

Technical Report

Remediation Assessment

**Fansteel, Inc.
Muskogee, Oklahoma**

Volume 1 of 4

Earth Sciences Consultants, Inc.
One Marquis Plaza
5315 Campbells Run Road
Pittsburgh, PA 15205
412/787-3200
FAX 412/787-3208

Technical Services Headquarters
Export, Pennsylvania

Branch Offices
Akron, Ohio
Denver, Colorado
Philadelphia, Pennsylvania

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Executive Summary

Executive Summary

This report documents the performance and results of the remediation assessment conducted at the Fansteel, Inc. (Fansteel) Muskogee, Oklahoma facility. This work was performed in accordance with Earth Sciences Consultants, Inc.'s work plan entitled Work Plan - Remedial Assessment, Fansteel Metals, Muskogee, Oklahoma (revised July 1992). This work was approved by the Nuclear Regulatory Commission (NRC) by incorporation into Fansteel's NRC License No. SMB-911, amendment date December 21, 1992.

The work performed as part of the remediation assessment included the installation of soil borings, monitoring wells, and test pits; the collection and analysis of soil, sediment, surface water, groundwater, air, and pond residue samples; and the performance of a radioactivity scoping survey.

The results of these activities indicate that chemical and radiological contamination is present in site soils and groundwater particularly in plant areas formerly utilized for the processing of tantalum and columbium bearing ores. Impacts are generally isolated to plant areas surrounding Ponds Nos. 2 and 3 and areas to the east of the Chemical "A" and Chemical "C" plant buildings. Soil and groundwater contamination was also detected to the east of the wastewater treatment ponds and Pond No. 5, however, at levels typically lower than that exhibited in the areas associated with manufacturing and ore processing.

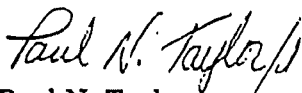
Licensed residues contained within Ponds Nos. 2 and 3 exhibited characteristically hazardous concentrations of chromium. Wastewater treatment residues present in Ponds Nos. 5, 6, 7, 8, and 9 exhibited elevated levels of radioactivity. Slightly elevated levels of radioactivity and chemical contamination were detected in sediments, soils, surface water, and groundwater samples collected from the southwest portion of the site, in the area referred to as the borrow pit.

A buildings and equipment surface radioactivity scoping survey was performed in the eastern and southern areas of the site. Buildings and equipment associated with ore processing activities exhibited elevated surface radioactivity. The Chemical "C" Building is contaminated throughout by radioactive ore residues. Isolated areas of radioactive contamination were found

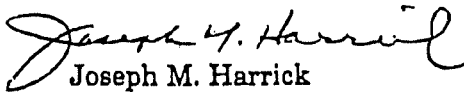
in the Chemical "A" and R&D buildings. Roof areas in the eastern plant appear to have been affected by radioactive fugitive dust. Paved ore storage and ore transportation areas west of the Chemical "A" Building also exhibited elevated levels of surface radioactivity.

Air monitoring activities conducted prior to and during the performance of the remediation assessment did not indicate the presence of elevated levels of suspended particulates or airborne radioactivity. Additionally, investigations of the shale bedrock aquifer indicate that this zone of saturation has not been affected by plant operations.

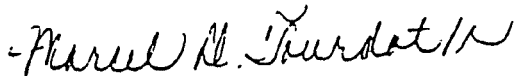
Respectfully submitted,



Paul N. Taylor
Project Manager



Joseph M. Harrick
Practice Area Manager,
Liability Management Programs



Marcel D. Tourdot
Executive Vice President, Regional Manager

PNT/JMH/MDT:ksm

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**Technical Report
Remediation Assessment
Fansteel, Inc.
Muskogee, Oklahoma**

1.0 Introduction

This report documents the remediation assessment performed by Earth Sciences Consultants, Inc. (Earth Sciences) at the Fansteel, Inc. (Fansteel) facility in Muskogee, Oklahoma. Earth Sciences was retained by Kirkpatrick & Lockhart on behalf of Fansteel to conduct the remediation assessment. The purposes of the remediation assessment were to characterize soil and groundwater quality and determine the magnitude and extent of potential contaminants of concern present on the subject site. Earth Sciences utilized technically appropriate investigative methods, in conjunction with available information regarding plant operations and site conditions, throughout the performance of the remediation assessment. The remediation assessment was performed in accordance with the approved Remedial Assessment Work Plan dated July 1992 (revised) prepared to facilitate its implementation.

1.1 Site Location and Setting

The Fansteel Muskogee plant occupies approximately 110 acres of land at a location 2.5 miles northeast of Muskogee, Oklahoma (Figure 1). The site lies along the western edge of the Arkansas River (Webber Falls Reservoir) and is bounded on the north by land owned by Muskogee Port Authority, on the south by U.S. Highway 62, and on the west by State Highway 165 and a service road. The facility was constructed in 1956 on alluvial soils and unconsolidated alluvium approximately 20 to 30 feet thick which are underlain by shale bedrock. Prior to the construction of the facility, the site was undeveloped. As expected in an area adjacent to a major river, the water table at the site is shallow. Groundwater flows largely toward the river with minor variations due to topographic influences and possibly site structures. Figure 2 presents a site plan of the Muskogee plant.

1.2 Facility Process Descriptions

Fansteel's Muskogee plant produced tantalum and columbium metals. Tantalum is used primarily in the electrical/electronics industry in the production of tantalum capacitors.

Columbium is marketed for use in heat-resistant alloys. The Fansteel processing facility had been in operation for approximately 33 years until operations ceased in 1990. The area had not been developed for any use prior to construction of the Fansteel facility and no previous structures existed.

The site has continued to be occupied by Fansteel since termination of processing in 1990. Chemical processing equipment used in the extraction of tantalum and columbium values from ores and slags was sold and removed from the site in 1990, 1991, and 1992. Site operations since 1990 have been limited to environmental monitoring; maintenance of buildings, grounds, and equipment remaining at the site; and cleanup of operating areas.

The Fansteel facility in Muskogee was constructed for the production of tantalum and columbium metal products. Raw materials utilized on site consisted of raw and beneficiated ores. Slag from tin extraction which contains commercially valuable concentrations of tantalum and columbium was also used as a raw material. The raw materials were ground and digested in hydrofluoric acid to extract the tantalum and columbium in the Chemical "C" Building (solid residues from the ore digestion process were stored in impoundments located in the east plant area). The digest was then treated by various liquid/liquid extraction processes to separate the dissolved tantalum and columbium which were then precipitated, purified, calcined, and refined to produce intermediate products (tantalum and columbium powders). These production processes occurred in the Chemical "A" Building, Chemical "C" Building, and the sodium reduction building and employed the following additional reagents: methyl isobutyl ketone (MIBK), sulfuric acid, potassium fluoride, sodium metal, sodium chloride, nitric acid, sodium hydroxide, and ammonia. Liquid wastes were treated and discharged. Detailed process flow diagrams are presented in the July 1992 (revised) Remedial Assessment Work Plan.

The raw materials used for tantalum and columbium production contained uranium and thorium as naturally occurring trace constituents. These radioactive species were present in the process raw materials at an approximate concentration of 0.15 percent each of uranium oxide and thorium oxide. This concentration is sufficient to cause the ores and slags to be classified by the Nuclear Regulatory Commission (NRC) as source materials. Consequently, Fansteel operated under NRC License No. SMB-911 for the possession of source materials.

Uranium and thorium in the raw materials were not extracted from the ores by the digestion process. The radioactive species remained in the ore digestion residues which were retained in the east plant area, specifically Ponds Nos. 2 and 3. Therefore, the ore residues are classified as source material by the NRC.

The Northwest Property Area (Figure 2), during plant operations, was never utilized for the processing, generation, or disposal of licensed material. This portion of the site was involved with processing the intermediate products (tantalum and columbium powder) which were free of licensed material. The intermediate products were pressed and sintered into shapes in the Sintering Building. These sintered products were either sold as is or further refined prior to sale by electron beam melting in the Electron Beam Building. The Northwest Property Area has been assessed for both chemical and radiological parameters. Additionally, a radiation decommissioning survey was performed on this portion of the property. The results of these activities have been documented in the Radiation Survey and Remediation Assessment Northwest Property Area report dated July 1993. Fansteel has applied for release for unrestricted use for this portion of the property.

1.3 Project Background

The U.S. Atomic Energy Commission (precursor of NRC) granted Source Material License No. SMB-911 to Fansteel on January 27, 1967. Fansteel had been operating under this license as amended from that date. The NRC controls discharge of radionuclides to surface water and storage/management of radioactive materials on site. Discharge of other species is regulated by Oklahoma Water Resources Board (OWRB) under Waste Disposal Permit No. CW-69-020 and by U.S. Environmental Protection Agency (USEPA) under National Pollutant Discharge Elimination System (NPDES) Permit No. OK0001643. OWRB approved a monthly groundwater monitoring plan as part of the waste disposal permit. The Muskogee facility is exempt from regulation under the Resource Conservation and Recovery Act (RCRA) because it is an ore processing facility. However, it is subject to statutory requirements of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Oklahoma State Department of Health (OSDH) and the Occupational Safety and Health Administration also have regulatory authority over certain aspects of facility operations. NRC has primacy over most facility operations; however, OWRB and USEPA may participate in the project if environmental conditions warrant remediation under CERCLA.

Pond No. 3, located in the northern portion of the plant site (Figure 2), had been in existence for approximately 10 years in 1989. The pond was designed and constructed as a total retention structure for ore/slag residues produced during the digestion and liquid/liquid exchange processes that occurred in Chemical "C" Building. Materials stored in the pond included digested ores and slags and fluid comprised of hydrofluoric and sulfuric acids and containing MIBK, heavy metals, and low-level radioactive species.

Pond No. 3 was constructed by excavating the alluvial soils to the top of the local shale bedrock. Because groundwater was encountered in this alluvium, a french drain network was installed around the structure to collect groundwater and route it to a wet well shown in Figure 2. Dikes were constructed above the former grade of the area to the configurations shown in Figure 2. A single synthetic liner was installed in the pond with the intent to retain all fluids and residues discharged to the structure.

The original design of the french drain collection system allowed groundwater to discharge to the small valley east of Outfall 003 (Figure 2). Some time after the pond was placed into service, the pH of the groundwater collected by the french drain decreased suggesting that the integrity of the liner may have been compromised. The wet well discharge to local surface watercourses was then ceased by plugging the outlet pipe; the collected fluids were then pumped from the wet well to Pond No. 3 or to the plant's wastewater treatment facility. The quantity of fluid pumped from the wet well fluctuated with weather conditions but typically had been approximately 10 gallons per minute.

On June 18, 1989, a large supernatant discharge from Pond No. 3 occurred from the wet well (collection sump) and french drain system adjacent to the subject pond and several seeps near the southwestern corner of Pond No. 3 (Figure 3) causing portions of the french drain system to collapse. The suspected cause of this release was a failure of the Pond No. 3 liner. The released fluid traveled along the natural drainage course around the western and northern sides of Pond No. 3 and discharged through storm water Outfall 003. Plant personnel immediately mobilized Fansteel employees and local contractors to contain the discharges.

Fluid discharge to the river was terminated by the construction of a temporary dike near Outfall 003 and a second dike near the northwestern corner of Pond No. 3. Fansteel's

personnel estimated that approximately 90,000 gallons of fluid was released into the Arkansas River before the discharge was arrested. Fansteel notified the National Response Center, State Response Commission, Muskogee Local Emergency Committee, and NRC immediately after the release was brought under control and again in writing on June 22, 1989 in accordance with PL99-499 (Superfund Amendments and Reauthorization Act Title III, Section 304) and related regulations. The fluids from the temporary ponds and Pond No. 3 were subsequently removed and routed to the plant's wastewater treatment system as directed by NRC. Pond No. 3 was approaching capacity when the release occurred.

A draft outline of a proposed remediation assessment work plan for the Pond No. 3 area entitled "Remediation Strategy, Pond No. 3" was submitted to NRC, USEPA, and OWRB in March 1990. Preliminary approval of this document was granted by the regulatory agencies with the stipulation that the entire site be included in the investigation rather than the Pond No. 3 area exclusively. On June 8, 1990, a draft remediation assessment work plan to assess conditions throughout the site was submitted to the NRC, OWRB, and OSDH for review and comment. The work plan underwent a series of agency reviews and revisions until it was eventually approved and incorporated into Fansteel's NRC license on December 21, 1992.

1.4 Purpose and Objectives

The remediation assessment was performed at the Muskogee facility to determine the potential impact of past site operations and existing site conditions on the surrounding environment. The results of this study will be utilized to ensure an efficient and environmentally sound closure of the site. Shallow soils, alluvium, bedrock, groundwater, surface water, and waste residues were characterized to determine if contaminants of environmental concern exist at the site. Studies were conducted to determine the hydraulic properties of the alluvial aquifer underlying the subject site and to determine the horizontal and vertical extent of contaminant plumes identified during the investigation. Additionally, air monitoring was conducted during the investigation to evaluate the potential for airborne transportation of contaminants. The goal of the investigation was to present sufficient data to develop technically feasible and cost-effective remedial alternatives to ensure that any risk to the environment from the identified contaminants of concern will be minimized.

1.5 Report Format

The following chapters of this report present and discuss the scope of work employed during the assessment and the results of the investigation. Chapter 2.0 presents the scope of work and field activities utilized during the performance of the remediation assessment. Chapter 3.0 discusses regional and site-specific geology and hydrogeology. Chapter 4.0 summarizes the results of the remediation assessment and Chapter 5.0 presents pertinent conclusions.

2.0 Scope of Work and Field Activities

The subsurface investigations conducted at the Fansteel facility included the installation and sampling of soil borings, groundwater monitoring wells, test pits, surface water, sediments, and ambient air. A combination of field instrumentation surveys, laboratory analyses, and hydrogeologic field testing procedures was utilized to determine physical, chemical, and radiological characteristics of soils and groundwater beneath the site. Specific details of investigation activities performed at this facility are discussed in detail below.

2.1 Drilling and Soil Sampling

A total of 96 borings (including 67 soil borings, 25 shallow monitoring wells, and 4 bedrock monitoring wells) were completed at the subject facility by A. W. Poole Drilling of Clinton, Oklahoma. Soil Borings B-1 through B-74 (Designations B-16, B-18, B-37, B-40, B-43, B-44, and B-45 were not utilized during boring numbering) were completed to characterize soil conditions only and, therefore, were advanced to the top of the uppermost zone of saturation. Boreholes for shallow Monitoring Wells MW-51S through MW-75S were advanced to the top of bedrock to characterize soil and shallow groundwater conditions. Boreholes for deep Monitoring Wells MW-151D, MW-161D, MW-167D, and MW-174D were advanced into bedrock to characterize groundwater conditions within the underlying shale. Boring logs containing detailed descriptions of subsurface materials encountered, field instrument readings, and all other pertinent drilling information are presented in Appendix A. In addition, all downhole drilling equipment was decontaminated before initial use and between borings using potable water passed through a high-pressure, high-temperature sprayer.

Boreholes for the soil borings and deep monitoring wells were advanced using 3-3/4-inch inside diameter continuous flight hollow-stem augers fitted with a 5-foot-long-by-3-inch-diameter continuous split-spoon sampler. Split-spoon samples were collected continuously throughout the depth of the boreholes. The sampling equipment was steam cleaned between uses to minimize the potential for cross contamination. Boreholes for the shallow monitoring wells were advanced through the unconsolidated materials using 6-1/4-inch inside diameter hollow-stem augers to facilitate their conversion into 4-inch monitoring wells. Continuous split-spoon samples were also collected at these locations.

Soil samples were screened in the field with a photoionization device (H-Nu) to detect any volatile organic constituents which might be present. Soil samples were also screened using a Bicon R meter and thin window beta/gamma detector for evidence of radioactive materials.

Three soil samples were selected for laboratory analysis for radiological and/or chemical analyses from each of the borings with the exception of MW-151D, MW-161D, MW-167D, and MW-179D. No soil samples were selected from deep monitoring well boreholes due to their proximity to MW-51S, MW-61S, MW-67S, and MW-74S respectively. However, continuous split-spoon samples were collected to obtain subsurface lithostratigraphic information from the deep monitoring well boreholes. For chemical analysis, samples were selected from the 0- to 6-inch interval, the depth interval immediately above the saturated zone, and an intermediate interval displaying the highest organic vapor reading or physical evidence of contamination. Similarly, samples for radiological analyses were secured from the depth interval of 0 to 6 inches, the interval immediately above the zone of saturation, and an intermediate interval displaying the highest beta/gamma reading. In some instances, the intermediate level for both chemical and radiological analyses coincided.

Soil samples designated for laboratory analysis were placed on ice and shipped to the appropriate receiving laboratory. Samples receiving radiological analyses were shipped to Accu-Labs Research, Inc. (Accu-Labs) in Golden, Colorado and samples receiving chemistry analyses were shipped to Antech Ltd. (Antech), an Earth Sciences Consultants, Inc. affiliated and OWRB-approved laboratory. Section 2.13 of this report represents specific analytical parameters. All standard protocols regarding chain of custody procedures were strictly adhered to. Soil samples not selected for laboratory analysis were archived on site for future reference, if needed.

Following completion, Borings B-1 through B-74 were grouted to the ground surface with a cement/bentonite grout (6 to 1 mixture). Borings MW-51S through MW-75S were completed by converting them to monitoring wells. Borings MW-151D, MW-161D, MW-167D, and MW-174D were advanced through bedrock to their total depths using core drilling techniques. Coring was conducted at these locations to obtain an accurate lithologic profile of the first bedrock unit underlying the site.

Prior to coring activities at MW-151D, MW-161D, MW-167D, and MW-174D, the augers were advanced to a point of refusal generally 35 to 40 feet below ground surface. The boreholes were then increased in diameter by using recirculating water-rotary drilling techniques. A 7-7/8-inch-diameter pilot bit was initially advanced within the auger holes to depths corresponding to approximately 4 feet into bedrock. The boreholes were then reamed to the final 12-1/4-inch diameter to this same depth. After the rock cuttings and sediments were flushed from the boreholes, 8-inch inside diameter threaded steel casing with a steel and concrete drive shoe attached to the lowermost section of pipe was lowered to the bottom of the borings and extended approximately 6 inches above ground surface. The casings were subsequently pressure grouted in place by pumping a cement/bentonite slurry down the casing and injecting an 8-inch-diameter barbed rubber plug under pressure into the fitted drive shoe. This technique forced the grout to circulate between the borehole annulus and the casing. A sufficient volume of cement/bentonite grout was injected prior to pressurizing the plug to ensure recirculation to ground surface. After allowing a minimum of 48 hours for the grout to cure, the rubber plug and concrete base of the drive shoe were reamed out using the 7-7/8-inch tricone drill bit and water-rotary techniques. This procedure was followed to prevent any unconsolidated materials from collapsing into the borings during subsequent drilling activities and to prevent the potential for groundwater within the shallow water-bearing zone to migrate vertically into deeper zones of saturation.

Rock cores were obtained utilizing diamond-tipped core bits and collected in an HQ stainless steel core barrel (5-inch-diameter outer barrel). Steel rods were used to hoist the 10-foot-long core barrel to the surface. Once removed from the boreholes, cores were initially screened for the presence of organic vapors utilizing an H-Nu meter and for radiation using a beta/gamma meter. The cored rock sections were then logged for lithology, color, grain size, hardness, sedimentary structures, and fractures. Rock quality designation (RQD) was measured along with total core recovery. RQD is a cumulative measure of all portions of a core greater than 4 inches in length and provides a qualitative description of the competence and degree of fracturing in strata. Rock core samples were placed in core boxes, identified, and staged on site.

Core drilling was advanced into shale bedrock and was completed after identifying evidence of groundwater migration. The bottom of the core holes were sealed utilizing bentonite pellets

to ensure that the monitoring wells communicated with the fractured horizon detected. This installation procedure was conducted after discussions with and concurrence by the NRC's personnel. Following the completion of coring and with concurrence of NRC's personnel, the boring was reamed with a 7-7/8-inch-diameter tricone drill bit using water-rotary drilling techniques. All soil and rock cuttings produced during subsurface drilling activities were collected into Department of Transportation (DOT)-approved 55-gallon drums and stored on site for proper management by Fansteel. All recirculated fluids produced during drilling activities were pumped into a tanker for subsequent management by Fansteel.

2.2 Monitoring Well Installation and Development

A total of 29 monitoring wells (identified as MW-51S through MW-75S, and MW-151D, MW-161D, MW-167D, and MW-174D) were installed at the Fansteel site to determine the geochemical character of groundwater at this location. Monitoring Wells MW-51S through MW-75S were installed within the alluvium at the top of bedrock. Monitoring Wells MW-151D, MW-161D, MW-167D, and MW-174D were installed to communicate with fractures within the uppermost bedrock shale unit (McCurtain Shale). These series of wells provide for the evaluation of groundwater chemistry within the two uppermost continuous zones of saturation beneath the facility.

All monitoring wells were constructed of 4-inch-diameter, flush-joint, threaded polyvinyl-chloride (PVC) riser pipe and well screens. As proposed in the work plan, well screens were 15 feet in length in the shallow wells and 10 feet in length in the deeper bedrock well. The well screens were factory slotted 0.01 inch and fitted with a flush-joint threaded PVC bottom cap. All PVC riser pipe and screen were steam cleaned on site prior to installation.

Groundwater Monitoring Wells MW-51S through MW-75S were constructed by placing the screen fitted with an end cap through the hollow-stem augers. Sections of solid riser pipe were then added to the screen extending to the ground surface. As the augers were removed, the annular space surrounding the PVC was filled with chemically inert clean silica sand sized appropriately for the slot size (2040 grade sand) to approximately 2 feet above the top of the screen. An approximate 1- to 2-foot-thick fine silica sand filter pack followed by approximately 2 feet of bentonite pellets was placed sequentially above the coarse sand. The bentonite pellets

were then hydrated with 5 gallons of potable water and allowed time to expand forming a low-permeability clay seal. The annular space remaining above the bentonite seal was filled with a cement/bentonite (6 to 1 mixture) grout. A 6-inch-diameter steel well guard equipped with a locking cap was grouted in place at the surface of each well. Following the completion of each well, a lock was installed on each steel guard to ensure the integrity of the well.

Groundwater Monitoring Wells MW-151D, MW-161D, MW-167D, and MW-174D were constructed similar to the shallow wells. However, due to the placement of steel casing, augers were not required for installation. In addition, a slightly larger bentonite seal (4 feet thick) was installed to support a substantially larger overlying grout component. Well installation details for all wells are presented in Appendix A. Table 1 presents a monitoring well installation data summary.

The monitoring wells were developed using surge and bail methods to remove fine-grained sediments and any materials introduced during drilling and well installation. Development continued until turbidity of the discharge water was reduced to a level acceptable to the supervising geologist and field pH and specific conductance stabilized. pH and specific conductance readings were considered to have stabilized when readings from three consecutive bailers did not vary by more than 10 percent. Water collected as a result of monitoring well development was contained in double-lined DOT 55-gallon drums and contained on site for proper management by Fansteel. Wells were developed with a 3-1/2-inch PVC bailer which was decontaminated between wells using rinses of hexane, methanol, and 5 percent nitric acid solution followed by a thorough distilled water wash.

2.3 Groundwater Sampling

Groundwater samples were collected from Monitoring Wells MW-51S through MW-75S on February 24 through March 2, 1993. Monitoring Wells MW-151D, MW-161D, MW-167D, and MW-174D were sampled on March 3, 1993. Monitoring Well MW-151D was sampled again on April 30, 1993.

In order to ensure the collection of samples representative of formational water, each well was evacuated prior to sampling. Initially, static water elevations were obtained by measuring water depth with a Solinst Model 121 water level meter to the nearest 0.01 foot. After static

water levels were recorded, the standing water volume in each well was calculated and recorded on Earth Sciences' Well Evacuation/Sampling sheet. Calculations were performed using the following formula:

$$\text{Volume (gallons)} = \pi r^2 h \times (7.48 \frac{\text{gal}}{\text{ft}^3})$$

where

$$\pi = 3.14,$$

r = inside well casing radius in feet, and

h = height of the water column in the well.

Wells were purged by removing a minimum of three well volumes of water or until they were bailed dry, whichever came first. The following information was recorded in triplicate on a field sheet: pH, conductivity, and temperature. Each well was purged using dedicated 3-1/2-inch PVC bailers in conjunction with new clean nylon rope.

Prior to well evacuation, a calibration check was performed on each field instrument. Equipment requiring calibration included the pH meter and specific conductivity meter. The dissolved oxygen meter and Eh meter were calibrated prior to groundwater sampling activities. The pH meter was calibrated by placing the probe in standard solutions of 4.00, 7.00, and 10.00 pH units and adjusting the calibration control. For measurement of specific conductivity, the Micron Extraction Procedure meter was calibrated by zeroing the indicator dial with deionized water. The dissolved oxygen meter was field calibrated by adjusting the air temperature and mean sea level elevation dials to conform to field conditions. The Eh meter was calibrated by placing the probe in Zoebel solution which has a known stable redox potential. The instrument is then adjusted according to the known calibration solution and groundwater temperatures. A record of the calibration check was included on the well evacuation/water sampling sheets.

The wells were sampled within 24 hours following the time of well evacuation. Prior to sampling, the water level in the well was again obtained to ensure adequate recovery since

purging and recorded on the field sheets. The dissolved oxygen probe was lowered into the well and a measurement of dissolved oxygen was obtained and recorded. The water level meter and dissolved oxygen probe were decontaminated between sampling locations using rinses of hexane, methanol, and 5 percent nitric acid solution followed by a thorough distilled water wash.

Groundwater samples were obtained using dedicated 3-1/2-inch PVC bailers in conjunction with new clean nylon rope. After collecting the samples with minimal disturbance, the water samples were decanted directly from the bailer into the appropriate sample containers which contained the appropriate preservative. Volatile organic compounds (VOC) were collected first to minimize potential volatilization. Each 40-milliliter vial was filled such that no airspace was present. Following the collection of VOCs, other samples were collected in appropriate sample containers and properly preserved. Field measurements of pH, conductivity, and temperature were collected from a clean disposable plastic cup. In addition, general field observations including turbidity, odor, immiscible layers, and color were recorded for each groundwater sample. The redox potential was measured with an Eh meter at each well location on March 4, 1993 using a clean disposable plastic cup. Section 2.13 of this report presents specific analytical parameters. As with the soil samples, groundwater samples requiring radiological analyses were submitted to Accu-Labs and those requiring chemical analyses were submitted to Antech. Proper chain of custody protocols were adhered to regarding sample handling and transportation.

2.4 Test Pit Excavation and Soil Sampling

A total of 13 test pits (TP-1 through TP-13) were excavated at the Fansteel site (Figure 2) to investigate the potential presence of buried drums in a central area of the site situated between the service building to the west, the Chemical "A" Building to the east, the R&D building to the north, and Pond No. 8 to the south. The test pits were excavated in this area even though a geophysical survey did not identify any unidentifiable magnetic anomalies in any area of the site.

All 13 test pits were excavated to a depth of approximately 5 feet below ground surface. The test pits were profiled for depth, subsurface horizons, color, structure, moisture, or groundwater presence, rock fragments, etc. All excavation activities were supervised and logged by

a qualified Earth Sciences geologist. Each test pit was screened with an H-Nu and a beta gamma meter to detect any volatile organic vapors or radioactive materials which may have been present. Test pit logs are presented in Appendix B. One soil sample was selected for laboratory analysis based upon visual observations and instrumentation responses. The soil samples were analyzed for a variety of radiological and chemical parameters which are presented in Section 2.13 of this report.

2.5 Pond Residue Sampling

Pond residues were sampled at 25 different locations within Ponds Nos. 2 (3 locations), 3 (5 locations), 5 (3 locations), 6 (2 locations), 7 (2 locations), 8 (5 locations), and 9 (5 locations). Pond sampling locations are identified in Figure 2. Because the residues contained within these ponds generally could not support a drill rig and standard split-spoon sampling techniques would not effectively sample the residues, an alternative method was used. Residue samples were collected at each location using a hollow-steel sampling barrel connected to an air compressor. The sampling barrel and air compressor were mounted on a pontoon barge which maneuvered from sampling location to sampling location by means of a steel cable and winch. Once at a sampling location, the sample barrel was inserted into the pond residues and a slight vacuum was created on the inside of the sample barrel. The barrel was then manually advanced through the pond residues until the bottom of the pond was encountered. The vacuum was maintained and the sample barrel was then slowly extracted from the residues. The residue samples were then extracted from the sample barrel by reversing the vacuum and exerting a small amount of pressure to the inside of the barrel.

Once extracted, the residue sample was divided into equal thirds, placed into stainless steel buckets, and homogenized. The homogenized samples were then placed into appropriate sample containers resulting in three samples per location. The sample barrel and stainless steel buckets were decontaminated between sample locations by swabbing the interior of the barrel and scrubbing the buckets with deionized water and soap followed by rinses of deionized water, a 5 percent nitric acid solution, methanol, and a final deionized water rinse. The barge and all sampling equipment were thoroughly steam cleaned between ponds and surveyed with beta/gamma meters to ensure that all residual radioactivity had been removed.

As stated earlier, three residue samples were collected from each sample location corresponding to the top third, middle third, and bottom third of residues present. The samples were analyzed for a variety of radiological and chemical parameters by Accu-Labs and Antech respectively. A specific list of analytical parameters is presented in Section 2.13 of this report.

2.6 Surface Water and Sediment Sampling

A total of seven surface water and six surface sediment samples were collected at the locations identified in Figure 2. In general, a sediment sample was collected at each surface water sampling location for comparative purposes. However, no sediment was available for sampling at Outfall 001 (SS-001). Surface water was collected directly into laboratory supplied sample containers. A new disposable sampling trowel was used at each location to sample sediments. The sediments and surface water samples were analyzed for a variety of radiological and chemical parameters as discussed in Section 2.13 of this report.

2.7 Seep Sampling

During the performance of the remediation assessment, the pool elevation of the Arkansas River prohibited access to the riverbank and an inspection for seeps could not be performed at that time. In early August 1993, after a period of significant rainfall, Earth Sciences' personnel returned to the site and completed the seep inspection. No seeps were identified which exhibited a sufficient enough flow to allow for sample collection and, as a result, no seep samples were collected.

2.8 Hydrogeological Testing

Hydrogeologic testing was conducted to determine representative hydraulic properties of both the shallow alluvial and shale bedrock aquifers beneath the Fansteel site. This information is valuable in defining possible contaminant pathways, determining the potential environmental risk associated with groundwater contamination, and developing technically feasible remedial alternatives for groundwater remediation. Methods which incorporate appropriate hydraulic testing without significant discharge of contaminated groundwater have been selected.

Hydraulic conductivity, storativity, specific yield, transmissivity, hydraulic gradients, and average linear flow velocity were calculated for both the alluvial and shale bedrock aquifers

beneath the site. Hydraulic conductivities will be calculated using aquifer type (confined or unconfined) and hydraulic test (slug or pump) specific models. Storativity, specific yield, and transmissivity for each aquifer will be calculated using standard formulas and aquifer characteristics determined during drilling activities. A potentiometric surface map will be generated for each aquifer from data collected during the remediation assessment. The hydraulic gradients will be determined using information provided on these potentiometric surface maps. To determine the rate of groundwater migration beneath the site, the average linear flow velocity in the downgradient direction will be calculated using the formula:

$$V = \frac{k \cdot i}{n_e}$$

where

V = average linear flow velocity,
k = hydraulic conductivity,
i = groundwater flow gradient, and
n_e = effective porosity.

2.8.1 Slug Tests

Slug tests were performed on 19 of the newly installed monitoring wells at the site after development. Fifteen of the shallow wells and the 4 deep wells were slug tested to characterize the hydraulic properties of both the alluvial and shale bedrock aquifers. The tests were performed by placing a solid PVC pipe (slug) below the static water level and measuring the subsequent rate of fall of the water level in the well. In-Situ Hermit digital environmental data loggers interfaced with pressure transducers were used to record the rate of water level recovery in the monitoring wells during the testing periods. Recovery data generated during these tests will be reduced using the H. Bouwer and R. C. Rice method (1976, "A Slug Test for Determining the Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells," Water Resources Research, Vol. 12, No. 3) to determine the hydraulic conductivity (K) of the aquifers. Appropriate computer modeling software will be used to aid in these calculations.

2.8.2 Pumping Tests

A pump test was conducted at Monitoring Well MW-53S after Earth Sciences' personnel determined that this location was not impacted by site operations in either the alluvial or shale bedrock aquifers. The pump tests required the installation of three 2-inch-diameter PVC observation wells and one 4-inch-diameter PVC pumping well in the alluvial aquifer. Only an initial decontamination of drilling equipment and no soil sampling activities were necessary because the proposed pumping tests were conducted on wells at background locations. The pumping well was drilled and installed utilizing the standard procedures presented in Sections 2.1 and 2.2 of this report. All drilling and pumping activities were supervised by a qualified hydrogeologist.

After well development, an electric-submersible pump was lowered into the well and a step test was conducted to determine maximum well yield. Upon completion of the step test, the water level in the pumping well was allowed to equilibrate and a steady rate nonequilibrium pumping test was performed in the shallow aquifer. Monitoring Well MW-53S was pumped for 3,900 minutes (65 hours). The total duration of the pump test including recovery was 72 hours. Based on step test data, it was determined that a pumping rate of 0.1 gallon per minute would be adequate to maintain well yield. Water level measurements from the pumping and observation wells were measured and recorded using In-Situ Hermit digital environmental data loggers interfaced with pressure transducers during the pumping test and throughout the water level recovery period following completion of the pumping test. Data were reduced using Jacob's Straight-Line Method and other appropriate methods to determine the hydraulic properties of each aquifer. Applicable computer modeling software was used to aid in these calculations.

2.9 Background Radiological Sampling

Background radiological conditions for the Fansteel facility were determined in order to establish baseline conditions against which radiological values measured on the site could be compared. The background was determined by obtaining instrument readings and soil samples from 30 off-site locations near the Fansteel facility. The background measurement locations are shown in Figure 3. The following measurements were performed at each background location:

- Gamma radiation in counts per minute at the ground surface utilizing a Ludlum Model 44-10 gamma scintillation probe and a Ludlum Model 2221 single channel analyzer operated in the scaler mode.
- Gamma radiation in counts per minute at an elevation of 1 meter above the ground surface utilizing a Ludlum Model 44-10 gamma scintillation probe and a Ludlum Model 2221 single channel analyzer operated in the scaler mode.
- Beta-gamma radioactivity in counts per minute at the ground surface utilizing a Ludlum Model 44-9 pancake type Geiger-Muller probe and a Ludlum Model 2221 single channel analyzer operated in the scaler mode.
- Gross alpha and gross beta radioactivity of the 6 inches of surface soil. Gross alpha and gross beta radioactivity were determined by laboratory analysis.
- Concentration of specific radionuclides in the top 6 inches of surface soil. Specific radionuclide concentrations were determined by laboratory analysis utilizing gamma spectroscopy and radiochemical analysis.

The results of the background investigation were utilized to calculate the average off-site gross alpha and gross beta radioactivity as well as the average concentration of uranium and thorium in the off-site soils.

2.10 Site Radiological and Geophysical Survey

Radiological and geophysical survey activities were conducted over the southern and eastern portion of the Fansteel facility. The following operations were performed:

- Instrumental survey of exterior grounds, paved areas, roads, concrete pads, etc.
- Instrumental survey of building exterior surfaces.
- Instrumental survey of building interior surfaces.
- Instrumental survey of equipment and facilities.
- Laboratory analysis of samples of soil, subsurface materials, sediments, surface water, groundwater, and pond residues for gross alpha and gross beta radioactivity as well as identification and quantitation of specific radionuclides.

Instrument surveys were conducted at defined locations. In the case of the instrumental surveys performed on the exterior grounds and exterior and interior building surfaces, the survey locations are described by the imposition of a regularly shaped geometric grid over the areas to be surveyed. The dimensions and spacing of these grids vary with the area being surveyed. It should be noted that the site radiological survey was performed to identify areas of potential concern and not intended as a comprehensive decommissioning survey.

2.10.1 Instrumental Survey of Exterior Grounds

2.10.1.1 Radiological Survey

External areas of the Fansteel property were subject to an instrumental survey to determine the presence of surficial contamination by radioactive materials and to indicate the possible presence of subsurface accumulations of radioactivity. Measurements of alpha, beta, and gamma radioactivity were obtained at the ground surface at designated points covering the entire area of land occupied by Fansteel. Additionally, gamma radioactivity measurements were obtained at an elevation of 1 meter at each of these points. The following instruments were used for performing these surveys:

- Ludlum Model 43-68 gas proportional probe attached to a Ludlum Model 2221 or Model 2200 single channel analyzer for alpha and beta activity measurements.
- Ludlum Model 43-10 or 43-5 alpha scintillation probe attached to a Ludlum Model 2221 or 2200 single channel analyzer for alpha activity measurements.
- Ludlum Model 44-10 gamma scintillation probe attached to a Ludlum Model 2221 or Model 2200 single channel analyzer for gamma radiation measurements.
- Ludlum Model 44-9 pancake type Geiger-Muller probe attached to a Ludlum Model 2221 or 2200 single channel analyzer or Ludlum Model 3 ratemeter for measurement of beta and/or gamma radioactivity.

A survey grid was established over the south and east plant area of the property for the location of sample points. Two different spacings of grid points were utilized. Surveys were performed within the boundaries of the areas utilized for manufacturing, processing, storage,

and waste management at a 10-meter interval. These areas were considered more likely to exhibit radioactivity than other areas on the Fansteel property. Outside the designated remediation assessment study areas, surveys were conducted at a 25-meter interval. The location of exterior grounds survey points is shown in Figure 4. Survey measurements were obtained at the numbered locations shown in the figure. Soil samples were collected at some of the survey grid points which exhibited elevated radioactivity with respect to background in the area. These samples were analyzed for gross alpha and gross beta.

2.10.1.2 Geophysical Survey

Each exterior survey point was also examined for the presence of subsurface metal objects which might indicate the presence of buried drums, tanks, or other containers. This investigation was conducted using electromagnetic metal detectors (Fisher Model "Pulse 8X").

2.10.2 Instrumental Survey of Building Exterior Surfaces

Radioactivity surveys were conducted over the exterior surfaces of the buildings located on the south and east plant portion of the Fansteel property. A 1-meter square grid was established to locate survey points on each building exterior wall. A portion of the grid squares were then surveyed for the presence of radioactivity. Building exterior and roof surfaces were surveyed at a density of at least 5 percent of the available grid square, i.e., one grid square in 25.

The same types of instruments were utilized for this survey as described in Section 2.10.1.1.

The following measurements were obtained from each surveyed 1-meter square area:

- Three measurements of beta activity, consisting of one 1-minute count from the upper right-hand quadrant, the center, and the lower left-hand quadrant.
- One measurement of alpha activity consisting of one 1-minute count from the center of the square.
- One measurement of gamma activity consisting of one 1-minute count at the surface of the center of the square.
- One measurement of gamma activity consisting of one 1-minute count at a distance of 1 meter normal to the center of the square.

Building locations are shown in Figure 2.

2.10.3 Instrumental Survey of Building Interior Surfaces

Building interior surfaces were surveyed in the same manner as the building exterior surfaces. The same type of grid, instruments, and measurement techniques were used for the interior building surface surveys as for the building exterior surface surveys. Building interior surveys were conducted at a density of 11.1 percent of the available grid squares, i.e., one grid square in nine.

2.10.4 Instrumental Survey of Equipment and Facilities

Equipment and furnishings located inside the buildings were also surveyed. A regularly spaced grid cannot normally be established for items of equipment, furniture, etc., because of their small size and irregular shape. Consequently, survey point locations were arbitrarily assigned for these items. Survey points were selected such that each identified item of equipment or facility component was measured for surficial radioactivity. Items with an apparent surface area of 4 square meters or more had additional survey points located such that one set of measurements was obtained for every 4 square meters of surface area. The same types of instruments and measuring techniques were used for the survey of equipment and facilities as were utilized for the building surface surveys.

The radiological survey of the Fansteel property was conducted as two separate studies. The northwest portion of the property, consisting of approximately 35 acres of ground and 6 buildings, was treated as a separate parcel for purposes of the radiological survey. Results of the radiological survey for this portion of the property were reported in Radiation Survey and Remediation Assessment Northwest Property Area dated July 1993. The radiation survey addressed in this report concerns the remainder of the Fansteel property, consisting of approximately 75 acres and 11 buildings. The boundaries of the plant area and buildings subject to the radiation survey discussed herein are shown in Figure 2.

2.11 Air Monitoring

Air monitoring was conducted prior to and during the performance of remediation assessment field activities in order to determine if airborne particulate matter and/or radioactivity were being released from the site. Five air monitoring stations were established at the locations

shown in Figure 2. Air samples were collected over 24-hour periods in accordance with the procedures outlined in the remediation assessment work plan. Samples were analyzed gravimetrically for total suspended particulates (TSP). Gross alpha and gross beta radioactivity were also measured on the particulate materials retained on the TSP filters.

2.12 Site Survey

All test borings and site monitoring wells were located according to a surveyed site grid system. Test borings were surveyed for ground surface elevations and monitoring wells were surveyed for ground surface, top of PVC, and top of steel casing elevations. All elevations are referenced to a U.S. Geological Survey datum and are accurate to 0.01 foot. All surveying was performed by Newell and Associates, a licensed Oklahoma surveyor.

2.13 Laboratory Analysis

Samples were collected and transported for analysis at the Muskogee facility following standard procedures outlined in the previous sections of this chapter. Contaminants of concern at the site were defined based on past site operations and historical groundwater, soil, and waste chemistry data. All samples collected for chemical analysis were analyzed by Earth Sciences' affiliated laboratory, Antech. All radiological parameters were analyzed by Accu-Labs.

Groundwater and surface water samples collected for laboratory analysis were analyzed for total metals (tantalum, columbium, tin, lead, nickel, antimony, arsenic, barium, cadmium, calcium, chromium, mercury, selenium, and silver), total fluoride, total ammonia, total sulfate, nitrate, gross alpha, gross beta, and MIBK. Dissolved metals analyses (same specific metals as above) were performed on 20 percent of the aqueous samples collected for comparative purposes. The selection of aqueous samples for dissolved metals analysis was based on elevated total metals analytical results. Additionally, groundwater samples collected from 13 of the site monitoring wells were analyzed for the USEPA Target Compound List (TCL) parameters to verify that the contaminants of concern list identified at the site is comprehensive. Included in this analysis are all monitoring wells downgradient of the facility (MW-60S, MW-61S, MW-151D, MW-161D, MW-62S, MW-66S, MW-67S, MW-167D, MW-73S, and MW-74S), one monitoring well directly downgradient of Pond No. 3 (MW-71S), and three upgradient wells to establish background conditions (MW-51S, MW-151D, and MW-52S). Generally, if gross alpha was detected in excess of 15 picocuries per liter or gross beta was detected in excess of

50 picocuries per liter in a sample, individual radionuclide analyses were performed to determine the contributing species.

Soil and sediment samples collected for laboratory analysis at the site were analyzed for total metals (tantalum, columbium, tin, lead, nickel, antimony, arsenic, barium, cadmium, calcium, chromium, mercury, selenium, and silver), total fluoride, total ammonia, total sulfate, gross alpha, gross beta, and MIBK).

Generally, if gross alpha or gross beta was detected at levels significantly above background concentrations in site soil or sediment samples, individual radionuclide analyses were performed to determine the contributing species. The selection of soil or sediment samples chosen for individual radionuclide determinations was based on the number, location, distribution, and extent of apparent contamination of the samples.

Additionally, 20 percent of the soil samples were analyzed for the USEPA Toxicity Characteristic Leaching Procedure (TCLP) metals to determine the mobility of any contaminant detected. Soil samples were selected for TCLP metals analysis based on the highest total metals concentrations detected.

Waste samples collected from the facility's ponds (Ponds Nos. 3, 5, 6, 7, 8, 9, 1S, and 1N) were analyzed for total metals (antimony, arsenic, barium, beryllium, cadmium, chromium, columbium, lead, mercury, molybdenum, nickel, selenium, silver, tantalum, and tin) utilizing inductively coupled argon plasma procedures, TCLP metals, major anions and cations, total cyanide, VOCs, semivolatile organic compounds, uranium, thorium₂₃₀, radium₂₂₆, radium₂₂₈, gross alpha, and gross beta.

3.0 Geology and Hydrogeology

This chapter discusses the regional geology and hydrogeology as it pertains to the Fansteel facility located in Muskogee, Oklahoma. The site-specific geology and hydrogeology is also presented in this chapter and is based on specific information and data obtained during the performance of the remediation assessment. The regional geologic setting is discussed in Section 3.1 and the regional hydrogeology is presented in Section 3.2. Sections 3.3 and 3.4 discuss site-specific geology and hydrogeology.

3.1 Regional Geology

The city of Muskogee, Oklahoma is located in the unglaciated Osage Section of the Central Lowlands Physiographic Province. The eastern boundary of the section is delineated by the lapping of westward dipping Pennsylvanian rocks onto the western edge of the Ozark and the Ouachita uplifts. On the south, the Osage Section abuts the Arkansas Valley and Ouachita Mountains. Much of the Osage Section can be described as scarped plains. The topography ranges from nearly featureless plain and low escarpments to bold escarpments that rise as much as 600 feet above the adjacent plains. Lowlands or plains mark the weak rock belts and hills or escarpments the areas of resistant rock.

Bedrock in the southeastern portion of the Osage Section consists of mostly thin- to massive-bedded sandstone, shale, siltstone, and limestone of Pennsylvanian Age. The sandstone beds are hard and well cemented and the shales and siltstones are compact and dense. Units identified in the Muskogee area include the Hartshorne Sandstone, the McCurtain Shale, and the Warner Sandstone, in ascending order. Permeability in this type of bedrock is generally low and groundwater movement depends on secondary porosity (joints and fractures) rather than primary porosity (intergranular).

Although the subject site is physically located in the Osage Section, the regional structural geology is influenced by its proximity to the Boston Mountains Section of the Ozark Plateau Physiographic Province and the Arkansas Valley Section of the Ouachita Physiographic Province. The Boston Mountains form a fairly narrow east-west belt at the extreme southern margin of the Ozark Dome (uplift). Rocks of the Boston Mountains Section are early and middle Pennsylvanian in age and are predominantly sandstone and shale. Faulting is

conspicuous in the Boston Mountains, particularly in Cherokee and Adair counties of Oklahoma. However, the number and magnitude of these faults rapidly subsides until they are eventually unrecognizable west of the Arkansas River. On the southern margin of the Boston Mountains, near the subject site, bedrock dips steepen rapidly as the strata descend into the synclinerium in the Arkansas Valley to the south.

The Arkansas Valley Section is an east-west belt that extends from Oklahoma to the Coastal Plain in Arkansas. The Arkansas Valley is a trough both topographically and structurally. It is transitional between the essential homoclinal structure of the south flank of the Boston Mountains to the north and the complexly folded strata of the Ouachita Mountains to the south. Intensity of folding increases from the Ozark Uplift (north) to the Ouachita Mountains (south). Closed folding with an east-west trend characterizes the Arkansas Valley. The structures and associated ridges commonly overlap one another en echelon. Rocks in the Arkansas Valley, with the exception of a few igneous intrusions, are Carboniferous in age and belong mainly to the Atoka, Stanely, and Jackfork groups. The Atoka Group which consists mostly of shale and thin sandstone forms an erosional scarp located approximately 4 miles from the Arkansas River (and the subject site) and is the closest bedrock outcrop. The subject site is located on the northern flank of the Arkansas Valley. Bedrock dips typically are to the south toward the axis of the basin.

Bedrock in the area of the subject site is nearly entirely overlain by alluvial deposits. The general regional topography of the bedrock beneath the alluvial deposits is relatively uniform with minor variations due to differential erosion. Terrace deposits having upper surfaces ranging from 20 to 120 feet above the floodplain border the alluvial deposits in segments on both sides of the Arkansas River. These deposits are composed predominantly of silt, fine sand, coarse sand, and gravel near the base. The city of Muskogee is on a terrace segment that extends north and east of the city to the bank of the Arkansas River.

Alluvium is formed in lenticular segments along the Arkansas River from 1 to 3 miles wide and 3 to 11 miles long which roughly parallel the river flow direction. Deposits of alluvium underlying the floodplain consist of clay, silt, sand, and gravel in proportions that vary locally. A general feature of the alluvium is the gradation in grain size from gravel or coarse-grained

sand near the base of the deposit to silt and clay near the surface. Its total thickness averages 42 feet and its saturated thickness is approximately 25 feet.

3.2 Regional Hydrogeology

Shale bedrock permeability is generally low and, therefore, does not readily transmit groundwater in the Muskogee area as discussed previously in Section 3.1. However, a small amount of water is produced from bedrock aquifers throughout the area for domestic and stock use, presumably from fractures or joints within the bedrock. Depths to water measured in wells completed into the bedrock average approximately 30 feet below ground surface.

Alluvial deposits are the most important aquifer in the Muskogee area and along the Arkansas River in general. Precipitation is the primary recharge, averaging approximately 36 to 40 inches per year (Todd, 1983). Natural discharge is mainly by seepage into streams and evapotranspiration. Quantities of groundwater adequate for domestic or stock use are available almost everywhere on the alluvial floodplain. Wells completed into the alluvium have been recorded to yield between 300 and 5,000 gallons per minute (Todd, 1983).

Groundwater in the alluvium is predominantly a hard, calcium, magnesium bicarbonate type. The quality is affected by precipitation, geology, water movement, and hydraulics of the alluvium. The water is suitable for irrigation and for domestic, stock, and limited industrial purposes.

3.3 Site Geology and Hydrogeology

In February 1991 (revised July 1992), Earth Sciences submitted a Remedial Assessment Work Plan for the Fansteel facility in its entirety. Earth Sciences' personnel conducted a background literature search to obtain regional geologic and hydrogeologic information concerning rock units and unconsolidated deposits in the vicinity of the Fansteel facility. Information obtained during this search was used to postulate geologic and hydrogeologic conditions underlying the subject facility and develop a site-specific work plan to evaluate such conditions.

The Remedial Assessment Work Plan proposed to define geologic conditions of the subsurface through an extensive drilling program that included collection of continuous split-spoon samples of the unconsolidated materials and obtaining core samples of the underlying bedrock.

The hydrogeologic conditions in the Northwest Property Area were to be defined by observing water inflow zones during drilling, slug tests, and static water level measurements. The following sections present a detailed summary of site geologic and hydrogeologic conditions at the Fansteel property area based on these activities.

3.3.1 Site Geology

A total of 96 soil borings were advanced at the subject property as specified in the remediation assessment work plan. Twenty-five of these soil borings were converted into shallow ground-water monitoring wells (MW-51S through MW-75S) and four into deep monitoring wells (MW-151D, MW-161D, MW-167D, and MW-174D). In addition, three observation wells (OW-1, OW-2, and OW-3) were installed as part of the pumping tests performed at the subject site. The shallow monitoring wells were installed to the top of bedrock, fully penetrating the unconsolidated materials. The deep monitoring wells were installed into the McCurtain Shale which represents the first bedrock unit encountered beneath the site. The remaining soil borings not converted into monitoring wells were also drilled into unconsolidated materials to determine the depth to groundwater in these locations and to provide additional information regarding the chemical character of the sediments beneath the site. However, because these three borings were not fully advanced to bedrock, the thickness of the water-bearing zone at these locations was unquantifiable. The locations of the soil borings and monitoring wells are presented in Figure 2 included with this report.

As shown in geologic Cross Sections A-A', B-B', and C-C' (Figure 5) and the boring logs contained in Appendix A, unconsolidated deposits underlying the Fansteel site range in thickness from approximately 8.75 feet (MW-75S) to approximately 34.5 feet (OW-1). These unconsolidated materials consist of natural soils and heterogeneous fill material. The fill is probably a heterogenous mixture of man-made materials and reworked natural soils used during the grading of the site. Fill material was not identified in most of the soil borings, however, where encountered, thicknesses ranging from 0.5 foot (MW-58) to 24 feet (OW-2) were observed.

The natural soils observed at the subject site are alluvial terrace deposits composed predominantly of silty and sandy clay, silt, fine sand, and coarse sand. It is typical of alluvial deposition for the more coarse-grained deposits to be found near the base of the materials.

Coarse-grained materials are heavier and will remain suspended in a medium- to high-energy environment for a shorter period of time than fine-grained sediments. This depositional environment is evident in the sequence of materials encountered beneath the Fansteel site.

The alluvial soil deposits observed beneath the subject property can be divided into two units. At the base of the unconsolidated deposits and overlying bedrock is a medium- to coarse-grained sand unit ranging in thickness from approximately 1.5 feet (MW-56S) to 17.5 feet (MW-54S). This sand unit is generally saturated throughout its entirety with few exceptions.

Additionally, at the base of the lower coarse-grained unit, a sand and gravel layer was observed in seven of the soil borings. This very coarse-grained layer, where observed, ranged in thickness from 0.5 foot (B-20) to 5.0 feet (B-64). Except for the occurrence in OW-2, the sand and gravel layer appears to be confined to the northeastern portion of the subject property.

Overlying the sand unit and comprising the major portion of the unconsolidated materials are a series of finer-grained deposits. These fine-grain materials range from 3 feet (MW-69S) to 27 feet (OW-1) in thickness and consist of predominantly silty and sandy clay at the top grading to clayey sand toward the bottom. As is evidenced at Well MW-51S, occasional coarse-grained lenses of materials may be found within the predominantly finer-grained matrix.

The bedrock encountered beneath the facility is the McCurtain Shale. Site monitoring wells MW-151D, MW-161D, MW-167D, and MW-174D were designed to monitor hydrogeologic conditions in the McCurtain Shale. As part of the monitoring well installation process, rock cores of the McCurtain Shale were retrieved and logged in detail. Monitoring Well MW-174D had the deepest penetration of the McCurtain Shale, 56.3 feet. Based on the boring logs contained in Appendix A for Monitoring Wells MW-151D, MW-161D, MW-167D, and MW-174D, the McCurtain Shale encountered at this location is predominantly medium to dark gray, siliceous, and moderately hard. Few relatively intense zones of horizontal fracturing were observed which included the presence of a few fractures on a 45-degree plane from horizontal. RQD values ranged from 0 to 100 percent. In general, the lower RQD values were recorded near the top of bedrock surface and typically increased with increasing depth corresponding to lessening degrees of weathering. Some of the fractures in the basal 30 feet of shale are clay filled indicating groundwater flow through fractures in this portion of the shale. Due to the

injection of water during coring activities, zones of saturation within the shale were detected using secondary identification indicators such as staining, contact features, and fracture/filling characteristics.

Although encountered at different portions of the facility during other remediation assessment activities, the strike and dip of the McCurtain Shale beneath the facility was not able to be calculated from drilling information because the unit was not fully penetrated and the uppermost surface represents an erosional surface. However, a strike and dip measurement from an outcrop of the McCurtain Shale on the west bank of the Arkansas River east of the Fansteel property boundary indicated the strike to be N20°W with a dip of 14 degrees to the southwest.

A top of bedrock map (Figure 6) was prepared for the Fansteel site using drill hole data collected during this assessment. As shown in Figure 6, the top of bedrock wholly consists of the McCurtain Shale with no detectable lithologic boundaries. The top of bedrock surface slopes from west to east over the majority of the Fansteel site. However, along the southern boundary of the subject site, the bedrock surface begins to rise slightly. Consequently, the overall morphology of the bedrock surface beneath the Fansteel site resembles an elongate swale with a north-south axis. Figure 6 depicts a depression on the bedrock surface in the northeast quadrant of the site roughly centered around Monitoring Well MW-72S. This depression in the bedrock surface most likely is a result of construction activity associated with the installation of the french drain circumventing Pond No. 3, rather than natural erosional or depositional processes.

3.4 Site Hydrogeology

Hydrogeologic conditions of the Fansteel property were determined using groundwater elevation data (Table 1), slug tests, data (Appendix C), and interpretation of geologic data discussed in preceding sections. Twenty-nine groundwater monitoring wells were installed to communicate with two distinct zones of saturation. Monitoring Wells MW-51S through MW-75S were installed to communicate with the unconsolidated zone of saturation and Monitoring Wells MW-151D, MW-161D, MW-167D, and MW-174D were installed to communicate with a water-bearing zone within the shale bedrock.

Groundwater within the unconsolidated deposits is located at the base of the sediments within the coarse-grained materials. The unconfined saturated sand unit overlying bedrock is laterally persistent across the subject area. The saturated thickness of this unit ranges from approximately 1.5 feet at Monitoring Well MW-56S to 17.5 feet at MW-54S. Perched zones of saturation were not encountered. In the instance where a coarse-grained lens of material was encountered overlying a finer-grained material, the lens was dry.

A groundwater contour map (Figure 7) was constructed based on groundwater elevation data for wells communicating with this unit across the entire facility. As indicated in Figure 7, a groundwater divide in the unconsolidated zone of saturation in the Northwest Property Area results in radial flow northeast, southeast, and southwest to other portions of the facility at hydraulic gradients of 0.0076, 0.003, and 0.0064 respectively. Hydraulic gradient calculations are presented in Appendix C.

3.4.1 Single Well Aquifer Characterization

Slug tests were conducted in each well to determine the hydraulic conductivity and transmissivity of the unconsolidated zone of saturation. The hydraulic conductivity of the northeast water-bearing zone ranged from 1.32×10^{-2} centimeter per second at Well MW-65S to 5.95×10^{-3} centimeter per second at Well MW-63S. The mean hydraulic conductivity for the northeast water-bearing zone was calculated as 5.43×10^{-3} centimeter per second. The hydraulic conductivity of the southwest water-bearing zone ranged from 5.15×10^{-3} centimeter per second at Well MW-56S to 3.12×10^{-3} centimeter per second at Well MW-54S. The mean hydraulic conductivity for the southwest water-bearing zone was calculated as 4.18×10^{-3} centimeter per second. The hydraulic conductivity of the southeast water-bearing zone ranged from 3.86×10^{-3} centimeter per second at Well MW-59S and 7.21×10^{-3} centimeter per second at Well MW-58S. The mean hydraulic conductivity for the southeast water-bearing zone was calculated as 5.56×10^{-3} centimeter per second.

Average linear groundwater velocity calculations were calculated for the shallow aquifer using effective porosity values of 15 and 20 percent for variations of sand, gravel, and some silty clay. The average linear velocity for the northeast and the southeast flow direction was consistent across the area ranging from 1.77×10^{-4} centimeter per second to 2.74×10^{-4} centimeter per second. However, average linear velocity for the southwest direction was slightly lower,

ranging from 6.27×10^{-5} centimeter per second to 8.36×10^{-5} centimeter per second. Slug test and average linear groundwater velocity calculations are presented in Appendix C.

The volume of groundwater flow through the unconsolidated zone of saturation in the Fansteel site was calculated for the three flow directions, the southeast, southwest, and northeast. Groundwater flow associated with these areas was determined to be 0.53, 0.4, and 0.52 gallon per minute respectively. Calculations for volume of groundwater flow are presented in Appendix H.

Groundwater within the McCurtain Shale was encountered at Well MW-151D, MW-161D, MW-167D, and MW-174D in the Fansteel property area. These deep monitoring wells were installed to communicate with a zone of fractured shale which was determined to produce a measurable quantity of water. The rock core above and below this fractured sequence was determined to be dry based on core inspection. Groundwater in this zone of saturation was encountered under confined conditions and is separated from the overlying unconsolidated zone of saturation by approximately 30 feet of shale bedrock. The significant difference in static groundwater elevation observed between nested Monitoring Wells MW-51S, MW-61S, MW-67S, and MW-74S (designed to communicate with the overlying unconsolidated material) and Monitoring Wells MW-151D, MW-161D, MW-167D, and MW-174D (designed to communicate with the shale bedrock) indicates that these pairs of monitoring wells communicate with two distinct zones of saturation.

A potentiometric surface map (Figure 8) was constructed based on groundwater elevations obtained from all site monitoring wells communicating with the McCurtain Shale. As shown in Figure 8, groundwater in the shale bedrock unit beneath the Fansteel property area has a bidirectional flow direction; one component of flow is to the west-northwest and the second to the east. The flow to the northwest has a hydraulic gradient of 0.017. The hydraulic gradient of the easterly flow is 0.00565. Hydraulic gradient calculations are presented in Appendix H.

3.4.2 Single Well Aquifer Characterization Tests

Slug tests were performed at Monitoring Wells MW-151D, MW-161D, MW-167D, and MW-174D to determine the hydraulic conductivity and transmissivity of the shale bedrock zone of saturation at this location (Table 7). The hydraulic conductivities of bedrock Monitoring

Wells MW-151D, MW-161D, MW-167D, and MW-174D were 3.82×10^{-6} , 1.54×10^{-5} , 1.08×10^{-3} , and 9.72×10^{-6} centimeter per second respectively. However, it should be noted that the saturated zone in MW-167 was 17 feet compared to 5.5, 6.0, and 7.25 feet in the other three bedrock monitoring wells. This may account for the anomalously high hydraulic conductivity at this location. Based on these hydraulic conductivities, mean conductivities were calculated for the two bedrock flow directions. The mean conductivity for the westerly flow is 8.30×10^{-6} centimeter per second. The mean conductivity for the easterly flow (includes MW-167D) is 5.45×10^{-5} centimeter per second.

An average linear groundwater velocity was calculated using effective porosities of 5 and 10 percent. Five percent was assumed to account for little fracturing within the saturated zone and 10 percent was assumed to account for moderate fracturing within the saturated zone. Based on an effective porosity of 5 percent, the average linear groundwater velocity was calculated to be 9.38×10^{-7} and 1.85×10^{-5} centimeter per second for the westerly and easterly flow directions respectively. Based on an effective porosity of 10 percent, the average linear groundwater velocity was calculated to be 4.69×10^{-7} and 9.27×10^{-6} centimeter per second for the westerly and easterly flow directions respectively.

The volume of groundwater flow through the McCurtain Shale zone of saturation in the eastern portion of the Fansteel property area was determined to be 5.18×10^{-5} gallon per minute. The volume of groundwater flow through the shale in the western portion of the subject property is 8.30×10^{-6} gallon per minute. Slug test and average linear groundwater velocity calculations are presented in Appendix C.

3.4.3 Multiwell Aquifer Characterization Test

A 65-hour pumping test was conducted in the southwestern quadrant of the Fansteel property to further characterize the unconsolidated aquifer. Because no impacts were observed to the McCurtain Shale, a pumping test was not required for this aquifer. Monitoring Well MW-53S was utilized as the pumping well for the unconsolidated aquifer while Monitoring Wells MW-52S, MW-54S, MW-61S, MW-63S, and MW-68S, and Observation Wells OW-1, OW-2, and OW-3 were used as observation points.

A step test performed on the pumping well indicated that the well could not sustain pumping rates more than 1.0 gallon per minute. A rate of 0.5 gallon per minute produced a slight decrease in hydraulic head over time. Consequently, a rate of 0.1 gallon per minute was determined to be the highest rate at which the pumping well could be pumped in order to retain its yield for the duration of the pump test. Based on water level measurements made at the designated observation points, it does not appear that the pumping test produced a measurable response in the unconsolidated aquifer. Although, Observation Points OW-1 and OW-2 were located only 40 and 35 feet respectively from the pumping well, no effects of the pumping were observed. Consequently, the zone of influence produced by the pumping appears to be confined to a radius of less than 35 feet.

4.0 Remediation Assessment Results

4.1 Chemical Characteristics

The chemical characteristics of soil, groundwater, and pond residues were determined using the methodologies and analytical parameters presented in Chapter 3.0 of this report. The following sections present a summary of the results of the chemical analysis performed on various media present on site.

4.1.1 Site Soils

Soil samples were collected and analyzed from all of the soil borings, shallow monitoring well boreholes, and test pits installed at the site. Generally, three soil samples for chemical analysis were selected from each soil boring and shallow monitoring well borehole based on the criteria described in Chapter 3.0 of this report. One soil sample was selected for chemical analysis from each of the test pits. All soil samples were analyzed for the following parameters:

- Total metals (antimony, arsenic, barium, cadmium, calcium, chromium, columbium, lead, mercury, nickel, silver, selenium, tantalum, and tin)
- Ammonia
- Fluoride
- Sulfate
- pH
- MIBK (4-methyl-2-pentanone)

Additionally, 20 percent of all soil samples selected for analysis was also analyzed for TCLP metals to determine the mobility of certain constituents. Soil samples were selected for TCLP metals analysis based on the highest total metals concentration detected. Results of the soil sample analyses were compared to typical concentration ranges or proposed RCRA corrective action levels, if available, to identify potential areas which may be of concern. These concentration ranges and proposed corrective action levels are summarized in Table 2. Analytical results for soils analyses are presented in Table 3 for soil borings and shallow monitoring well boreholes and Table 4 for test pits.

With the exception of antimony, mercury, selenium, and silver, the metals analyzed were detected in the majority of site soil samples at various concentrations. Antimony, generally not

identified in site soil samples, was present at concentrations up to 56 milligrams per kilogram (mg/kg) in Boring B-64, 9.5 - 12.5 feet) when identified. Arsenic ranged from not detected to a concentration of 33 mg/kg (B39, 12.0 feet to 13.0 feet). Barium was detected in the great majority of samples collected at the site and ranged in concentrations from 10 mg/kg (B-33, 0 - 0.5 feet) to 3,100 mg/kg (B-56, 4.5 - 7.0 feet). Cadmium ranged from not detected to a concentration of 36 mg/kg (B-50, 0 - 0.5 feet). Calcium was widely distributed throughout site soils at a concentration up to 220,000 mg/kg (B-55, 1.0 feet to 2.0 feet). Chromium was identified in site soils up to a concentration of 240 mg/kg (B-61, 0 feet to 0.5 feet). Columbium detected in all but a few soil samples ranged in concentrations from 1.2 mg/kg (B-5, 0 feet to 0.5 feet; B-20, 2.5 feet to 4.0 feet; B-47, 0 feet to 0.5 feet; MW-65S, 23.5 feet to 26.2 feet; and TP-6, 0.8 foot) to 2,100 mg/kg (MW-66S, 0 feet to 2 feet). Lead, another metal detected in the vast majority of site soil samples, ranged in concentrations from 0.58 mg/kg (B-42, 0.5 foot to 2.0 feet) to 91 mg/kg (B-25, 23.5 feet to 26.8 feet). Mercury was detected in only a small number of site soil samples with the highest concentration identified being 1.4 mg/kg (B-61, 0 foot to 0.5 feet). Nickel ranged from not detected to 79 mg/kg (B-1, 19.5 feet to 22 feet). Silver was identified in only one sample collected at the site (MW-55S, 14.5 feet to 17.0 feet) at a concentration of 2.5 mg/kg. Selenium was not detected in many site soil samples but, when identified, ranged in concentrations from 0.26 mg/kg (MW-65S, 0 feet to 0.5 feet) to 0.50 mg/kg (B-68, 7.5 feet to 10.0 feet). Tantalum was present in the majority of soil samples at concentrations ranging from 1.2 mg/kg (B-36, 23.0 feet to 24.5 feet) to 1,500 mg/kg (MW-66S, 0 feet to 2 feet). Tin ranged from not detected up to a concentration of 2,200 mg/kg (B-64, 9.5 feet to 12.5 feet).

Total concentrations of the following metals were present in site soils either within typical concentration ranges and/or below proposed RCRA corrective action levels: arsenic, barium, cadmium, calcium, chromium, lead, mercury, nickel, selenium, and silver. Total concentrations of antimony exceeded the proposed RCRA corrective action level of 30 mg/kg in only two site soil samples: B-64 (9.5 feet to 12.5 feet), 56 mg/kg and B-72 (15 feet to 16 feet), 40 mg/kg.

Tin which currently does not have a proposed corrective action level was present in the majority of site soil samples at concentrations outside its typical range of less than 0.1 to 7.4 mg/kg. The highest concentrations of tin detected in site soils were present in the following samples: B-1 (12 feet to 14.5 feet), 1,800 mg/kg; B-35 (11 feet to 12 feet), 440 mg/kg;

B-36 (11 feet to 13 feet), 480 mg/kg; B-47 (15 feet to 17.5), 710 mg/kg; B-64 (9.5 feet to 12.5 feet), 220 mg/kg; and B-72 (15 feet to 16 feet), 630 mg/kg.

Columbium and tantalum currently do not have established typical concentration ranges or proposed RCRA corrective action levels. The highest concentrations of columbium detected in site soils were present in the following samples: B-1 (12 feet to 14.5), 730 mg/kg; B-2 (9.5 feet to 12 feet), 510 mg/kg; B-4 (2 feet to 4.5 feet), 320 mg/kg; B-49 (0 feet to 0.5 feet), 330 mg/kg; B-64 (9.5 feet to 12.5 feet), 400 mg/kg; MW-66S (0 feet to 2 feet), 2,100 mg/kg; and MW-67S (0 feet to 2), 740 mg/kg. The highest concentrations of tantalum were observed in B-4 (2 feet to 4.5 feet), MW-66S (0 feet to 2 feet), and MW-67S (0 feet to 2 feet) at 330, 1,500 and 130 mg/kg respectively.

As stated earlier, 20 percent of the soil samples collected throughout the site were analyzed for TCLP metals. Only one of the samples analyzed for TCLP metals exhibited a leachable metal concentration of concern. This sample was collected from B-56 (4.5 feet to 7.0 feet) and exhibited a leachable concentration of barium of 200 mg/l.

Fluoride was detected in all site soil samples submitted for analyses up to a concentration of 66,000 mg/kg in B-1 (12 feet to 14.5 feet). No RCRA corrective action level has been proposed for fluoride at this time. The typical range of fluoride concentrations in soil is less than 10 mg/kg to 1,900 mg/kg. This concentration range was exceeded by a number of site soil samples, most notably: B-1 (12 feet to 10.5 feet, 17 feet to 19.5 feet, and 19.5 feet to 22 feet), 66,000, 13,000, and 10,000 mg/kg respectively; B-2 (9.5 feet to 12 feet, 24.5 feet to 27 feet, and 27 feet to 31 feet), 60,000, 24,000, and 23,000 mg/kg respectively; B-15 (9.2 feet to 10 feet), 9,100 mg/kg; B-22 (0 feet to 0.5 foot), 5,600 mg/kg; B-29 (0 feet to 0.5 foot, 0.5 foot to 2.5 feet, and 23 feet to 24.5 feet), 6,400, 43,000, and 6,500 mg/kg respectively; B-35 (10 feet to 11 feet and 11 feet to 12 feet), 17,000 and 53,000 mg/kg; B-36 (11 feet to 13 feet), 13,000 mg/kg; B-49 (0 feet to 0.5 foot), 7,900 mg/kg; B-51 (24 feet to 26 feet), 5,400 mg/kg; B-52 (0.5 foot to 2.5 feet), 5,600 mg/kg; B-54 (0.5 foot to 2.0 feet), 31,000 mg/kg; B-55 (1 foot to 2 feet and 7 feet to 9.5 feet), 6,800 and 5,800 mg/kg; B-59 (12.5 feet to 15 feet), 8,800 mg/kg; B-61 (0 feet to 0.5 foot), 13,000 mg/kg; B-62 (15 feet to 17 feet), 5,200 mg/kg; B-64 (18 feet to 20 feet), 14,000 mg/kg; B-70 (12.5 feet to 14.0 feet), 5,200 mg/kg; B-72 (12.5 feet to 15 feet and 15 feet to 16 feet), 6,800 and 12,000 mg/kg; MW-66S (0 feet to 2 feet and 14.5 feet to 17 feet), 8,900 and 6,100

mg/kg; MW-67S (12.0 feet to 14.5 feet and 19.5 feet to 22.0 feet) 12,000 and 5,100 mg/kg; MW-71S (2 feet to 4.5 feet), 6,000 mg/kg; and TP-6 (0.8 foot), 6,200 mg/kg.

Ammonia was also identified in site soil samples at concentrations up to 1,780 mg/kg in MW-67S (19.5 feet to 22 feet). No typical concentration ranges for ammonia in soil have been established and no RCRA corrective action levels have been proposed at this time. The highest concentrations of ammonia detected in site soils were exhibited by the following samples: B-1 (17 feet to 19.5 feet), 780 mg/kg; B-35 (10 feet to 11 feet), 480 mg/kg; B-58 (9.5 feet to 12 feet), 1,100 mg/kg; B-61 (15 feet to 17 feet), 560 mg/kg; B-62 (15 feet to 17 feet), 540 mg/kg; B-63 (15 feet to 17.5 feet), 520 mg/kg; and MW-67S (12 feet to 14.5 feet, 19.5 feet to 22 feet, and 22 feet to 24.5 feet), 1,580, 1,780, and 1,300 mg/kg respectively.

Sulfate was detected in site soils at concentrations up to 10,000 mg/kg in B-9 (12 feet to 15 feet). No typical concentration ranges or proposed RCRA corrective action levels have been established for sulfate. The highest concentrations of sulfate were detected in the following site soil samples: B-9 (12 feet to 15 feet and 15 feet to 17 feet), 10,000 and 4,200 mg/kg; B-12 (17.5 feet to 19 feet), 600 mg/kg; B-19 (0 feet to 0.5 foot), 1,420 mg/kg; B-35 (11 feet to 12 feet), 640 mg/kg; B-36 (11 to 13 feet), 700 mg/kg; B-48 (24.5 feet to 26 feet), 540 mg/kg; B-53 (23 feet to 24.9 feet), 740 mg/kg; B-58 (9.5 feet to 12 feet), 860 mg/kg; B-63 (15 feet to 17.5 feet), 660 mg/kg; MW-59S (9.5 feet to 12 feet), 780 mg/kg; MW-64S (0 feet to 0.5 foot), 680 mg/kg; MW-67S (19.5 feet to 22 feet and 22 feet to 24.5 feet), 1,120 and 960 mg/kg; MW-71S (19.5 feet to 22 feet), 1,500 mg/kg; and MW-73S (13.02 feet to 14.2 feet), 520 mg/kg.

MIBK was also identified in several site soil samples. A proposed RCRA corrective action level has been established for MIBK. This level is 4,000 micrograms per kilogram ($\mu\text{g}/\text{kg}$). The following site soil samples exhibited concentrations of MIBK in excess of the proposed RCRA corrective action level: B-1 (12 feet to 14.5 feet, 17 feet to 19.5 feet, and 19.5 feet to 22 feet), 75,000, 65,000, and 64 $\mu\text{g}/\text{kg}$ respectively; B-2 (9.5 feet to 12 feet, 24.5 feet to 27 feet, and 27 feet to 31 feet), 14,000, 25,000, and 5,700 $\mu\text{g}/\text{kg}$ respectively; B-35 (10 feet to 11 feet and 11 feet to 12 feet), 23,000 and 91,000 $\mu\text{g}/\text{kg}$; B-36 (11 feet to 13 feet), 6,900 $\mu\text{g}/\text{kg}$; B-47 (15 feet to 17 feet and 24.5 feet to 26 feet), 190,000 and 20,000 $\mu\text{g}/\text{kg}$; B-59 (12.5 feet to 15 feet), 22,000 $\mu\text{g}/\text{kg}$; B-64 (9.5 feet to 12.5 feet and 18 feet to 20 feet), 30,000 and 33,000 $\mu\text{g}/\text{kg}$; B-72 (15 feet to 16 feet), 7,600 $\mu\text{g}/\text{kg}$; MW-73S (13 feet to 14.2 feet and 14.7 feet to 15 feet), 45,000 and

10,000 $\mu\text{g}/\text{kg}$; and MW-64S (14.5 feet to 17 feet and 19.5 feet to 22 feet), 19,000 and 83,000 $\mu\text{g}/\text{kg}$.

4.1.1.1 Distribution of Contaminants of Concern in Site Soils

Figure 9 illustrates the location of the parameters of concern identified in excess of typical soil concentration ranges or proposed corrective action levels. As stated earlier, ammonia does not have a typical soil concentration range or proposed corrective action level. Figure 9 identifies the location of ammonia concentrations generally detected in excess of 10 mg/kg. As this figure illustrates, the vast majority of soil contamination is confined to the eastern area of the site, downgradient or in the immediately vicinity of the Chemical "A" Building, Chemical "C" Building, Pond No. 2, and Pond No. 3. The most pervasive constituents identified in this portion of the site (MIBK, ammonia, fluoride, tin, and columbium) are consistent with plant operations and activities historically conducted in this area.

The presence of these constituents appears to be well distributed throughout the soil column in this area with the exception of MIBK and ammonia. MIBK and ammonia, almost without exception, were present at depths greater than 5 feet in the borings in this area and do not appear to present a surficial concern. Antimony was identified in only two borings in this area at concentrations only slightly in excess of typical ranges and, therefore, does not appear to present significant concern.

Barium which is not widely distributed in site soils at significant levels was identified at one specific location (B-56) at a concentration that presents some concern. Leachable concentrations of barium were present in soils from B-56 at levels sufficient to classify these materials as characteristically hazardous. Barium was not identified in soil borings immediately surrounding this location at significant concentrations. Therefore, the presence of the elevated concentration of barium within B-56 appears to be a discrete and isolated occurrence. Columbium, fluoride, and ammonia were also identified at relatively elevated concentrations in soils to the east of Ponds Nos. 5, 6, 7, 8, and 9. However, the concentrations of these constituents were typically less than that exhibited in soils to the east of the Chemical "A" Building and in the area of Ponds Nos. 2 and 3.

4.1.2 Pond Residues

Residue samples were collected from each of the ponds located on the Fansteel site including Ponds Nos. 2, 3, 5, 6, 7, 8, and 9. The residue samples were collected in accordance with the sampling methodologies outlined in Chapter 3.0 of this report. Each residue sample was analyzed for the following parameters:

- Total metals: antimony, arsenic, barium, beryllium, cadmium, chromium, columbium, lead, mercury, molybdenum, nickel, selenium, silver, tin, and tantalum.
- TCLP metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, and nickel).
- Ammonia, chloride, fluoride, nitrate, sulfate, and cyanide.
- Aluminum, calcium, iron, potassium, magnesium, manganese, and sodium.
- Alkalinity, pH, and specific conductance.
- VOCs.
- Semivolatile organic compounds.

These parameters were utilized to define the characteristics of the pond residues. The following sections discuss the analytical results for the residue samples on a pond-by-pond basis.

4.1.2.1 Pond No. 2

A total of nine residue samples were collected from three sampling locations within Pond No. 2 (Figure 2). Silver was present in Pond No. 2 residue at concentrations ranging from 10 to 52.7 mg/kg. Arsenic was detected in only three residue samples at concentrations up to 74.3 mg/kg. Barium ranged in concentrations from 284 to 2,180 mg/kg. Beryllium was detected at concentrations ranging from 10.3 to 33.1 mg/kg. Cadmium was not detected in any of the Pond No. 2 residue samples. Chromium ranged in concentrations from 153 to 740 mg/kg. Mercury was identified at concentrations ranging from 0.260 to 2.74 mg/kg. Molybdenum ranged in concentrations from 21 to 40 mg/kg. Nickel ranged from nondetected to 103 mg/kg. Lead ranged from nondetected to 167 mg/kg. Antimony was detected at concentrations ranging from 61.9 to 576 mg/kg. Selenium was not detected in any Pond No. 2 residue samples. Tin ranged in concentrations from 830 to 6,000 mg/kg. Columbium ranged in concentrations from 1,200 to 11,000 mg/kg and tantalum ranged from 970 to 7,100 mg/kg. Cyanide ranged from not detected to 11 mg/kg.

Analysis of the nine residue samples for TCLP metals indicated that all residue samples exhibited leachable concentrations of chromium. Five of the residue samples contained leachable concentrations of chromium in excess of 5.0 milligrams per liter (mg/l), the maximum contaminant level (MCL). The concentrations of leachable chromium in the five samples ranged from 5.0 to 20.0 mg/l.

Ammonia was present in Pond No. 2 residues at concentrations ranging from 1.3 to 8.9 mg/l. Chloride ranged from nondetected to 5.7 mg/l. Fluoride was detected from 110 to 650 mg/l. Nitrate ranged in concentrations from 0.12 to 0.46 mg/l. Sulfate was detected at concentrations from 2.6 to 510 mg/l. Aluminum ranged from nondetected to 270 mg/l. Calcium was present at concentrations ranging from 13 to 300 mg/l. Iron ranged from 110 to 640 mg/l. Potassium was identified at concentrations ranging from 15 to 170 mg/l. Magnesium ranged from 16 to 50 mg/l. Manganese was present at concentrations ranging from 27 to 150 mg/l. Sodium ranged from not detected to 58 mg/l.

The alkalinity of all Pond No. 2 residue samples was below 2.0 mg/l calcium carbonate. Specific conductance ranged from 845 to 5,660 micromhos per centimeter. The pH of Pond No. 2 residues ranged from 2.33 to 3.38 standard units. The only VOC detected in Pond No. 2 residue samples was MIBK, identified in each of the nine residue samples at concentrations ranging from 43,000 to 730,000 micrograms per liter ($\mu\text{g/l}$).

No semivolatile organic compounds were detected in Pond No. 2 residue samples with the exception of di-N-butyl phthalate. However, this constituent was also detected in quality assurance/quality control (QA/QC) samples associated with the residue samples and may be associated with plastic sample collection equipment. It is not believed that di-N-butyl phthalate is actually present in Pond No. 2 residues. The results for the analysis of Pond No. 2 residues are summarized in Table 5. Figure 10 illustrates the location of various parameters of concern identified in Pond No. 2 residues.

4.1.2.2 Pond No. 3

A total of 15 residue samples were collected at 5 separate locations within Pond No. 3 in accordance with the methodologies presented in Chapter 3.0 of this report. Silver concentrations within Pond No. 3 residues ranged from 9.6 to 37 mg/kg. Arsenic ranged from

not detected to 109 mg/kg. Barium was detected at concentrations from 288 to 1,720 mg/kg. Beryllium ranged from 8.5 to 39.8 mg/kg. Cadmium was identified in only one Pond No. 3 residue sample at a concentration of 5.9 mg/kg. Chromium concentrations ranged from 1,540 to 1,970 mg/kg. Mercury ranged from not detected to 3.5 mg/kg. Molybdenum, nickel, lead, and antimony were detected at concentrations up to 49, 56.4, 137, and 241 mg/kg respectively. Selenium was not detected in any of the 15 Pond No. 3 residue samples. Tin was identified at concentrations ranging from 210 to 3,900 mg/kg. Columbium ranged from 720 to 4,400 mg/kg and tantalum ranged from 260 to 2,200 mg/kg. Cyanide ranged from not detected to concentrations up to 160 mg/kg.

TCLP metal analysis of Pond No. 3 residue samples indicated that leachable concentrations of chromium were present at levels above the MCL for this metal, 5.0 mg/l. Thirteen of the 15 residue samples collected from this pond exhibited leachable concentrations of chromium ranging from 6.7 to 36 mg/l.

Ammonia was detected in Pond No. 3 residues at concentrations ranging from 2.9 to 7.5 mg/l. Chloride ranged from not detected to 48 mg/l. Fluoride was identified at concentrations ranging from 32 to 670 mg/l. Nitrates ranged from not detected to 2.6 mg/l. Sulfates ranged from 2.6 to 540 mg/l. Aluminum ranged from not detected to 100 mg/l. Calcium was present at concentrations ranging from 20 to 270 mg/l. Iron, potassium, magnesium, manganese, and sodium were identified at concentrations up to 380, 170, 55, 140, and 37 mg/l respectively.

Alkalinity was detected in only one Pond No. 3 residue sample at 3.0 mg/l calcium carbonate. Specific conductance ranged from 714 to 6,220 microhms per centimeter. The pH of Pond No. 3 residue samples ranged from 2.10 to 5.56 standard units.

The only VOC detected in Pond No. 3 residues was MIBK. MIBK was identified in each of the 15 Pond No. 3 residue samples at concentrations ranging from 34,000 to 1,300,000 $\mu\text{g}/\text{kg}$.

No semivolatile organic compounds were detected in Pond No. 3 residues with the exception of di-N-butyl phthalate which is believed to be associated with plastic samples collection equipment. Analytical results for Pond No. 3 residue samples are summarized in Table 6.

Figure 10 identifies the location of various parameters of concern present in Pond No. 3 residues.

4.1.2.3 Pond No. 5

A total of five residue samples were collected from Pond No. 5 at three separate sampling locations in accordance with the methodologies presented in Chapter 3.0 of this report. No silver, arsenic, cadmium, cyanide, or selenium was detected in Pond No. 5 residue samples. Barium was identified at concentrations ranging from 28.1 to 119 mg/kg. Beryllium ranged from 3.2 to 15.6 mg/kg. Chromium was detected in Pond No. 5 residues at concentrations ranging from 45.8 to 164 mg/kg. Mercury was present at levels up to 0.410 mg/kg and molybdenum at concentrations up to 21 mg/kg. Nickel ranged in concentrations from 17.5 to 143 mg/kg. Lead was detected at concentrations up to 89.8 mg/kg. Antimony ranged from 140 to 4,200 mg/kg. Columbium and tantalum were detected in each residue sample from Pond No. 5. Columbium ranged from 870 to 8,100 mg/kg and tantalum ranged from 270 to 5,200 mg/kg.

TCLP metals analysis of the Pond No. 5 residue samples did not identify the presence of metals above established MCLs. Leachable concentrations of nickel were detected in one Pond No. 5 residue sample at a concentration of 1.3 mg/l. No MCL has been established for nickel.

Ammonia was detected in four of the five Pond No. 5 residue samples at concentrations up to 16 mg/l. Chloride was identified in only two samples at concentrations of 6 and 19 mg/l. Fluoride was detected in each sample at concentrations ranging from 3.8 to 9.6 mg/l. Nitrate and sulfate were detected in each Pond No. 5 residue sample at concentrations up to 7.6 and 900 mg/l respectively.

Aluminum and iron were not detected in any of the pond No. 5 residue samples. Calcium ranged from 57 to 610 mg/l. Potassium, magnesium, manganese, and sodium were present at trace levels up to 38, 19, 13, and 39 mg/l respectively.

The alkalinity of Pond No. 5 residues ranged from 21 to 60 mg/l calcium carbonate. Specific conductances ranged from 384 to 2,500 micromhos per centimeter. The pH of Pond No. 5 residues ranged from 7.93 to 10.31 standard units.

No VOCs or semivolatile organic compounds were detected within the Pond No. 5 residue samples with the exception of bis(2-ethylhexyl) phthalate and di-N-butyl phthalate. The presence of these phthalates are believed to be associated with plastic sample collection equipment used to handle the residue samples. The results for the analysis of Pond No. 5 residue samples are summarized in Table 7. Figure 10 identifies the location of various parameters of concern identified in Pond No. 5 residues.

4.1.2.4 Pond No. 6

Two residue samples were collected from the bottom sediments of Pond No. 6 in accordance with the sampling methodologies outlined in Chapter 3.0 of this report. No silver, arsenic, cyanide, molybdenum, lead, or selenium were detected in sediment samples from Pond No. 6. Barium was detected at 74.2 and 195 mg/kg in the two residue samples. Beryllium, cadmium, chromium, and mercury were identified at 9 and 10.9 mg/kg, not detected and 11 mg/kg, 183 and 249 mg/kg, and 0.221 and 0.414 mg/kg respectively in the two sediment samples. Antimony was present in both samples at 126 and 134 mg/kg. Tin was detected at 1,100 and 1,400 mg/kg. Columbium and tantalum were detected at 260 and 2,700 mg/kg (columbium) and 310 and 960 mg/kg (tantalum).

No TCLP metals were detected in Pond No. 6 sediment samples. Ammonia was present at 0.51 and 0.84 mg/l; chloride at 2.2 and 3.9 mg/l, and fluoride at 4.6 and 11 mg/l. Nitrate was detected in only one sediment sample at 0.14 mg/l. Sulfates were present at 73 and 1,200 mg/l.

Aluminum, iron, magnesium, manganese, and sodium were not detected in Pond No. 6 sediments. Calcium was detected at 41 and 520 mg/l and potassium was present at 15 and 17 mg/l.

The alkalinity of the two Pond No. 6 sediment samples was 8 and 18 mg/l calcium carbonate. Specific conductance was measured at 283 and 2,093 micromhos per centimeter. The pH of the two sediment samples was 7.93 and 8.08 standard units.

No VOCs or semivolatile organic compounds were detected within the two Pond No. 6 samples. Analytical results for Pond No. 6 are summarized in Table 8. Figure 10 identifies the location of various parameters of concern detected in Pond No. 6.

4.1.2.5 Pond No. 7

A total of two sediment samples from Pond No. 7 were collected for analysis in accordance with the sampling protocols outlined in Chapter 3.0 of this report. No silver, arsenic, cyanide, cadmium, molybdenum, or selenium were detected in these two sediment samples. The following metals were detected in the two sediment samples at the concentrations identified: barium (79.7 and 91.7 mg/kg), beryllium (21.4 and 22.5 mg/kg), chromium (358 and 406 mg/kg), mercury (1.72 and 2.98 mg/kg), nickel (61.1 and 95 mg/kg), lead (98.4 and 102 mg/kg), antimony (366 and 623 mg/kg), tin (3,000 and 3,400 mg/kg), columbium (5,700 and 7,600 mg/kg), and tantalum (1,600 and 1,900 mg/kg). No TCLP metals were detected in the two sediment samples.

Ammonia was detected at 3.3 and 7.8 mg/l. Chloride was present at 8.9 and 22 mg/l and fluoride was identified at 5.4 and 9.9 mg/l. No nitrate was detected in the two Pond No. 7 sediment samples. Sulfates were detected at 140 and 720 mg/l in the two samples.

No aluminum, iron, magnesium, or manganese was detected in Pond No. 7 samples. Calcium was identified at 64 and 240 mg/l, potassium at 30 and 39 mg/l, and sodium at 40 and 53 mg/l.

The alkalinity of the two sediment samples was determined to be 14 and 20 mg/l calcium carbonate. The specific conductance of the two samples was measured at 735 and 1,530 micromhos per centimeter. The pH of Pond No. 7 sediments was 8.02 and 9.57 standard units.

No VOCs or semivolatile organic compounds were detected in Pond No. 7 sediments. Analytical results for Pond No. 7 are summarized in Table 9. Figure 10 illustrates the location of various parameters of concern identified in Pond No. 7 residues.

4.1.2.6 Pond No. 8

A total of 15 residue samples were collected from 5 separate locations within Pond No. 8 in accordance with the sampling protocols outlined in Chapter 3.0 of this report. No silver, cadmium, lead, selenium, or cyanide were detected in any of the Pond No. 8 residue samples. The following metals were detected at the indicated concentration ranges: arsenic (not detected to 91.1 mg/kg), barium (24.2 to 105 mg/kg) beryllium (8.4 to 27.3 mg/kg), chromium

(74.7 to 992 mg/kg), mercury (0.197 to 1.24 mg/kg), molybdenum (not detected to 38 mg/kg), nickel (27.4 to 159 mg/kg), antimony (106 to 513 mg/kg), tin (360 to 1,800 mg/kg), columbium (1,500 to 5,500 mg/kg), and tantalum (650 to 3,700 mg/kg).

No TCLP metals were detected in the Pond No. 8 residue samples above established MCLs. Nickel which does not have an established MCL associated with TCLP analysis was detected in one sample at 1.3 mg/l.

Ammonia was identified in Pond No. 8 residues at concentrations ranging from 7.3 to 19 mg/l. Chloride was detected at concentrations from 21 to 47 mg/l. Fluoride ranged from 2.4 to 9.0 mg/l. Nitrate, when detected, was present at concentrations up to 0.43 mg/l. Sulfate ranged from 190 to 1,200 mg/l.

No aluminum, iron, magnesium, or manganese was detected in Pond No. 8 residues. Calcium, potassium, and sodium were present at concentrations up to 1,300, 74, and 98 mg/l respectively.

The alkalinity of Pond No. 8 residues ranged from 16 to 2,080 mg/l calcium carbonate. The specific conductance of the residue samples was measured at 1,050 to 8,350 micromhos per centimeter. The pH of the residues in Pond No. 8 ranged from 7.84 to 12.67 standard units. All pond residue samples with the exception of P8-2C (14 feet to 20 feet) exhibited pH near 11.0 standard units or less. Residue Sample P8-2C exhibited a pH of 12.67 standard units. This pH does not appear to be representative of residues contained within Pond No. 8.

MIBK was detected in each of the 15 Pond No. 8 residue samples at concentrations ranging from 4,800 to 190,000 $\mu\text{g}/\text{kg}$. Acetone was also detected in one residue sample at 3,000 $\mu\text{g}/\text{kg}$. No semivolatile organic compounds were identified in Pond No. 8 residues with the exception of di-N-butyl phthalate. Di-N-butyl phthalate was also detected in QA/QC samples associated with Pond No. 8 residues and is believed to be associated with the use of plastic sample collection trowels. The analytical results for Pond No. 8 are summarized in Table 10. Figure 10 illustrates the location of various parameters of concern detected in Pond No. 8.

4.1.2.7 Pond No. 9

A total of 15 residue samples were collected from 5 separate locations within Pond No. 9 in accordance with the methodologies outlined in Chapter 3.0 of this report. No silver, cadmium, molybdenum, lead, or selenium were detected in Pond No. 9 residue samples. Cyanide, arsenic, barium, mercury, and antimony when detected were present at concentrations up to 460, 74.5, 37.2, 1.73, and 362 mg/kg respectively. Beryllium was detected at concentrations ranging from 11.5 to 17.0 mg/kg, chromium ranged from 189 to 816 mg/kg, and nickel ranged from 37.2 to 88.3 mg/kg. Tin ranged from 580 to 1,500 mg/kg, columbium ranged from 2,100 to 5,500 mg/kg, and tantalum ranged from 640 to 1,300 mg/kg. TCLP metals analysis did not identify the presence of leachable concentrations of metals above established MCLs.

Ammonia was detected in Pond No. 9 residues at concentrations ranging from 2.0 to 18 mg/kg. Chloride and fluoride were identified at the following concentration ranges: 18 to 68 mg/l and 3.9 to 13 mg/l. Nitrate, when detected, was present at concentrations up to 0.32 mg/l. Sulfates ranged from 140 to 1,600 mg/l.

No aluminum, iron, magnesium, or manganese were detected in Pond No. 9 residue samples. Calcium was detected at concentrations ranging from 61 to 520 mg/l. Potassium concentrations ranged from 24 to 65 mg/l and sodium was present from 35 to 100 mg/l in Pond No. 9 residue samples.

The alkalinity on Pond No. 9 residue samples ranged from not detected up to 111 mg/l calcium carbonate. Specific conductances ranged from 952 to 2,400 micromhos per centimeter. The pH of Pond No. 9 residues was measured at 8.44 to 10.93 standard units.

MIBK was detected in all but one of the Pond No. 9 residue samples at concentrations ranging from 6,000 to 190,000 µg/kg. 1,1,1-Trichloroethane was identified in one Pond No. 9 residue sample at 4,700 µg/kg. No other VOCs were detected in the residue sample. No semivolatile organic compounds were detected in Pond No. 9 residues with the exception of bis(2-ethylhexyl) phthalate and di-N-butyl phthalate. The presence of the phthalates is believed to be associated with the use of plastic sample collection equipment. The results of Pond No. 9 residue analyses are summarized in Table 11. Figure 10 illustrates the location of various parameters of concern detected in Pond No. 9.

4.1.2.8 Distribution of Contaminants of Concern in Pond Residues

The residues present in each of the ponds located on site appear to be fairly well homogenized. Although the chemistry of the residues may differ from pond to pond, each individual pond residues chemistry is fairly consistent from sample location to sample location and from depth to depth. No significant trends could be identified in any of the ponds which would indicate the presence of particularly contaminated or relatively clean "layers" or locations.

A variety of metals is present in the residues contained in each of the ponds, the most notable being chromium which was identified in Ponds Nos. 2 and 3 at levels considered characteristically hazardous. MIBK was detected at relatively significant concentrations in Ponds Nos. 2, 3, 8, and 9 residues. No MIBK was detected in residues contained in Ponds Nos. 5, 6, or 7. As might be expected, fluoride concentrations were present at the highest concentrations in Ponds Nos. 2 and 3. Ammonia concentrations were similar from pond to pond. Ponds Nos. 2 and 3 exhibit acidic pH. Ponds Nos. 5, 6, 7, 8, and 9 exhibit slightly basic pH.

4.1.3 Surface Water and Sediments

A total of 6 sediment and 7 surface water samples were collected at locations identified in Figure 2. The following sections discuss the results of the analysis of these samples.

4.1.3.1 Sediments

Sediment samples were analyzed for the following chemical parameters:

- Total metals (antimony, arsenic, barium, calcium, cadmium, chromium, fluoride, lead, nickel, mercury, selenium, silver, tin, columbium, and tantalum).
- Ammonia, sulfate, and pH.
- MIBK.

No silver, mercury, antimony, or selenium were detected in the sediment samples. Arsenic, barium, calcium, cadmium, chromium, nickel, lead, and columbium were detected in one or more of the sediment samples, however, the concentrations exhibited by these metals were within typical soil concentrations ranges and, where applicable, were below proposed RCRA corrective action levels.

Tin was detected in SS-002 (22 mg/kg), SS-003 and SS-005 (17 mg/kg), and SS-1 (28 mg/kg) at concentrations slightly above the typical soil concentration range for this metal (less than 0.1 to 7.4 mg/kg). Fluoride was identified in sediment Samples SS-002 (3,700 mg/kg) and SS-003 (2,100 mg/kg) at concentrations outside the typical soil concentration range for this parameter (less than 10 to 1,900 mg/kg). Tantalum does not currently have a typical soil concentration range or proposed RCRA corrective action level. Tantalum was detected in the sediment samples at concentrations ranging from 5.6 mg/kg (SS-005 and SS-2) to 13 mg/kg (SS-003 and SS-1).

Ammonia was detected only in sediment sample SS-002 at a concentration of 26 mg/kg. Sulfate was present in all sediment samples at concentrations ranging from 44 to 66 mg/kg. The pH of the sediment sample ranged from a low of 6.26 standard units in SS-3 to a high of 7.18 standard units in SS-003. No MIBK was detected in any of the six sediment samples. The analytical results of the sediment samples are summarized in Table 12. Figure 9 illustrates the location of the various parameters identified in sediment samples at concentrations in excess of typical ranges or proposed action levels.

4.1.3.2 Surface Water

A total of seven surface water samples were collected and analyzed for the following parameters:

- Total metals (silver, arsenic, barium, calcium, cadmium, chromium, mercury, nickel, lead, antimony, selenium, tin, columbium, and tantalum).
- Fluoride, ammonia, nitrate, and sulfate.
- MIBK.

The surface water analytical results were compared to established USEPA Drinking Water Standard MCLs, Table 13 where applicable, to identify potential areas of concern.

No silver, mercury, or selenium were detected in any of the surface water samples. Arsenic was detected in all seven surface water samples; however, only one exhibited concentrations of this metal above its established MCL of 50 $\mu\text{g/l}$. This sample was SS-001 which contained 188 $\mu\text{g/l}$ of arsenic. Barium was detected in all surface water samples with the exception of SS-001.

All detected concentrations of barium were below its established MCL. Calcium which does not have an established MCL ranged in concentrations from 11,600 $\mu\text{g/l}$ in SS-003 to 111,000 $\mu\text{g/l}$ in SS-001. Cadmium was detected in all surface water samples with the exception of SS-002 and was present at concentrations above its MCL of 5 $\mu\text{g/l}$ in the following samples: SS-001 (6.48 $\mu\text{g/l}$), SS-003 (5.11 $\mu\text{g/l}$), SS-005 (12.2 $\mu\text{g/l}$), SS-1 (20.8 $\mu\text{g/l}$), SS-2 (15.2 $\mu\text{g/l}$), and SS-3 (5.51 $\mu\text{g/l}$). Chromium was detected in all surface water samples except SS-3 and was present above its MCL of 100 $\mu\text{g/l}$ in only one sample, SS-1 (110 $\mu\text{g/l}$). Nickel which does not have an MCL was detected in only two surface water samples, SS-002 (28.4 $\mu\text{g/l}$) and SS-1 (103 $\mu\text{g/l}$). Lead was detected in all surface water samples at concentrations ranging from 1.74 to 276 $\mu\text{g/l}$. No MCL is currently in effect for lead; however, an action level of 15 $\mu\text{g/l}$ has been imposed at the tap of drinking water supplies. Antimony was detected in only one sample, SS-002, at a concentration of 85.1 $\mu\text{g/l}$. No MCL has been established for antimony. Tin which also does not have an MCL was detected in two surface water samples, SS-001 (72 $\mu\text{g/l}$) and SS-1 (120 $\mu\text{g/l}$). Columbium and tantalum were only detected in SS-1 both at 300 $\mu\text{g/l}$. No MCL has been established for either of these metals.

Fluoride which has an MCL of 4.0 mg/l was detected in each of the seven surface water samples. Fluoride was present at concentrations above its MCL in SS-001 (9.4 mg/l) and SS-002 (12 mg/l). Ammonia was identified only in SS-001 (6.7 mg/l), SS-002 (8.4 mg/l), and SS-3 (0.12 mg/l). Ammonia currently does not have an established MCL. Nitrate were detected in all but one surface water sample, SS-003. An MCL for nitrate has been established of 10 mg/l and was equaled or exceeded in SS-001 (10 mg/l) and SS-002 (15 mg/l). The MCL for sulfate is 250 mg/l and was exceeded in only one surface water sample, SS-001 (390 mg/l).

MIBK was detected only in surface water Sample SS-001 at a concentration of 500 $\mu\text{g/l}$. An MCL of 2,000 $\mu\text{g/l}$ has been established by the state of Oklahoma for MIBK. The analytical results of surface water samples are summarized in Table 14. Figure 11 illustrates the locations where parameters of concern were identified in excess of established MCLs.

4.1.4 Groundwater

All 29 monitoring wells installed at the site were sampled and analyzed for the following parameters:

- Total metals (antimony, arsenic, barium, cadmium, calcium, chromium, lead, mercury, nickel, selenium, silver, tin, tantalum, and columbium).
- Total fluoride, total ammonia, total nitrate, and total sulfate.
- MIBK.
- Dissolved metals (same specific metals as total analyses) analysis was performed on groundwater samples from MW-55S, MW-62S, MW-63S, MW-65S, MW-66S, MW-67S, MW-73S, and MW-74S for comparative purposes.
- TCL parameters were analyzed for in the following wells: MW-51S, MW-52S, MW-60S, MW-61S, MW-62S, MW-66S, MW-67S, MW-71S, and MW-74S.

The following sections discuss the results of the chemical analysis of site groundwater samples. As with the surface water samples, analytical results for groundwater were compared to established MCLs (Table 13) to identify potential areas of concern.

4.1.4.1 Unconsolidated Zone of Saturation (Shallow Monitoring Wells)

A total of 24 monitoring wells were installed to communicate with the unconsolidated zone of saturation present on site (MW-51S through MW-75S). The only total metals detected in groundwater samples from shallow monitoring wells in excess of established MCLs or action levels were aluminum, arsenic, cadmium, chromium, manganese, and lead. The MCL for aluminum is 200 $\mu\text{g/l}$. This level was exceeded in samples collected from the following wells: MW-51S (1,090 $\mu\text{g/l}$), MW-52S (5,620 $\mu\text{g/l}$), MW-60S (5,240 $\mu\text{g/l}$), MW-61S (6,040 $\mu\text{g/l}$), MW-62S (1,980 $\mu\text{g/l}$), MW-66S (13,200 $\mu\text{g/l}$), MW-67S (37,900 $\mu\text{g/l}$), MW-71S (26,700 $\mu\text{g/l}$), and MW-74S (394,000 $\mu\text{g/l}$). The drinking water MCL for arsenic is 50 $\mu\text{g/l}$. This level was exceeded in groundwater samples collected from the following wells: MW-57S (70.2 $\mu\text{g/l}$), MW-58S (330 $\mu\text{g/l}$), MW-59S (126 $\mu\text{g/l}$), MW-60S (391 $\mu\text{g/l}$), MW-61 (405 $\mu\text{g/l}$), MW-62S (538 $\mu\text{g/l}$), MW-63S (1,100 $\mu\text{g/l}$), MW-64S (177 $\mu\text{g/l}$), MW-65S (403 $\mu\text{g/l}$), MW-66S (205 $\mu\text{g/l}$), MW-67S (2,830 $\mu\text{g/l}$), MW-70S (126 $\mu\text{g/l}$), MW-71S (494 $\mu\text{g/l}$), MW-73S (116 $\mu\text{g/l}$), and MW-74S (149 $\mu\text{g/l}$).

The drinking water MCL for cadmium is 5 $\mu\text{g/l}$. The following monitoring wells exhibited concentrations of cadmium in excess of 5 $\mu\text{g/l}$: MW-51S (18.1 $\mu\text{g/l}$), MW-52S (10.1 $\mu\text{g/l}$), MW-53S (7.17 $\mu\text{g/l}$), MW-55S (28.5 $\mu\text{g/l}$), MW-57S (8.45 $\mu\text{g/l}$), MW-58S (5.18 $\mu\text{g/l}$), MW-59S (5.86

$\mu\text{g/l}$), MW-60S (7.2 $\mu\text{g/l}$), MW-61S (6.38 $\mu\text{g/l}$), MW-62S (5.39 $\mu\text{g/l}$), MW-63S (5.55 $\mu\text{g/l}$), MW-64S (6.39 $\mu\text{g/l}$), MW-65S (10.1 $\mu\text{g/l}$), MW-66S (6.03 $\mu\text{g/l}$), MW-67S (6.69 $\mu\text{g/l}$), MW-68S (11 $\mu\text{g/l}$), MW-69S (10.2 $\mu\text{g/l}$), MW-70S (5.32 $\mu\text{g/l}$), MW-71S (12.8 $\mu\text{g/l}$), MW-72S (9.12 $\mu\text{g/l}$), MW-73S (79 $\mu\text{g/l}$), MW-74S (119 $\mu\text{g/l}$), and MW-75S (5.65 $\mu\text{g/l}$).

Chromium was detected in only two shallow groundwater monitoring wells at concentrations in excess of its drinking water MCL of 100 $\mu\text{g/l}$. These wells included MW-73S (126 $\mu\text{g/l}$) and MW-74S (1,500 $\mu\text{g/l}$). Manganese was identified in nine wells in excess of its drinking water MCL of 50 $\mu\text{g/l}$. These wells included MW-51S (207 $\mu\text{g/l}$), MW-52S (619 $\mu\text{g/l}$), MW-60S (6,290 $\mu\text{g/l}$), MW-61S (1,370 $\mu\text{g/l}$), MW-62S (718 $\mu\text{g/l}$), MW-66S (17,200 $\mu\text{g/l}$), MW-67S (321 $\mu\text{g/l}$), MW-71S (20,000 $\mu\text{g/l}$), and MW-74S (266,000 $\mu\text{g/l}$).

Lead currently does not have a drinking water MCL; however, the USEPA has imposed an action level of 15 $\mu\text{g/l}$ at the tap for drinking water suppliers. Six shallow monitoring wells exhibited concentrations of lead in excess of 15 $\mu\text{g/l}$. These wells included MW-54S (34.6 $\mu\text{g/l}$), MW-55S (16.7 $\mu\text{g/l}$), MW-56S (55.3 $\mu\text{g/l}$), MW-57S (15.8 $\mu\text{g/l}$), MW-69S (110 $\mu\text{g/l}$), and MW-73S (110 $\mu\text{g/l}$).

Total silver, barium, copper, mercury, and selenium were either not detected in the groundwater samples collected from the shallow monitoring wells or present at concentrations below established MCLs.

Beryllium, calcium, cobalt, iron, potassium, magnesium, sodium, nickel, antimony, tin, thallium, vanadium, zinc, columbium, and tantalum do not have established MCLs. These metals were detected in one or more of the shallow monitoring wells with the exception of thallium. Thallium was not detected in any of the 25 shallow wells. The remainder of these metals were detected at the following total concentration ranges: beryllium from 1.19 $\mu\text{g/l}$ (MW-51S) to 253 $\mu\text{g/l}$ (MW-74S); calcium from 1,070 $\mu\text{g/l}$ (MW-67S) to 500,000 $\mu\text{g/l}$ (MW-56S); cobalt from not detected (MW-51S, 62S, and 67S) to 290 $\mu\text{g/l}$ (MW-74S); iron from 926 $\mu\text{g/l}$ (MW-51S) to 832,000 $\mu\text{g/l}$ (MW-74S); potassium from 1,850 $\mu\text{g/l}$ (MW-51S) to 235,000 $\mu\text{g/l}$ (MW-60S); magnesium from 638 $\mu\text{g/l}$ (MW-67S) to 48,000 $\mu\text{g/l}$ (MW-62S); sodium from 32,400 $\mu\text{g/l}$ (MW-52S) to 696,000 $\mu\text{g/l}$ (MW-60S); nickel from not detected (MW-51S, MW-52S, MW-53S, MW-62S, and MW-70S) to 2,380 $\mu\text{g/l}$ (MW-74S); antimony from not detected (MW-51S,

MW-52S, MW-53S, MW-54S, MW-58S, MW-59S, MW-60S, MW-61S, MW-62S, MW-64S, MW-66S, MW-68S, MW-70S, MW-71S, MW-74S, and MW-75S) to 284 $\mu\text{g/l}$ (MW-74S); tin from not detected (MW-51S, MW-52S, MW-57S, MW-58S, MW-60S, MW-61S, MW-62S, MW-63S, MW-64S, MW-66S, MW-68S, MW-69S, MW-70S, and MW-75S) to 160,000 $\mu\text{g/l}$ (MW-56S); vanadium from not detected (MW-51S) to 2,640 $\mu\text{g/l}$ (MW-74S); zinc from 18.3 $\mu\text{g/l}$ (MW-61S) to 1,480 $\mu\text{g/l}$ (MW-74S); columbium from not detected (MW-51S, MW-52S, MW-53S, MW-59S, MW-61S, MW-62S, MW-63S, MW-64S, MW-65S, MW-66S, MW-67S, MW-68S, MW-70, and MW-75S) to 1,900 $\mu\text{g/l}$ (MW-74S); and tantalum from not detected (MW-53S, MW-63S, MW-64S, MW-65S, MW-66S, MW-67S, MW-68S, MW-70S, and MW-71S) to 600 $\mu\text{g/l}$ (MW-74S).

Dissolved metals analysis was performed on groundwater samples collected from MW-55S, MW-62S, MW-63S, MW-65S, MW-66S, MW-67S, MW-73S, and MW-74S. The dissolved metals analysis was performed for comparative purposes with total metal concentrations. Dissolved concentrations of silver were only detected in MW-73S (60 $\mu\text{g/l}$) and MW-74S (27 $\mu\text{g/l}$). The concentrations of dissolved silver present in these well samples were below the established MCL for this metal (100 $\mu\text{g/l}$). Dissolved arsenic concentrations exceeded the MCL for this metal (50 $\mu\text{g/l}$) in the following wells: MW-62S (550 $\mu\text{g/l}$), MW-63S (650 $\mu\text{g/l}$), MW-65S (300 $\mu\text{g/l}$), MW-66S (430 $\mu\text{g/l}$), MW-67S (4,000 $\mu\text{g/l}$), MW-73S (180 $\mu\text{g/l}$), and MW-74S (910 $\mu\text{g/l}$). Dissolved concentrations of barium were not exhibited by any of the wells sampled at concentrations in excess of this metal's MCL. Dissolved concentrations of cadmium were identified above its established MCL (5 $\mu\text{g/l}$) in the following wells: MW-55S (5.5 $\mu\text{g/l}$), MW-63S (5.1 $\mu\text{g/l}$), MW-66S (10 $\mu\text{g/l}$), MW-73S (190 $\mu\text{g/l}$), and MW-74S (110 $\mu\text{g/l}$). Dissolved concentrations of chromium were only detected in MW-73S (1,400 $\mu\text{g/l}$) and MW-75S (1,500 $\mu\text{g/l}$). The concentrations of chromium detected in both of these wells exceed this metals established MCL of 100 $\mu\text{g/l}$. Mercury was not detected in any of the eight wells at concentrations in excess of its MCL. Dissolved concentrations of selenium were not identified in any of the eight wells sampled. Dissolved lead was detected in the following wells at trace concentrations: MW-55S (1.6 $\mu\text{g/l}$), MW-67S (3.6 $\mu\text{g/l}$), MW-73S (2.0 $\mu\text{g/l}$), and MW-74S (5.2 $\mu\text{g/l}$).

Calcium, nickel, antimony, tin, columbium, and tantalum do not have established MCLs. These metals were detected at the following dissolved concentrations in the wells identified below: calcium was detected in MW-55S (13,000 $\mu\text{g/l}$), MW-62S (180,000 $\mu\text{g/l}$), MW-63S (280,000 $\mu\text{g/l}$),

MW-65S (53,000 $\mu\text{g/l}$), MW-66S (67,000 $\mu\text{g/l}$), MW-67S (1,000 $\mu\text{g/l}$), MW-73S (8,000 $\mu\text{g/l}$), and MW-74S (9,900 $\mu\text{g/l}$); nickel was detected in MW-55S (68 $\mu\text{g/l}$), MW-63S (53 $\mu\text{g/l}$), MW-65S (54 $\mu\text{g/l}$), MW-66S (120 $\mu\text{g/l}$), MW-73S (2,300 $\mu\text{g/l}$), and MW-74 (2,300 $\mu\text{g/l}$); antimony was detected in MW-55S (6.0 $\mu\text{g/l}$), MW-63S (4.2 $\mu\text{g/l}$), MW-65S (7.2 $\mu\text{g/l}$), MW-66S (4.3 $\mu\text{g/l}$), MW-67S (12 $\mu\text{g/l}$), and MW-74S (4.0 $\mu\text{g/l}$); tin was identified in MW-62S (53 $\mu\text{g/l}$), MW-63S (61 $\mu\text{g/l}$), MW-67S (110 $\mu\text{g/l}$), MW-73S (1,300 $\mu\text{g/l}$), MW-73S (1,400 $\mu\text{g/l}$), and MW-74S (1,500 $\mu\text{g/l}$); and tantalum was detected in MW-62S (100 $\mu\text{g/l}$), MW-63S (200 $\mu\text{g/l}$), MW-67S (100 $\mu\text{g/l}$), MW-73S (900 $\mu\text{g/l}$), and MW-74S (800 $\mu\text{g/l}$).

Total concentrations of fluoride were detected in excess of its established MCL (4 mg/l) in the following wells: MW-55S (52 mg/l), MW-57S (19 mg/l), MW-60S (7.4 mg/l), MW-61S (25 mg/l), MW-62S (10 mg/l), MW-63S (20 mg/l), MW-64S (39 mg/l), MW-65S (42 mg/l), MW-66S (51 mg/l), MW-67S (3,600 mg/l), MW-68S (5.0 mg/l), MW-69S (21 mg/l), MW-70S (16 mg/l), MW-71S (54 mg/l), MW-72S (50 mg/l), MW-73S (12 mg/l), MW-74S (8.5 mg/l), and MW-75S (38 mg/l).

Ammonia which does not have an established MCL was detected in 17 of the 25 shallow monitoring wells at concentrations ranging from 0.39 mg/l (MW-73S) to 3,500 mg/l (MW-67S). Total nitrate was detected above its MCL (10 mg/l) in the following wells: MW-52S (41 mg/l), MW-57S (30 mg/l), MW-61S (29 mg/l), MW-62S (160 mg/l), MW-66S (59 mg/l), and MW-67S (69 mg/l). Sulfate was detected in 16 of 25 shallow monitoring wells at concentrations in excess of its MCL of 250 mg/l. These wells included MW-52S (2,000 mg/l), MW-56S (2,000 mg/l), MW-57S (270 mg/l), MW-58S (800 mg/l), MW-59S (1,600 mg/l), MW-60S (780 mg/l), MW-62S (1,000 mg/l), MW-63S (1,900 mg/l), MW-64S (740 mg/l), MW-65S (420 mg/l), MW-66S (880 mg/l), MW-67S (2,900 mg/l), MW-71S (590 mg/l), MW-72S (1,200 mg/l), MW-73S (800 mg/l), and MW-74S (1,600 mg/l).

MIBK was detected in MW-64S (430 $\mu\text{g/l}$), MW-67S (820 $\mu\text{g/l}$), MW-71S (37 $\mu\text{g/l}$), MW-73S (120,000 $\mu\text{g/l}$), and MW-74S (83,000 $\mu\text{g/l}$). The state of Oklahoma has established an MCL for MIBK of 2,000 $\mu\text{g/l}$. The only other VOCs detected in site wells were methyl ethyl ketone (MEK), 1,2-dichloroethene, and 2-hexanone. These constituents were only detected in MW-74S at 21, 64, and 33 $\mu\text{g/l}$ respectively. None of these three VOCs have established MCLs. No semivolatile organic compounds were detected in the monitoring wells with the exception of di-N-butyl phthalate which was identified in MW-67S (14 $\mu\text{g/l}$) and MW-74S (36 $\mu\text{g/l}$). Table 15

summarizes the results of groundwater samples collected from the shallow monitoring wells. Figure 11 illustrates the location of various parameters of concern detected above established MCLs.

4.1.4.1.1 Distribution of Contaminants of Concern in the Unconsolidated Zone of Saturation

Figure 11 illustrates the location of various contaminants of concern in shallow monitoring wells. As with site soils, groundwater is most significantly impacted in the areas of the site downgradient of the Chemical "A" Building and in the immediate vicinity of Ponds Nos. 2 and 3. Groundwater in this area of the site exhibits elevated concentrations of ammonia, fluoride, and MIBK. Concentrations of metals are also generally higher in the monitoring wells in this portion of the site than in other facility areas.

Groundwater samples collected from wells in the vicinity of the wastewater treatment ponds also exhibit some impacts associated with fluoride and ammonia. No MIBK was identified in groundwater in this portion of the site.

4.1.4.2 Shale Bedrock Zone of Saturation

A total of four groundwater monitoring wells were installed at the Fansteel facility to communicate with the shale bedrock zone of saturation (MW-151D, MW-161D, MW-167D, and MW-174D). Groundwater samples collected from these wells were analyzed for the list of parameters identified in Section 4.1.4 of this report.

Silver, barium, chromium, mercury, nickel, selenium, tin, columbium, and tantalum were either not detected or present at concentrations below established MCLs within samples collected from the four bedrock monitoring wells. Arsenic was detected in each bedrock monitoring well (MW-151D, 120 $\mu\text{g/l}$; MW-161D, 4.6 $\mu\text{g/l}$; MW-167D, 3.88 $\mu\text{g/l}$; and MW-174D, 11.3 $\mu\text{g/l}$). The drinking water MCL for arsenic is 50 $\mu\text{g/l}$. Calcium was detected in each of the four wells at concentrations ranging from 20,100 $\mu\text{g/l}$ (MW-151D) to 83,600 $\mu\text{g/l}$ (MW-167D). Cadmium was identified only in MW-151D (6.3 $\mu\text{g/l}$). The MCL for cadmium is 5.0 $\mu\text{g/l}$. Lead was detected in each bedrock monitoring well at concentrations ranging from 8.71 $\mu\text{g/l}$ (MW-167D) to 122 $\mu\text{g/l}$ (MW-161D). Antimony was detected only in MW-151D (38.2 $\mu\text{g/l}$) and MW-174D (30.8 $\mu\text{g/l}$).

Fluoride was detected in each well at concentrations below 4 mg/l, the MCL for this constituent. Ammonia was detected in MW-161D (0.33 mg/l), MW-167D (0.22 mg/l), and MW-174D (0.44 mg/l). Nitrate was detected in each of the four wells at concentrations ranging from 0.31 mg/l (MW-161D) to 10 mg/l (MW-151D).

MIBK was detected only in MW-174D at a trace concentration of 13 µg/l. The method detection limit for MIBK is 10 µg/l. However, this well was sampled again on April 30, 1993 and MIBK was not detected at this time. The presence of MIBK in the initial sample collected from this well immediately after installation is believed to be associated with residual contamination resulting from well installation that was not completely removed during initial well development. The analytical results for the analysis of groundwater from the bedrock wells are summarized in Table 16. Figure 11 illustrates the location of various parameters detected above established MCLs.

4.1.4.2.1 Distribution of Contaminants of Concern in the Shale Bedrock Zone of Saturation

Figure 11 also summarizes the occurrence of specific chemical contaminants of concern in the bedrock zone of saturation. Generally, the bedrock zone of saturation does not exhibit concentrations of the various constituents of concern at levels which pose a significant concern. Fluoride is not present in any of the bedrock monitoring wells at concentrations above MCLs. Ammonia was detected in the three downgradient bedrock monitoring wells; however, the concentrations are orders of magnitude less than those associated with the unconsolidated zone of saturation. Results of the most recent sampling activities indicate that MIBK is not present in the bedrock zone. The analytical results demonstrate that groundwater impacts of concern are confined to the shallow zone of saturation. The bedrock zone of saturation does not appear to have been adversely impacted by site operations.

4.2 Radiological Characteristics

Based on the field activities described in Sections 3.9 and 3.10 of this report, the following determinations were obtained relating to the presence of radioactive materials on the south and east plant area of the Fansteel property.

4.2.1 Soils

4.2.1.1 Background Soils

Radiochemical analysis of the soils obtained from 30 background locations was utilized to establish a baseline for comparison of site soils. The background soil samples were assumed to be unaffected by Fansteel's manufacturing operations. The background soil samples were also assumed to be representative of the total content and distribution of radionuclides which would be present on the Fansteel property without regard to any manufacturing activity. Figure 3 presents the location of the 30 background soil samples and Table 17 summarizes the results of their analyses.

Average values of gross alpha and gross beta activity were calculated from the background soil analytical results. The average gross alpha activity measured in the background soils was found to be 15.6 picocuries per gram (pCi/g). Results were distributed normally around this value, i.e., the calculated sample standard deviation was 4.5 pCi/g. No background sample results exceeded two standard deviations from the mean value of alpha activity. One sample (Sample No. 9) showed alpha activity less than the mean value by more than two standard deviations but less than three. The average gross beta activity measured in the background samples was found to be 20.5 pCi/g. Results were distributed normally around the mean, i.e., the calculated sample standard deviation was 4.6 pCi/g. No background sample exceeded two standard deviations from the mean value of beta activity. One sample (Sample No. 3), showed beta activity less than the mean value by more than two standard deviations but less than three. Based on the normal distribution of gross activity results, the average values for gross alpha and gross beta radioactivity can be confidently applied to the results of similar analyses at the Fansteel site as a background correction for purposes of detecting impacts to the site by radioactive materials managed at the facility.

One reservation must be enunciated regarding the background radiochemistry values for gross alpha activity. The results of the background radiochemistry survey exhibited a higher level of alpha activity than might have been expected. These slightly elevated results are most probably due to fallout from the nearby Oklahoma Gas and Electric (OG&E) coal-fired electricity generation plant. Both uranium and thorium are emitted from coal-burning facilities. The OG&E plant has been in operation in excess of 20 years and so may have

contributed measurable amounts of these long-lived radionuclides to the surface soil on the land surfaces surrounding the generation plant. The Fansteel facility would be expected to have received approximately the same addition as the areas sampled for the determination of the radiochemical background.

Background soil samples were also analyzed for specific radionuclides of concern, specifically uranium and thorium. The concentration of uranium (including U-238, U-235, and U-234) averaged 1.08 pCi/g with a sample standard deviation of 0.62 pCi/g. The concentration of thorium (including Th-232, Th-230, and Th-228) averaged 3.33 pCi/g with a sample standard deviation of 0.92 pCi/g. These results indicate a normal distribution of radionuclide concentrations in the background soil. These average concentrations will be used to provide a background radionuclide concentration for interpreting the results of soil samples obtained from the Fansteel site.

Examination of the background soils for Radium-226 (a Uranium-238 decay product) and Radium-228 (a Thorium-232 decay product) indicates that the parent radionuclides are in a condition of approximate equilibrium with their decay products. Results of the background soil sample radiochemical analysis are also presented in Table 18.

4.2.1.2 Site Soils

Site soils were investigated for radioactive materials using both an instrument survey of the ground surface and by laboratory analysis of soils obtained from borings, test pits, and monitoring well installations. These investigations indicate the presence of radioactive materials in site soils at various locations on the east plant area of the Fansteel property.

4.2.1.2.1 Instrument Survey Results

The results of the instrument survey of site soils are presented in Table 17. The location of the soil instrument survey points is shown in Figure 4. The instrument survey of the exterior grounds was able to yield relatively little additional information on the concentration of radionuclides in the soil. Surveys of surface alpha and beta activity are only marginally useful because of the short range of alpha and beta particles through soil. Gamma radiation surveys are generally capable of detecting the presence of concentrations of radionuclides in soils. However, the presence of large quantities of radioactive materials in Pond No. 2, Pond No. 3,

and, to a lesser extent, Pond No. 5 contributed a sufficiently high and variable background to preclude meaningful interpretation of the results of the surface gamma radiation survey.

The results of the surface alpha radioactivity survey generally support the findings of the subsurface radiochemical analysis. Elevated surface alpha radioactivity was observed in the immediate surroundings of the residue impoundments, Pond No. 2 and Pond No. 3. Additional elevated surface alpha particle activity was detected in the area east of the Chemical "A" Building and along the railroad spur terminus northwest of the Chemical "C" Building.

Surface alpha particle surveys are more useful on finished surfaces. The paved ore storage pad located west of the Chemical "A" Building showed widespread areas of elevated alpha particle activity on the surface. Areas used for traffic carrying ores or residues between the storage pad and the materials entrance for the Chemical "A" Building similarly showed elevated surface activity, probably due to fugitive ore material or processing residues. These areas will be remediated with regard to radioactive materials as part of site decommissioning activities.

4.2.1.2.2 Soil Analysis Results

Results of the soil radiochemical analyses performed on samples recovered from soil borings, monitoring wells, test pits, and surface sediments are presented in Tables 3, 4, and 12. Locations of soil samples for radiochemical analysis are shown in Figure 2. Gross alpha and gross beta analysis was performed by counting 100 milligrams of dried soil using a gas flow proportional counter. Specific radionuclides were determined by gamma spectrometry and radiochemical analysis.

The following criteria were used to identify soil areas that may have been affected by radioactive materials used at the Fansteel site:

- Gross alpha radioactivity in excess of 20 pCi/g. This level of radioactivity represents one standard deviation above the local background alpha activity of 15 pCi/g.
- Total uranium (U-238, U-235, and U-234) in excess of 6.1 pCi/g. This concentration of uranium represents 5 pCi/g above the local background concentration of uranium in soil.

- Total thorium (Th-232 and Th-230) in excess of 8.3 pCi/g. This concentration of thorium represents 5 pCi/g above the local background concentration of thorium in soil.

Soils meeting one or more of these criteria for consideration as potentially affected by radioactive materials from the Fansteel manufacturing operations are found throughout the site, as shown in Figure 12. Potentially affected soils are found in various locations from the surface to depths in excess of 20 feet below the surface. Most of the contaminated soils and the soils with the highest levels of contamination are located along the eastern edge of the property, east of the manufacturing, processing, and waste management areas of the facility. The location, concentration, and extent of contamination in each area is discussed in further detail in the following sections.

4.2.1.2.2.1 Borrow Pit Area

The borrow pit is located in the southwest corner of the plant property. The original surface soils in the borrow pit have been partially removed for use in constructing berms, impoundments, improving drainage, and other uses at the site. Three samples of surface soil were obtained and six soil borings were evaluated as part of the soils investigation. Two of the soil borings were developed as shallow monitoring wells. Two of the soil borings, B-10 and MW-56S, exhibited elevated gross alpha activity.

Soil Boring B-10 exhibited gross alpha activity of 42 pCi/g in the sample obtained between 2.0 and 4.5 feet below the surface. Radiochemical analysis of this sample showed both uranium and thorium in the soil at levels above the local background but below the threshold criteria cited previously. Other decay products of uranium and thorium are also present in a condition of equilibrium. Other sampled intervals did not exhibit elevated radioactivity.

The boring for MW-56S exhibited gross alpha radioactivity of 23 pCi/g in the top 6 inches of soils sampled. Radiochemical analysis of this sample showed uranium and thorium concentrations approximately equal to the local background average. Other decay products of uranium and thorium are present in a condition of equilibrium. Other sampled intervals did not exhibit elevated radioactivity.

Based on the results of the soil sampling alone, the radioactivity detected in this area might be attributed to a random accumulation of fugitive material or to a naturally occurring concentration of uranium or thorium-bearing minerals. However, as discussed in Sections 4.2.3.1 and 4.2.4.1 following, groundwater and surface water in this area of the property also indicate elevated concentrations of radioactivity. This combination of indicators suggests that radioactive materials may have impacted this area at some time in the past.

4.2.1.2.2 Wastewater Treatment Ponds (Ponds Nos. 6, 7, 8, and 9)

The wastewater treatment ponds are located in the southeast corner of the Fansteel property. These ponds are currently used to store sludges, principally calcium carbonate and calcium fluoride, generated during the treatment of plant wastewater. Additionally, the location designated as Pond No. 5 has in the past been used for the storage of radioactive material containing residues from the processing of ores at this facility. Fifteen soil borings were advanced in this area. Seven of these borings were developed as monitoring wells. One sediment sample from a surface water outfall was also sampled. One of the soil borings, B-17, exhibited elevated gross alpha radioactivity and elevated concentrations of thorium.

Boring B-17 exhibited gross alpha radioactivity of 27 pCi/g and thorium at a concentration of 13.6 pCi/g at a depth of 0.5 to 2.5 feet below the ground surface. The principal contributor to the total thorium is Thorium-230 which was reported present at 11 pCi/g. Radiochemical analysis of other members of the Uranium-238 decay series shows these elements to be present but at concentrations less than would be required for equilibrium, i.e., in the range of 1 to 3 pCi/g. The result reported for B-17 appears to be a local anomaly since no other soil borings in this area of the property indicate elevated radioactivity, nor was elevated radioactivity detected in any of the other samples obtained from this borehole.

4.2.1.2.3 Eastern Outslope

The eastern outslope comprises the area lying south of the closed impoundment designated Pond No. 2, north of the wastewater treatment ponds, and east of the main chemical processing building referred to as the Chemical "A" Building or Building No. 16. Twenty-seven boreholes were sampled in this area, 4 of which were developed as monitoring wells. Sediment from 2 runoff or treated water outfalls were also sampled. All but 6 of the boreholes show elevated radioactivity levels. Sediment from Outfall 002 also exhibited elevated radioactivity.

Elevated gross alpha radioactivity was identified in the following boreholes: B-32, B-33, B-74, B-50, B-66, B-49, B-63, MW-65S, B-48, B-47, B-58, B-51, B-52, B-64, B-65, B-54, B-55, B-56, B-61, B-73, and B-62. Elevated uranium was found in B-74, B-33, B-50, B-49, MW-65S, B-47, B-64, B-65, B-54, B-55, B-56, B-61, B-73, and B-62. Elevated thorium was found in B-47, B-51, B-52, B-54, B-55, B-56, B-61, and B-73. Elevated gross alpha was detected in the sediments associated with Outfall 002. Radioactivity in the boreholes was detected at depths from the surface material to 20 feet below the surface. The majority of the contamination is found within the top 2.5 feet of soil in this area. Levels of radioactivity range from near the criterion concentration to more than 100 pCi/g. This entire area appears to be affected by radioactive materials which may have resulted from plant operations.

4.2.1.2.2.4 Residue Pond Area

This area comprises the boundaries of the embankments of Pond No. 2, Pond No. 3, the Chemical "C" Building (also referred to as Building No. 13) and the area of land lying east of these ponds to the Arkansas River. These impoundments are used for the storage of ore processing residues from the production of tantalum and columbium. A total of 24 boreholes were developed in this area, 9 of which were developed as monitoring wells. Sediment associated with 1 surface water outfall was also sampled. Eleven of the boreholes and the sediment sample exhibited elevated radioactivity.

Elevated alpha radioactivity was detected in the following boreholes: B-15, B-29, B-36, MW-71S, B-60, B-59, B-38, B-72, B-39, MW-75S, and B-22. Elevated uranium was detected in B-29, B-36, MW-71S, B-59, B-72, MW-75S, and B-22. Elevated thorium was detected in MW-75S. Elevated gross alpha radioactivity and elevated uranium were found in the sediment obtained from Outfall 003. Radioactivity in this area was distributed from the surface to depths in excess of 20 feet. However, as with the eastern slope area, most of the radioactivity was found in the upper 2.5 feet of soil. The contamination found at depth, i.e., from soils recovered from MW-71S, B-59, and B-72, was almost exclusively due to uranium. Radioactive decay products were found in these locations at concentrations much lower than the parent uranium. This indicates that the contamination may be associated with uranium mobilized by infiltrating groundwater through Pond No. 2 or Pond No. 3 rather than from ore or slag residues present in the soils at these locations. This entire area appears to have been affected by radioactive materials derived from plant operations.

4.2.1.2.2.5 Central Area

The central area comprises the balance of the property. Soil samples were obtained from 12 test pits and 14 soil borings. Three of the soil borings were also developed as monitoring wells. Radioactive contamination is essentially absent from the central plant area. Gross alpha radioactivity in excess of the criterion was detected from two of the test pits (TP-5 and TP-10) and one borehole, B-28. Results from these locations are from the surface soil and are either at the criterion value of 20 pCi/g (TP-5) or slightly above it. Gross alpha radioactivity at TP-10 was 21 pCi/g. Gross alpha radioactivity at B-28 was 22 pCi/g. These values may be attributed to fugitive emissions of ore or residue, and do not indicate significant contamination of soils in this area of the site.

4.2.2 Pond Residues

Samples were obtained from each of the ponds on the site as identified in Figure 2. These consisted of the two ore processing residue impoundments (Pond No. 2 and Pond No. 3), an empty basin (Pond No. 5) formerly used for residue storage, and four basins (Pond No. 6, Pond No. 7, Pond No. 8, and Pond No. 9) used for treatment of wastewaters and storage of water treatment residues, principally calcium carbonate and calcium fluoride.

4.2.2.1 Pond No. 2 and Pond No. 3

Pond No. 2 and Pond No. 3 were sampled at the locations shown in Figure 2. At each location, a sample of the entire column of process residue was obtained. The sample was divided into thirds by vertical interval. The uppermost aliquot was identified as the "A" sample, the middle aliquot as "B", and the bottom aliquot as "C." The samples were analyzed for gross alpha, gross beta, and specific radionuclides by gamma ray spectroscopy. Analytical results are presented in Tables 5 and 6.

The ore processing residues retain the radioactive species that were present in the ores processed at the facility. All samples exhibited significant radioactivity, with gross alpha values in the thousands of picocuries per gram range. Uranium and thorium were present in all samples at hundreds of picocuries per gram. Evaluation of the decay product activities shows that the residues are in a condition of approximate equilibrium. Figure 13 illustrates the location of pond sampling points exhibiting elevated levels of radioactivity.

4.2.2.2 Wastewater Treatment Residue Impoundments

Ponds Nos. 6, 7, 8, and 9 were sampled at the locations shown in Figure 2. Ponds No. 6 and 7 are the final polishing basins where treated wastewater is retained prior to discharge. Only a small amount of residue is present in each of these ponds. Consequently, only one sample increment was obtained from sample location associated with Ponds Nos. 6 and 7. Ponds Nos. 8 and 9 are essentially full of wastewater treatment residue. This residue is composed primarily of calcium carbonate and calcium fluoride derived from treatment of process water and other wastewaters generated at the facility. Each sample from Ponds Nos. 8 and 9 was divided into three aliquots in the same manner as the samples from the ore processing residue impoundments. Each sample was analyzed for gross alpha and gross beta radioactivity and for specific radionuclides. Analytical results are presented in Tables 8, 9, 10, and 11.

All of the wastewater treatment residue samples contain radioactivity in excess of the criterion value of 20 pCi/g. All of the wastewater treatment residue samples contain uranium and thorium in excess of the criterion value of 5 pCi/g. Examination of the activity of the radioactive decay products in the wastewater treatment residues indicates that equilibrium activities exist through radium. Activities of elements below radium in the decay sequence are present in less than equilibrium activities. The activity of these species will therefore tend to increase over time as equilibrium is re-established. Figure 13 illustrates the location of pond sampling points exhibiting elevated levels of radioactivity.

4.2.2.3 Pond No. 5

Pond No. 5 is a dry basin that has been used both for storage of ore processing residues and for wastewater treatment. The ore processing residues have been substantially removed. An accumulation of wastewater treatment residues remain in the basin. The material remaining in Pond No. 5 was sampled at the locations shown in Figure 2. Each sample was divided into three aliquots in the same manner as the samples from the active wastewater treatment residue impoundments. Each sample aliquot was analyzed for gross alpha and gross beta radioactivity and for specific radionuclides. Results of these analyses are presented in Table 7.

All of the sample locations have radioactivity in excess of the criterion value of 20 pCi/g gross alpha radioactivity except for the "C" aliquot of Samples P5-1 and P5-3. All of the sample

locations have uranium and thorium concentrations in excess of the criterion of 5 pCi/g except the "C" aliquot of Samples P5-1 and P5-3. Radioactivity levels in the Pond No. 5 materials are slightly higher than the levels found in the other wastewater treatment ponds. Figure 13 illustrates the location of pond sampling points exhibiting elevated levels of radioactivity.

4.2.3 Surface Water and Sediments

Surface water and sediments were sampled at the locations shown in Figure 2. The samples were analyzed for gross alpha and gross beta radioactivity and for specific radionuclides. The results of these analyses are presented in Tables 12 and 14. For purposes of evaluating surface water for the presence of radioactive contamination, the OWRB values of 15 picocuries per liter (pCi/l) for alpha radioactivity and 50 pCi/l for beta radioactivity were utilized. Water containing radioactivity in excess of these values is presumed to have been affected by plant operations, except as noted.

4.2.3.1 Surface Water

Two of the surface water sources, S-1 and S-002, contained gross alpha and gross beta radioactivity in excess of criterion. Sample S-1 consisted of runoff from the borrow pit area located in the southwest corner of the Fansteel property. This sample exhibited elevated alpha and beta radioactivity 110 pCi/l and 150 pCi/l respectively. Specific radionuclide analysis identified elevated concentrations of uranium, thorium, and radium. These results may indicate that surface waters in this area have been affected by radioactive materials.

S-002 is a permitted discharge point for runoff from the east side of the plant property. Runoff discharging through this point flows through the east outslope area discussed in Section 4.2.1.2.3. Soils in this area appear to have been impacted with radioactive residues. These residues are located primarily in the near surface soils and so would be subject to transport in any surface runoff. The water sampled at S-002 contained elevated gross alpha and gross beta radioactivity as well as uranium and radium. Figure 14 identifies the surface water locations exhibiting elevated levels of radioactivity.

4.2.3.2 Sediment

Sediment samples were obtained from each surface water sample location. Sediments from discharge Points S-002 and S-003 exhibited elevated levels of radioactivity.

S-002 is the permitted discharge point for runoff from the east side of the plant and was discussed previously in Section 4.2.3.1. Sediment associated with the discharge point exhibited slightly elevated gross alpha radioactivity, i.e., 28 pCi/g.

S-003 is the permitted discharge point for the french drain system used for controlling groundwater in the vicinity of Pond No. 3. The sediment associated with the discharge point contained slightly elevated gross alpha radioactivity, 24 pCi/g, and elevated uranium, 12.4 pCi/g. Figure 12 identifies surface sediment sampling locations exhibiting elevated levels of radioactivity.

4.2.4 Groundwater

Twenty-five monitoring wells were developed in the unconsolidated zone of saturation on the south and east portion of the Fansteel property. Four monitoring wells were developed in the bedrock zone of saturation. The location of these wells is shown in Figure 2. Water from these wells was sampled and analyzed for gross alpha and gross beta radioactivity as well as for specific radionuclides. Results of these analyses are presented in Table 15 for the shallow groundwater zone and Table 16 for the deep groundwater zone.

4.2.4.1 Unconsolidated Zone of Saturation (Shallow Wells)

Groundwater in the unconsolidated zone of saturation is generally contaminated with radioactivity over the south and east portion of the site. All but three of the monitoring wells installed to communicate with the unconsolidated zone of saturation exhibit some degree of radiological contamination. However, some of this contamination may be from sources other than manufacturing and processing operations conducted at Fansteel. Figure 14 identifies groundwater monitoring wells exhibiting elevated levels of radioactivity.

MW-52S and MW-56S are located in the borrow pit area, i.e., the southwest corner of the property. Both of these wells exhibited elevated gross alpha radioactivity. MW-52S contained 79 pCi/l and 160 pCi/l respectively of gross alpha and gross beta radioactivity. MW-56S contained 76 pCi/l and 34 pCi/l of gross alpha and gross beta radioactivity. Additionally, MW-56S contains 68 pCi/l of uranium. MW-52S contains elevated concentrations of radium and thorium. The groundwater in the borrow pit area appears to have been affected by radioactive materials.

MW-59S, MW-60S, MW-61S, MW-57S, and MW-62S are located along the eastern (downgradient) side of the wastewater treatment residue impoundments. MW-59S, MW-60S, and MW-57S exhibited elevated gross alpha and gross beta radioactivity. MW-61S and MW-62S show elevated gross beta radioactivity only. The elevated gross beta in these wells appears to be associated with elevated levels of naturally occurring Potassium-40 rather than contamination with exogenous radionuclides.

MW-59S exhibited elevated gross alpha and gross beta radioactivity at 19 pCi/l and 110 pCi/l respectively. MW-60S exhibited gross alpha and gross beta radioactivity of 24 pCi/l and 240 pCi/l respectively. MW-57S exhibited 23 pCi/l and 120 pCi/l of gross alpha and gross beta radioactivity. Radium was the only specific radionuclide detected in these wells at significant concentrations.

The source of this groundwater contamination may be associated with the radioactive materials contained in the wastewater treatment residues. The presence of radium in the groundwater samples together with the relative absence of uranium and thorium (which would be immobilized in the wastewater treatment residues) supports this identification of the impoundments as the source of the groundwater contamination in this area of the plant.

MW-65S, MW-66S, and MW-67S are located in the east outslope area, directly east of the main process area of the plant. All three of these wells exhibited elevated gross alpha and gross beta radioactivity. Of these wells, MW-65 shows the least contamination with 19 pCi/l gross alpha and 100 pCi/l gross beta activity. This well is located most upgradient of the three wells in this area and is removed from the majority of the contaminated soils previously identified. MW-66S contains 140 pCi/l of gross alpha activity and 120 pCi/l of gross beta radioactivity. MW-67S is the most contaminated well in the area with 1,300 pCi/l gross alpha and 440 pCi/l gross beta radioactivity. The concentration of uranium in MW-67S is also substantial.

MW-68S, MW-70S, MW-71S, MW-73S, MW-74S, MW-72S, MW-75S, and MW-69S surround the ore processing residue impoundments, Pond No. 2 and Pond No. 3. MW-72S and MW-75S, located north and east of Pond No. 3, do not exhibit contamination by radioactive materials. MW-70S shows only gross beta radioactivity above the water quality criteria. Elevated gross beta in the absence of elevated gross alpha may indicate elevated concentrations of naturally

occurring Potassium-40. Pending additional information, groundwater containing only beta activity in excess of the water quality criteria will not be considered affected by manufacturing or processing activities.

Pond No. 2 is an unlined ore processing residue impoundment. Consequently, the wells associated with this impoundment are strongly affected. MW-73S contains 830 pCi/l of gross alpha radioactivity and 1,300 pCi/l of gross beta. MW-74S, located downgradient and immediately adjacent to Pond No. 2, contains 2,600 pCi/l of gross alpha radioactivity and 930 pCi/l of gross beta. MW-71 which is located on the upgradient side of Pond No. 2 contains only 29 pCi/l of gross alpha and 140 pCi/l gross beta radioactivity.

MW-68S located on the west side of Pond No. 3 and MW-69S located on the north side of Pond No. 3 also exhibited some contamination. MW-68S contains 52 pCi/l of gross alpha radioactivity and 59 pCi/l of gross beta. MW-69S contains 30 pCi/l of gross alpha activity. Gross beta radioactivity in this well is less than the criterion concentration of 50 pCi/l. Both MW-68S and MW-69S are located in areas that were potentially affected by the lining failure in Pond No. 3. As such, the presence of contaminants may be associated with this single event. If this is the case, contamination concentrations in these wells may be expected to decrease over time. The absence of radioactive contamination in MW-72S which is located downgradient of Pond No. 3 indicates that the liner of Pond No. 3 is generally intact and not leaking.

Monitoring Wells MW-63S, MW-64S, and MW-55S are located in the central area immediately west of the main processing area. This was an area in which soil analysis showed little if any radioactive contamination present. Groundwater obtained from MW-63S and MW-64S exhibited elevated gross beta radioactivity, but not elevated gross alpha. Pending further investigation, these wells will not be considered to have been affected by plant operations. MW-55S does exhibit elevated gross alpha radioactivity, 40 pCi/l. Gross beta radioactivity in this well is below the criterion concentration. MW-55S is in an area that was potentially affected by the release of materials from Pond No. 3. As with MW-68S and MW-69S, contaminant concentrations for this well may be expected to diminish over time.

4.2.4.2 Bedrock Zone of Saturation

Four monitoring wells were developed in the bedrock zone of concentration: MW-151D, MW-161D, MW-167D, and MW-174D. The locations of these wells is presented in Figure 2. Water from these wells was analyzed for gross alpha and gross beta radioactivity. MW-151D initially exhibited gross alpha and gross beta radioactivity in excess of the water quality criteria cited in Section 4.2.3. Subsequent sampling and analysis of water from this well exhibited gross alpha and gross beta activity at levels below these criteria. The initial concentrations are therefore believed to be due to laboratory error or to trace contaminants introduced during well installation or development. Radionuclide concentrations in the other bedrock monitoring wells were below the cited water quality criteria. Based on these results, radioactive contaminated groundwater appear to be confined to the unconsolidated zone of saturation.

4.2.5 Buildings and Equipment

A preliminary scoping survey was performed on the buildings and equipment in the east plant area. This survey was performed to identify buildings, portions of buildings, and equipment that will require decontamination or other measures during NRC license decommissioning activities. Locations of the buildings surveyed during this activity are identified in figures contained in Appendix D. The results of the radiation survey are summarized in Appendix E.

Building No. 13, also referred to as the Chemical "C" Building, was formerly used for the ore digestion process. This building is contaminated with radioactive material throughout.

Individual areas of walls and floors and individual items of equipment in Building No. 16, also referred to as the Chemical "A" Building, are contaminated with radioactivity in excess of the applicable standard for release for unrestricted use. These areas and items will be delineated in the decommissioning plan which will be prepared for the site. Additionally, much of the roof surface shows elevated radioactivity, probably caused by fugitive dust from ore crushing or processing operations.

The other buildings on the east plant area appear to be uncontaminated. Roof areas on these structures do exhibit some elevated radioactivity from fugitive dust emissions and/or windblown material.

4.3 Air Monitoring Results

The results for TSP and radioactivity measurements were compared against background values for the site determined during the third quarter of 1992. The results of the air quality monitoring are included in this report as Appendix F. Data for the air quality evaluation were supplied by Fansteel.

Background air quality results were evaluated with regard to concentrations of TSP and radionuclides. The background average upwind concentration of TSP was 55.8 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) with a standard deviation of $33.2 \mu\text{g}/\text{m}^3$. The 90 percent confidence interval for the concentration of TSP includes the range from 1.4 to $110.2 \mu\text{g}/\text{m}^3$.

The concentrations of gross alpha and gross beta activity in the air samples, as determined by measuring the activity of the air sample filters, were too variable to calculate meaningful statistics. Because of this, the most restrictive airborne radionuclide effluent limit applicable to the Fansteel facility, i.e., Thorium-230, was used as a standard for comparison. All background upwind air samples had an activity of less than 3×10^{-14} microcurie per milliliter ($\mu\text{Ci}/\text{ml}$) of air, the effluent limitation for airborne Thorium-230 as established by the NRC in 10 Code of Federal Regulations (CFR) 20, Appendix B, Table 2. The upwind background concentrations of airborne radionuclides varied from not detectable to $3.16 \times 10^{-15} \mu\text{Ci}/\text{ml}$.

The same air quality parameters were measured during the performance of remediation assessment field activities during February of 1993. The concentration of airborne TSP during the remediation assessment field activities averaged $49.9 \mu\text{g}/\text{m}^3$ with a standard deviation of $18.6 \mu\text{g}/\text{m}^3$. None of the air quality samples obtained during the remediation assessment field activities fell outside the 90 percent confidence interval for upwind background TSP concentrations.

Concentrations of alpha emitting radionuclides exhibited the same behavior during the performance of remediation assessment field activities as was observed during the period in which background values were measured. The concentration of alpha particle activity was too variable for the development of meaningful statistics. All the measured concentrations were well below the most restrictive applicable airborne radioactivity effluent limitation of $3.0 \times 10^{-14} \mu\text{Ci}/\text{ml}$ of air. The maximum observed airborne radioactivity was $1.09 \times 10^{-15} \mu\text{Ci}/\text{ml}$ of air.

Based on these measurements, no measurable increase in TSP or radioactive constituents left the site as airborne material during the performance of the remediation assessment. Concentrations of TSP and radioactivity were below applicable standards at all times during the remediation assessment field activities.

4.4 QA/QC

The QA/QC procedures utilized during the performance of the remedial assessment at the Fansteel site are summarized in the QA Project Plan (QAPP) which was prepared for this project. The QAPP can be found in Appendix A of the Remedial Assessment Work Plan (July 1993 revised) prepared for the implementation of this work scope.

Analytical QA/QC documentation for the work performed on this project is contained within Appendix G of this report. This information includes matrix spike, matrix spike duplicate, field blank, equipment blank, trip blanks, and method blank results for each matrix sampled on site. Soil and sediments QA/QC data are summarized on Table G-1. Groundwater QA/QC data are summarized in Table G-2 and pond residue QA/QC data are summarized on Table G-3.

All method blank and trip blanks associated with samples collected from the facility were free of the contaminants of concern analyzed for in site samples. All equipment blank samples associated with site soil samples exhibited trace concentrations of sulfates. Low concentrations of fluoride were also present in three of the equipment blanks. Ammonia was detected near the method detection limit of 0.10 mg/l in one equipment blank. Additionally, trace concentrations of lead, arsenic, chromium, and tin were identified in several equipment blanks. No MIBK was detected in any of the equipment blanks associated with soil samples collected from the site. Barium and di-N-butyl phthalate were detected in the equipment blanks associated with the pond residues samples.

Trace concentrations of fluoride, sulfate, aluminum, calcium, copper, manganese, lead, zinc, and tantalum were identified in field blanks associated with the groundwater samples collected from the site. Several of these constituents are most likely associated with the water used to prepare the blank samples. The concentrations of these constituents exhibited by the field blanks are low compared to actual site samples, and their occurrence in the field blanks does not invalidate associated site sample data.

Fourteen groundwater samples were analyzed for TCL parameters using Contract Laboratory Program (CLP) protocols to verify that the list of specific parameters used to characterize site conditions was comprehensive. The results of these analyses are discussed in Section 4.1.4 of this report. The CLP data packages associated with the analysis of these 14 samples are contained in Appendix G. The data packages have been determined to be in compliance with the terms and conditions of the contract, both technically and for completeness.

5.0 Summary of Results

Based upon the results of this remedial assessment, Earth Sciences presents the following summary:

- The most pervasive chemical contaminants of concern identified in site soils included MIBK, ammonia, columbium, fluoride, and tin. The vast majority of these constituents was located in plant areas surrounding Pond No. 3 and to the east of Ponds Nos. 2 and 3, the Chemical "A" Building, and the Chemical "C" Building. These constituents are well distributed throughout the soil column in this area with the exception of MIBK and ammonia. MIBK and ammonia, almost without exception, were present at depths greater than 5 feet and do not appear to present a surficial concern. Columbium, fluoride, and tin were also identified at relatively elevated concentrations in soils to the east of Ponds Nos. 5, 6, 7, 8, and 9. A leachable concentration of barium was identified in one soil boring (B-56) located to the east of the Chemical "A" Building near Pond No. 2 which was in excess of 100 mg/l. Based upon surrounding data points, this concentration of barium appears to be an isolated occurrence.
- Radioactivity in site soils was detected in the manufacturing and processing area of the facility. Radioactivity was most prevalent in the soils located in the immediate vicinity of the ore processing residue ponds and the area lying east of these ponds and the Chemical "A" and Chemical "C" buildings. Soil radioactivity was concentrated in the top 2.5 feet of soil, although some locations did exhibit radioactivity to depths greater than 15 feet below the surface. These locations are consistent with historical manufacturing practices. Radioactivity was also detected in the southwest area of the plant in sufficient extent to require further investigation since this area is not known to have been used for manufacturing and processing activities.
- Similar to site soils, the shallow groundwater zone is most significantly impacted in the area of the site to the east of Ponds Nos. 2 and 3, the Chemical "A" Building, and the Chemical "C" Building. Groundwater in this area of the site exhibits elevated concentrations of ammonia, fluoride, and MIBK. Concentrations of a variety of metals (including columbium, tantalum, tin, arsenic, and chromium) are also generally higher in the monitoring wells in this portion of site than in other facility areas. Groundwater samples collected from wells in the vicinity of the wastewater treatment ponds (Nos. 6, 7, 8, and 9) and Pond No. 5 also exhibit some impact associated with fluoride and ammonia; however, no MIBK was detected in these wells.
- Groundwater throughout the south and east area of the property exhibited elevated radioactivity. Radioactivity was most prevalent in the areas adjacent to the ore processing residue ponds and the area lying east of these ponds and the Chemical "A" and Chemical "C" buildings. Elevated radioactivity was also detected in the groundwater downgradient (east) of the

wastewater treatment impoundments. The groundwater underlying the southwest plant area exhibits elevated radioactivity as well.

- The shale bedrock groundwater-bearing zone does not appear to be impacted by either chemical or radiological constituents of concern associated with plant operations.
- Surface water present in the southwest borrow pit area exhibits concentrations of barium, cadmium, lead, columbium, and tantalum. Ammonia was detected in one surface water sample from this area at low concentrations. Surface water discharge samples contained relatively low concentrations of ammonia, fluoride, and cadmium, MIBK was also identified in one surface water discharge sample (SS-001).
- Surface water was affected by radioactivity in two locations: NPDES Outfall 002 which discharges storm water runoff from the surface area east of the Chemical "A" Building exhibited elevated radioactivity. Water from surface water Source S-1 located in the southwest plant area also contains elevated radioactivity.
- The chemistry of the pond residues differs from pond to pond, as expected. However, the residues contained in each of the ponds appear to be fairly well homogenized. A variety of metals is present in each of the ponds on site, the most notable being chromium. Leachable concentrations of chromium in excess of 5.0 mg/l were identified in residue samples collected from Ponds Nos. 2 and 3. MIBK was identified within Ponds Nos. 2, 3, 8, and 9 residues. Fluoride was detected in all pond residues with the highest concentrations being identified in Ponds Nos. 2 and 3. Ammonia was present in each of the ponds at similar concentrations.
- The ore processing residues stored in Ponds Nos. 2 and 3 retain most of the radioactivity originally contained in the ores. The ore processing residues are licensed by the NRC as source materials. Radioactivity is also present throughout the wastewater treatment residue impoundments, Ponds Nos. 5, 7, 8, and 9.
- Surface contamination with radioactive materials is limited to roof surfaces subject to deposition of fugitive dust and areas formerly utilized for the management or processing of ores and ore residues. These areas include the entire Chemical "C" Building and specific locations in the Chemical "A" Building and R&D Building. Paved areas used for ore storage and transportation located west of the Chemical "A" Building also exhibit surface contamination with radioactive materials.
- Based upon the results of air monitoring activities, airborne concentrations of TSP and radioactivity were below applicable standards at all times prior to and during the performance of the remedial assessment.
- A groundwater divide in the unconsolidated zone of saturation is present on site which isolated the northwestern portion of the site from the remainder of the facility. This divide results in radial groundwater flow directions from

the northwestern plant area to the northeast, southeast, and southwest. Single well aquifer characterization tests indicated the hydraulic conductivities and average linear groundwater velocities associated with the three different flow directions were relatively low. The pumping test conducted on the shallow groundwater-bearing zone indicated that one groundwater well completed in this zone would not sustain pumping rates of much more than 0.1 gallon per minute for an extended period of time. Pumping of the well at this rate exhibited no effect on observation wells located no more than 35 feet away.