REVISED PROPOSED PLAN

FOR THE

GROUNDWATER REMEDIATION UNIT
BLACKWELL ZINC SITE
BLACKWELL, OKLAHOMA

PREPARED BY

THE OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY
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JUNE 16, 2003

THE REVISED PROPOSED PLAN FOR THE GROUNDWATER REMEDIATION UNIT, BLACKWELL ZINC SITE, BLACKWELL, OKLAHOMA

The Oklahoma Department of Environmental Quality (DEQ) has evaluated various alternatives for remediating elevated metals concentrations in groundwater at the Blackwell Zinc Company Smelter Site in Blackwell, Oklahoma (the "Site"). This *Revised Proposed Plan for Remedial Action at the Groundwater Remediation Unit, Blackwell Zinc Site, Blackwell, Oklahoma* (the "Revised Proposed Plan") describes the remedial action alternatives evaluated by the DEQ and identifies a preferred alternative for public review and comment.

The DEQ invites the public to review and comment on this Revised Proposed Plan, which summarizes information that is presented in greater detail in the *Supplemental Focused Feasibility Study, Groundwater Remediation Unit, Blackwell Zinc Site* ("SFFS"; Montgomery Watson 2001), the *Addendum to the Supplemental Focused Feasibility Study, Groundwater Remediation Unit, Blackwell Zinc Site* ("ASFFS"; Integral 2003), and several previous reports. These reports are available for public review at the information repositories listed at the end of this document.

This Revised Proposed Plan is open for formal public comment from June 16, 2003 through at least July 16, 2003. The comment period may be extended by the DEQ up to an additional 30 days upon request by the public.

The DEQ will hold a Public Meeting on the Revised Proposed Plan on Thursday, July 10, 2003 at 6pm at the following location:

Blackwell City Hall
221 West Blackwell Avenue
Blackwell, Oklahoma

The public meeting will provide an opportunity for questions and verbal comment on the Revised Proposed Plan. Written comments should be sent to:

George Thomas, Project Manager
Oklahoma Department of Environmental Quality
Land Protection Division
P.O. Box 1677
Oklahoma City, OK 73101-1677

Only after the public has had an opportunity to review and comment on the Revised Proposed Plan will the DEQ make a final decision on the groundwater remedial action to be taken at the Site.

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ACRONYMS AND ABBREVIATIONS

ARAR	Applicable or Relevant and Appropriate Requirement
ASFFS	Addendum to the Supplemental Focused Feasibility Study
BIA	Blackwell Industrial Authority
BZC	Blackwell Zinc Company
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
DEQ	Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
FFS	Focused Feasibility Study
FS	Feasibility Study
gpm	gallons per minute
GRU	Groundwater Remediation Unit
LDR	Land Disposal Restrictions
MCL	Maximum Contaminant Level
µg/L	micrograms per liter
mg/L	milligrams per liter
MOU	Memorandum of Understanding
NPDES	National Pollutant Discharge Elimination System
NOV	Notice of Violation
NPL	National Priorities List
OPDES	Oklahoma Pollutant Discharge Elimination System
OSDH	Oklahoma State Department of Health
PDC	Phelps Dodge Corporation
POTW	Publicly Owned Treatment Works
PRB	Permeable Reactive Barrier
PRG	Preliminary Remediation Goal
RAO	Remedial Action Objective
RBC	Risk-Based Concentration

RCRA	Resource Conservation and Recovery Act
RG	Remediation Goal
ROD	Record of Decision
SFFS	Supplemental Focused Feasibility Study
SRU	Soils Remediation Unit
WAT	Whole Aquifer Treatment
WET	Whole Effluent Toxicity
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

Past Blackwell Zinc smelter operations resulted in contaminated groundwater beneath Blackwell. It is generally located to the north and south between Doolin Avenue and Ferguson Avenue and to the west and east between 20th Street and Main Street. This groundwater plume contains elevated concentrations of cadmium and zinc and is considered by the DEQ to be a potential risk to the health of the people and environment of the area. The DEQ has evaluated various alternatives for remediating this problem.

The DEQ's preferred remedial action alternative is pumping contaminated groundwater, treating it to meet DEQ surface water quality standards and discharging the treated water. The treatment facility will use biological treatment to reduce the toxicity and metal concentration.

This Revised Proposed Plan describes in detail the problem, numerous alternative solutions evaluated, and the DEQ's preferred alternative. This Revised Proposed Plan will be available for public review and comment beginning June 16, 2003 and ending July 16, 2003. A public meeting held at the Blackwell City Hall on July 10, 2003 at 6:00 pm will provide additional opportunity for the public to comment on the Revised Proposed Plan. The DEQ will consider all input and concerns prior to making a final decision regarding the remedial action alternative for this site.

1 INTRODUCTION

This Revised Proposed Plan describes remedial action alternatives that the Oklahoma Department of Environmental Quality (DEQ) has considered for addressing cadmium and zinc contamination in the Groundwater Remediation Unit (GRU) of the Site. This plan also identifies the remedial action alternative preferred by the DEQ. The DEQ has selected its preferred remedial action alternative based on information cooperatively developed and presented by the Blackwell Zinc Company, Inc. (BZC) (through its current owner, Phelps Dodge Corporation) and the City of Blackwell (City) in reports titled *Supplemental Focused Feasibility Study, Groundwater Remediation Unit, Blackwell Zinc Site* ("SFFS"; Montgomery Watson 2001) and *Addendum to the Supplemental Focused Feasibility Study, Groundwater Remediation Unit, Blackwell Zinc Site* ("ASFFS"; Integral 2003). The DEQ oversaw the development of these reports.

The Site consists of approximately 160 acres in northwest Blackwell that were used by BZC from 1916 to 1974 to smelt zinc and cadmium ores and other areas outside of this acreage where hazardous substances attributable to historical smelter operations have come to be located in and about the City of Blackwell. The Site has been divided for administrative purposes into three operable units, called the Soil Remediation Unit, the Ecological Remediation Unit, and the Groundwater Remediation Unit. The DEQ previously issued Records of Decision (RODs) for the Soil Remediation Unit and the Ecological Remediation Unit. The ROD for the Soil Remediation Unit was issued in April 1996 and addressed soil contamination in residential, recreational, and commercial/industrial areas that are subject to human health risk-based remediation goals. The ROD for the Ecological Remediation Unit was issued in March 1998 and addressed grasslands, riparian areas, and streams subject to ecological risk-based remediation goals.

The GRU is the subject of this Proposed Plan. The GRU (Figure 1) encompasses the area of cadmium and zinc contamination in groundwater that extends from the former smelter site (Onsite Subarea) to the vicinity of Ferguson Avenue and First Street (Ferguson Avenue Subarea). It also includes interconnected surface water features and subsurface sanitary sewers and storm drains that are subject to infiltration of contaminated groundwater (Figure 1). Cadmium and zinc concentrations in groundwater are highest within the Onsite Subarea and the Ferguson Avenue Subarea.

The purposes of this Revised Proposed Plan for the GRU are to:

- Summarize the relevant information about the GRU and define the remedial action objectives;
- Describe the remedial action alternatives considered;

- Describe the DEQ's preferred remedial action alternative and explain the rationale for proposing that alternative; and
- Solicit public comment on the DEQ's preferred remedial action alternative and rationale for rejecting other alternatives.

Both the 2001 SFFS and ASFFS provide the technical basis for the DEQ's selection of a preferred remedial alternative for addressing groundwater contamination in the GRU. Groundwater investigations and the associated regulatory process for the GRU have been ongoing since 1991. The table below provides a chronological summary of the key events and studies that provide much of the background and context for the DEQ's identification of a preferred remedial action alternative for the GRU.

CHRONOLOGICAL SUMMARY OF KEY EVENTS AND GROUNDWATER STUDIES	
1916 to 1974	*Operation of the Blackwell Zinc Company smelter*
1974	*Smelter facility closed and site donated to the Blackwell Industrial Authority*
1991-1995	*Groundwater Remedial Investigation*
1995	*Blackwell Technical Report 95-12 (Mintech 1995)*
1996	*Work Plan: Blackwell Zinc Site, Groundwater Remediation Unit, Focused Feasibility Study (PTI 1996)*
January 1998	*Focused Feasibility Study, Blackwell Zinc Site, Groundwater Remediation Unit (PTI 1998)*
August 1998	*Groundwater Remediation Unit Proposed Plan (DEQ 1998)*
October 2000	*Supplemental Groundwater, Surface Water, and Sewer Investigation (Exponent 2000a)*
May 2001	*Supplemental Focused Feasibility Study (Montgomery Watson 2001)*
January 2002	*Work Plans for Laboratory and Field Analysis to Support the Focused Feasibility Study Addendum of In-Situ Remediation of Groundwater, Blackwell, Oklahoma (Exponent 2002)*
December 2001 to November 2002	*Implementation of laboratory and field treatability studies, including supplemental source characterization, electron-donor injection field testing, and PRB laboratory column testing at the University of Waterloo*
March 2003	*Addendum to the Supplemental Focused Feasibility Study (Integral 2003)*

2 BACKGROUND

The Site is located 90 miles north of Oklahoma City in the northwest portion of Blackwell (Figure 1). The BZC, which is a wholly owned, indirect subsidiary of Phelps Dodge Corporation (through its subsidiary Cyprus Amax Minerals Company), owned and operated the former Blackwell Zinc smelter facility from 1916 to 1974. During its operational life, the facility was used to refine ore concentrates containing zinc and cadmium. Zinc- and cadmium-containing wastes from the smelting process were also managed on the site during the period of operations.

In about 1974, after closing and salvaging the Blackwell Zinc Smelter facility, the BZC donated the smelter site to the Blackwell Industrial Authority (BIA), a public trust of the State of Oklahoma whose sole beneficiary is the City of Blackwell. Since 1974, the BIA has been developing the former smelter site as an industrial park, which has resulted in the BIA selling or leasing certain portions of the former smelter site to other parties for commercial purposes. Currently, the Site is bordered to the west by pastures and other industry, to the north by pastures, to the east by residential neighborhoods, and to the south by an idle, undeveloped area, beyond which is a small residential area (Blackwell Heights).

In 1992, the Oklahoma State Department of Health (OSDH), now the DEQ, entered into a Consent Order with the BZC, the City of Blackwell, and the BIA regarding the investigation and cleanup of contamination resulting from historical operations of the Blackwell Zinc smelter. The goal of the 1992 Consent Order was to ensure that an appropriate investigation and remediation of the Site were conducted under state oversight to protect human health and the environment. On July 1, 1993, the newly created DEQ assumed the environmental duties of the OSDH.

In April 1994, the DEQ and EPA signed a memorandum of understanding (MOU) for a pilot project to allow the State to use its authority to complete a Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA)-quality Site investigation and remediation . The EPA agreed to defer a final determination to list the Site on the National Priorities List (NPL) as long as the pilot project proceeded in a timely manner and achieved CERCLA-quality results.

Initial investigations of groundwater conditions in Blackwell were carried out between 1991 and 1997. Results are summarized in the *Blackwell Technical Report 95-12* (Mintech 1995) and the *Blackwell Zinc Site Groundwater Focused Feasibility Study* (PTI 1998). On the basis of these studies, the DEQ, in August 1998, issued a Proposed Plan that identified monitored natural attenuation with institutional controls as the preferred remedial action alternative for the GRU. In response, the City of Blackwell filed extensive comments on the 1998 Proposed Plan, largely relating to concerns about the ongoing potential for infiltration of metals-bearing groundwater to the City's wastewater collection and treatment facilities. Infiltration of metals-bearing groundwater to the City's storm drain collection system was detected in 1998. In December 1999, Phelps Dodge Corporation acquired Cyprus Amax Minerals Company, parent of BZC. In February 2000, the Water Quality Division of the DEQ issued a Notice of Violation (NOV) to the City of Blackwell alleging several violations of the City's National Pollutant Discharge Elimination System (NPDES)/Oklahoma Pollutant Discharge Elimination System (OPDES) Permit for its wastewater treatment plant (WWTP). Among the violations were failures of the Whole Effluent Toxicity (WET) test criteria for treated effluent from the WWTP, which were attributed to infiltration of groundwater containing elevated concentrations of cadmium and zinc into the wastewater collection system.

In March 2000, the DEQ Water Quality Division issued a related but separate NOV to Phelps Dodge Corporation citing violations that included: 1) causing pollution to waters of the state in violation of the state public nuisance statute; 2) discharging a pollutant into waters of the state without a permit; and 3) introducing into a Publicly-Owned Treatment Works (POTW) as a user, a pollutant which causes a pass-through interference on the operation of the POTW.

In June 2000, the DEQ entered into a Consent Order with the City of Blackwell and Phelps Dodge Corporation. This Consent Order required the parties to correct the violations listed in the NOVs and to address the outstanding remediation issues at the Site, particularly those related to the GRU. Subsequently, the City and PDC proposed, and the DEQ accepted, a plan of action for addressing the NOVs and remediating groundwater in the GRU. This plan included additional studies to further characterize groundwater contamination in the GRU and the preparation of the SFFS/ASFFS to identify new remedial action alternatives for the GRU. This process has been the subject of multiple amendments to the June 2000 Consent Order.

2.1 SOURCES OF CONTAMINATION

The primary source of cadmium and zinc releases to groundwater was a zinc sulfate pond that contained process water used in the cadmium recovery process at the former smelter, shown on Figure 2. The pond operated from the 1950s to the early 1970s and contained an acidic zinc sulfate solution enriched in cadmium. Although the pond was lined with asphalt for a portion of its operational life, substantial volumes of the zinc sulfate solution seeped into the subsurface. Because of its high concentrations of sulfate, metals, and other chemical constituents, the process solution was denser than naturally occurring groundwater and migrated downward to the bedrock that forms the base of the shallow groundwater system. Although the zinc sulfate pond was permanently drained and backfilled when the smelter closed in 1974, concentrations of cadmium and zinc in groundwater have remained relatively constant in the GRU since groundwater studies began in the early 1990s. This strongly suggests the presence of an ongoing subsurface source of these metals that extends in a heterogeneous fashion between the Onsite Subarea and the Ferguson Avenue Subarea. Sampling results obtained during the groundwater investigation provide evidence that metals from the zinc sulfate pond accumulated and remain near the top of the bedrock in the Onsite Subarea, and that some of the metals also migrated and accumulated in the Ferguson Avenue Subarea. Sampling results also indicate that residual solution from the pond is present in the shallow clay unit above the groundwater table immediately beneath the former pond.

To a much lesser extent, leaching from smelter residuals that remain in surface and subsurface soils on the former smelter site is also believed to contribute some cadmium and zinc to groundwater (PTI 1998). Soils remediation has occurred as part of the Soils Remediation Unit (SRU), including excavation and removal of soils, consolidation, and capping. Soil remediation on the BIA property is unlikely to have significantly reduced the leaching potential of cadmium and zinc, because the residual sources of cadmium and zinc to groundwater are believed to be present primarily in subsurface soils and/or the water-bearing zone itself which were not addressed as part of the SRU.

2.2 NATURE AND EXTENT OF CONTAMINATION

2.2.1 GROUNDWATER

The cadmium and zinc groundwater plume extends from the Onsite Subarea to the Ferguson Avenue Subarea (Figure 2). The affected aquifer is a layer of sand and gravel that begins about 8 to 15 feet below ground surface (bgs) and extends down to a total depth of up to 40 feet. Groundwater in this shallow aquifer flows generally to the east-southeast from the Onsite Subarea towards the Ferguson Avenue Subarea. As summarized in the table below, the plume contains cadmium at concentrations of up to approximately 29 mg/L, and zinc at concentrations up to 297 mg/L. The highest concentrations occur in the Onsite Subarea and the Ferguson Avenue Subarea, as shown on Figure 2. Concentrations are somewhat lower in the intermediate region of the plume between the two subareas. Cadmium and zinc groundwater concentrations have been relatively stable since groundwater was initially characterized in 1991. This stability in cadmium and zinc concentrations indicates an ongoing source that continues to release these constituents into groundwater, influencing water quality over a broad area.

TOTAL CADMIUM AND ZINC CONCENTRATIONS IN THE PLUME AREA OF THE BLACKWELL GRU				
Area	Cadmium		Zinc	
	Minimum	Maximum	Minimum	Maximum
Onsite Subarea	0.005	24.2	< 0.010	297
Ferguson Ave Subarea	0.005	28.9	< 0.010	167
Other Areas	0.005	3.45	0.029	18.6
Note: All concentration values are in units of mg/L.				

2.2.2 SANITARY SEWERS AND STORM DRAINS

Almost all of the contaminated groundwater in the GRU is captured by infiltration into leaking sanitary sewer lines and storm drains in the Ferguson Avenue Subarea. Groundwater that enters the sanitary sewer lines subsequently flows to the City of Blackwell's municipal WWTP. Infiltration to the storm drain system discharges to the Ferguson Avenue Tributary through an outfall beneath the Main Street Bridge. Groundwater infiltration to the sanitary sewers and storm drains has provided nearly complete hydraulic control of the plume, preventing its expansion beyond the current extent shown on Figure 2. A small amount of contaminated groundwater, however, is not captured by the leaking sewers and seeps through the banks of the Ferguson Avenue Tributary between 6th Street and Main Street.

Concentrations of total cadmium and zinc in the influent and effluent streams of the City of Blackwell's WWTP have varied widely over the last several years. It is believed that these variations depend on changes in groundwater elevations that occur in response to climate, specifically precipitation, which, in turn, lead to variable rates of infiltration of contaminated groundwater into the leaking sanitary sewer lines. During especially wet periods, metals that pass through the WWTP have resulted in periodic violations of the City's NPDES/OPDES permit conditions for discharge of treated wastewater effluent to the Chikaskia River.

2.2.3 SURFACE WATER

The shallow groundwater system in Blackwell is hydraulically interconnected with surface water in the Ferguson Avenue Tributary and the Legion Park Tributary (Figure 1). Both tributaries flow from west to east and ultimately drain to the Chikaskia River. Shallow groundwater discharges into the channels of both tributaries, forming isolated perennial pools in their upstream sections, and perennial flow conditions in their downstream sections.

In the Ferguson Avenue Tributary upstream (west) of Main Street, cadmium and zinc concentrations are less than 0.5 mg/L cadmium and 2 mg/L zinc. These concentrations are much lower than in the groundwater plume itself, but periodically have exceeded the State of Oklahoma's water quality criteria for these metals in aquatic systems. Concentrations as high as about 5 mg/L cadmium and 23 mg/L zinc have been measured in groundwater that discharges to the tributary via an outfall beneath the Main Street Bridge. These concentrations are similar in magnitude to concentrations in groundwater within the Ferguson Avenue Subarea. Discharge from this outfall has resulted in elevated metals concentrations in downstream portions of the Ferguson Avenue Tributary east of Main Street. Although the tributary flows into the Chikaskia River, monitoring of the river downstream of the discharge point has shown that metals concentrations are not substantially elevated. Dissolved cadmium and zinc results have typically been near or below the detection limits of 0.0005 mg/L for cadmium and 0.010 mg/L for zinc. These concentrations are considerably below the State of Oklahoma's ambient water quality criteria for these metals.

Concentrations of total and dissolved cadmium and zinc were measured at five locations in the Legion Park Tributary between Doolin Avenue and 13th Street (Figure 1) in January 2003. This section of the Legion Park Tributary contained very little water, and samples were collected from shallow isolated pools at various locations along the tributary bed. Dissolved metals concentrations varied from 0.006 to 0.301 mg/L for cadmium and 0.360 to 12.7 mg/L for zinc. The shallow pools in this segment of the Legion Park Tributary are believed to be surface expression of the shallow groundwater system. The measured cadmium and zinc concentrations in the Legion Park Tributary are consistent with groundwater concentrations at the outer periphery of the cadmium and zinc plume. As described in the Blackwell Zinc Site Ecological Assessment (PTI 1996a), the seasonally dry conditions and the general absence of riparian and aquatic vegetation in the Legion Park Tributary upstream of Doolin Avenue renders this channel segment unsuitable as riparian or aquatic habitat.

2.3 SUMMARY OF SITE RISKS

Potential risks to human health and ecological systems that may be posed by cadmium and zinc in groundwater were evaluated as part of the remedial investigation and feasibility study process for the GRU. Land use within the GRU includes residential and industrial areas with some undeveloped pastureland. Land uses are not expected to change significantly in the future. High-quality, treated drinking water supplies are provided throughout Blackwell by the City, and groundwater is not known to be used as a drinking water source in the GRU. Some residents in the GRU, however, currently use residential wells for outdoor garden watering. Areas where ecological receptors may be exposed to cadmium and zinc in groundwater are the Ferguson Avenue Tributary, the Chikaskia River, and the Legion Park Tributary. Potential human health and ecological risks associated with these exposure pathways are described below.

2.3.1 HUMAN EXPOSURE PATHWAYS

Three potential human exposure pathways have been identified within the GRU: 1) incidental dermal contact and incidental ingestion of groundwater, 2) incidental dermal contact and incidental ingestion of surface water interconnected with groundwater in the GRU, and 3) occupational exposure to construction workers in excavations that extend below the water table within the groundwater plume. The pathways are summarized by location in the table below.

HUMAN EXPOSURE PATHWAYS					
Location	Groundwater Contaminant Source	Groundwater Exposure Pathways (1)		Surface Water Exposure Pathways (2)	
		Ingestion (3)	Dermal	Ingestion	Dermal
Onsite Subarea	Yes	Possible	Possible	No	No
Plume Center	Yes	Possible	Possible	No	No
Ferguson Ave Subarea	Yes	Possible	Possible	Possible	Possible
Lower Section of Ferguson Avenue Tributary	No	No	No	Possible	Possible
Legion Park Tributary Downstream of 13th Street	No	No	No	Possible	Possible

Notes:
1 Potential groundwater exposure pathways include pumping from residential wells and excavations that extend below the water table inside the groundwater plume.
2 Potential surface water exposure pathways include discharges from groundwater and storm drains to the Ferguson Avenue Tributary and Legion Park Tributary downstream of 13th Street.
3 Groundwater ingestion exposure pathways will be managed through groundwater and land use controls that are currently being developed by the City of Blackwell.

All City residents have access to the City's public drinking water system, which supplies treated water from the Chikaskia River. Based on the availability of City water, past notices regarding metals contamination in groundwater and a survey of domestic wells, contaminated groundwater is not known to be used as a drinking water source by any residents of Blackwell. Some domestic wells, however, remain in use for outdoor watering. The City, in cooperation with the DEQ and PDC, has taken steps to ensure that groundwater is not used as a drinking source. In 1992, a letter of notification was issued with water bills urging well owners to discontinue use of groundwater as a drinking water source until further notice. In 1996, the City sent notices to residents regarding the use of smelter residues that included a reminder that the ban on use of groundwater wells within the GRU was still in place. In late 2002, the City and PDC initiated a domestic well survey to identify all residential, commercial, and industrial wells (whether in use or not) within or in the immediate vicinity of the plume of contaminated groundwater in the GRU. In conjunction with this survey, the City mailed notices to landowners and residents to convey the potential risks associated with use of contaminated groundwater.

Because the City provides high quality treated drinking water to all residents of Blackwell, it is unlikely that any resident would use groundwater from a domestic well as a primary source of drinking water. Any potential exposure to cadmium through groundwater ingestion would, therefore, likely be incidental, such as occasional drinking of water from an outdoor watering hose on a hot day. However, the presence of residential wells allows the hypothetical potential for consumption of this water as drinking water. Therefore, the use of groundwater from domestic wells within the area where groundwater cadmium concentrations exceed the federal maximum contaminant level (MCL) of 5 µg/L for drinking water is considered to represent a potential concern for human health exposures. Metals also may be taken up into the roots and leaves of vegetables in residential garden produce irrigated with contaminated groundwater and may allow for an unacceptable level of human exposure to cadmium. Though unlikely, metals could also gradually accumulate to problematic levels in residential surface soils from long-term watering with contaminated groundwater. Direct dermal contact with contaminated groundwater in the GRU could occur through the use of private domestic wells or by exposures of construction workers to groundwater in excavations that extend below the water table.

Discharge of metals-bearing groundwater to surface water in the Ferguson Avenue Tributary and the Legion Park Tributary presents a complete human health exposure pathway. Because the water depth in these tributaries typically varies from 0.5 to 1 foot during non-winter months, children can come into contact with the water while wading. Anything other than incidental ingestion of this water is considered unlikely due to the shallow depths and poor aesthetic quality of the water. A risk-based concentration (RBC) for cadmium of 3,500 µg/L was derived for recreational exposure during wading (Exponent 2000b). This RBC considers both dermal and incidental ingestion pathways and defines the surface water concentration in the tributaries below which adverse health effects are unlikely to occur. Except for discharges from a storm drain outfall to the Ferguson Avenue Tributary beneath the Main Street Bridge, measured surface water concentrations in the Ferguson Avenue Tributary and Legion Park Tributary are lower than this 3,500 µg/L risk-based threshold.

2.3.2 ECOLOGICAL EXPOSURE PATHWAYS

Three complete ecological exposure pathways have been identified for cadmium and zinc in the groundwater:

- Aquatic organisms in the Chikaskia River are exposed to metals that infiltrate into the sanitary sewer, pass through the WWTP, and are part of the WWTP discharge.
- Aquatic organisms in the Ferguson Avenue Tributary are exposed to metals that infiltrate into the storm sewer and discharge into the tributary below the

Main Street bridge and also to metals that enter the tributary through groundwater seepage in the Ferguson Avenue Subarea.

- Aquatic organisms in the Chikaskia River are exposed to metals that are discharged from the Ferguson Avenue Tributary.

2.3.2.1 Chikaskia River at the POTW

The results of two studies—the Ecological Assessment (PTI 1996) and the Water Effects Ratio study of cadmium in the City of Blackwell's POTW effluent (PTI 1997)—indicated that metals from the Blackwell Zinc Smelter Site did not pose significant risks to the aquatic ecosystem in the Chikaskia River. However, the metals concentrations in the POTW effluent have periodically exceeded discharge permit limits in the last several years since those reports were produced. This increase has caused failures for one species in whole effluent toxicity (WET) tests (*Ceriodaphnia dubia*), typically when the concentrations of total cadmium and zinc in the effluent exceed approximately 60 μg/L and 400 μg/L, respectively. The failure of the *Ceriodaphnia* WET test indicates a potential adverse effect on invertebrate communities, at least within the mixing zone of the POTW outfall. The other WET test organism, the fathead minnow, has shown much higher tolerance to any discharge of these metals from the POTW.

2.3.2.2 Ferguson Avenue Tributary

The primary ecological concerns for the Ferguson Avenue Tributary are the potential adverse effects to aquatic organisms in perennial pools in the upstream segments of the tributary (i.e., the Ferguson Avenue Subarea) and in potential good quality habitat areas in downstream segments of the tributary near its confluence with the Chikaskia River. Some higher trophic-level animals such as belted kingfisher and mink may prey on aquatic organisms in these portions of the tributary. As discussed in the Environmental Assessment (PTI 1996), the feeding range of the belted kingfisher and the mink are significantly greater than these relatively small areas. Therefore, the potential intake of cadmium and zinc through fish ingestion from the Ferguson Avenue Tributary would be small in relation to their overall diet. This means that the potential for adverse effects is not significant.

There are some shallow pools in the upstream portions of the Ferguson Avenue Tributary that provide year round aquatic habitat. Even so, ecological risk to the aquatic organisms in these isolated pools would not be significant because the habitat is limited due to physical limitations such as wide temperature and oxygen fluctuations, and because there is a low probability that unique or sensitive species occur in the shallow pools.

2.3.2.3 Chikaskia River Downstream of Ferguson Avenue Tributary

As reported in the Environmental Assessment (PTI 1996), fish communities in the Chikaskia River were sampled by the DEQ fish crew in September 1995. The red shiner (*Notropis lutrensis*), the most abundant species, was selected as the ecological receptor for evaluating the effects of metals concentrations in surface water on the fish community of the Chikaskia River. In addition, red shiners were evaluated as a food resource for higher trophic level ecological receptors: the belted kingfisher (*Ceryle alcyon*) and mink (*Mustela vison*). The belted kingfisher and mink were selected as ecological receptors as both species are closely associated with aquatic ecosystems and both receptors eat primarily fish and other aquatic organisms. Results of the Environmental Assessment (PTI 1996) indicated that no effects were apparent in the fish community of the Chikaskia River, and no risk was predicted for either the belted kingfisher or mink.

2.3.2.4 Legion Park Tributary

The presence of cadmium and zinc in isolated, shallow pools in the upstream portions of Legion Park Tributary (i.e., between 13th Street and Doolin Avenue) does not represent a complete ecological exposure pathway. Suitable aquatic and riparian habitat is absent in this segment of the tributary due to seasonally dry conditions and the lack of riparian and aquatic vegetation (PTI 1996).

3 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS, REMEDIAL ACTION OBJECTIVES, AND PRELIMINARY REMEDIATION GOALS

3.1 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Applicable or Relevant and Appropriate Requirements (ARARs) are the federal, state, and local standards and requirements that must be considered in developing and implementing a remedial action in the Blackwell GRU. A large number of ARARs have been identified for the Blackwell GRU. A comprehensive list of the ARARs that were considered for selection of the Remedial Action Objectives is presented in a table attached at the end of this document.

3.2 REMEDIAL ACTION OBJECTIVES

Remedial Action Objectives (RAOs), which are derived from the ARARs, are chemical- and medium-specific goals for protecting human health and the environment. RAOs typically specify the exposure routes, receptors, and risk levels of concern. The following RAOs have been established for the GRU to protect human health, prevent expansion of the groundwater plume, prevent degradation of natural ecosystem, and comply with sewage discharge regulations:

Protect Human Health

- Prevent human ingestion of groundwater drawn from those regions within the aquifer that have been affected by metals at concentrations that exceed established federal maximum contaminant levels (MCLs) for drinking water supplies.
- Protect recreational users from risks associated with exposure to elevated cadmium concentrations in the Ferguson Avenue Tributary and Legion Park Tributary.

Prevent Expansion of the Groundwater Plume

- Prevent the migration of metals-bearing groundwater beyond the current configuration of the metals plume in the aquifer beneath the City of Blackwell, and stabilize or reduce cadmium and zinc concentrations in groundwater.

Prevent Degradation of Natural Ecosystems

- Prevent any adverse impact on the aquatic ecology in the Chikaskia River caused by the discharge of metals-bearing groundwater from the former zinc smelter site.
- Prevent deterioration in water quality in the Ferguson Avenue Tributary that would result in deterioration of existing ecological conditions.

Comply with Wastewater Effluent Discharge Permit Regulations

- Prevent a point-source discharge from occurring in the Ferguson Avenue Tributary that does not meet Oklahoma water quality standards.
- Eliminate violations of the City's National/Oklahoma Pollutant Discharge Elimination System (NPDES/OPDES) permit for discharge of treated sanitary sewer effluent to the Chikaskia River due to metals-bearing groundwater from the former smelter entering the sanitary sewer system.
- Prevent metals-bearing groundwater that is entering the City's WWTP from causing the City to be unable to manage wastewater treatment sludge consistent with federal sludge disposal requirements.

3.3 PRELIMINARY REMEDIATION GOALS

Preliminary Remediation Goals (PRGs) are specific contaminant concentrations that are protective of human health and the environment and that comply with ARARs. Specific PRGs established for the Blackwell GRU are shown in the table on the next page.

PRELIMINARY REMEDIATION GOALS FOR THE BLACKWELL GRU	
PRG Description	**Numerical Standard or Goal**
Prevent expansion of the groundwater plume	The plume is defined as the extent of groundwater with concentrations of total cadmium higher than 5 µg/L as shown on Figure 2
Prevent use of metals-contaminated groundwater	Applies to all groundwater with concentrations of total cadmium above the drinking water standard of 5 µg/L
Stabilize or reduce existing metals concentrations in the groundwater plume	Existing concentrations are summarized in Section 2.2.1 and shown on Figure 2
Prevent violations of NPDES/OPDES discharge permit limits for cadmium and zinc in effluent from the City's POTW, to the extent that any violations are caused by infiltration of metals-bearing groundwater into the wastewater collection system	Cadmium: 63.97 µg/L monthly average and 128.28 µg/L daily maximum Zinc: 917 µg/L monthly average and 1,840 µg/L daily maximum
Prevent metals-bearing groundwater from adversely affecting the ability of POTW effluent to pass the whole effluent toxicity (WET) test as specified in the City's NPDES/OPDES permit.	The WET test must show that an effluent dilution of 28 percent is lower than the No Observed Lethal Effect Concentration, which is defined as the greatest effluent concentration at or below which there is no statistical difference in lethality to test organisms (at a 95 percent confidence) compared to control organisms exposed to 0 percent effluent.
Meet NPDES/OPDES requirements for discharge from a groundwater treatment plant to the Chikaskia River or Ferguson Avenue Tributary	Chikaskia River: projected discharge limits are 26.04 µg/L monthly average and 52.25 µg/L daily maximum for cadmium, and 2,638.26 µg/L monthly average and a 5,292 µg/L daily maximum for zinc. Ferguson Avenue Tributary: projected discharge limits are 2.58 µg/L monthly average and 5.17 µg/L daily maximum for cadmium, and 261.1 µg/L monthly average and 523.9 µg/L daily maximum for zinc.
Protect sensitive aquatic habitat areas in the Chikaskia River potentially affected by periodic discharges of metals from the Ferguson Avenue Tributary	Numerical surface water quality criteria for cadmium and zinc in the Chikaskia River are derived the Oklahoma Water Quality Standards: Cadmium: 2.58 µg/L monthly average and 5.17 µg/L daily maximum. Zinc: 261.1 µg/L monthly average and 523.9 µg/L daily maximum.
Protect recreational users of the Ferguson Avenue Tributary and Legion Park Tributary from unacceptable exposures to metals in surface water	A risk-based PRG of 3,500 µg/L for cadmium has been established for surface water in the tributaries. This PRG considers both chronic effects due to long-term exposure of children during wading, and acute effects that could arise from incidental ingestion of a small quantity of surface water.
Comply with the City of Blackwell's municipal wastewater ordinance for discharges of treated groundwater to the sewer system.	The City ordinance specifies the following concentration limits for discharges into the sewer system: Cadmium: 50 µg/L monthly average and 1,000 µg/L daily maximum. Zinc: 5,000 µg/L monthly average.

After the DEQ receives and reviews public comments on this Revised Proposed Plan, the DEQ will establish final Remediation Goals (RGs) for the Blackwell GRU.

4 REMEDIAL ACTION ALTERNATIVES

A remedial action alternative is a set of activities that is intended to achieve the RAOs and RGs. Remedial action alternatives were developed and evaluated for the Blackwell GRU in both the SFFS and the ASFFS. The SFFS considered nine remedial action alternatives. The ASFFS further developed and refined the two most promising remedial action alternatives from the SFFS and considered several new alternatives. All of the remedial action alternatives, with the exception of the no-action alternative, share several common elements:

For Presentation

- **Groundwater Containment**—Engineered measures that physically limit or contain contaminant migration
- **Groundwater Removal**—Extraction of groundwater via pumping for ex-situ treatment and/or discharge
- **Groundwater Treatment**—Ex-situ (above-ground) engineered processes for groundwater treatment, or in-situ (below-ground) natural and engineered processes that degrade or immobilize contaminants within the aquifer
- **Discharge**—Discharge of treated groundwater and residual solids from the treatment process.
- **Institutional Controls and Monitoring**—Legal and administrative measures, such as groundwater and land use restrictions, public education, and monitoring that limit potential human and/or ecological exposures to residual contamination

4.1 SUMMARY OF REMEDIAL ACTION ALTERNATIVES FROM THE 2001 SFFS

The 2001 SFFS developed and evaluated nine alternatives for remedial action at the Blackwell GRU. This section provides a very brief overview of the two most promising alternatives from the SFFS that were carried forward for further development and evaluation in the ASFFS. It also summarizes the No Action Alternative from the SFFS.

4.1.1 SFFS ALTERNATIVE 1: NO ACTION

Consideration of the No Action Alternative is required under CERCLA as the baseline to which all other alternatives are compared. Under this alternative, no remedial actions for groundwater would be taken in the GRU. Groundwater monitoring and institutional controls are not included in this alternative. For the foreseeable future, this alternative would not reduce the potential risks to human health and the environment associated with exposures to contaminated groundwater in the GRU.

4.1.2 SFFS ALTERNATIVE 4: GROUNDWATER EXTRACTION AND TREATMENT, WITH DISCHARGE OF TREATED GROUNDWATER TO THE CHIKASKIA RIVER

This alternative includes extraction of contaminated groundwater in the vicinity of the Ferguson Avenue Subarea and treatment by chemical (lime) addition to remove metals. Treated groundwater would be discharged through an outfall to the Chikaskia River. It is anticipated that the lime treatment process would be capable of meeting NPDES/OPDES discharge requirements for the Chikaskia River. This alternative, in conjunction with institutional controls and monitoring, would achieve the RGs for the GRU and could be implemented cost effectively.

4.1.3 SFFS ALTERNATIVE 7: SEWER LINE REPAIR/REPLACEMENT AND PASSIVE IN-SITU GROUNDWATER TREATMENT

In-situ treatment refers to natural and engineered processes that result in the in-situ treatment of contaminants (i.e., without removing the groundwater from the subsurface). The SFFS considered two in-situ groundwater treatment strategies for the GRU. The first is termed "permeable reactive barrier" (PRB) technology, and the second is termed "whole aquifer treatment" (WAT) technology. In the case of PRB, in-situ groundwater treatment would be accomplished through installation of a reactive material that is permeable to groundwater, but that would cause zinc and cadmium to precipitate as insoluble species within the PRB wall. WAT technology involves the injection of a reactive solution into the metals plume to facilitate the precipitation of cadmium and zinc as insoluble minerals. In-situ groundwater treatment would occur primarily in Ferguson Avenue Subarea. This alternative may be combined with repair or replacement of affected portions of the storm sewer and/or sanitary sewer.

4.2 REMEDIAL ACTION ALTERNATIVES FROM THE 2003 ASFFS

The screening process for the alternatives developed in the 2001 SFFS ultimately concluded that SFFS Alternatives 4 and 7 should be retained for further consideration as potential preferred alternatives. Insufficient technical information was available when the SFFS was prepared, however, to conduct a thorough feasibility assessment of in-situ groundwater treatment for the Blackwell GRU. In the interest of selecting an optimal alternative, the DEQ, PDC, and the City concurred that additional evaluation, including field and laboratory treatability testing of in-situ technologies, should be performed. The findings of this additional research, which was conducted from late 2001 through 2002, were incorporated into a revised evaluation of an expanded set of remedial action alternatives in the ASFFS. The ASFFS ultimately considered eleven separate ex-situ and in-situ remedial action alternatives for the GRU. The alternatives fall into three general categories:

- **Category A: Groundwater Dewatering and Ex-Situ Treatment**
- **Category B: Hydraulic Control, Sewer Repair, and Ex-Situ Treatment**
- **Category C: In-Situ Treatment, Hydraulic Control, and Sewer Repair.**

The Category A and B alternatives are based on the ex-situ treatment approach that was originally developed as Alternative 4 in the 2001 SFFS. The Category C alternatives are based on the in-situ treatment approach that was originally developed as Alternative 7 in the 2001 SFFS.

4.2.1 CATEGORY A: GROUNDWATER DEWATERING AND EX-SITU TREATMENT

Category A includes four remedial action alternatives that share several elements designed to meet the RAOs for the Blackwell GRU, thereby reducing potential risks to human health and the environment. Groundwater within the GRU would be extracted to: 1) provide hydraulic control and prevent the plume from spreading into uncontaminated areas, 2) lower the water table below the sanitary and storm sewer lines that are vulnerable to plume infiltration, and 3) prevent unacceptable levels of metals from entering the Ferguson Avenue Tributary or the Chikaskia River. Extracted groundwater would then be treated ex-situ (above ground), and the treated water would be discharged to the Chikaskia River (or possibly the Ferguson Avenue Tributary). Institutional controls would be implemented to provide additional protection against incidental ingestion and direct dermal contact with metals-bearing groundwater. Long-term monitoring of groundwater and surface water quality would be conducted to ensure the protectiveness of the remedy.

The four Category A alternatives differ only based on the method of groundwater treatment and are described as:

- **Alternative A1: Groundwater Dewatering and Active Chemical Treatment**
- **Alternative A2: Groundwater Dewatering and Active Biological Treatment**
- **Alternative A3: Groundwater Dewatering and Passive Biological Treatment by Permeable Reactive Media**
- **Alternative A4: Groundwater Dewatering and Semi-Passive Biological Treatment by Electron Donor Amendment**

Groundwater extraction methods, treatment processes, discharge requirements, institutional controls, monitoring, and costs of Alternatives A1 through A4 are described below.

4.2.1.1 Alternative A1: Groundwater Dewatering and Active Chemical Treatment

4.2.1.1.1 Groundwater Extraction

Groundwater extraction for Alternative A1 would be achieved using vertical pumping wells and/or subsurface drains (trenches) at strategic locations within the groundwater plume. The required groundwater extraction rate is estimated to be 200 gallons per minute (gpm), based on a hydraulic analysis presented in the 2001 SFFS. However, there is considerable uncertainty in this flow estimate, which would need to be addressed during remedial design. It is envisioned that groundwater extraction would be accomplished using approximately eight extraction wells in the southeast portion of groundwater plume, in the vicinity of leaking sanitary sewers and storm drain lines. In addition to the extraction wells, a groundwater cutoff barrier or slurry wall may be installed along the southern edge of the plume. The barrier or slurry wall would prevent the horizontal subsurface movement of groundwater while a drain would capture contaminated groundwater flowing towards the barrier. However, the cutoff barrier or slurry wall will only be installed if necessary as a contingency to meet RGs related to water quality in the Ferguson Avenue Tributary.

Expansive soils are present in many parts of Blackwell. Shrinking and swelling of these soils in response to climate (precipitation and temperature) causes cracks in building foundations and breakage of shallow underground water lines and sewers. Under existing conditions, the shallow groundwater in the GRU is generally in direct contact with the base of the surficial silty clay deposits in the City and may supply moisture to the overlying soils by capillary action. If any of the Category A alternatives becomes the selected remedy for the GRU, the potential for dewatering to affect soil moisture conditions (especially during dry periods) and the potential for soil shrinking or swelling will be evaluated during remedial design. Any such impacts may be mitigated by reducing pumping rates during dry periods.

4.2.1.1.2 Treatment

This alternative provides for treatment of extracted groundwater by a conventional lime precipitation process to remove metals. The treatment process would involve chemical (lime) addition, mixing-flocculation-clarification, filtration, and final pH adjustment. Lime is added to the extracted groundwater stream, increasing the pH to 10 – 11 and inducing the precipitation of cadmium and zinc as hydroxide and carbonate minerals. These minerals are gravity settled and any residual solids are removed by filtration.

A groundwater treatability study conducted as part of the 2001 SFFS demonstrated that lime treatment is capable of achieving the RGs for discharge of treated water to the Chikaskia River. The primary advantage of lime precipitation is that it is a well-established technology that is relatively straightforward to operate and maintain. The treatment process generates a considerable volume of waste sludge that will require disposal. It is anticipated that this sludge would be stable and non-hazardous, and thus would be suitable for disposal in a sanitary landfill. The lime precipitation facility could be located within the property boundaries of the City's water treatment plant or within the boundaries of the POTW. The lime precipitation facility would be housed as a completely separate process from the City's existing treatment operations, but would be within the fence line of these properties, thus providing the necessary infrastructure for the groundwater treatment process (e.g., security, access to power).

4.2.1.1.3 Discharge

Treated groundwater under Alternative A1 would be discharged to either the Chikaskia River or the Ferguson Avenue Tributary. Selection of the appropriate discharge point hinges on several factors, foremost of which are the permitted discharge limits for cadmium and zinc and the potential impacts of the flow on the receiving water body or facility. The final discharge option would be determined during the remedial design phase of the project.

4.2.1.1.4 Institutional Controls and Monitoring

All of the remedial action alternatives except for the No Action Alternative include Institutional Controls and Monitoring as key components of the remedy. Three classes of institutional controls—groundwater and land use restrictions, public education, and monitoring—will be applied as part of the selected remedy for the GRU.

4.2.1.1.4.1 Use Restrictions

As an integral part of remedial action for the GRU, the City is developing use restrictions to prevent unacceptable human exposures to contaminated groundwater and to limit activities that may result in an increase in the magnitude and/or extent of groundwater contamination. When developed, these institutional controls will include the following components:

- The City will adopt a zoning ordinance that establishes a "Groundwater Protection Zone." Groundwater extraction and use will be regulated within this zone to prevent human exposures to cadmium in groundwater that could pose an unacceptable risk to human health, to prohibit activities that could adversely affect the groundwater remedial action, and to ensure that excavations below the water table include provisions for proper exposure controls and management of contaminated groundwater. The Groundwater Protection Zone will encompass a land area where the quality of underlying groundwater in the GRU does not meet the federal maximum contaminant level (MCL) of 5 μg/L for cadmium in drinking water, plus an additional buffer zone of 300 feet. This buffer zone will ensure that pumping from wells contiguous to the Groundwater Protection Zone does not spread contaminated groundwater into new areas. The anticipated initial limits of the Groundwater Protection Zone are shown on Figure 3. The City will periodically review and, if necessary, update the boundaries of the Groundwater Protection Zone based on groundwater monitoring to be implemented as part of the selected remedial action alternative. Specific procedures for defining and updating the Groundwater Protection Zone boundaries will be specified in the City ordinance and will be subject to the DEQ's review and approval.

- Within the Groundwater Protection Zone, all groundwater wells, extraction systems, and use will be prohibited. Exceptions will be for those activities associated with groundwater remediation and monitoring and short-term dewatering of excavations during construction activities below the water table.
- All major excavation below the groundwater table and within the Groundwater Protection Zone will require a permit issued by the City. The permit shall require that the property owner employ appropriate groundwater handling procedures and health and safety measures for protection of the excavation workers from exposures to contaminated groundwater.
- The City will adopt a zoning ordinance that establishes a "Soil Protection Zone." The Soil Protection Zone will include land use controls needed to maintain the protectiveness of the ROD for the Soil Remediation Unit.

4.2.1.1.4.2 Public Education

Public education and public information programs are designed to improve community awareness of groundwater contamination issues, any potential hazards posed by the groundwater, remediation progress, and site management developments. Specific public education activities associated with the selected remedial action for the Blackwell GRU include public information sessions such as open houses or availability sessions and direct mail of fact sheets to residents potentially affected by groundwater remediation activities and use restrictions.

4.2.1.1.4.3 Monitoring

A monitoring program will be established to ensure that the remedy for the GRU achieves the RAOs and RGs and is therefore protective of human health and the environment. Specific objectives of the monitoring program are:

1. Demonstrate that the selected remedy for the GRU is achieving complete hydraulic capture of the plume.

2. Provide the data necessary to allow for periodic re-assessment of the boundaries of the Groundwater Protection Zone.

3. Ensure that metals concentrations in surface water of the Ferguson Avenue and Legion Park Tributaries are below RGs.

4. Demonstrate that the remedy has reduced infiltration of metals-bearing groundwater to the City's sanitary and storm sewer systems, such that metals concentrations in the influent to the City's WWTP do not lead to further violations of the City's NPDES/OPDES discharge permit requirements.

5. Ensure that effluent from groundwater extraction and treatment associated with the selected remedy meets permitted discharge standards.

The first three objectives will be achieved through periodic groundwater and surface water quality monitoring. Groundwater samples will be collected from strategic locations within and along the margins of the groundwater plume. Surface water samples will be collected from the Ferguson Avenue and Legion Park Tributaries. The fourth objective will be achieved through periodic monitoring of groundwater elevations and continued sampling of the influent and effluent of the City's WWTP. The fifth and final objective will most likely be achieved by monitoring the quality of treated effluent from the groundwater extraction and treatment system associated with the selected remedy.

A detailed monitoring plan will be developed as part of the Remedial Design for the GRU.

4.2.1.1.5 Cost

The table below presents a summary of the estimated capital, operation and maintenance, and total present worth costs for implementation of Remedial Action Alternative A1.

Costs for Remedial Action Alternative A1			
Alternative	**Capital Cost**	**Operation and Maintenance Cost (1)**	**Total Present Worth Cost (1)**
A1: Active Chemical Treatment	$3,252,000	$3,921,000	$7,170,000
Notes: 1. 30 year present value based on a 7% discount rate.			

4.2.1.2 Alternative A2: Groundwater Dewatering and Active Biological Treatment

4.2.1.2.1 Groundwater Extraction

The groundwater extraction system for Alternative A2 is the same as for Alternative A1.

4.2.1.2.2 Treatment

This alternative relies on an active biological reactor to produce hydrogen sulfide gas which, when mixed with extracted groundwater, would result in the precipitation of sparingly soluble cadmium and zinc sulfides. These minerals would then be settled from solution in a gravity clarifier, and the treated water would be passed through a filter to remove any residual particulates. Hydrogen sulfide gas would be generated in a separate biological reactor using a portion of the treated groundwater that would be split off from the plant effluent, amended with an "electron donor" (e.g., ethanol), and passed to the bioreactor. The addition of the electron donor stimulates the microbial reduction of sulfate and consequent generation of hydrogen sulfide in the bioreactor. This process could be located within the property boundaries of the City's Water Treatment Plant or southeast of town, near the City's POTW.

Although biological treatment systems to remove metals from water are much less widely applied than lime precipitation systems, a sufficient number of biological treatment systems are in operation to consider this a demonstrated technology (Lawrence and Kratochvil 2003). The technology is becoming more widely applied because it can be a cost-effective method for removing metals and sulfate, and because the resulting sulfide minerals are less soluble than the hydroxide and carbonate minerals formed by lime treatment. Pilot testing of active biological treatment for the Blackwell GRU would be required during remedial design primarily to demonstrate the efficiency of metals removal from groundwater and the characteristics of the metal sulfide sludge produced by the process.

The risk of a hydrogen sulfide release to the atmosphere from a bioreactor is relatively low because hydrogen sulfide is produced only as needed, and the gas would not be accumulated or stored onsite. Nevertheless, special considerations would be required during plant design and operation to safeguard against releases of hydrogen sulfide to the atmosphere. Hydrogen sulfide has a strong and unpleasant odor, and can be hazardous or lethal at high concentrations. To minimize the potential for atmospheric releases, gas flow would be maintained in a closed system. System performance would be continually monitored and adjusted to minimize the quantity of excess hydrogen sulfide gas beyond that needed to achieve complete metals treatment. A passive caustic scrubber would be used to remove excess hydrogen sulfide gas from the system. Other safeguards would include, as necessary, automated monitoring and shutdown systems, backup power supplies, double containment vessels, special worker safety equipment, and safety training programs.

Zinc concentrations in the sulfide sludge produced by the ex-situ biological treatment process would be high enough to economically recycle the zinc at a smelter, thus eliminating the need for landfill disposal. This represents a distinct advantage of active ex-situ biological treatment over conventional active chemical treatment through lime precipitation.

4.2.1.2.3 Discharge

As with Alternative A1, treated groundwater produced under Alternative A2 would be discharged to the Chikaskia River or the Ferguson Avenue Tributary.

4.2.1.2.4 Institutional Controls and Monitoring

The institutional controls and monitoring components of Alternative A2 would be the same as those described previously for Alternative A1.

4.2.1.2.5 Cost

The table below presents a summary of the estimated capital, operation and maintenance, and total present worth costs for implementation of Remedial Action Alternative A2.

Costs for Remedial Action Alternative A2			
Alternative	**Capital Cost**	**Operation and Maintenance Cost (1)**	**Total Present Worth Cost (1)**
A2: Active Biological Treatment	$3,123,000	$2,835,000	$5,960,000
Notes: 1. 30 year present value based on a 7% discount rate.			

4.2.1.3 Alternative A3: Groundwater Dewatering and Passive Ex-Situ Biological Treatment by Reactive Media

4.2.1.3.1 Groundwater Extraction

The groundwater extraction system for Alternative A3 is the same as for Alternative A1.

4.2.1.3.2 Treatment

Under this alternative, extracted groundwater would be treated in an above ground treatment cell that contains a reactive medium consisting of zero-valent iron and mulch (compost). These materials produce a chemically reducing environment (primarily microbially-mediated, sulfate-reducing conditions) that favors the formation of insoluble metal minerals (e.g., cadmium and zinc sulfides, cadmium metal), thus removing the metals from the extracted groundwater. Laboratory tests conducted for the ASFFS demonstrate that the mixture of zero-valent iron and compost is capable of meeting RGs for the Blackwell GRU.

The primary advantage of the passive biological treatment system over the active ex-situ processes (Alternatives A1 and A2) is that the passive system would not require as much routine, day-to-day operation and maintenance. Other than operation of pumps and monitoring requirements, the system would require few other active inputs—thus reducing the daily operating cost and administrative burden. The primary disadvantages are the large required size, the uncertainty of the system's operational life, and the creation of a large volume of solid waste. The use of reactive media for metals removal is a relatively new technology, and there is considerable uncertainty in the longevity of its treatment effectiveness. Available data from existing field applications of this technology suggest that the media could provide for approximately 10 years of treatment. However, this estimate is poorly constrained. Once the reactive capacity of the media is consumed, the media would need to be removed and replaced with fresh materials, and the spent media properly disposed of. Cadmium concentrations in the exhausted substrate potentially would be high enough to exceed the regulatory thresholds for land disposal. In such a case, onsite treatment (stabilization) to render the material non-hazardous or disposal in a landfill certified to receive hazardous waste would be required.

The passive biological reactor would occupy a large area (estimated at 2.7 acres) and thus could not be located within the property boundary of the City's Water Treatment Plant. Instead, the reactor would be located in the undeveloped parcel (former railroad property) in the Ferguson Avenue Subarea.

4.2.1.3.3 Discharge

As with Alternative A1, treated groundwater produced under Alternative A3 would be discharged to the Chikaskia River or the Ferguson Avenue Tributary.

4.2.1.3.4 Institutional Controls and Monitoring

The institutional controls and monitoring components of Alternative A3 would be the same as those described previously for Alternative A1.

4.2.1.3.5 Cost

The table below presents a summary of the estimated capital, operation and maintenance, and total present worth costs for implementation of Remedial Action Alternative A3.

Costs for Remedial Action Alternative A3			
Alternative	Capital Cost	Operation and Maintenance Cost (1)	Total Present Worth Cost (1)
A3: Passive Biological Treatment			
Disposal as Hazardous Waste (2)	$10,864,000	$21,031,000	$31,900,000
Disposal as Non-Hazardous Waste (3)	$10,864,000	$11,247,000	$22,100,000

Notes:
1. 30 year present value based on a 7% discount rate.
2. Assumes treatment cell media requires replacement and disposal as a hazardous waste every 10 years.
3. Assumes treatment cell media requires replacement and disposal as a non-hazardous waste every 10 years.

4.2.1.4 Alternative A4: Groundwater Dewatering and Semi-Passive Ex-Situ Biological Treatment by Electron Donor Injection

4.2.1.4.1 Groundwater Extraction

The groundwater extraction system for Alternative A4 is the same as for Alternative A1.

4.2.1.4.2 Treatment

Alternative A4 achieves cadmium and zinc removal in a manner similar to Alternatives A2 and A3, only in a semi-passive treatment system. Under Alternative A4, a large above-ground treatment cell would be constructed consisting of a coarse gravel layer overlain by a layer of finer gravel and soils. The extracted groundwater would be amended with electron donor solution and fed into the treatment cell. Microbial reduction of sulfate would occur in the groundwater as it traveled through the gravel layer, resulting in the production of hydrogen sulfide and the precipitation of cadmium and zinc sulfide minerals. Excess hydrogen sulfide would migrate as a gas into the overlying soil layer, where it would react with atmospheric oxygen to form sulfate.

This semi-passive approach is still in the early stages of development. However, it has been tested on the field-scale and a number of these systems are in full-scale operation. Advantages of this system are that it does not entail substantial active inputs other than pumping and electron donor amendment thereby reducing the daily operating cost. In addition, the longevity of the treatment reactor is not limited by the availability of the reactant (electron donor solution is continuously added). In the long-term, the system may become inefficient due to reduced permeability caused by the accumulation of solid precipitates in the cell.

It is likely that a large volume spent treatment media, which may require periodic removal and disposal during the life of the facility, will be a hazardous waste that would require disposal in a landfill certified to receive hazardous waste. Another consideration is that the soil layer above the treatment cell would need to be amended with calcium carbonate or another agent to neutralize sulfuric acid that would form when excess hydrogen sulfide gas released from the system into the soil reacts with oxygen. The system would also require careful monitoring and management to control the generation of hydrogen sulfide.

Similar to the passive ex situ reactor (Alternative A3), the semi-passive reactor would occupy a large area (approximately 2 acres) and could not be located within the property of the City's water treatment plant. Instead, the reactor would be located in the undeveloped parcel (former railroad property) in the Ferguson Avenue Subarea.

4.2.1.4.3 Discharge

As with Alternative A1, treated groundwater produced under Alternative A4 would be discharged to the Chikaskia River or the Ferguson Avenue Tributary.

4.2.1.4.4 Institutional Controls and Monitoring

The institutional controls and monitoring components of Alternative A4 would be the same as those described previously for Alternative A1.

4.2.1.4.5 Cost

The table below presents a summary of the estimated capital, operation and maintenance, and total present worth costs for implementation of Remedial Action Alternative A4.

Costs for Remedial Action Alternative A4			
Alternative	**Capital Cost**	**Operation and Maintenance Cost (1)**	**Total Present Worth Cost (1)**
A4: Semi-Passive Biological Treatment			
Disposal as Hazardous Waste (2)	$2,718,000	$8,596,000	$11,310,000
Disposal as Non-Hazardous Waste (3)	$2,718,000	$4,581,000	$7,299,000

Notes:
1. 30 year present value based on a 7% discount rate.
2. Assumes treatment cell media requires replacement and disposal as a hazardous waste every 10 years.
3. Assumes treatment cell media requires replacement and disposal as a non-hazardous waste every 10 years.

4.2.2 CATEGORY B: HYDRAULIC CONTROL, SEWER REPAIR, AND EX-SITU TREATMENT

Like the Category A alternatives, the four Category B alternatives rely on a combination of measures that are designed to meet the RAOs for the Blackwell GRU, thereby reducing potential risks to human health and the environment. Alternatives B1 – B4 differ from A1 – A4, however, in that they rely on repair and ongoing maintenance of leaking sections of the City's sanitary and storm sewer systems, rather than lowering the water table below the level of the sewers, to reduce infiltration of metals-bearing groundwater into these sewer systems. Thus, under these alternatives, groundwater would be extracted at a rate sufficient to provide hydraulic capture of the plume, but not sufficient to lower the water table below the sanitary and storm sewer lines that are vulnerable to plume infiltration. The extracted water would be treated ex-situ, and the treated water would be discharged to the Chikaskia River (or possibly the Ferguson Avenue Tributary). Institutional controls would be implemented to provide additional protection against incidental ingestion and direct dermal contact with metals-bearing groundwater. Long-term monitoring of groundwater and surface water quality would be conducted to ensure the protectiveness of the remedy.

The four Category B alternatives differ from one another only based on the method of groundwater treatment and are described as:

- **Alternative B1: Hydraulic Control, Sewer Repair, and Active Chemical Treatment**
- **Alternative B2: Hydraulic Control, Sewer Repair, and Active Biological Treatment**
- **Alternative B3: Hydraulic Control, Sewer Repair, and Passive Biological Treatment by Reactive Media**
- **Alternative B4: Hydraulic Control, Sewer Repair, and Semi-Passive Biological Treatment by Electron Donor Amendment.**

Groundwater extraction methods, discharge requirements, and costs of Alternatives B1 through B4 are described below. The treatment options for Alternatives B1 through B4 are identical to Alternatives A1 through A4 and are not repeated here.

4.2.2.1 Sewer Line Repair/Replacement

Under Alternatives B1 – B4, existing sections of leaking sanitary sewer lines and storm drains would be repaired. These include a section of storm drain approximately 700 feet long, between 1st Street and 3rd Street on Lawrence Avenue, and a section of sanitary sewer approximately 1,900 feet long, south of Santa Fe Avenue in the Ferguson Avenue Subarea. These alternatives also require that, over time, any sections of the sanitary and storm sewer system that deteriorate and begin to receive significant infiltration of metals-bearing groundwater be repaired and/or replaced.

4.2.2.2 Groundwater Extraction

Groundwater extraction would be required under Alternatives B1 – B4 to provide for hydraulic control of the plume following repair of the leaking sewer sections. All four alternatives would employ approximately five pumping wells that would be installed at strategic locations within the groundwater plume. It is estimated that a groundwater extraction system of approximately 80 gpm average operating capacity and 160 gpm peak capacity during high groundwater conditions (wet years) would be sufficient to achieve hydraulic control of the plume. In addition to the extraction wells, a groundwater cutoff barrier or slurry wall may be installed along the southern edge of the plume as a contingency for meeting RGs related to water quality in the Ferguson Avenue Tributary. The barrier or slurry wall would prevent the horizontal subsurface movement of groundwater to the Tributary while a drain would capture contaminated groundwater flowing towards the barrier.

4.2.2.3 Treatment

Ex-situ treatment under Alternatives B1 through B4 would be accomplished by the same processes described above for Alternatives A1 through A4.

4.2.2.4 Discharge

As with Alternatives A1 – A4, treated groundwater produced under Alternatives B1 – B4 would be discharged to the Chikaskia River or the Ferguson Avenue Tributary.

4.2.2.5 Institutional Controls and Monitoring

The institutional controls and monitoring components of Alternatives B1 – B4 would be the same as those described previously for Alternative A1.

4.2.2.6 Cost

The table below presents a summary of the estimated capital, operation and maintenance, and total present worth costs for implementation of Remedial Action Alternatives B1 – B4. Based on this analysis, Alternative B2 has the lowest overall cost.

Remedial Action Alternatives B1 – B4			
Alternative	**Capital Cost**	**Operation and Maintenance Cost (1)**	**Total Present Worth Cost (1)**
B1: Sewer Repair and Active Chemical Treatment	$2,480,000	$2,786,000	$5,270,000
B2: Sewer Repair and Active Biological Treatment	$2,574,000	$2,629,000	$5,200,000
B3: Sewer Repair and Passive Biological Treatment			
Disposal as Hazardous Waste (2)	$6,310,000	$11,219,000	$17,530,000
Disposal as Non-Hazardous Waste (3)	$6,310,000	$6,607,000	$12,917,000
B4: Sewer Repair and Semi-Passive Biological Treatment			
Disposal as Hazardous Waste (2)	$2,081,000	$4,781,000	$6,860,000
Disposal as Non-Hazardous Waste (3)	$2,081,000	$2,853,000	$4,934,000

Notes:
1. 30 year present value based on a 7% discount rate.
2. Assumes treatment cell media requires replacement and disposal as hazardous waste every 10 years.
3. Assumes treatment cell media requires replacement and disposal as a non-hazardous waste every 10 years.

4.2.3 CATEGORY C: IN-SITU TREATMENT, HYDRAULIC CONTROL, AND SEWER REPAIR

The three Category C alternatives are designed to meet the RAOs for the Blackwell GRU and reduce potential risks to human health and the environment by treating groundwater in-situ (i.e., within the aquifer), followed by extraction of the treated water and discharge to the Chikaskia River (or possibly the Ferguson Avenue Tributary). Groundwater would be extracted at a rate sufficient to provide hydraulic capture of the plume, but not sufficient to lower the water table below the sanitary and storm sewer lines that are vulnerable to plume infiltration. Therefore, a sewer repair and maintenance program would be required to reduce infiltration of metals-bearing groundwater to the City's sanitary and storm sewer systems. Institutional controls would be implemented to provide additional protection against incidental ingestion and direct dermal contact with metals-bearing groundwater. Long-term monitoring of groundwater and surface water quality would be conducted to ensure the protectiveness of the remedy.

Category C includes the following three in-situ alternatives:

- **Alternative C1: Permeable Reactive Barrier Treatment**
- **Alternative C2: Long-Term Treatment by Electron Donor Injection Treatment**
- **Alternative C3: Whole Aquifer Treatment by Electron Donor Injection Treatment.**

Treatment technologies, groundwater extraction and discharge requirements, and costs of these alternatives are described below.

4.2.3.1 Alternative C1: Permeable Reactive Barrier Treatment

4.2.3.1.1 Treatment

Permeable reactive barrier technology involves the installation of an in-situ treatment wall filled with a permeable reactive material across the saturated thickness of the aquifer. The reactive material then induces the removal of the metals from groundwater as it passes through the barrier. In the case of cadmium and zinc, the most promising reactive material is a mixture of zero-valent iron and mulch, which together create a reduced environment that favors the removal of the metals as low-solubility, reduced mineral species (e.g., zinc and cadmium sulfide minerals, elemental cadmium).

Laboratory treatability tests performed as part of the ASFFS demonstrated that PRB technology is capable of achieving the RGs for the Blackwell GRU. The testing also yielded estimates of critical design criteria (e.g., hydraulic residence time, treatment longevity). The conceptual design includes a 200 feet long by 165 feet wide by 15 feet deep PRB, located in the Ferguson Avenue Subarea. Thus, the PRB cell would occupy an area of approximately 0.8 acres. This large size is required to meet the minimum residence time requirements for sufficient removal of metals by sulfate reduction at an average design flow rate of 80 gpm (160 gpm maximum). The PRB would probably be located in the undeveloped parcel (former railroad property) in the Ferguson Avenue Subarea.

The use of reactive media for metals removal is a new technology, and there is considerable uncertainty in the longevity of its treatment effectiveness. Available data from existing field applications of this technology suggest that the media could provide for approximately 10 years of treatment. However, this estimate is poorly constrained. Once the reactive capacity of the media is consumed, the PRB cell would require complete replacement. The spent PRBs would be left in place as waste cells that would likely require additional specific land use controls for long-term management.

4.2.3.1.2 Groundwater Extraction and Discharge

The current configuration of the groundwater plume is controlled by the discharge of groundwater to leaking sections of the sanitary and storm sewer systems. Without additional provisions, the response of the aquifer after these sewer lines are repaired under Alternative C1 may lead to an expansion of the groundwater plume and, ultimately, to an unacceptable discharge to either the Ferguson Avenue Tributary or the Chikaskia River. Extraction of treated groundwater "downstream" of the in-situ treatment processes would be required under these alternatives to provide for hydraulic control of the plume. The groundwater extraction system must also be designed to direct plume flow through the in-situ treatment zone. It is assumed that Alternative C1 would include a subsurface drain within or immediately downgradient of the in-situ treatment zone to extract groundwater after it is treated. The groundwater extraction system would be designed to capture a flow of 80 gpm (average) and 160 gpm (maximum) through the treatment zone. The treated groundwater collected by the drain would be discharged to the Chikaskia River or another receiving body (i.e., the Ferguson Avenue Tributary).

4.2.3.1.3 Institutional Controls and Monitoring

The institutional controls and monitoring components of Alternative C1 would be the same as those described previously for Alternative A1.

4.2.3.1.4 Cost

The table below presents a summary of the estimated capital, operation and maintenance, and total present worth costs for implementation of Alternative C1.

Remedial Action Alternative C1			
Alternative	Capital Cost	Operation and Maintenance Cost (1)	Total Present Worth Cost (1)
C1: In-Situ PRB (2)	$6,681,000	$5,199,000	$11,880,000
Notes: 1. 30 year present value based on a 7% discount rate. 2. Assumes treatment cell media requires replacement every 10 years.			

4.2.3.2 Alternative C2: Long-Term Treatment by Electron Donor Injection

4.2.3.2.1 Treatment

Alternative C2 consists of electron donor injection to achieve long-term in-situ treatment of groundwater in the Ferguson Avenue Subarea. Soluble carbohydrates would be injected into the subsurface to stimulate microbial reduction of sulfate to sulfide, and the subsequent removal of cadmium and zinc by precipitation of metal-sulfide minerals. The effectiveness of this technology was evaluated in a 10-week pilot study conducted in the Onsite Subarea of the Blackwell GRU.

A series of groundwater injection and extraction wells would be installed for groundwater extraction, mixing with an electron donor solution, and reinjection of the mixture into the shallow aquifer, such that a treatment zone would be created near the downgradient end of the Ferguson Avenue Subarea.

The pilot test demonstrated that the electron donor injection process can release arsenic contained in naturally occurring iron oxide minerals in the aquifer. This release would be of finite duration, continuing until the available iron and arsenic is depleted from the treatment zone. Excess hydrogen sulfide is also likely to accumulate in groundwater in the treatment zone over time. Additional remediation measures would be required to remove arsenic and hydrogen sulfide from groundwater downgradient of the electron donor treatment area. This would most likely be accomplished via an in-situ air sparging system consisting of a series of air-injection wells. Oxygen introduced into the aquifer by the sparging system would oxidize hydrogen sulfide (to sulfate) and ferrous iron (to hydrous ferric oxides) in groundwater. The hydrous ferric oxides would, in turn, remove arsenic from solution through sorption/co-precipitation reactions. It may be necessary to inject additional ferrous iron into the aquifer to achieve sufficient arsenic removal. Because of the potential for hydrogen sulfide gas generation, Alternative C2 would require monitoring of soil gas above the treatment zone. In addition, the treatment zone should be located in an area away from buildings and sewer lines where hydrogen sulfide gas could accumulate.

Cadmium and zinc sulfides will remain in the aquifer matrix indefinitely under Alternative C2. Specific land use controls (e.g., excavation restrictions) would likely be required to prevent future human exposures to these materials. Controls would also be required to prevent atmospheric oxygen from coming into contact with the metal sulfides, which could lead to releases of soluble sulfuric acid, cadmium, and zinc.

4.2.3.2.2 Groundwater Extraction and Discharge

Groundwater extraction and discharge for Alternative C2 would be the same as described previously for Alternative C1.

4.2.3.2.3 Institutional Controls and Monitoring

The institutional controls and monitoring components of Alternative C2 would be the same as those described previously for Alternative A1.

4.2.3.2.4 Cost

The table below presents a summary of the estimated capital, operation and maintenance, and total present worth costs for implementation of Alternative C2.

Remedial Action Alternative C2			
Alternative	Capital Cost	Operation and Maintenance Cost (1)	Total Present Worth Cost (1)
C2: In-Situ Electron Donor Injection	$1,873,000	$2,761,000	$4,630,000
Notes: 1. 30 year present value based on a 7% discount rate.			

4.2.3.3 Alternative C3: In-Situ Whole Aquifer Treatment by Electron Donor Injection

4.2.3.3.1 Treatment

In-situ whole aquifer treatment involves the injection of a concentrated carbohydrate solution amended with ferrous sulfate into shallow groundwater throughout the plume area. As with Alternative C2, this injection process would stimulate microbial reduction of sulfate to sulfide and remove dissolved cadmium and zinc from groundwater as metal sulfide minerals. The addition of ferrous sulfate to the electron donor solution would result in the formation of iron sulfide minerals that would coat the aquifer matrix. Because iron sulfides are less stable than cadmium and zinc sulfides, cadmium and zinc in groundwater will exchange with the iron to form cadmium and zinc sulfides. These chemical exchange reactions would provide long-term, in-situ treatment of cadmium and zinc released to groundwater from subsurface residual sources. Geochemical modeling conducted for the ASFFS demonstrates that whole aquifer treatment is theoretically achievable. However, the effectiveness of this treatment process has not been demonstrated for site-specific conditions in the Blackwell GRU or in field scale applications elsewhere, and practical factors, such as slow reaction kinetics, reduced surface reactivity with time, and aquifer heterogeneity have the potential to reduce the effectiveness of such reactions.

Alternative C3 would require injection of electron donor and ferrous sulfate throughout the contaminated zone of the shallow aquifer. The injection process would involve installation of a large number (approximately 1,900) of closely-spaced injection points in a grid across the footprint of the groundwater plume.

As described under Alternative C2, Alternative C3 could cause an unacceptable release of arsenic to groundwater. To address this potential, Alternative C3 includes installation of an in-situ air sparging system in the Ferguson Avenue Subarea upgradient from the area of groundwater extraction to oxidize dissolved iron and remove arsenic from groundwater. Alternative C3 also has the potential to generate both hydrogen sulfide and methane gases in the subsurface. The mixture of electron donor and ferrous sulfate in the injected solution would be designed to minimize the potential for generating these gases. However, it would be difficult to maintain these conditions in the heterogeneous aquifer and it is possible that localized zones would exist where excess hydrogen sulfide is generated or methanogenic conditions are established. As a result, careful control and monitoring would be required under Alternative C3 to ensure that toxic and/or explosive conditions do not develop. This requirement is of particular importance under Alternative C3, because much of the treatment must take place in a large area beneath local residences and near sewer lines in the City.

Cadmium and zinc sulfides will remain in the aquifer matrix indefinitely. Specific land use controls (e.g., excavation restrictions) would likely be required to prevent future human exposures to these materials. Controls would also be required to prevent atmospheric oxygen from coming into contact with the metal sulfides, which could lead to releases of soluble sulfuric acid, cadmium, and zinc.

4.2.3.3.2 Groundwater Extraction and Discharge

Groundwater extraction and discharge for Alternative C3 would be the same as described previously for Alternative C1.

4.2.3.3.3 Institutional Controls and Monitoring

The institutional controls and monitoring components of Alternative C3 would be the same as those described previously for Alternative A1.

4.2.3.3.4 Cost

The table below presents a summary of the estimated capital, operation and maintenance, and total present worth costs for implementation of Alternative C3.

Remedial Action Alternative C3			
Alternative	**Capital Cost**	**Operation and Maintenance Cost [(1)]**	**Total Present Worth Cost [(1)]**
C3: Whole Aquifer Treatment by Electron Donor Injection	$10,086,000	$474,000	$10,560,000
Notes: 1. 30 year present value based on a 7% discount rate.			

5 SCREENING OF REMEDIAL ACTION ALTERNATIVES

Remedial alternatives A1 – A4, B1 – B4, and C1 – C3 were initially screened using the following three primary evaluation criteria to identify alternatives that should be retained for detailed analysis (U.S. EPA 1988):

- **Effectiveness** is the potential for the alternative to achieve RAOs and RGs, considering the chemical and physical characteristics of the site;
- **Implementability** relates to the technical and administrative issues and constraints involved in implementing an alternative; and
- **Cost** involves estimating and comparing the relative costs of each alternative to eliminate those of significantly higher cost that are no more effective and/or implementable than lower cost alternatives.

The results of the screening are summarized in the table below. Shaded alternatives are eliminated from further consideration.

PRELIMINARY SCREENING SUMMARY				
Alternative	**Effectiveness**	**Implementability**	**Cost**	**Retained?**
No Action	Low	High	Low	No
A1 Dewatering and Active Chemical Treatment	High	Medium	Medium	Yes
A2 Dewatering and Active Biological Treatment	High	Medium	Low	Yes
A3 Dewatering and Passive Biological Treatment	Medium	Medium	High	No
A4 Dewatering and Semi-Passive Biological Treatment	Medium	Medium	High	No
B1 Hydraulic Control, Sewer Repair and Active Chemical Treatment	High	High	Low	Yes
B2 Hydraulic Control, Sewer Repair and Active Biological Treatment	High	Medium	Low	Yes
B3 Hydraulic Control, Sewer Repair and Passive Biotreatment	Medium	Medium	High	No
B4 Hydraulic Control, Sewer Repair and Semi-Passive Biological Treatment	Medium	Medium	Medium	Yes
C1 In-Situ Treatment by Permeable Reactive Barrier	Medium	Medium	High	No
C2 In-Situ Long-Term Electron Donor Treatment	Medium	Medium	Low	Yes
C3 In-Situ Whole Aquifer Treatment	Medium	Low	High	No

6 DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

The six remedial action alternatives for the Blackwell GRU that were retained from the initial screening were subjected to a detailed analysis using nine criteria developed by U.S. EPA to evaluate remedial action alternatives under CERCLA. Definitions of the criteria are provided in the table below. The purpose of the detailed analysis is to provide sufficient comparative information to allow the DEQ to identify a preferred remedial action alternative for the Blackwell GRU.

U.S. EPA EVALUATION CRITERIA FOR REMEDIAL ACTION ALTERNATIVES	
Threshold Criteria	
Overall Protection of Human Health and the Environment	This criterion considers how each alternative would achieve and maintain protection of human health and the environment. This evaluation draws from other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, compliance with ARARs, and ability to meet RAOs and RGs. The focus of this evaluation is whether a specific alternative would achieve adequate protection and on how potential site risks would be eliminated, reduced or controlled through treatment, engineering or institutional controls.
Compliance with ARARs	This criterion assesses how each remedial action alternative would comply with the ARARs identified for the remedial action.
Primary Balancing Criteria	
Long-Term Effectiveness and Permanence	This criterion considers the long-term effectiveness of each alternative in maintaining protection of human health and the environment after implementation of the remedy. Issues addressed for each alternative include the potential long-term risks remaining after remedial implementation, the magnitude of such risks, and the long-term reliability of the management controls.
Short-Term Effectiveness	This criterion considers the protection of human health and the environment during construction and implementation of a remedial action. It focuses on protection of workers and the community during construction, potential environmental impacts, and the time needed to meet RAOs.
Reduction in Toxicity, Mobility, or Volume	This criterion addresses the preference under CERCLA for remedial actions that permanently and significantly reduce the mobility, toxicity, or volume of hazardous substances through treatment.
Implementability	This criterion evaluates the feasibility of remedy implementation. It addresses construction and operation issues, availability of goods and services, the reliability of technology, and monitoring considerations. Administrative issues include the degree of required coordination with other agencies, such as obtaining permits or approvals for onsite and offsite activities.
Cost	This criterion considers the estimated total capital and operation and maintenance costs of each alternative, expressed as a net present worth over a 30 year period.
Modifying Criteria	
Regulatory Acceptance	This criterion identifies the DEQ's preferred alternative, as well as any agency concerns about the proposed remedial action. Regulatory acceptance is expressed in the Proposed Plan and the Record of Decision (ROD) once the public comment period has ended.
Community Acceptance	This criterion identifies community preferences and concerns regarding the preferred alternative. Community acceptance is evaluated based on comments and other feedback received during the public comment period on this Proposed Plan. Community concerns are generally addressed in a Responsiveness Summary contained in the ROD.

6.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

All six of the remedial action alternatives that were retained from the preliminary screening (i.e., A1, A2, B1, B2, B4, and C2) would meet the RAOs established for the Blackwell GRU and would therefore be protective of human health and the environment. These alternatives include groundwater use restrictions, which will protect against incidental ingestion of and direct dermal contact with metals-bearing groundwater. Groundwater extraction will provide hydraulic control of the groundwater plume, thus preventing plume expansion. Hydraulic control would also prevent or substantially reduce the discharge of metals to the Ferguson Avenue Tributary, thus protecting recreational users of the Tributary from exposure to metal contaminants.

Alternatives A1 and A2 prescribe lowering of the groundwater table below the invert of the sanitary and storm sewer sections vulnerable to metals infiltration. If completely effective, these actions would eliminate the infiltration of plume water to the sewer systems and, thus, metals loading to the City's POTW. The other four alternatives (B1, B2, B4, and C2) include an ongoing monitoring and repair program for leaking sewer sections to minimize the infiltration of plume water. Under all of the alternatives (particularly under alternatives B1, B2, B4, and C2), some minor infiltration of metals-bearing groundwater to sewer lines may still occur. Any such residual infiltration must be limited to levels that do not cause violations of the City's effluent discharge limits and do not adversely impact management of sludge from the WWTP. These levels will be established during the remedial design phase and confirmed during actual operation of the selected remedy.

Laboratory testing demonstrated that the lime precipitation technology prescribed under Alternatives A1 and B1 can provide sufficient treatment such that discharge of treated groundwater to the Chikaskia River would not adversely impact the ecology of the river. Field pilot testing of in-situ electron donor injection (Alternative C2) demonstrated that this treatment process is capable of providing sufficient treatment to permit discharge to the Chikaskia River, but may not provide sufficient removal of zinc to permit discharge to the Ferguson Avenue Tributary. Alternatives A2, B2, and B4 rely on the same biologically-based removal mechanisms as electron donor injection. As a result, it is anticipated that treated groundwater from these systems could be safely discharged to the Chikaskia River. Further, the active treatment system specified under Alternatives A2 and B2 would provide considerable operator control relative to Alternatives B4 and C2. As a result, it is anticipated that metals removal could be optimized under Alternatives A2 and B2 such that it may be possible for treated groundwater to meet the more stringent limits for discharge to the Ferguson Avenue Tributary.

In contrast to the six retained remedial action alternatives, the No Action Alternative would not be protective of human health and the environment for the foreseeable future.

6.2 COMPLIANCE WITH ARARS

All six of the remedial action alternatives (i.e., A1, A2, B1, B2, B4, and C2) could be implemented in a manner that would comply with the federal, state, and local ARARs presented in Section 3. While groundwater in the Blackwell GRU will not meet drinking water MCLs under any of the alternatives, institutional controls preventing exposure to metals-bearing groundwater will allow these alternatives to be protective of human health. Due to the elevated cadmium concentrations, untreated groundwater extracted from the plume may be classified as hazardous waste under the Resource Conservation and Recovery Act (RCRA). However, treatment of groundwater to remove the cadmium (and other constituents) should render the water non-hazardous and reduce cadmium and zinc concentrations in the treated groundwater to levels that will allow its discharge into the Chikaskia River or Ferguson Avenue Tributary.

Discharge of treated groundwater to the Chikaskia River or the Ferguson Avenue Tributary would require permitting and monitoring to ensure that treated groundwater meets the relevant Oklahoma Water Quality Standards and discharge permit requirements.

Groundwater treatment under all of the alternatives except C2 would generate solids residuals that would require handling and disposal and/or recycling. Active chemical treatment (Alternatives A1 and B1) would generate a metals-bearing sludge that would require disposal. However, it is anticipated that this sludge would be stable and non-hazardous. As a result, the Land Disposal Restrictions (LDR) under RCRA should not pose a compliance problem for treatment sludge. The metals-bearing sludge generated under Alternatives A2 and B2 could be recycled for recovery of zinc metal, and thus would not be subject to LDR requirements. These alternatives would also generate a biological sludge. However, this sludge would not contain metals and would be suitable for land application or disposal in a municipal landfill. Under Alternative B4, the treatment media used in the semi-passive treatment cell would require periodic replacement when the cell became inefficient due to permeability reductions. The spent media would likely be characteristically hazardous and thus subject to LDR requirements. It is probable that these materials would require stabilization prior to disposal in a hazardous waste landfill.

Active biological treatment (Alternatives A2 and B2) would involve the generation, handling, and treatment of hydrogen sulfide gas—triggering additional air permitting, safety, and process control requirements. Semi-passive biological treatment (Alternative B4) would also generate hydrogen sulfide gas. The treatment system would be designed to provide for the passive treatment and venting of the gas to the atmosphere within acceptable levels. Nonetheless, it is probable that hydrogen sulfide management would require special considerations for design and permitting of this system.

6.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

The six remedial action alternatives largely meet the criteria for long-term effectiveness and permanence. In all cases, residual contamination would remain within the contaminated zone of the aquifer for the foreseeable future. However, the risk for human exposure would be minimal due to restrictions on groundwater use. All of the alternatives require long-term maintenance of institutional controls to preserve the groundwater use restrictions. It is probable that the extraction systems would require long-term operation to prevent plume expansion and unacceptable levels of contaminant discharge to sanitary and storm sewer lines and to surface water (i.e., the Ferguson Avenue Tributary and Chikaskia River). Treatment system operation requirements would be less for semi-passive biological treatment (Alternative B4) and in-situ electron donor injection (Alternative C2) than for active treatment processes (Alternatives A1, A2, B1, and B2). In-situ electron donor injection will result in short-term releases of arsenic from the aquifer matrix and long-term production of sulfide in groundwater. It is anticipated that these compounds may be treated in situ via air sparging, though the effectiveness of an air-sparging system is untested.

6.4 SHORT-TERM EFFECTIVENESS

Each of the remedial action alternatives will also be effective in the short term. With good management practices, there would be little potential for an uncontrolled release or exposure of community members or workers to metals-bearing groundwater or hazardous treatment chemicals. Alternatives A2, B2, B4, and C2 will require monitoring for, and, if necessary, abatement of, potentially hazardous vapors (e.g., hydrogen sulfide, methane, alcohol vapors) and noxious odors. Other short-term impacts could include traffic and access requirements for installation of the extraction and treatment facilities. Each of the alternatives requires that potentially hazardous chemicals such as acid and ethanol be shipped to the treatment facility. Alternative B4 would result in a significant increase in local truck traffic during treatment cell construction and replacement, while construction and operation of the remaining alternatives would involve lesser truck traffic. Short-term risks could be effectively managed using conventional construction techniques including dust abatement and traffic control. Alternative A2 and B2 will require specific controls to prevent an unacceptable release of hydrogen sulfide gas to the atmosphere.

6.5 REDUCTION IN TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

Groundwater extraction under all of the alternatives may promote a gradual decline in metals concentrations over the entire plume area and a gradual reduction in the total area of the plume with cadmium concentrations above the drinking water standards, thus reducing the toxicity of metals in the plume over the long term. It is not anticipated, however, that any of the alternatives would reduce metals concentrations to below drinking water standards in the entire groundwater plume within a 30 year time span. Because Alternatives A1 and A2 involve higher groundwater pumping rates (i.e., more than twice the rate expected under Alternatives B1, B2, B4, and C2), they are expected to more quickly reduce the mass of zinc and cadmium in the aquifer. If groundwater extraction ceases, contaminant concentrations may rebound due to the influence of residual source mass in the subsurface. In-situ treatment would result in a significant reduction of contamination within the active treatment zone, but concentrations in other areas the plume (i.e., upgradient of the Ferguson Avenue Subarea) will be largely unchanged.

The mobility of cadmium and zinc within the plume will be controlled by groundwater extraction and use restrictions under all six alternatives, thus preventing the expansion of the groundwater plume and discharge of metals-bearing groundwater to surface water. Alternatives A1 and A2 would control discharge of metals-bearing groundwater to sewer lines by lowering the water table below the inverts of vulnerable sanitary and storm sewer lines. Under the other alternatives, discharges to sewer lines would be controlled by an ongoing sewer monitoring and repair program.

Alternatives A1 and B1 would generate metals-bearing solids residuals that would require landfill disposal. Alternative B4 would generate metals-bearing solid residuals that will likely require stabilization and disposal as a hazardous waste. Alternatives A2 and B2 would produce a recyclable metals-bearing sludge from which zinc metal could be recovered by smelting for economic reuse. Alternative C2 would not generate a solids residuals waste stream, because the treatment process involves in-situ stabilization of the metals.

6.6 IMPLEMENTABILITY

In general, all of the alternatives would be relatively straightforward to implement. Each of the remedies can be modified to account for unexpected site conditions (e.g., additional pumping wells to accommodate changes in groundwater extraction requirements). Groundwater extraction, specified under all of the alternatives, is considered to be technically feasible and reliable given site specific conditions. Groundwater dewatering under Alternatives A1 and A2 may present a technical and administrative challenge to ensure that the water table is lowered below all sections of sewer vulnerable to infiltration of metals-bearing groundwater. The potential effects of groundwater dewatering on soil moisture conditions, especially during dry periods, and any resulting geotechnical and/or structural impacts (e.g., subsidence, foundation cracks, and/or utility line breakage) would need to be evaluated during remedial design. Any such impacts may be mitigated by reducing groundwater pumping rates during dry periods, when groundwater levels are naturally lower and metals loading to the City's POTW typically drops to very low levels even in the absence of active groundwater pumping.

Groundwater extraction under Alternative C2 may also present a challenge to ensure that the electron donor treatment zone captures the entire flow of the groundwater plume in the Ferguson Avenue Subarea. However, it is anticipated that the groundwater extraction objectives under Alternatives A1, A2, and C2 can be achieved during the early stages of system operation.

Of the treatment processes under consideration, active chemical treatment (Alternatives A1 and B1) is the best-established. Lime precipitation is a widely-applied treatment application that involves readily available processes and equipment. Active biological treatment (Alternatives A2 and B2) is less widely applied. However, the fundamental mechanisms of active biological treatment are well understood, the required system processes and equipment are readily available, and operational requirements are well established from experience at several operating plants elsewhere. These plants also demonstrate that this technology is highly effective for metals removal under treatment conditions similar to those in the Blackwell GRU. Active biological treatment would require appropriate monitoring and controls to manage hydrogen sulfide gas. All four of the active treatment processes (Alternatives A1, A2, B1, and B2) would involve significant operator input.

Semi-passive biological treatment and in-situ electron donor injection (Alternatives B4 and C2) have been demonstrated at a small number of sites, but are still in the development stages. In general, both of these systems are fairly simple to design and install, and each system would require minimal operator input relative to the active treatment alternatives. Both systems have uncertain operational life times due to the potential of reduced permeability effects resulting from solids accumulation in the treatment zone. In addition, the effectiveness of air sparging to address arsenic and sulfide produced in groundwater downgradient of the electron donor treatment zone is untested. Alternative B4 would likely generate a substantial volume of hazardous solids residuals. Management and disposal options for this waste would be limited.

Land access constraints are an important consideration for all of the alternatives. Construction of the discharge line to the Chikaskia River under Alternatives A1, B1, and may be constrained by existing development along the pipeline corridor through Blackwell. Alternatives A1 and A2 would also require an extensive piping system to convey groundwater pumped from all regions of the aquifer where sewer lines are vulnerable to infiltration of metals-bearing groundwater. Alternatives B4 and C2 would require construction on open land, away from local residences and buildings. It is anticipated that suitable open areas would be available in the Ferguson Avenue Subarea.

6.7 COST

The present worth costs for the six retained alternatives are summarized in the table below.

Present Worth Costs for Remedial Action Alternatives A1, A2, B1, B2, B4, and C2

Alternative	Capital Cost	Operation and Maintenance Costs (1)	Total Present Worth Cost (1)
A1: Groundwater Dewatering and Active Chemical Treatment	$3,252,000	$3,921,000	$7,170,000
A2: Groundwater Dewatering and Active Biological Treatment	$3,123,000	$2,835,000	$5,960,000
B1: Hydraulic Control, Sewer Repair, and Active Chemical Treatment	$2,480,000	$2,786,000	$5,270,000
B2: Hydraulic Control, Sewer Repair, and Active Biological Treatment	$2,574,000	$2,629,000	$5,200,000
B4: Hydraulic Control, Sewer Repair, and Semi-Passive Biological Treatment	$2,081,000	$2,853,000 to $4,781,000	$4,934,000 to $6,860,000
C2: In-Situ Electron Donor Injection	$1,873,000	$2,761,000	$4,630,000

Note:
1. 30 year present value based on a 7% discount rate.

6.8 COMMUNITY ACCEPTANCE

The acceptance of the preferred alternative and/or other alternatives by the Blackwell community will be evaluated through the public participation process and any comments received during the formal public comment period.

6.9 REGULATORY ACCEPTANCE

The DEQ has reviewed the remedial action alternatives presented in the SFFS and ASFFS and has identified a preferred alternative that meets the State's regulatory requirements for a CERCLA-quality remedy. Federal acceptance will be evaluated based on any comments received from the EPA or other federal agencies during the formal public comment period.

6.10 COMPARATIVE ANALYSIS OF ALTERNATIVES

The chart on the next page presents a comparative analysis of the six remedial alternatives. Alternatives A1, A2, B1, and B2 rank similarly in their overall performance against the CERCLA criteria. Alternatives B4 and C2 have lower overall rankings.

SUMMARY COMPARISON OF REMEDIAL ACTION ALTERNATIVES

		EVALUATION CRITERIA								
		Threshold		Balancing					Modifying	
		Protectiveness	Compliance with ARARs	Long-Term Effectiveness	Short-Term Effectiveness	Reduction of Toxicity, Mobility, or Volume	Implementability	Cost (millions)	Regulatory Acceptance	Community Acceptance
A1	Groundwater Dewatering and Active Chemical Treatment	●	●	◕	●	◒	◕	$7.2	●	●
A2	Groundwater Dewatering and Active Biological Treatment	●	●	◕	●	◕	◒	$6.0	◕	◕
B1	Hydraulic Control, Sewer Repair, Active Chemical Treatment	●	●	◕	●	◔	●	$5.3	◕	◕
B2	Hydraulic Control, Sewer Repair, Active Biological Treatment	●	●	◕	●	◒	◕	$5.2	◒	◒
B4	Hydraulic Control, Sewer Repair, Semi-Passive Biological Treatment	●	●	◕	◕	◔	◕	$4.9 - 6.9	◒	◒
C2	In-Situ Electron Donor Injection, Sewer Repair, Hydraulic Control	●	●	◒	◒	◔	◕	$4.6	◒	◒

LEGEND

- ● Meets or exceeds criteria
- ◕ Meets criteria, with few stipulations
- ◒ Meets criteria, with some stipulations
- ◔ May not attain criteria
- ○ Does not attain criteria

7 THE DEQ'S PREFERRED ALTERNATIVE

The DEQ's preferred alternative for the Blackwell GRU is presented in this document to solicit public comment. The final remedial program will be documented in the Record of Decision (ROD).

Based on consideration of all of the evaluation criteria, the DEQ's preferred remedial action alternative is Groundwater Dewatering and Ex-Situ Active Treatment (Alternatives A1 or A2). Although Alternatives B1 and B2 would also meet the goals of remediation at lower overall cost than Alternatives A1 and A2, groundwater dewatering is considered to be a more reliable method of reducing inflows of metals-bearing groundwater to the City's POTW. Furthermore, Alternatives A1 and A2 will treat a larger quantity of metals-bearing groundwater than Alternatives B1 and B2 because dewatering of the vulnerable sewer lines requires a higher groundwater extraction rate than does hydraulic control. It should be recognized, however, that the degree of aquifer dewatering that can be achieved may be governed by the possible need to control excessive drying and subsequent deformation in the overlying clay strata. If such deformation occurs, it could lead to some infrastructure and foundation movement and/or damage. This issue will require additional evaluation during the Remedial Design phase of the project. Alternatives B4 and C2 are not recommended due to their lower overall rankings than the other alternatives.

Active biological treatment (Alternative A2) is currently preferred over conventional lime treatment (Alternative A1) due to the lower overall cost of biological treatment, its smaller solid waste stream (some of which can be recycled economically for recovery of zinc metal), and its potential to achieve a higher degree of cadmium and zinc removal than conventional lime treatment. Because additional treatability testing and design studies are required to confirm the effectiveness and implementability of biological treatment in Blackwell, the final selection of the treatment process will be determined during the Remedial Design phase of the project.

8 WHAT'S NEXT?

The Revised Proposed Plan is open for formal public comment from June 16, 2003 through at least July 16, 2003. Comments or requests to extend the comment period should be addressed in writing to George Thomas of the DEQ at the address given on Page 1.

A community meeting about this plan will be held as indicated at the beginning of this document. The meeting will be an opportunity for citizens to ask questions about the Revised Proposed Plan and to provide comments in person. After the public comment period closes, the DEQ will respond to written and verbal comments on the Revised Proposed Plan in a document called a responsiveness summary. After considering all public comments, the DEQ will decide on the final remedy for the Groundwater Remediation Unit and will document it in a formal DEQ Record of Decision (ROD), with the responsiveness summary attached. The DEQ ROD will be available for review at:

City Hall
221 West Blackwell Avenue
Blackwell, Oklahoma 74631
(580) 363-7250

Blackwell Public Library
123 West Padon
Blackwell, Oklahoma 74631
(580) 363-1809

Department of Environmental Quality
Superfund Division
707 North Robinson
Oklahoma City, Oklahoma 73102
(405) 702-5100

9 FOR MORE INFORMATION

If you would like to review the reports or any other documents contained in the updated Administrative Record file for the Blackwell Zinc Site, please visit one of the information repositories listed in the previous section. If you have any questions about the DEQ's Revised Proposed Plan, please call:

George Thomas: (405) 702-5126

10 REFERENCES

DEQ. 1998. Proposed Plan for Remedial Action at the Groundwater Remediation Unit, Blackwell Zinc Site, Blackwell, Oklahoma. Prepared by Oklahoma Department of Environmental Quality.

Exponent. 2000a. Supplemental Groundwater, Surface Water, and Sewer Investigation, Groundwater Remediation Unit, Blackwell Zinc Site, Blackwell, Oklahoma. Prepared for Phelps Dodge Corporation, Tempe, Arizona by Exponent, Boulder, Colorado.

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Lawrence, R., and D. Kratochvil. 2003 (in preparation). ARD Treatment for Selective Metal Recovery and Environmental Control Using Biological Reduction Technology—Commercial Case Studies. To be published in Proceedings of the 35th Canadian Mineral Processors Operators Conference, January 21-23, 2003, Ottawa, Canada.

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PTI. 1996. Ecological Assessment Blackwell Zinc Site Ecological Remediation Unit. Prepared for Cyprus Amax Minerals Company by PTI Environmental Services, Bellevue, Washington.

PTI. 1997. City of Blackwell Wastewater Treatment Plant NPDES Permit Revision. Prepared by PTI Environmental Services, Bellevue, Washington.

PTI. 1998. Focused Feasibility Study, Blackwell Zinc Site Groundwater Remediation Unit. Prepared for Cyprus Amax Minerals Company by PTI Environmental Services, Boulder, Colorado.

U.S. Environmental Protection Agency (EPA). 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA. Interim Final. U.S. Environmental Protection Agency. EPA/540/G89/004.

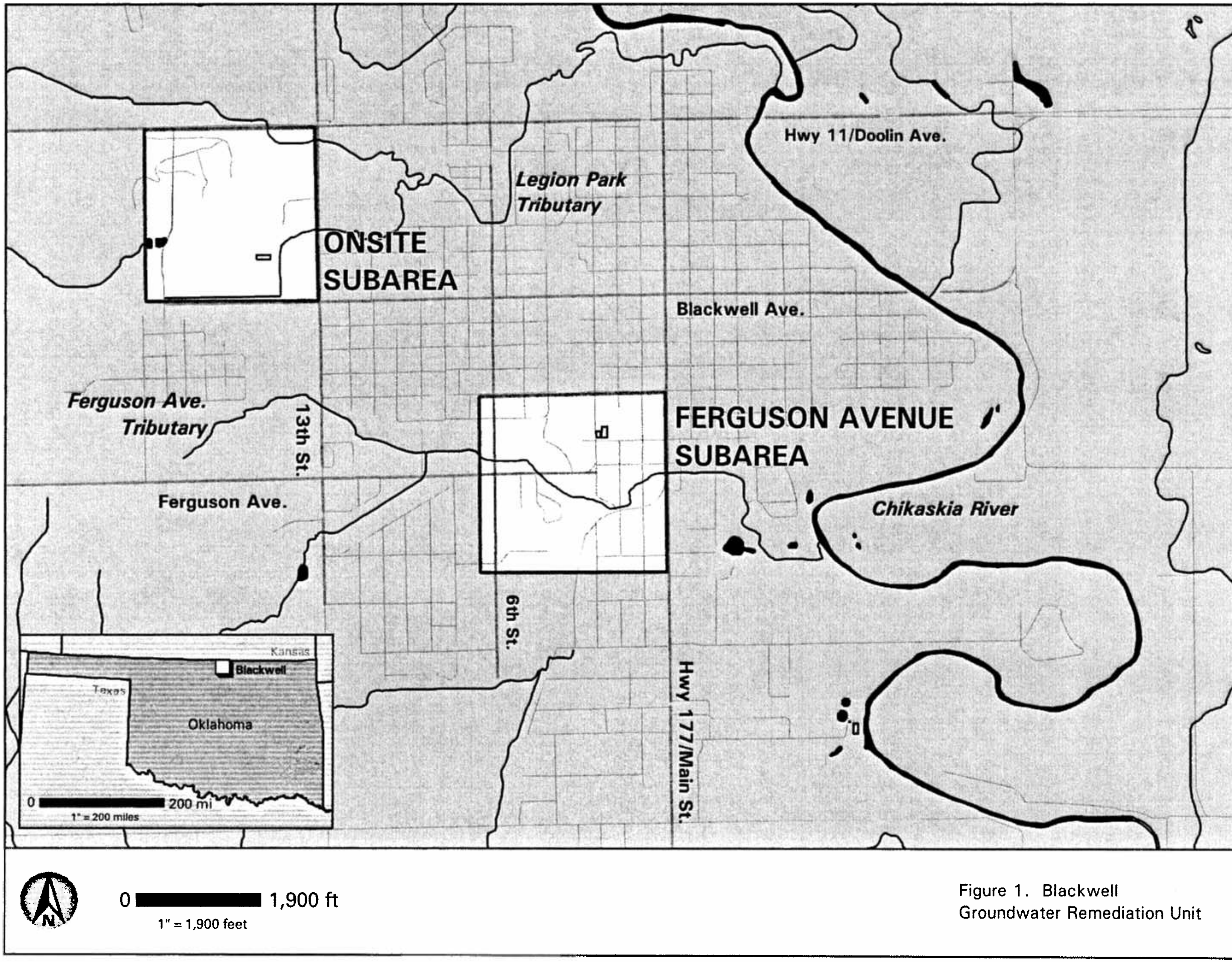

Figure 1. Blackwell Groundwater Remediation Unit

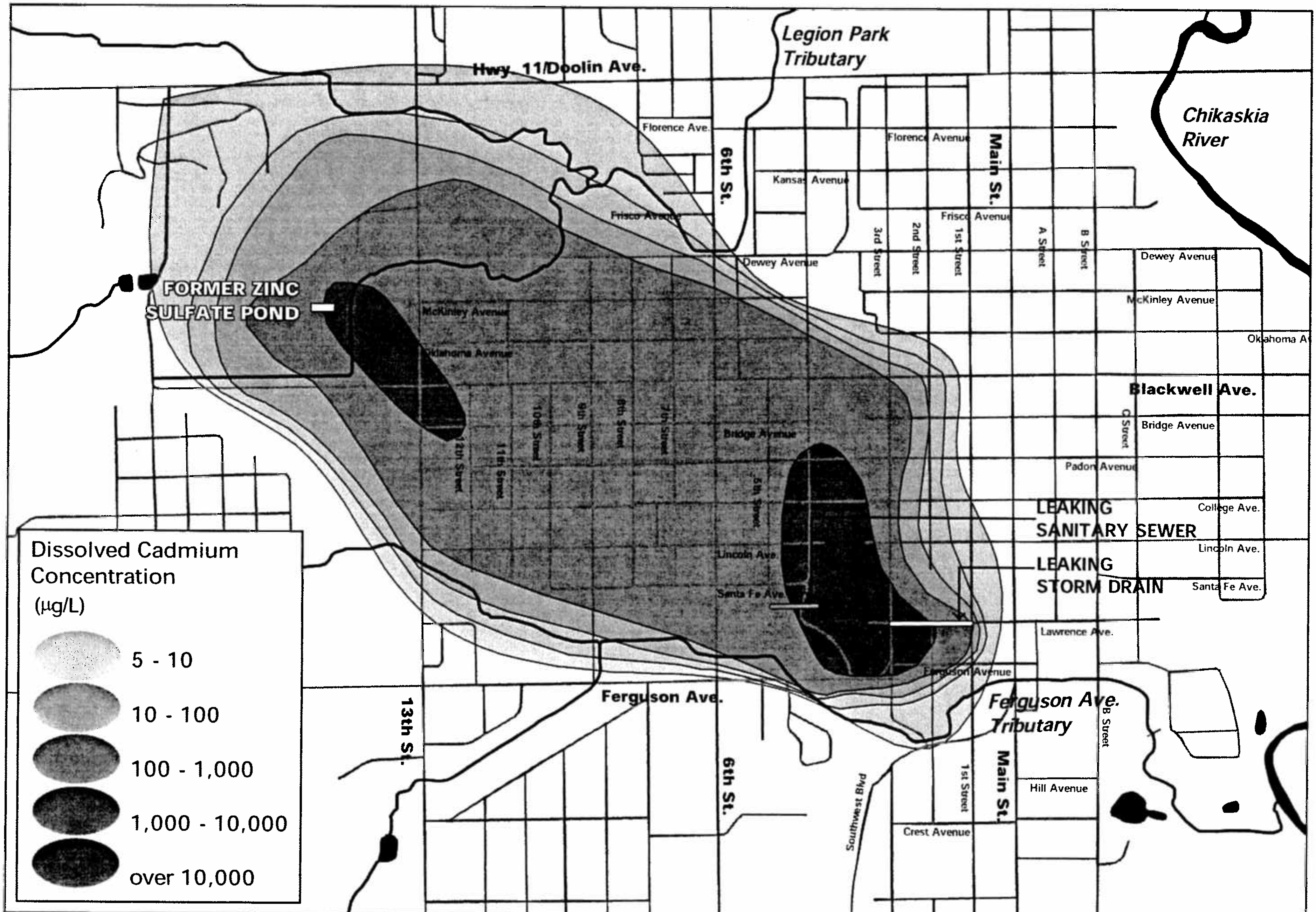

Figure 2. Approximate Extent of Dissolved Cadmium in the Blackwell Groundwater Remediation Unit

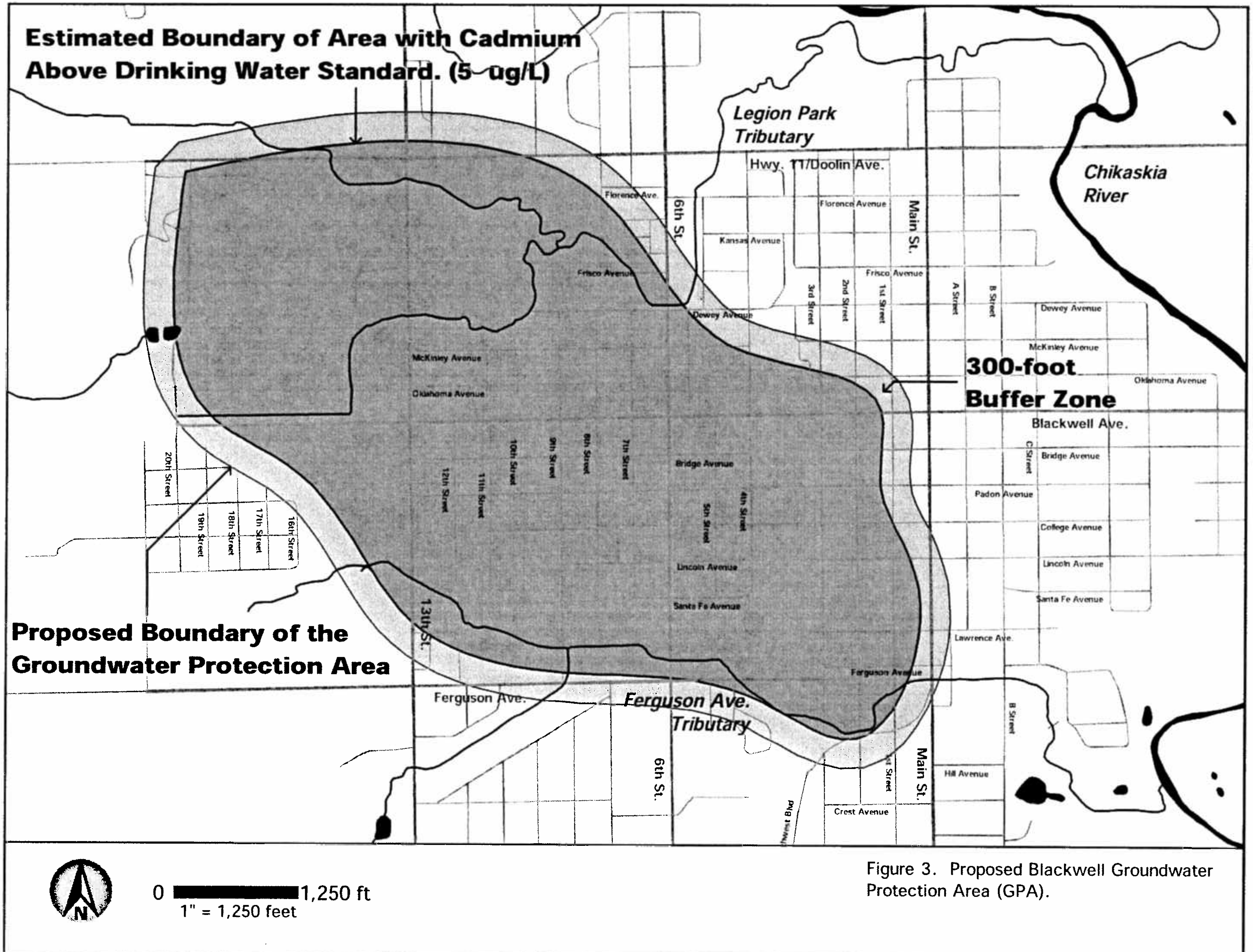

Figure 3. Proposed Blackwell Groundwater Protection Area (GPA).

Applicable or Relevant and Appropriate Requirements for the Blackwell GRU

Requirement	Application	Citation	Description	Category	Comments
FEDERAL					
Federal Ambient Water Quality Criteria	Waters of the United States	EPA Quality Criteria for Water, as amended	The criteria objectives are to restore and maintain the chemical, physical, and biological integrity of the nation's waters.	To Be Considered	Water quality criteria are non-enforceable guidance developed under the Clean Water Act and are used by states to establish water quality standards.
Federal Dredge and Fill Requirements	Dredging, filling, or related activities in "waters of the United States"	40 CFR Part 230; 33 CFR Part 330	Establishes permitting requirements and standards for dredge and fill and hazardous waste cleanup activities in streams.	Applicable	To the extent remediation activities constitute dredging and filling in waters of the United States, including streams, tributaries, and wetlands, 404 permits will be required from the Army Corps of Engineers.
Federal Wetlands Protection Requirements	Wetlands as defined under the 1987 U.S. Army Corps of Engineers Wetlands Manual	Executive Order 11990; Section 404 of the Clean Water Act	Federal wetlands policy requires that actions minimize the destruction, loss, or degradation of wetlands.	Applicable	Construction of remediation structures must consider potential impacts on wetlands. Because wetland impacts are unlikely, a permit under Section 404 of the Clean Water Act is unlikely to be required.
Federal Occupational Safety and Health Regulations	Hazardous waste site workers	29 CFR Part 1910	Establishes requirements for training, medical monitoring, and personnel protection.	Applicable	During the remedial action, all activities must conform to OSHA requirements.
Federal Safe Drinking Water Act					
National Primary Drinking Water Standards	Public water systems	40 CFR Part 141	Establishes health-based standards for public water systems (maximum contaminant levels [MCLs]).	Relevant and Appropriate	MCLs are relevant as health-based cleanup standards, even though groundwater in the GRU is not a public drinking water supply.
Maximum Contaminant Level Goals	Public water systems	40 CFR Part 141	Establishes MCL goals based on chemical concentrations that would result in no known or anticipated adverse health effects.	Relevant and Appropriate	MCL goals are non-enforceable health goals, but may be relevant and appropriate.
National Secondary Drinking Water Standards	Public water systems	40 CFR Part 143	Establishes standards for the aesthetic qualities of public water systems (secondary MCLs).	Relevant and Appropriate	Secondary MCLs are not federally enforceable but are intended as guidelines for the states.
Federal Emergency Planning and Community Right-to-Know Regulations	"Extremely hazardous substances," "hazardous chemicals," or "toxic chemicals"	40 CFR Parts 355, 370, 372;	Requires emergency planning and submission of annual reports in the event of certain chemicals being present at, or manufactured, processed, or otherwise used by, a facility.	Applicable	Annual reports will need to be prepared and submitted for hazardous chemicals present at the remediation facility above certain thresholds, or (2) toxic chemicals deemed to be manufactured, processed, or otherwise used above certain thresholds by the remediation facility.

Applicable or Relevant and Appropriate Requirements for the Blackwell GRU

Requirement	Application	Citation	Description	Category	Comments
Federal Hazardous Waste Regulations	Materials that are "generated" after the effective date of the hazardous waste program and that meet the hazardous waste definition	40 CFR Parts 260 through 270	Provides criteria, including the TCLP test, for determining whether waste materials qualify as hazardous waste and sets forth requirements for the generation, transportation, treatment, storage, and disposal of hazardous waste, including the requirement of a permit for hazardous waste treatment, storage or disposal and various restrictions on land disposal.	Applicable	All waste generated in connection with remediation activities must be evaluated for whether it meets hazardous waste criteria. Various exemptions apply to the remedial action alternatives under consideration for the GRU. Nevertheless, state hazardous waste regulations require the preparation of disposal plans if hazardous waste is generated for treatment, storage, recycling, or disposal. Also, potential tax credits for capital investments can be provided if waste materials are reused or recycled, or if volumes are significantly reduced during remediation activities.
Federal Land Disposal Restrictions (LDRs)	Hazardous wastes	40 CFR Part 268	Establishes treatment standards for hazardous wastes that are land disposed.	Relevant and Appropriate	While metal-bearing, extracted groundwater and should not be considered hazardous wastes and therefore should not be subject to LDR requirements, such requirements may nonetheless be relevant and appropriate to alternatives involving land disposal. Further, treatment sludge may qualify as hazardous wastes and, if so, would be subject to LDR requirements.
Fish and Wildlife Conservation Act of 1980	Non-game fish and wildlife	16 USC 2901	The goal of the Act is to conserve and promote the conservation of non-game fish and wildlife and their habitats.	Relevant and Appropriate	Remedial action must be undertaken in a manner consistent with the protection of aquatic and riparian habitat in the Chikaskia River and its tributaries.
National Flood Insurance Reform Act of 1994, Flood Disaster Protection Act of 1973, and National Flood Insurance Act of 1968	Flood insurance	42 USC 4001 et seq.	Requires mandatory flood insurance for certain structures constructed within the 100-year flood plain.	To Be Considered	A remediation structure may be located within the 100-year flood plain, and flood plain resources may be affected by construction.
General Pretreatment Regulations for Existing and New Sources of Pollution	Industrial Discharges to Publicly Owned Treatment Works	40 CFR Part 403	These regulations establish responsibilities of Federal, State, and local government, industry and the public to implement Pretreatment Standards to control pollutants from industrial users which may pass through or interfere with POTW treatment processes or which may contaminate sewage sludge.	To Be Considered	Would only be applicable for remedial action alternatives involving pretreatment of groundwater prior to treatment by a POTW.
National Pollutant Discharge Elimination System Requirements	Point source discharges to "waters of the United States"	40 CFR Part 122	Prohibits discharges to surface waters without a permit and establishes standards for obtaining such permits.	Applicable	To the extent remediation activities entail discharging to the Ferguson Avenue Tributary or the Chikaskia River, NPDES or state equivalent will be required.

Applicable or Relevant and Appropriate Requirements for the Blackwell GRU

Requirement	Application	Citation	Description	Category	Comments
STATE OF OKLAHOMA					
Oklahoma Emergency Planning and Community Right-to-Know Regulations	"Extremely hazardous substances," "hazardous chemicals," or "toxic chemicals"	27 O.S. § 4-1-103, OAC 252:020	Requires emergency planning and submission of annual reports in the event of certain chemicals being present at, or manufactured, processed, or otherwise used by, a facility.	Applicable	Annual reports will need to be prepared and submitted for hazardous chemicals present at the remediation facility above certain thresholds, or (2) toxic chemicals deemed to be manufactured, processed, or otherwise used above certain thresholds by the remediation facility.
Oklahoma Hazardous Waste Regulations	Materials that are "generated" after the effective date of the hazardous waste program and that meet the hazardous waste definition	OAC 252:205-1-1 through 205-21	Provides criteria, including the TCLP test, for determining whether waste materials qualify as hazardous waste and sets forth requirements for the generation, transportation, treatment, storage, and disposal of hazardous waste, including the requirement of a permit for hazardous waste treatment, storage or disposal and various restrictions on land disposal.	Applicable	All waste generated in connection with remediation activities must be evaluated for whether it meets hazardous waste criteria. Various exemptions apply to the remedial action alternatives under consideration for the GRU. Nevertheless, state hazardous waste regulations require the preparation of disposal plans if hazardous waste is generated for treatment, storage, recycling, or disposal. Also, potential tax credits for capital investments can be provided if waste materials are reused or recycled, or if volumes are significantly reduced during remediation activities.
Oklahoma Land Disposal Restrictions (LDRs)	Hazardous wastes	OAC 252:205-3-1	Establishes treatment standards for hazardous wastes that are land disposed.	Relevant and Appropriate	While metal-bearing, extracted groundwater and should not be considered hazardous wastes and therefore should not be subject to LDR requirements, such requirements may nonetheless be relevant and appropriate to alternatives involving land disposal. Further, treatment sludge may qualify as hazardous wastes and, if so, would be subject to LDR requirements.
Oklahoma Air Permitting Program	Air emissions	27A O.S. § 2-5-112 et seq., OAC 252:100-6-47	Establishes permitting requirements for activities that emit pollutants to the air.	Applicable	An air permit may be required for any equipment used or activity taken in connection with a remedial alternative that emits pollutants to the air (e.g., H_2S, use of combustion equipment, etc.).
Oklahoma Air Quality Standards	Ambient Air	OAC 252:100-3-1 through 3-4	Provides primary and secondary air quality and allowable deterioration standards.	Applicable	Remedial actions that result in air emissions (e.g., combustion equipment, etc.) could trigger application of these standards if such emissions were significant.
Oklahoma Brownfields Program	Remediation of a Brownfields site	27 A O.S. § 2-15-101 et seq., OAC 252:220	Provides liability protection for voluntary remediation of a Brownfields site.	To Be Considered	Blackwell Site may be eligible under a grandfather clause provided in this act.

Applicable or Relevant and Appropriate Requirements for the Blackwell GRU

Requirement	Application	Citation	Description	Category	Comments
Oklahoma Flood Plain Management Program	Development on state-owned or operated floodplain	82 O.S. § 1601 et seq., OAC 785:55-1-1 through 5-2	Provides minimum criteria and permitting requirements for construction or other improvements within floodplains.	Relevant and Appropriate	While remediation activities do not appear to be contemplated for state lands within floodplains, such activities may be contemplated for private or municipal lands within floodplains. Therefore, these regulations may be relevant and appropriate.
Oklahoma Groundwater Pollution Control Regulations	Groundwater remediation	OAC 252:610-5-1 through 5-5	Enforces the state water quality standards for groundwater by requiring prior ODEQ approval of all groundwater remediation projects.	Applicable	Any person proposing remediation of groundwater must obtain prior ODEQ approval of a site assessment and remediation plan and a permit for any discharge to waters of the state resulting from such remediation.
Oklahoma Groundwater Use Program	Taking and use of groundwater	82 O.S. § 1020.7, OAC 785:30-1-1 through 13-9	Establishes permitting requirements and standards for taking and using groundwater.	Applicable	Groundwater that is extracted will be subject to a permit from the OWRB. No permit can be issued without the written permission of the surface owner of the land on which the well is to be located.
Oklahoma Pollutant Discharge Elimination System Requirements	Point source and nonpoint source discharges to "waters of the state"	27 O.S. § 2-6-201 et seq., OAC 252:605-1-1 through 7-51	Prohibits discharges to surface water and groundwater without a permit and establishes standards for obtaining such permits.	Applicable	These regulations apply if groundwater is removed, treated, and discharged to the Ferguson Avenue Tributary, Chikaskia River, or into an aquifer.
Oklahoma Pre-treatment Program	Discharge to POTW	OAC 252:622-1-1 through 33-1	Prohibits the introduction of pollutants into a POTW without a permit or in manner that interferes with or bypasses the POTW, or causes the POTW to fail a toxicity test.	Applicable	The program does not apply to the groundwater currently infiltrating into the City's sewer system, but it does apply to any discharge to the POTW of treated groundwater after extraction.
Oklahoma Public Water Supply Standards	Public water systems	OAC 252:631-1-1 through 3-21	These regulations establish MCL standards for public drinking water systems.	Relevant and Appropriate	While neither groundwater nor surface water is a public drinking water supply, the MCLs are relevant and appropriate health-based cleanup standards.
Oklahoma Solid Waste Management Regulations	Solid waste disposal	O.S. § 2-10 et seq., OAC 252:520-1 through 25-4	Establishes guidelines, including permitting requirements, applicable to any person who generates, collects, transports, or disposes of solid waste.	Applicable	Treatment plant sludge that is not hazardous will be subject to generation, accumulation, and disposal requirements.
Oklahoma Stream Appropriation Program	Appropriation of "stream water"	OAC 785:20-1-1 through 11-8	Establishes procedures and requirements for appropriating "stream waters," including water in ponds, lakes, and reservoirs as well as "wastewater or effluent released into a definite stream".	Not applicable	Not an ARAR because it is unlikely that remedial activities consisting of groundwater withdrawals that affect water accumulations in the Ferguson Avenue Tributary pools would be considered an appropriation of stream water.
Oklahoma Underground Injection Control (UIC) Requirements	Underground injection well	27 O.S. § 2-6-701, OAC 252:652-1-1 through 5-2	Establishes permit requirements for underground injection of fluids, including waste materials.	Applicable	UIC requirements may apply if treated groundwater is re-injected into aquifer, potentially affecting drinking water sources.

Applicable or Relevant and Appropriate Requirements for the Blackwell GRU

Requirement	Application	Citation	Description	Category	Comments
Oklahoma Water Quality Standards	Waters of the State	OAC 785:45-1-1 through 7-3 and 785:46-1-1 through 15-10	Establishes criteria for waters of the state, classifies waters according to their beneficial use, and provides standards and policies to maintain the quality of the state's waters	Applicable	Both surface water and groundwater are included under this regulation.
Oklahoma Well Drilling and Pump Installation Licensing Requirements	Well drilling and pump installation	OAC 785:35-1-1 through 11-3	Establishes minimum requirements for construction of wells, installing pumps, and plugging and capping wells	Applicable	These requirements will apply to any remedial activity entailing the construction of a groundwater well.
MUNICIPAL					
City of Blackwell Floodplain Ordinance	Development within the City of Blackwell	Ordinances 2458 (April, 1987) and 2683 (May, 1997)	Requires permit for construction activities within designated floodplain	Applicable	Remedial activities may require construction or disturbance of private or municipal lands within designated floodplains within the City of Blackwell.
Municipal Building Code	Construction activities	City of Blackwell Building Code Ordinance 2623 (March, 1994)	Requires a building permit for any construction activity	Applicable	These standards apply to all remedial action alternatives considered for the GRU (except the No Action alternative).
Municipal Sewer Use Ordinance	Discharges to the municipal sewer	City of Blackwell Sewer Use Ordinance 2623 (March 1994) 2632 (May 1994) 2661 (October 1995) 2709 (December 2000)	Establishes criteria for discharges to the municipal sewer system by users	Applicable	These standards apply to any discharge of treated groundwater to the municipal sewer system. The standards for cadmium are 50 µg/L monthly average and 1,000 µg/L daily maximum. The standard for zinc is 5,000 µg/L monthly average.
Municipal Zoning Code	Land uses	City of Blackwell Zoning Code Ordinance 2182 (June 1978)	Prohibits certain land uses or activities within certain areas without a special use permit	Applicable	These standards may restrict the location of the treatment system to certain areas within the City (e.g., industrial zone, not in floodplains, etc.).

Note:
- ARAR – applicable or relevant and appropriate requirements
- ODEQ – Oklahoma Department of Environmental Quality
- OSHA – Occupational Safety and Health Administration
- GRU – Groundwater Remediation Unit
- MCL – maximum contaminant level
- TCLP – toxicity characteristic leaching procedure