by the State of Missouri (personal communication with Missouri Department of Water Pollution Control, April, 1989). Beyond the town of Buchner it flows into the Missouri River, approximately 5 miles downstream (USATHAMA 1980, USA/LCAAP 1989b). The Big Ditch flows northwest across the southeastern portion of LCAAP. The unnamed ditch originates just south of Area 11 and flows north to join Ditch B near the northern border of the plant. A small drainage ditch crosses Areas 16 and 17 near the border between these two areas.

Veteran's Lake is a 6.5-hectare (16 acre) manmade lake located in the upland area at the northeastern end of LCAAP and is used for recreational purposes and is stocked with fish (USATHAMA 1980). Largemouth bass, bluegill, and channel catfish, are managed for sport fishing. Other fish species found in the ponds at LCAAP include blue catfish, green sunfish, and golden shiner (USA/LCAAP 1988a). A pond, formerly used by cattle, is located in Area 3, near the northwest boundary of the plant. It is probably poor habitat for aquatic species since it has been regularly used by cattle (i.e., turbidity of the water and low oxygen content). The pond is not stocked and is not used for fishing.

5.6.1.3 Endangered/Threatened Species

No sensitive species or communities occur on the immediate site or surrounding area based on a review of available files by the Missouri Department of Conservation (1989). The U.S. Army also states that there are no endangered or threatened species of plants or animals at LCAAP, based on their available information (USA/LCAAP 1988).

5.6.2 Selection of Indicator Species or Species Groups

As the previous discussion indicates, the upland area surrounding the industrialized areas at LCAAP support a variety of plant and animal species. Because of this diversity, it is not feasible to assess impacts to every species potentially affected. A common approach to this problem in ecological evaluations is to select "indicator" species or species groups for detailed evaluation and to assume that impacts to these indicators are representative of potential impacts to other species at the site. The selection of indicator species or groups is driven by several factors, including species diversity at the site, the potential for exposure, the availability of toxicity data, and the "health" of the potentially impacted populations (e.g., threatened or endangered species). Each of these factors was considered in the selection of indicators at the sites.

The selection of indicator species of plants at LCAAP is driven primarily by the availability of toxicity data since no differences in exposure potential exists between the species and no endangered or threatened plants are known to occur at the site. Unfortunately, toxicity information specific to the plant species that occur at the site is not available. Therefore, an indicator species is not selected, but rather, plants as a group are selected as indicators.

For terrestrial species, the potential for exposure is an important factor in selecting indicator species. Feeding habits vary greatly among the potential receptors at LCAAP and such differences can have direct impacts on potential exposure. Because some of the contaminants of potential concern at LCAAP can bioaccumulate in the food chain, carnivorous or piscivorous (fish-eating) animals could be exposed to higher levels of these contaminants than herbivorous (plant-eating) or omnivorous animals. However, because of the small size of fish in the lowland areas, consumption by wildlife is considered unlikely.

In this assessment deer, rabbits, and quail are selected as indicator species for potential impacts associated with drinking contaminated water. The robin, a common songbird, was selected to assess potential impacts to terrestrial animals that may feed on soil organisms (e.g., earthworms) in the industrialized area of the plant.

The selection for aquatic indicator species is driven by the availability of toxicity data. Toxicity criteria are available for aquatic life in general and therefore no particular species is selected as an indicator. Upland water bodies are not expected to be affected by chemicals of concern at LCAAP; thus, only the main ditches in the lowland areas will be evaluated for potential impacts to aquatic organisms.

5.6.3 Potential Exposure Pathways and Quantification of Exposure

This section describes the exposure pathways and methods used to estimate exposures to plants, terrestrial wildlife, and aquatic organisms.

In this assessment, maximum concentrations detected in various media for a given area were used to evaluate potential exposure to the environment since very few samples were collected (typically 2 or 3 samples) and this upper confidence interval on the arithmetic mean could not be calculated (or this value would exceed the maximum concentration).

5.6.3.1 Terrestrial Plants

Terrestrial plants may be exposed to chemicals of potential concern that are in the soils. In this study only Areas 13 and 9 were sampled for soils. The mean and maximum concentrations of the chemicals of potential concern in the surface soils (less than 2 feet depth) in Area 13 will be used to assess whether current levels of contaminants exceed concentrations known to be phytotoxic in at least some species. Area 9 surface soils are not assessed since this area is largely covered with stones and therefore, is generally unsuitable habitat for plant growth.

5.6.3.2 Terrestrial Wildlife

Terrestrial wildlife may be exposed to chemicals of potential concern in the soil, surface water, and sediment. Exposure may occur directly by ingestion of or direct contact with contaminated soil, sediments, or water, or indirectly, by ingestion of food that has accumulated chemicals via the food chain or from contaminated media. Exposure of wildlife to site-related contamination from consuming fish is unlikely since no sizeable fish are known to occur in any of the drainage ditches that are potentially contaminated; therefore, this pathway will not be further evaluated in this assessment. Exposures to deer from ingesting contaminated soil or plants that have bioaccumulated chemical contaminant, were not estimated because these animals are not likely to forage near the contaminated buildings in the areas where soil data are available, and suitable plant food is not available in most of these areas. Exposures of wildlife to site-related chemicals resulting from the ingestion of potentially contaminated surface water in certain industrialized areas were considered possible and therefore were included in this analysis. The methods used to estimate doses are given below. In addition, exposures to animals, such as the robin, from ingesting soil organisms, such as earthworms, were considered reasonable and were included in this analysis. The methods used to estimate doses are also given below.

Ingestion of Contaminated Surface Water. Wildlife could be exposed to contaminants in surface waters at LCAAP if the water is used as a drinking water source. Exposure of deer via this pathway will be assessed since it is reasonable to assume that some of the deer at LCAAP obtain some of their daily water from the surface water in the ditches adjacent to the woodlands. Deer have been seen using the Area 16 seep areas for drinking water and as mineral licks. For this assessment, doses to deer will be calculated assuming they use primarily undeveloped areas on-site for some of their drinking water.

These areas are: Area 13 drainage ditch, Area 16 leachate seep, Area 16 drainage ditch, cattle pond, Ditch A, Ditch B, and the Big Ditch. Exposures of rabbits and bobwhite quail via drinking water are also assessed for these same areas. Deer are assumed to receive only 10 percent of their daily water from the site because they are likely to spend much of their time in the uplands area where other sources of water are abundant. Rabbits and quail are assumed to receive 100 percent of their daily water from the selected exposure point because these species have relatively much smaller home ranges than deer. Daily water intake volumes used to estimate exposures (given in mg of chemical per kg of body weight) are as follows: deer 1.5 liters, rabbit (eastern cottontail) 0.25 liters, and bobwhite 0.1 liters (USDA 1988). Body weights used in the analysis were 68.0 kg for deer (white-tailed deer), 1.0 kg for rabbit (eastern cottontail), and 0.17 kg for bobwhite (USDA 1988). The results are presented in Table 5-52.

Ingestion of Contaminated Food. Terrestrial species such as robins may be exposed to chemicals of potential concern that are in surface soils by ingesting soil invertebrates, such as earthworms. Doses to robins (Turdus migratorius) were calculated for this pathway assuming that a robin's diet consists of 44 percent animal matter (Martin et al. 1961), and all of this fraction is comprised of soil invertebrates, such as earthworms. Robins were assumed to weigh 0.082 kg (Poole 1938) and consume an amount of food equivalent to 12 percent of their body weight per day (approximately 9.8 g food). Thus, the amount of soil invertebrates consumed is 4.3 g (44 percent of 9.8 g). Surface soil data are available for Areas 9 and 13; however, the soil in Area 9 is largely covered with stones and therefore was not considered a reasonable foraging area for robins. The chemicals of concern in surface soils in Area 13 are arsenic, barium, chromium, and lead. Bioaccumulation factors for surface soil to earthworms (dry weight soil to live weight earthworms) are 0.15 for chromium and 0.27 for lead ((Diercxsens et al. 1985). It was assumed that these uptake factors would be the same for other soil invertebrates that may be consumed by robins. No uptake factor is available for arsenic or barium; and therefore, doses were not estimated. Robins were

TABLE 5-52

ESTIMATED DOSES TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS

Chemical/ Animal	Mean Conc. in Water (ug/l) (a)	Mean Estimated Dose (mg/kg)
Area 13 Drainage Ditch:		
1,3,5-Trinitrobenzene		
Deer	0.6	1.32E-06
Bobwhite Quail	0.6	3.53E-04
Rabbit	0.6	1.50E-04
Bis(2-ethylhexyl)phthalate		
Deer	60	1.32E-04
Bobwhite Quail	60	3.53E-02
Rabbit	60	1.50E-02
Antimony		
Deer	15.5	3.42E-05
Bobwhite Quail	15.5	9.12E-03
Rabbit	15.5	3.87E-03
Chromium		
Deer	38.5	8.49E-05
Bobwhite Quail	38.5	2.26E-02
Rabbit	38.5	9.62E-03
Copper		
Deer	180	3.97E-04
Bobwhite Quail	180	1.06E-01
Rabbit	180	4.50E-02
Lead		
Deer	13.7	3.02E-05
Bobwhite Quail	13.7	8.06E-03
Rabbit	13.7	3.42E-03
Robin	13.7	8.06E-03
Nickel		
Deer	21.9	4.83E-05
Bobwhite Quail	21.9	1.29E-02
Rabbit	21.9	5.47E-03
Area 16 Leachate Seep (a):		
1,1-Dichloroethane		
Deer	30	6.62E-05
Bobwhite Quail	30	1.76E-02
Rabbit	30	7.50E-03
Benzene		
Deer	2.46	5.43E-06
Bobwhite Quail	2.46	1.45E-03
Rabbit	2.46	6.15E-04
Chloroethane		
Deer	40	8.82E-05
Bobwhite Quail	40	2.35E-02
Rabbit	40	1.00E-02
Ethylbenzene		
Deer	10	2.21E-05
Bobwhite Quail	10	5.88E-03
Rabbit	10	2.50E-03

TABLE 5-52

ESTIMATED DOSES TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS

Chemical/ Animal	Mean Conc. in Water (µg/l) (a)	Mean Estimated Dose (mg/kg)
Methylene chloride		
Deer	40	8.82E-05
Bobwhite Quail	40	2.35E-02
Rabbit	40	1.00E-02
Phenol		
Deer	2000	4.41E-03
Bobwhite Quail	2000	1.18E+00
Rabbit	2000	5.00E-01
Tetrachloroethene		
Deer	2	4.41E-06
Bobwhite Quail	2	1.18E-03
Rabbit	2	5.00E-04
Toluene		
Deer	120	2.65E-04
Bobwhite Quail	120	7.06E-02
Rabbit	120	3.00E-02
trans-1,2-Dichloroethene		
Deer	16.8	3.71E-05
Bobwhite Quail	16.8	9.88E-03
Rabbit	16.8	4.20E-03
Trichloroethene		
Deer	12.9	2.85E-05
Bobwhite Quail	12.9	7.59E-03
Rabbit	12.9	3.23E-03
Beryllium		
Deer	2.21	4.87E-06
Bobwhite Quail	2.21	1.30E-03
Rabbit	2.21	5.53E-04
Copper		
Deer	500	1.10E-03
Bobwhite Quail	500	2.94E-01
Rabbit	500	1.25E-01
Lead		
Deer	140	3.09E-04
Bobwhite Quail	140	8.24E-02
Rabbit	140	3.50E-02
Robin	140	8.24E-02
Nickel		
Deer	150	3.31E-04
Bobwhite Quail	150	8.82E-02
Rabbit	150	3.75E-02
Silver		
Deer	0.53	1.17E-06
Bobwhite Quail	0.53	3.12E-04
Rabbit	0.53	1.32E-04
Zinc		
Deer	2400	5.29E-03
Bobwhite Quail	2400	1.41E+00
Rabbit	2400	6.00E-01

TABLE 5-52

ESTIMATED DOSES TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS

Chemical/ Animal	Mean Conc. in Water (ug/l) (a)	Mean Estimated Dose (mg/kg)
Area 16 Drainage Ditch:		
Bis(2-ethylhexyl)phthalate		
Deer	40	8.82E-05
Bobwhite Quail	40	2.35E-02
Rabbit	40	1.00E-02
trans-1,2-Dichloroethene		
Deer	5	1.10E-05
Bobwhite Quail	5	2.94E-03
Rabbit	5	1.25E-03
Trichloroethene		
Deer	2	4.41E-06
Bobwhite Quail	2	1.18E-03
Rabbit	2	5.00E-04
1,3,5-Trinitrobenzene		
Deer	6.1	1.35E-05
Bobwhite Quail	6.1	3.59E-03
Rabbit	6.1	1.52E-03
Copper		
Deer	25.6	5.65E-05
Bobwhite Quail	25.6	1.51E-02
Rabbit	25.6	6.40E-03
Lead		
Deer	6.9	1.52E-05
Bobwhite Quail	6.9	4.06E-03
Rabbit	6.9	1.73E-03
Robin	6.9	4.06E-03
Nickel		
Deer	22.6	4.99E-05
Bobwhite Quail	22.6	1.33E-02
Rabbit	22.6	5.65E-03
Cattle Pond:		
Antimony		
Deer	70.8	1.56E-04 (d)
Bobwhite Quail	70.8	4.16E-02 (d)
Rabbit	70.8	1.77E-02 (d)
Arsenic		
Deer	5.3	1.17E-05 (d)
Bobwhite Quail	5.3	3.12E-03 (d)
Rabbit	5.3	1.33E-03 (d)
Copper		
Deer	72	1.59E-04
Bobwhite Quail	72	4.24E-02
Rabbit	72	1.80E-02
Ditch A:		
HMX		
Deer	1.4	3.09E-06
Bobwhite Quail	1.4	8.24E-04
Rabbit	1.4	3.50E-04
Copper		
Deer	21.5	4.74E-05
Bobwhite Quail	21.5	1.26E-02
Rabbit	21.5	5.37E-03

TABLE 5-52

ESTIMATED DOSES TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS

Chemical/ Animal	Mean Conc. in Water (ug/l) (a)	Mean Estimated Dose (mg/kg)
Nickel		
Deer	19.5	4.30E-05
Bobwhite Quail	19.5	1.15E-02
Rabbit	19.5	4.87E-03
Silver		
Deer	0.2	4.41E-07
Bobwhite Quail	0.2	1.18E-04
Rabbit	0.2	5.00E-05
Zinc		
Deer	720	1.59E-03
Bobwhite Quail	720	4.24E-01
Rabbit	720	1.80E-01
Ditch B:		
Bis(2-ethylhexyl)phthalate		
Deer	10	2.21E-05
Bobwhite Quail	10	5.88E-03
Rabbit	10	2.50E-03
Antimony		
Deer	4.9	1.08E-05
Bobwhite Quail	4.9	2.88E-03
Rabbit	4.9	1.23E-03
Arsenic		
Deer	10.4	2.29E-05
Bobwhite Quail	10.4	6.12E-03
Rabbit	10.4	2.60E-03
Beryllium		
Deer	0.4	8.82E-07
Bobwhite Quail	0.4	2.35E-04
Rabbit	0.4	1.00E-04
Copper		
Deer	100	2.21E-04
Bobwhite Quail	100	5.88E-02
Rabbit	100	2.50E-02
Lead		
Deer	11.9	2.63E-05
Bobwhite Quail	11.9	7.00E-03
Rabbit	11.9	2.98E-03
Robin	11.9	7.00E-03
Nickel		
Deer	18.4	4.06E-05
Bobwhite Quail	18.4	1.08E-02
Rabbit	18.4	4.60E-03
Selenium		
Deer	7.1	1.57E-05
Bobwhite Quail	7.1	4.18E-03
Rabbit	7.1	1.77E-03
Zinc		
Deer	620	1.37E-03
Bobwhite Quail	620	3.65E-01
Rabbit	620	1.55E-01

TABLE 5-52

ESTIMATED DOSES TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS

Chemical/ Animal	Mean Conc. in Water (ug/l) (a)	Mean Estimated Dose (mg/kg)
Big Ditch:		
Benzene		
Deer	1.5	3.31E-06
Bobwhite Quail	1.5	8.82E-04
Rabbit	1.5	3.75E-04
Trichloroethene		
Deer	1.6	3.53E-06
Bobwhite Quail	1.6	9.41E-04
Rabbit	1.6	4.00E-04
Copper		
Deer	6.2	1.37E-05
Bobwhite Quail	6.2	3.65E-03
Rabbit	6.2	1.55E-03
Zinc		
Deer	450	9.93E-04
Bobwhite Quail	450	2.65E-01
Rabbit	450	1.13E-01

(a) Mean concentrations in water were present in Table 5-7.
(b) No TRV derived because of sufficient toxicity information was not available.
(c) Possible carcinogen; value is for noncarcinogenic effects only.
(d) TRV estimated from LD50 multiplied by 5x10-4 as proposed by Layton et al. 1987.

assumed to obtain all of their daily food from the contaminated area. This results in a conservative estimate of their daily dose, but is reasonable because of their small home range. The estimated maximum daily doses for a robin based on maximum concentrations in soil are 0.894 mg/kg chromium, and 0.30 mg/kg lead.

5.6.3.3 Aquatic Life

Aquatic life may be exposed to chemicals of potential concern by direct contact with contaminated water and sediment and by ingestion of contaminated sediments and food. However, exposure and toxicity data (dose-response data) are seldom available to assess exposure via all of these pathways, and aquatic exposure assessments are most often limited to assessments of exposure to contaminated water. In this assessment, potential risks to aquatic organisms will be assessed by comparing chemical concentrations in surface water to EPA Ambient Water Quality Criteria (EPA 1986), and to interim sediment quality criteria where available. For some inorganic chemicals the AWQCs are dependent on water hardness, and in this assessment they were calculated using a hardness of 160 mg/L $CaCO_3$. This value is the low end of the range of hardness values discussed in Section 5.6.1.2 and provides a conservative estimate of the AWQC. Higher hardness values would result in higher AWQCs.

Chemical concentrations at the downstream sampling point nearest to the plant boundary will be used to assess potential impacts of on-site chemical levels in the big ditches to on off-site surface water quality. The sampling points used were SW-09 for Ditch A, SW-17 for Big Ditch and SW-15 for Ditch B.

5.6.4 Toxicity of Chemicals of Potential Concern at the Site

This section presents an assessment of the toxicity of the chemicals of potential concern in the surface soil and surface waters at LCAAP to aquatic and terrestrial wildlife, and plants. Toxicity reference values (TRVs) to be used to assess potential impacts to these receptors are identified in this section. The TRV for a representative animal species is the estimated oral daily dose (for terrestrial species) or ambient concentration (for aquatic species) of a chemical that is unlikely to result in adverse noncarcinogenic chronic effects in the majority (i.e., non-sensitive portion) of the individuals of that species. In other words, the TRV is an estimated chronic NOEL for a representative species. The TRV is likely to be protective of populations of that species if it is less than the dose levels that result in adverse reproductive effects. Because chronic NOELs are usually not available for representative species the TRV is usually estimated by using "safety factors" to extrapolate from the results of a toxicity study conducted with another species under controlled laboratory conditions. Safety factors are estimated values that are derived to account for differences in sensitivities among species (i.e., interspecies differences), differences in exposure duration (e.g., subacute vs. chronic), and differences in endpoints (i.e., LOELs vs. NOELs). Thus, the TRV is equal to the NOEL or LOEL divided by the product of the safety factors.

When available, TRV's are derived from studies with species similar to those receptor species expected to occur at LCAAP. Data on chronic or subchronic toxicity were used whenever available. Uncertainty factors also are applied to toxicity data which represent sublethal, lowest observed effect levels (LOELS). In this assessment, a safety factor of 10 is applied to a LOEL derived from a chronic study, and a safety factor of 100 is applied to a LOEL derived from a subchronic study. An additional safety factor of 10 is applied to all toxicity values determined for species different than the receptor species at the site, unless the species are considered closely related, that is within the same taxonomic order. For example, in this assessment an interspecies safety factor is not used to extrapolate the maximum tolerable levels for poultry (reported in NAS 1980) to bobwhite quail since these birds are both in the order galliformes and are considered reasonably close relatives. However, a safety factor of 10 is used to extrapolate the poultry values to robins, because robins are in a different taxonomic order (passeriformes) The use of a safety factor in this case is supported by the fact that passerine (species within the order passeriformes) and non-passerine birds may be inherently different in their sensitivities to toxic substances, since passerines have higher metabolic rates than non-passerine species of the same body size (Schmidt-Nielsen 1983). The safety factors used in this assessment are similar to those proposed by Newell et al. (1987) for estimated safe levels for wildlife. In cases where only acute toxicity values were available (i.e., 135TNB, DCLE, C6H6, and TRCLE), chronic NOELs were estimated by multiplying the acute oral LD_{50} by 5×10^{-4} as proposed by Layton et al. (1987).

Ambient water quality criteria for the protection of aquatic life have been developed by EPA for some of the chemicals of potential concern in surface water and these values will be used as TRVs to assess potential impacts to aquatic species. For some of the metals (such as lead and zinc) the ambient water quality criteria are based in part on water hardness values and for these calculations a hardness value of 160 mg/L $CaCO_3$ was used (as described in Section 5.6.3.3). This hardness value represents the low end of range of hardness values measured in the ditches at LCAAP and thereby provides a conservative estimate of the AWQCs. Lowest observed effect levels (LOELs) reported by EPA (1986) were used in cases where no AWQCs were available.

There is a large degree of uncertainty associated with all the TRVs derived in this assessment. However, they are used here as best estimates of the maximum concentrations/doses that are likely to result in no adverse effects in terrestrial and aquatic species. In many cases, toxicity values used in this assessment are derived from studies with laboratory species or species different from the receptor species believed to occur at the site. For example, in some cases TRVs for deer were derived using results from studies in rats although these species differ from one another in physiology and life habits. Another source of uncertainty is the uncertainty factors themselves. However, based on a review of the literature the values used in this assessment are similar to those proposed elsewhere (e.g., Newell et al. 1987, Dourson and Stara 1983, and Weill and McCollister 1963) and do not seem unreasonably conservative based on available toxicity information.

5.6.4.1 Toxicity To Terrestrial Plants

The toxicity reference values used in this assessment to estimate potential risks to plants are summarized in Table 5-53. Insufficient data were available to derive TRV for other chemicals of potential concern in soil in Area 15.

Arsenic. Arsenic is toxic to plants, and can inhibit mitosis, photosynthesis, and respiration, and interfere with nucleic acid and protein synthesis. Soil arsenic concentrations of 500 mg/kg have been reported to completely inhibit growth in six vegetable crops (NRC 1977). Arsenic concentrations in soil of 25 to 85 mg/kg resulted in significant decreases in crop yields (NRCC 1978 in Eisler 1988). Concentrations of arsenic in soil (dry weight) from 15 to 50 mg/kg (mean of five studies = 28 mg/kg) have been reported to be phytotoxic (Kabata-Pendias and Pendias 1984). The lowest value reported to cause injury in plants is 1.0 mg/kg (USEPA 1985a). In this analysis the value of 15 mg/kg is used as a TRV to assess potential risks to plants

Chromium. The chromium content of plants is controlled mainly by the amount of soluble chromium in the soils. Chromium (VI) is the most soluble and available to plants, but it is also the most unstable form under normal soil conditions. Usually chromium distribution in plants results in the highest concentrations in the roots, then the leaves and stems and the lowest concentrations in the grain (Kabata-Pendias and Pendias 1984). Typical symptoms of chromium phytotoxicity are wilting of plant tops, root injury, chlorosis in young leaves, brownish-red leaves and chlorotic bands on cereals (Kabata-Pendias and Pendias 1984). Kabata-Pendias and Pendias (1984) reported levels of 75 to 100 mg/kg (dry weight) as phytotoxic; the mean value of four studies was approximately 94 mg/kg. In this analysis a TRV of 75 mg/kg is

TABLE 5-53

TOXICITY REFERENCE VALUES (TRVs) FOR PLANTS FOR CHEMICALS OF POTENTIAL CONCERN IN SURFACE SOIL AT THE LAKE CITY ARMY AMMUNITIONS PLANT (a)

CHEMICAL	TRVs (mg/kg) (b)
Arsenic	15
Chromium	75
Lead	100

(a) TRVs were developed only for those parameters for which sufficient toxicity information was available.

(b) These TRVs are the lowest values presented in Kabata-Pendias and Pendias (1984).

used to assess potential adverse effects to plants from exposure to chromium in surface soils.

Lead. Lead inhibits plant growth, and reduces photosynthesis, mitosis, and water absorption (Eisler 1988). Inhibition of photosynthesis is attributed to the blocking of protein sulfhydryl groups and to changes in phosphate levels in the cell (Eisler 1988). Lead levels of approximately 500 mg/kg in soil reduced pollen germination by greater than 90 percent in two weed species (Eisler 1988). Normal germination rates were observed at soil lead levels of 46 mg/kg but other adverse effects were observed at lead levels of 12 to 312 mg/kg soil (Eisler 1988). Kabata-Pendias and Pendias (1984) reported phytotoxic concentrations from five studies of 100 to 400 mg/kg (mean = 180 mg/kg). A TRV of 100 mg/kg is used in this analysis.

5.6.4.2 Toxicity To Terrestrial Wildlife

The toxicity reference values used in this assessment to estimate potential impacts to terrestrial wildlife are summarized in Table 5-54.

Antimony. No information was found on the toxicity of antimony to terrestrial wildlife or domestic animals. Antimony was found to have a 36-hour LD_{50} of 115 mg/kg body weight (bw) in rabbits tested by Oelkers (1937). No chronic toxicity studies were available for wildlife. The chronic TRV for antimony used in this assessment for mammals is 0.06 mg/kg body weight, based on the available LD_{50} of 115 mg/kg for rabbits and a safety factor of 2,000.

Arsenic. Quantitative data on the toxicity of arsenic to terrestrial wildlife species are limited, but arsenic has been shown to induce death in wild rabbits and hares following acute oral exposures. Median lethal doses (LD_{50}) have been reported in the range of 10.5 to 40.4 mg/kg body weight (NRC 1977). Median lethal concentrations in the diets of wild birds have been reported in the range of 480 ppm (approximately 58 mg/kg-body weight) for the bobwhite quail to 5,000 ppm for mallards (Heath et al. 1972, Hill et al.

TABLE 5-54

TOXICITY REFERENCE VALUES (TRVs) FOR TERRESTRIAL ANIMALS FOR CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER AND SURFACE SOILS AT THE LAKE CITY ARMY AMMUNITIONS PLANT

Chemical/ Animal	TRV (mg/kg)
ORGANICS:	
1,1-Dichloroethane	
Deer	0.36 (b)(c)
Bobwhite Quail	-- (a)
Rabbit	0.36 (b)(c)
1,3,5-Trinitrobenzene	
Deer	0.225 (c)
Bobwhite Quail	-- (a)
Rabbit	0.225 (c)
Benzene	
Deer	1.5 (b)(c)
Bobwhite Quail	-- (a)
Rabbit	1.5 (b)(c)
Bis(2-ethylhexyl)phthalate	
Deer	0.19
Bobwhite Quail	-- (a)
Rabbit	0.19
Chloroethane	
Deer	-- (a)
Bobwhite Quail	-- (a)
Rabbit	-- (a)
Ethylbenzene	
Deer	1.36
Bobwhite Quail	-- (a)
Rabbit	1.36
HMX	
Deer	-- (a)
Bobwhite Quail	-- (a)
Rabbit	-- (a)
Methylene chloride	
Deer	0.6
Bobwhite Quail	-- (a)
Rabbit	0.6
Phenol	
Deer	0.15 (c)
Bobwhite Quail	-- (a)
Rabbit	0.15 (c)
Tetrachloroethene	
Deer	1.4
Bobwhite Quail	-- (a)
Rabbit	1.4
Toluene	
Deer	3
Bobwhite Quail	-- (a)
Rabbit	3
trans-1,2-Dichloroethene	
Deer	1.7
Bobwhite Quail	-- (a)
Rabbit	1.7
Trichloroethene	
Deer	3 (b)(c)
Bobwhite Quail	-- (a)
Rabbit	3 (b)(c)
INORGANICS:	
Antimony	
Deer	0.06 (c)
Bobwhite Quail	-- (a)
Rabbit	0.06 (c)
Arsenic	
Deer	0.005 (c)
Bobwhite Quail	0.029 (a)
Rabbit	0.005 (c)
Barium	
Robin	-- (a)
Beryllium	
Deer	1
Bobwhite Quail	-- (a)
Rabbit	10
Chromium	
Deer	0.3 (c)
Bobwhite Quail	12.5
Rabbit	0.3 (c)
Robin	12.5
Copper	
Deer	1
Bobwhite Quail	37.5
Rabbit	6
Lead	
Deer	0.45
Bobwhite Quail	3.75
Rabbit	0.9
Robin	0.375
Nickel	
Deer	0.75
Bobwhite Quail	37.5
Rabbit	1.5
Selenium	
Deer	-- (a)
Bobwhite Quail	-- (a)
Rabbit	-- (a)
Silver	
Deer	1.5
Bobwhite Quail	12.5
Rabbit	3
Zinc	
Deer	7.5
Bobwhite Quail	7.5
Rabbit	15

(a) No TRV derived because sufficient toxicity information was not available.
(b) Possible carcinogen; value is for noncarcinogenic effects only.
(c) TRV estimated from LD50 multiplied by 5X10-4 as proposed by Layton et al. 1987.

1975). Chronic poisonings in wild animals have not been clearly documented. In laboratory species, arsenic has been found to be carcinogenic, teratogenic, embryotoxic, and fetotoxic. No chronic toxicity studies were available for wildlife. The chronic TRV for arsenic used in this assessment for mammals is 0.005 mg/kg body weight, based on the lowest available LD_{50} of 10.5 mg/kg for arsenic and a safety factor of 2,000. The chronic TRV for arsenic used in this assessment for birds is 0.029 mg/kg body weight, based on the lowest available LD_{50} of 480 mg/kg and a safety factor of 2,000.

Benzene. No information is available on the toxicity of benzene to terrestrial wildlife or domestic animals (USEPA 1985). It is very slightly to slightly acutely toxic to mammals. The acute oral LD_{50} reported for a number of laboratory studies with rats ranged between 3,000 - 6,000 mg/kg (USEPA 1981). An LD_{50} for mice of 4,700 mg/kg also has been reported (RTECS 1980). Toxic effects in laboratory animals include central nervous system effects, hematological effects, and immune system depression. Benzene has induced tumor formation in rats. No information is available for birds.

The toxicity reference value used in this assessment for mammals is 1.5 mg/kg and is based on the lowest acute LD50 (3,000 mg/kg) and a safety factor of 2000. No toxicity reference value was established for birds.

Beryllium. No information on the toxicity of beryllium to terrestrial wildlife is available. No effect was observed in rats exposed to 1 mg/kg beryllium for 2 years (USEPA 1985). No effect was reported in dogs at a dose of 10 mg/kg for 19 months (USEPA 1985).

The NOEL of 10 mg/kg is used as the TRV for rabbits. In this analysis a toxicity reference value of 1 mg/kg is used for deer based on the 10 mg/kg NOEL and a safety factor of 10 (for interspecies sensitivity). No toxicity reference value for birds was established.

Bis(2-ethylhexyl)phthalate. Information on the toxicity of bis(2-ethylhexyl)phthalate to wildlife is unavailable. The LD_{50} for mice is 30,000 mg/kg (Sax 1984). Bis(2-ethylhexyl)phthalate has caused cancer in laboratory animals. Other toxic effects in laboratory animals include decreased growth, increased liver and kidney weights, reduced fetal weight, and increased number of fetal resorptions (USEPA 1980). The lowest chronic effect level in lab animals is 19 mg/kg based on increased liver weights in guinea pigs (Carpenter et al. 1953).

The TRV for mammals for bis(2-ethylhexyl)phthalate of 0.19 mg/kg is based on the chronic LOEL of 19 mg/kg in a study with guinea pigs and a safety factor of 100.

Chloroethane. Toxicity information is not available for chloroethane for terrestrial wildlife, so no TRV was derived. Refer to the toxicity summary for humans for more information.

Chromium. It appears that the primary source of uptake of chromium by small mammals is through ingestion of contaminated soil while grooming (Taylor 1980 in Eisler 1986). Short biologic half-life and fractional assimilation indicates a reduced toxic effect, especially under chronic exposures. Feeding studies done on cotton rats demonstrated low assimilation (0.8%) and rapid loss (99% in one day) of hexavalent chromium. The LD_{50} is 19.8 mg/kg chromium (VI) and 600-2,600 mg/kg for chromium III (USEPA 1987). Hexavalent chromium was fatal to dogs in three months when fed 100 ppm in their diet, but was not lethal at 11.2 ppm over four years when administered in their water (Steven et al. 1976 in Eisler 1986). They also found the toxic threshold in rats to be 1,000 ppm chromium (VI) in the diet and 100% survival when exposed to 134 ppm in their drinking water for three months.

Data on hexavalent chromium effects on birds are few. Male domestic chickens fed a diet containing up to 100 ppm hexavalent chromium for 32 days showed no adverse effects in survival, growth, or food utilization efficiency (Rosomer et al. 1961 in Eisler 1986).

The chronic TRV for mammals is 0.3 mg/kg based on the lowest LD_{50} for rats for chromium III and a safety factor of 2,000.

The TRV used for robins is 12.5 mg/kg. This is based on the maximum tolerable dose for poultry of 125 mg/kg and a safety factor of 10 for interspecies extrapolation.

Copper. Data are available on the toxicity of copper in wild birds. Canada geese (Branta canadensis) ingesting pond water containing 100 ppm copper as copper sulfate developed acute copper toxicosis (NAS 1980). Copper toxicity is associated with hemolytic crisis, hepatic necrosis, and death. Maximum tolerable dietary levels for turkey and chickens are 300 ppm (NAS 1980).

Data on copper toxicity in wild mammalian species was not available in the literature. However, an acute oral LD_{50} of 60 mg copper/kg-body weight has been reported for horses (NAS 1980). The LD_{50} for $CuSO_4$ in rats is approximately 300 mg/kg bw, or 120 mg copper/kg bw (NAS 1980). Copper tolerance in mammals varies widely partly due to differences in sulfur metabolism and in dietary levels of other trace elements such as iron, molybdenum, selenium, sulfur, and zinc (NAS 1980). NAS(1980) suggested the following maximum tolerable levels for dietary copper: 25 ppm for sheep, 100 ppm for cattle, rabbits 200 ppm, 250 ppm for swine, and 800 ppm for horses.

The toxicity reference dose for quail of 37.5 mg/kg was derived using the maximum tolerable level for chickens of 300 ppm and a dietary conversion factor of 0.125 mg/kg per ppm in feed from Lehman (1954). For rabbits the 200 ppm maximum tolerable value was used with a dietary conversion factor of 0.030 mg/kg per ppm (Lehman 1954) to derive the reference dose of 6 mg/kg. For deer the TRV is based on the maximum tolerable dose for sheep of 1 mg/kg (derived from a maximum tolerable dietary level of 25 ppm and a dietary conversion factor for sheep of 0.040 mg/kg-body weight per ppm in feed, Lehman 1954).

Dichloroethanes. Limited information is available on the toxicity of dichloroethanes to wildlife. Based on an oral LD_{50} for rats of 725 mg/kg (RTECS 1980) 1,1-dichloroethane can be classified as slightly toxic in mammals.

The TRV for mammals for 1,1-dichloroethane of 0.36 mg/kg was derived from the rat oral LD50 of 725 mg/kg and a safety factor of 2,000. No TRV was derived for birds.

Dichloroethenes. No information on the toxicity of dichloroethenes to wildlife is available. Dichloroethenes are moderately to slightly toxic to mammals. Laboratory rat oral LD_{50}s for 1,1-dichloroethene, 1,2-dichloroethene (total), and trans-1,2-dichloroethene are 200, 770, and 1,300 mg/kg-body weight, respectively (RTECS 1980, USEPA 1981). A NOEL of 17 mg/kg/day has been reported for mice for 1,2-dichloroethene (total).

The mammalian TRV of 1.7 mg/kg is based on the chronic NOEL for mice of 17 mg/kg and a safety factor of 10 for interspecies extrapolation.

HMX. Toxicity information is not available for HMX for terrestrial wildlife, so no TRVs were derived. Refer to the toxicity summary for humans for more information.

Ethylbenzene. No information on the toxicity of ethylbenzene to terrestrial wildlife was available (USEPA 1985). Laboratory studies have found an oral LD_{50} of 3,000 mg/kg in the rat. Test animals subjected to both acute and chronic exposures developed liver and kidney pathologies and nervous system disorders. No toxic effects were seen during a 6-month oral exposure of 13.6 and 136 mg ethylbenzene/kg of body weight/day to rats (USEPA 1985). No information is available for birds.

The NOEL was used as the TRV for rabbits. The NOEL of 13.6 was divided by 10 to establish a toxicity reference value for deer for this assessment of 1.36 mg/kg. No TRV was established for birds.

Lead. The majority of information on lead toxicity in birds is on body burdens in waterfowl that have ingested spent lead shot and died. However, limited dose-response information is available for a few species. Neurological effects were observed within 24 hours of dosing in mallard ducks (*Anas platyrhynchos*) that had ingested and absorbed lead shot for a total intake of 423.8 mg/kg body weight (Mautino and Bell 1987). These effects decreased 8 days after dosing. Inhibition of delta-ALAD was apparent 1 week after dosing. Assuming a mallard weighs approximately 1.2 kg (calculated from Terres 1980) and consumes an amount of food equivalent to 10% of its body weight each day, the dosage of 423.8 mg/kg body weight is equivalent to an approximate lead concentration in the food of 4,600 mg/kg. Stone and Soares (1974 in NAS 1980) found that 1,000 ppm dietary lead reduced egg production and caused soft-shelled eggs. Morgan et al. (1975 in NAS 1980) found 500 ppm of dietary lead acetate inhibited growth and produced anaemia.

In American kestrels (*Falco sparverius*) fed 10 or 50 mg/kg lead in the diet for 7 months, no effects were noted with respect to survival, egg laying, initiation of incubation, or egg shell thickness (Pattee 1984). In 1-day-old American kestrels fed 125 or 625 mg/kg body weight lead for 10 days, growth in kestrals fed either dose was seriously depressed by day 6, and hematocrit values were significantly depressed by day 10 (Hoffman et al. 1985). Forty percent of the birds receiving 625 mg/kg lead died within 6 days. No effects were observed in kestrels exposed to a lower dose of 25 mg/kg body weight. Assuming complete absorption of the administered dose, and that a kestrel weighs 0.11 kg (calculated from Terres 1980) and consumes an amount of food equivalent to 10% of its body weight, the 25 mg/kg body weight dosage corresponds to an approximate lead concentration in food of 280 mg/kg. Therefore, the 50 mg/kg level identified in the Pattee (1984) study is the highest NOEL identified for birds based on the studies reviewed.

The acute oral LD_{50} in mice is 5 mg/kg for triethyllead, 10 mg/kg for tetraethyllead, 17 mg/kg for trimethyllead, and 70-100 mg/kg for tetramethyllead (Eisler 1988). No adverse effects have been observed in sheep, cattle, or chickens from chronic exposure to 10 ppm dietary lead (NAS 1980). NAS (1980) has set the maximum tolerable dose for domestic animals at 30 ppm.

The toxicity reference values of 3.75 mg/kg/day for quail and 0.9 mg/kg/day for rabbits were determined using the maximum tolerable doses in NAS (1980) for poultry and rabbits, respectively. Dietary conversion factors of 0.125 mg/kg per ppm for chickens and 0.03 mg/kg per ppm for rabbits were used to convert concentrations in feed to doses per unit body weight (Lehman 1954). The TRV for deer was based on the maximum tolerable dose for cattle of 0.45 mg/kg (derived from a maximum tolerable dietary level of 30 ppm and a conversion factor for cattle of 0.015 mg/kg-body weight per ppm in food, Lehman 1954). The TRV for robins of 0.375 mg/kg is based on the maximum tolerable dose for poultry and a safety factor of 10.

Methylene Chloride. No information is available on the toxicity of methylene chloride to terrestrial wildlife. Methylene chloride is slightly toxic to mammals. Oral LD_{50}s are 2,136 mg/kg for rats (USEPA 1985) and 1,987 mg/kg for mice (USEPA 1985). The lowest lethal dose for rabbits is 1,900 mg/kg (RTECS 1980). No toxicity information is available for birds.

The TRV for mammals was based on a chronic NOEL for rats of 5.85 mg/kg/day and a safety factor of 10 for interspecies extrapolation. No TRV was derived for birds.

Nickel. No adverse effects were observed in Japanese quail (Coturnix) at up to 5,000 ppm nickel for 5 days (Hill and Camardese 1986). Chickens showed no adverse effects at 300 ppm nickel after 4 weeks. At 500 ppm decreased growth was observed (Weber and Reid 1968 in NAS 1980). In a feeding study with mallard ducklings fed 0, 200, 800, or 1,200 mg/kg dietary nickel from day 1 to day 90 of age, neurological effects were observed in the highest dose group within 14 days of dosing (Cain and Pafford 1981). The weights of the ducks in the highest dose group were significantly decreased at 28 days of age, and the weight/length ratio of females in the 800 mg/kg group were significantly different from controls at days 30 and 60. A NOEL of 200 mg/kg can be identified for this study. No information was available on nickel toxicity in raptor species or in other species at a concentration lower than the NOEL for ducks.

Mammals have shown a low to moderate toxicity to nickel. They appear to have a mechanism which limits absorption of the element in the intestine (Gough et al. 1979). The oral LD_{50} for nickel is 136 mg/kg in mice and 116 mg/kg in rats (NAS 1980). Death and runting occurred in first and third generation rats given 5 ppm nickel in drinking water during weaning. No adverse effects were reported in cattle fed 50 ppm (approximately 0.75 mg/kg-body weight) nickel for up to 6 weeks (Odell et al. 1970c: 1971 in NAS 1980) and this is the maximum tolerable level for cattle recommended by NAS (1980). At higher levels (100 ppm) decreased food intake was observed in young cattle, and decreased growth rate occurred at 1,000 ppm (NAS 1980).

A toxicity reference value for quail was determined using the 300 ppm NOEL in the study with chickens and a dietary conversion factor of 0.125 mg/kg/day (from Lehman 1954). The TRV for rabbits of 1.5 mg/kg was based on the maximum tolerable dietary level for rabbits (50 ppm) in NAS (1980) and a dietary conversion factor of 0.03 mg/kg-body weight per ppm in food (Lehman 1954). The toxicity reference value for deer of 0.75 mg/kg was derived from the maximum tolerable level in cattle of 50 ppm (converted to mg/kg using a factor of 0.015 from Lehman 1954).

<u>Phenol</u>. Toxicity information for terrestrial wildlife and domestic animals is limited. Acute oral LD_{50}s are 414 mg/kg for rat and 300 mg/kg for mouse (RTECS 1980). No chronic toxicity studies were available for wildlife. The chronic TRV for phenol used in this assessment for mammals is 0.15 mg/kg

body weight, based on the lowest available LD_{50} (300 mg/kg) and a safety factor of 2,000.

Silver. Information on the toxicity of silver to wildlife is not available, however poultry and rats have been relatively well studied. Silver is not known to have any biological functions in animals (NAS 1980). Silver causes multiple deficiencies of vitamin E, selenium, and copper, and the symptoms associated with these deficiencies are manifested (NAS 1980). Toxic effects in rats include decreased weight gain, liver necrosis, and increased mortality (NAS 1980). The maximum tolerable level of silver in the diet for swine is 100 ppm (NAS 1980).

Turkeys showed decreased weight gain at 300 ppm (Jensen et al. 1974 in NAS 1980). In the same study at 900 ppm toxic symptoms included enlarged heart, dystrophic gizzard musculature, and severely depressed weight gain. In another study with turkeys no adverse effects were observed at 100 ppm (Bunyan et al. 1968 in NAS 1980). Chickens also showed no adverse effects at diets up to 100 ppm silver, but at 200 ppm increased mortality was observed (Hill et al. 1964 in NAS 1980). NAS (1980) has recommended a maximum tolerable level of dietary silver for poultry of 100 ppm.

The toxicity reference value for quail is based on the maximum tolerable level of 100 ppm and the dietary conversion factor in Lehman (1954) (0.125 mg/kg/day per ppm for chickens). The TRVs for deer and rabbit were derived using the 100 ppm level in NAS (1980) and dietary conversion factors of 0.015 (based on cattle) and 0.030, respectively (from Lehman 1954).

Tetrachloroethene. No information on the toxicity of tetrachloroethene to terrestrial wildlife was available in the literature. Tetrachloroethene is very slightly toxic to mammals. Acute oral LD_{50}s are 8,850 and 8,100 mg/kg for rats and mice, respectively (RTECS 1980). No information is available for birds.

The TRV for mammals for tetrachloroethene is 1.4 mg/kg. This is based on the chronic NOEL for mice (14 mg/kg) and a safety factor of 10 for interspecies extrapolation. No TRV was derived for birds.

Toluene. Little information is available on the toxicity of toluene to terrestrial species. Rabbits given a single oral dose of 275 mg/kg body weight, excreted 74% of the total dose within 24 hours, indicating a short biologic half-life (El Masry et al. 1956 in USEPA 1981). Oral LD_{50}s for rats range from 4,300 to 7,500 mg/kg (USEPA 1981). A NOEL of 30 mg/kg/day has been reported for a study with rats. Information on avian toxicity is not available.

A toxicity reference value for deer and rabbits of 3.0 mg/kg was established for this analysis using the NOEL for rats and a safety factor of 10. No TRV was established in this assessment for birds.

Selenium. Toxicity information is not available for selenium for terrestrial wildlife, so no TRVs were derived. Refer to the toxicity summary for humans for more information.

Trichloroethene. No information is available on the toxicity of trichloroethene to terrestrial wildlife. Trichloroethene is very slightly toxic to mammals based on available LD_{50}s. Acute LD_{50}s in several mammalian laboratory species range from 6,000 to 7,000 mg/kg (USEPA 1985). No information is available for birds.

The TRV for mammals is 3 mg/kg. This value is based on the acute oral LD_{50} of 6,000 mg/kg and a safety factor of 2000. No TRV was derived for birds.

1,3,5-TNB. Toxicity information for terrestrial wildlife species is not available. Oral LD_{50}s for laboratory rodents are 450 mg/kg for rats, 572 mg/kg for mice, and 730 mg/kg for guinea pigs (EPA 1987). Chronic toxicity information is not available.

The mammalian TRV for 1,3,5-TNB of 0.225 mg/kg was derived from the rat oral LD50 of 450 mg/kg and a safety factor of 2,000. No TRV was derived for birds because of insufficient toxicity information.

Zinc. The most sensitive aquatic vertebrate species tested in acute assays is the rainbow trout with a 96-hour LC_{50} of 90 ug/liter (Garton 1972); however, a 7-day EC_{50} of 30 ug/liter based on growth inhibition was reported for the green algae (Selenastrum capricornutum) (Bartlett et al. 1974 in USEPA 1987). In chronic studies the lowest maximum acceptable toxicant concentration (MATC) reported for an invertebrate was 47 ug/liter for Daphnia magna (USEPA 1986). The flagfish (Jordanella floridae) had an MATC of 36.4 ug/l and was the most sensitive of seven fish species tested (USEPA 1986). Zinc has shown bioconcentration factors of 51 to 1,130 in freshwater animals (USEPA 1986). A whole body bioconcentration factor of 432 was reported for the flagfish following 100 days of exposure (Spehar 1978).

NAS (1980) reported results for a number of studies conducted with chickens, turkeys, ducks, and Japanese quail. In general these studies indicate that decreased weight gain is first observed at zinc dietary concentrations of 270 ppm in Japanese quail, at 800 ppm in chickens, and at 4,000 ppm in turkeys. NAS recommended a maximum tolerable level of 1,000 ppm for poultry. Decreased hemoglobin and hematocrit were observed in young Japanese quail at doses as low as 125 ppm after 2 weeks of treatment (NAS 1980). No significant adverse effects were observed in the quail at 62.5 ppm. Severe effects were observed in ducks after 60 days at the lowest concentration tested of 3,000 ppm, including decreased body weight, paralysis of the legs, low hemoglobin and hematocrit levels, and decreased pancreas and gonad weights (NAS 1980).

Zinc poisoning has been reported in cattle. In one outbreak, poisoning was caused by food accidentally contaminated with zinc at a concentration of 20 g/kg. An estimated intake of 140 g of zinc per cow per day for about 2 days was reported. The exposed cows exhibited severe enteritis, and some died or had to be slaughtered. Postmortem findings showed severe pulmonary emphysema with changes in the myocardium, kidneys, and liver. In pigs given dietary zinc at concentrations greater than 1,000 mg/kg, decreased food intake and weight gain were observed. At dietary levels greater than 2,000 mg/kg, deaths occurred as soon a 2 weeks after exposure. Severe gastrointestinal changes and brain damage, both of which were accompanied by hemorrhages, were observed, as well as changes in the joints. NAS (1980) recommends the following maximum tolerable dietary levels of zinc: 300 ppm for sheep, 500 ppm for cattle, 500 ppm for rabbits, and 1,000 ppm for swine.

The quail toxicity reference value of 7.5 mg/kg/day was derived using the Japanese quail NOEL of 62.5 ppm. A dietary conversion factor of 0.12 mg/kg per ppm feed was determined assuming a body weight for Japanese quail of 100 grams (Welty 1975) and a food consumption rate of 12 grams per day (Hill and Camardese 1986). The maximum tolerable level for rabbits of 500 ppm (NAS 1980) was used with the conversion factor of 0.030 (from Lehman 1954) to derive a rabbit toxicity reference value of 15 mg/kg/day. For deer the maximum tolerable level for cattle (500 ppm) was used with the conversion factor of 0.015 mg/kg body weight per ppm in food (Lehman 1954) to derive a TRV of 7.5 mg/kg.

5.6.4.3 Toxicity To Aquatic Organisms

The toxicity reference values used in this analysis to assess potential impacts to aquatic organisms are given in Table 5-55.

Antimony. No ambient water quality criteria have been established for antimony. Available data indicate that acute and chronic toxicity to freshwater aquatic life at concentration as low as 9,000 and 1,600 ug/l respectively, and would occur at lower concentrations to more sensitive species (USEPA 1986).

Arsenic. Arsenic is toxic to aquatic animal species, and induces its toxic effects via enzyme inhibition. In aquatic species, arsenic has induced

TABLE 5-55

AMBIENT WATER QUALITY CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN AT THE LAKE CITY ARMY AMMUNITIONS PLANT

CHEMICAL	CHRONIC AWQC (ug/l) (a)
Benzene	730 (b)
Bis(2-ethylhexyl)phthalate	3 (c)
Trichloroethylene	21900 (d)
Antimony	1600 (d)
Arsenic (+5)	48 (d)
Beryllium	5.3 (d)
Copper	18 (e)
Lead	5.8 (e)
Nickel	235 (e)
Selenium	5
Silver	0.12
Zinc	158 (e)

(a) Values are from EPA 1986, unless otherwise indicated.

(b) No AWQC available, value is an estimated chronic LOEL based on freshwater acute LOEL (lowest LC 50) of 5,300 ug/l and saltwater acute:chronic ratio of 7.3.

(c) No AWQC available, value is chronic LOEL (EPA 1985).

(d) Insufficient data to develop criteria, value is chronic LOEL.

(e) Hardness dependent criteria, 160 mg/l $CaCO_3$ is used.

death following acute exposures and has caused death and deformity following chronic exposures. EPA (1986) has established, for aquatic species, a continuous concentration criterion of 190 ug/l and a 1-hour average concentration criterion of 360 ug/l for trivalent arsenic. The chronic LOEL for pentavalent arsenic is 48 ug/L (USEPA 1986).

Bioconcentration factors (BCF) of between 3 and 17 have been reported for the snails Stagnicola emarginata and Helisoma campanulatum, respectively (USEPA 1985b). EPA (1985b) found no accumulation of arsenic in trout (whole body). A BCF of 4 and a biologic half-life of one day was derived for bluegills (USEPA 1978). Oladimeji et al. (1982 in USEPA 1985b) found that preexposure of rainbow trout to arsenic (III) enhanced the elimination of subsequent dosing. These studies suggest that some elimination pathway is induced in freshwater fish through exposure to low (non-lethal) doses of arsenic (III).

Benzene. Data are not considered sufficient to develop ambient water quality criteria for benzene (USEPA 1986). The acute LOEL is 5,300 ug/l for juvenile trout (the most sensitive species tested). USEPA's ambient water quality criteria document (USEPA 1980) lists LC_{50} data for six freshwater fish species. The LC_{50}'s range from 5,300 ug/l for rainbow trout (flow-through test) to 386,000 ug/l for mosquito fish (Gambusia affinis) (static exposure, nominal concentration). The difference in LC_{50}s may be attributed to the variability of test procedures (flow-through vs. static) in addition to any interspecific variability. No data are available on chronic effects to freshwater aquatic life (USEPA 1980). A BCF of 4.4 was found in a 48-hour static exposure of Pacific herring to benzene (Korn et al. 1977).

Beryllium. Insufficient data are available to develop ambient water quality criteria for beryllium (USEPA 1986). The LOELs for acute and chronic toxic effects in freshwater organisms are 130 and 5.3 ug/L, respectively. Acute toxicities have been found to range from 130 to 20,000 ug/L apparently variable according to water hardness (USEPA 1980). A BCF of 19 has been reported for freshwater fish (USEPA 1986).

Bis(2-ethylhexyl)phthalate. No ambient water quality criteria are available. EPA (1986) report acute and chronic LOELs for phthalate esters for aquatic organisms of 940 and 3 ug/l, respectively. *Daphnia magna* exposed to bis(2-ethylhexyl)phthalate had an LC_{50} of 11,000 ug/L. Chronic toxicity was observed at 8.4 ug/L in rainbow trout (USEPA 1985). *Daphnia magna* had significant adverse reproductive effects at 3 ug/L (USEPA 1985).

Bioconcentration factors for fish and aquatic invertebrates range from 54 to 2,680 (USEPA, 1980). Bis(2-ethylhexyl)phthalate has a log Kow of 5.11, indicating a high potential for bioaccumulation as is demonstrated by a BCF in scud (*Gammarus pseudolimnaeus*) of 13,600 after 7 days of exposure to 0.1 ug/L. While this is high, it is somewhat offset by a biologic half-life of about 4 weeks (Mayer and Sanders 1973). A BCF of 800 was found by Mayer (1976) in fathead minnows exposed to 2.5 ug/L bis(2-ethylhexyl)phthalate for 28 days. The weighted average bioconcentration factor for the edible portions of all freshwater and estuarine species consumed in the U.S. was 130 (USEPA 1985).

Copper. The primary mechanism of copper toxicity in aquatic organisms is osmoregulatory disruption and failure (Rand and Petrocelli 1985). Copper toxicity decreases with increasing water hardness. Data suggest that acclimation increases tolerance to copper. Continued ingestion of copper in excess of nutritional requirements leads to accumulation, especially in the liver (Rand and Petrocelli 1985). USEPA (1986) recommended that the 4-day average concentration of copper (in ug/liter) should not exceed the value given by $e^{(0.8545[\ln(\text{hardness})]-1.465)}$, and the 1-hour average concentration should not exceed the value given by $e^{(0.942[\ln(\text{hardness})]-1.464)}$. The values corresponding to the 4-day and 1-hour average concentrations at a water hardness of 50 mg/liter $CaCO_3$ are 6.5 and 9.2 ug/liter respectively. In acute assays, the most sensitive species is *Daphnia magna* with an EC_{50} of 6.5 ug/liter (Chapman et al. manuscript as cited in USEPA 1985). However, an EC_{50} of 1 ug/liter based on growth reduction is reported for the green alga *Chlorella sp*. (Steeman-Nielsen and Wium-Anderson 1970). The lowest maximum acceptable toxicant concentration was 3.873 ug/liter for the brook trout (*Salvelinus* fontinalis) (Sauter et al. 1976 as cited in USEPA 1985). Copper has a low potential for bioaccumulation in freshwater organisms (USEPA 1986). A muscle bioconcentration factor of 1.0 was reported for bluegill (Lepomis macrochirus) exposed for 660 days (Benoit 1975). A bioconcentration factor of 290 was reported for fathead minnows (Lind et al. as cited in USEPA 1980).

Lead. In acute assays, invertebrate species are more sensitive than vertebrate species. The 48-hour EC_{50} of 124 ug/l is reported for the scud at a water hardness of 46 mg/l $CaCO_3$ (Spehar 1978). The lowest maximum acceptable toxicant concentration from chronic studies is 19 mg/l for rainbow trout (Salmo gairdneri) at a water hardness of 128 mg/l $CaCO_3$ (Davies et al. 1976). Lead toxicity decreases with increasing water hardness. USEPA (1986) has established 4-day and 1-hour average concentration criteria for lead not to be exceeded by the values given by $e^{(1.273[\ln(\text{hardness})]-4.705)}$ and $e^{(1.273[\ln(\text{hardness})]-1.460)}$, respectively, more than once every three years. Using an average water hardness of 50 mg/liter, the 4-day and 1-hour criteria correspond to 1.3 and 34 ug/liter, respectively. A whole-body bioconcentration factor of 45 was reported for bluegills (Atchison et al. 1977 in USEPA 1985).

Nickel. The adverse effects of nickel in aquatic organisms include alteration of cell membranes, formation of precipitates on gills, hematological effects and reproductive impairment. Toxicity of nickel to freshwater organisms decreases with increasing water hardness. USEPA (1986) has proposed 4-day and 1-hour concentration criteria not to exceed the value given by $e^{(0.8460[\ln(\text{hardness})]+1.1645)}$ and $e^{(0.8460[\ln(\text{hardness})]+3.3612)}$, respectively. At a water hardness of 50 mg/l $CaCO_3$, the corresponding values are 88 and 790 ug/liter, respectively. Calamari et al (1982) found a BCF of 1.1 for fish.

Selenium. The acute and chronic water quality criteria established for the protection of freshwater organisms by the EPA are 20 ug/L and 5 ug/L, respectively (USEPA 1987).

Silver. Silver is one of the most toxic metals to aquatic organisms, and was particularly toxic to development stages of rainbow trout (Birge et al. 1981). Water hardness has an antagonistic effect on acute toxicity of silver. EPA (1986) has established a criterion for silver not to exceed the value given by $e^{(1.72[\ln(\text{hardness})]-6.52)}$ at any time. At a water hardness of 50 mg as $CaCO_3$, the acute criterion is 1.2 ug/liter. Data indicate that chronic toxicity to freshwater aquatic life may occur at silver concentrations as low as 0.12 ug/liter. Although no measured bioconcentration factors (BCF) were available for silver, Chapman et al. (1968) estimated a BCF of 3,080 for edible portions of freshwater fish.

Trichloroethene. Insufficient data are available to establish an ambient water quality criteria (USEPA 1986). Trichloroethene has shown acute toxicity to freshwater aquatic life at a concentration as low as 45,000 ug/l and acute toxicity could occur at lower concentrations with more sensitive species (USEPA 1986). The chronic LOEL is 21,900 ug/l (USEPA 1986).

Zinc. Zinc is an essential trace element for aquatic organisms, and is important to cell growth and differentiation. Exposure to sublethal concentrations of zinc causes extensive edema and necrosis of liver tissue. Death results from gill necrosis and hypoxia. Zinc toxicity decreases as water hardness increases (USEPA 1986). USEPA (1986) has proposed that the one-hour concentration should not exceed the value given by $e^{(0.8473[\ln(\text{hardness})]+0.8604)}$ and the 4-day average should not exceed the value given by $e^{(0.8473[\ln(\text{hardness})]+0.7614)}$. At a water hardness of 50 mg/liter, the 1-hour and 4-day criteria are 65 and 59 ug/liter, respectively. The EC_{50} for the cladoceran *Daphnia magna* is 655 ug/l at a hardness of 196 mg/l $CaCO_3$ (USEPA 1987). *Daphnia magna* have shown chronic effects at 42 to 52 ug/l zinc at water hardness values of 104 to 211 mg/l $CaCO_3$ (USEPA 1987). The LC_{50} for fathead minnow (*Pimephales promelas*) fry is 870 ug/l at a water hardness of 174 to 198 mg/l $CaCO_3$ (USEPA 1987). Juvenile longfin dace (*Agosia chrysogaster*) are also acutely sensitive to zinc, the LC_{50} is 790 ug/l at a hardness of 217 mg/l $CaCO_3$ (USEPA 1987). Rainbow trout (*Salmo gairdneri*) exhibited avoidance behavior at a hardness at a zinc concentration of 47 ug/l (hardness = 112 mg/l $CaCO_3$) (USEPA 1987).

5.6.5 Risk Assessment

Potential risks to plants, terrestrial wildlife, and aquatic life at LCAAP are estimated by comparing the estimated exposure levels calculated according to the methods presented in Section 5.6.3 with the TRVs presented in Section 5.6.4. The results of these comparisons are discussed below.

5.6.5.1 Plants

Potential adverse effects to plants were assessed by comparing the concentrations of the chemicals of concern in surface soils in Area 13 with the available TRVs for plants (see Table 5-56). The maximum concentration of lead was less than the lead TRV for plants. Thus adverse effects to plants are not expected to occur in this area from exposure to lead. The maximum concentration of arsenic (30.8 mg/kg) is approximately 2 times greater than the TRV (15 mg/kg) and the maximum concentration of chromium (115 mg/kg) is greater than the chromium TRV. Thus, based on this comparison, adverse effects to some species of plants could occur from exposure to arsenic and chromium in the surface soils of this area. However, this area is currently vegetated with grass and it does not appear that the plants that are present are experiencing adverse effects.

5.6.5.2 Terrestrial Wildlife

Ingestion of Surface Water. Risks to wildlife were estimated based on consumption of surface waters from selected areas of LCAAP (described in Section 5.6.3.2). The estimated doses are compared to the TRVs as shown in Table 5-57. All of the estimated doses were well below the available TRVs for the indicator species evaluated with the exception of doses of phenol from the Area 16 seep by rabbit. The dose of phenol to rabbits exceeded the TRV by a

TABLE 5-56

CHEMICAL CONCENTRATIONS (mg/kg, dry weight) IN SURFACE SOIL IN AREA 13 OF LAKE CITY ARMY AMMUNITIONS PLANT COMPARED TO PLANT TOXICITY REFERENCE VALUES (mg/kg)

CHEMICAL	MAXIMUM	TRV's (a)	MAXIMUM: TRV RATIO
Arsenic	30.8	15	>1 (2.05)
Chromium	115	75	>1 (1.53)
Lead	20.3	100	<1 (0.20)

(a) These TRV's are the lowest concentrations in soil reported to have toxic effects on plants in Kabata-Pendias and Pendia (1984). Insufficient data were available to derive plant TRVs for other chemicals of concern.

TABLE 5-57

RISK TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS: COMPARISON OF ESTIMATE DOSE TO TOXICITY REFERENCE VALUE DOSES

Chemical/ Animal	Mean Estimated Dose (mg/kg)	TRV (mg/kg)	Dose:TRV Ratio
Area 13 Drainage Ditch:			
1,3,5-Trinitrobenzene			
Deer	1.32E-06	0.225 (d)	<1 (5.9E-06)
Bobwhite Quail	3.53E-04	-- (b)	--
Rabbit	1.50E-04	0.225 (d)	<1 (6.7E-04)
Bis(2-ethylhexyl)phthalate			
Deer	1.32E-04	0.19	<1 (7.0E-04)
Bobwhite Quail	3.53E-02	-- (b)	--
Rabbit	1.50E-02	0.19	<1 (7.9E-02)
Antimony			
Deer	3.42E-05	0.06 (d)	<1 (5.7E-04)
Bobwhite Quail	9.12E-03	-- (b)	--
Rabbit	3.87E-03	0.06 (d)	<1 (6.5E-02)
Chromium			
Deer	8.49E-05	0.3	<1 (2.8E-04)
Bobwhite Quail	2.26E-02	12.5	<1 (1.8E-03)
Rabbit	9.62E-03	0.3	<1 (3.2E-02)
Copper			
Deer	3.97E-04	1	<1 (4.0E-04)
Bobwhite Quail	1.06E-01	37.5	<1 (2.8E-03)
Rabbit	4.50E-02	6	<1 (7.5E-03)
Lead			
Deer	3.02E-05	0.45	<1 (6.7E-05)
Bobwhite Quail	8.06E-03	3.75	<1 (2.1E-03)
Rabbit	3.42E-03	0.9	<1 (3.8E-03)
Robin	8.06E-03	0.375	<1 (2.1E-02)
Nickel			
Deer	4.83E-05	0.75	<1 (6.4E-05)
Bobwhite Quail	1.29E-02	37.5	<1 (3.4E-04)
Rabbit	5.47E-03	1.5	<1 (3.7E-03)
Area 16 Leachate Seep (a):			
1,1-Dichloroethane			
Deer	6.62E-05	0.36 (c)(d)	<1 (1.8E-04)
Bobwhite Quail	1.76E-02	-- (b)	--
Rabbit	7.50E-03	0.36 (c)(d)	<1 (2.1E-02)
Benzene			
Deer	5.43E-06	1.5 (c)(d)	<1 (3.6E-06)
Bobwhite Quail	1.45E-03	-- (b)	--
Rabbit	6.15E-04	1.5 (c)(d)	<1 (4.1E-04)
Chloroethane			
Deer	8.82E-05	-- (b)	--
Bobwhite Quail	2.35E-02	-- (b)	--
Rabbit	1.00E-02	-- (b)	--
Ethylbenzene			
Deer	2.21E-05	1.36	<1 (1.6E-05)
Bobwhite Quail	5.88E-03	-- (b)	--
Rabbit	2.50E-03	1.36	<1 (1.8E-03)

TABLE 5-57

RISK TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS: COMPARISON OF ESTIMATE DOSE TO TOXICITY REFERENCE VALUE DOSES

Chemical/ Animal	Mean Estimated Dose (mg/kg)	TRV (mg/kg)	Dose:TRV Ratio
Methylene chloride			
Deer	8.82E-05	0.6	<1 (1.5E-04)
Bobwhite Quail	2.35E-02	-- (b)	--
Rabbit	1.00E-02	0.6	<1 (1.7E-02)
Phenol			
Deer	4.41E-03	0.15 (d)	<1 (2.9E-02)
Bobwhite Quail	1.18E+00	-- (b)	--
Rabbit	5.00E-01	0.15 (d)	<1 (3.3E+00)
Tetrachloroethene			
Deer	4.41E-06	1.4	<1 (3.2E-06)
Bobwhite Quail	1.18E-03	-- (b)	--
Rabbit	5.00E-04	1.4	<1 (3.6E-04)
Toluene			
Deer	2.65E-04	3	<1 (8.8E-05)
Bobwhite Quail	7.06E-02	-- (b)	--
Rabbit	3.00E-02	3	<1 (1.0E-02)
trans-1,2-Dichloroethene			
Deer	3.71E-05	1.7	<1 (2.2E-05)
Bobwhite Quail	9.88E-03	-- (b)	--
Rabbit	4.20E-03	1.7	<1 (2.5E-03)
Trichloroethene			
Deer	2.85E-05	3 (c)(d)	<1 (9.5E-06)
Bobwhite Quail	7.59E-03	-- (b)	--
Rabbit	3.23E-03	3 (c)(d)	<1 (1.1E-03)
Beryllium			
Deer	4.87E-06	1	<1 (4.9E-06)
Bobwhite Quail	1.30E-03	-- (b)	--
Rabbit	5.53E-04	10	<1 (5.5E-05)
Copper			
Deer	1.10E-03	1	<1 (1.1E-03)
Bobwhite Quail	2.94E-01	37.5	<1 (7.8E-03)
Rabbit	1.25E-01	6	<1 (2.1E-02)
Lead			
Deer	3.09E-04	0.45	<1 (6.9E-04)
Bobwhite Quail	8.24E-02	3.75	<1 (2.2E-02)
Rabbit	3.50E-02	0.9	<1 (3.9E-02)
Robin	8.24E-02	0.375	<1 (2.2E-01)
Nickel			
Deer	3.31E-04	0.75	<1 (4.4E-04)
Bobwhite Quail	8.82E-02	37.5	<1 (2.4E-03)
Rabbit	3.75E-02	1.5	<1 (2.5E-02)
Silver			
Deer	1.17E-06	1.5	<1 (7.8E-07)
Bobwhite Quail	3.12E-04	12.5	<1 (2.5E-05)
Rabbit	1.32E-04	3	<1 (4.4E-05)
Zinc			
Deer	5.29E-03	7.5	<1 (7.1E-04)
Bobwhite Quail	1.41E+00	7.5	<1 (1.9E-01)
Rabbit	6.00E-01	15	<1 (4.0E-02)

TABLE 5-57

RISK TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS: COMPARISON OF ESTIMATE DOSE TO TOXICITY REFERENCE VALUE DOSES

Chemical/ Animal	Mean Estimated Dose (mg/kg)	TRV (mg/kg)	Dose:TRV Ratio
Area 16 Drainage Ditch:			
Bis(2-ethylhexyl)phthalate			
Deer	8.82E-05	0.19	<1 (4.6E-04)
Bobwhite Quail	2.35E-02	-- (b)	--
Rabbit	1.00E-02	0.19	<1 (5.3E-02)
trans-1,2-Dichloroethene			
Deer	1.10E-05	1.7	<1 (6.5E-06)
Bobwhite Quail	2.94E-03	-- (b)	--
Rabbit	1.25E-03	1.7	<1 (7.4E-04)
Trichloroethene			
Deer	4.41E-06	3 (c)(d)	<1 (1.5E-06)
Bobwhite Quail	1.18E-03	-- (b)	--
Rabbit	5.00E-04	3 (c)(d)	<1 (1.7E-04)
1,3,5-Trinitrobenzene			
Deer	1.35E-05	0.225 (d)	<1 (6.0E-05)
Bobwhite Quail	3.59E-03	-- (b)	--
Rabbit	1.52E-03	0.225 (d)	<1 (6.8E-03)
Copper			
Deer	5.65E-05	1	<1 (5.6E-05)
Bobwhite Quail	1.51E-02	37.5	<1 (4.0E-04)
Rabbit	6.40E-03	6	<1 (1.1E-03)
Lead			
Deer	1.52E-05	0.45	<1 (3.4E-05)
Bobwhite Quail	4.06E-03	3.75	<1 (1.1E-03)
Rabbit	1.73E-03	0.9	<1 (1.9E-03)
Robin	4.06E-03	0.375	<1 (1.1E-02)
Nickel			
Deer	4.99E-05	0.75	<1 (6.6E-05)
Bobwhite Quail	1.33E-02	37.5	<1 (3.5E-04)
Rabbit	5.65E-03	1.5	<1 (3.8E-03)
Cattle Pond:			
Antimony			
Deer	1.56E-04 (d)	0.06	<1 (2.6E-03)
Bobwhite Quail	4.16E-02 (d)	-- (b)	--
Rabbit	1.77E-02 (d)	0.06	<1 (3.0E-01)
Arsenic			
Deer	1.17E-05 (d)	0.005 (d)	<1 (2.3E-03)
Bobwhite Quail	3.12E-03 (d)	0.029 (d)	<1 (1.1E-01)
Rabbit	1.33E-03 (d)	0.005 (d)	<1 (2.7E-01)
Copper			
Deer	1.59E-04	1	<1 (1.6E-04)
Bobwhite Quail	4.24E-02	37.5	<1 (1.1E-03)
Rabbit	1.80E-02	6	<1 (3.0E-03)
Ditch A:			
HMX			
Deer	3.09E-06	-- (b)	--
Bobwhite Quail	8.24E-04	-- (b)	--
Rabbit	3.50E-04	-- (b)	--
Copper			
Deer	4.74E-05	1	<1 (4.7E-05)
Bobwhite Quail	1.26E-02	37.5	<1 (3.4E-04)
Rabbit	5.37E-03	6	<1 (9.0E-04)

TABLE 5-57

RISK TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS: COMPARISON OF ESTIMATE DOSE TO TOXICITY REFERENCE VALUE DOSES

Chemical/ Animal	Mean Estimated Dose (mg/kg)	TRV (mg/kg)	Dose:TRV Ratio
Nickel			
Deer	4.30E-05	0.75	<1 (5.7E-05)
Bobwhite Quail	1.15E-02	37.5	<1 (3.1E-04)
Rabbit	4.87E-03	1.5	<1 (3.2E-03)
Silver			
Deer	4.41E-07	1.5	<1 (2.9E-07)
Bobwhite Quail	1.18E-04	12.5	<1 (9.4E-06)
Rabbit	5.00E-05	3	<1 (1.7E-05)
Zinc			
Deer	1.59E-03	7.5	<1 (2.1E-04)
Bobwhite Quail	4.24E-01	7.5	<1 (5.6E-02)
Rabbit	1.80E-01	15	<1 (1.2E-02)
Ditch B: --------			
Bis(2-ethylhexyl)phthalate			
Deer	2.21E-05	0.19	<1 (1.2E-04)
Bobwhite Quail	5.88E-03	-- (b)	--
Rabbit	2.50E-03	0.19	<1 (1.3E-02)
Antimony			
Deer	1.08E-05	0.06 (d)	<1 (1.8E-04)
Bobwhite Quail	2.88E-03	-- (b)	--
Rabbit	1.23E-03	0.06 (d)	<1 (2.0E-02)
Arsenic			
Deer	2.29E-05	0.005 (d)	<1 (4.6E-03)
Bobwhite Quail	6.12E-03	0.029 (d)	<1 (2.1E-01)
Rabbit	2.60E-03	0.005 (d)	<1 (5.2E-01)
Beryllium			
Deer	8.82E-07	1	<1 (8.8E-07)
Bobwhite Quail	2.35E-04	-- (b)	--
Rabbit	1.00E-04	10	<1 (1.0E-05)
Copper			
Deer	2.21E-04	1	<1 (2.2E-04)
Bobwhite Quail	5.88E-02	37.5	<1 (1.6E-03)
Rabbit	2.50E-02	6	<1 (4.2E-03)
Lead			
Deer	2.63E-05	0.45	<1 (5.8E-05)
Bobwhite Quail	7.00E-03	3.75	<1 (1.9E-03)
Rabbit	2.98E-03	0.9	<1 (3.3E-03)
Robin	7.00E-03	0.375	<1 (1.9E-02)
Nickel			
Deer	4.06E-05	0.75	<1 (5.4E-05)
Bobwhite Quail	1.08E-02	37.5	<1 (2.9E-04)
Rabbit	4.60E-03	1.5	<1 (3.1E-03)
Selenium			
Deer	1.57E-05	-- (b)	--
Bobwhite Quail	4.18E-03	-- (b)	--
Rabbit	1.77E-03	-- (b)	--
Zinc			
Deer	1.37E-03	7.5	<1 (1.8E-04)
Bobwhite Quail	3.65E-01	7.5	<1 (4.9E-02)
Rabbit	1.55E-01	15	<1 (1.0E-02)

TABLE 5-57

RISK TO TERRESTRIAL ANIMALS AT THE LAKE CITY ARMY AMMUNITIONS PLANT FROM INGESTION OF SURFACE WATER FROM SELECTED AREAS: COMPARISON OF ESTIMATE DOSE TO TOXICITY REFERENCE VALUE DOSES

Chemical/ Animal	Mean Estimated Dose (mg/kg)	TRV (mg/kg)	Dose:TRV Ratio
Big Ditch:			
Benzene			
Deer	3.31E-06	1.5 (c)(d)	<1 (2.2E-06)
Bobwhite Quail	8.82E-04	-- (b)	--
Rabbit	3.75E-04	1.5 (c)(d)	<1 (2.5E-04)
Trichloroethene			
Deer	3.53E-06	3 (c)(d)	<1 (1.2E-06)
Bobwhite Quail	9.41E-04	-- (b)	--
Rabbit	4.00E-04	3 (c)(d)	<1 (1.3E-04)
Copper			
Deer	1.37E-05	1	<1 (1.4E-05)
Bobwhite Quail	3.65E-03	37.5	<1 (9.7E-05)
Rabbit	1.55E-03	6	<1 (2.6E-04)
Zinc			
Deer	9.93E-04	7.5	<1 (1.3E-04)
Bobwhite Quail	2.65E-01	7.5	<1 (3.5E-02)
Rabbit	1.13E-01	15	<1 (7.5E-03)

(a) Concentration values are from one sample.

factor of three. The concentration of phenol in Area 16 seep is 2,000 ug/L. Therefore, rabbit may experience adverse effects from ingestion of surface water from the Area 16 seep area from exposure to phenol. Thus, no adverse effects are expected to any of these species as a result of exposure to the chemicals of concern by using these areas for drinking water with the exception noted above. As shown in Table 5-51, insufficient data were available to derive TRVs for certain chemicals detected in surface water for certain indicator species.

Ingestion of Soil Invertebrates. Risks to wildlife from ingesting soil invertebrates (e.g., earthworms) that may accumulate chemicals of concern in surface soils also was assessed using the robin as a representative species. The estimated daily doses for a robin based on maximum concentrations in soil in Area 13 are 0.894 mg/kg chromium, and 0.30 mg/kg lead. The TRVs derived for robins are 12.5 mg/kg for chromium and 0.375 for lead. The estimated mean and maximum doses of chromium and lead are all below the TRVs. Thus, no adverse effects are likely to occur to robins through this exposure pathway. Earthworm bioconcentration factors were not available for arsenic or barium, thus potential risks from exposure to this chemical could not be quantitatively evaluated. However, arsenic and barium in the food of birds and mammals does not bioaccumulate and is readily excreted.

5.6.5.3 Aquatic Life

Potential adverse effects to aquatic life were estimated by comparing the AWQCs to the concentrations of the chemicals of concern at the sampling points farthest downstream (and nearest the plant boundary) for the largest ditches exiting the plant (see Table 5-58). The results of these comparisons are discussed below. Interim sediment quality criteria are not available for the chemicals of concern detected at these sampling points and therefore, potential adverse effects were not evaluated.

TABLE 5-58

CHEMICAL CONCENTRATIONS (ug/l) IN SURFACE WATER IN DITCH A, DITCH B, AND THE BIG DITCH AT THE LAKE CITY ARMY AMMUNITIONS PLANT COMPARED TO AMBIENT WATER QUALITY CRITERIA

CHEMICAL	DITCH A (a)	DITCH B (b)	BIG DITCH (c)	CHRONIC AWQC (g)
Benzene	--	--	1.5	730 (h)
Bis(2-ethylhexyl)phthalate	--	10	--	3 (f)
Trichloroethene	--	--	1.6	21900 (d)
Antimony	--	5	--	1600 (d)
Arsenic	--	10.4	--	48 (Pent)(d)
Beryllium	--	0.4	--	5.3 (d)
Copper	21.5	100	6.22	18 (e)
Lead	--	11.9	--	5.3 (e)
Nickel	--	16.8	12.1	235 (e)
Selenium	--	7.12	--	5
Silver	0.21	--	--	0.12
Zinc	720	491	450	158 (e)

(a) Sample SW-09; data presented in Table 5-7.

(b) Sample SW-15; data presented in Table 5-7.

(c) Sample SW-17; data presented in Table 5-7.

(d) Insufficient data to develop criteria, value is chronic LOEL.

(e) Hardness dependent criteria, 160 mg/l CaCO3 is used.

(f) No AWQC available, value is chronic LOEL (EPA 1985).

(g) Values are from EPA 1986, unless otherwise indicated.

(h) No AWQC available, value is an estimated chronic LOEL based on freshwater acute LOEL (lowest LC 50) of 5,300 ug/l and saltwater acute:chronic ratio of 7.3.

-- = Chemical was not selected as chemical of potential concern at this location.

Ditch A, Sampling Point SW-09. The concentration of copper (21.5 ug/l) slightly exceeds the chronic AWQC (18 ug/l). The concentration of silver (0.21 ug/L) also is slightly greater than the chronic AWQC of 0.12 ug/L. Adverse chronic effects could occur to some aquatic organisms at the measured concentration of silver. The concentration of zinc (720 ug/l) exceeds the chronic AWQC by approximately five times and adverse effects to some aquatic species could occur. This concentration also exceeds the acute AWQC of 174 ug/L (calculated for a hardness of 160 mg/l $CaCO_3$, see Section 5.6.4.3) by at least four times. Thus acute effects to aquatic organisms could also occur. The measured concentration of zinc is in the range of values associated with acute toxicity in microcrustaceans (such as Daphnia magna) and juvenile fish (e.g., fathead minnow and longfin dacc, see Section 5.6.4.3). No other chemicals of concern were above the detection limits in this area.

Ditch B, Sampling Point SW-15. The concentrations of antimony, arsenic, beryllium, and nickel are all below the AWQCs (or LOELs). No adverse effects are expected from exposure to these concentrations. Copper exceeds the AWQC by five times. The concentration of lead is approximately two times greater than the AWQC. Selenium was detected at 7.12 ug/L which is slightly above the AWQC of 5 ug/L. The concentration of zinc is more than three times the chronic AWQC. Thus, based on these comparisons, adverse chronic effects to some aquatic organisms could occur from exposure to copper, lead, selenium, and zinc at the measured concentrations. The measured concentration of zinc (491 ug/l) is also about three times greater than the acute AWQC of 174 ug/L (calculated for a hardness of 160 mg/l $CaCO_3$, see Section 5.6.4.3). Thus acute effects to aquatic organisms such as microcrustaceans (e.g., Daphnia magna) and some species of juvenile fish could occur (for more information on acute effect levels see Section 5.6.4.3). No AWQC is available for bis(2-ethylhexyl)phthalate; however, the measured concentration is approximately four times greater than the chronic LOEL. Adverse effects could occur in some aquatic species chronically exposed to this concentration of bis(2-ethylhexyl)phthalate.

Big Ditch, Sampling Point SW-17. The measured concentrations of benzene, trichloroethene, copper, and nickel are all below the AWQCs (or LOELs). No adverse effects would be expected from exposure to these chemicals at these concentrations. The concentration of zinc is approximately three times greater than the chronic AWQC. Thus, chronic adverse effects could occur in some aquatic species. The concentration of zinc (450 ug/l) is also about 2.5 times greater than the acute AWQC of 174 ug/L (based on a hardness of 160 mg/l $CaCO_3$, see Section 5.6.4.3). Thus adverse acute effects to aquatic organisms such as microcrustaceans (e.g., Daphnia magna) and some species of juvenile fish could occur (for more information on acute effect levels see Section 5.6.4.3) from exposure to zinc at the measured concentration.

5.6.6 Conclusions

Absolute conclusions regarding the potential environmental impacts of the LCAAP study areas cannot be made because there are many uncertainties surrounding the estimates of toxicity and exposure. However, given the available data and limitations the general conclusions regarding the potential for environmental impacts are summarized below.

Plants. In the one area evaluated for toxicity to plants (Area 13), no adverse effects to plants are expected. Although the levels of arsenic and chromium exceed the plant-TRVs, grass species in the vicinity of Area 13 do not appear to be adversely affected.

Terrestrial Wildlife. No adverse effects to terrestrial wildlife are expected from ingestion of surface water in site ditches. However, rabbits that ingest surface water from the Area 16 seep may experience adverse chronic effects from exposure to high levels of phenol. Sufficient toxicity information was not available for mammals for chloroethane and HMX and therefore potential risk from exposure to these chemicals could not be evaluated. Toxicity information was not available for birds for benzene, beryllium, bis(2-ethylhexyl)phthalate, chloroethane, 1,1-dichloroethane, ethylbenzene, HMX, methylene chloride, tetrachloroethene, toluene, selenium, trans-1,2-dichloroethene, trichloroethene, and 1,3,5-TNB. Therefore, the potential risks to birds from exposure to these chemicals could not be further evaluated. No adverse effects are expected to wildlife consuming soil organisms that may bioaccumulate contaminants in soil. However, earthworm bioconcentration factors were not available for arsenic and barium, thus potential risks from exposure to these chemicals could not be evaluated, although arsenic and barium in the food of birds and mammals does not bioaccumulate and is readily excreted.

Aquatic Organisms. The measured concentrations of copper, silver, and zinc in Ditch A exceed the chronic AWQCs. In Ditch B, the levels of bis(2-ethylhexyl)phthalate, copper, lead, selenium, and zinc exceed the chronic AWQCs. The level of zinc in Big Ditch is greater than the chronic AWQC. Thus, potential adverse chronic effects to some species of aquatic organisms could occur from exposure to these chemicals at the measured concentrations. The measured concentrations of zinc (in all three ditches) exceed the acute AWQC by two to four times and thus adverse acute effects could occur in sensitive aquatic organisms such as microcrustaceans (such as Daphnia magna) and some species of juvenile fish. Concentrations in sediments were not evaluated because interim sediment quality criteria were not available for the chemicals of concern. In evaluating these results it should be noted that these on-site ditches have not been classified by the State of Missouri and the relevance of AWQC to these water bodies is questionable. Potential impacts to aquatic organisms downstream of the sampling points in classified water bodies would be reduced as the chemical concentrations decline as a result of dilution and any transformation processes that may occur.

5.7 UNCERTAINTIES IN THE BASELINE RISK ASSESSMENT

As in any risk assessment, the estimates of risk for the LCAAP site have many associated uncertainties. Some of these uncertainties associated with this assessment (such as restricted scope of sampling in certain areas/media) can be addressed by additional sampling and analysis; others are more related to inherent limitations in the available toxicological literature or in risk assessment itself.

With respect to the scope of this RI, the investigation was not designed to exhaustively characterize chemical contamination in soil, sediment, and surface water. Therefore, the results of the baseline risk assessment in regards to these media should be regarded as preliminary. To more fully evaluate potential source areas, potential surface soil and subsurface soil samples would need to be collected in the potential source areas identified in Section 4 of the RI that were not sampled during the RI. Relatively high levels of barium and lead were found in Area 15 subsurface soil samples, however since there is no groundwater monitoring data from Area 15, the impact to groundwater cannot be determined.

Data gaps still exist with respect to sampling of off-site residential wells beyond the western property line of the LCAAP site. In lieu of this data, monitoring data collected along the western perimeter of the facility were used to preliminarily evaluate groundwater ingestion exposure of these off-site residents. Installation of additional monitoring wells at and beyond the western boundary of the LCAAP site could further define the extent of contaminant migration to potential receptors. In addition, samples collected from off-site residential wells in this area would more accurately quantify the current potential exposure to these off-site residents.

Another data gap exists with respect to surface water sampling. As discussed in Section 5.6, concentrations of chemicals of potential concern found in surface water on-site were compared with AWQC to ensure the protection of aquatic life further off-site downstream, since no downstream samples were collected during the RI. Creeks further downstream may be large enough to support aquatic life, thus surface water samples collected off-site further downstream would give a more accurate estimate of potential impacts on aquatic life in the creek.

Other sources of uncertainty pertain principally to data quality including sampling and analysis, exposure parameter and exposure point concentration determination, and toxicological data. These are discussed below. Some uncertainty with respect to data quality is associated with the quality of the monitoring data that was used to characterize treated water. These data were not collected by the RI team and did not undergo proper QA/QC review. As discussed previously, there was uncertainty associated with the presence of thallium which resulted in a hazard index above one. Thallium was not detected in untreated groundwater nor in any other RI data. Therefore, its detection in one sample is suspect. Additional sampling should be performed in order to determine whether thallium is indeed present in the treated water. Also in this RI, for some metals, the reported concentrations of dissolved metal was greater than the reported concentration of the total metal. This is theoretically impossible since total analysis should detect the chemical in both the dissolved and particulate phase, and therefore cannot be less than the dissolved. These results may be the result of lack of precision or accuracy in the analytical methods used in the laboratory analyses conducted for the total and dissolved metals. To be conservative, in using this data in this baseline risk assessment, the dissolved analysis for inorganic chemicals was used when estimating risk if it was greater than the total analysis. This contributes to the uncertainties of the results of the evaluation of metals data for groundwater.

An additional source of uncertainty pertaining to sampling data, which may significantly affect the interpretation of the results of this risk assessment, is the contribution of natural background sources to the chemicals observed in the various media at the site. It is possible that some of the inorganic chemicals that were found to be statistically elevated above background concentrations (using a statistical t-test, as discussed in previous sections of the RI) may not be site-related (this may be the result of the uncertainty inherent in the statistical test or uncertainty surrounding sampling results [to reduce the statistical and sampling uncertainty, additional background samples could be collected since only 4 samples were collected during the RI]). If this is the case, then the potential impacts associated with inorganic chemicals of potential concern in groundwater would be incorrectly associated with past activities at the site. In fact, naturally occurring levels of arsenic in soil and groundwater are often associated with significant levels of risk. A clarification of this issue is of particular importance at the LCAAP site because arsenic in groundwater was accounting for the majority of the carcinogenic risk for several exposure pathways (although the t-test revealed that the arsenic was elevated above background in various media in several study areas at the site). It also is possible that the radioactivity found at the site is related to background, since no site-specific background samples were analyzed for radioactive materials. Additional analysis also would be required to identify the specific alpha and beta emitters present in order to more accurately assess risks associated with exposure to radioactive parameters.

With respect to the exposure scenarios evaluated in this risk assessment, there are several areas of uncertainties associated with estimating exposure point concentrations and exposure parameters used in quantifying risk. These areas of uncertainty are as follows:

- It was assumed that the chemical concentrations in groundwater would remain constant during the period of exposure since there was limited quantitative information concerning the source strength and behavior of chemicals of potential concern at the LCAAP site. This assumption may result in overestimates of risk because chemical concentrations may decrease over time due to various chemical degradation pathways and dilution, although it should be noted that chemical transformations also may yield increased levels of chemical by-products with time. With respect to the future impact of source areas to groundwater, the extent of this source contribution to groundwater at the LCAAP site is difficult to fully evaluate at this time because this preliminary assessment focussed on groundwater and few soil data are available.

- Information concerning off-site groundwater flow patterns and other off-site hydrogeology characteristics have not been fully studied in this RI. In addition, as has been noted previously, no residential well data were available for the residential areas located downgradient of Areas 3 and 8 (identified study areas where groundwater may migrate further downgradient beyond the perimeter of the LCAAP site). Therefore, it is unknown at this time whether wells at the nearby off-site residences located beyond the western LCAAP boundary could be potentially affected by groundwater that migrates further downgradient from these two on-site areas. In order to preliminarily evaluate exposure to the potentially exposed off-site residents downgradient from Areas 3 and 8, data from these two areas were used to estimate exposure point concentrations. However, it is likely that concentrations of chemicals currently found on-site along the western boundary will potentially decrease with time due to dilution and certain degradation pathways (as the plume potentially migrates further downgradient) (it should be noted, however, that chemical transformations also may yield increased levels of chemical by-products with time).

- Additional uncertainties are associated with exposure estimates of how often, if at all, an individual would come into contact with the chemicals of concern and the period of time over which such exposures would occur. For example, no site specific data were available on the period of time in which persons work at the LCAAP site and therefore estimates were based on worker studies as presented in EPA (1989a). Generally, conservative assumptions were made regarding periods of exposure and it is likely that these time estimates will overestimate the risks associated with exposure to contamination in the various areas. Other standard assumptions used throughout this assessment (e.g., ingestion of 2 liters of water, exposure duration of 70 years, and an exposure frequency of 365 days), are assumed to represent upper bounds of potential exposure and have been used when site-specific data are not available. Risks for certain individuals within an exposed population will be higher or lower depending on their actual length of time at one residence, drinking water intakes, body weights, etc.

- There also are a number of uncertainties associated with the environmental assessment that should be noted when reviewing the conclusions for the LCAAP study areas. For example, there are many uncertainties surrounding the approaches used to estimate intakes to wildlife. Exposure estimates for wildlife were based on assumptions regarding daily water ingestion rates and body weights for certain species. These assumptions could result in overestimates or underestimates of exposure for the animals actually occurring at the LCAAP site. In addition, exposures and risks to selected receptors were assumed to be representative of potential exposures and risks in other wildlife at the site, when in fact, other species could be more or less sensitive.

The toxicity assessment in this report also contributes to uncertainty. Toxicological data error is also a large source of error in this risk assessment. As EPA notes in its Guidelines for Carcinogenic Risk Assessment (EPA 1986): There are major uncertainties in extrapolating both from animals to humans and from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility. Human populations are variable with respect to genetic constitution, diet, occupational and home environment, activity patterns and other cultural factors.

There is also a great deal of uncertainty in assessing the toxicity of a mixture of chemicals. In this assessment, the effects of exposure to each of the contaminants present in the environmental media have initially been considered separately. However, these substances occur together at the site, and individuals may be exposed to mixtures of the chemicals. Prediction of how these mixtures of toxicants will interact must be based on an understanding of the mechanisms of such interactions. The interactions of the individual components of chemical mixtures may occur during absorption, distribution, metabolism, excretion, or activity at the receptor site. Individual compounds may interact chemically, yielding a new toxic component or causing a change in the biological availability of an existing component, or may interact by causing different effects at different receptor sites. Suitable data are not currently available to rigorously characterize the effects of chemical mixtures similar to those present at the LCAAP site. Consequently, as recommended in EPA's Risk Assessment Guidelines for Superfund (EPA 1989b) and in EPA's Guidelines for Health Risk Assessment of Chemical Mixtures (EPA 1986), chemicals present at the LCAAP site were assumed to act additively, and potential health risks were evaluated by summing excess cancer risks and calculating hazard indices for chemicals exhibiting carcinogenic and noncarcinogenic effects, respectively. This approach to assessing the risk associated with mixtures of chemicals assumes that there are no synergistic or antagonistic interactions among the chemicals considered and that all chemicals have the same toxic end points and mechanisms of action. To the extent that these assumptions are incorrect, the actual risk could be under- or overestimated.

Toxicity criteria were not available for certain chemicals of concern including chloroethane, copper, dimethylphthalate, lead, tetryl, oil and grease, total uranium, gross alpha activity and gross beta activity. Therefore, these chemicals could not be quantitatively evaluated in this assessment. Therefore, the risks may be underestimated with respect to their omission. In fact, the maximum concentration of lead detected in Area 8 and

10 exceeded the current Federal Maximum Contaminant Level of 50 ug/L (40 CFR, Part 141-National Primary Drinking Water Regulations).

In addition, numerous tentatively identified compounds (TICs) were found in samples collected during the RI. These TIC compounds consist of base neutral and acid extractable compounds (BNAs) with concentrations generally below 30 ug/L. The TICs that were detected at higher concentrations (200 ug/L - 500 ug/L) generally consisted of alkane glycol (Areas 2, 5, 6, and 8) (compound found in antifreeze), gasolines and fuel oils (Areas 5, 6, and 10), and benzene derivatives (Area 17). The TICs are discussed in detail in Section 4 of this report. In most cases, the TICs could not be identified as a specific compound. No toxicity criteria wre available for those TICs identified as a specific compound. Therefore, these chemicals could not be evaluated in this risk assessment. In addition, the monitoring data for these compounds did not meet QA/QC requirements; therefore, it would be inappropriate to use the TIC data in a baseline risk assessment. The TICs detected in groundwater generally have low toxicity relative to the other chemicals of concern selected. Therefore, inclusion of TICs in the risk assessment (if this were possible) would not significantly alter the conclusion of the baseline risk assessment. It should be noted that 20 BNA TICs were identified in production well 17AA at concentrations as high as 500 ug/L. Therefore, further analysis of this well should be performed to characterize the chemicals of concern in production well 17AA.

There also is considerable uncertainty associated with the toxicity of the chemicals of potential concern to plants and animals. Primary among these uncertainties are the toxicity reference values (TRVs) used to assess risks to birds and mammals. In many cases the TRVs were derived from studies with laboratory species or domestic animals, since very few studies are available for terrestrial wildlife for the chemicals of potential concern at LCAAP. For example, results from studies with laboratory rats were used in some cases to estimate toxicity in wild rabbits, even though these animals differ in physiology and life habits. Uncertainty factors were used in these cases to extrapolate from one species to another. In addition, dietary conversion factors were used to convert dietary concentrations of chemical to dose per unit body weight and there is some uncertainty associated with these factors. Uncertainty factors were also used to extrapolate results from subchronic studies to estimate chronic toxicity. In some cases values from acute toxicity tests were used to estimate TRVs because chronic toxicity information was not available. For aquatic species, there are uncertainties associated with the AWQCs estimated for some of the metals. A water hardness of 160 mg/liter $CaCO_3$ was used to estimate these AWQCs, even though the streams of the LCAAP area have a water hardness of 160 to 405 mg/liter $CaCO_3$. There is a lack of toxicity information for terrestrial plants. In most cases where information for a chemical was available, only the lowest observed toxic effect levels were given. Very little information is available concerning concentrations that reportedly have no adverse effects on plants.

As a result of the uncertainties described above, this risk assessment should not be construed as presenting an absolute estimate of risks to human or environmental populations. Rather, it is rather a conservative analysis intended to indicate the potential for adverse impacts to occur.

5.8 SUMMARY AND CONCLUSIONS OF THE BASELINE RISK ASSESSMENT

The baseline risk assessment conducted in the preceding sections for the LCAAP site addresses potential hazards to human health and indigenous plant and animal species posed by contamination in the site study areas in the absence of remedial actions. This assessment has been based on sampling data generated during the RI conducted for this site. In this context it should be noted that the RI sampling plan was not designed to characterize chemical contamination in off-site groundwater and as a result certain potential exposures are evaluated in a preliminary fashion. In addition, all potential source areas were not investigated in the RI and therefore the potential future impact of these source areas could not be fully evaluated.

The main components and results of the human health assessment are summarized below in Sections 5.8.1 through 5.8.3 and the conclusions of the assessment of impacts on environmental receptors are summarized in Section 5.8.4. Data gaps that currently exist are summarized in Section 5.8.5.

5.8.1 Chemicals of Potential Concern

All of the organic chemicals detected at above reportable limits (with the exception of unknown compounds [i.e., TICs]) were considered for evaluation in the assessment. Many of the same chemicals suspected (based on the site history) of being disposed in potential source areas at the site were found in groundwater sampled from production wells, groundwater collected from the monitoring wells installed downgradient of suspected source areas, surface and subsurface soil collected in various areas at LCAAP site, surface water and sediment samples collected in different ditches across the site, and sump and sump outflow sediment samples. Explosive compounds such as RDX and HMX and heavy metal compounds such as arsenic, barium, beryllium, cadmium, chromium, copper, lead, nickel, silver, and zinc were selected as chemicals of potential concern in nearly all media sampled and in several areas of the site. Several organic and inorganic chemicals were detected and selected for evaluation in off-site residential wells along the northern LCAAP boundary. Since no representative background data were available for comparison with data from the off-site wells along the northern LCAAP boundary, all of the inorganic chemicals that were selected as chemicals of potential concern on the site and found in the off-site wells were conservatively selected as chemicals of potential concern for the off-site wells. In general, volatile contaminants were only identified as chemicals of potential concern in media that were collected near suspected solvent disposal source areas.

5.8.2 Human Exposure Pathways

The principal exposure pathways through which humans might potentially be exposed to site contaminants under current and future land use conditions were:

- ingestion of, and inhalation of VOCs released from, treated groundwater from the production wells by on-site workers and residents, based on monitoring data collected by LCAAP personnel;
- hypothetical ingestion of, and inhalation of VOCs released from, untreated groundwater from the production wells by on-site workers and residents based on production well monitoring data collected during the RI;
- hypothetical ingestion of, and inhalation of VOCs released from, untreated groundwater by on-site workers and residents using groundwater from wells in the production well capture zone (all on-site areas except Areas 3, 8, 16, and 17);
- ingestion of, and inhalation of VOCs released from, groundwater by residents using off-site residential wells located north of the LCAAP site boundaries;
- hypothetical ingestion of, and inhalation of VOCs released from, groundwater located west of the plant (based on data collected at the perimeter of Area 3 and data from Area 8). Since off-site residential wells are located beyond the western border of the LCAAP facility this constitutes a preliminary assessment of the potential impact of site groundwater on this population; and
- hypothetical ingestion of and inhalation of VOCs released from, groundwater by on-site workers and residents from wells that in the future may be installed downgradient of each study area.

Exposure scenarios for each of the potential exposure pathways shown above were developed, and estimates of the concentrations of chemicals to which these populations might potentially be exposed (exposure point concentrations) were determined. For the pathways that were quantitatively evaluated, it was assumed that chemical concentrations in groundwater will remain constant over the duration of the exposure period. The extent that identified sources at the LCAAP site will contribute to future groundwater contamination is unknown given the limited data available from potential source areas at this time. Given the fact that many of the sources areas have been closed or are inactive, it is unlikely that the concentrations of chemicals will increase and will likely decrease overtime. However, it should be noted that products of certain organic chemical biodegradation pathways may yield fairly persistent, toxic, and mobile products (e.g., degradation of tetrachloroethene and trichloroethene to 1,1-dichloroethene which in turn degrades to the highly mobile and toxic compound, vinyl chloride).

No human exposure pathways related to surface water/sediment or soil contamination were quantitatively evaluated in this baseline risk assessment. due to the extremely low probability of any current activities that could result in exposures occurring in these areas. However, potential risks to future construction workers from exposures to contaminated soils and dusts were qualitatively evaluated in this risk assessment. These media also were evaluated in the environmental assessment with respect to their potential to impact ecological receptors (as discussed in Section 5.8.4) and as potential sources of groundwater contamination as briefly discussed below. Surface and subsurface soils collected from Areas 8D, 9, 13A (open waste drainage area), 14B (sludge disposal area), and 15A (temporary surface impoundment) appear to be sufficient to characterize the extent of soil contamination in these specific areas. As discussed in Section 5.3, although above background levels of inorganic contamination were found in soils in these areas their current impact on groundwater appears to be low (with the exception of Area 15 for which no groundwater data were available). Given the relatively high levels of barium and lead found in Area 15 subsurface soil and the lack of groundwater monitoring data in Area 15, the impact of this sampled potential source area on groundwater cannot be evaluated at this time. As discussed in Section 5.3, relatively low (but above background) levels of inorganic contamination were found in the surface water and sediment samples collected in the area wide ditch system (with the exception of the Area 13 drainage ditch which had high levels of chromium and lead), therefore the overall potential impact of surface water and sediment sampled on groundwater quality is probably low. Sediment samples collected from the sumps across the site also appear to be sufficient to characterize the extent of contamination. As discussed in Section 5.3, very high levels of inorganic contamination (i.e., barium, copper, lead, and zinc) were found in sump sediments across the site. The sump sediments are potential sources of surface water and sediment contamination in the area-wide ditch system and groundwater contamination.

5.8.3 Risk Characterization

Quantitative risk assessment involves estimating intakes by potentially exposed populations based on the assumed exposure scenario. These intakes are then combined with reference doses (RfDs, defined as acceptable daily doses for noncarcinogens) or slope factors (for carcinogens) to derive estimates of noncarcinogenic hazard or excess lifetime cancer risks of the potentially exposed populations. For carcinogens, the excess lifetime cancer risk is expressed as a probability. A 10^{-6} risk indicates that, as a result of the exposure being considered, an exposed individual has a probability of one in a million of getting cancer. A risk range of 10^{-6} to 10^{-4} is often used as a range for health protectiveness by regulatory agencies (EPA 1990).

Given the history of many of the source areas and the rate of groundwater flow in the alluvial sand aquifer, it is believed that the concentrations of certain chemicals (e.g., trichloroethene, trans-1,2-dichloroethene) of potential concern currently detected in groundwater will not increase in the future and will probably decrease due to degradation, dilution, and decreases in the release from potential source areas. Overall, however, the trend in concentrations of chemicals of potential concern in groundwater over time is uncertain, and therefore the estimated risks presented in this assessment must be interpreted with this in mind.

There are several other areas of uncertainty surrounding the interpretation of the risk assessment results. First of all, analytical precision or accuracy errors can be the source of a great deal of uncertainty. For instance, in this study the reported concentrations of certain filtered inorganics were greater than the reported concentrations in unfiltered inorganics, which is theoretically impossible. In this assessment the higher of the filtered and unfiltered concentrations were used in this assessment. Second, naturally occurring sources of inorganics may be contributing to the concentration of certain inorganics at the site (however, a statistical test was used to minimize the influence of background levels). Third, many site-specific exposure parameter values were not available, therefore these values were based on values recommended by EPA and/or professional judgement. Finally, there is a great deal of uncertainty in the toxicity criteria used in estimating risk and the effect of chemical mixtures. In addition, several chemicals of concern do not have toxicity criteria and numerous TICs could not be evaluated in the risk assessment (due to a lack of toxicity data and TIC data does not meet QA/QC requirements). This would tend to underestimate risks. In fact, the maximum concentration of lead detected in Area 8 and 10 exceeded the current Federal Maximum Contaminant Level of 50 ug/L (40 CFR, Part 141-National Primary Drinking Water Regulations). However, inclusion of the TICs (if this were possible) would have little impact on the conlusions of the risk assessment given the relative concentrations and low toxicity of the TICs (primarily alkanes). Given the uncertainty in extrapolating both from animals to humans and from high to low doses, EPA has incorporated safety factors into the toxicity criteria which ensure that estimated risks are not underestimated. As a result of the uncertainties described above, this risk assessment should not be construed as presenting an absolute estimate of risks to humans or environmental populations. Rather it is a conservative analysis intended to indicate the potential for adverse impacts to occur and in certain instances to guide additional data gathering efforts which would reduce the uncertainty.

The major conclusions of the quantitative risk characterization are presented below and in the summary Table 5-59.

- Ingestion of treated groundwater from the production wells by on-site workers yielded total excess lifetime cancer risks of approximately 10^{-5} for the RME case. Bromodichloromethane, bromoform, chloroform, dibromochloromethane, trichloroethene, and radium 226 and radium 228 were the only suspected carcinogenic compounds detected in treated water. The hazard index for the RME case was below a value of one, when thallium was excluded. The CDI:RfD for TL was 10 for the RME case. However, thallium was not detected in any groundwater samples collected for the RI or in any other media. Therefore, the presence of thallium is not considered likely to be due to waste disposal practices at the LCAAP site.

- Ingestion of treated groundwater from the production wells by on-site residents yielded total excess lifetime cancer risks of approximately 10^{-4} for the RME case. Bromodichloromethane, bromoform, chloroform, dibromochloromethane, trichloroethene, and radium 226 and radium 228 were the only suspected carcinogenic compounds detected in treated water. The hazard index for the RME case was below a value of one, when Thallium was excluded. The CDI:RfD for Thallium was 30 for the RME case. However, thallium was not detected in any groundwater samples collected for the RI or in any other media. Therefore, the presence of thallium is not considered likely to be due to waste disposal practices at the LCAAP site.

- Inhalation of VOCs by on-site residents showering with treated groundwater from the production wells yielded total excess lifetime cancer risks of approximately 10^{-5}. Bromoform, chloroform, and

TABLE 5-59

MAJOR CONCLUSIONS OF THE QUANTITATIVE RISK CHARACTERIZATION

Exposure Pathway	Total Excess Lifetime Carcinogenic Risk for the RME	Non-Carcinogenic Hazard Index for the RME	Comments
Current ingestion of treated water by facility workers	7E-06	10	Thallium was the only chemical with a CDI:RfD ration >1. Thallium was never detected in RI data from groundwater or any other medium. Presence of thallium may be due to lab or treatment process.
Current use of treated water by on-site residents	Ingestion: 7E-05	30	Bromodichloromethane, dibromochloromethane, and radium 226 and 228 accounting for majority of carcinogenic risk. Thallium was the only chemical with a CDI:RfD ration of >1. Thallium was never detected in RI data from groundwater or any other medium. Presence of thallium due to lab or treatment process
	Inhalation: 1E-05	<1	Chloroform and trichloroethene accounting for majority of carcinogenic risk.
Hypotheticl ingestion of untreated Production Well water by on-site residents (a)	2E-03	<1	Assumes no water treatment process in place. Vinyl chloride and arsenic accounting for the majority of the risk. Well 17FF highly contaminated with vinyl chloride. Arsenic levels above background in 5 of 7 production wells.
Hypothetical ingestion of untreated Production Well capture zone water by on-site residents (a)	2E-03	2	Assumes no water treatment process in place. Chrysene, vinyl chloride, arsenic, and beryllium contributed significantly to the carcinogenic risk. Based on comparison to results above (ingestion of untreated production well water). May indicate no increase in carcinogenic risk even if groundwater downgradient of suspected sources is captured by the production wells. Several inorganics and 1,3,5-TNB accounted for majority of carcinogenic risk.
Current use of groundwater from residential well Danner	Ingestion: No carcinogenic chemicals detected Inhalation: No VOCs detected	<1	
Current use of groundwater from residential well Fergeson	Ingestion: No carcinogenic chemicals detected Inhalation: No VOCs detected	<1	
Current use of groundwater from residential well Hedrickj-A	Ingestion: 1E-05 Inhalation: No VOCs detected	<1	RDX only carcinogenic chemical detected.
Current use of groundwater from residential well Hedrickj-B	Ingestion: No carcinogenic chemicals detected Inhalation: No VOCs detected	<1	
Current use of groundwater from residential well Hedrickjv	Ingestion: No carcinogenic chemicals detected Inhalation: No VOCs detected	<1	

TABLE 5-59 (Continued)

MAJOR CONCLUSIONS OF THE QUANTITATIVE RISK CHARACTERIZATION

Exposure Pathway	Total Excess Lifetime Carcinogenic Risk for the RME	Non-Carcinogenic Hazard Index for the RME	Comments
Current use of groundwater from residential well Lirely	Ingestion: No carcinogenic chemicals detected	<1	
	Inhalation: No VOCs detected		
Current use of groundwater from residential well Pennington	Ingestion: No carcinogenic chemicals detected	<1	
	Inhalation: No VOCs detected		
Current use of groundwater from residential well Tcarlton	Ingestion: No carcinogenic chemicals detected	<1	
	Inhalation: No VOCs detected		
Current use of groundwater from residential well Turley	Ingestion: 9E-06	<1	RND only carcinogenic chemical detected.
	Inhalation: No VOCs detected		
Current use of groundwater from residential well Ure	Ingestion: 1E-05	<1	Carbon tetrachloride, 1,4-dichlorobenzene, RDX, and tetrachloroethene were only carcinogenic chemicals detected. RDX primarily accounting for carcinogenic risk.
	Inhalation: 5E-6	<1	Carbon tetrachloride accounting for majority of carcinogenic risk.
Current use of groundwater from residential well Carlton	Ingestion: No carcinogenic chemicals detected		
	Inhalation: No VOCs detected		
Current use of groundwater from residential well north of Area 17	Ingestion: No carcinogenic chemicals above detection limit	<1	Assumes well is used year round (even though it reportedly becomes dry during dry seasons). CDI:RfD ratio for chromium was 0.5.
	Inhalation: No carcinogenic VOCs detected	<1	
Hypothetical ingestion of groundwater along western boundary: (Prelimianry Assessment for off-site residents)	8E-04	2	Arsenic and beryllium contributing significantly to carcinogenic risk. Several inorganics and bis(2-ethylhexyl)phthalate accounting for the majority of the noncarcinogenic risk. Disposal areas in Area 3 and 8 may be potential source of groundwater contamination.
Hypothetical ingestion of groundwater in Area 1 by future on-site residents (a)	6E-03	6	Arsenic accounting for the majority of the carcinogenic risk. Antimony and arsenic accounting for the majority of the noncarcinogenic risk. Highest detected concentration of arsenic at Well 1-3 (110 ug/l), which is downgradient of Area 1 sources.

TABLE 5-59 (Continued)

MAJOR CONCLUSIONS OF THE QUANTITATIVE RISK CHARACTERIZATION

Exposure Pathway	Total Excess Lifetime Carcinogenic Risk for the RME	Non-Carcinogenic Hazard Index for the RME	Comments
Hypothetical ingestion of groundwater in Area 2 by future on-site residents (a)	8E-04	9	Arsenic, bis(2-ethylhexyl)phthalate and beryllium accounting for the majority of the carcinogenic risks. The presence of bis(2-ethylhexyl) phthalate may be due to lab or field contamination. Cadmium only chemical with a CDI:RfD ratio above one. Surface impoundments in Area 2 may be potential sources of contamination.
Hypothetical ingestion of groundwater in Area 3 by future on-site residents (a)	2E-03	3	Arsenic accounting for the majority of the carcinogenic risk. RDX and several inorganics contributing to noncarcinogenic risk. Burial burial pits and/or Area 12 suspected sources of arsenic contamination. RDX detected at high levels at well 3-8.
Hypothetical ingestion of groundwater in Area 4 by future on-site residents (a)	3E-04	10	Arsenic accounting for the majority of the carcinogenic risk. 1,3,5-TNB and chromium accounting for the majority of noncarcinogenic risk. A further upgradient disposal area and the surface impoundments are suspected sources of arsenic, chromium and 1,3,5-TNB contamination.
Hypothetical ingestion of groundwater in Area 5 by future on-site residents (a)	2E-03	4	Arsenic, beryllium, and vinyl chloride accounting for the majority of the carcinogenic risk. Several inorganics contributed to the noncarcinogenic risk. Surface impoundment in Areas 5B and 5C may be potential source areas for these chemicals.
Hypothetical ingestion of groundwater in Area 6 by future on-site residents (a)	3E-04	<1	Beryllium accounting for the majority of the carcinogenic risk. High concentrations of beryllium from well 6-6. Hazard index below one.
Hypothetical ingestion of groundwater in Area 7 by future on-site residents (a)	2E-03	5	Arsenic, RDX and vinyl chloride accounting for the majority of the carcinogenic risks. RDX is the only chemical with a CDI:RfD ratio greater than one. The closed lagoon in Area 7B and the closed and active lagoons in Area 7A and 7D are potential sources of arsenic and RDX contamination, respectively.
Hypothetical ingestion of groundwater in Area 8 by future on-site residents (a)	2E-03	4	Arsenic, bis(2-ethylhexyl)phthalate, and beryllium primarily accounting for the carcinogenic risks, while bis(2-ethylhexyl)phthalate was the only chemical with hazard index greater than one. The disposal pits located in Areas 8A and 8B are potential sources of these chemicals. The presence of bis(2-ethylhexyl)phthalate may be due to lab or field contamination.
Hypothetical ingestion of groundwater in Area 9 by future on-site residents (a)	8E-04	10	Arsenic and bis(2-ethylhexyl)phthalate primarily accounting for the carcinogenic risk. 1,3,5-TNB and bis(2-ethylhexyl)phthalate primarily accounting for the noncarcinogenic risk. The presence of 1,3,5-TNB groundwater may be due to some upgradient source. Bis(2-ethylhexyl)phthalate contributed significantly to risks, but its presence may be due to lab or field contamination.

TABLE 5-59 (Continued)

MAJOR CONCLUSIONS OF THE QUANTITATIVE RISK CHARACTERIZATION

Exposure Pathway	Total Excess Lifetime Carcinogenic Risk for the RME	Non-Carcinogenic Hazard Index for the RME	Comments
Hypothetical ingestion of groundwater in Area 10 by future on-site residents (a)	3E-03	9	Arsenic and beryllium comprised the majority of the cancer risk. Bis(2-ethylhexyl)phthalate, barium, and cadmium accounting for the majority of the noncarcinogenic risks. The presence of the phthalate probably was due to lab or field contamination.
Hypothetical ingestion of groundwater in Area 11 by future on-site residents (a)	7E-04	2	RDX accounting for the majority of the carcinogenic risk. The burning ground in Area 11 may be a potential source of RDX. Bis(2-ethylhexyl) phthalate contributed to carcinogenic risk, but its presence may be due to lab or field contamination. No chemical-specific CDI:RfD ratio exceeded a value of one.
Hypothetical ingestion of groundwater in Area 12 by future on-site residents (a)	1E-03	30	RDX, arsenic and beryllium accounting for the majority of the carcinogenic risk. 1,3,5-TNB accounting for the majority of the noncarcinogenic risk. Chromium also contributed significantly to noncarcinogenic risk. Sources in Area 12 may be contributing to explosive and inorganic contaminants.
Hypothetical ingestion of groundwater in Area 14 by future on-site residents (a)	1E-03	3	Arsenic accounting for the majority of the carcinogenic risk. Chromium contributed significantly to noncarcinogenic risk. The sludge disposal area in Area 14B may be a source of these compounds. Bis(2-ethylhexyl)phthalate contributed to the carcinogenic risk, but its presence may be due to lab or field contamination.
Hypothetical ingestion of groundwater in Area 16 by future on-site residents (a)	8E-04	2	Vinyl chloride, arsenic and beryllium accounting for the majority of the carcinogenic risk. Disposal areas in Area 16B and 16C and the abandoned landfill may be potential source areas for these chemicals. No chemical-specific CDI:RfD ratios exceeded a value of one.
Hypothetical ingestion of groundwater in Area 17 by future on-site residents (a)	2E-03	400	Several VOCs and arsenic accounting for the majority of the carcinogenic risk. trans-1,2-Dichloroethene and trichloroethene accounting for the majority of the noncarcinogenic risk. The highest CDI:RfD ratio of 400 was due to trans-1,2-dichloroethene. The solvent pits in Area 17B were identified as sources for VOC contamination. Area 17 was not used for disposing inorganics, therefore arsenic contamination may be due to an upgradient source.
Hypothetical ingestion of groundwater in Area 18 by future on-site residents (a)	6E-03	0.8	The PAH chrysene accounting for the majority of the carcinogenic risk. The CPF used for chrysene was based on the toxicity of the potent PAH, benzo(a)pyrene, since there is no available CPF for chrysene. The source of chrysene is unknown. No CDI:RfD ratios exceeded a value of one.

(a) Exposure to on-site facility workers would be approximately three times below that of exposure to on-site residents based upon available exposure assumptions.

trichloroethene were the only suspected carcinogenic VOCs in the treated production well water. 1,1,1-Trichloroethane, which was the only VOC with an inhalation RfD., had a CDI:RfD ratio well below one.

- Hypothetical ingestion of untreated groundwater from the production wells by on-site residents yielded total excess lifetime cancer risks of approximately 10^{-3} for the RME case. Vinyl chloride and arsenic were the chemicals primarily driving the risk. Vinyl chloride was detected only in production well 17FF, while arsenic was detected in several production wells across the site. The hazard indices for the RME case was below a value of one. It should be noted that the LCAAP plant currently treats the production well groundwater, and therefore these risks are only applicable if the current treatment system is not used. These estimated risks can be used to indicate the need for continued treatment of production water at LCAAP. Based on available exposure assumptions, it should be noted that potential risks of exposure to facility workers from this pathway would be approximately three times lower than the risks to on-site residents.

- Hypothetical ingestion of untreated groundwater by on-site residents using groundwater from the production well capture zone yielded a total excess lifetime cancer risk of approximately 10^{-3} for the RME case. Chrysene, vinyl chloride, arsenic, and beryllium were comprising the majority of the risk. Similar carcinogenic risks were found for both the production wells and capture zone production wells. This may indicate that there may be no increased risk to ingestion of production well water even if all of the groundwater currently downgradient of potential source areas was drawn into the production wells. The hazard index for the RME case was 2. It should be noted that the LCAAP plant currently treats the production well groundwater, and therefore these risks are only applicable if the current treatment system is not used. Based on available exposure assumptions, hypothetical risks of exposure to facility workers from this pathway would be approximately three times lower than the risks to on-site residents.

- Ingestion of groundwater by residents in off-site areas using residential wells Hedrickj-A, Turley, and Ure, each yielded carcinogenic risks of approximately 10^{-5}. Carbon tetrachloride, 1,4-dichlorobenzene, RDX, and trichloroethene were the only carcinogenic chemicals of potential concern detected in the off-site wells located along the northern LCAAP boundary. Ingestion of groundwater by residents in the off-site area near Area 17 yielded the highest hazard indices of all off-site wells (0.6 for the RME case). No hazard index was greater than one for any of the off-site residential wells sampled.

- Inhalation of VOCs by off-site residents showering with groundwater from the Ure well yielded a carcinogenic risk of approximately 10^{-5}. None of the other residential wells were found to contain carcinogenic VOCs. The Ure well and the well north of Area 17 were the only residential wells found to contain VOCs with potential noncarcinogenic effects. The hazard indices for both of these wells were well below one.

- Hypothetical ingestion of groundwater located along the western border of the plant (residential wells are located beyond the western border of the plant) yielded an excess lifetime cancer risk of 10^{-3}. Arsenic and beryllium accounted for the majority of the risk for the RME case. The hazard index for the RME case was 2. Antimony and arsenic accounted for the majority of the noncarcinogenic risk for the RME case. Several source areas within Areas 3 and 8 may be contributing to the contamination of the chemicals that significantly contributed to these risks. It should be noted that the potential dilution and degradation of chemicals of potential concern during off-site migration of this perimeter groundwater was not considered, and thus the risks presented for this pathway most likely presents upperbound preliminary estimates of potential exposure for off-site residents.

- Section 5.5.2.2 presents in detail the estimated hypothetical risks from ingestion of groundwater by on-site residents from wells that in the future may be installed downgradient of each study area. Although such use of groundwater in this area is considered highly unlikely they were evaluated for the following reasons: (1) evaluation of the potential degradation of groundwater as a potential resource in each study area; (2) identification of specific sources that may be contributing significantly to groundwater chemicals that are driving the risk assessment. In general, total excess lifetime cancer risks for the RME case ranged from 10^{-2} to 10^{-4}, with the risk for most areas at 10^{-3}. Often arsenic accounted for the majority of the cancer risk in the different study areas. For certain areas, chemicals of potential concern that were significantly contributing to the cancer risks include beryllium, bis(2-ethylhexyl)phthalate, RDX, trichloroethene, and vinyl chloride. The hazard indices for the RME case exceeded one in all of the sixteen areas with the exception of Area 6 and Area 18. In areas where the hazard indices exceeded a value of one, the values ranged from 2 (from Areas 11 and 16) to 400 (from Area 17). Chemicals of potential concern with CDI:RfD ratios that exceeded a value of one include: antimony, arsenic, barium, bis(2-ethylhexyl)phthalate, cadmium, chromium, trans-1,2-dichloroethene, RDX, 1,3,5-TNB, and trichloroethene. Potential source areas that may be significantly contributing to groundwater chemicals that are contributing to the risk assessment are discussed in detail in Section 5.5.2.2. Based on available exposure assumptions, hypothetical risks of exposure to facility workers from this pathway would be approximately three times lower than hypothetical risks to on-site residents.

- Volatile chemicals present in tap water may also be emitted into indoor air, for example as a result of showering, laundering, and dishwashing.

In this assessment, these risks have only been quantified for the current residential pathways (on- and off-site) due to the large number of groundwater scenarios evaluated. The on- and off-site residential scenarios, which are discussed above, were selected for quantification as they represent the true current use of treated production well water and residential well water, respectively. Under the other scenarios involving the use of groundwater containing volatile chemicals for water supply, the contribution of this pathway to risks can be quantitatively assessed as follows. Studies have shown that exposures through inhalation of vapors emitted from water containing volatilize chemicals may be associated with risks similar to those associated with direct ingestion (Foster and Chrostowski 1987). Therefore, the risks presented above for the groundwater ingestion scenarios may be slightly higher due to showering, laundering, etc. However, the risks would not be altered by more than an order of magnitude.

5.8.4 Environmental Assessment

Absolute conclusions regarding the potential environmental impacts of the chemicals of concern at LCAAP cannot be made because there are a number of uncertainties associated with the estimates of toxicity and exposure and these should be noted when reviewing the conclusions for the LCAAP study areas.

However, given the available data and limitations the general conclusions regarding the potential for environmental impacts are summarized below.

Plants. In the one area evaluated for toxicity to plants (Area 13), no adverse effects to plants are expected. Although the levels of arsenic and chromium exceed the plant-TRVs, grass species in the vicinity of Area 13 do not appear to be adversely affected.

Terrestrial Wildlife. No adverse effects to terrestrial wildlife are expected from ingestion of surface water in site ditches. However, rabbits that ingest surface water from the Area 16 seep may experience adverse chronic effects from exposure to high levels of phenol. Sufficient toxicity information was not available for mammals for chloroethane and HMX and therefore potential risk from exposure to these chemicals could not be evaluated. Toxicity information was not available for birds for benzene, beryllium, bis(2-ethylhexyl)phthalate, chloroethane, 1,1-dichloroethane, ethylbenzene, HMX, methylene chloride, tetrachloroethene, toluene, selenium, trans-1,2-dichloroethene, trichloroethene, and 1,3,5-TNB. Therefore, the potential risks to birds from exposure to these chemicals could not be further evaluated. No adverse effects are expected to wildlife consuming soil organisms that may bioaccumulate contaminants in soil. However, earthworm bioconcentration factors were not available for arsenic and barium, thus potential risks from exposure to these chemicals could not be evaluated, although arsenic and barium in the food of birds and mammals does not bioaccumulate and is readily excreted.

Aquatic Organisms. The measured concentrations of copper, silver, and zinc in Ditch A exceed the chronic AWQCs. In Ditch B, the levels of bis(2-ethylhexyl)phthalate, copper, lead, selenium, and zinc exceed the chronic AWQCs. The level of zinc in Big Ditch is greater than the chronic AWQC. Thus, potential adverse chronic effects to some species of aquatic organisms could occur from exposure to these chemicals at the measured concentrations. The measured concentrations of zinc (in all three ditches) exceed the acute AWQC by two to four times and thus adverse acute effects could occur in sensitive aquatic organisms such as microcrustaceans (such as *Daphnia magna*) and some species of juvenile fish. Concentrations in sediments were not evaluated because interim sediment quality criteria were not available for the chemicals of concern. In evaluating these results it should be noted that these on-site ditches have not been classified by the State of Missouri and the relevance of AWQC to these water bodies is questionable. Potential impacts to aquatic organisms downstream of the sampling points in classified water bodies would be reduced as the chemical concentrations decline as a result of dilution and any transformation processes that may occur.

5.8.5 Data Gaps

The following data gaps have been identified based on the analysis presented in this assessment.

- In order to evaluate all of the potential sources of groundwater contamination, surface soil and subsurface soil samples need to be collected in the source areas identified in Section 4 of the RI, within each of the study areas that were not sampled for these media during the RI. Given the relatively high levels of barium and lead found in Area 15 subsurface soil and the lack of groundwater monitoring data in Area 15, the impact of this sampled potential source area on groundwater cannot be evaluated at this time. Therefore, groundwater sampling downgradient of the surface impoundment in Area 15 may be warranted.

  Soil contamination also needs to be fully characterized in order to assess potential impacts of any future construction activities that might occur in source areas.

- Groundwater monitoring data collected along the perimeter of the facility were used to preliminarily estimate exposure from ingesting groundwater from residential wells located beyond the western property lines of the LCAAP site. Installation of additional monitoring wells at and beyond the northern and western boundaries of the LCAAP site could further define the extent of the contaminant migration.

- As discussed in Section 5.6, concentrations of chemicals of potential concern found in surface water on-site were compared with AWQC to preliminarily assess the potential impacts on aquatic life further downstream and off-site. Since creeks further downgradient may be large enough to support aquatic life, sampling these water bodies would enable a more accurate assessment of potential impacts of site contaminants on aquatic life to be made.

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Preliminary Evaluation of Remedial Technologies

SECTION 6

PRELIMINARY EVALUATION OF REMEDIAL TECHNOLOGIES

6.1 PURPOSE

The purpose of this section is to identify a broad range of remedial technologies for contaminated media at LCAAP. The objective of these technologies is to decontaminate or stabilize the contaminated materials in order to protect human health and the environment. The broad range of selected technologies will ultimately be developed into alternatives, and the selected alternative(s) will implement permanent solutions to the extent practicable. In this section, a preliminary evaluation of remedial technologies is conducted. The development and selection of remedial alternatives will not be performed at this time. The technologies identified are based on information presented in this report. Additional technologies may be included when further characterization of the sites is completed and when the feasibility study is performed. The future development of technologies will be in accordance with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) and the Superfund Amendments and Reauthorization Act (SARA).

6.2 GENERAL REMEDIAL RESPONSE ACTION

Section 121 of SARA identifies a strong statutory preference for remedies that are highly reliable and provide long-term protection. In addition to the principal requirements that a selected remedy be protective of human health and the environment and be cost-effective, other selection criteria include the following:

- Preferred remedial actions are those in which the principal element is treatment to permanently or significantly reduce the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants.
- Where practical treatment technologies are available, off-site transport and disposal without treatment is the least favored alternative
- Permanent solutions and alternative treatment technologies or resource recovery technologies should be assessed and used to the maximum extent practicable.

The following discussion provides a general overview of the technologies that could be used to protect public health and the environment, based on the current understanding of the LCAAP wastes and on the potential for population exposure. During the feasibility study, additional technologies may be identified and evaluated. The discussion is divided into two general categories as prescribed in the NCP: source control response actions and migration control response actions.

6.2.1 Source Control Response Actions

Source control response actions are aimed at protecting public health and the environment by altering the nature of the source (i.e., the organic, and/or inorganic hazardous constituents in the waste) to reduce the toxicity, mobility, and/or volume of its constituents, thereby limiting the potential for exposure to contaminants via the pathways described in Section 5. Potential source control response actions include no action, access restrictions, removal, reprocessing/treatment, temporary storage, and disposal.

Access Restrictions

Access restrictions involve the use of physical barriers (e.g., fences) and/or institutional controls (e.g., deed restrictions and condemnation of property) to reduce the potential for public exposure to contaminated materials. These restrictions, in and of themselves, are not typically effective in terms of protecting public health and the environment. Therefore, access restrictions are usually implemented in conjunction with other source control response actions.

Removal

Removal of contaminated materials may involve decontamination, demolition, and/or excavation. Decontamination and demolition actions generally refer to contaminated structures, and as such, are not applied to the waste sites currently identified at LCAAP. Excavation involves removing contaminated soil and hauling it to a designated area for disposal. Excavation technology is reliable, can be easily implemented with common construction equipment, and can be extremely effective means of removing contaminated materials. Removal of contaminated liquids, e.g., surface water or groundwater, by mechanical means, such as pumping, may be more difficult to implement but is technically feasible. Removed materials can then be treated and/or disposed on-site or off-site.

Reprocessing/Treatment

Reprocessing/treatment includes a wide range of treatment technologies which can be implemented for contaminated liquids, sludges, and soils. Treatment technologies can be divided into three general categories:

- On-site treatment of the waste matrix without removing the waste from the site.
- Off-site treatment at an approved RCRA facility.

- In-situ treatment, providing in-place treatment.

Hazardous waste treatment can be accomplished within the above categories by chemical, physical, and/or biological technologies.

Chemical treatment technologies are used to alter the nature of the hazardous chemical constituents and can affect waste toxicity, mobility, and/or volume. When radioactive contaminants are also present, a chemical extraction or leaching process can be used to remove the radioactive components from the waste matrix to reduce the volume and/or mobility of contaminants. The liquid leachate can then be reprocessed to recover the radioactive components. Chemical treatment of liquid wastes can involve precipitation, coagulation, adsorption, ion exchange, or oxidation/reduction techniques.

Physical treatment technologies are used to alter the structure of the waste constituents to facilitate stabilization and disposal. Physical treatment can reduce toxicity, mobility, and/or volume of contaminated liquids, sludges, or soils. Contaminated liquids at the site could be treated by sedimentation, granular media filtration, microscreening, air stripping, steam stripping, or vapor distillation. Contaminated sludges (e.g., in ponds and pits) could be treated by dewatering technologies such as centrifugation, pressure, or vacuum filtration, horizontal belt filtration, screening, drying beds, or gravity thickening. Three classes of physical treatment technologies that could be considered for contaminated soils and dewatered sludges are incineration, stabilization, and separation.

Biological treatment or bioreclamation is a technique for treating zones of contamination by microbial degradation. The basic concept involves altering environmental conditions to enhance microbial catabolism or cometabolism of organic contaminants, resulting in the breakdown and detoxification of those contaminants. The technology has been developed rapidly over recent years, and bioreclamation appears to be one of the most promising of the in-situ treatment techniques.

Microbial metabolic activity can be classified into three main categories: aerobic respiration, in which oxygen is required as a terminal electron acceptor; anaerobic respiration, in which sulfate or nitrate serves as a terminal electron acceptor; and fermentation, in which the microorganism rids itself of excess electrons by exuding reduced organic compounds. Depending upon the nature of the contaminant and its ability to be biologically degraded, appropriate metabolic categories and associated technologies identified could be the powdered activated carbon treatment, (PACT), rotating biological contactors (RBC), activated sludge processes or extended aeration systems. The selection of a particular system should be based on pilot plant and bench-scale studies.

Temporary Storage

Temporary storage is the isolation of contaminated material in a manner designed to protect public health and the environment until a permanent disposal option becomes available. Temporary storage can involve the placement of contaminated material on an engineered pad and covering the material with a synthetic membrane, clay cap, or other protective layer. Temporary storage can also be achieved by placing the contaminated material in an existing engineered structure or in a structure newly constructed for containment purposes.

Disposal

Disposal involves the placement of contaminated material in a confined environment for permanent disposition. This can be an extremely effective means of reducing waste mobility and the associated potential for population exposure. Disposal locations for the large volumes of low-specific-activity wastes, resulting from excavation or treatment residues, can potentially be either on-site or off-site.

On-site disposal would entail disposing of the LCAAP wastes in a facility designed in accordance with all ARARs. This appears to be a technically feasible source control response action. Off-site (land-based) disposal is also technically feasible; however, due to the RCRA land ban regulations, it may be difficult to implement the technology for solvent-contaminated waste.

6.2.2 Migration Control Response Actions

Migration control response actions are designed to mitigate exposure of the population to contaminants that are transported via any of the pathways described in Section 5. An additional objective of migration control measures is to limit activities that could disturb the waste and result in the migration of contaminated materials present at the LCAAP. Potential migration control response actions include no action, access restrictions, and containment/treatment.

Access Restrictions

Access restrictions involve the use of physical barriers (e.g., fences) and/or the implementation of institutional controls (e.g., deed restrictions and condemnation of property). These methods could be used to reduce contaminant migration by human or animal activities and to limit exposure to off-site areas where contamination has already migrated. Access restrictions are not effective in reducing the impact of environmental factors (e.g., wind and precipitation) on contaminant migration. In general, access restrictions may not serve as a reliable means of protecting public health and the environment in the absence of other supporting response actions.

Containment/Treatment

Containment/treatment involves the use of media-specific technologies for migration control. The purpose of containment, which can involve containment of contaminated material within an engineered structure or in-situ, is to reduce contaminant migration and, therefore, the potential exposure of the population. Containment technologies, in and of themselves, do not reduce waste toxicity or volume.

Media-specific containment technologies for migration control include:

- Air — capping, in conjunction with pipe and trench vents, with treatment of vented air.
- Soil — excavation/containment, liners, isolation (e.g., in-situ), and stabilization via vegetation.
- Sludges/Sediment — excavation/containment, liners, isolation (e.g., in-situ), and stabilization via vegetation.
- Surface water — dikes, terraces, channels, downpipes, grading, and surface seals (with containment of runoff).
- Groundwater — slurry/cutoff walls, grout curtains, subsurface drains/other leachate containment systems, and groundwater pumping.

When used in conjunction with containment technologies, media-specific treatment technologies for migration control may reduce waste volume as well as toxicity and mobility. Media-specific treatment technologies for migration control include:

- Air — carbon adsorption or thermal treatment of vented air.
- Soil — excavation/dewatering and encapsulation (e.g., vitrification, stabilization).
- Sludges/Sediment — excavation/dewatering and encapsulation (e.g., vitrification, stabilization).
- Surface water — runoff collection (e.g., with dikes or channels) in conjunction with physical/chemical/biological treatment systems.

- Groundwater — groundwater pumping/leachate collection in conjunction with physical/chemical/biological treatment systems.

Within each general response action identified in Sections 6.2.1 and 6.2.2, several remedial action technologies can be identified to remediate the site contaminated media, which are groundwater, soils, surface water, and sediments. The applicable general response actions, as they would apply for each contaminated media, are listed in Table 6-1. A combination of these general response actions would be used to meet the remedial action goals.

A summary of the applicable general response action technologies is presented in Table 6-2.

6.3 REMEDIAL ACTION TECHNOLOGIES

For each of the general response action technologies, specific remedial technologies were identified. Additional technologies that may be appropriate for the proposed action will be identified and evaluated as per SARA requirements during the feasibility study process.

For the purpose of the present scope of work, the identified technologies are categorized and assessed according to the following five categories as recommended by the current NCP.

- No action.
- Alternatives for treatment or disposal at an off-site facility, as appropriate.
- Alternatives that attain applicable or relevant and appropriate federal public health and environmental requirements.
- Alternatives that exceed applicable or relevant and appropriate federal public health and environmental requirements.
- Alternatives that do not attain applicable or relevant and appropriate public health and environmental requirements but will reduce the likelihood of present or future threat from the hazardous substances and that will provide significant protection to public health and welfare and the environment. This must include an alternative that closely approaches the level of protection provided by the applicable or relevant and appropriate requirements.

TABLE 6-1

GENERAL RESPONSE ACTIONS

Contaminated Media	General Response Action
Soils	Access Restriction Removal Reprocessing/Treatment Temporary Storage Disposal Containment/Treatment
Sludges/Sediments	Access Restriction Removal Reprocessing/Treatment Temporary Storage Disposal Containment/Treatment
Surface Water	Access Restriction Removal Reprocessing/Treatment Temporary Storage Disposal Containment/Treatment
Groundwater	Access Restriction Removal Reprocessing/Treatment Temporary Storage Disposal Containment/Treatment

TABLE 6-2

SUMMARY OF GENERAL RESPONSE ACTION TECHNOLOGIES

Response Action	Source Control Technology	Type of Contamination	Comments
Access Restrictions	Physical barriers	Soils, sludges, bulk wastes, surface water, groundwater	Temporarily limits exposure to migrated contaminants. Limits land use.
	Institutional controls; Deed restrictions	Soils, sludges, bulk wastes, surface water groundwater	Temporarily limits exposure to migrated contaminants. Limits land use.
	Condemnation	Property	Temporarily limits exposure to migrated contaminants. Limits land use.
Removal	Excavation	Soils, bulk	Reduces exposure to chemical contaminants; allows unrestricted use of area. Requires storage or disposal facility and access restrictions during excavation.
	Decontamination	Structural surfaces	Reduces exposure to chemical contaminants; allows unrestricted use of area. Requires storage or disposal facility and access restrictions during decontamination.
	Demolition	Structures	Reduces exposure to chemical contaminants; allows unrestricted use of area. Requires storage or disposal facility and access restrictions during demolition.
	Pumping	Surface water	Reduces exposure to chemical contaminants; allows subsequent treatment. Requires containment/treatment facility and access restrictions during treatment.
Reprocessing/Treatment	Chemical treatment Leaching/ Extraction	Soils, bulk waste	Reduces exposure to chemical contaminants; may reduce toxicity, mobility, or volume of waste constituents; allows unrestricted use of treated area. May require bench-scale testing; requires treatment facility and access restrictions during treatment.

TABLE 6-2 (CONTINUED)

SUMMARY OF GENERAL RESPONSE ACTION TECHNOLOGIES

Response Action	Source Control Technology	Type of Contamination	Comments
Reprocessing/Treatment Cont.	Precipitation, coagulation, adsorption, ion exchange, lime softening, etc.	Surface water, groundwater	May reduce toxicity, mobility, or volume; allows unrestricted use of treated area. May require bench-scale testing; requires treatment facility and access restrictions during treatment.
	Physical Treatment		
	Sedimentation, filtraction, vapor recompression/distillation, air/steam stripping	Surface water, groundwater	May reduce waste toxicity, mobility, or volume. May require bench-scale testing; requires treatment facility and access restrictions during treatment.
	Dewatering	Sludges	May reduce waste mobility, or volume; allows unrestricted use of treated area. May require bench-scale use of treated area. Requires treatment facility and access restrictions during treatment.
	Incineration	Soils, sludges	Destroys organic contaminants. Not effective for metals. Disposal of ash a key concern.
	Stabilization	Soils, sludges	May reduce waste mobility. Limits future land use; requires treatment facility and access restrictions during treatment.
	Sand sifting	Soils, bulk wastes	Reduces waste volume. Suitability of process for alluvial materials is unknown. Requires further testing and development; requires access restrictions during treatment.
	Paramagnetic separation, soil sorting, selective mineral separation	Soils, bulk wastes, dewatered sludges	Reduces waste volume; may allow unrestricted use of treated area. Requires further testing and development; requires access restrictions during treatment.

TABLE 6-2 (CONTINUED)

SUMMARY OF GENERAL RESPONSE ACTION TECHNOLOGIES

Response Action	Source Control Technology	Type of Contamination	Comments
	Biological Treatment		
	Activated sludge, trickling filters, surface impoundments, in-situ.	Surface water, groundwater	May reduce waste toxicity, mobility, or volume. Requires treatment facility and/or area; may require bench-scale testing and access restrictions during treatment.
Temporary Storage	On-site	Soils, sludges, bulk wastes, liquids	Reduces waste mobility and exposure to chemical contaminants while a more permanent remedy is being developed. Limits future land use; requires storage facility (outdoor area or engineered structure) and access restrictions during storage.
	Off-site	Soils, sludges, bulk wastes, liquids	An off-site temporary storage facility would probably not be available for several years.
Disposal	On-site	Soils, sludges, bulk wastes, liquids	Reduces waste mobility and exposure to chemical contaminants. Limits future land use; requires specific siting and construction of disposal facility and access restrictions during the long term.
	Off-site	Soils, sludges, bulk wastes, liquids	Reduces waste mobility and exposure to chemical contaminants; allow unrestricted use of decontaminated area. Requires siting and construction of a disposal facility and access restrictions at the facility for the long term. (Disposal site not currently available.)
	Ocean disposal	Soils, sludges, bulk wastes, liquids	Not currently available and may not be available within a reasonable time. Transportation to the ocean port would be expensive.
Containment/treatment	Engineered system or in-situ	Soils, sludges, bulk wastes, surface water, groundwater	Reduces waste mobility and, in conjunction with treatment, may also reduce waste toxicity or volume. Requires containment/treatment system(s); may require access restructions during containment/treatment period.

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Section 105 of SARA requires the President (who subsequently delegated this responsibility to the U.S. EPA) to propose amendments to the NCP by 17 April 1988. The U.S EPA is currently drafting a revision to the NCP in response to this requirement. The revised NCP has not yet been issued in final form. Nonetheless, the identification of categories for remedial action alternatives that are recommended by the U.S. EPA in its proposed revisions will also be considered in the current evaluation, in the interest of addressing those requirements that may be promulgated before the proposed remedial actions are complete. These categories are:

- No action.
- Containment (migration control) or institutional controls -- involving little or no treatment, but protective of human health and the environment by causing a reduction in waste mobility and related exposure risks.
- Treatment (source control) with disposal of the remaining wastes either on-site or off-site -- ranging from (a) treatment as the principal element of the alternative, to reduce the principal threat(s) posed by a site (i.e., may not involve the highest degree of treatment or treatment of all wastes) to (b) treatment that will minimize the need for long-term management of the wastes (including monitoring).

On the basis of the technologies available, the following general remedial action alternatives have been identified;

- No action.
- On-site disposal.
- Off-site disposal.
- On-site treatment with on-site disposal.
- On-site treatment with off-site disposal.
- Off-site treatment with off-site disposal.

These alternatives address the chemically contaminated media, such as soils, sludges, and water. They represent a wide range of remedial actions, from no action to treatment and disposal. The following descriptions of the general remedial action alternatives include a variety of engineering options that could be implemented, either singly or in various combinations. The technologies and their specific categories by media are listed in Table 6-3.

No Action

The no-action alternative provides a baseline for comparison to other alternatives. If this option were selected, there would be no reduction in the toxicity, mobility, or volume of the contaminated materials. The potential for human exposure to

TABLE 6-3

APPLICABLE REMEDIAL TECHNOLOGIES

Environmental Media	Remedial Response Action	Available Remedial Technology
Groundwater/Surface Water	No Action:	None
	Institutional Controls:	Land Use/Deed Restrictions Surface Water Monitoring
	Containment:	Capping: Single Layer Cap Synthethic Membrane Asphalt Concrete Clay Multi-media
		Vertical Barriers: Slurry Walls Vibrating Beam Grout Curtains Sheet Metal Piling Concrete Wall Berms and Dikes
		Horizontal Barriers: Surface Contouring
	Collection:	Pumping Interceptor Drains
	Treatment:	
	In-situ	Microbial Degradation Limestone Treatment Bed Activated Carbon Bed Chemical Treatment Solar Treatment
	Off-site	Publicly Owned Treatment Works (POTW) RCRA Facility
	On-site	Biological Treatment Coagulation/Sedimentation Dissolved Air Flotation Activated Alumina Ion Exchange Reverse Osmosis Air Stripping Steam Stripping Solvent Extraction Oxidation/Reduction Filtration Gravity Concentration Carbon Adsorption
	Disposal:	Off-site Disposal into POTW

TABLE 6-3 (CONT.)

APPLICABLE REMEDIAL TECHNOLOGIES

Environmental Media	Remedial Response Action	Available Remedial Technology
Soil	No Action:	None
	Institutional Controls:	Access and Deed Restrictions Site Fencing Monitoring Surface Runoff
	Diversion:	Surface Controls: Grading Revegetation Soil Cover
	Containment:	Capping: Synthetic Membrane Clay Asphalt Concrete Multilayer
		Vertical Barriers: Slurry Walls Vibrating Beam Grout Curtain Sheet Metal Piling Concrete Wall Berms and Dikes
	Removal:	Excavation
	Treatment:	
	On-site	Classification Gravity Concentration Incineration Chemical Detoxification Fixation/Stabilization Solvent Extraction (soil washing) Screening Flotation
	In-situ	Microbial Degradation Chemical Detoxification Soil Aeration Solution Mining Vitrification (modified) Solidification/Immobilization
	Off-site	Incineration

TABLE 6-3 (CONT.)

APPLICABLE REMEDIAL TECHNOLOGIES

Environmental Media	Remedial Response Action	Available Remedial Technology
Soil (Continued)	Disposal:	
	On-site	RCRA Landfill Land Encapsulation
	Off-site	RCRA Landfill
	Temporary Storage:	
	On-site	Storage Facility
	Off-site	Storage Facility
Sediment/Sludge	No Action:	None
	Institutional: Controls	Access and Deed Restrictions Site Fencing
	Diversion:	Surface Controls: Grading Revegetation Soil Cover Realignment of Stream
	Containment:	Capping: Synthetic Membrane Clay Asphalt Concrete Multilayer
		Vertical Barriers: Slurry Walls Vibrating Beam Grout Curtains Sheet Metal Piling Concrete Wall Berms and Dikes
	Removal:	Dredging
	Treatment:	
	On-site	Gravity Concentration Incineration Chemical Detoxification Fixation/Stabilization Screening Attenuation

TABLE 6-3 (CONT.)

APPLICABLE REMEDIAL TECHNOLOGIES

Environmental Media	Remedial Response Action	Available Remedial Technology
Sediment/Sludge (Continued)		Flotation Dewatering/Drying Centrifugation Gravity Concentration Filtration
	In-situ	Microbial Degradation Chemical Detoxification Soil Vapor Extraction Solution Mining Vitrification
	Off-site	RCRA Facility
	Disposal:	
	On-site	RCRA Landfill
	Off-site	RCRA Landfill
	Temporary Storage:	
	On-site	Interim Storage Facility
	Off-site	Interim Storage Facility

radioactive and chemical contaminants would probably continue for the short term at the levels presented in the baseline risk assessment. However, as off-site migration continues, long-term exposure would likely increase -- in terms of both levels of exposure and size of the potentially affected population. These exposures could become quite large if changes in land use near the LCAAP site were to occur. Redevelopment of the site could also result in the uncontrolled release of contaminated materials.

On-Site Disposal

On-site disposal would reduce waste mobility. Implementation of this alternative would involve a determination of site suitability and the construction of an on-site disposal facility. After closure of the facility, monitoring and maintenance activities would be performed as needed. These activities would include periodic inspection of the cover, environmental monitoring, and security precautions. Permanent access restrictions and other institutional controls would be required to protect public health. A buffer zone would be created between the disposal facility and surrounding areas.

Off-Site Disposal

Off-site disposal would reduce waste mobility. Implementation of this alternative would involve the siting and construction of an off-site disposal facility for the LCAAP wastes. Once an off-site disposal facility became available, the removal, transport, and disposal of the wastes from the LCAAP site could be implemented. Other considerations applicable to on-site disposal would also apply to off-site disposal.

On-Site Treatment with On-Site Disposal

On-site treatment with on-site disposal would reduce the mobility and could reduce the toxicity and/or volume of the contaminated materials. This alternative would involve many of the same issues as the on-site disposal alternative. In addition, treatment systems for the various forms of contaminated materials would have to be constructed and operated on site, and access restrictions would be required during treatment operations. If this alternative were selected, contaminated surface water, groundwater, soils, and sludges would be treated and subsequently disposed of with all activities occurring on-site.

On-Site Treatment with Off-Site Disposal

On-site treatment with off-site disposal would reduce the mobility and could reduce the toxicity and/or volume of the contaminated materials. This alternative would involve the same issues that are addressed for the previous alternative.

Off-Site Treatment with Off-Site Disposal

Off-site treatment with off-site disposal would reduce the mobility and could reduce the toxicity and/or volume of the contaminated materials. This alternative would involve the same issues related to the off-site disposal alternative, plus the identification of an off-site treatment facilities.

Conclusions and Recommendations

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

The Remedial Investigation at LCAAP was designed to:

- Evaluate and characterize the possible sources, pathways, and extent of the contamination.
- Define the risk that the contamination poses to the environment, the plant, and the general public.
- Begin initial studies for remedial action.

The findings of the investigation have resulted in different levels of understanding of these issues at each of the 18 study areas, and plant-wide at LCAAP. The following subsections itemize and discuss conclusions and recommendations based on the following issues:

- Source characterization.
- Pathway characterization.
- Extent of contamination.

The results of the RI at LCAAP have been presented and discussed in previous sections of this report. Recommendations for additional study are based upon needs for further characterization of sources, pathways, and contamination extent. If the problem has been adequately defined for a site, data requirements for remedial action or screened technologies may be addressed. In addition, recommendations are proposed for data requirements dealing with plant-wide issues. Conclusions regarding the endangerment assessment are discussed in Sections 5.66 and 7.22 of this report, and in the Executive Summary Section.

7.1 AREA 1 - BUILDING 83 WASTEWATER LAGOONS

7.1.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 1.

Source Characterization

- The actual physical extent of the surface impoundments has not been adequately defined. The depths of the various impoundments remain unknown, as does the existence of the potential fourth impoundment in Area 1B.
- Soils within, beneath, and adjacent to the surface impoundments have not been characterized for contaminants.

- One or more additional source areas may exist, as indicated by significant explosive compound and/or inorganic detections in sidegradient and upgradient groundwater samples (1-7, 1-7A, and 1-10).

Pathway Characterization

- Groundwater flows northeast at Area 1, although local directional variations may be present due to topographical controls.
- The Big Ditch transverses the upgradient perimeter of the area and probably receives some surface water runoff.
- Surficial drainage pathways through culverts and swales were not sampled.

Extent of Contamination

The following organic compounds were identified in the groundwater at Area 1. The inorganic constituents shown exceeded ARARs:

Explosives	VOC	BNA	Inorganics
RDX	111TCE	Pyrene	Arsenic
Tetryl	11DCLE	Di-n-octylphthalate	Barium
		Bis(2-ethylhexyl)-phthalate	Beryllium
			Cadmium
			Chromium
			Lead
			Nickel

- Upgradient and sidegradient groundwater samples indicate that unknown sources may exist south and/or southwest of the present monitoring well network. Sidegradient and downgradient well locations detected explosives, VOCs, BNAs and inorganic contamination.
- Monitoring well 1-9, the furthest downgradient well, contained explosives and high inorganics concentrations. From this result, it is evident that contaminated groundwater from Area 1 probably affects Area 2 groundwater quality.

7.1.2 Recommendations for Area 1

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 1.

Source Characterization

- Observations made during the field investigation indicate that at least one additional source location may exist and that further review of air photographs and plant drawings may be beneficial. A geophysical survey is also recommended to better define the character of past disposal areas.

- After the geophysical survey is completed, soil borings should be drilled and soil samples collected to determine the types and magnitude of the waste constituents, and to better define the geometry of the source locations.

Pathway Characterization

- Soils within the surface drainage pathways should be analyzed. Potential contaminants may be migrating from Building 83 via drainage ditches and swales.

Extent of Contamination

- The sampling of surface water and sediment from the Building 83 drainage ditches and swales should adequately define the extent of potential surface contamination.

- In order to ensure the accurate characterization of groundwater quality upgradient of the area, a shallow monitoring well should be installed south of the Big Ditch midway between wells 1-4 and 1-5.

- Monitoring wells downgradient of a fourth potential impoundment and downgradient from Building 83 are recommended to further define the extent of groundwater contamination. The precise locations of the new 1989 GWQAP wells should be reviewed as they may satisfy this recommendation.

7.2 AREA 2 - BUILDING 85 WASTEWATER LAGOONS

7.2.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 2.

Source Characterization

- The Area 2B surface impoundments appear to be sources of explosives, VOCs, and inorganic contamination.

- Radial shallow groundwater flow (groundwater mounding) is occurring around the impoundments as shown in Table

B-2 of Appendix B. The shallow water table tends to follow surficial topography, in this case the elevated structure of the impoundments.

- The effects of the Area 2C surface impoundment on groundwater quality remains undefined since there are no downgradient monitoring wells nearby.
- Some groundwater contamination may be originating from Area 1.
- Soils within, beneath, and adjacent to the surface impoundments have not been characterized for contaminant levels.

Pathway Characterization

- Groundwater flows northeast at Area 2, converging with Area 4 groundwater.
- No surficial drainage pathways at Area 2 were sampled. The overflows at Area 2A ultimately drained overland to Ditch A.
- Ditch A is a local groundwater discharge zone, potentially allowing groundwater contamination to reach the surface.

Extent of Contamination

The following organic and inorganic constituents were identified in the groundwater at Area 2. The inorganics shown exceeded ARARs:

Explosives	VOC	BNA	Inorganics
26DNT	Benzene	Bis(2-ethylhexyl) phthalate	Beryllium
RDX	T12DCE		Cadmium
	TRCLE		Chromium
			Nickel
			Selenium

- Contamination extends from the furthest upgradient well location to the furthest downgradient well location.
- Due to the mounding effect created by the impoundments, no representative upgradient monitoring wells may have existed at Area 2 during this RI. The new 1989 GWQAP wells 2-10, 2-11, 2-17, and 2-18 may currently provide upgradient groundwater quality data, however. Area 1 wells are more appropriate to use for upgradient comparisons in this report.

- Groundwater quality at the base of the upper aquifer will be characterized with the recent installation and sampling of new deep monitoring wells at Area 2 in 1989.
- Magnitude and extent of surficial contamination within drainage pathways are unknown.

7.2.2 Recommendations for Area 2

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 2.

Source Characterization

- Sampling of the Area 2B surface impoundments during the 1989-1990 closure operations should adequately characterize the waste constituents present.
- Further review of air photographs and plant drawings should be performed in order to delineate the boundaries of the closed surface impoundment at Area 2C. Records of the 1972 closure should be examined to evaluate any analytical results which may exist. Should data gaps remain, soil borings may be required to assess the impoundment as a potential contaminant source.

Pathway Characterization

- Groundwater flow directions have been adequately defined.
- Surficial contaminant pathways will be defined according to the recommendations proposed in the "Extent of Contamination" section.

Extent of Contamination

- To better define the extent of groundwater contamination downgradient of Area 2, additional wells were installed as part of the GWQAP performed by LCAAP in 1989.
- In order to characterize the extent of surficial contamination, surface soil and sediment samples should be collected at Area 2A and at Ditch A near Area 2 (Figure 4-35).

7.3 AREA 3 - SAND PITS

7.3.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 3.

Source Characterization

- The Area 3 burial sites appear to be contributing explosives, VOCs, and inorganic constituents to the groundwater.
- The exact boundaries and vertical extent of the burial sites remain undefined.
- Unexplained BNA contamination occurs in the Area 3 pond sediments. See Section 7.19.
- Soils beneath and adjacent to the burial sites have not been characterized for contaminants.
- Some contaminated groundwater may be originating at upgradient source areas, including Areas 7, 12, and 14.

Pathway Characterization

- Shallow groundwater flows northwest and deep groundwater flows southwest.
- Vertical gradients are slightly upward, with mostly lateral groundwater flow.
- Surface water recharges the aquifer. Groundwater probably discharges west of LCAAP at the Little Blue River.
- Ditch B and the pond eventually receive most overland drainage from Area 3 (Figure 4-35).
- Sediment samples from the pond contained 11 different BNA compounds, and elevated inorganic concentrations were present in both sediment and pond water.
- Ditch B sediment contains similar BNA and inorganic constituents.

Extent of Contamination

The following organic compounds were identified in the groundwater at Area 3. The inorganic constituents shown exceeded ARARs:

Explosives	VOC	BNA	Inorganics
HMX	T12DCE	Bis(2-ethylhexyl) phthalate	Barium
RDX	TRCLE		Chromium
13DNB	11DCE		Lead
135TNB			
24DNT			

- Groundwater contamination extends across the entire area.
- Contaminated groundwater may potentially be migrating off the site boundary at the west edge of Area 3.
- Groundwater entering Area 3 may have previously been contaminated with various explosives and inorganics from upgradient source areas (Areas 7, 12, and 14).

7.3.2 Recommendations for Area 3

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 3.

Source Characterization

- A review of aerial photographs and plant drawings should be performed in order to identify the number and areal extent of burial sites at Area 3. A geophysical survey may be required should this review be inconclusive.
- Following completion of these tasks, soil borings are recommended at each identified burial site. Soil samples should be collected and analyzed from each soil boring to characterize the types and concentrations of waste constituents.

Pathway Characterization

- In order to better characterize the groundwater flow conditions within the alluvial valley, the northern boundary of the valley should be defined by performing soil borings and a seismic geophysical survey.

Extent of Contamination

- After all of the source areas at Area 3 have been identified, it may be necessary to install and sample additional downgradient monitoring wells along the property boundaries. However, the addition of the 1989 GWQAP wells 3-9 and 3-10 may provide adequate downgradient data.

7.4 AREA 4 - BUILDING 139 (SOUTH) TREATED EXPLOSIVE WASTEWATER SURFACE IMPOUNDMENT AREA

7.4.1 Conclusions

The following conclusions were reached from the Remedial Investigation conducted at Area 4.

Source Characterization

- Prior to closure, the four surface impoundments may have contributed explosives and inorganics to the groundwater.
- Upgradient contaminant sources are likely to exist east of Area 4.

Pathway Characterization

- Groundwater flows northwest, converging with Areas 1 and 2 groundwater.
- The upper aquifer discharges groundwater to portions of Ditch A, west of Area 4.
- Most surface drainage eventually flows to Ditch A.

Extent of Contamination

The following organic compounds were identified in the groundwater at Area 4. The inorganic constituents shown exceeded ARARs:

Explosives	BNA	Inorganics
135TNB	Di-n-octylphthalate	Cadmium
HMX	Bis(2-ethylhexyl)phthalate	Chromium
RDX		Nickel
13DNB		

- Groundwater contamination extends across the entire area.
- Groundwater contamination may potentially discharge to Ditch A. Portions of Ditch A have been characterized as having effluent conditions and thus may be receiving contaminated groundwater discharge.

7.4.2 Recommendations for Area 4

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 4.

Source Characterization

- Details of the surface impoundment closure operations should be reviewed in conjunction with this RI in order to best characterize potential source conditions at Area 4.

- Should data gaps remain concerning the surface impoundment waste characterization, soil borings may be required in order to define chemical and physical conditions.

- Monitoring well 4-6, which was removed during the 1989 GWQAP, detected organic and inorganic contaminants, which are potentially from an unknown upgradient source. Further air photograph and plant drawing interpretations should be performed on the area east of well 4-6.

Pathway Characterization

- Surface and subsurface migration pathways at Area 4 have been adequately defined. Shallow groundwater flow directions are toward Ditch A to the west.

Extent of Contamination

- With the removal of well 4-6, there are no monitoring wells upgradient of Area 4. At least one upgradient monitoring well should be installed east of the area. Downgradient groundwater quality has been adequately defined.

7.5 AREA 5-BUILDING 139 (NORTH) TREATED EXPLOSIVE WASTEWATER SURFACE IMPOUNDMENT AREA

7.5.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 5.

Source Characterization

- The two surface impoundments (Areas 5B and 5C) received wastes containing explosives, VOCs, BNAs, and inorganics.

- The vertical and horizontal extent of the Area 5C closed impoundment remains undefined.

- Soils within, beneath, and adjacent to the Area 5C impoundment have not been characterized for contaminants.

- The Area 5C closed impoundment appears to be a primary source of VOCs (Trans-1,2-dichloroethene and TRCLE) to the groundwater.

- Upgradient sources of explosives and inorganics (possibly Area 6) appear to be impacting groundwater quality at Area 5.

Pathway Characterization

- Shallow groundwater flow at Area 5 is toward the west-northwest.
- Some shallow groundwater probably discharges into Ditch A due to effluent conditions.
- Most overland flow drains to Ditch A.

Extent of Contamination

The following organic compounds were identified in the groundwater at Area 5. The inorganic constituents shown exceeded ARARs:

Explosives	VOCs	BNAs	Inorganics
RDX	11TCE	Bis(2-ethylhexyl) phthalate	Cadmium
	11DCLE		Chromium
	11DCE		Nickel
	Chloroethane		
	T12DCE		
	TCLE		
	Vinyl Chloride		
	Methylene Chloride		

- Groundwater contamination extends across the entire area.
- Ditch A probably receives some contamination both overland and from shallow groundwater discharge. Some of the contamination is transported downstream within Ditch A. Surface water sample SW-11 contained detectable concentrations of HMX (Figure 4-35).
- Most contaminated groundwater migrates northwest and west toward Area 7 and/or south of Area 7.
- Groundwater entering Area 5, especially near the northern portion, is probably contaminated with explosives and inorganics from Area 6 and perhaps Area 10.
- Deep monitoring wells were installed in 1989 at Area 5, providing basal hydrogeology and groundwater chemistry information.

7.5.2 Recommendations for Area 5

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 5.

Source Characterization

- Data collected as part of the 1989 closure of the Area 5B surface impoundment should be reviewed in conjunction with this RI in order to best characterize the waste constituents and their potential for past release into the groundwater.
- In order to characterize the Area 5C closed impoundment, fill material within the impoundment and soil beneath the impoundment should be sampled by drilling a soil boring.
- If the precise location of the Area 5C impoundment cannot be defined through further photographic interpretation, a geophysical survey is recommended to facilitate the placement of the soil boring location.

Pathway Characterization

- The surface and subsurface migration pathways of contaminants from the suspected source areas are sufficiently defined.

Extent of Contamination

- A deep monitoring well was installed as part of the 1989 GWQAP to the top of bedrock downgradient of Area 5 to assess deep groundwater flow from the suspected source areas. Information collected from the drilling and sampling of that well should be reviewed in conjunction with this RI.

7.6 AREA 6 - BUILDING 65 SURFACE IMPOUNDMENT

The following conclusions were reached from the Remedial Investigation at Area 6.

7.6.1 Conclusions

Source Characterization

- Prior to its recent closure, the surface impoundment appears to have been a previous source of explosive and inorganic contamination to the groundwater.
- Area 10 is potentially an upgradient source of explosives (RDX) and inorganics (especially chromium) groundwater contamination.
- Data collected during the RCRA closure operations should be reviewed in conjunction with this RI in order to best

define the environmental impacts of the surface impoundment.

Pathway Characterization

- Groundwater flows west, towards the northern portion of Area 5. The geology within the upper aquifer at Area 6 is well defined, especially with information obtained during the 1989 GWQAP.
- Surficial drainage is principally through roadside ditches which direct flow to Ditch A.

Extent of Contamination

The following organic compounds were identified in the groundwater at Area 6. The inorganic constituents shown exceeded ARARs:

Explosives	BNAs	Inorganics
13DNB	Bis(2-ethylhexyl)phthalate	Barium
24DNT		Chromium
HMX		Lead
RDX		Nickel
Tetryl		

- The groundwater is contaminated across the entire site.
- Most of the higher contaminant concentrations were detected from well 6-3, which is located immediately east of the impoundment. The elevated structure of the previously active surface impoundment may have caused some radial flow due to groundwater mounding. This localized flow condition may have introduced contaminants into the sensing zone of "upgradient" well 6-3.
- Upgradient Area 10 groundwater contamination may affect Area 6 groundwater quality.
- The downgradient extent of groundwater and ditch contamination is well defined with the sampling of wells 6-5 and 6-6, and Ditch A sample locations 10 and 11.
- Ditch A potentially receives some shallow groundwater discharge, and therefore potential source areas within Areas 5, 6 and 10 may be the origin of a detection of HMX in surface water sample SW-11 (Figure 4-35).

7.6.2 Recommendations for Area 6

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 6.

Source Characterization

- Data obtained during the closure of the Area 6A surface impoundment should be reviewed in conjunction with this RI in order to best characterize its potential impacts on the surrounding sampling media.
- Plant drawings and aerial photographs should be reviewed in the vicinity between Areas 6 and 10 to assess the potential for unknown source locations upgradient of monitoring well 6-7.

Pathway Characterization

- The surface and subsurface contaminant migration pathways associated with the Area 6A surface impoundment have been sufficiently defined. Boring logs from 1989 will provide additional information.

Extent of Contamination

- Area 10 is a source of explosive and inorganic groundwater contamination. In order to verify its potential effect on Area 5 and Area 6 groundwater quality, the installation of a shallow monitoring well is proposed midway between Area 6 and Area 10. This well may help explain the presence of explosive and inorganic contamination in upgradient monitoring wells at Area 6.
- The presence of some explosive and inorganic surface water and/or sediment contamination within Ditch A suggests the possibility of further contamination upgradient toward the Area 6A surface impoundment. Additional surface water and sediment samples are recommended from the ditches, culverts, and/or swales leading from the impoundment to the west.

7.7 AREA 7 - INDUSTRIAL WASTEWATER LAGOONS AREA

7.7.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 7.

Source Characterization

The subsurface soil investigation identified the following organic and inorganic constituents. The inorganics shown exceeded statistical background levels:

Explosives	Oil and Grease	Inorganics
26DNT		Arsenic
		Barium
		Beryllium
		Cadmium
		Copper
		Lead
		Mercury
		Zinc

- The vertical and horizontal extent of some suspected source areas remains undefined, especially at the Area 7D closed impoundment.

- Soil contamination within, beneath, and adjacent to various suspected source areas remains undefined.

- Deep groundwater quality within the alluvial valley adjacent to and upgradient of Area 7 previously remained undefined. Additional monitoring wells were installed as part of the 1989 GWQAP. Data gathered from that project have not been incorporated into this RI. Deep groundwater downgradient of Area 7 is contaminated with explosives.

- Multiple sources of contamination exist at Area 7. Areas 7A, 7B, 7D, and 7E may have contributed explosives and inorganics to the groundwater. HMX, RDX, and numerous inorganics concentrations increase downgradient of these areas.

- The storm sewer system (including Ditch 2) located south of Building 1 previously received Building 1 sump wastewater. This discharge could have potentially contaminated the groundwater in the area of Ditch 2 and monitoring well 7-9. Also, the sump outfall at Buildings 97 and 97A (sample locations 21 and 22 in Figure 4-36) has the potential as an explosive and inorganic source area.

Pathway Characterization

- Shallow groundwater flows northwest toward Areas 3 and 12.

- Deep groundwater flows west-southwest. Local variations may occur due to bedrock topography and production well pumping.

- Production wells within Areas 7 and 12 potentially capture most of the contaminated groundwater migrating from Area 7, including both deep and shallow depths.

- Overland flow eventually goes to Ditch 2 and Ditch A (Figure 4-35).

- Intermittent surface water within Ditch 2 and Ditch A recharges the upper aquifer near Area 7 due to the influent conditions (see Figure 3-2).

Extent of Contamination

The following organic compounds were identified in the groundwater at Area 7. The inorganic constituents shown exceeded ARARs:

Explosives	VOCs	BNAs	Inorganics
135TNB	12DCLE	Bis(2-ethylhexyl) phthalate	Chromium
HMX	Chlorobenzene		
RDX	Chloroform		
	Methylene Chloride		
	Ethylbenzene		
	TCLEE		
	Toluene		
	TRCLE		

The following organic and inorganic constituents were identified from ditch sediments collected from Area 7 sump and sump outfall sampling locations. The inorganics shown exceeded statistical background values.

Explosives	Oil and Grease	Inorganics
24DNT		Antimony
RDX		Barium
26DNT		Cadmium
Cyclotetramethylenetetranitramine		Chromium
		Copper
		Lead
		Mercury
		Zinc

- The groundwater is contaminated with explosives and VOCs at downgradient locations, and is contaminated with inorganics across the entire area, including upgradient and downgradient locations.

- Some groundwater contaminants migrating from Area 7 within the shallow aquifer will flow towards Areas 3 and 12. Some of the contaminants migrating in the deep portion of the aquifer may flow north of Area 8. Much of of the Area 7 groundwater is captured by nearby production wells.

- Ditch sediments within Area 7 are contaminated and may migrate downstream during active stream flow.
- Deep groundwater quality was unknown adjacent to and upgradient of Area 7 prior to the 1989 addition of deep monitoring wells as part of the GWQAP.
- Since Ditch 2 and Ditch A are groundwater recharge zones, there is the potential for downward migration of contaminants.

7.7.2 Recommendations for Area 7

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 7.

Source Characterization

- In order to characterize the contamination at all of the potential source areas within Area 7, numerous subsurface soil samples should be collected. Soil borings should be drilled through the closed impoundments at Areas 7B and 7D, through the burning pit at Area 7E, and through the fuel spill area at Area 7C. These soil borings will allow a visual observation of potentially-contaminated soils and the collection of subsurface soils for chemical analysis.
- Aerial photographs should be reviewed in the vicinity of the Area 7D buried impoundment in order to delineate approximate boundaries. A soil boring should then be drilled, as described above.
- Wastewater and sediment samples were analyzed from the active surface impoundment at Area 7A during the 1988 retrofitting program. The results should be interpreted in conjunction with the Area 7 RI.

Pathway Characterization

- The surface and subsurface migration pathways of potential contaminants from the various source areas are moderately well defined. This is especially true with the addition of the new monitoring wells installed as part of the GWQAP.

Extent of Contamination

- The effect of upgradient groundwater contamination from Areas 1, 2, 4, 5, 6, and 10 on Area 7 groundwater quality should be further defined with the installation of an upgradient shallow and an upgradient deep monitoring well. The shallow well should be located midway between Areas 5 and 7, upgradient in relation to shallow groundwater flow. The deep well should be located midway between Areas 7 and 9, upgradient in relation to deep groundwater flow. Exact well locations should be chosen using the additional groundwater data obtained subsequent to this RI.

- The various soil borings recommended will characterize the vertical extent of soil contamination beneath the source locations.

- In order to assess the potential extent of sediment contamination within Ditch 2, it is recommended that samples be collected to a depth of 5 feet at a few locations downgradient from the Building 1 storm sewer outfalls.

7.8 Area 8 - IWTP WASTE DISPOSAL AREA

7.8.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 8.

Source Characterization

- The actual physical extent of the burial sites along the eastern portion of the area has not been adequately defined.

- Soils within, beneath, and adjacent to many of the various sites have not been characterized for contaminants.

- The industrial wastewater sludge burial sites are sources of explosives, VOCs, inorganics, and BNA contamination to the groundwater.

- Areas 8E and 8F may be source areas for radioactive material, as indicated by the elevated alpha and beta measurements at wells 3 and 4. Additional radiological analyses of groundwater from these wells will verify the measurements.

Pathway Characterization

- Groundwater flows north beneath Area 8 downslope along the bedrock valley wall before turning west (deep groundwater) and northwest (shallow groundwater).
- All surface water flows into the Big Ditch before exiting the site to the west.
- Locally, the Big Ditch is within a groundwater recharge zone, and potential surface water and sediment contamination could infiltrate downward to affect groundwater chemistry.

Extent of Contamination

The following organic and inorganic constituents were identified in the groundwater at Area 8. The inorganics shown exceeded ARARs:

Explosives	VOCs	BNAs	Inorganics	Radiological
RDX	111TCE	N-nitrosodiphenylamine	Barium	Alpha
	11DCLE		Cadmium	Beta
	Toluene	Bis(2-ethylhexyl)-phthalate	Chromium	
	T12DCE		Lead	
	TRCLE		Nickel	

- Contaminant occurrences and concentrations in the groundwater increase downgradient of the area.
- The geology and groundwater quality at the base of the aquifer have not been defined downgradient of Area 8.
- Surface water sampled from the Big Ditch downstream of Area 8 detected VOC contamination (benzene and TRCLE at 1.5 and 1.6 ug/l, respectively); therefore, the Big Ditch may transport contaminated surface water beyond the plant boundary.

7.8.2 Recommendations for Area 8

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 8.

Source Characterization

- The buried disposal areas not sampled during Phase 1 of the RI should be characterized by drilling soil borings and collecting soil samples. Visual and chemical evaluations of the subsurface soils should extend through the fill material into undisturbed soil.

- Any soil borings drilled within Areas 8E and 8F should be monitored for potential radioactivity.
- If chemical analyses were performed during the 1988 oil and grease pit reclamation, the results should be interpreted in conjunction with the next phase of this RI.

Pathway Characterization

- The surface and subsurface migration pathways of contaminants at Area 8 have been adequately defined.

Extent of Contamination

- In order to characterize the upgradient groundwater quality, a monitoring well should be installed south of Area 8E.
- In order to accurately assess shallow groundwater quality downgradient of the entire area two shallow monitoring wells should be installed north of the Big Ditch adjacent to Area 8C and 8D.
- In order to characterize the geology and groundwater quality at the base of the aquifer near Area 8, a deep monitoring well should be installed immediately north of the Big Ditch.
- The surface water and sediment within the Big Ditch adjacent to Area 8D should be analyzed since downgradient sample SW-17 (Figure 4-35) showed some VOC contamination. This surface water and sediment sample may verify whether or not the VOC contamination originated from Area 8.

7.9 AREA 9 - BUILDING 60 TREATMENT FACILITY

7.9.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 9.

Source Characterization

The following inorganic constituents identified in the soil and/or sediment at Area 9 exceeded statistical background levels. No organic compounds were detected.

Inorganics

Mercury	Chromium
Zinc	Copper
Arsenic	Cyanide
Barium	Lead
Beryllium	Selenium
Cadmium	

- Surface soil area-wide and sediments within the nearby drainage ditch contain elevated concentrations of 11 inorganic parameters directly related to past operations and overflow events.

- Soil contamination on-site remains undefined below a 2-foot depth. Within the drainage ditch, contamination remains undefined below a 6-inch depth.

- The soil at the Building 4 sump outfall northeast of Area 9 is contaminated with very high inorganic concentrations (chromium, copper, lead, zinc) and oil and grease concentrations. Sediment samples collected just upstream and downstream of the sump outfall also detected high inorganic concentrations (chromium, copper, lead, mercury and zinc).

- Potential leakage from the Building 4 storm sewer system and infiltration of surface water could potentially be sources of groundwater contamination.

- The geology and groundwater quality at the base of the aquifer remain undefined.

Pathway Characterization

- Shallow groundwater flows in a westerly direction toward Building 3.

- Deep groundwater flows southwest, from Areas 16, 17 and 18 toward production wells 17J and 17JJ.

- Overland flow is towards the northeast and Ditch B-1. The creek is a groundwater discharge zone; therefore, potentially contaminated groundwater may discharge to the ditch (Figure 3-2).

Extent of Contamination

The following organic and inorganic constituents were identified in the shallow groundwater at Area 9. The inorganic shown exceeded ARARs.

Explosives	BNAs	Inorganics
135TNB	Bis(2-ethylhexyl)phthalate	Cadmium
RDX		

- The shallow groundwater contamination is present downgradient and sidegradient of potential source areas (spill areas and the cyanide leaching bed).
- The vertical extent of groundwater contamination is undefined because no deep monitoring wells exist at the site.
- Shallow groundwater contamination exits Area 9 to the west and any potential deep groundwater contamination would exit Area 9 to the southwest, according to the hydraulic flow conditions described in Section 3.6.2.
- Sediment contaminated with inorganics (chromium, lead, mercury, copper, and zinc) has accumulated within the nearby drainage ditch and has migrated downstream.
- Surface soils at the site are contaminated with inorganics (mercury and zinc) to a depth of approximately 2 feet.
- Deeper soil contamination remains undefined near source areas and within the drainage pathways. Soil boring locations within the fenced area show inorganic concentrations decreasing from 0 to 2 feet. No samples were collected below 2 feet.

7.9.2 Recommendations for Area 9

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 9.

Source Characterization

- The types and concentrations of contamination at the various source areas within the fenced area have been sufficiently defined to a depth of 2 feet.

Pathway Characterization

- The surface and subsurface migration pathways of potential contamination at Area 9 are adequately defined, especially with the addition of new deep monitoring wells installed as part of the GWQAP. Although no new wells were installed at Area 9, the data gathered plant-wide should be sufficient to verify groundwater flow directions at the base of the aquifer.

Extent of Contamination

- The deep monitoring well proposed for Area 7, which would be located midway between Areas 7 and 9, should sufficiently characterize potential contaminant migration at the base of the aquifer downgradient of Area 9.

- Sump outflow sample SP-19 contained very high inorganic concentrations (Section 4.21). The vertical extent of contamination at the sump discharge location should be assessed by collecting subsurface soil samples to a depth of at least 5 feet.

- Any future studies at Area 9 should use the data obtained during the plant wide sump investigation when formulating work plans.

- To assess the vertical extent of inorganic contamination within the nearby drainage ditches, subsurface soil samples should be analyzed to a depth of at least 5 feet adjacent to and downstream of Area 9, since the soil chemistry has not been characterized below a depth of 2 feet.

7.10 AREA 10 - FIRING RANGE WASTE DUMP

7.10.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 10.

Source Characterization

- Area 10 is a source of explosive and inorganic contamination in the groundwater. RDX, barium, cadmium, and lead are found at concentrations exceeding ARARs sidegradient and downgradient of the waste dump.

- Soils within, beneath, and adjacent to the site have not been fully characterized for contaminants.

- Potential upgradient sources may be the remainder of the firing range northeast of Area 10.

- Upgradient groundwater chemistry remains undefined due to the damaged condition of well 10-1.

Pathway Characterization

- Groundwater beneath Area 10 flows west toward Areas 5 and 6.
- Area 10 may be a source area for potential contaminants in the groundwater at Areas 5 and 6. RDX, barium, cadmium and lead are all present in the groundwater at Areas 5, 6 and/or 10.
- Overland flow during rainfall is toward the south along roadside ditches. Area 10 ditches lead to a drainage way which eventually discharges to East Fire Prairie Creek near Area 4.

Extent of Contamination

The following organic and inorganic constituents were identified in the groundwater at Area 10. The inorganics shown exceeded ARARs:

Explosives	BNAs	Inorganics
RDX	Di-n-octylphthalate	Barium
	Bis(2-ethylhexyl)phthalate	Cadmium
		Lead

- RDX and inorganic contamination exists in all downgradient and sidegradient groundwater.
- Upgradient groundwater quality remains undefined.
- The extent of soil contamination within Area 10 remains undefined except for the previously-reported declining lead concentrations within the waste pile.

7.10.2 Recommendations for Area 10

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 10.

Source Characterization

- Soil samples should be collected and analyzed from within and southwest of the waste dump to evaluate the potential waste constituents present.
- To verify the lack of any upgradient sources of groundwater contamination, upgradient monitoring well 10-1, which is damaged, should be retrofitted or abandoned. If abandoned, a new well should be installed further east, and sampled.

Pathway Characterization

- The surface and subsurface migration pathways of contaminants at Area 10 are moderately defined. Groundwater probably flows downslope over the Pennsylvanian-aged bedrock valley wall within the thin overburden.

Extent of Contamination

- The installation of a new upgradient monitoring well is proposed to define the potential for any upgradient groundwater contamination.

- The monitoring well proposed in Subsection 7.6.2 to be installed midway between Areas 6 and 10 will define the extent of groundwater contamination downgradient of Area 10.

- In order to characterize overland flow of potential contamination from Area 10, sediment samples should be collected from the drainage ditch south of the site which leads to Ditch A.

7.11 AREA 11 - BURNING GROUNDS

7.11.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 11.

Source Characterization

- The burning grounds appear to have contributed explosives contamination to the groundwater. The single detections of trans-1,2-dichloroethane and cadmium appear to be anomalous and probably do not reflect actual groundwater conditions.

- The soil contamination within and adjacent to the site remains undefined.

Pathway Characterization

- Groundwater flows north towards Area 16.

- Bedrock topography is a major factor controlling the local groundwater flow direction.

- Surface water flow occurs in swales and ditches leading northwest to the Area 16 and 17 ditches.

Extent of Contamination

The following organic and inorganic constituents were identified in the groundwater at Area 11. The inorganic shown exceeded ARARs.

Explosives	VOCs	BNAs	Inorganics
HMX	trans-1,2-dichloroethane	Bis(2-ethylhexyl)phthalate	Cadmium
RDX			

- Downgradient groundwater is contaminated with explosives and, to a minor extent, volatile organics and inorganics.

- Local soil contamination is undefined.

7.11.2 Recommendations for Area 11

The following recommendations are proposed to provide the date necessary to complete the Remedial Investigation at Area 11.

Source Characterization

- In order to characterize the burning grounds as a source area of explosive contaminants, surface and subsurface soil samples should be collected from zero to five feet. Soil borings should be drilled directly through locations of previous open-ground burning, and surface and subsurface soil samples collected.

- Soil analytical data collected as part of the 1989 GWQAP should be reviewed in conjunction with this RI.

Pathway Characterization

- Overall surface and subsurface migration pathways at the site are adequately defined. Since groundwater flow directions are controlled by the bedrock topographic surface, localized flow directions may deviate from those shown in Figure 3-14.

Extent of Contamination

- Groundwater contamination at Area 11 has been sufficiently characterized.

- Horizontal and vertical extent of soil contamination should be assessed by collecting samples to a depth of 5 feet across the burning grounds if the 1989 GWQAP has not already done so.

- In order to define the potential of overland contaminant migration from the burning grounds, some surface soil samples should be collected from the shallow drainage ditches or swales leading downslope from the site.

7.12 AREA 12 - LABORATORY WASTE LAGOON

7.12.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 12.

Source Characterization

- The NPL Lagoon appears to be a source of explosives and inorganic groundwater contamination, especially RDX, HMX, Tetryl, 135TNB, arsenic and chromium.
- Deep groundwater quality upgradient of potential source areas remains undefined.
- Production well analytical results indicate the potential for additional sources within the area. Production well 17-AA contained concentrations of VOCs, none of which were detected in monitoring well samples at Area 12.
- Past sump discharges have contaminated ditch soils. The sump and sump outflow investigation identified oil and grease and inorganics contamination within Ditch 3.
- None of the wastewater sampled from the Area 12 sewer system discharge contaminants to the ditch system. The sewer line which contained laundry facility effluent contaminated with several unknown VOCs is directed into the IWTP.
- The suspected disposal site at Area 12B has not been investigated.

Pathway Characterization

- Shallow groundwater flows west and northwest towards Area 3 and the plant boundary (excluding the affects of production well 17-AA).
- Deep groundwater flows west towards the plant boundary (excluding the effects of production well 17-AA).
- Production well pumping within Area 12 greatly affects groundwater flow and contaminants transport. Well 17-AA likely captures much of the Area 12 groundwater.

- Overland flow occurs within Ditch 3 and Ditch A, which are groundwater recharge zones.
- The oil and grease constituents within Ditch 3 may potentially migrate downward to the water table and also downstream within the ditch towards Ditch A.

Extent of Contamination

The following organic and inorganic constituents were identified in the groundwater at Area 12, including monitoring wells and production well 17-AA. The inorganics shown exceeded ARARs.

Explosives	VOCs	BNAs	Inorganics
135TNB	T12DCE	Bis(2-ethylhexyl) phthalate	Barium
HMX	TRCLE		Chromium
RDX		N-nitrosodiphenylamine	
Tetryl			

The following organic and inorganic constituents were identified in the ditch sediment at Area 12. The inorganics shown exceeded statistical background levels.

Inorganics	Oil and Grease
Cadmium	
Chromium	
Copper	
Lead	
Mercury	
Zinc	

- Explosive compound contamination occurs at all downgradient well locations.
- No deep groundwater quality data exist for locations immediately upgradient of Area 12.
- The extent of soil contamination is undefined at all potential source areas within Area 12.

7.12.2 Recommendations for Area 12

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 12.

Source Characterization

- In order to characterize the potential contamination at the laboratory waste lagoon, a soil boring should be drilled and subsurface soil samples collected from the fill material and soil beneath the lagoon.

- In order to verify the existence of a buried disposal pit at Area 12B, a soil boring should be drilled to a depth of at least 5 feet below grade. If visual inspection of the samples warrants, soil samples should be collected and analyzed in order to assess the existence of contaminants.

Pathway Characterization

- Most of the surface and subsurface migration pathways of contaminants are adequately defined. The recommendations addressing source characterization and extent of contamination will further characterize the migration pathways at Area 12.

Extent of Contamination

- The extent of soil contamination within the potential source Areas 12A and 12B will be defined by the recommendations addressing source characterization.
- In order to determine the vertical extent of contamination within Ditch 3, samples should be collected to a depth of at least 2 feet below grade.
- If the subsurface soil samples from the suspected burial site within Area 12B are found to contain contaminated material, a new monitoring well should be installed near the present location of dry monitoring well 12-1 in order to assess potential groundwater contamination downgradient of the burial site.
- To determine whether the deep groundwater contamination at Area 12 is originating from upgradient locations, a deep monitoring well should be installed near Building 10.

7.13 AREA 13 - BUILDING 35 DRAINAGE AREA

7.13.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 13.

Source Characterization

- Soil contamination has been detected within the drainage ditch and open area at the surface. These soils are contaminated with BNAs and inorganics. Vertical extent of soil contamination at these pathways remains undefined.

- Surface water within the drainage ditch is contaminated with inorganics and trace explosives (135TNB).
- Surface water samples were collected during a dry period. Relative contamination concentrations may change during rainfall events which could mobilize explosive, BNA and inorganic constituents from the soil into the surface water. Conversely, rainfall could dilute the contaminant levels in the surface water.
- Groundwater quality beneath Area 13 remains undefined.

Pathway Characterization

- Overland flow occurs within the drainage ditch system which eventually leads to Ditch A.
- The groundwater at Area 13 flows northeast, following the bedrock topography.

Extent of Contamination

The following organic and inorganic constituents were identified in the Area 13 ditch sediment and/or surface soil. The inorganic constituents shown exceeded statistical background levels.

BNAs	Inorganics
Anthracene	Chromium
Chrysene	Copper
Flourene	Lead
Phenanthrene	Nickel
Pyrene	Arsenic
	Barium
	Cadmium
	Mercury
	Zinc

- Surface soil and ditch sediment contains above background levels of inorganic constituents at all seven sampling locations.
- Inorganic concentrations in the sediment increase downstream within the drainage ditch, indicating the potential migration of contaminants. No other known source areas exist along the drainage ditch.
- Vertical extent of soil contamination is undefined.
- One surface water sample from the drainage ditch at Area 13 contained a trace level of 135TNB. No inorganic constituents exceeded ARARs.

- The extent of potential groundwater contamination is undefined.

7.13.2 Recommendations for Area 13

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 13.

Source Characterization

- The contaminants within the open drainage area soils have been adequately defined.
- Inorganic concentrations within the drainage ditch sediment exceed background levels, but do not exceed 1 mg/g.

Pathway Characterization

- The surface and subsurface migration pathways of potential contaminants have been adequately defined.

Extent of Contamination

- In order to define the horizontal and vertical extent of contamination within the drainage ditch, samples of the sediment should be collected and analyzed to a depth of 2.5 feet at the previous sediment sample locations and at a location further downgradient from sample DS13-4.
- The installation and sampling of at least one shallow monitoring well immediately downgradient from the Area 13 open drainage and ditch system would indicate whether or not previous discharges have affected local groundwater quality.

7.14 AREA 14 - FUEL TANK, BURNING GROUND, AND SLUDGE DISPOSAL AREA

7.14.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 14.

Source Characterization

The soil boring samples at Area 14 contained oil and grease in the upper two samples. Arsenic, barium, and cadmium concentrations exceeded statistical background concentrations.

- The physical extent of the sludge burial site has been well defined.

- The geology and shallow groundwater quality is well defined.

- The source of explosives in the downgradient deep groundwater sample may be the sludge burial area or may be upgradient of Area 14.

- Groundwater quality downgradient of the fuel tanks remains undefined.

Pathway Characterization

- Shallow groundwater not captured by production well 17-DD flows west, towards Area 3.

- Deep groundwater flows southwest, towards production well 17-DD (while pumping) and Areas 3 and 12.

- Vertical flow gradients are downward, accentuating the downward migration of contaminants from the sludge disposal site.

- Overland flow is towards Ditch B to the north (Figure 4-29).

Extent of Contamination

The following organic and inorganic constituents were identified in the groundwater at Area 14. The inorganics shown exceeded ARARs:

Explosives	BNAs	Inorganics
RDX	Bis(2-ethylhexyl)phthalate	Cadmium Chromium Selenium

- Shallow groundwater is contaminated with inorganic constituents at all well locations.

- Deep groundwater is contaminated downgradient from the burial site.

- Potential groundwater contamination has not been evaluated nearer to the fuel tanks.

- Contaminated groundwater may migrate beyond Area 14.

- Soil contamination has been identified within the sludge burial pit to a depth of 10 feet. Potential soil contamination below that depth remains undefined.

7.14.2 Recommendations for Area 14

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 14.

Source Characterization

- The contaminants within the sludge burial site have been adequately characterized. The vertical extent below a depth of 10 feet has not been characterized.

- Groundwater quality downgradient of the fuel tanks should be assessed if observations made by the Army Corp of Engineers during tank removal indicate the presence of soil contamination.

Pathway Characterization

- The surface and subsurface migration pathways of potential contamination have been adequately defined.

Extent of Contamination

- An additional soil boring should be drilled through the Area 14B sludge disposal site and sampled from 0 to 20 feet in order to verify Phase I results and to define the vertical extent of elevated inorganics concentrations beyond 10 feet in depth.

7.15 AREA 15 - TEMPORARY SURFACE IMPOUNDMENT

7.15.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 15.

Source Characterization

- Antimony, arsenic, barium, beryllium, cadmium, lead, and copper were identified at concentrations exceeding statistical background levels.

- The soil within the impoundment is a source of oil and grease and inorganics contamination.

- The horizontal extent is defined by the surrounding berm.

- Although groundwater quality at the site remains undefined, the low levels of contaminants in the soils do not pose a threat to groundwater quality.

Pathway Characterization

- No overland flow can occur away from the site due to the surrounding berm.
- Groundwater at Area 15 flows north.

Extent of Contamination

- Soil contaminant levels decrease with depth.
- Inorganic contamination exists to approximately 5 feet in depth. Oil and grease is present to a depth of 2.5 feet.
- Soil contamination remains undefined below 5 feet in depth.

7.15.2 Recommendations for Area 15

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 15.

Source Characterization

- Source characteristics have been sufficiently defined.

Pathway Characterization

- The surface and subsurface migration pathways of potential contaminants have been adequately defined.

Extent of Contamination

- In order to define the vertical extent of soil contamination below a depth of 5 feet, a soil boring should be drilled and sampled to a depth of 20 feet.

7.16 AREA 16 - ABANDONED LANDFILL

7.16.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 16.

Source Characterization

The following organic and inorganic constituents were identified in the Area 16A leachate surface water sample. The inorganics shown exceeded ARARs.

VOCs	BNAs	Inorganics
11DCLE	Phenol	Lead
Benzene		
Chloromethane		
Ethylbenzene		
Toluene		
T12DCE		
TRCLE		

The leachate sediment sample contained the following organic and inorganic constituents. The inorganic shown exceeded statistical background levels.

BNAs	Inorganics
Benzo(a)anthracene	Arsenic
Benzo(a)pyrene	
Benzo(k)fluoranthane	
Chrysene	

- The horizontal extent of the Area 16A abandoned landfill is fairly well defined. The burial depths remain undefined.
- The waste burial location designated as Area 16C is not defined clearly. The exact physical extent is unknown.
- Soil contamination within, beneath, and adjacent to most potential source areas remains entirely undefined.
- Groundwater is contaminated by various sources at Area 16, potentially including the abandoned landfill, the abandoned trench, the waste burial area, and the paint and solvent waste tanks.
- Contaminants found in the groundwater consist of explosives, VOCs, BNAs, inorganics and potentially radioactive material.
- Area 11 contamination (especially explosives) may affect Area 16 groundwater chemistry. Figures 3-12 and 3-14 show the potential for contaminant transport between the two areas.
- Leachate discharging from the abandoned landfill is contaminated with VOCs, BNAs and inorganics.

Pathway Characterization

- Groundwater flows northwest, towards Area 18.
- All overland flow trends northwest (Figure 4-35), eventually going to Ditch B-1 and Ditch B. Much of the local runoff flows to the Area 16/17 creek, which leads to Ditch B-1.

Extent of Contamination

The following organic and inorganic constituents were identified in the groundwater at Area 16. The inorganics shown exceeded ARARs.

Explosives	VOCs	BNAs	Inorganics
13DNB	111TCE	1,2-dichlorobenzene	Cadmium
135TNB	112TCE	Di-n-octylphthalate	Chromium
HMX	11DCE	Dimethyl phthalate	
NB	12DCLE	Bis(2-ethylhexyl)phthalate	
RDX	TRCLE		
	Benzene		
	Carbon tetrachloride		

The Area 16/17 creek surface water contained the following organic constituents. No inorganics exceeded ARARs.

Explosives	BNAs
135TNB	Bis(2-ethylhexyl)phthalate

The Area 16/17 creek sediments contained the following organic and inorganic constituents. The inorganics shown exceeded statistical background levels.

BNAs	Inorganics
Di-n-octylphthalate	Arsenic
Fluoranthene	Cadmium
Acenaphthene	Chromium
Anthracene	Copper
Benzo(a)anthracene	Lead
Benzo(a)pyrene	Beryllium
Chrysene	
Di-n-butylphthalate	
Fluorene	
Indeno(1,2,3-cd)pyrene	
Phenanthrene	
Pyrene	
Naphthalene	

- Groundwater is contaminated across the entire area, at all depths within the upper aquifer.

- There was a large discrepancy between round 1 and round 2 VOC results.

- Upgradient groundwater contamination from Area 11 may affect Area 16 groundwater quality. Area 16 groundwater contamination may affect groundwater downgradient within Area 18.

- Contamination exists within the Area 16/17 creek, including explosives, BNAs, and inorganics. A source upstream of Area 11 and 16 may exist based on the BNA analytical results from ditch sediment sample DS16-5.

- The effluent stream portions of Ditch B-1 have the potential to receive contaminated groundwater since these groundwater discharge zones are located downgradient of Area 16.

- The vertical extent of soil contamination, and the depth of waste material burial, remains undefined.

- Elevated uranium activity at well 16-2 indicates that Area 16C may contain some buried uranium.

7.16.2 Recommendations for Area 16

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 16.

Source Characterization

- In order to definitively characterize the geometry, stratigraphy and contaminant composition of Area 16A (Abandoned Landfill), Area 16B (Abandoned Trench), Area 16C (Waste Burial), and Area 16D (Paint and Solvent Tanks), soil borings should be drilled through the fill material to allow the collection and analysis of subsurface soil samples.

- Soil borings should also be drilled and sampled through the old firing range of Area 16F and the burning ground of Area 16G in order to evaluate them as potential source locations.

- Additionally, a soil boring should be drilled through the GPR anomaly located in the extreme southern portion of Area 16 (Figure 4-32).

- Soil vapor surveys may provide additional information regarding the magnitude and extent of known and/or suspected VOC source areas.

Pathway Characterization

- The surface and subsurface migration pathways of contaminants at Area 16 are complicated due to the sloping overburden of varying thickness, the irregular bedrock topography, the influent and effluent stream conditions, and the partially characterized landfill/ disposal sites on site. Recommendations given for source characterization and extent of contamination are intended to reduce the pathway characterization data gaps.

Extent of Contamination

- Due to the large discrepancy of VOC analytical results between the round 1 and 2 sampling events, any subsequent analyses should be reviewed in order to clarify the understanding of actual groundwater quality at Area 16.

- The soil boring samples would define the extent of contamination through the fill material, but in order to define the extent below that depth, some soil borings should be drilled and sampled to the top of the water table.

- Multiple soil borings should be drilled and sampled through the Area 16A abandoned landfill in order to characterize its stratigraphy, contaminant composition, and degree of saturation. Monitoring wells should be installed at three boring locations in order to collect leachate/groundwater samples and water level data.

- In order to define the upstream extent of sediment contamination with the on-site creek, at least two sediment samples should be collected at varying distances upstream of sample location DS16-5. Sediment samples should be composited to a depth of 1 foot in order to ensure the collection of sediments from previous sedimentation events.

7.17 AREA 17 - SANITARY LANDFILL AND SOLVENT PITS

7.17.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 17.

Source Characterization

- The solvent pits are sources of explosive and VOC contamination in the groundwater. A potential for radiological contamination is based on elevated beta activities measured in wells 17-9 and 17-10, which are not downgradient of potential source locations within Area 16.

- The exact physical extent of the pits remain undefined.
- Soil contamination within, beneath, and adjacent to the pits remains undefined.
- An unknown source of explosive and VOC contamination may exist directly downgradient of the sanitary landfill, as indicated by well 17-3 analytical results. If not, the pits are the likely source.

Pathway Characterization

- Shallow groundwater flows northwest, towards monitoring wells 16-6 and 16-7, and Area 18.
- Groundwater flow within the bedrock is dominated by strong downward gradients, as measured from the weathered shale monitoring wells. Horizontal flow follows bedrock topography to the northwest.
- Some shallow groundwater may discharge to Ditch B-1.
- All overland flow trends northwest, eventually going to Ditch B-1 and Ditch B. Some of the runoff flows to the Area 16/17 creek, which leads to Ditch B-1.
- Much of the runoff from the sanitary landfill, the solvent pits, and other upland areas infiltrates to the water table due to the flat topography of the lowland area.

Extent of Contamination

The following organic and inorganic constituents were identified in the groundwater at Area 17. The inorganics shown exceeded ARARs:

Explosives	VOCs	BNAs	Inorganics
135TNB	111TCE	Bis(2-ethylhexyl) phthalate	Barium
24DNT	112TCE		Lead
26DNT	1,2-dichloropropane		
HMX	Benzene		
RDX	Chloroform		
Tetryl	Ethylbenzene		
	Methylene Chloride		
	TCLEE		
	Toluene		
	T12DCE		
	TRCLE		
	Vinyl Chloride		

- Groundwater is contaminated at all locations downgradient (northwest) of the solvent pits.

- Groundwater contamination exists at all depths within the upper aquifer downgradient of Area 17, and has migrated at least as far as wells 16-6 and 16-7. Monitoring wells detecting contaminants at Area 17 have been screened at all depths within the overburden and the weathered bedrock.

- Some contaminated groundwater may discharge into Ditch B-1.

- The extent of soil contamination across the entire area remains undefined.

7.17.2 Recommendations for Area 17

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 17.

Source Characterization

- In order to characterize the stratigraphy and chemical composition of the solvent pits at Area 17B, soil borings should be drilled through the fill material to allow the collection and analysis of subsurface soil samples. A scintillation counter should be used to monitor the fill material for suspected radiological activity.

- In order to verify the presence or lack of radiological activity at Area 17, some downgradient wells should be sampled and analyzed, including a resampling of wells 17-9 and 17-10.

- Potential sources of well 17-3 organic compound contamination should be identified by a search for disturbed soil or other evidence of unknown disposal sites near the sanitary landfill.

- Evidence of potential disposal sites should be investigated along the upstream portions of the on-site creek to identify unknown sources of potential contamination in upgradient creek sample DS16-5.

Pathway Characterization

- The surface and subsurface migration pathways of potential contaminants have been relatively well defined. Boring logs describing the stratigraphy exist for numerous locations at Area 17. Overland flow patterns are readily apparent. Some questions remain concerning the effects of burial sites on localized groundwater flow.

Extent of Contamination

- In order to fully characterize the extent of groundwater contamination downgradient of the solvent pits, deep and shallow monitoring wells should be installed immediately downgradient of the solvent pits to replace dry well 17-6.
- In order to define the vertical extent of soil contamination beneath the solvent pits, soil borings should be drilled and sampled through the pits to the top of the water table.

7.18 AREA 18 - WASTE BURNING AND BURIAL PITS

7.18.1 Conclusions

The following conclusions were reached from the Remedial Investigation at Area 18.

Source Characterization

- The burial pits are probable sources of VOC contamination in the local groundwater.
- The physical extent of the various disposal sites remains undefined.
- Potential soil contamination remains undefined throughout Area 18.

Pathway Characterization

- Shallow groundwater flows west and northwest.
- Deep groundwater flows west.
- Vertical gradients downgradient of the burial sites are probably slight, and lateral groundwater flow is prevalent since Area 18 is not a production well location.
- Surface runoff is divided toward Ditch B and Ditch B-1.
- Some contaminated groundwater may discharge into Ditch B-1 due to slightly effluent conditions.

Extent of Contamination

The following organic constituents were identified in the groundwater at Area 18. No inorganics exceeded ARARs.

Explosives	VOCs	BNAs
HMX	11DCE	Chrysene
RDX		Bis(2-ethylhexyl) phthalate

- The groundwater contamination (minor levels of explosive compounds) extends across the entire area.
- Much of the groundwater contamination (especially explosives) may have originated upgradient of the site, at Areas 11, 16, 17. Contaminant migration rates may be sufficient enough to implicate these upgradient areas as sources, based on the steep hydraulic gradients there.
- Deep groundwater quality immediately downgradient of the disposal sites remains undefined. Production well 17-FF does likely capture some of the downgradient groundwater, however.
- Shallow groundwater quality immediately downgradient of most of the disposal areas is not thoroughly defined.
- Extent of soil contamination within, adjacent to, and beneath the disposal sites remains undefined.

7.18.2 Recommendations for Area 18

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation at Area 18.

Source Characterization

- Geophysical surveys should be conducted over the suspected burial sites to better delineate their boundaries.
- In order to characterize the stratigraphy and chemical composition of the disposal sites, soil borings should be drilled through the fill material to allow the collection and analysis of subsurface soil samples.

Pathway Characterization

- Surface and subsurface migration pathways of potential contaminants have been adequately defined.

Extent of Contamination

- Two deep monitoring wells should be installed between Areas 14 and 18 in order to characterize the extent of deep groundwater contamination downgradient of Area 18. These wells will give some indication of the effectiveness of the production well 17-FF captive zone and its remedial effects.

- Two shallow monitoring wells should be installed between wells 18-4 and 18-5 to better characterize the shallow groundwater contamination immediately downgradient of the disposal sites.

- The soil boring samples will define the extent of contamination through the fill material. In order to define the extent below that depth, selected soil borings should be drilled beneath the pits to the top of the water table.

7.19 PLANT-WIDE SUMP, SUMP OUTFLOW, STORM SEWER, DITCH AND POND SAMPLES

7.19.1 Conclusions

The following conclusions were reached for the Remedial Investigation of the plant-wide sump, sump outfall, and sewer systems, and of the pond and ditches potentially affected by waste-handling practices which utilized the building sumps.

Source Characterization

The analytical results of the sump, sump outflow, storm sewer, ditch and pond investigations are extensive. Results are presented and discussed in detail in Section 4.

- Many building sumps contain bottom sediment. Sediment from eight building sumps were sampled, all of which contained inorganics, explosives, and oil and/or grease contamination.

- Approximately 35 sumps serving Buildings 1, 2, 3, 4, and 97 were inspected; six were actively receiving water through inlet pipes. The origin and chemistry of the water which was actively flowing into the sumps during the field investigation remains mostly undefined.

- None of the observed building sumps contained functioning filter bags designed to collect solids from the inflowing wastewater.

- A total of 34 sump and sump outflow samples were collected. Of these, 26 were from outfall locations within open drainage pathways.

- Most of the building sumps have not been sampled to date.

- Most building sumps appear to overflow into the plant-wide storm sewer system which ultimately discharges to the plant-wide drainage ditch system.

- The storm sewer wastewater sampled at Area 12 does not discharge contaminants to the ditch system. The sewer line which contained several unidentified VOCs is routed to the IWTP.

- The potential for leakage from the sumps and sewers remains undefined; however, the age and design of these potential sources suggest the likelihood of leakage.

- Contaminant types and concentrations are usually similar between sump sediments and their associated drainage ditch sediments.

- Contaminants within the ditch and pond surface water and sediment may originate from additional sources other than building sumps, including open drainage areas, spills, seeps, groundwater discharge zones, and other unknown upgradient sources.

- The sediment within the pond at Area 3 is contaminated with BNA compounds and inorganics (copper and lead). Subsurface soil contamination adjacent to and beneath the pond remains undefined. Section 4.19.2.5 discusses the analytical results.

- The origin of the Area 3 pond contamination remains unknown.

Pathway Characterization

- Sump contaminants have the potential to discharge into various drainage ditches. The overflow pipes within most of the observed sumps were situated a foot or more above the water lines. A few contained water flowing in and out. The potential for most of the sumps to discharge to the storm sewers or ditches may depend on precipitation. Heavy rainfall may raise the water lines sufficiently to allow overflow into the discharge pipes.

- The effects of heavy rainfall or flooding upon the sumps and sewers remains undefined, especially the release of contaminants from the sediment.

- Leaking sumps and storm sewers may allow the downward migration of contaminants to the water table.
- Contaminants reaching the drainage ditches have the ability to migrate downgradient within the ditches. This migration occurs during periods of heavy rainfall and/or surficial run-off.
- Drainage ditch contaminants have the potential to infiltrate vertically to the water table.
- Some of the sumps discharge or have discharged to open areas and not directly to drainage ditches. Contaminant migration overland toward nearby drainage ditches at these locations would be slower and may result in greater infiltration to the subsurface.

Extent of Contamination

- Based on the contaminated sediments analyzed from the eight building sumps it is possible that more of the 35+ sumps are also contaminated.
- Potential subsurface contamination caused by leaking sumps and storm sewers remains undefined.
- Potential subsurface contamination caused by infiltration within open areas and drainage ditches remains undefined.
- Ditch sediment contamination decreases proportionally with the distance to the sump and/or sewer discharge location.
- Sump-associated contaminants have been identified hundreds of feet downgradient of sump and/or sewer discharge locations within associated drainage ditches.
- Contaminated sediments within the Area 3 pond are not sump related. Vertical extent of the subsurface contamination at the pond location remains undefined.

7.19.2 Recommendations

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation of the plant-wide sumps, sewers, sump outflows, ditches and pond.

Source Characterization

- Many sumps have not been sampled. All sumps which are not designed to discharge into the IWTP should be sampled and analyzed for sediment/sludge contamination.

- Some of the previously sampled sumps should be analyzed for VOCs and BNAs in order to better define the organic constituents.

- In order to characterize the chemistry of the standing water within the sumps which contain contaminated sediment, the water within some of these sumps should be sampled and analyzed.

- Water which is actively flowing into the sumps through inlet pipes should be analyzed if the origin of the water suggests a potential for contamination. Flow should be stopped immediately if contaminants are identified.

- In order to assess the leakage factor of the sumps, all sumps should be leak tested. This recommendation will also provide information for the pathway characterization.

- Following an interpretation of test results, a sump sealing/abandonment program should be initiated.

- In order to explain the presence of contaminated sediment within the pond, a detailed information search should be performed, including the evaluation of air photographs and plant records.

Pathway Characterization

- One or more of the sumps should be monitored during a period of heavy rainfall in order to characterize the effects of precipitation on the water levels within the sumps.

Extent of Contamination

- All building sumps should be inspected and assessed with regard to source locations, discharge locations, sump design, condition, and content. The assessments will facilitate the interpretation of plant-wide contamination and the design of remedial alternatives.

- Any sumps shown or suspected to leak should have their subsurface soils sampled and analyzed in order to determine the magnitude and extent of vertically-migrated contaminants.

- Selected plant-wide ditch and open drainage areas containing contaminated surface soils should be characterized for vertical migration of contaminants by the collection of soil samples to a minimum depth of 5 feet.
- The vertical extent of sediment/soil contamination within the pond should be defined by the collection of samples to a depth of at least 5 feet.

7.20 PRODUCTION WELLS

7.20.1 Conclusions

The following conclusions were reached from the analysis of the seven production well samples.

Source Characterization

- The sources of the groundwater contamination identified in all seven production well samples vary across the site. The effect of individual sources on individual wells is determined by the relative locations, the natural groundwater flow directions, the production well capture zone duration and extent, and the mobility of the contaminants.
- All seven production wells contained slightly-elevated inorganic concentrations. Wells 17-AA, 17-FF, and 17-JJ also contained VOCs.
- VOC sources of the well 17-AA detection of T12DCE and TRCLE may be located within Area 12, probably sidegradient or downgradient of all five of the sampled monitoring wells since no VOCs were detected in any of the monitoring wells.
- VOC sources of the well 17-FF detection of benzene, T12DCE, TRCLE and vinyl chloride are probably located within Areas 16, 17 and 18 since like or related VOCs were identified at monitoring well locations within all three areas.
- The well 17-JJ detection of TRCLE (only one detection of 1.2 ug/l) is too insignificant to estimate a source location. This could be due to field or laboratory contamination.

Pathway Characterization

- The capture zones created by the production wells are estimated to intercept practically all groundwater flowing through the alluvial valley (Subsection 3.6.5.).
- The effects of the alluvial valley walls and the effects of extensive well interference would tend to increase the extent of each capture zone.
- Groundwater flow is predominantly lateral except within a close proximity to each actively pumping production well. Downward flow of groundwater and associated contaminants close to the production wells is due to the partially penetrating well screens at the base of the alluvial aquifer.

Extent of Contamination

- The seven sampled production wells are located across the entire lowlands portion of the LCAAP. VOC contamination within the production wells is predominant at the west and east ends of the site, indicating the capture of contaminated groundwater from Areas 12, 16, 17, and 18.
- Inorganic contamination within the production wells is slight, with no concentrations exceeding standards.
- Explosive and BNA compound analyses do not indicate any contamination.
- No elevated radiological activity extends to any of the production well locations.

7.20.2 Recommendations

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation of the production wells and residential well.

Source Characterization

- The two rounds of groundwater sampling conducted as part of this investigation, and the sampling conducted by LCAAP on a quarterly basis at the production wells have adequately defined the groundwater chemistry at those locations.
- The purging and sampling of all additional functioning production wells on-site would further define the groundwater chemistry.

Pathway Characterization

- The migration pathways of potential groundwater contamination have been relatively well defined throughout most of the site. In order to define the potential migration of contaminated groundwater off-site, monitoring wells should be installed at the site boundary at locations outside the influence of production well capture zones.
- The actual extent of capture zone influence within the aquifer will never be definitively characterized. However, groundwater modelling efforts currently being performed by USATHAMA involving the LCAAP production well effects on local and regional groundwater flow conditions will provide additional information.

Extent of Contamination

- Groundwater chemistry remains largely undefined outside the site boundary. The sampling and analysis of all nearby residential wells, which is being initiated, would facilitate the evaluation of off-site contaminant migration.
- Some monitoring wells should be installed along the west perimeter of the LCAAP in order to define the downgradient extent of groundwater contamination.

7.21 RADIOLOGICAL INVESTIGATION

7.21.1 Conclusions

The following conclusions were reached from the 38 groundwater samples collected and analyzed for radiological activity.

Source Characterization

- Suspected source areas include Areas 16 and 17, based on previous waste handling appraisals, and on the elevated radiological activities measured in downgradient groundwater samples 16-2, 17-9 and 17-10.
- Area 8 may be a source area also, based on elevated radiological activities measured in downgradient groundwater samples 3 and 4; however, higher solids content in groundwater samples can result in higher beta activity. Groundwater samples from wells 3 and 4 at Area 8 were very silty.

Pathway Characterization

- Although previous surficial radiation surveys at the firing range have indicated radiological activity, it is possible that potential source areas are sufficiently covered with fill material to prevent measurable emittance of radiological activity to the surface.
- Buried source material may contribute contamination to the groundwater. If so, the contamination at Areas 8, 16 and 17 would migrate as described in Subsections 7.8.1, 7.16.1, and 7.17.1.
- Radiological sampling was performed only at those areas suspected of having buried depleted uranium.

Extent of Contamination

- Only three monitoring wells were sampled and analyzed for radiological parameters within Areas 16 and 17, and all three measured above typical on-site values. Since wells 17-9 and 17-10 are a cluster, only two discrete locations were actually tested, leaving the extent of the increased measurements largely undefined.
- Of the six monitoring wells sampled and analyzed within Area 8, five of them (1 through 5) measured above background radiological activity. This implicates the southern portion of Area 8 as a potential source area; however, none of the wells near the center of the site (8-1 through 8-5) were tested. This leaves the extent of the elevated values largely undefined.
- No other significant values were obtained in groundwater samples across LCAAP, indicating the extent of elevated radiological activity in groundwater to be limited to the two localized areas within Area 8, and within Areas 16 and 17.

7.21.2 Recommendations

The following recommendations are proposed to provide the data necessary to complete the Remedial Investigation of radiological activity on site.

Source Characterization

- Since most of the suspected source areas have been proposed to have soil borings drilled, detailed radiation monitoring should be performed on the fill material at each location. Laboratory analysis of fill samples should also be performed.

- If the detailed site reconnaissance of upgradient locations within and adjacent to Areas 8, 16 and 17 identify any additional burial sites, radiation monitoring and sampling should be performed as described above.

Pathway Characterization

- Most of the surface and subsurface migration pathways of potential contaminants have been adequately defined. This is especially true with the additional data collected from the 1989 GWQAP.

Extent of Contamination

- Most wells have not been analyzed for radiological parameters. In order to better define contaminant source locations and extent, monitoring wells near those wells in Areas 8, 16, and 17 which contained elevated values should be sampled and analyzed.
- Additionally, Area 10 wells should be tested if they haven't been previously.

7.22 ENVIRONMENTAL ASSESSMENT

Absolute conclusions regarding the potential environmental impacts of the chemicals of concern at LCAAP cannot be made because there are a number of uncertainties associated with the estimates of toxicity and exposure and these should be noted when reviewing the conclusions for the LCAAP study areas. However, given the available data and limitations the general conclusions regarding the potential for environmental impacts are summarized below.

Plants. In the one area evaluated for toxicity to plants (Area 13), no adverse effects to plants are expected. Although the levels of arsenic and chromium exceed the plant-TRVs, grass species in the vicinity of Area 13 do not appear to be adversely affected.

Terrestrial Wildlife. No adverse effects to terrestrial wildlife are expected from ingestion of surface water in site ditches. However, rabbits that ingest surface water from the Area 16 seep may experience adverse chronic effects from exposure to high levels of phenol. Sufficient toxicity information was not available for mammals for chloroethane and HMX and therefore potential risk from exposure to these chemicals could not be evaluated. Toxicity information was not available for birds for benzene, beryllium, bis(2-ethylhexyl)phthalate, chloroethane, 1,1-dichloroethane, ethylbenzene, HMX, methylene chloride, tetrachloroethene, toluene, selenium, trans-1,2-dichloroethene, trichloroethene, and 1,3,5-TNB. Therefore, the potential risks to birds from exposure to these chemicals could not be further evaluated. No adverse effects are expected to wildlife consuming soil organisms that may bioaccumulate contaminants in soil. However, earthworm bioconcentration factors were not available for arsenic and barium, thus potential risks from exposure to these chemicals could not be evaluated, although arsenic and barium in the food of birds and mammals does not bioaccumulate and is readily excreted.

Aquatic Organisms. The measured concentrations of copper, silver, and zinc in Ditch A exceed the chronic AWQCs. In Ditch B, the levels of bis(2-ethylhexyl)phthalate, copper, lead, selenium, and zinc exceed the chronic AWQCs. The level of zinc in Big Ditch is greater than the chronic AWQC. Thus, potential adverse chronic effects to some species of aquatic organisms could occur from exposure to these chemicals at the measured concentrations. The measured concentrations of zinc (in all three ditches) exceed the acute AWQC by two to four times and thus adverse acute effects could occur in sensitive aquatic organisms such as microcrustaceans (such as *Daphnia magna*) and some species of juvenile fish. Concentrations in sediments were not evaluated because interim sediment quality criteria were not available for the chemicals of concern. In evaluating these results it should be noted that these on-site ditches have not been classified by the State of Missouri and the relevance of AWQC to these water bodies is questionable. Potential impacts to aquatic organisms downstream of the sampling points in classified water bodies would be reduced as the chemical concentrations decline as a result of dilution and any transformation processes that may occur.

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SECTION 8

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