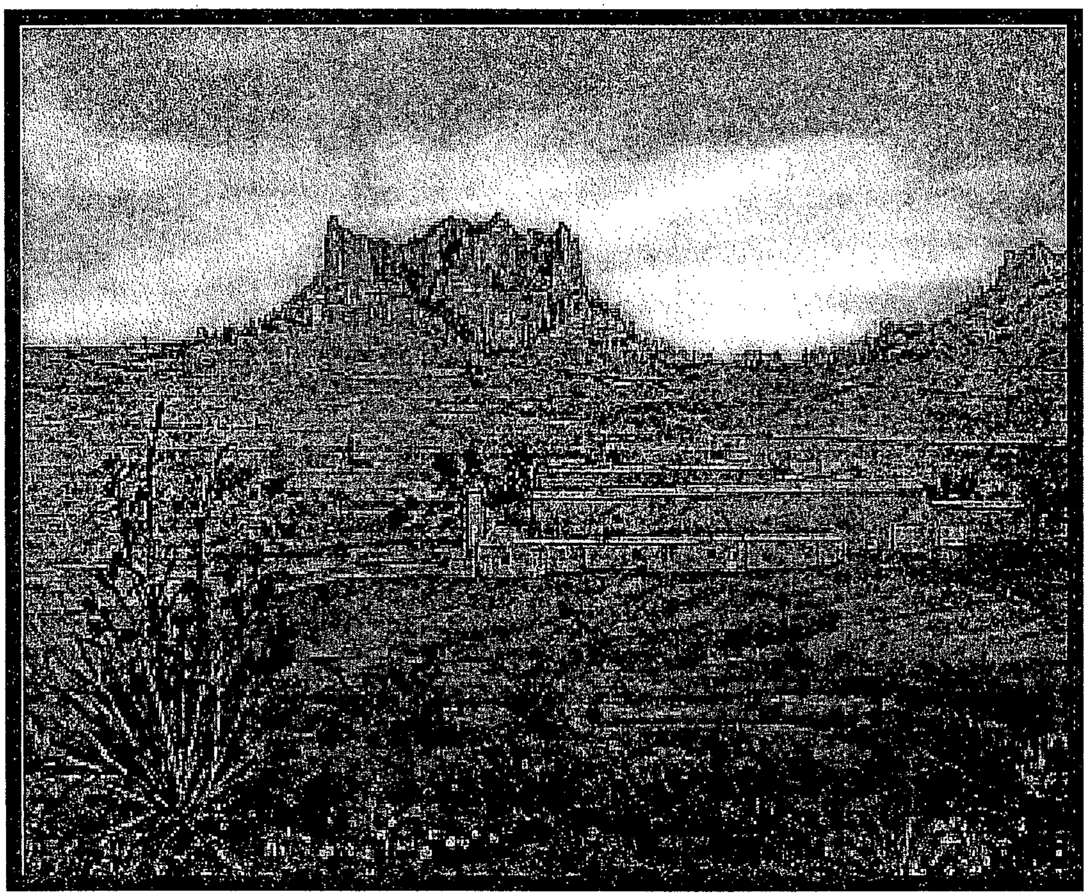
Application for Amendment of USNRC Source Materials License SUA-1534 Three Crow Expansion Area Crawford, Nebraska

Technical Report Volume I



Prepared by
Crow Butte Resources, Inc.
86 Crow Butte Road
Crawford, Nebraska 69339

August 2010

CROW BUTTE RESOURCES, INC.

Nuclear Regulatory Commission

Technical Report

Volume I

Three Crow Expansion Area

August 2010

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1 PROPOSED ACTIVITIES

1.1 Licensing Action Requested

Crow Butte Resources Inc. (CBR) makes this amendment application to the United States Nuclear Regulatory Commission (NRC) for amendment of Radioactive Source Materials License SUA-1534, which concerns development of additional uranium in-situ leach mining resources located in Dawes County and Sioux County, Nebraska. The area proposed for use as a satellite facility to the main CBR Central Processing Facility (CPF) is referred to as the Three Crow Expansion Area (TCEA). By letter dated Nov. 27, 2007, Crow Butte Resources, Inc. applied for the renewal of Source Materials License No. SUA-1534. This renewal will allow for the continued operation of the current Crow Butte operations. In response to a May 27, 2008 Notice of Opportunity for Hearing, NRC action on the license renewal application is pending. In the meantime, the current license stays in effect.

This amendment application has been prepared using suggested guidelines and standard formats from both state and federal agencies. The application is presented primarily in the NRC format found in NRC Regulatory Guide (Reg. Guide) 3.46, *"Standard Format and Content of License Applications, Including Environmental Reports, For In Situ Uranium Solution Mining"* (June 1982). NRC document NUREG-1569, *Standard Review Plan for In Situ Leach Uranium Extraction License Applications* (June 2003) was used to ensure that all information is provided to allow NRC Staff to complete their review of this amendment application.

1.2 Crow Butte Uranium Project Background

The original development was performed by Wyoming Fuel Corporation, which constructed a Research and Development (R&D) Facility in 1986. The project was subsequently acquired and operated by Ferret Exploration Company of Nebraska until May 1994, when the name was changed to Crow Butte Resources, Inc. This change was only a name change and not an ownership change. CBR is the owner and operator of the Crow Butte Project.

The land (fee and leases) at the CPF is owned by Crow Butte Land Company, which is a Nebraska corporation. All of the officers and directors of Crow Butte Land Company are U.S. Citizens. Crow Butte Land Company is owned by Crow Butte Resources, Inc., which is the licensed operator of the facility. Crow Butte Resources, which does business as Cameco Resources, is also a Nebraska corporation. All of its officers are U.S. citizens, as are two-thirds of its directors. Crow Butte Resources is owned by Cameco US Holdings, Inc., which is a U.S. corporation registered in Nevada. For Cameco US Holdings, three-quarters 0f the officers are U.S. citizens, as are two-thirds of the directors. Cameco US Holdings is held my Cameco Corporation, which is a Canadian corporation that is publicly traded on both the Toronto and New York Stock Exchanges.

The Research and Development Facility was located in N1/2 SE1/4 of Section 19, Township (T) 31 North (N), Range (R) 51 West (W). Operations at this facility were initiated in July 1986, and mining took place in two wellfields (WF-1 and WF-2). Mining in WF-2 was completed in 1987 and restoration of that wellfield has been completed. WF-1 was incorporated into Mine Unit 1 of Commercial Operations.

The current production wellfield is located within the current license area as shown in **Figure 2.1-2**. The main production facility is located in Section 19, T31N, R51W, Dawes County, Nebraska. The original license area is approximately 2,875 acres and the surface area affected over the estimated life of the project is approximately 1,265 acres.

CBR has successfully operated the current production area since commercial operations began in 1991. Production of uranium has been maintained at design quantities throughout that period with no adverse environmental impacts. Groundwater restoration was successfully completed in Mine Unit 1 in 1999. Mine Unit 1 is currently undergoing surface reclamation activities. The operating history and schedules for the current production area are discussed in more detail in Section 1.7.

1.3 Site Location and Description

The location of the original Crow Butte license area is in portions of Sections 11, 12, 13, and 24 of T31N, R52W and Sections 18, 19, 20, 29, and 30 of T31N, R51W, Dawes County, Nebraska. The CPF is situated approximately 4.0 miles southeast of the City of Crawford.

The proposed TCEA is located in Sections, 28, 29, 30, and 33 of T31N, R52W, and Section 25 of T31N, R53W. **Figure 1.3-1** shows the general location of the current license area and the proposed TCEA.

All of the mineral resources leased within the TCEA are privately owned. There is no state or federal minerals. **Figure 1.3-2** shows land ownership in the proposed TCEA.

1.4 Ore Body Description

In the current license area, uranium is recovered by in-situ leaching from the Chadron Sandstone at a depth that varies from 400 feet to 900 feet below ground surface (bgs). The overall width of the mineralized area varies from 1000 feet to 5000 feet. The ore body ranges in grade from less than 0.05% to greater than 0.5% U_3O_8, with an average grade estimated at 0.27 percent U_3O_8.

In the TCEA, uranium will also be recovered from the Chadron Sandstone. The depth of the Chadron Sandstone in the TCEA ranges from 580 to 940 feet bgs. The width varies from 2,100 feet to 4,000 feet. The ore body ranges in grade from less than 0.05 percent to 0.5 percent U_3O_8, with an average grade estimated at 0.22 percent U_3O_8. The ore-grade uranium deposits underlying the TCEA are depicted in **Figure 1.4-1**.

1.5 Solution Mining Method and Recovery Process

The in-situ leaching (ISL) process for uranium recovery consists of an oxidation step and a dissolution step. Gaseous oxygen or hydrogen peroxide is used to oxidize the uranium, and bicarbonate is used for dissolution. The uranium-bearing solution that results from the leaching of uranium underground is recovered from the wellfield and the uranium is extracted in the CPF process building. The CPF process uses the following steps:

- Loading of uranium complexes onto ion exchange (IX) resin;
- Reconstitution of the solution by the addition of bicarbonate and oxygen;

- Elution of the uranium complexes from the resin;
- Drying and packaging of the uranium.

1.5.1 Advantages of ISL Uranium Mining

ISL uranium mining is a proven technology that has been successfully demonstrated commercially in Wyoming, Texas, and at the Crow Butte Project in Nebraska. ISL mining of uranium is environmentally superior to conventional open pit and underground uranium mining as evidenced by the following:

- ISL mining results in significantly less surface disturbance since mine pits, waste dumps, haul roads, and tailings ponds are not needed;
- ISL mining requires much less water demand than conventional mining and milling, avoiding the water usage associated with pit dewatering, conventional milling, and tailings transport;
- The lack of heavy equipment, haul roads, waste dumps, etc. result in very little air quality degradation at ISL mines;
- Fewer employees are needed at ISL mines, thereby reducing transportation and socioeconomic concerns;
- Aquifers are not excavated, but remain intact during and after ISL mining;
- Tailings ponds are not used, thereby eliminating a major groundwater pollution concern:
- State of the art lined evaporation ponds may be used to manage liquid waste streams; and
- ISL uranium mining results in leaving the majority of other contaminants (e.g., heavy metals) where they naturally occur instead of moving them to waste dumps and tailings ponds where their presence is of more environmental concern.

1.5.2 Ore Amenability to the ISL Mining Method

Amenability of the uranium deposits in the current Crow Butte license area to ISL mining was demonstrated initially through core studies. Results of the core studies were confirmed in the R&D project at the CPF site using bicarbonate/carbonate leaching solutions with oxygen. Reports concerning the results of the R&D activities, including restoration of affected groundwater, were previously submitted to NRC and the Nebraska Department of Environmental Quality (NDEQ).

The information and experience gained during these pilot programs formed the basis for the commercial uranium ISL mining operations. The current commercial project, including the successful restoration of groundwater in Mine Unit 1, demonstrates that such a program can be implemented at the TCEA with minimal short-term environmental impacts and with no significant risk to the public health or safety. The remainder of this application describes the mining and reclamation plans for the current Crow Butte license area and the TCEA, and the concurrent environmental monitoring programs employed to ensure that any impact to the environment or public is minimal.

1.6 Operating Plans, Design Throughput, and Production

The CPF is licensed for a flow rate of 9,000 gallons per minute, excluding restoration flow, under License No. SUA-1534. Total annual production is limited to 2 million pounds of yellowcake.

Uranium extracted from the Three Crow wellfield will be processed at a satellite facility located within the TCEA. The Three Crow Satellite Facility "satellite facility" will operate at an overall flow rate of 6,000 gallons per minute (gpm), plus an additional 1,500 gpm restoration flow rate. The anticipated bleed rate is assumed to be 0.5 to 1.5 percent of the total mining flow.

The expected annual production rate will be approximately 600,000 pounds U_3O_8. Indicated ore resources as U_3O_8 for the TCEA are 3,750,481 pounds (lbs) with an additional inferred estimate of 1,135,452 lbs. Total reserves are estimated at 4,900.000 lbs. The proposed TCEA encompasses approximately 1,643 acres. The planned mine units and other surface disturbances will impact approximately 671 acres based on the current CBR operating plans and knowledge of available reserves.

The uranium extracted from the TCEA will be loaded onto IX resin at the satellite facility. The IX resin will then be transported by tanker truck to the CPF for elution, drying and packaging. Barren resin will be returned to the satellite facility by tanker truck.

1.7 Proposed Operating Schedules

1.7.1 Current Production Area

Sufficient reserves in the current license area have been estimated to allow mining operations to continue until the end of 2014. Completion of groundwater restoration in the current license area is scheduled for 2023. Projected production and restoration schedules for the CPF are shown in **Figure 1.7-1**. The current status of the 11 mine units are shown in **Table 1.7-1**. In 2008 the total annual production rate for the CPF was 592,541 pounds U_3O_8 and in 2009 it was 751,632 pounds U_3O_8.

Additional mine unit plans are developed approximately one year prior to the planned commencement of new mining operations. For the current production area, planning and construction are underway for Mine Unit 11. The layout of the current and planned mine units in the current license area is shown in **Figure 1.7-2**.

1.7.2 Three Crow Expansion Area Schedule

Assuming favorable regulatory action by the NRC and State of Nebraska regulatory agencies, CBR projects initial construction of the satellite facility and associated assets will begin in 2014. Production is scheduled to begin in late 2014 and last for approximately 7 years. Groundwater restoration activities at TCEA are expected to begin in late 2017 with Mine Unit 1. Groundwater restoration will extend for approximately 6 years with final site decommissioning completed by mid-2025.

Projected production and restoration schedules for the TCEA are shown in **Figure 1.7-3**. The layout of the proposed TCEA and mine units is shown in **Figure 1.7-4**.

1.7.3 North Trend Expansion Area Schedule

On May 30, 2007, Cameco Resources submitted to NRC an application for amendment of Radioactive Source Materials License SUA-1534 for the development of additional in-situ leach mining resources at the North Trend Expansion Area (NTEA). The NTEA is located in Sections 21, 22, 27, 28, 33, and 34 of Township 31 North, Range 51 West, Dawes County, Nebraska. The southernmost boundary of the NTEA is located approximately one-half mile north of the City of Crawford and approximately 1.7 miles northwest of the northern boundary of the current CBR Uranium Project. Similar to the TCEA, uranium extracted from the NTEA will be loaded onto IX resin, which will be transported by tanker truck to the CPF for elution, drying and packaging.

1.8 Waste Management and Disposal

1.8.1 Liquid Waste

There are currently three wastewater disposal options for the proposed satellite facility: evaporation in solar evaporation ponds, deep well injection, and land application. The specific method utilized depends upon the volume and characteristics of the waste stream.

The operation of the CPF results in three sources of water that are collected on the site. They include the following:

- **Water generated during well development** - This water is recovered groundwater that has not been exposed to any mining process or chemicals. The water is discharged directly to one of the solar evaporation ponds and silt, fines and other natural suspended matter collected during well development is settled out. Alternatively, this water may be land applied, used in processing, or disposed of in a deep disposal well following treatment.
- **Liquid process waste** - The operation of the CPF in two primary sources of liquid waste, an eluent bleed and a production bleed. This water is also routed to the evaporation ponds or injected into the deep disposal well.
- **Aquifer restoration** - Following mining operations, restoration of the affected aquifer commences which results in the production of wastewater. The restoration waste is primarily brine from the reverse osmosis unit, which is sent to the waste disposal system. The permeate is either reinjected into the wellfield or sent to the waste disposal system.

Operation of the satellite facility will result in the following liquid waste streams:

- **Water generated during well development** - This water is recovered groundwater and is similar to well development water currently produced at the CPF. This water may be disposed of in the evaporation ponds or used in processing or disposed of in a deep disposal well following treatment.
- **Liquid process waste** - The operation of the satellite facility results in one primary source of liquid waste, a production bleed. This bleed will be routed to either the deep disposal well or evaporation ponds.

- **Aquifer restoration** - Following mining operations, restoration of the affected aquifer commences, which results in the production of wastewater similar to that produced during current restoration activities at the CPF.

Domestic sewage will be disposed of in an on-site wastewater treatment (i.e., septic) system permitted by the NDEQ under the Class V Underground Injection Control (UIC) Regulations.

Sources and methods of handling liquid wastes are discussed in more detail in Section 4.

1.8.2 Solid Waste

Solid wastes generated consist of spent resin, resin fines, filters, miscellaneous pipe and fittings, and domestic trash. These wastes are classified as contaminated or non-contaminated waste according to radiological survey results. Contaminated byproduct waste that cannot be decontaminated is packaged and stored until it can be shipped to a licensed waste disposal site or licensed mill tailings facility. Non-contaminated solid waste is collected on the site on a regular basis and disposed of in a sanitary landfill permitted by the NDEQ.

1.8.3 Contaminated Equipment

Materials and equipment that become contaminated as a result of normal operations are decontaminated if possible and disposed of by conventional methods. Equipment and materials that cannot be decontaminated are treated in the same manner as other contaminated solid waste.

1.9 Groundwater Restoration

Restoration activities will be carried out at the TCEA concurrent with mining activities. The restoration process will be similar to that used to restore wellfields at the current Crow Butte license area, and consist of four basic activities:

- **Groundwater transfer**- groundwater is transferred between the mining unit commencing restoration and a mine unit commencing production or another water source.
- **Groundwater sweep**- water is pumped from the wellfield, which results in an influx of baseline quality water from the wellfield perimeter.
- **Groundwater treatment**- water from injection wells is pumped to the restoration plant where IX, reverse osmosis, filtration or other treatment methods take place.
- **Wellfield recirculation** - water is recirculated by pumping from the production wells and reinjecting the recovered solution. This will act to homogenize the quality of the aquifer.

Following these restoration phases, a groundwater stabilization monitoring program is initiated. Once the restoration values are reached and maintained, restoration is deemed complete. Results are documented in a Restoration Report and submitted to the NDEQ and the NRC for approval. Groundwater restoration is described in more detail in Section 6.

1.10 Decommissioning and Reclamation

At the completion of mine life and after groundwater restoration has been completed, all injection and recovery wells will be plugged and the site decommissioned. Decommissioning will include satellite facility disassembly and disposal, pond reclamation and land reclamation of all disturbed areas. Applicable NRC Regulatory Guidelines will be followed. Decommissioning and reclamation are discussed in more detail in Section 6.

1.11 Surety Arrangements

Crow Butte Resources maintains a NRC-approved financial surety arrangement consistent with 10 CFR 40, Appendix A, Criterion 9 to cover the estimated costs of reclamation. Crow Butte maintains an Irrevocable Standby Letter of Credit issued by the Royal Bank of Canada in favor of the State of Nebraska in the present amount of $28,902,051. The surety amount is revised annually in accordance with the requirements of SUA-1534. The surety amount will be revised to reflect the estimated costs of reclamation activities for the TCEA as development activities proceed.

Table 1.7-1 Current Production Area Mine Unit Status

Mine Unit	Production Initiated	Current Status
Mine Unit 1	April 1991	Groundwater Restored; Reclamation Underway
Mine Unit 2	March 1992	Groundwater Restoration
Mine Unit 3	January 1993	Groundwater Restoration
Mine Unit 4	March 1994	Groundwater Restoration
Mine Unit 5	January 1996	Groundwater Restoration
Mine Unit 6	March 1998	Production
Mine Unit 7	July 1999	Production
Mine Unit 8	July 2002	Production
Mine Unit 9	October 2003	Production
Mine Unit 10	August 2007	Production
Mine Unit 11	Pending	Production to start mid-2010

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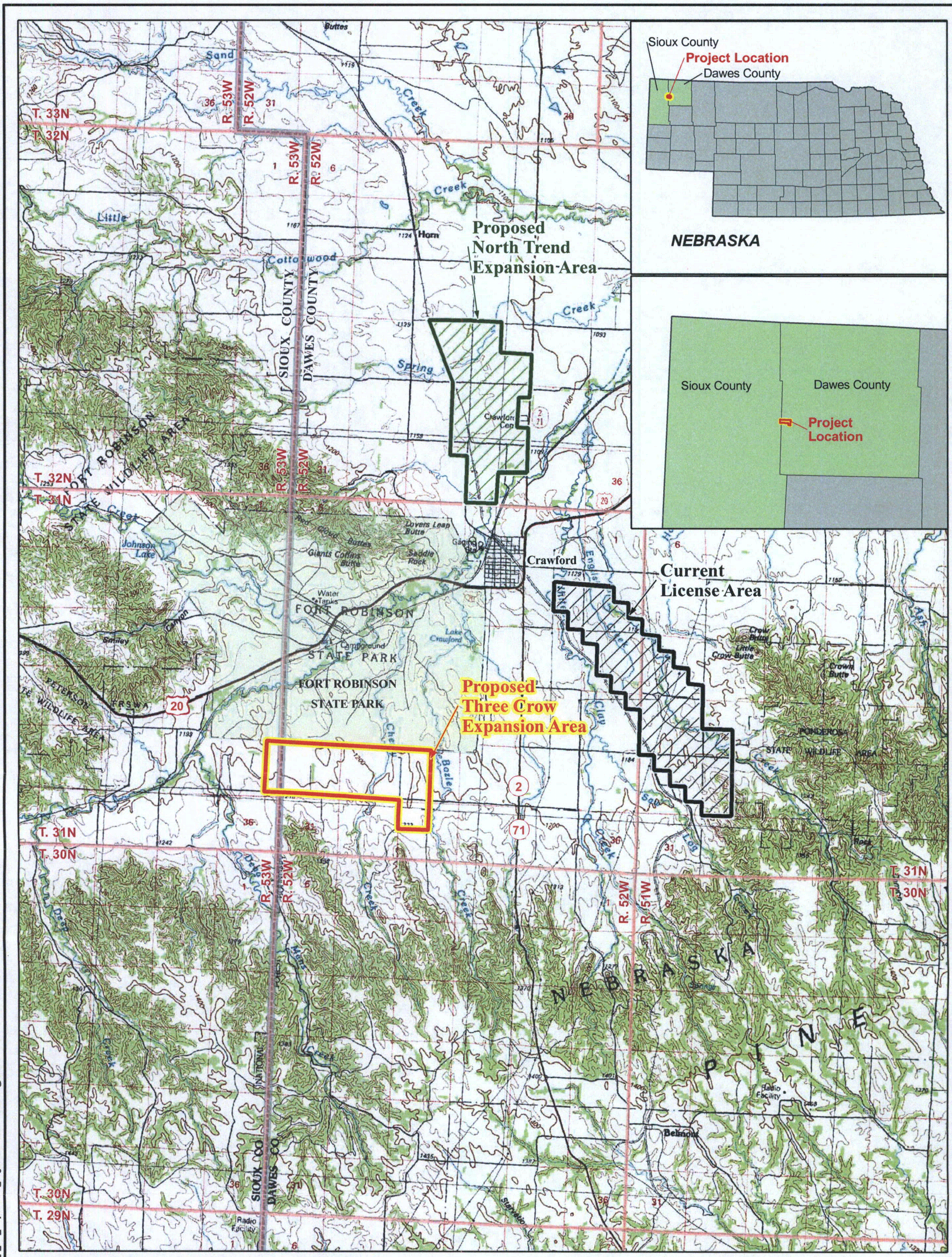

Source: USGS 1:100,000 scale topographic map - Crawford (1984), NE

LEGEND

- Proposed Three Crow Expansion Area
- Proposed North Trend Expansion Area
- Current License Area

N
W — E

0 5,000 10,000
Scale in Feet

CROW BUTTE RESOURCES, INC.

FIGURE 1.3-1
WESTERN NEBRASKA/DAWES COUNTY
PROJECT LOCATION MAP

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: LW

ARCADIS
630 Plaza Drive, Ste. 100
Highlands Ranch, CO 80129
P: 720-344-3500 F: 720-344-3535
www.arcadis-us.com

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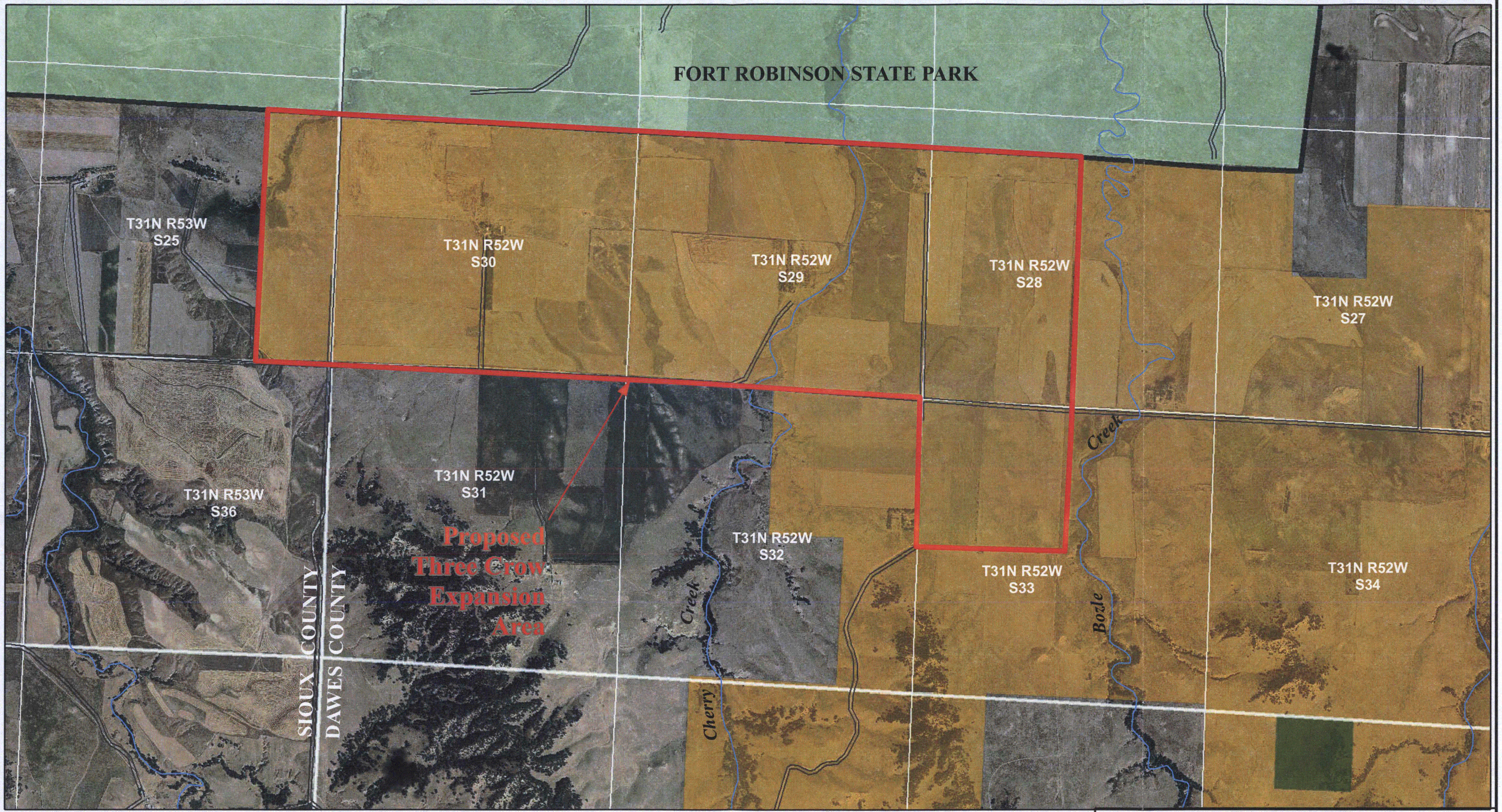

LEGEND

- Drainage
- Road
- Proposed Three Crow Expansion Area
- Private Leased Land
- State of Nebraska Land
- U.S. Forest Service Land

0 500 1,000 1,500
Scale in Feet

N W E

PROJECTION:
NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601
SOURCE:
AERIAL - NAIP 2006, SIOUX COUNTY & DAWES COUNTY, NEBRASKA;
LAND OWNERSHIP: NE-GAP ANALYSIS LAND STEWARDSHIP AND MANAGEMENT, ACOE, 1998

CROW BUTTE RESOURCES, INC.

FIGURE 1.3-2
THREE CROW EXPANSION AREA
PROPERTY LAND OWNERSHIP MAP

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: LW

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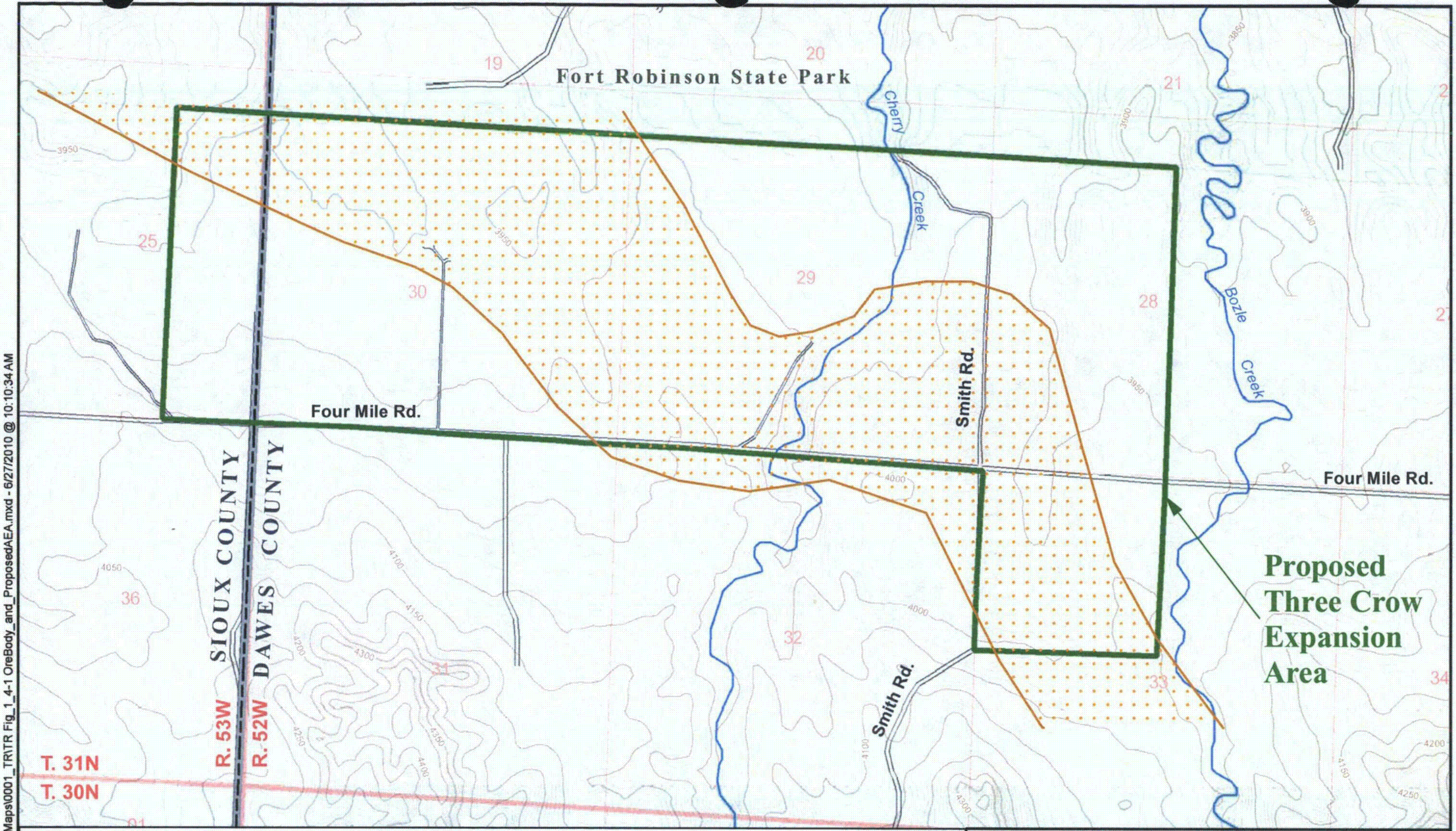

LEGEND

- General Ore Trend
- Proposed Three Crow Expansion Area
- River/Creek
- County Boundary
- Elevation Contour (10-Ft Interval)
- Road

0 1,000 2,000
Scale in Feet

N W E

PROJECTION:
NAD 1927, STATE PLANE
NEBRASKA NORTH FIPS 2601

ALL ELEVATIONS ARE IN FT-AMSL

CROW BUTTE RESOURCES, INC.

FIGURE 1.4-1
THREE CROW EXPANSION AREA ORE BODY

PROJECT: CO001396.00003 MAPPED BY: JC CHECKED BY: MS

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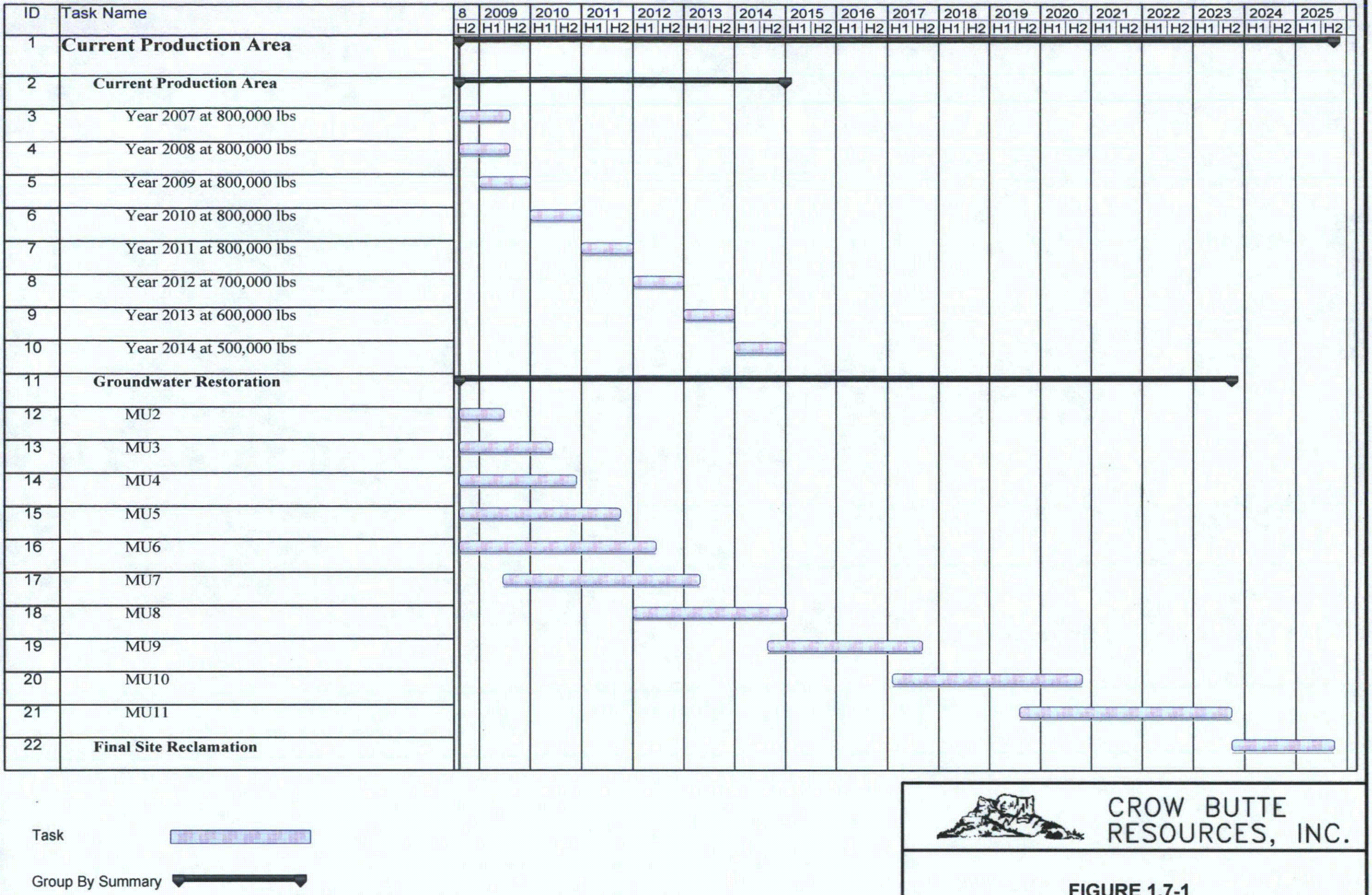

CROW BUTTE RESOURCES, INC.

FIGURE 1.7-1
CURRENT PRODUCTION AREA
MINE UNIT SCHEDULE

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: LW

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K:\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0001_TR\TR Fig_1_7-2 Current Project Layout.mxd - 6/27/2010 @ 10:00:44 AM

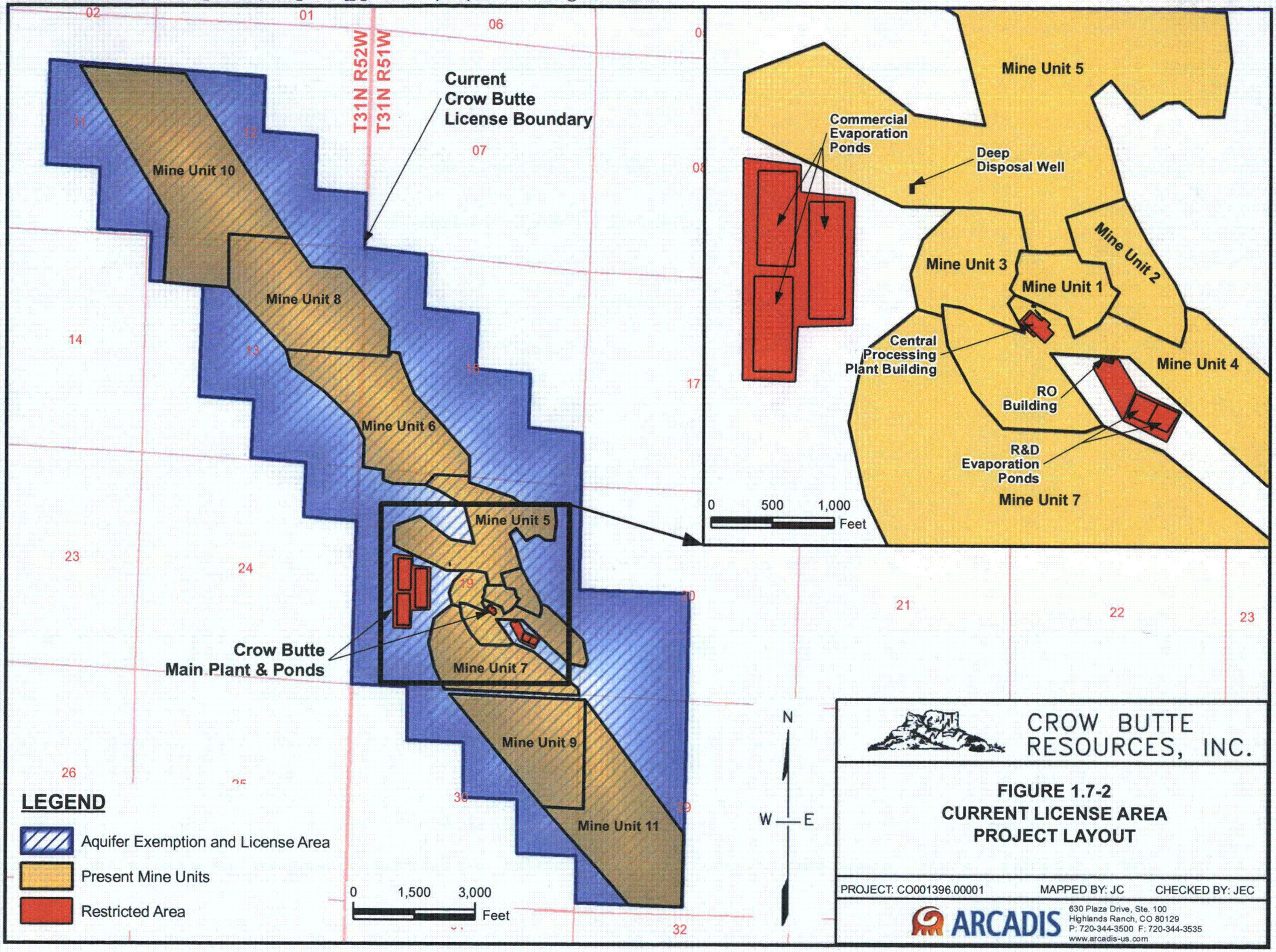

FIGURE 1.7-2
CURRENT LICENSE AREA
PROJECT LAYOUT

THREE CROW MINING AND RESTORATION SCHEDULE

ID	Task Name	Start	Finish	Predecessors
1	**Facility Construction**	Wed 1/1/14	Tue 12/2/14	
2	**Production**	**Tue 12/2/14**	**Wed 6/1/22**	
3	Mine Unit 1	Tue 12/2/14	Wed 11/1/17	1
4	Mine Unit 2	Tue 6/2/15	Fri 6/1/18	1
5	Mine Unit 3	Thu 12/31/15	Mon 12/31/18	1
6	Mine Unit 4	Mon 6/6/16	Thu 6/6/19	1
7	Mine Unit 5	Mon 1/2/17	Fri 1/3/20	1
8	Mine Unit 6	Thu 6/1/17	Wed 1/1/20	1
9	Mine Unit 7	Tue 1/2/18	Fri 1/1/21	1
10	Mine Unit 8	Fri 6/1/18	Tue 6/1/21	1
11	Mine Unit 9	Wed 1/2/19	Wed 6/1/22	1
12	**Groundwater Restoration**	**Thu 11/2/17**	**Tue 10/29/24**	
13	Mine Unit 1	Thu 11/2/17	Wed 2/19/20	3
14	Mine Unit 2	Mon 6/4/18	Fri 9/18/20	4
15	Mine Unit 3	Tue 1/1/19	Mon 4/19/21	5
16	Mine Unit 4	Fri 6/7/19	Thu 9/23/21	6
17	Mine Unit 5	Mon 1/6/20	Fri 4/22/22	7
18	Mine Unit 6	Tue 6/2/20	Thu 9/1/22	8
19	Mine Unit 7	Mon 1/4/21	Wed 4/19/23	9
20	Mine Unit 8	Wed 6/2/21	Fri 9/22/23	10
21	Mine Unit 9	Thu 6/2/22	Tue 10/29/24	11
22	**Site Reclamation**	Fri 5/31/24	Mon 9/8/25	17

Task

Group By Summary

CROW BUTTE RESOURCES, INC.

FIGURE 1.7-3
THREE CROW EXPANSION AREA
MINING AND RESTORATION SCHEDULE

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: JEC

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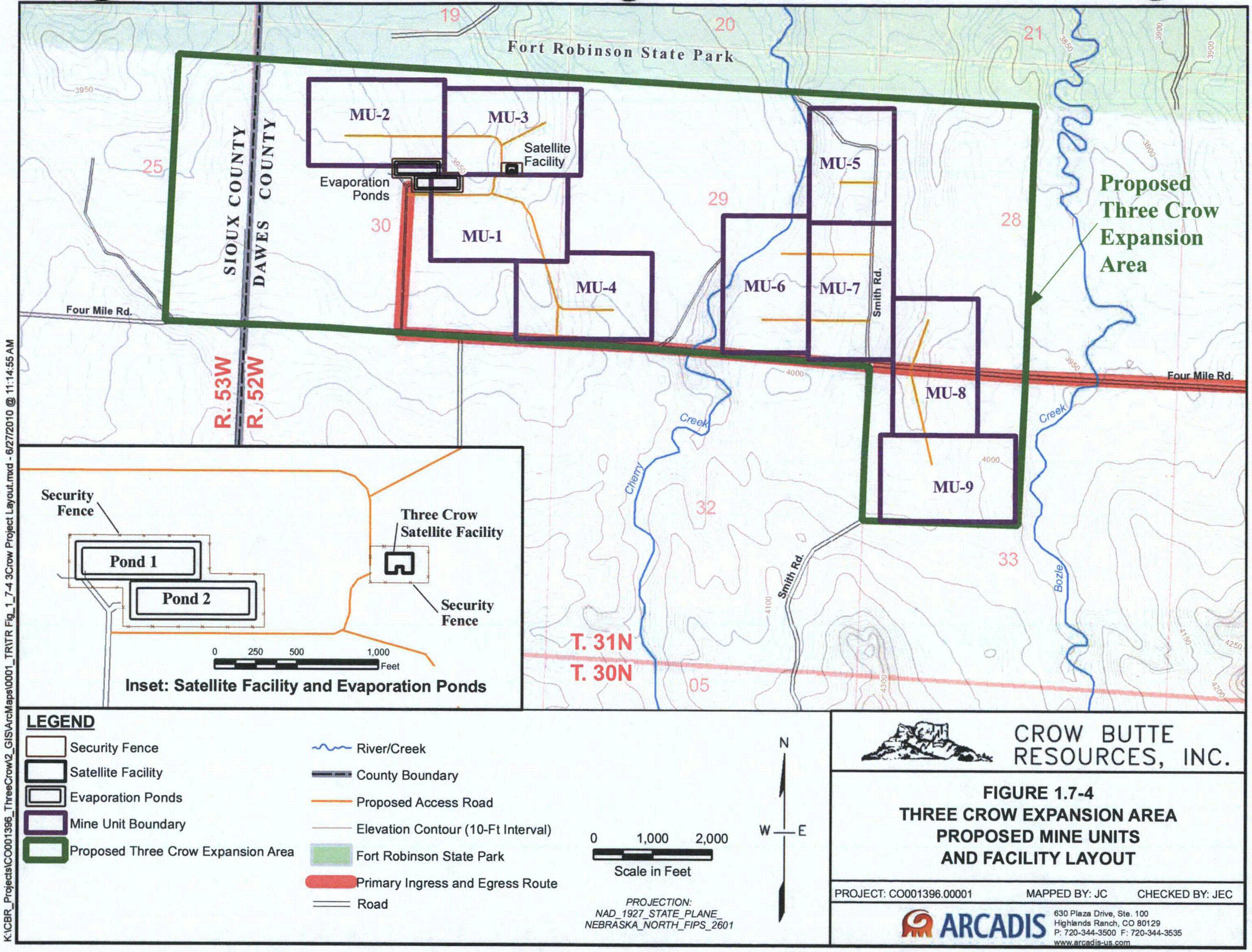


FIGURE 1.7-4
THREE CROW EXPANSION AREA PROPOSED MINE UNITS AND FACILITY LAYOUT

2 SITE CHARACTERISTICS

2.1 Site Location and Layout

The location of the current license area is Sections 11, 12, 13 and 24 of T31N, R52W and Sections 18, 19, 20, 29, and 30 of T31 N, R51W, Dawes County, Nebraska. The proposed TCEA is located in Sections 28, 29, 30, and 33, of T31N, R52W and Section 25 of T31N, R53W.

The maps used in this section and other sections of this amendment application are Vector 7.5 minute quad maps. These are CAD/GIS drawings where each road, stream, and contour line are individual entities. The layers in these maps were derived from the U.S. Census Bureau TIGER/Line data, USGS Digital Line Graph (DLG) Data, USGS Digital Elevation Model (DEM) data, Bureau of Land Management (BLM) Section Line data, National Geodetic Survey (NGS) Benchmark data, and USGS Geographical Names Information System (GNIS) data. This base map was then used for each of the figures prepared for this document with the addition of the pertinent information for that figure.

The longitude and latitude for the site boundary vertices and satellite facility are summarized in **Table 2.1-1**.The datum on topographic maps presented in the application is NAD 1927, and the geographic coordinate reference system (map projection) is:

NAD_1927_StatePlane_Nebraska_North_FIPS_2601 US_Foot.

Figure 2.1-1 shows the general area surrounding the project area, including the proposed TCEA, Area of Review (AOR and Zone of Endangering Influence [ZOEI]).

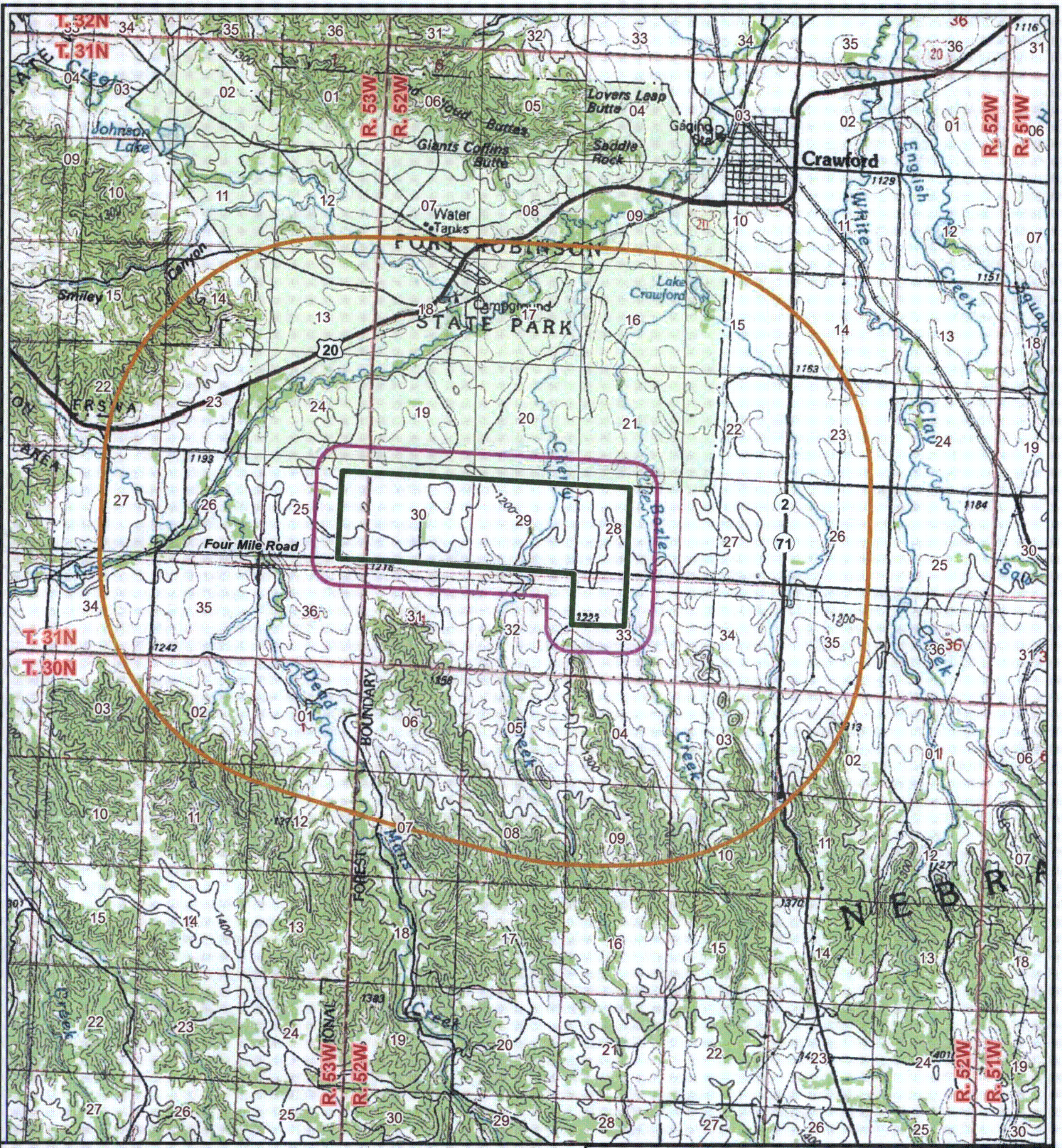
Figure 1.7-2 shows the general project site layout and Restricted Areas for the current license area including the CPF building area, the Reverse Osmosis (RO) facility, the current mine unit boundaries, the deep disposal well, and the R&D and commercial evaporation ponds.

Figure 1.7-4 shows the proposed location of the satellite facility, evaporation ponds, mine units, access roads, fencing, and Restricted Areas within the TCEA. The latitude and longitude for the center of the satellite facility is provided in **Table 2.1-1**.

Figure 1.3-1 shows the project location in relation to the CPF and the proposed NTEA. This figure shows topographical features, drainage and surface water features, nearby population centers and political boundaries as well as principal highways, railroads, transmission lines, and waterways.

Table 2.1-1 Geographic Location of TCEA License Boundary and Satellite Facility

Layer	Geographic Projection: NAD 83 (Degrees)		Geographic Projection: NAD 27 (Degrees)		NAD_1927_StatePlane_Nebraska_North_FIPS_2601 (US_Foot)	
	Latitude	Longitude	Latitude	Longitude	Northing	Easting
License Boundary	42.62554	-103.44117	42.62558	-103.44069	489627	1074216
License Boundary	42.62595	-103.45758	42.62598	-103.45709	489954	1069811
License Boundary	42.62595	-103.45821	42.62598	-103.45773	489961	1069641
License Boundary	42.62599	-103.46268	42.62602	-103.46220	490024	1068440
License Boundary	42.62603	-103.46417	42.62606	-103.46368	490053	1068040
License Boundary	42.62612	-103.47063	42.62615	-103.47014	490158	1066305
License Boundary	42.62622	-103.47514	42.62625	-103.47466	490243	1065091
License Boundary	42.62622	-103.48537	42.62625	-103.48488	490357	1062342
License Boundary	42.63848	-103.48526	42.63852	-103.48478	494822	1062553
License Boundary	42.63841	-103.48039	42.63844	-103.47991	494740	1063861
License Boundary	42.63793	-103.43989	42.63796	-103.43941	494123	1074743
License Boundary	42.63782	-103.43143	42.63785	-103.43095	493992	1077015
License Boundary	42.62480	-103.43134	42.62483	-103.43086	489247	1076849
License Boundary	42.61854	-103.43142	42.61858	-103.43094	486972	1076736
License Boundary	42.61846	-103.44127	42.61849	-103.44079	487048	1074086
License Boundary	42.62151	-103.44127	42.62154	-103.44079	488157	1074130
License Boundary	42.62554	-103.44117	42.62558	-103.44069	489627	1074216
Center of Satellite Facility	**42.63389**	**-103.46448**	**42.63392**	**-103.46400**	**492920**	**1068072**



LEGEND

- Proposed Three Crow Expansion Area
- ZOEI Boundary (1/4-Mile Buffer)
- AOR Boundary (2 1/4-Mile Buffer)

NOTE: Both buffer distances are relative to the boundary of the proposed Three Crow Expansion Area.

N / W — E

0 3,000 6,000

Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601
SOURCES: USGS 100K TOPO, CONTOUR ELEVATIONS IN METER

CROW BUTTE RESOURCES, INC.

FIGURE 2.1-1
THREE CROW EXPANSION AREA
2.25-MILE AREA OF REVIEW

PROJECT: CO001396.00001	MAPPED BY: JC	CHECKED BY: LW

ARCADIS
630 Plaza Drive, Ste. 100
Highlands Ranch, CO 80129
P: 720-344-3500 F: 720-344-3535
www.arcadis-us.com

K:\CBR_Projects\...001396_ThreeCrow\2_GIS\ArcMaps\0001_TRTR Fig_2_1-1 3Crow AOR.mxd - 5/5/2010 @ 3:47:09 PM

2.2 Uses of Adjacent Lands and Waters

This section provides data to evaluate the effects to the physical, ecological, and social characteristics of the proposed uranium mining on the surrounding environs. A discussion of land and water use in the current Crow Butte license area is contained in the permit application submitted for NRC License Number SUA-1534. A discussion of land and water use for the proposed NTEA is presented in a license amendment application submitted to the NRC on May 30, 2007. That application is pending.

This section describes the nature and extent of present and projected land and water use and trends in population or industrial patterns. The information for the CPF was initially developed over a 9-month period in 1982 as part of the Research and Development (R&D) License Application, updated in 1987 for the Commercial License Application, and in 1997 and 2007 during license renewal. The information for the TCEA was developed in 2008 and updated in 2009 and 2010. Preliminary data were obtained from several sources, followed by field studies to to check land uses. Interviews with various state and local officials provided additional information.

NUREG 1569 requires a discussion of land and water use in the proposed TCEA, and within a 2.0-mile (3.3 km) distance from the site boundary. The NDEQ requires an assessment of a 2.25-mile radius (3.62 km) of the proposed project site boundary (Area of Review [AOR]) for the Class III UIC application. Therefore, the NRCs 2.0-mile radius has been extended to 2.25-miles for consistency with differing agency requirements. Land use within the TCEA and the 2.25-mile AOR is illustrated on **Figure 2.2-1**. Population, land use, and water use data were updated from previous Crow Butte License Applications through additional data collection and review, personal communications, and site reconnaissance. Population distribution characteristics were updated in 2004 and 2009 using current U.S. Census data and other applicable sources (U.S. Census 2010).

In general, little change has been noted in area land use in recent decades, reflecting the stagnant nature of economic activity in the area and slight decline in the populations of the City of Crawford and Dawes County.

2.2.1 General Setting

The TCEA is located in western Dawes and eastern Sioux Counties, Nebraska, just north of the Pine Ridge Area. The center of the TCEA is located approximately 4.0 miles southwest of the City of Crawford (**Figure 2.2-1**). The main access route to the TCEA is via State Highway 2/71 south from the City of Crawford, then west along Four Mile Road. U.S. Highway 20 provides access to the City of Crawford from points east and west. The current Crow Butte License Area is 4.0 miles east of the TCEA.

2.2.2 Land Use

Land use of the TCEA and surrounding AOR is dominated by agricultural uses (**Figure 2.2-1 and Figure 2.8-1**). **Table 2.2-1** describes major land use types, including those depicted on **Figure 2.2-1**. Land use acreages for the AOR (**Table 2.2-2**) and TCEA (**Table 2.2-3**) are presented in

Figure 2.2-1 in 22 1/2° sectors centered on each of 16 compass points radiating out from the proposed satellite facility. Major land uses within the TCEA and AOR are further discussed below.

Livestock grazing on rangeland comprises the greatest portion of land use within the 2.25-mile AOR (42.5 percent). Recreational lands of Fort Robinson State Park (26.9 percent), cropland (18.4 percent), and forest land (11.7 percent) are the other significant land uses. Scattered rural residences are mostly associated with agricultural operations.

Recreational lands are the secondary land uses for the 2.25-mile AOR. Fort Robinson State Park, the largest state park in Nebraska, is located along the northern boundary of the TCEA and is partially located within the 2.25-mile AOR (**Figure 2.2-1**). The park is west of the City of Crawford, and includes portions of the Red Cloud Agency Historical Site and the White River Trail.

Residential and commercial land uses in Dawes County are concentrated within the city limits of Crawford and Chadron. Industrial land uses within the city limits of Crawford are generally associated with railroad facilities.

Within the TCEA, crop production is the dominant land use (57.6 percent), primarily for the cultivation and production of wheat. Livestock production is the secondary land use of the TCEA (35.2 percent).

Figure 2.8-1 and **Table 2.2-3** indicate that additional minor land uses occur within the TCEA. Areas of rangeland that have been variously degraded by agricultural, commercial, or industrial uses are present throughout Nebraska. Within the TCEA, these areas (Rangeland Rehabilitation) are currently being rehabilitated for more sustainable use as cropland or rangeland. Likewise, the presence of structural modifications to the landscape in the form of houses, barn, and other outbuilding is indicated by the Structural Biotope land use. Because these modifications are scattered and do not alter the overall land use of their surroundings, they are not considered to be major land uses such as those presented in **Table 2.2-1**, **Table 2.2-2, Figure 2.2-1** and **Figure 2.8-1**. Minor amounts of forested land are also present in the TCEA.

2.2.2.1 Agriculture

Several of the soil types found in the vicinity of the TCEA are classified as prime farmland. However, in Dawes County, soils are classified by the U.S. Natural Resource Conservation Service (NRCS) as prime farmland only if irrigated. According to 2009 Census of Agriculture for Nebraska (NASS 2009a), nearly 9 percent of Dawes County agricultural land is irrigated, and about 16 percent of harvested cropland acreage is irrigated (NASS 2009a). The remainder of the irrigated land is used for pasture, habitat, or rangeland (NASS 2009b).

Table 2.2-4 through **Table 2.2-6** show agricultural productivity within Dawes County and the TCEA. Wheat and hay are the major crops grown on croplands within the area. Most of these crops are used for livestock feed while the remaining crops are commercially sold. In 2007, total wheat production in Dawes County was 1,163,400 bushels, a decrease of 12 percent from 2006 production (NASS 2009c). Sorghum for grain, sunflowers, and sugar beets were produced in Dawes County prior to 2002, but were no longer produced in 2008. Native grasslands are often used for grazing or for cut hay.

In 2007, an average of 54,000 head of livestock was reported in Dawes County (NASS 2009b). The livestock inventory for Dawes County indicates that cattle account for more than 90 percent of all livestock. According to a report prepared for the Economic Development Department of the Nebraska Public Power Corporation (NPPC 2005), the market value of livestock products accounted for 85.7 percent of the total market value of all agricultural products sold in 2002. Livestock values remained consistent between the years 1990 and 2002, the most recent year for which livestock values are available. In 2002, cash receipts for livestock and products totaled $34.0 million in Dawes County (NASS 2009b). Livestock and livestock products had a value of $28.61 per acre, indicating that livestock production on rangeland within the AOR has a potential value of approximately $290,000.

2.2.2.2 Recreational

Recreational opportunities provided by federal and state lands in the county have become an increasingly important component of the local economy. There are no developed recreation facilities within the TCEA; however, developed recreation is located within portions of the AOR occupied by Fort Robinson State Park, and includes camping and hiking facilities along the White River. Other Park facilities include lodging, showers, electrical hookups, pit toilets, ski and snowmobile trails, a rodeo arena, and a museum. Additional recreational activities available within the Park include hunting, fishing, hiking, swimming, and horseback riding. The Park also contains commercial establishments that provide activities such as historic interpretation, museums, and an activity center.

No other recreation areas or facilities are located within the TCEA and the surrounding AOR. Nearby recreational facilities in Dawes County include the Ponderosa State Wildlife Management Area (SWMA), Chadron State Park, Soldier Creek Wilderness Area, the Red Cloud Picnic Area and several trails in the Nebraska National Forest (DeLorme Maps 2005). Approximate distances from the proposed satellite facility to local and regional recreational facilities are presented in **Table 2.2-7**.

2.2.2.3 Residential

In 2008, there were a total of 533 houses in the City of Crawford, with 468 occupied (345 owner occupied and 123 renter occupied) (City-Data 2010a). The housing density was 467 houses/condos per square mile. The last US census was in 2000, with Crawford reported to contain 537 housing units, of which 473 were occupied (US Census 2010).

Based on site reconnaissances in October 2008 and February 2010 and a Nebraska Department of Natural Resources aerial photo of the area, there is one occupied housing unit in the TCEA. This residence is located in NW1/4 SE1/4 Section 29, T31N, R52W, as shown on **Figure 2.2-2**. Three abandoned housing units, with associated outbuildings, were also identified in the TCEA. The AOR contains an additional 37 housing units, of which 23 are occupied. There are a total of 24 occupied housing units within the TCEA and the 2.25-mile AOR.

Table 2.2-8 shows the distance to the nearest residence within the 2.25-mile AOR and to the nearest site boundary from the center of the TCEA for each 22 1/2° sector centered on each compass point. There are two housing units within 1 km (0.62 miles) of the center point of the proposed TCEA. Six dwelling units are within 2 km (1.24 miles).

2.2.2.4 Habitat

Habitat lands are those dedicated wholly or partially to the production, protection, or management of species of fish or wildlife. Significant areas classified as habitat nearest to the TCEA include the Peterson SWMA, located nearly 2.5 miles west of the TCEA boundary; the Fort Robinson SWMA, located four miles north of the TCEA boundary; and the Ponderosa SWMA, which is five miles east of the TCEA boundary and adjacent to the current license area as shown in **Figure 2.2-1** (NGPC 2007). There is no land within the TCEA that is used primarily for wildlife habitat. Wildlife habitat is a secondary use of rangeland, forestland, and recreational land within the TCEA and the 2.25-mile AOR. An evaluation of habitat in the TCEA is included in Section 2.8, with habitat types in the TCEA shown in **Figure 2.8-1**.

2.2.2.5 Industrial and Mining

Other than exploratory mining drilling and oil and gas test holes, there are no industrial or mining activities within the TCEA. Two abandoned gravel pits are located on Fort Robinson State Park within the 2.25-mile AOR that may be mined periodically for local road construction purposes (**Figure 2.2-3**).

Besides Crow Butte Resources, Conoco, Amoco Minerals, Santa Fe Mining, and Union Carbide have also drilled exploratory testing holes for uranium mining in the general area. There are no other industrial facilities within the 2.25-mile review area.

There are no oil and gas test holes located within the TCEA or the 0.25-mile Zone of Endangering Influence (ZOEI), but four abandoned wells are present within the 2.25-mile AOR (**Figure 2.2-3**). Based on review of public records, all the referenced oil and gas test holes have been properly plugged and abandoned in accordance with the Nebraska Oil and Gas Conservation Commission regulations (NOGCC 2009). A discussion of oil and gas test holes pertinent to the TCEA is presented in Section 2.6.1.2.3.

Other than CBR uranium recovery activities, there are no other known planned uranium recovery operations in Nebraska. There are no other nuclear fuel cycle facilities located or proposed within an 80-km (50-mile) radius of the proposed TCEA. Project descriptions and locations of operating and proposed uranium recovery facilities in neighboring Wyoming and South Dakota can be found at the NRC website (NRC 2009). The nearest operating uranium recovery facility to the proposed TCEA is the Smith Ranch-Highland uranium in situ leach facility located near Douglas (Converse County) of western Wyoming (NRC 2009). Other proposed uranium in situ facilities nearest to the TCEA that have filed applications in the region are Powertech Uranium's Dewey-Burdock facility located in Fall River and Custer Counties of South Dakota and Uranium One's Moore Ranch project that will be located in Converse County Wyoming

2.2.2.6 Commercial and Services

There are retail and commercial establishments at Fort Robinson State Park. These establishments include museums, a restaurant, an activity center, room rental, a campground, and other facilities that provide recreation activities to Park visitors. The establishments are clustered within the developed areas of the Park along State Highway 20, approximately 1.4 miles north of the TCEA north boundary. No other commercial establishments are located within the TCEA and the 2.25-mile review area.

2.2.2.7 Transportation and Utilities

Nebraska Highway 2/71 and U.S. Highway 20 converge in the City of Crawford north-northeast of the TCEA. The TCEA is accessed from Highway 2/71 on Four Mile Road. The 2008 average daily traffic counts for a segment of Highway 2/71 near the Four Mile Road intersection was 895 vehicles, including 115 heavy commercial vehicles. Traffic levels on SH-2 increase to 915 vehicles just south of the City of Crawford, and are generally lower to the south of Four Mile Road on Highway 2/71 (NDOR 2009). Private roads connect with Four Mile Road to provide access to residences and agriculture within the TCEA. The junction of the Burlington Northern and D M & E Railroads is located in the City of Crawford. No railways cross the TCEA 2.25-mile AOR.

2.2.2.8 Land Use References

City-Data.com 2010. *Crawford, Nebraska.* [Web Page]. Located at: http://www.city-data.com/city/Crawford-Nebraska.html. Accessed on: February 25, 2010.

DeLorme Maps. 2005. Nebraska Atlas and Gazetteer; Third Edition. Yarmouth, Maine.

National Agricultural Statistics Service (NASS). 2009a Census of Agriculture Volume 1 Chapter 2: Nebraska County Level Data. Issued February, 2009. [Web Page]. Located at: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Nebraska/index.asp. Accessed on: December 21, 2009.

National Agricultural Statistics Service. (NASS). 2009b. Quick Stats Nebraska County Data - Livestock. [Web Page]. Located at: http://www.nass.usda.gov/QuickStats. Accessed on: December 15, 2009.

National Agricultural Statistics Service. (NASS). 2009c. Quick Stats Nebraska County Data-Crops. [Web Page]. Located at: http://www.nass.usda.gov/QuickStats/PullData_US_CNTY.jsp. Accessed on: December 15, 2009.

Nebraska Department of Roads (NDOR). 2009. Annual Average 24-Hour Traffic; Year Ending December 31, 2008. [Web Page]. Located at: http://www.dor.state.ne.us/maps/#traffvol. Accessed on: December 18, 2009.

Nebraska Game and Parks Commission. (NGPC). 2007. Nebraska Game and Parks Interactive Map. [Web Page]. Located at: http://mapserver.ngpc.state.ne.us/website/gpc_land/viewer.htm. Accessed on: January 25, 2007.

Nebraska Oil and Gas Conservation Commission (NOGCC). 2009. [Web Page]. Located at: http://www.nogcc.ne.gov/ (Well data and publications). Accessed on: December 16, 2009.

Nebraska Public Power Corporation. (NPPC). 2005. Economic Importance of and Economic Impacts Associated with Livestock Production in Dawes County. Prepared by Donis N. Petersan, Ph.D., CEcD Economist. Economic Development Department, Nebraska Public

Power District. [Web Page]. Located at: http://sites.nppd.com/library.asp#ag. Accessed on: August 25, 2008.

U.S. Census. 2010. Census 2000 Summary File 1 (SF 1) 100-Percent Data, Detailed Tables. [Web Page]. Located at: http://factfinder.census.gov/servlet/DTGeoSearchByListServlet?ds_name=DEC_2000_SF1_U&_lang=en&_ts=188137217426. Accessed on: February 1, 2010.

U.S. Department of Agriculture. Natural Resources Conservation Service (NRCS). 2007. National Cooperative Soil Survey Web Soil Survey. [Web Page]. Located at: http://websoilsurvey.nrcs.usda.gov/app/. Accessed on: January 25, 2007.

U.S. Nuclear Regulatory Commission (NRC). 2009. Locations of Fuel Cycle Facilities. [Web Page]. Located at: http://www.nrc.gov/info-finder/materials/fuel-cycle. Accessed on: February 25, 2010.

2.2.3 Water Use

2.2.3.1 Dawes County Water Use

Every five years since 1950 the USGS has assessed U.S. water use (USGS 2009) and includes water-use estimates for the State of Nebraska. For Nebraska water-use data, the USGS works in cooperation with the Nebraska Department of Natural Resources (NDNR). The latest study examines usage in 2005. These USGS water use reports are generated every five (5) years, with 2005 being the most recent data compilation. The 2005 USGS report presents water usage in each state by county. The next report will be issued in 2010.

Estimated water use in 2005 for Dawes County, Nebraska is presented in **Table 2.2-9** (USGS 2005). The total 2005 population for Dawes County was 8,636 people, with public supply groundwater and surface water use totaling 2.59 million gpd (Mgal/da). Irrigation utilizing groundwater and surface water accounted for a total of 24.55 Mgal/da to irrigate an estimated 13 thousand acres.

A summary of the number and types of registered non-abandoned water wells located in Dawes County as of February 18, 2010, is presented in **Table 2.2-10.** Note this table refers to registered wells. Under current Nebraska law, water supply wells used solely for domestic purposes and completed prior to September 09, 1993, do not have to be registered (NRS 2008). Therefore, there are a number of domestic/agricultural and agricultural unregistered wells located in Dawes County. CBR identifies such wells through interviews with landowners and local drillers.

There are a total of 5,512 registered water wells in Dawes County used for a variety of purposes, as described in **Table 2.2-10**. According to the NDNR, there are a total of 226 domestic and 224 livestock wells located in Dawes County. There are 37 public water supply wells located in Dawes County (NDNR 2010a). Domestic and livestock water wells make up the majority of the wells identified in the TCEA.

2.2.3.2 City of Crawford Community Water Supply

Public Water Supply Description

The White River and associated tributaries indirectly supply some of the drinking water to the City of Crawford citizens via an infiltration gallery. The City of Crawford municipal water system, which consists of this infiltration gallery (850 gpm), is also supplied by two water supply wells (**Table 2.2-11**) (City of Crawford 2010a; NDHHS 2010). These wells have an average depth of 100 feet. The water system has a pumping capacity of 155 gallons per minute (gpm) and serves approximately 90 percent of the city population of 1,028 (City-Data.com 2010). The overhead storage capacity is 1,750,000 gallons and the raw water storage is 500,000 gallons. The average daily demand is 250,000 gallons, with a historic peak daily demand of 1,000,000 gallons. The system has a maximum capacity of 2,830,000 gpd. The static pressure is 58 pounds per square inch and the residual pressure is 25 pounds per square inch. The city rapid sand filters water treatment plant has a daily capacity of 1,500,000. Additional information regarding the City of Crawford water system is summarized in **Table 2.2-12** (Teahon, L. 2007; Teahon, L. and Grantham, R. 2010).

Based on the Crawford Municipal Water Conservation Plan (Spring 2003), the average per capita water use in 2002 (including residential and business customers; public facilities including parks etc.; and water lost to system leaks) was 323 gpd.

Wellhead Protection Area

The City of Crawford has a designated wellhead protection area and adopted controls pursuant to the Nebraska Wellhead Protection Area Act (Nebraska Revised Statutes § 46-1501 – 46-1509) for the purpose of protecting the public water supply system. The boundaries of the Wellhead Protection Area (WHPA) are described in the City of Crawford Ordinance 575 [May 10, 2005] (City of Crawford 2010b). The area includes 960 acres in Sections 15, 16, 21 and 22 of T31N R52W, Dawes County. The WHPA boundary is shown in **Figure 2.2-4**. There are two public water supply wells located within the designated WHPA (Wells 454 and 455). The minimum allowable horizontal distance in feet separating a city water supply well from potential sources of contamination are listed in **Table 2.2-13.**

As shown in **Figure 2.2-4**, the nearest point of the northern TCEA permit boundary to the nearest boundary of the City of Crawford WHPA is approximately 4,500 linear feet (approximately 0.85 mile). The City's Well W-454 within the WHPA boundary, the closest well to the TCEA permit boundary, is located approximately 9,600 feet (approximately 1.82 miles) from the nearest TCEA permit boundary. Therefore, all proposed assets within the TCEA boundary that could be affected by constraints in **Table 2.2-13** are located at a distance of over 4-times the minimum allowed distances separating the city water supply wells from other water wells, including but not limited to domestic supply wells, irrigation wells, and stock wells. Therefore, operations at the TCEA would not be expected to impact the city WHPA.

2.2.3.3 Three Crow Project Area

The TCEA lies within the watersheds of Bozle Creek, Cherry Creek, and the eastern portion of Dead Man's Creek, which are small southern tributaries to the major regional water course, the White River (**Figure 2.7-2, Figure 2.7-3**). These creeks originate in the Pine Ridge south of the

TCEA. From the headwaters, these creeks drain north over range and agricultural land to the White River. Contributions to flow come from springs in the Arikaree Group, snowmelt, runoff and the shallow Brule sands. The latter may receive inflow from the creek during periods of high flow. Due to the time variable nature of these water sources, discharges at various points along the creeks may experience wide fluctuations on a month to month and yearly basis.

The White River is used to support agricultural production, wildlife habitat, and both warm- and cold-water aquatic life. For the period of record from 1931 to 1991, USGS data (USGS 2004) indicate that the average monthly mean flow ranged from 6.3 to 122 ft^3/sec, with a mean value of 20.4 ft^3/sec. Based on data from the NDNR (NDNR 2010b), for the White River at the City of Crawford, the flow of the White River from 1999 to 2007 ranged from 4.1 to 21.9 ft^3/sec, with an annual mean of 20.2 ft^3/sec. Average flow measurements by the NDEQ for this sampling location from 2003 to 2009 averaged approximately 20.6 ft^3/sec (Lund 2010). Historical extremes related to flow in the White River are discussed in Section 2.7.

The Crawford National Fish Hatchery formerly was located near Crawford City Park, adjacent to the White River.

No surface water impoundments are located within the TCEA. There are four impoundments located within the AOR (**Figure 2.7-3**). The Grabel Ponds (identified as one pond), Cherry Creek Pond and Ice House Pond are located on the Fort Robinson State Park. The Sulzbach Pond is located on private property. These surface ponds are discussed in Section 2.7.1.2.

In general, groundwater supplies in the vicinity of the TCEA are limited due to topography and shallow geology (University of Nebraska-Lincoln 1986). Groundwater quality within the White River drainage generally is poor (Engberg and Spalding 1978). Locally, groundwater is obtained at limited locations from shallow alluvial sediments. The primary groundwater supply is the Brule Formation, typically encountered at depths from approximately 30 to 200 feet, with the exception of locations where the overlying alluvium is not present. In general, the static water level for Brule Formation wells in the TCEA ranges from 30 to 80 feet below ground surface (bgs), depending on local topography (**Figures 2.6-3a through 2.6-3e and 2.9-4**). Groundwater from the underlying Basal Chadron Sandstone aquifer is not used as a domestic supply within the TCEA because of the greater depth (580 to 940 feet bgs) and inferior water quality. Gosselin et al. (1996) state that: (1) "*the sands near the bottom of the Chadron Formation yield sodium-sulphate water with high total dissolved solids*," and (2) in proximity to "*uranium deposits in the Crawford area, groundwater from the Chadron Formation is not suitable for domestic or livestock purposes because of high radium concentrations*."

In addition, it is economically impractical to install water supply wells into the deeper Basal Chadron Sandstone in the vicinity of the TCEA, in contrast to the vicinity of the NTEA where most Basal Chadron Sandstone wells either flow at the surface or have water levels very close to surface elevation because of artesian pressure.

Based on National Groundwater Association website (NGWA 2004), average water use for rural (domestic) wells in Nebraska is approximately 380 gpd. Assuming an average family size of four persons, this correlates well with data from USGS who suggest an average per capita use on the order of 97 gpd (USGS 1999). Since there is only one residence located within the proposed TCEA (NW1/4 SE1/4 Section 29, T31N R52W), water use would be expected to use an average of 380 gpd (**Figure 2.2-4**). Since there are twenty-three occupied residences within the 2.25-mile AOR, water use would be expected to average about 8,740 gpd for the entire area.

A summary of groundwater quality data collected in 2007, 2008 and 2009 that establish background conditions in the vicinity of the TCEA are presented in **Table 2.2-14**. The data are presented for two hydrogeologic units: the Chadron Sandstone (mining zone) and the Brule Formation, which supplies the majority of groundwater in the project area. Four of the private wells being monitored are located within the TCEA permit boundary (Wells 270, 272. 273 and 277) and the remaining wells (Wells 269, 274, 275, 313, and 314) are located less than 0.5 mile from the permit boundary (**Figure 2.2-4**). Detailed discussions of the groundwater baseline data collected for TCEA are presented in Sections 2.9.

CBR conducted a water user survey in 2005 to identify and locate all private water supply wells with a 2.25-mile radius of the proposed TCEA. The water user survey determined the location, depth, casing size, depth to water, and flow rate of all wells within the area that were (or potentially could be) use for domestic, agricultural, or livestock uses. CBR updated the well survey in 2008, 2009, and 2010 for all groundwater wells within the AOR. **Table 2.2-15** and **Appendices 6 and** 7 list the active and abandoned groundwater wells, respectively, within the TCEA and AOR. The locations of all identified active and abandoned water supply wells are depicted on **Figure 2.2-4**.

There are a total of eighty-nine active private/public water supply wells within the TCEA and AOR (**Table 2.2-15, Appendix F**). Forty-nine wells are classified as agricultural use, seventeen wells are classified as domestic use, twelve wells are domestic/agricultural use, four wells are classified as livestock or observation use, one well is used by the City of Crawford as a test well for a municipal system, and six City of Crawford water supply wells, with four of these six wells being part of the city infiltration gallery (**Figure 2.2-4, Appendix F**). Within the TCEA, there are seven private water supply wells that are completed in the Brule Formation. There are an additional seventy-two private water supply wells and ten public water supply wells located outside of the TCEA permit boundary. The majority of the total eighty-nine private water supply wells are completed in the Brule Formation. However, there are six groundwater wells without well construction (e.g., well depth) or water quality information (Wells 300, 322, 395, 400, 402, and 432). Well construction and water quality information for these wells are not available in the NDNR water well data retrieval database (NDNR 2010a) or known by the well owner. Wells 300 and 432 are old wells with hand pumps, and Wells 322 and 402 have windmills, which would suggest that these are shallow wells completed in the Brule Formation.

Well depth information is unknown for Well 270, which is located within the TCEA permit boundary; however, water quality data from this well is consistent with the Brule Formation (see Section 2.10). Similarly, well depth information is unknown for Well 364, but a field conductivity measurement collected by CBR (386 μhmos) indicates that this is a Brule Formation well. There are five private water supply wells located outside, but within one mile, of the TCEA permit boundary, that are part of the project monitoring program (Wells 269, 274, 275, 313, and 314). The completion depths and water quality information collected to date for these wells indicate that they are completed in the Brule Formation. Well 313 will be replaced with Well 312 for future monitoring of private water supply wells. Well 313 and 314 are located close together, so additional data are only needed from one of these wells. Well 312 will allow for more representative sampling of the area north of the permit boundary.

Based on available information, all water supply wells within the TCEA and AOR are completed in the relatively shallow Brule Formation, with no domestic or agricultural use of groundwater from the Basal Chadron Sandstone (**Figure 2.2-4 and Table 2.2-15**).

Based on population projections (see Section 2.3), future water use within the TCEA and the AOR will likely will be a continuation of present use. It is unlikely that any irrigation development will occur within the license area due to the limited water supplies, topography, and climate. Irrigation within the review area is anticipated to be consistent with the past (e.g., limited irrigation in the immediate vicinity of the White River). It is anticipated that the City of Crawford municipal water supply will continue to be provided by the groundwater and infiltration galleries related to the White River and associated tributaries.

2.2.3.4 Water Use References

City-Data.com. 2010. *City of Crawford 2008*. [Web Page]. Located at: http://www.city-data.com/city/Crawford-Nebraska.html. Accessed on: March 11, 2010.

City of Crawford. 2010a. *Public Works*. [Web Page]. Located at: http://www.crawfordnebraska.net/water.html. Accessed on: March 11, 2010.

City of Crawford. 2010b. *Municipal Code of the City of Crawford, Nebraska. 2005*. [Web Page]. Located at: http://www.crawfordnebraska.net/police/coonline.html. Accessed on: March 10, 2010.

Engberg, R.A. and Spalding, R.F. 1978.Groundwater Quality Atlas of Nebraska; prepared by USGS and the University of Nebraska-Lincoln, Conservation and Survey Division, Resource Atlas No. 4.

Gosselin, D. C., Headrick, J., Chen, X-H., Summerside, S. E., 1996. Regional Analysis of Rural Domestic Well-water Quality -- Hat Creek-White River Drainage Basin; from *Domestic Water-well Quality in Rural Nebraska*, Nebraska Department of Health.

Lund, John. 2010. Personnel Communication. [Janaury 09 email to Larry Teahon, Crow Butte Resources, Inc., Crawford, NE. RE: White River flow and water quality data. Nebraska Department of Environmental Quality (NDEQ) Surface Water Unit Supervisor, Lincoln, Nebraska. 1 page plus attachments.

National Groundwater Association. (NGWA). 2004. [Web Page]. Located at: http://www.ngwa.org/_pdf/states/ne.pdf. Accessed in: 2004.

Nebraska Department of Health & Human Services (NDHHS). 2010. Water Supply Details. [Web Page]. Located at: https://sdwis.dhhs.ne.gov:8443/DWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=712799&tinwsys_st_code=NE&wsnumber=NE3104505. Accessed on: February 20, 2010.

Nebraska Department OF Natural Resources. (NDNR). 2010a. Groundwater Well Registration Information: Registered Groundwater Wells Data Retrieval (Download entire State of Nebraska Wells (Shape file - 15MB) [(Download entire State of Nebraska Wells (Shape file - 15MB) [State Plane NAD83/Feet]). [Web Page]. Located at: http://www.dnr.state.ne.us. Accessed on: February 19, 2010.

Nebraska Department of Natural Resources. (NDNR). 2010b. Data Bank. Department of Natural Resources Stream Gaging [Web Page]. Located at: http://dnr.ne.gov/docs/hydrologic.html. Discharge Records of Streams, Canals, Pumps and Storage in Reservoirs 2007. Accessed on: February 15, 2010.

Nebraska Revised Statutes. (NRS). 2008. Chapter 46: Irrigation and Regulation of Water. Section 46-602: Registration of water wells; forms; replacement; change in ownership; illegal water well; decommissioning required.

Teahon, L. 2007. Personal communication between Larry Teahon of Crow Butte Resources, Inc. and Bob Absalon of the City of Crawford. February 2007.

Teahon, L. and Grantham, R. 2010. Personal communication between Larry Teahon and Rhonda Grantham of Crow Butte Resources, Inc., and George Serres and L.J. Maloney of the City of Crawford. April 2010.

University of Nebraska-Lincoln, Conservation and Survey Division. 1986. The Groundwater Atlas of Nebraska, Resource Atlas No. 4.

United States Geological Survey. (USGS) 2009. Water Use in the United States. [Web Page]. Located at: http://water.usgs.gov/watuse/. Accessed on: December 2, 2009.

USGS. 2005. Estimated Use of Water in the United States County-Level Data for 2005. [Web Page]. Located at: http://water.usgs.gov/watuse/data/2005/index.html. Accessed on: December 2, 2009.

USGS. 2004. National Water Information System. [Web Page]. Located at: (http://nwis.waterdata.usgs.gov/ne/nwis/monthly/?site_no=06444000&agency_cd=USGS). Accessed in: 2004.

USGS. 1999. National Handbook of Recommended Methods for Water Data Acquisition – Chapter 11. [Web Page]. Located at: http://water.usgs.gov/pubs/chapter11/.http://water.usgs.gov/pubs/chapter11/. Accessed on: May 20, 2008.

Table 2.2-1 **Major Land Use Definitions**

Croplands (C)	Harvested cropland, including grasslands cut for hay, cultivated summer-fallow, and idle cropland.
Commercial and Services (C/S)	Those areas are used predominantly for the sale of products and services. Institutional land uses, such as various educational, religious, health, and military facilities are also components of this category.
Forested Land (F)	Areas with a tree-crown density of 10 percent or more are stocked with trees capable of producing timber or other wood products and exert an influence on the climate or water regime. This category does not indicate economic use.
Habitat (H)	Land dedicated wholly or partially to the production, protection or management of species of fish or wildlife.
Industrial (I)	Areas such as rail yards, warehouses, and other facilities used for industrial manufacturing or other industrial purposes.
Mines, Quarries, or Gravel Pits (M)	Those extractive mining activities that have significant surface expression.
Pastureland (P)	Land used primarily for the long-term production of adapted, domesticated forage plants to be grazed by livestock or occasionally cut and cured for livestock feed.
Rangeland (R)	Land, roughly west of the 100th meridian, where the natural vegetation is predominantly grasses, grass like plants, forbs, or shrubs; which is used wholly or partially for the grazing of livestock. This category includes wooded areas where grasses are established in clearings and beneath the overstory.
Urban Residential (UR)	Residential land uses range from high-density, represented by multi-family units, to low-density, where houses are on lots of more than 1 acre. These areas are found in and around Crawford and Ft. Robinson. Areas of sparse residential land use, such as farmsteads, will be included in categories to which they are related.
Water (W)	Areas of land mass that are persistently water-covered.
Recreational (RC)	Land used for public or private leisure, including developed recreational facilities such as parks, camps, and amusement areas, as well as areas for less intensive use such as hiking, canoeing, and other undeveloped recreational uses.

Table 2.2-2 Present Major Land Use Within a 2.25-Mile (3.6-KM) Radius of the Proposed Three Crow License Boundary

COMPASS SECTOR[1]	LAND USE[2,3] (ACRES)						TOTAL ACRES
	C	F	R	RC	RR	SB	
E	700.4	-	1,158.2	112.7	22.0	4.5	1,997.8
ENE	649.5	-	369.6	857.1	0.3	-	1,876.5
ESE	522.7	100.5	1,561.8	-	-	6.4	2,191.5
N	-	-	13.5	836.0	-	-	849.5
NE	96.9	-	29.1	1,288.5	-	-	1,414.5
NNE	-	-	15.2	942.3	-	-	957.6
NNW	0.0	-	16.7	990.8	-	-	1,007.5
NW	8.1	-	344.9	928.0	-	-	1,281.0
S	148.7	571.6	560.1	-	0.5	-	1,280.9
SE	303.9	618.2	1,279.9	-	-	-	2,202.0
SSE	117.8	740.8	862.0	-	-	-	1,720.6
SSW	111.8	395.9	672.4	-	20.0	-	1,200.1
SW	340.7	321.1	690.8	-	39.0	-	1,391.5
W	621.6	0.4	787.9	-	-	11.0	1,420.9
WNW	226.0	6.7	772.9	408.1	-	1.1	1,414.8
WSW	522.0	19.4	944.4	-	5.9	0.8	1,492.4
TOTAL	4,370.0	2,774.6	10,079.5	6,363.5	87.7	23.8	23,699.1

[1] 22 1/2° sectors centered on each of the 16 compass points

[2] See Table 2.2-1 for an explanation of major land use types: C = cropland; F = forested land; R = rangeland; RR = rangeland rehabilitation; SB = structural biotope; RC = recreational. Land uses not identified: mines, quarries or gravel pits; pastureland; water; habitat; commercial/services; urban residential; industrial

[3] Values are inclusive of TCEA

Table 2.2-3 **Present Land Use of the TCEA Within the Proposed Three Crow License Boundary**

COMPASS SECTOR[1]	LAND USE[2] (ACRES)					TOTAL ACRES
	C	F	R	RR[3]	SB[3]	
E	190.7	-	122.4	22.0	4.5	339.6
ENE	60.6	-	11.8	0.3	-	72.7
ESE	237.8	-	157.2	-	6.4	401.4
N	-	-	11.4	-	-	11.4
NE	10.4	-	10.7	-	-	21.1
NNE	-	-	12.8	-	-	12.8
NNW	-	6.7	14.2	-	-	20.9
NW	6.6	-	20.4	-	-	27.0
S	33.9	-	3.2	0.5	-	37.6
SE	114.8	-	35.4	-	-	150.2
SSE	43.3	-	3.4	-	-	46.7
SSW	19.4	-	2.7	20.0	-	42.1
SW	23.1	-	6.6	39.0	-	68.8
W	66.5	0.4	65.8	-	11.0	143.7
WNW	54.4	-	41.9	-	1.1	97.4
WSW	84.3	-	58.9	5.9	0.8	149.8
TOTAL	945.9	7.1	578.8	87.7	23.8	1,643.2

[1] 22 1/2° sectors centered on each of the 16 compass points

[2] See Table 2.2-1 for an explanation of major land use types: C = cropland; F = forested; R = rangeland; RR = Rangeland Rehabilitation; SB = Structural Biotope. Land uses not identified: forested land; recreational; mines, quarries or gravel pits; pastureland; water; habitat; commercial/services; urban residential; industrial

[3] See Section 2.2.2 for a discussion of these land types.

Table 2.2-4 Agricultural Yields for Croplands in Dawes County 2008

Crop	Harvested		Yield		Production
	Acres[a]	km^2	Per acre	Per km^2	
Corn for Grain (bu)[b]	900	3.64	171.0 bu	42,255 bu	153,900 bu
Corn for Silage (bu))[b]	2,000	8.09	13.2 bu	3,262 bu	26,400 bu
Oats (bu)	400	1.62	22.0 bu	5,436 bu	8,800 bu
Winter Wheat (bu)	37,600	152.16	37.5 bu	9,266 bu	1,408,800 bu
All hay[c] (tons)	51,000	136.38	1.6 tons	455 tons	93,600tons

Source: NASS 2009b

Notes: bu bushels

[a] 1 acre = 0.0040469 km^2

[b] The most recent available data are from 2007.

[c] Includes wild and tame alfalfa.

Table 2.2-5 Potential Agricultural Production for Cropland in the Three Crow Expansion Area and 2.25-Mile AOR

Crop	Percent of Total Planted[a]	Total Cropland (acres)[b]	Percent of Planted/ Harvested[a]	Harvested (acres)	Harvested (km^2)	County Yield (bu/acre)	County Yield (bu/km^2)	TCEA and AOR Yield (bu)
Wheat	33.3	4,430.4	89.03	3,956.3	16	37.5	9,266	148,361

Source: NASS 2009c

Notes: [a] Same as average percent acres planted and harvested for Dawes County.

[b] 1 acre = .0040469 km^2.

bu bushels

Table 2.2-6 Livestock Inventory, Dawes County, 2007

Livestock	Number	Percent of Total	Animal Units [a]	
			Pounds (000s)	Percent
All Cattle, except dairy	69,405	96.2	69,405	99.5
Dairy cattle	24	0.03	24	0.03
Hogs and pigs	321	0.4	71	0.1
Sheep and lambs	1,294	1.8	259	0.4
Chickens	1,092	1.5	5	0.008
Total animals	72,136	100.0	69,763.9	100.0

Source: NRCS 2007

Notes: [a] Animal unit conversions:

1 cow	=	1,000 lb.
1 hog	=	220 lb.
1 sheep	=	200 lb.
1 chicken	=	5 lb.
1 animal unit	=	1,000 lb.

Table 2.2-7 Recreational Facilities Within 50 Miles of the Proposed TCEA

Name of Recreational Facility	Distance From Satellite Facility (miles)
Fort Robinson State Park recreation facilities	2.4
Legend Buttes Golf Course	3.5
Crawford City Park	4.1
Peterson Wildlife Management Area	4.4
Ponderosa Wildlife Management Area HQ	6.6
Soldier Creek Wilderness	8.8
Whitney Lake	12.7
Roberts Trailhead and Campground	15.7
Hudson-Meng Bison Bonebed	16.3
Toadstool Geologic Park	16.7
Pine Ridge National Recreation Area	18.9
Box Butte Reservoir and Wildlife Area	21.1
Agate Fossil Beds National Monument	22.2
Chadron State Park	22.7
Red Cloud Campground	23.6
Warbonnet Battlefield	24.6
Gilbert-Baker Wildlife Area	25.6
Museum of the Fur Trade	29.8
Ridgeview County Club Golf Course	24.9
Walgren Lake State Recreation Area	42.0

Source: DeLorme Maps, 2005

Table 2.2-8 Distance to Nearest Residence and Site Boundary from Center of TCEA for each Compass Sector

Compass Sector[1]	Nearest Residence (ft.)	Nearest Site Boundary (ft.)
North	None	1,580
North-Northeast	None	1,671
Northeast	None	2,115
East-Northeast	14,937	3,631
East	6,097	8,905
East-Southeast	3,903	9,501
Southeast	7,859	4,270
South-Southeast	14,108	3,155
South	6,498	2,853
South-Southwest	11,185	3,023
Southwest	2,775	3,839
West-Southwest	12,248	6,192
West	6,493	5,609
West-Northwest	11,503	4,790
Northwest	None	2,370
North-Northwest	None	1,752

[1] 22 $^1/_2$° Sectors centered on each of the 16 compass points
None = No residence within the 2.25-mile radius of the TCEA boundary for this specific sector.

Table 2.2-9 USGS Estimated Water Use in Dawes County 2005

Total Population Served	Public Supply (Million Gallons Per Day [Mgal/da])				Irrigation (Mgal/da)			1000s
	Ground-water Withdrawals	Surface Water Withdrawals	Total Withdrawals	Domestic Deliveries	Groundwater Withdrawals	Surface Water Withdrawals	Total Withdrawals	Acres Irrigated Total
8,636	1.47	1.12	2.59	1.77	14.24	10.31	24.55	13

Source: USGS 2005

Table 2.2-10 Summary of Non-Abandoned Registered Water Wells for Dawes County, NE on File As of February 18 2010

Number of Registered Wells						Average Well Depth	Average Static level	Average Pumping Level	Total Registered Acres, Irrigation [c]	Number Replacement Wells
Commercial	Domestic	Irrigation	Monitoring [a]	Other Wells [b]	Total					
500	226	97	628	4,061	**5,512**	536.15	176.70	293.90	13,773.90	23

Other Wells (Registered)

Ground Heat Exchange	Injection	Observation [d]	Other [e]	Recovery	Livestock	Public Water Supply [f]	Public Water Supply[g]	Total Other Wells
41	916	8	16	2,855	224	16	21	**4,061**

Source: NDNR 2010a.
[a] Monitoring (Ground Water Quality)
[b] Listed below [Other Wells (Registered)]
[c] The same acres may be reported under more than one well registration.
[d] Observation (Ground Water Levels)
[e] Other (Lake Supply, Fountain, Geothermal, Wildlife, Wetlands, Recreation, Plant & Lagoon, Sprinkler, Test, Vapor Monitoring)
[f] With spacing protection (A well owned and operated by a city, village, municipal corporation, metropolitan utilities district, reclamation district, or sanitary improvement district that provides water to the public fit for human consumption through at least 15 service connections, or regularly serve at least 5 individuals.
[g] Without spacing protection (A well *not* owned or operated by a city, village, municipal corporation, metropolitan utilities district, reclamation district, or sanitary improvement district that provides the public water fit for human consumption through at least 15 service connections or regularly serves at least 25 individuals.

Table 2.2-11 City of Crawford Community Water Supply System Sources of Water

Name of Sources of Water	Type	Status
971 Gallery Well East	Infiltration Gallery	Active
972 Gallery Well Middle	Infiltration Gallery	Active
973 Gallery Well West	Infiltration Gallery	Active
Soldier Creek Infiltration Gallery	Infiltration Gallery	Active
Well 981	Well	Active
Well 982	Well	Active
Dead Man's Creek Intake	Infiltration Gallery	Inactive
White River Infiltration Gallery	Infiltration Gallery	Inactive

Service connections: 50 commercial and 450 residential

Table 2.2-12 Summary of City of Crawford Water System

Description	Capacity
Raw Water Storage Capacity	500,000 gallons
Treated Water Capacity West Tank East Tank	 1,000,000 gallons 750,000 gallons
Average Daily Use (2006)	419,181 gallons
Maximum Daily Use	1,000,000 gallons
Supply Wells	
South Well #1 (100 feet deep); NDNR Registration No. G-93533 NW1/4 SW1/4 Section 15 T31N R52W	104 gpm
West Well #2 (100 feet deep); NDNR Registration No. G-93532 NW1/4 SW1/4 Section 15 T31N R52W	54 gpm
Infiltration Gallery	
Wet Well (27 feet); NDNR Registration No. G-93531 SE1/4 SW1/4 Section 8 T31N R52W	900 gpm
Dewatering Wells (20 to 26 feet deep); NDNR Registration Nos. G-093528, G-093529 and G-093530 SE1/4 SW1/4 Section 8 T31N R52W	33 gpm (each)
Wellhead Protection Area	
960 acres Sections 15, 16, 21, and 22 T31N R52W	--

Sources: Teahon, L. 2007
Teahon, L. and Grantham, R. 2010
City of Crawford 2010a.

Table 2.2-13 City of Crawford Minimum Horizontal Distances Separating Public Water Supply Wells from Potential Sources of Contamination

Category	Distance	
	Feet	Meters
All water wells, including but not limited to: domestic supply wells, irrigation wells, stock wells, and heat pump wells	1,000	300
Sewage lagoon	1,000	300
Absorption or disposal field for waste	500	150
Cesspool	500	150
Dump	500	150
Feedlot or feedlot runoff	500	150
Corral	500	150
Pit toilet	500	150
Sanitary landfill	500	150
Chemical or petroleum product storage	500	150
Septic tank	500	150
Sewage treatment plant	500	150
Sewage wet well	500	150
Sanitary sewer connection	100	30
Sanitary sewer manhole	100	30
Sanitary sewer line	50	15
Sanitary sewer line (permanently watertight)	10	3

Source: City of Crawford 2010b.

Table 2.2-14 Summary of Groundwater Quality for Three Crow Vicinity

Constituent	Private Wells in AOR[a] Brule Formation		Three Crow Expansion Area Wells[b] Brule Formation		Three Crow Expansion Area Wells[c] Basal Chadron Formation	
	Range	Mean	Range	Mean	Range	Mean
	mg/l (unless stated otherwise)					
Calcium	7 – 99	54	14 -101	50.25	8 - 24	13.0
Magnesium	1 – 9	4.2	1 - 14	4.96	2 - 7	3.7
Sodium	16 - 75	28.6	14 - 83	35	333 - 474	399
Potassium	6 - 20	11.7	6 - 12	9.1	6 - 9	9.6
Bicarbonate	170 - 313	227	194 - 478	246	353 - 418	396
Sulfate	4 - 75	19	9 -25	16.4	225 - 361	271.4
Chloride	1 - 42	10	4 - 23	8.54	166 - 274	186
Specific Conductance (µmhos/cm)	246 - 633	436	239 – 735	410	1690 - 2190	1867
Total Dissolved Solids (TDS)	215 - 448	313	221 - 499	302	980 - 1300	1098
pH (Std. units)	7.38 – 8.4	7.82	7.49 – 8.74	7.98	7.82 – 8.75	8.23
Anions (meq/l)	3.0 – 6.24	4.75	3.67 – 8.78	4.78	16.3 – 20.6	17.7
Cations (meq/l)	3.37 – 6.46	5.07	3.43 – 8.06	4.68	16 – 21.8	18.6
Uranium (mg/l)	0.008 – 0.0272	0.0161	0.0032– 0.0264	0.0134	0.0004 – 0.0385	0.0087
Dissolved Ra-226[d] (pCi/l)	0.006 – 0.5	0.28	0.065 – 0.41	0.126	0.23 - 181	18.1
Suspended Ra-226[d] (pCi/l)	--	--	0.04 – 0.20	0.087	--	--

[a] 9 private water supply wells (2007 – 2009)
[b] 7 CBR TCEA Brule monitor wells (includes Well 274 [Miller Well]) (2008 – 2009) [Note Suspended Ra-226 analyses were for 3 sampling events in 2009 for wells BOW 2006-5, BOW 2006-6 and BOW 2006-7]
[c] 10 CBR TCEA Basal Chadron monitor wells (2008 – 2009)
[d] Values less than detection limits reduced by one-half to provide a conservative estimate.
mg/l = milligrams/liter
meq/l = milliequivalents per liter
pCi/l = picocuries per liter
µmhos/cm = micromhos per centimeter

Table 2.2-15 Active and Abandoned Water Supply Wells in the TCEA and 2.25-Mile Area of Review

Well #	Estimated Depth (ft)	Formation	Well Use	Well Status	Within TCEA
ACTIVE WELLS					
0009	110	Brule Fm	Agricultural	Active	No
0010	80	Brule Fm	Agricultural	Active	No
0044	90	Brule Fm	Domestic	Active	No
0045	90	Brule Fm	Domestic	Active	No
0046	130	Brule Fm	Domestic	Active	No
0047	50	Brule Fm	Domestic	Active	No
0053	80	Brule Fm	Domestic	Active	No
0054	80	Brule Fm	Agricultural	Active	No
0070	125	Brule Fm	Agricultural	Active	No
0071	100	Brule Fm	Agricultural	Active	No
0073	120	Brule Fm	Other Use[b]	Active	No
0139	80	Brule Fm	Domestic/Agricultural	Active	No
0142	200	Brule Fm	Domestic/Agricultural	Active	No
0143	100	Brule Fm	Domestic	Active	No
0146	200	Brule Fm	Agricultural	Active	No
0147	100	Brule Fm	Agricultural	Active	No
0148	200	Brule Fm	Agricultural	Active	No
0260	260	Brule Fm	Domestic	Active	No
0261	300	Brule Fm	Agricultural	Active	No
0265	32	Brule Fm	Domestic	Active	No
0266	15 – 20	Brule Fm	Agricultural	Active	No
0267	15 – 20	Brule Fm	Agricultural	Active	No
0268	15 – 20	Brule Fm	Agricultural	Active	No
0269	65	Brule Fm	Domestic	Active	No
0270	A	Brule Fm	Domestic/Agricultural	Active	**Yes**
0271	100 – 120	Brule Fm	Domestic/Agricultural	Active	**Yes**
0272	60	Brule Fm	Domestic/Agricultural	Active	**Yes**
0273	140	Brule Fm	Agricultural	Active	**Yes**
0274	160	Brule Fm	Domestic	Active	No
0275	200	Brule Fm	Domestic	Active	No
0276	300	Brule Fm	Domestic	Active	No
0277	60	Brule Fm	Domestic	Active	**Yes**
0278	25 – 30	Brule Fm	Domestic/Agricultural	Active	No
0279	260	Brule Fm	Agricultural	Active	No
0280	160	Brule Fm	Agricultural	Active	No
0281	100	Brule Fm	Agricultural	Active	**Yes**
0282	200	Brule Fm	Agricultural	Active	No
0283	200	Brule Fm	Agricultural	Active	No
0284	90	Brule Fm	Agricultural	Active	No
0286	90	Brule Fm	Agricultural	Active	**Yes**
0287	50	Brule Fm	Agricultural	Active	No
0300	a	a	Agricultural	Active	No

Table 2.2-15 Active and Abandoned Water Supply Wells in the TCEA and 2.25-Mile Area of Review

Well #	Estimated Depth (ft)	Formation	Well Use	Well Status	Within TCEA
0310	50	Brule Fm	Agricultural	Active	No
0311	200	Brule Fm	Agricultural	Active	No
0312	150	Brule Fm	Agricultural	Active	No
0313	150	Brule Fm	Agricultural	Active	No
0314	150	Brule Fm	Agricultural	Active	No
0322	a	a	Agricultural	Active	No
0332	120	Brule Fm	Agricultural	Active	No
0333	100	Brule Fm	Agricultural	Active	No
0334	100	Brule Fm	Domestic	Active	No
0335	160	Brule Fm	Agricultural	Active	No
0337	90	Brule Fm	Domestic/Agricultural	Active	No
0338	60	Brule Fm	Agricultural	Active	No
0339	30	Brule Fm	Domestic/Agricultural	Active	No
0360	190	Brule Fm	Agricultural	Active	No
0361	250	Brule Fm	Agricultural	Active	No
0364	a	Brule Fm	Domestic/Agricultural	Active	No
0367	80	Brule Fm	Agricultural	Active	No
0368	170	Brule Fm	Domestic/Agricultural	Active	No
0369	120	Brule Fm	Agricultural	Active	No
0371	140	Brule Fm	Agricultural	Active	No
0372	80	Brule Fm	Agricultural	Active	No
0373	140	Brule Fm	Agricultural	Active	No
0374	200	Brule Fm	Domestic/Agricultural	Active	No
0381	40-50	Brule Fm	Agricultural	Active	No
0386	160	Brule Fm	Agricultural	Active	No
0390	80	Brule Fm	Domestic	Active	No
0395	a	a	Domestic	Active	No
0398	95	Brule Fm	Domestic	Active	No
0400	a	a	Agricultural	Active	No
0402	a	a	Agricultural	Active	No
0412	133	Brule Fm	Agricultural	Active	No
0421	60	Brule Fm.	Agricultural	Active	No
0432	a	a	Agricultural	Active	No
0434	125	Brule Fm	Domestic/Agricultural	Active	No
0446	200	Brule Fm	Agricultural	Active	No
0447	60	Brule Fm	Agricultural	Active	No
0448	200	Brule Fm	Agricultural	Active	No
0450	260	Brule Fm	Livestock/Observation	Active	No
0451	200	Brule Fm	Livestock/Observation	Active	No
0452	200	Brule Fm	Livestock/Observation	Active	No
0453	200	Brule Fm	Livestock/Observation	Active	No
0454	103	Brule Fm	City of Crawford (public water supply)	Active	No

Table 2.2-15 Active and Abandoned Water Supply Wells in the TCEA and 2.25-Mile Area of Review

Well #	Estimated Depth (ft)	Formation	Well Use	Well Status	Within TCEA
0455	102	Brule Fm	City of Crawford (public water supply)	Active	No
0456	21	Alluvium	City of Crawford (public water supply)	Active	No
0457	20	Alluvium	City of Crawford (public water supply)	Active	No
0458	28	Alluvium	City of Crawford (public water supply)	Active	No
0459	27	Alluvium	City of Crawford (public water supply)	Active	No
ABANDONED WELLS					
0003	100	Brule Fm.	Agricultural	Abandoned	No
0279A	75	Brule Fm.	Agricultural	Abandoned	No
AW0285	a	a	Agricultural	Abandoned	No
0291	a	a	a	Abandoned	No
0292	a	a	a	Abandoned	No
0293	a	a	a	Abandoned	No
0294	a	a	a	Abandoned	No
0295	a	a	a	Abandoned	No
0296	a	a	a	Abandoned	No
0297	80	Brule Fm	a	Abandoned	**Yes**
0299	80	Brule Fm	a	Abandoned	No
0318	75	Brule Fm	a	Abandoned	No
0325	80	Brule Fm	Domestic	Abandoned	No
0365	a	a	Agricultural	Abandoned	No
0376	a	a	Agricultural	Abandoned	No
0388	a	a	Domestic	Abandoned	No
0391	a	a	a	Abandoned	No
0392	80	Brule Fm	Agricultural	Abandoned	No
0410	90 – 100	Brule Fm	a	Abandoned	**Yes**
0411	a	a	a	Abandoned	**Yes**
0413	a	a	a	Abandoned	**Yes**
0414	a	a	a	Abandoned	No
AW0415	200	Brule Fm	a	Abandoned	No
0419	a	a	a	Abandoned	No
0420	65	Brule Fm	a	Abandoned	No

Table 2.2-15 Active and Abandoned Water Supply Wells in the TCEA and 2.25-Mile Area of Review

Well #	Estimated Depth (ft)	Formation	Well Use	Well Status	Within TCEA
0279AW	75	Brule Fm	a	Abandoned	No
G-022460A	100	Brule Fm	Agricultural	Abandoned	No
G-022460B	100	Brule Fm	Agricultural	Abandoned	No
200450	110	Brule Fm	Agricultural	Abandoned	No
200443	100	Brule Fm	Agricultural	Abandoned	No

[a] Unknown
[b] Well used by City of Crawford as a test well for a municipal system
Note: Wells designated as completed in the Brule Formation, in many cases, are also included completed in the overlying alluvium.

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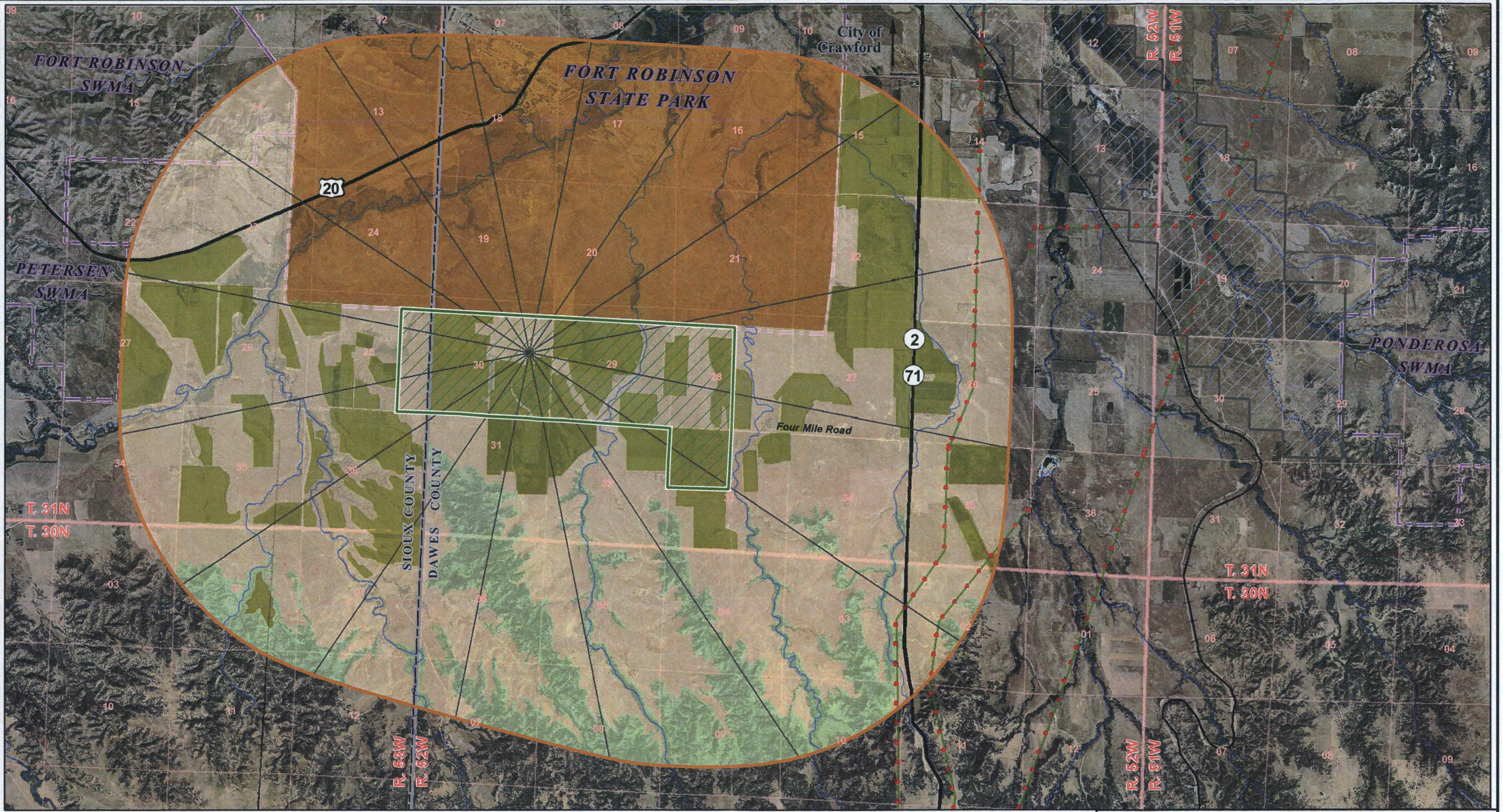


LEGEND

- Proposed Three Crow Expansion Area (TCEA)
- 2.25-Mile Buffer of Proposed TCEA Boundary
- Current License Area
- State Park or State Wildlife Management Area (SWMA)
- Grid Sector
- River/Creek
- Transmission Line
- Highway
- County Boundary
- Railroad

Land Use

- Cropland
- Forested Land
- Rangeland
- Recreational Land

0 2,000 4,000

Scale in Feet

N W E

PROJECTION:
NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601

SOURCE:
AERIALS: NAIP 2006, DAWES COUNTY AND SIOUX COUNTY, NE
LAND USE: CROW BUTTE RESOURCES, INC.
STATE PARK & SWMA: USGS 1:100,000 TOPOGRAPHIC MAP - CRAWFORD (1986), NE

CROW BUTTE RESOURCES, INC.

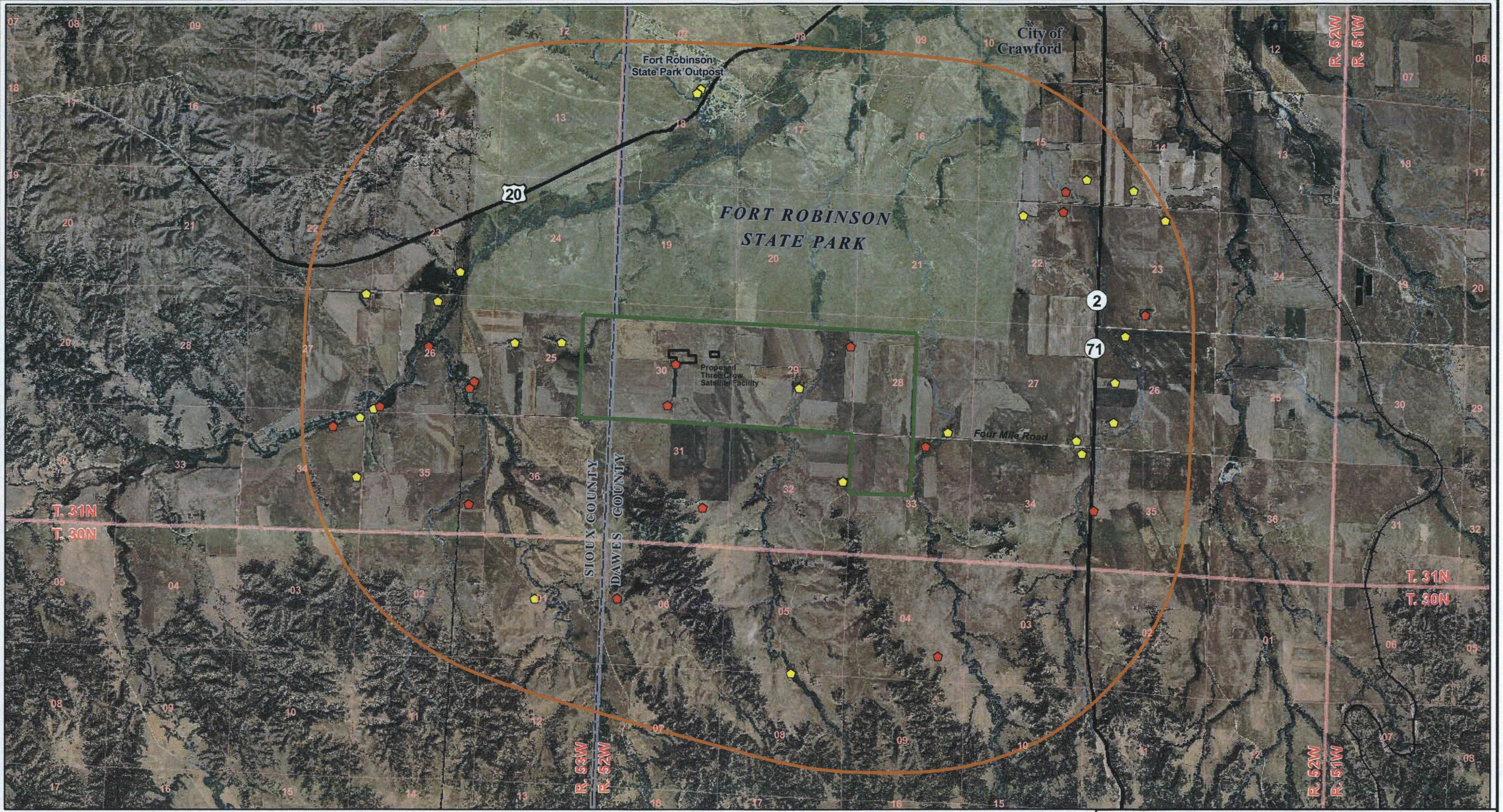
FIGURE 2.2-1
THREE CROW EXPANSION AREA LAND USE

PROJECT: CO001396.00002 | MAPPED BY: JC | CHECKED BY: JEC

ARCADIS

630 Plaza Drive, Ste. 100
Highlands Ranch, CO 80129
P: 720-344-3500 F: 720-344-3535
www.arcadis-us.com

K:\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0001_TR\TR Fig_2_2-1 Three Crow Land Use.mxd - 5/5/2010 @ 2:37:00 PM



LEGEND

- Occupied Dwelling
- Unoccupied Structure
- Proposed Three Crow Expansion Area (TCEA)
- 2.25-Mile Buffer of Proposed TCEA Boundary
- Proposed Three Crow Satellite Facility
- River/Creek
- Highway
- Railroad
- County Boundary
- Fort Robinson State Park

0 2,000 4,000
Scale in Feet

PROJECTION:
NAD_1927_STATEPLANE_
NEBRASKA_NORTH_FIPS_2601

SOURCE:
AERIALS: NAIP 2006, DAWES COUNTY AND SIOUX COUNTY, NE
RURAL RESIDENTIAL AND NON-RESIDENTIAL
STRUCTURES WERE DIGITIZED OFF AERIALS.

N
W E

CROW BUTTE RESOURCES, INC.

FIGURE 2.2-2
AERIAL PHOTO DEPICTING LOCATION OF RURAL RESIDENCES AND OTHER LAND FEATURES IN THE AREA OF REVIEW

PROJECT: CO001396.00002 | MAPPED BY: JC | CHECKED BY: JEC

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Highlands Ranch, CO 80129
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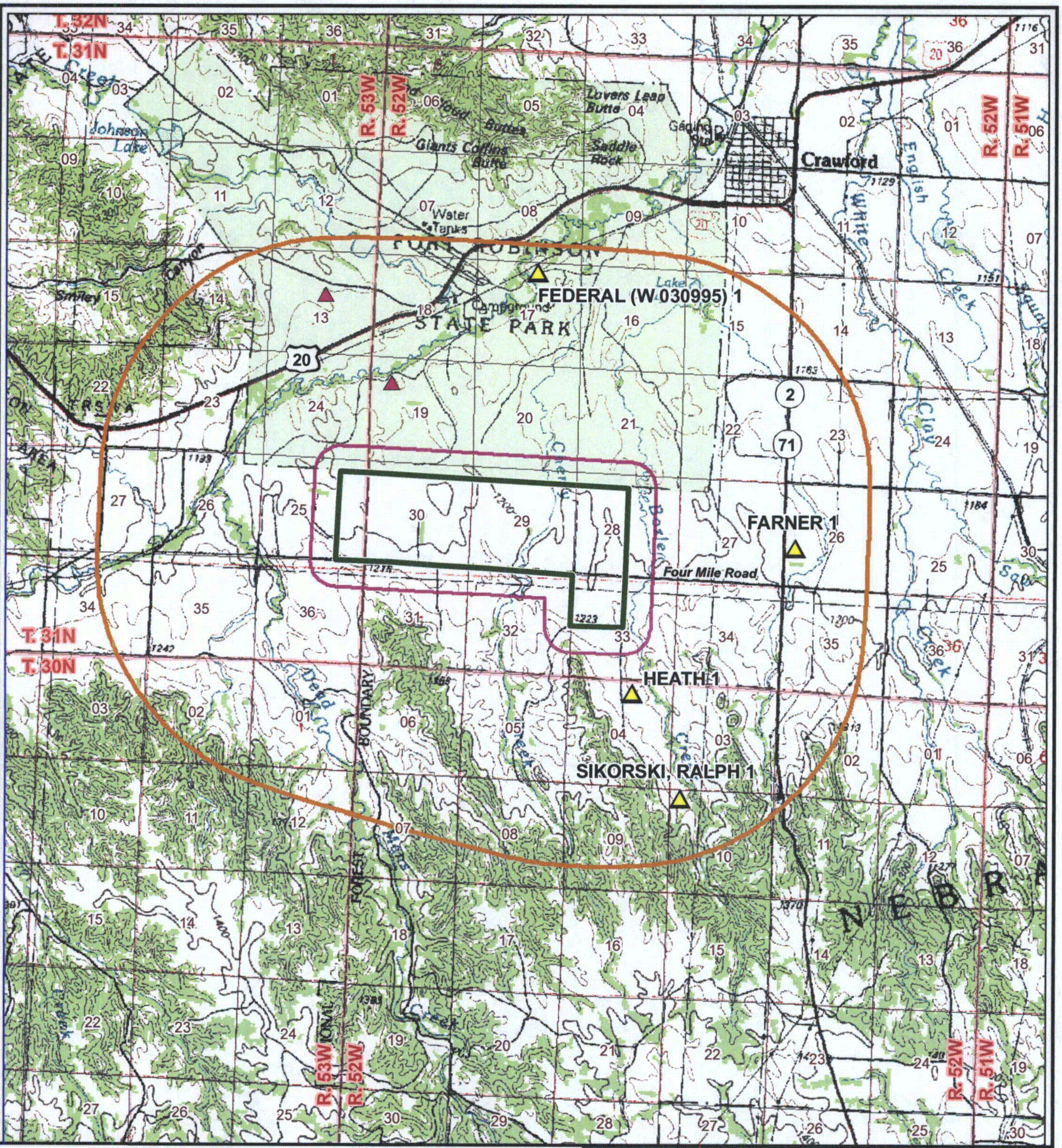
www.arcadis-us.com

K:\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMap\0001_TR\TR Fig_2_2-2_Aerial Photo Depicting Rural Residences.mxd - 5/5/2010 @ 1:51:33 PM



LEGEND

▲ Gravel Pit, Abandoned

Oil/Gas Exploration Holes

△ Dry Hole: Dry and Abandoned

Proposed Three Crow Expansion Area

ZOEI Boundary (1/4-Mile Buffer)

AOR Boundary (2 1/4-Mile Buffer)

SOURCES

Gravel Pits - Conservation and Survey Division, University of Nebraska - Lincoln, 1996 (http://nesen.unl.edu/csd/index.html)

O/G Test Holes - Nebraska Oil and Gas Conservation Commission, (http://www.nogcc.ne.gov/NOGCCPublications.aspx), 01/25/2010

USGS 1: 100,000 topographic map - Crawford (1984), NE
Contour Elevations in Meter

0 3,000 6,000
Scale in Feet

N W E

PROJECTION: NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601

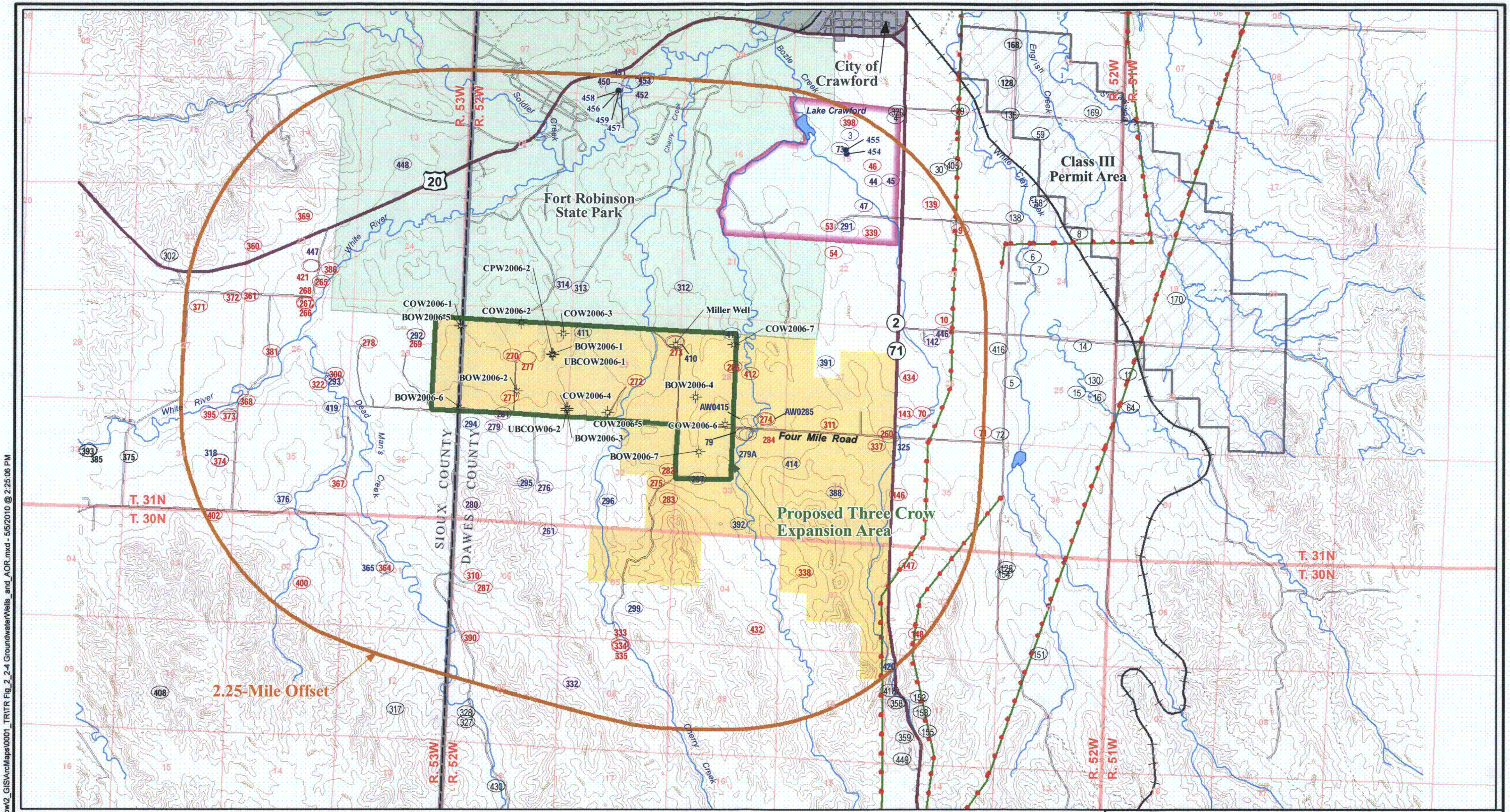
CROW BUTTE RESOURCES, INC.

FIGURE 2.2-3
THREE CROW EXPANSION AREA LOCATIONS OF GRAVEL PITS AND OIL/GAS TEST HOLES

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: LW

ARCADIS
630 Plaza Drive, Ste. 100
Highlands Ranch, CO 80129
P: 720-344-3500 F: 720-344-3535
www.arcadis-us.com

K:\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0001_TRTR Fig_2_2-3 Gravel Pits and OG Test Holes.mxd - 5/5/2010 @ 1:52:51 PM



LEGEND

- Monitoring Well
- **Private Wells**
  - 400 Active Surveyed Well
  - 280 Active Unsurveyed Well
  - 376 Abandoned Well
  - 359 Well Located outside of AOR
- Active Public Water Supply Well
- Proposed Three Crow Expansion Area
- 2.25-Mile Area of Review (AOR)
- River/Creek
- Lake
- Class III Permit Area
- Transmission Line
- Highway
- County Boundary
- Elevation Contour (50-Ft Interval)
- Road
- Trail
- Railroad
- Fort Robinson State Park
- Leased Area
- City of Crawford
- City of Crawford's Wellhead Protection Area

0 2,000 4,000
Scale in Feet

PROJECTION:
NAD_1927_STATEPLANE_
NEBRASKA_NORTH_FIPS_2601

ALL ELEVATIONS ARE IN FT-AMSL.

CROW BUTTE RESOURCES, INC.

FIGURE 2.2-4
LOCATION OF GROUNDWATER WELLS IN THE THREE CROW EXPANSION AREA AND 2.25-MILE AREA OF REVIEW

PROJECT: CO001396.00003 | MAPPED BY: JC | CHECKED BY: MS

ARCADIS
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www.arcadis-us.com

K:\CBR_Projects\CO001396_ThreeCrow2_GIS\ArcMap\0001_TRITR Fig_2_2-4 GroundwaterWells_and_AOR.mxd - 5/5/2010 @ 2:25:06 PM

2.3 Population Distribution

Information presented in this section concerns those demographic and social characteristics of the environs that may be affected by the proposed expansion of the Crow Butte Uranium Project to include operations in the TCEA. Data were obtained through the 1980, 1990, and 2000 Decennial Census; the 2009 U.S. Census Population Estimates program; and various State of Nebraska government agencies.

2.3.1 Demography

2.3.1.1 Regional Population

The area within an 80-km (50-mile) radius of the project site includes portions of six counties in northwestern Nebraska, two counties in southwestern South Dakota, and two counties in eastern Wyoming. Because the 80-km radius extends only slightly into two very rural counties in Wyoming, the regional demography in Wyoming is not discussed in detail beyond data summarized in **Table 2.3-1** through **Table 2.3-3**. **Figure 2.3-1** depicts significant population centers within an 80 km radius of the proposed TCEA.

Historical and current population trends in the project area counties and communities are contained in **Table 2.3-1**. Between 1960 and 1980, Box Butte County exhibited the fastest rate of growth with more than a 17 percent population increase, largely occurring in the latter half of the 1970s. Box Butte County lost population between 1980 and 2008, with the greater population losses occurring during the 1990s.

All of the Nebraska counties comprising the project area experienced slight growth or actual population decline between 1960 and 1980 and population decline between 1980 and 2008. The state experienced its fastest growth since the 1920s during the years between 1990 and 2000. The total state population in 2000 was 1.7 million, which was an 8.4-percent increase over the 1990 population of 1.6 million. The Nebraska counties in the project area experienced little of the state growth spurt. However, with the exception of Box Butte, the counties experienced a reversal of the downward trends of the 1980s. In general, population trends for the past two decades show that population in urban areas is increasing, while population in rural areas is declining. Areas within 80 km of the project site that are defined as urban (all territory, population, and housing units in urbanized areas and in places of more than 2,500 persons outside of urbanized areas) by the U.S. Census 2000 are the Cities of Chadron and Alliance, Nebraska (USCB 2003a).

Dawes County grew slightly between 1990 and 2000, gaining 0.4 percent in population. Most of this growth occurred in the City of Chadron. However, these population gains reversed between 2000 and 2008, when population in the county and incorporated communities in the county declined to levels lower than the 1990 populations. The City of Chadron and City of Crawford located in Dawes County are the nearest communities to the project site. The City of Chadron is located approximately 40 km (25 miles) northeast of the project site with a 2000 population of 5,634, an increase of 0.8 percent from 1990 (USCB 2003a). The City of Crawford, within 10 km (2.0 miles) of the site, had a 2008 population of 1,028 (City-Data.com 2010). The population declines in the City of Crawford were greater than the losses in other incorporated communities and the county as a whole.

Sioux County lost population at a slower rate in the years between 1990 and 2000 than in the previous decade. The slower decline of the county population occurred in part because the City of Harrison gained nearly 16 percent, which is a reversal of a trend that shows a decline in population since 1960. Between 1980 and 1985, the downward trend continued in Sioux and Morrill Counties, with Sheridan County exhibiting a slight turnaround. Between 1985 and 1990, the downward trend continued in the Nebraska counties, with the exception of Morrill County, which experienced an increase of 6.3 percent. However, this growth is a decrease from the 1980 population. The years between 2000 and 2009 saw accelerating decreases in the rate of population decline, showing greater losses than other Nebraska counties in the 80 km radius area (USCB 2003a).

Sheridan County has experienced an overall decline of nearly 29 percent since 1970. Population has declined in the Cities of Hay Springs and Rushville between 1980 and 2008, despite earlier gains in the 1980s (USCB 2003a).

Scotts Bluff County experienced population gains between 1990 and 2000 primarily because the City of Scottsbluff, which is an urban area just beyond the 80-km radius of TCEA, showed a strong increase in population of 7.4 percent between 1990 and 2000. The city continued to grow at a considerably slower rate between 2000 and 2008. Overall, the county experienced relatively small losses in population since 2000 (USCB 2003a).

Within South Dakota, portions of Fall River and Shannon Counties fall inside the 80-km study area. Fall River County experienced an overall population decline by more than 30 percent between 1960 and 2000 and a small increase of 1.4 percent between 1990 and 2000. The county population declined between 2000 and the present; however, the declines were not as steep as those in the 1980s. The City of Ardmore lost more than 80 percent of its population between 1960 and 1980, and was disincorporated in 1984. Shannon County, on the other hand, grew by 25.9 percent between 1990 and 2000; more than doubling the 1960 population. Shannon County continued to grow between 2000 and the present, although at a slower rate than in the 1990s. Much of the growth occurred in the Pine Ridge and Oglala Census Designated Places (CDP), which are urban areas as defined by the U.S. Census, but are not incorporated municipalities. Most of Fall River County is included within 80 km of the project site; however, only the southwest portion of Shannon County is within 80 km of the project site (USCB 2003b).

The population declines in the counties within the 80-km radius reflect trends in the overall region, where declines have been attributed to the declines in the rural farming based economy and limited economic opportunities for youth. Persistent drought conditions have also contributed to the shrinking of the agriculture-based economy. Rural residents have been migrating to larger cities, depopulating the largely rural Great Plains states. Many of the people migrating out of the state are young adults and families, which results in fewer people of childbearing age, and therefore, fewer children. This trend also contributes to the increasing proportion of the elderly population in the state (UNRI 2008).

2.3.1.2 Population Characteristics

2008 population by age and sex for counties within 80 km of the TCEA is shown in **Table 2.3-2**. Overall, 74.8 percent of the population in the region is more than 18 years old. Sioux and Niobrara Counties reported the highest percentage of persons older than 18 with 81.4 percent and 82.5 percent, respectively. About 25.2 percent of the population was less than 18 years old in

2008. Shannon County reported the youngest population, with 41.3 percent less than 18 years old, a considerably larger percentage than the other counties within the 80 km radius. Females slightly outnumbered males in most counties, with an overall population of 51.1 percent female to 48.9 percent male (USCB 2009a).

In 2000 slightly more than 75 percent of the ten-county population was classified as white. American Indians and persons of Hispanic origin comprised 21.2 percent and 4.3 percent, respectively, of the total population. Nearly 80 percent of the American Indians were Sioux living on the Pine Ridge Reservation in Shannon County, South Dakota (USCB 2009a).

2.3.1.3 Population Projections

The projected population for selected years by county within the 80-km radius of the proposed Crow Butte Project is shown in **Table 2.3-3**. The population is expected to decrease in the counties surrounding the project area. These counties are primarily rural, with agriculture-based economies. It is anticipated that the declining population trends of the last two decades will continue into the foreseeable future for these counties as population shift to more urban counties (i.e., Douglas, Lancaster, Sarpy, etc.). The projected population for Dawes County is expected to decrease by approximately 55 people (0.6 percent) between 2010 and 2020. This rate reflects recent increases in the population of the City of Chadron that are expected to continue until approximately 2015 (UNL-BBR 2009). In addition, Dawes County provides a scenic setting for a variety of outdoor recreation activities. The Pine Ridge region will probably increase in popularity with visitors and recreationists from outside of the region, as participation in outdoor recreational activities is expected to increase nationwide. An increase in visitor utilization of recreation facilities in Dawes County would revitalize the local economy, adding to the overall attractiveness of the region to potential residents.

2.3.1.4 Seasonal Population and Visitors

According to the Final Environmental Impact Statement for the Northern Great Plains Management Plans Revision (May 2001), the various state parks in northwest Nebraska, the Pine Ridge Ranger District and the Oglala National Grassland, are increasingly becoming regional tourist destinations.

Approximately 361,000 people visited Fort Robinson State Park in 2007. This number represents a 5.6-percent increase from 342,000 in 2001, but a decrease of 4.2 percent from the 1981 visitation of 377,000 people (NDED 2008). Approximately 50 percent of the visitors in 2002 were from other states, which is an increase in the number of out-of-state visitors from 1981, as the majority of 1981 visitors were Nebraskan families. It is likely that the decline of visitors from Nebraska has resulted from the overall decline of population in rural counties within a few hours commuting distance of the park.

There were 55,000 visitors to the Pine Ridge District of the Nebraska National Forest in 2001. Camping and motorized travel/sightseeing are the two most popular recreation categories within the Pine Ridge Ranger District and the Oglala National Grassland.

The forest provides a wide range of other undeveloped backcountry recreation opportunities such as hunting, hiking, backpacking, fishing and wildlife observation. The district provides the greatest number of miles of mountain biking trails in the state. District trails also attract horseback riders and off-highway motorized vehicle use. The Pine Ridge is an important destination for deer hunting, and provides the most popular turkey hunting area in Nebraska.

One source of seasonal population in this region is Chadron State College, located approximately 35 km (21.6 miles) from the site. During the fall enrollment of 2005, 2006, 2007, 2008 and 2009, the enrollment was 2,601, 2,767, 2,726, 2,769, and 2,744, respectively (CSC 2010a, CSC 2010b and TCR 2010). The average enrollment from 1994 through 1999 was 2,944, with a range of 2,768 – 3,189 (NCCPE 2005). Enrollment from 2009 (2,744) versus this later average of 2,944 is a 0.068 percent reduction in student enrollment. For the past five years (2005 – 2009), enrollment has been fairly consistent.

2.3.1.5 Schools

The City of Crawford is served by the City of Crawford Public School District. The Crawford High School and grade school are presently under capacity (Vogl, B. pers. comm. 2010). Enrollment for the fall term of 2009 was 108 in the grade school and 112 in the high school (NDE 2009); a decline of about 14 percent in total enrollment for both schools from March 2007 (Vogl, T. pers. comm. 2007). The grade school currently has a student to teacher ratio of 13 to 1 and the high school has a ratio of 8 to 1.

Families moving into the Crawford district as a result of the proposed TCEA operations would not stress the current school system because it is presently under capacity.

2.3.1.6 Sectorial Population

Existing population, as determined for the original analysis in the CBR commercial license application prepared in 1987 for the 80-km radius, was estimated for 16 compass sectors, by concentric circles of 1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70 and 80 km from the site (a total of 208 sectors). Sectorial population for the application prepared in 2004 was updated with data from the 2000 U.S. Census. Subtotals by sector and compass points as well as the total population are shown in **Table 2.3-4**.

Population within the 80-km radius was estimated using the following techniques:

U.S. Census 2000 data were used to estimate the total population within an 80-km radius, measured from the center of the proposed TCEA site. The data were created by Geographic Data Technology, Inc., a division of Earth Sciences and Research Institute (ESRI), from Census 2000 boundary and demographic information for block groups within the United States.

ArcInfo Geographic Information System (GIS) was used to extract data from U.S. Census 2000 population estimates for 40 Census Tract Block Groups located wholly or partially within the 80-km radius from the approximate center of the TCEA site. Urban areas within each county were generally assigned their own block group.

To assign a population to each sector, a percentage area of each sector within one or more block groups was calculated for all of the block groups.

2000 U.S. Census of population estimates for cities and counties in Nebraska, South Dakota and Wyoming were used to determine total urban population.

2.3.2 Local Socioeconomic Characteristics

2.3.2.1 Major Economic Sectors

In 2009, average annual unemployment rates in Dawes and Box Butte Counties decreased from the 2008 rates. **Table 2.3-5** summarizes unemployment rates and employment in the Nebraska project area counties, as well as the overall change in employment in economic sectors between 1994 and 2009. Dawes and Box Butte Counties exhibited unemployment rates at 4.4 percent in Dawes County and 6.8 percent in Box Butte County in 2009. The Dawes County unemployment rate was slightly less than the statewide rate of 4.7 percent, whereas the Box Butte County was significantly higher (NDOL 2010).

The major economic sectors in the project area have changed little in recent years, although individual sectors have shifted in their relative proportion in the overall economy. The area continues to depend on trades, government, and services. Economic sectors in the City of Crawford area include farming, ranching, cattle feed lots, tourism, and retail sales.

Agriculture accounted for a significant portion (19.2 percent) of the total employed labor force in Dawes County in 2009. During the same time period, farm employment was 2.0 percent of total employment in Box Butte County. Retail trade accounted for 14.7 percent of total employment in Dawes County, followed by local government employment (12.6 percent), leisure and hospitality (11.1 percent), education and health services (9.8 percent), and state government (6.5 percent). Mining and construction accounted for 5.0 percent. In Box Butte County, the largest four non-farm employment sectors are local transportation, communication and utility services (20.2 percent), local government (17.7 percent), production (8.6 percent), and leisure and hospitality (8.0 percent) (NDOL 2010).

Agriculture employment has a small share of total employment in both counties. However, agriculture provides the economic base for the counties, as other economic sectors support the agricultural industry. Events that affect agriculture are generally felt throughout rural economies. According to the Nebraska Department of Economic Development (NDED 2010), farm employment in Nebraska is expected to decline by nearly 14,000 jobs (20 percent) between 2000 and 2045, while overall non-farm employment will increase by nearly 26 percent. The decrease in jobs in the agricultural sector could continue to fuel migration from rural counties to urban areas, resulting in overall declines in other sectors of the local economy as dollars spent from personal income and agricultural business expenditures move out of the counties.

Per capita personal income is the income that is received by persons from all sources, including wages and other income over the course of one year. In 2007 (most recent available data), personal income in Dawes County was $23,537, which was 65 percent of the state average of $36,372. The county ranks 82nd out of 93 counties in the state (BEA 2010).

2.3.2.2 Housing

Between 1970 and 1980, total housing units increased by 17 percent in Dawes County from 3,388 to 3,965 units (USCB 1990a). After a decline in total units during the 1980s, growth increased by 2.4 percent from 3,909 units in 1990 to 4,004 units in 2000. The City of Chadron, the largest community in Dawes County and within 40 km (25 miles) of the project site, experienced a negligible increase (0.3 percent) in housing stock between 1980 and 1990, and a 5 percent increase between 1990 and 2000. Between 1980 and 1990, the City of Crawford housing stock decreased by nearly 7 percent to 576 (USCB 2003a). There were 4,021 housing units in Dawes County in 2008, an increase of 4 percent from the 4,004 housing units tallied in the 2000 Census (USCB 2010a). Box Butte County, which borders Dawes County to the south,) exhibited a 1 percent loss in total housing units between 1990 and 2000, and an increase of 35 percent from 2000 to 2007. In 2007, there were 5,485 housing units in Box Butte County (USCB 2003a, 2010b).

In 2000, Dawes and Box Butte Counties had homeowner vacancy rates of 1.7 and 1.4 percent, respectively. As of June 2007, there were six single family housing units for sale in the City of Crawford. Three of the units were listed at prices below $100,000. Two of the units were listed at prices between $100,000 and $150,000. One unit was listed at a price over $250,000. Three new single family housing units were constructed between 2006 and 2008 in the City of Crawford and average new home construction costs were $70,000 (NPPD 2009). The median gross rent for the City of Crawford in 2008 was $526 per month (City-Data.com 2010).

The demand for rental housing did not change significantly between 1990 and 2000, as rental vacancy rates were 11.8 percent in Dawes County and 15.4 percent in Box Butte County in 2000 (USCB 2003d), as compared with 1990 rental vacancy rates of 12.6 percent and 14.9 percent, respectively (USCB 1990b).

High interest rates and tax rates were the major deterrents for potential homebuyers in the project area in the past. Current deterrents are economic uncertainty and unemployment. Recent interest rates on most home mortgages have ranged between 5 and 7 percent.

The majority of housing demand expected over the next two decades in Dawes County is most likely to occur in the City of Chadron. However, housing stock in the City of Crawford increased slightly between 2000 and 2008. In the event that the various scenic and recreational amenities of the region stimulate the local tourist economy, it is likely that both population and housing stock would increase in the City of Crawford.

The purchase of homes by Crow Butte employees provides the City of Crawford with ad valorem property taxes. The City of Crawford levies taxes at a dollar per hundred of valuation. In 2009, the total levy was 0.46834, which would result in taxes on a $50,000 property of approximately $234 per year (NDPA&T 2010).

2.3.3 Environmental Justice

The 2000 Census provides population characteristics for Census Tracts, which contain Block Groups that are further divided into Blocks. There are no intercensal (years between the decennial census years) population estimates for Census Tracts and Block Groups. The Blocks are the smallest Census area that contains the race characteristics of the population in Dawes County. The TCEA contains all or a portion of 3 Blocks within Census Tract 9506 in Dawes County, and 2 Blocks within Census Tract 9501 in Sioux County. Block Groups are the smallest Census area that contains poverty level information. There is no poverty data for individual Blocks within each Block Group. There are two Block Groups that are located partially within the TCEA; however, the Block Groups area also includes most of the south portion of Dawes County and the north half of Sioux County.

The affected area selected for the Environmental Justice analysis includes the racial characteristics of the population within Census Tract Blocks within the TCEA. The population with an annual income below the poverty level was determined from Block Group characteristics.

The state of Nebraska was selected to be the geographic area to compare the demographic data for the population in the affected Blocks. This determination was based on the need for a larger geographic area encompassing affected area Block Groups in which equivalent quantitative resource information is provided. The population characteristics of the TCEA are compared with Nebraska population characteristics to determine whether there are concentrations of minority or low income populations in the TCEA relative to the state.

According to the 2000 Census and summarized in **Table 2.3-6**, the combined population of the Census Block Groups within the Expansion Area was 23. There were no minority populations identified within the Block Groups; the entire population was white. The nearest minority populations resided within the City of Crawford, located 2.8 miles north-northeast of the TCEA. Races in the City of Crawford consist of white non-Hispanic (93.0%), American Indian (4.7%), Hispanic (2.0%), person reporting two or more races (1.9%) and other race (0.9%) (City-Data.com 2010). The total percentage is greater than 100 percent because Hispanics could be counted in other races.

No concentrations of minority populations were identified as residing in rural areas near the proposed Project facilities. There would be no disproportionate impact to minority population from the construction and implementation of the Three Crow Project.

Block Group 3 has a smaller percentage of people living below the poverty level than either the state or Dawes County. Block Group 1 in Sioux County, is very close to Dawes County in the percentage of people living below the poverty level, and is significantly larger than the state level. Lower income levels are characteristic of predominantly rural populations and small communities that serve as a local center of agricultural activity. No adverse environmental impacts would occur to the population within the TCEA from proposed Project activities; therefore, there would be no disproportionate adverse impact to populations living below the poverty level in these Block Groups.

2.3.4 References

Bureau of Economic Analysis. (BEA). 2010. Personal Income and Per Capita Income by County for Nebraska 2005-2007. [Web Page]. Located at: http://www.bea.gov/regional/reis/. Accessed on: February 25, 2010.

Chadron State College. (CSC). 2010a. *Student Enrollment Information*. [Web Page]. Located at: http://www.csc.edu/ir/enrollment.csc. [225, 2006 and 2007 data]. Accessed on: February 25, 2010.

Chadron State College. (CSC). 2010b. *Enrollment Quick Facts*. [Web Page]. Located at: http://www.csc.edu/ir/quickfacts.csc. [2008 data]. Accessed on: February 25, 2010.

City-Data.com 2010. *Crawford, Nebraska*. [Web Page]. Located at: http://www.city-data.com/city/Crawford-Nebraska.html. Accessed on: February 25, 2010.

National Center for Education Statistics. 2010. Crawford Public Schools, Crawford, NE. [Web Page]. Located at: http://www.nces.ed.gov/ccd/schoolsearch/school_list.asp?Search=1&DistrictID=3105520 Accessed on: January 15, 2010.

Nebraskas Coordinating Commission for Postsecondary Education. (NCCPE). 2005. *2005 Nebraska Higher Education Progress Report for the LR75 Legislative Evaluation Task Force:* Volume *One*. [Web Page] Located at: http://www.ccpe.state.ne.us/publicdoc/ccpe/reports/LR174/2005/default.asp. Accessed on: February 25, 2010.

Nebraska Department of Economic Development. 2008. Attendance at Selected Nebraska Attractions 2005-2007. [Web Page]. Located at: http://www.neded.org/files/research/stathand/msect4d.htm. Accessed on: March 6, 2007.

NDED. 2010. Projected Nebraska Farm and Nonfarm Employment 1998 to 2045. [Web Page]. Located at: http://www.neded.org/files/research/stathand/csecc3.gif. Accessed on: January 15, 2010.

Nebraska Department of Education (NDE). 2009. Enrollment Trends; Crawford Public School. . [Web Page]. Located at: http://reportcard.nde.state.ne.us/20002001/District/DistrictSearch.asp?optSearch=5&DistrictID=&CountyID=. Accessed on: December 21, 2009.

Nebraska Department of Labor (NDOL). 2010. Labor Force/Work Force Summaries. [Web Page]. Located at: http://www.dol.nebraska.gov/nwd/center.cfm?PRICAT=3&SUBCAT=4F. Accessed on: February 26, 2010.

Nebraska Department Property Assessment and Taxation. (NDPA&T). 2010. Research Reports [Valuation, Taxes Levied, & Tax Rate Data]. [Web Page]. Located at: http://pat.nol.org/researchReports/map/index.html. Accessed on: February 25, 2010.

Nebraska Public Power District (NPPD). 2007. Community Facts – Crawford Nebraska. 48 pg.

The Chadron Record. (TCR). 2010.

U.S. Department of Commerce, Census Bureau (USCB). 1990a. 1990 Census of Population and Housing – Population and Housing Counts - Nebraska. CPH-2-29. [Web Page] Available online at: http://www.census.gov/prod/cen1990/cph2/cph-2.html.

USCB. 1990b. 1990 Census of Housing – General Housing Characteristics - Nebraska. CH-1-29. [Web Page] Available online at: http://www.census.gov/prod/cen1990/ch1/ch-1.html.

USCB. 2000a. Census 2000 Summary File 1 (SF 1) 100-Percent Data. All Blocks in a County – Dawes County, Nebraska. [Web Page]. Located at: http://factfinder.census.gov/servlet/DCGeoSelectServlet. Accessed on: February 25, 2010.

USCB. 2000b. Census 2000 Summary File 1 (SF 1) 100-Percent Data. All Blocks in a County – Sioux County, Nebraska. [Web Page]. Located at: http://factfinder.census.gov/servlet/DCGeoSelectServlet. Accessed on: February 25, 2010.

USCB. 2001. Census of Population and Housing – Profiles of General Demographic Characteristics – Nebraska. DP-1-29. Issued May 2001. [Web Page] Available on line at: http://www.census.gov/prod/cen2000/index.html.

USCB. 2003a. 2000 Census of Population and Housing - Population and Housing Unit Counts - Nebraska. PHC-3-29. Issued September 2003. [Web Page] Available on line at: http://www.census.gov/prod/cen2000/index.html.

USCB. 2003b. 2000 Census of Population and Housing - Population and Housing Unit Counts – South Dakota. PHC-3-43. Issued September 2003. [Web Page] Available on line at: http://www.census.gov/prod/cen2000/index.html.

USCB. 2003c. 2000 Census of Population and Housing - Population and Housing Unit Counts - Wyoming. PHC-3-52. Issued September 2003. [Web Page] Available on line at: http://www.census.gov/prod/cen2000/index.html.

USCB. 2003d. 2000 Census of Population and Housing – Summary Population and Housing Characteristics - Nebraska. PHC-1-29. Issued September 2003. [Web Page]. Available on line at: http://www.census.gov/prod/cen2000/index.html.

USCB. 2009a. 2008 Population Estimates – County Characteristics. [Web Page]. Located at: http://www.census.gov/popest/counties/asrh/CC-EST2008-agesex.html. Accessed on: February 27, 2010.

USCB. 2009b. Download Center - 2008 Population Estimates. [Web Page]. Located at: http://factfinder.census.gov/servlet/DCGeoSelectServlet?ds_name=PEP_2008_EST. Accessed on: December 20, 2009.

USCB. 2010a. Dawes County, Nebraska – Quick Facts. [Web Page]. Located at: http://quickfacts.census.gov/qfd/states/31/31045.html. Accessed on: February 27, 2010.

USCB. 2010b. Box Butte County, Nebraska – Quick Facts. [Web Page]. Located at: http://quickfacts.census.gov/qfd/states/31/31013.html. Accessed on: February 27, 2010.

University of Nebraska, Bureau of Business Research (UNL-BBR). 2009. Population Projections of Nebraska, 2000-2020. [Web Page]. Located at: http://www.bbr.unl.edu/PopProjections. Accessed: on December 20, 2009.

University of Nebraska Rural Initiative (UNRI). 2008. Nebraska Population Growth Continues to be Concentrated in Metropolitan Counties. 4 pg. [Web Page]. Available online at: http://ruralinitiative.nebraska.edu/growth/index.html.

Vogl, B. 2010. Personal communication with Jason Adams [ARCADIS] via phone regarding school capacities. February 26, 2010.

Vogl, T. 2007. Personal communication with Michael Griffin via email regarding school enrollments. March 6 and 7 2007.

Wyoming Department of Administration and Information, Economic Analysis Division. 2009. Wyoming Population Estimates and Forecasts from 2000 to 2030. [Web Page]. Located at: http://eadiv.state.wy.us/pop/wyc&sc30.htm. Accessed on: February 26, 2010.

Table 2.3-1 Historical and Current Population Change for Counties and Cities within 80 Km of the Three Crow Expansion Area Site, 1970-2008

State County City	Population					Average Annual Percent Change			
	1970	1980	1990	2000	2008	1970/ 1980	1980/ 1990	1990/ 2000	2000/ 2008
NEBRASKA									
Dawes	9,761	9,609	9,021	9,060	8,728	-1.6%	-6.1%	0.4%	-3.7%
Chadron	5,921	5,933	5,588	5,634	5,429	0.2%	-5.8%	0.8%	-3.6%
Crawford	1,291	1,315	1,115	1,107	1,028	1.9%	-15.2%	-0.7%	-7.1%
Whitney	82	72	38	87	87	-12.2%	-47.2%	128.9%	0.0%
Box Butte	10,094	13,696	13,130	12,158	11,043	35.7%	-4.1%	-7.4%	-9.2%
Alliance	6,862	9,869	9,765	8,959	8,109	43.8%	-1.1%	-8.3%	-9.5%
Hemingford	734	1,023	953	993	882	39.4%	-6.8%	4.2%	-11.2%
Morrill County	5,813	6,085	5,423	5,440	4,989,	4.7%	-10.9%	0.3%	-8.3%
Scotts Bluff County	36,432	38,344	36,025	36,951	36,554	5.2%	-6.0%	2.6%	-1.1%
Scottsbluff	14,507	14,156	13,711	14,732	14,785	-2.4%	-3.1%	7.4%	0.4%
Sheridan	7,285	7,544	6,750	6,198	5,337	3.6%	-10.5%	-8.2%	-13.9%
Hay Springs	682	794	693	652	549	16.4%	-12.7%	-5.9%	-15.8%
Rushville	1,137	1,217	1,127	999	849	7.0%	-7.4%	-11.4%	-15.0%
Sioux	2,034	1,845	1,549	1,475	1,187	-9.3%	-16.0%	-4.8%	-12.7%
Harrison	377	361	241	279	242	-4.2%	-33.2%	15.8%	-13.3%
SOUTH DAKOTA									
Fall River	7,505	8,439	7,353	7,453	7,145	12.4%	-12.9%	1.4%	-4.1%
Hot Springs	4,434	4,742	4,325	4,129	4,028	6.9%	-8.8%	-4.5%	-2.4%
Oelrichs	94	124	138	145	139	31.9%	11.3%	5.1%	-4.1%
Ardmore[1]	14	16	NA	NA	NA	14.3%			
Shannon	8,198	11,323	9,902	12,466	13,637	38.1%	-12.5%	25.9%	9.4%

Table 2.3-1 Historical and Current Population Change for Counties and Cities within 80 Km of the Three Crow Expansion Area Site, 1970-2008

State County City	Population					Average Annual Percent Change			
	1970	1980	1990	2000	2008	1970/ 1980	1980/ 1990	1990/ 2000	2000/ 2008
WYOMING									
Goshen	10,885	12,040	12,373	12,538	12,072	10.6%	2.8%	1.3%	-3.7%
Niobrara	2,924	2,924	2,499	2,407	2,428	0.0%	-14.5%	-3.7%	0.9%
Van Tassell	21	10	8	19	NA	-52.4%	-20.0%	125.0%	NA

[1] 1980 was the last year that Ardmore had a recorded population.
Sources: U.S. Bureau of the Census 2003a, 2003b, 2003c, 2009b

Table 2.3-2 Population by Age and Sex for Counties within the 80-Km Radius of the Three Crow Expansion Area, 2008

County	Age	Male	Female	Total	Total Percent Breakdown
			Nebraska		
Box Butte	Under 18	1,386	1,299	2,685	24.3%
	18 - 64	3,462	3,298	6,760	61.2%
	65+	660	938	1,598	14.5%
	Total	5,508	5,535	11,043	100.0%
Dawes	Under 18	896	831	1,727	19.8%
	18 - 64	2,753	2,893	5,646	64.7%
	65+	583	768	1,351	15.5%
	Total	4,232	4,492	8,724	100.0%
Morrill	Under 18	563	542	1,105	22.1%
	18 – 64	1507	1432	2,939	58.9%
	65+	402	543	945	19.0%
	Total	2,472	2,517	4,989	100.0%
Scotts Bluff	Under 18	4547	4470	9,017	24.7%
	18 - 64	10,314	10,933	21,247	58.1%
	65+	2,576	3,714	6,290	17.2%
	Total	17,437	19,117	36,554	100.0%
Sheridan	Under 18	624	561	1,185	22.2%
	18 - 64	1,499	1,452	2,951	55.3%
	65+	509	692	1,201	22.5%
	Total	2,632	2,705	5,337	100.0%
Sioux	Under 18	136	104	240	18.6%
	18 - 64	446	409	855	66.4%
	65+	95	97	192	14.9%
	Total	677	610	1,287	100.0%
			South Dakota		
Fall River	Under 18	766	605	1,371	19.2%
	18 – 64	2,021	1,994	4,015	56.2%
	65+	861	898	1,759	24.6%
	Total	3,648	3,497	7,145	100.0%
Shannon	Under 18	2,808	2,824	5,632	41.3%
	18 – 64	3,572	3,751	7,323	53.7%
	65+	293	389	682	5.0%
	Total	6,673	6,964	13,637	100.0%
			Wyoming		
Goshen	Under 18	1,367	1,218	2,585	21.4%
	18 – 64	3,724	3,528	7,252	60.1%
	65+	1,002	1,233	2,235	18.5%
	Total	6,093	5,979	12,072	100.0%

Table 2.3-2 Population by Age and Sex for Counties within the 80-Km Radius of the Three Crow Expansion Area, 2008

County	Age	Male	Female	Total	Total Percent Breakdown
Niobrara	Under 18	220	205	425	17.5%
	18 - 64	707	804	1,511	62.2%
	65+	223	269	492	20.3%
	Total	1,150	1,278	2,428	100.0%

Source: U.S. Bureau of the Census, 2009a

Table 2.3-3 Population Projections for Counties within an 80-Km Radius of the Current Crow Butte Project Area 2000-2020

County	Census 2000	Projected 2005	Projected 2010	Projected 2015	Projected 2020
Box Butte	12,158	11,374	11,023	10,319	9,588
Dawes	9,060	8,636	8,701	8,736	8,646
Morrill	5,423	5,165	5,084	4,993	4,886
Scotts Bluff	36,025	36,752	36,429	36,055	35,627
Sheridan	6,198	5,668	5,492	5,362	5,261
Sioux	1,475	1,458	1,407	1,344	1,271
Fall River	7,453	N/A	N/A	N/A	N/A
Shannon	12,466	N/A	N/A	N/A	N/A
Goshen	12,538	12,083	12,050	11,980	11,820
Niobrara	2,407	2,228	2,310	2,340	2,330

N/A No projection available
Sources: University of Nebraska-Lincoln, Bureau of Business Research 2009.
Wyoming Department of Administration and Information 2010.

Table 2.3-4 2004 Population within an 80-Km (50-Mile) Radius of the TCEA[a]

	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	Total
N	0	0	0	1	1	525	37	58	73	107	137	162	183	1,284
NNE	0	0	0	1	1	327	44	63	88	113	137	169	289	1,232
NE	0	0	0	1	1	7	33	60	249	233	134	133	682	1,533
ENE	0	0	0	1	1	7	29	48	679	5100	138	159	437	6,599
E	0	0	0	1	1	7	29	48	70	103	282	733	247	1,521
ESE	0	0	0	1	1	7	29	48	68	114	187	128	63	646
SE	0	0	0	1	1	7	29	58	161	242	262	471	8230	9,462
SSE	0	0	0	1	1	7	29	111	188	211	158	185	640	1,531
S	0	0	0	1	1	7	29	88	128	136	133	193	875	1,591
SSW	0	0	0	1	1	6	15	21	29	62	97	115	1083	1,430
SW	0	0	0	1	1	3	13	21	29	41	69	103	315	596
WSW	0	0	0	0	0	3	13	21	29	38	58	85	98	345
W	0	0	0	0	0	3	13	21	29	38	52	62	72	290
WNW	0	0	0	0	0	3	13	21	29	38	33	32	37	206
NW	0	0	0	1	1	3	13	21	29	38	60	89	66	321
NNW	0	0	0	1	11	270	17	21	29	65	133	153	168	868
Total	0	0	0	13	23	1,192	385	792	1,907	6,679	2,070	2,972	13,485	29,455

Notes:
[a] Current population living between 10 and 80 km of the mine site were estimated using 2000 census data. Field reconnaissance was conducted in 2004 to verify data collected within 2.25 miles (3.6 km). See Section 2.3.1 for a detailed description of the methodology.

Table 2.3-5 Annual Average Labor Force and Employment Economic Sectors For Dawes and Box Butte Counties 1994 And 2009

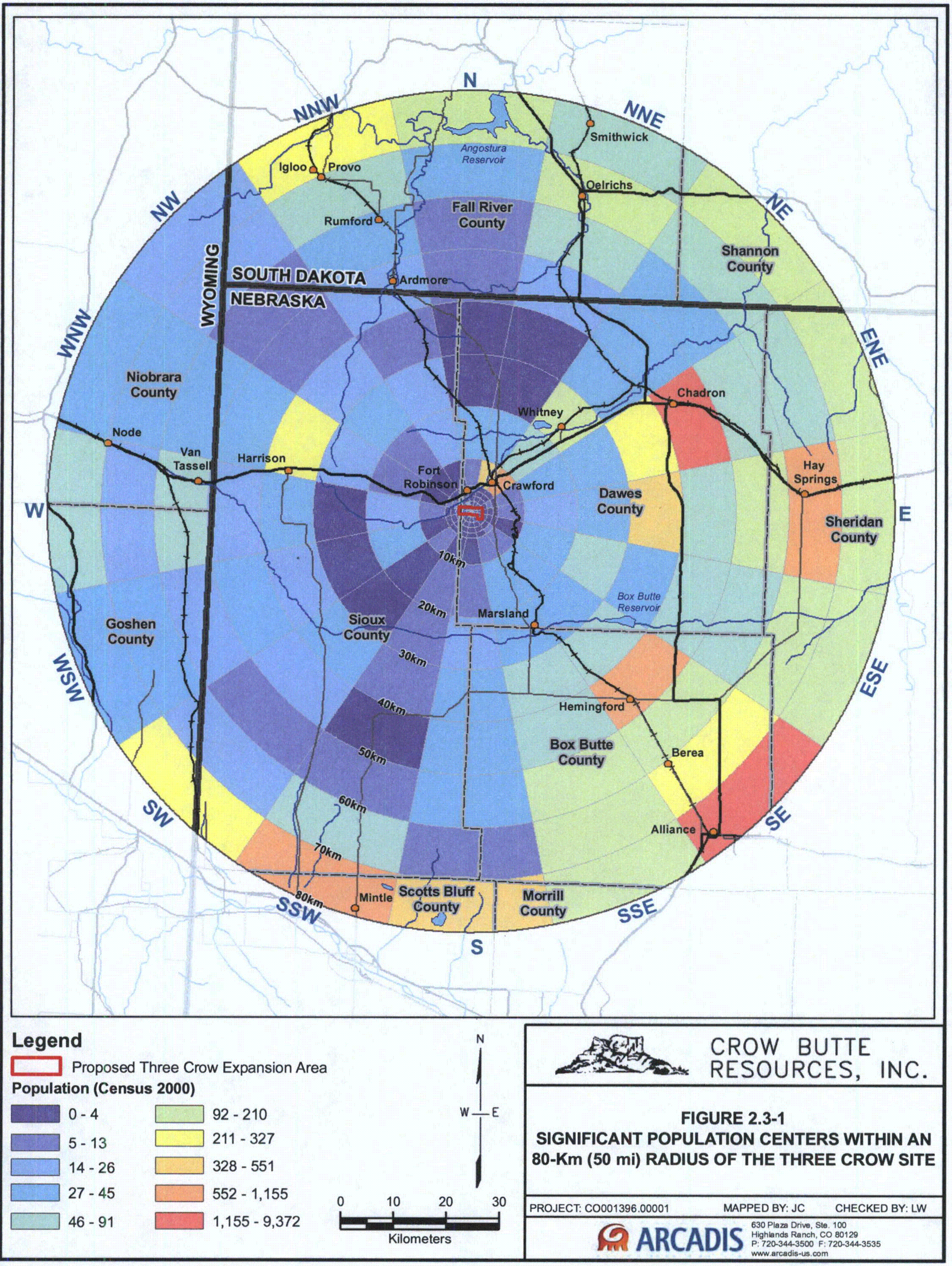
Sectors	Dawes		Box Butte	
	1994	2009	1994	2009
Labor Force	4,490	4,788	6,156	5,821
Unemployment	149	210	235	397
Unemployment Rate	3.3	4.4	3.8	6.8
Employment	4,341	4,578	5,921	5,424
Farm Employment	862	877	763	213
Non-Farm Employment Total	3,479	3,701	5,446	5,315
Manufacturing	165	13	402	N/A
Construction and Mining	136	228	80	126
Transportation, Communication, and Utilities	N/A	N/A	1,909	2,305
Retail	824	673	840	429
Wholesale	128	87	265	298
Financial, Insurance, and Real Estate	77	123	215	168
Information	N/A	46	N/A	103
Professional and Business Services	N/A	N/A	N/A	170
Education and Health Services	N/A	449	N/A	428
Leisure and Hospitality	N/A	507	N/A	433
Other Services	N/A	119	N/A	145
Government	1,384	1,000	955	1,095
Federal	144	124	65	61
State	721	297	67	75
Local	519	579	824	960

N/A = not available
Sources: NDOL 2010

Table 2.3-6 Race and Poverty Level Characteristics of the Population in the State of Nebraska, Dawes County, and Block Groups Within the TCEA – 2000

Population	Nebraska	Percent of Nebraska Pop.	Dawes County	Percent of Dawes County Pop.	Block Group 3, Census Tract 9506, Dawes County						Block Group 1, Census Tract 9501, Sioux County			
					Block 3145	Percent of Block 3145	Block 3148	Percent of Block 3148	Block 3149	Percent of Block 3149	Block 1200	Percent of Block 1200	Block 1360	Percent of Block 1360
Total Population	1,711,263	100.0%	9,060	100.0%	16	100.0%	0	0	2	100.0%	5	100.0%	0	0
White alone	1,533,261	89.6%	8,457	93.3%	16	100.0%	0	0	2	100.0%	5	100.0%	0	0
Black or African American	68,541	4.0%	73	0.8%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
American Indian and Alaska Native	14,896	0.9%	261	2.9%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Asian alone	21,931	1.3%	28	0.3%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Native Hawaiian and Other Pacific Islander	836	0.0%	5	0.1%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Some other race	47,845	2.8%	93	1.0%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Two or more races	23,953	1.4%	143	1.6%	0	0.0%	0	0	0	0.0%	0	0.0%	0	0
Hispanic or Latino	94,425	5.5%	220	2.4%										
Percent below poverty level:	9.40%	-	17.10%	-	8.3%*	-	8.3%*	-	8.3%*	-	17.2%*	-	17.2%*	-

* data for Block Group only
Source: USCB 2000a, 2000b, 2001



CROW BUTTE RESOURCES, INC.

FIGURE 2.3-1
SIGNIFICANT POPULATION CENTERS WITHIN AN 80-Km (50 mi) RADIUS OF THE THREE CROW SITE

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: LW

ARCADIS
630 Plaza Drive, Ste. 100
Highlands Ranch, CO 80129
P: 720-344-3500 F: 720-344-3535
www.arcadis-us.com

K:\CBR_Projects\CO001396_ThreeCrow2_GIS\ArcMaps\0001_TR\Fig_2_3-1_Pop_Rose_byBlock.mxd - 1/19/2010 @ 3:42:51 PM

2.4 Regional Historic, Archeological, Architectural, Scenic and Natural Landmarks

2.4.1 Historic, Archeological, and Cultural Resources

Previous cultural resource investigations in the general area surrounding the City of Crawford and Fort Robinson State Historic Park indicate that a variety of prehistoric and historic resources of potential significance exist in the vicinity. Resources include the Hudson-Meng prehistoric bison kill to the north of the area, several prehistoric camps and artifact scatters in the general areas, fur-trade period sites associated with the early history of City of Chadron, Fort Robinson, the Sidney-Deadwood Trail, the two historic railroads that cross where the City of Crawford emerged, and the City of Crawford itself. There has been extensive farming around the City of Crawford, which may have disturbed many earlier sites, but has also created historic farming sites and features.

The proposed TCEA is on private lands immediately south of Fort Robinson State Park. An architectural and structural properties search was completed at the Nebraska State Historic Preservation Office (SHPO) and an archaeological site search was completed at the Archaeology Division of the Nebraska State Historical Society (NSHS) in November 2005 for the project area Two previous cultural resources inventories had been documented near State Highway 2/71 east of the project area and the SHPO had no record of documented standing structures in the area. However, the SHPO noted that there were buildings shown on the topographic maps of the area, and these might include historic structures that would need to be recorded. One archaeological site (25DW238) was identified in the archeological site search east of the project area. An updated records search was requested in November 2007, and no new cultural resource inventories or documented sites were reported. Fort Robinson State Park, north of the project area, contains Fort Robinson and the Red Cloud Indian Agency. Together these sites are a National Historic Landmark. The Red Cloud Indian Agency was relocated to the City of Crawford area from Wyoming in 1873 and Fort Robinson was established in 1874 to protect the agency. Fort Robinson remained an active military post until 1948. There are no other reported National Register Properties or National Natural Landmarks in the vicinity of the project.

On January 16, 2008 letters identifying the nature and location of the proposed project were sent to the Nebraska Commission on Indian Affairs and the following 14 tribes: the Apache Tribe of Oklahoma; the Cheyenne River Sioux Tribe; the Cheyenne and Arapaho Tribes of Oklahoma; the Crow Creek Sioux Tribe; the Crow Nation; the Kiowa Tribe of Oklahoma; the Lower Brule Sioux Tribe; the Northern Arapaho Tribe; the Northern Cheyenne Tribe; the Oglala Sioux Tribe; the Pawnee Nation of Oklahoma; the Rosebud Sioux Tribe, the Santee Sioux Nation; and the Standing Rock Sioux Tribe. Follow up telephone calls were made in February and March to verify that the information had reached the appropriate persons in each tribe and to ask whether the tribes had any concerns about the project or were aware of any traditional concerns in the immediate vicinity of the project. Harvey Whitewoman of the Oglala Sioux called before the follow up calls were begun to ask what effect the proposed project might have on water quality. In addition, the Northern Cheyenne Tribe sent a memo expressing concern about "peripheral effects and development outside the project, and the Rosebud Sioux sent a letter indicating that they had no records of any sites in the project area, but that the Rosebud Sioux Tribe was against any uranium mine.

The identification and assessment of cultural resources within the TCEA entailed a cultural resource inventory of a 2,100-acre area of anticipated development. This area was inventoried by Greystone (now ARCADIS) archaeologists between January 9 and January 15, 2006 (Späth 2007). The proposed TCEA includes approximately 1,643 acres, which is entirely within the 2,100 acre cultural resources survey area. The TCEA was surveyed for the presence of cultural resources that may be impacted by the proposed mine development. Seven historic sites, one isolated historic farm implement, one isolated historic artifact, and two isolated prehistoric artifacts were located and identified. In addition, there are two historic farms just outside the TCEA. The historic sites in the TCEA are two artifact scatters, one farm complex, one rural residence, two abandoned sites with collapsed buildings, and a collapsed windmill and water tank. The individual objects and artifacts are an abandoned plow, a historic fraternal medallion and two prehistoric flakes. None of these sites are distinctive or outstanding, and all of the sites are recommended as not eligible for the National Register of Historic Places. Because these resources are considered not eligible, they are not historic properties. The proposed TCEA will have no effect on historic properties, and no further cultural resource work is recommended. The Nebraska SHPO has concurred that the reported resources are not eligible for the National Register of Historic Places and that the proposed project will not affect archaeological, architectural, or historic context properties (Steinacher and Puschendorf 2007).

Specific information included in cultural resource investigation falls under the confidentiality requirement for archeological resources under the National Historic Preservation Act, Section 304 (16 U.S.C. 470w-3(a)). Additionally, disclosure of such information is protected under Nebraska State Stature Section 84-712.05 (13 and 14). Information that is not considered confidential is presented in Appendix O of the TCEA Environmental Report. This information consists of a modified report with project description, study area, location map, affected environment, background information, methods, results (without confidential information) and evaluation and recommendations.

Under separate correspondence, a copy of the Cultural Resource Inventory Report and supporting correspondence (the Nebraska SHPO correspondence letter and the correspondence to the tribal authorities).is being submitted to the NRC. The contents of Appendices B and C and Figure 1 should be treated as "CONFIDENTIAL" information for the purpose of public disclosure of this NRC License Amendment. Each page of the confidential cultural resource information has been marked as follow:

Privileged Information – Disclosure of Site Information is Restricted, NHPA Section 304 (16 U.S.C. 470w-3(a))

The cover pages for each of the appendices have been marked with a more detailed statement, as follows:

For official use only
Submitted under 10 CFR 2.390
Disclusre of Site information is Restricted
NHPA Section 304 (16 U.S.C. 470w-3(a)
Nebraska Public Records Statutes (Neb. Rev. Stat. 84-712.05(13)).

2.4.2 Scenic Resources

2.4.2.1 Introduction

The TCEA is on private land that is not managed to protect scenic quality by any public agency. However, it is located in scenic landscape of the Pine Ridge area of northwestern Nebraska and is visible from sensitive viewing areas. The existing landscape and the visual effect of the proposed facilities have been inventoried and assessed for the proposed project using the Bureau of Land Management (BLM) Visual Resource Management (VRM) system.

2.4.2.2 Methods

The VRM system is the basic tool used by the BLM to inventory and manage visual resources on public lands. The VRM inventory process involves rating the visual appeal of a tract of land, measuring public concern for scenic quality, and determining whether the tract of land is visible from travel routes or observation points.

The scenic quality inventory was based on methods provided in BLM Manual 8410 – *Visual Resource Inventory*. The key factors of landform, vegetation, water, color, influence of adjacent scenery, scarcity, and cultural modifications were evaluated according to the rating criteria, and provided with a score for each key factor. The criteria for each key factor ranged from high to moderate to low quality based on the variety of line, form, color, texture, and scale of the factor within the landscape. A score was associated with each rating criteria, with a higher score applied to greater complexity and variety for each factor in the landscape. The results of the inventory and the associated score for each key factor are summarized in **Table 2.4-1**. According to NUREG-1569; 2.4.3(7), if the visual resource evaluation rating is 19 or less, no further evaluation is required. The total score of the scenic quality inventory is 13; however, an analysis was prepared to reflect the growing concern some residents may have for the scenic resource, as Dawes County is expected to continue to develop tourism in the region.

<u>Visual Resource Management Classes</u>

The elements used to determine the visual resource inventory class is the scenic quality, sensitivity levels, variety classes, and distance zones. Each of the elements used to identify the VRM Class is defined below:

Scenic Quality - Scenic quality is a measure of the visual appeal of a tract of land. In the visual resource inventory process, public lands are assigned an A, B, or C rating based on the apparent scenic quality, which is determined using seven key factors: landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modifications. During the rating process, each of these factors is ranked comparatively against similar features within the physiographic province.

Sensitivity Level – A degree or measure of viewer interest in the scenic qualities of the landscape. Factors to consider include 1) type of users; 2) amount of use; 3) public interest; 4) adjacent land uses; and 5) special areas. Three levels of sensitivity have been defined:

- Sensitivity Level 1 – The highest sensitivity level, referring to areas seen from travel routes and use areas with moderate to high use.

- Sensitivity Level 2 – An average sensitivity level, referring to areas seen from travel routes and use areas with low to moderate use.
- Sensitivity Level 3 – The lowest sensitivity level, referring to areas seen from travel routes and use areas with low use.

Distance Zones – Areas of landscapes denoted by specified distances from the observer, particularly on roads, trails, concentrated-use areas, rivers, etc. The three categories are foreground-middleground, background, and seldom seen.

- Foreground-Middleground – The area visible from a travel route, use area, or other observer position to a distance of 3 to 5 miles. The outer boundary of this zone is defined as the point where the texture and form of individual plants are no longer apparent in the landscape and vegetation is apparent only in pattern or outline.
- Background - The viewing area of a distance zone that lies beyond the foreground and middleground. This area usually measures from a minimum of 3 to 5 miles to a maximum of about 15 miles from a travel route, use area, or other observer position. Atmospheric conditions in some areas may limit the maximum to about 8 miles or increase it beyond 15 miles.
- Seldom Seen – The area is screened from view by landforms, buildings, other landscape elements, or distance.

The visual resource inventory classes are used to develop visual resource management classes, which are generally assigned by the BLM through the resource management plan process. VRM objectives are developed to protect scenic public lands, especially those lands that receive the greatest amount of public viewing. The following VRM classes are objectives that outline the amount of disturbance an area can tolerate before it no longer meets the visual quality of that class.

- Class I Objective: To preserve the existing character of the landscape. The level of change to the characteristic landscape should be very low and must not attract attention.
- Class II Objective: To retain the existing character of the landscape. The level of change to the characteristic landscape should be low.
- Class III Objective: To partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate.
- Class IV Objective: To provide for management activities which require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high.

The Scenic Quality, Sensitivity Level, and Distance Zone inventory levels are combined to assign the VRM Class to inventoried lands as shown in **Table 2.4-2.**

2.4.2.3 Affected Environment

The TCEA lies in the Pine Ridge Escarpment ecoregion, which is a subregion of the Western High Plains ecoregion. The Pine Ridge Escarpment is distinguished from the surrounding shortgrass and mixed grass prairies of the Western High Plains in northwestern Nebraska by dramatic sandstone and siltstone bluffs, escarpments, areas of exposed bedrock, and Ponderosa pine woodlands. Ponderosa pine is found on ridge tops, north-facing and east-facing slopes and, in lesser density, on south-facing and west-facing slopes (EPA 2000). The ecoregion features diverse and beautiful scenery that provides a setting for a variety of recreational activities as well as agriculture and other land uses.

The TCEA landscape is rural and agricultural in character, and is composed primarily of scenery that is common for the ecoregion. Vegetation cover consists of grassy meadows and croplands interspersed with shrubby riparian growth along drainages. The landscape colors are dominated by tan, gold and green vegetation. The colors and values (degrees of lightness and darkness) of soils and vegetation are similar, exhibiting little contrast during most months of the year, although the dark greens of Ponderosa pine in the backdrop of the TCEA exhibit striking color contrasts throughout the year. The scenic quality of the TCEA is enhanced by the backdrop of the spectacular Red Cloud Buttes north of Fort Robinson State Park (located adjacent to the north TCEA boundary), and of slopes covered with Ponderosa pine in the Nebraska National Forest to the south.

The characteristic landscape of the TCEA consists of flat to rolling hills dissected by deeply incised gorges formed by tributaries of White River, which is located north of the TCEA. The terrain becomes progressively higher in elevation to the north. The TCEA is blocked from view of portions of Four Mile Road by low ridges located in close proximity to the road.

The visual character of the landscape includes human modification from a variety of land uses, including open lands, cropland, roadways, rural residences, and utility corridors. Open land used for grazing activities is the dominant land use in the TCEA. Croplands, primarily wheat, are also evident from Four Mile Road. The TCEA is accessible from Four Mile Road, a gravel-surfaced county road, which in turn connects to State Highway 2/71 (SH-2/71), one of the primary north-south roadways through Dawes County. Human modifications to the natural landscape evident in the TCEA include private roads, rural residences, and electric distribution lines.

2.4.2.4 TCEA Visual Inventory

Most of the TCEA is characterized by the low, rolling plains and agricultural land uses that are characteristic of the Pine Ridge area in northwestern Nebraska. The scenic quality of the TCEA landscape is typical of the ecoregion, and is rated as Class B. Class A landscapes consisting of the rugged buttes of the Fort Robinson State Park are visible to the north of the project area. The buttes provide a scenic backdrop to the project area that is visible to travelers on Nebraska State Highway (SH) 2/71, which forms the east boundary of the project area.

Sensitive Viewing Areas

Sensitive viewing areas in the TCEA include Four Mile Road, the primary transportation route through the TCEA, and rural residences. Fort Robinson State Park (Park), which is located to the north of the TCEA, is also a sensitive viewing area because of the potential visibility of proposed facilities to Park visitors. In general, residents and other users of the region are accustomed to viewing human modification in the rural landscape, but could be sensitive to increased levels of development.

The characteristic landscape of the TCEA as viewed from Four Mile Road and the residences consists of a broad expanse of mixed grass prairie and cropland with scenic backdrops to the north and south. The TCEA is located approximately 1.5 miles west of SH-2, and is not visible from the highway. Public use of county and private roads within the TCEA is relatively low with motorists falling into the categories of local ranchers and residents.

The greatest number of viewers of the proposed facilities would be traveling on Four Mile Road. The majority of motorists on the road would be residents within and outside of the TCEA. There are 2 occupied residences within the TCEA. The TCEA landscape is also within the viewshed of three residences within the 2.25-mile AOR that are also within 0.5 miles of the TCEA. An additional 15 residences within the 2.25-mile AOR do not have views of most of the TCEA landscape because views are blocked by vegetation or landforms, or because specific features of the TCEA landscape are made indistinct by distance.

The level of use on Four Mile Road and residences within or near to the TCEA is low to moderate, or a Sensitivity Level 2. Viewers at isolated rural residences with views of the project area are few compared with viewers at other sensitive viewing areas, but these residents would generally have a strong level of concern for changes in the viewshed.

A potential sensitive viewing area is the Fort Robinson State Park (Park), located along the north boundary of the TCEA. The Park features a variety of developed recreation facilities, including campgrounds and other lodging facilities, trails, and museums. The majority of facilities and associated recreational activities occur at historic structures and developed areas in close proximity to U.S. Highway 20, and along the White River. A site reconnaissance of the Park was conducted to identify those areas within the Park that would provide views of proposed activities in the TCEA. The view towards the TCEA from developed areas of the park is limited to the immediate foreground distance zone (up to 0.5 miles), because the TCEA is blocked from view by an escarpment along the south bank of the White River, at the north edge of a terrace formed by fluvial downcutting. The escarpment rises in elevation an estimated average of 100 feet above the White River valley bottom which contains the Parks developed facilities. While the level of concern for scenic landscapes would be high for many Park visitors, the TCEA would not be visible from most of the Park.

The TCEA is visible from Smiley Canyon Scenic Drive, which is accessed from Highway 20 at the historic Park facilities. Ridge and hilly terrain blocks views of the TCEA as seen from most of the Scenic Drive; however, a broad, expansive view of the TCEA is spread before east-bound motorists who descend the Scenic Drive to the highway. The TCEA is approximately two miles southeast of the Scenic Drive, so the lines and forms of structures currently within the TCEA are difficult to discern from the surrounding landscape. Although the level of concern for scenic landscapes for motorists on the Scenic Drive would be high, the distance minimizes the visibility of specific features within the landscape that are small in scale relative to the landscape. Therefore, motorists on Smiley Canyon Scenic Drive have a low viewer sensitivity level to changes in the Project area landscape based the distance between the viewer and the landscape, short duration of view, and low user volume

VRM Class

Based on the project area Class B scenic quality, the Sensitivity Level 2 (Medium) as viewed from the Four Mile Road, Smiley Canyon Scenic Drive, residences, and the location of the project area in the foreground-middleground distance zone as seen from the sensitive viewing areas, the TCEA has been assigned Class III for both the visual resource inventory and the VRM objective.

2.4.2.5 Environmental Consequences

The visible surface structures proposed for the TCEA include wellhead covers, wellhouses, electrical distribution lines, and one satellite processing facility. The project will use existing and new roads to access each wellhouse and the satellite facility.

Each wellhead cover would consist of a weatherproof structure placed over each well. Each structure would be approximately 3 feet high and 2 feet in diameter. Each wellhouse consists of a small shed. The facility building would be approximately 100 feet by 130 feet in size. A permanent disturbance area around each wellhouse would be sized to provide an adequate vehicle turn-around. There would be an estimated 10 to 12 wellhouses in the TCEA.

Electric distribution lines would connect wellhouses to existing electric distribution lines. The distribution poles would be approximately 20 feet high. The poles would be wooden so that their natural color harmonizes with the landscape.

Short-term Effects

Temporary and short-term effects during the construction period to the visual character of the landscape at each well pad would result from wellhouse construction, well drilling, and associated construction of ancillary facilities, such as access roads and electric distribution lines. Drilling and other construction activities would typically occur 8 to 12 hours per day during the regular work week.

Following completion of facility installation, temporary disturbance areas would be reclaimed to pre-construction conditions. Only permanent disturbances associated with operations and maintenance of the facilities will remain following post-construction restoration.

Long-term Effects

Long-term effects for the project would result from the addition of structures to the landscape, such as the satellite facility, wellhouses, wellhead covers, and associated access roads and electric distribution lines. Effects from long-term activities would occur over the production life of the project.

Project development would alter the physical setting and visual quality of portions of the landscape, which would affect the overall landscape to some degree, as viewed from sensitive viewing areas. The proposed facilities would introduce new elements into the landscape and would alter the existing form, line, color, and texture, which characterize the existing landscape. The project would primarily affect croplands.

In foreground-middleground views, the satellite facility, wellhouses, and associated access road clearings would be the most obvious features of development. Clearings and access roads would be visible as light-tan exposed soils in geometrically-shaped areas with straight, linear edges that provide some textural and color contrasts with the surrounding cropland. The satellite facility, wellhouses, and wellhead covers would be painted to harmonize with the surrounding soil and vegetation cover. These facilities would be visible from Four Mile Road and the residences within or in close proximity to the TCEA, but would be subordinate to the rural landscape.

The electric distribution line poles would be an estimated 20 feet tall, and would be located throughout the project area to connect wellhouses with existing lines. The distribution lines are similar in appearance to those typical of the rural landscape, but would occur at a higher density than on adjacent lands. The lines would be obvious to viewers at the sensitive viewing areas, but would not change the rural character of the existing landscape.

Wellhead covers would be difficult to discern in the landscape from any sensitive viewing area. The form and textural contrast would be very weak because the relatively low profile (3 feet high) and small size of the facilities would disappear into the surrounding textures of soil and vegetation. Generally, color contrasts are most likely to be visible in foreground-middleground distance zone. However, the wellhead covers would be painted a tan color that would harmonize with the surrounding vegetation and soil colors. Therefore, contrast of line, form, texture, and color would be low. The facilities would not be noticeable to the casual observer. Wellhead covers would be visually subordinate to the landscape in foreground-middleground distance zone.

The objective of VRM Class III is to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. The existing rural/agricultural landscape would be retained, but would be modified with a noticeable, but minor, industrial component. Line and textural contrasts of the well houses, the satellite facility structures, and associated access roads and distribution lines would be visible from sensitive viewing areas; however, contrasts would be low to moderate. The VRM Class III objectives would be met by proposed long-term project facilities.

2.4.2.6 Mitigation

Mitigation measures are meant to minimize adverse contrasts of project facilities with the existing landscape. The measures should be applied to all facilities, even those that meet VRM objectives. Mitigation would enable proposed project facilities to harmonize with the surrounding landscape to the extent feasible.

In addition to selecting paint colors that harmonize with the surrounding landscape, several other measures would minimize adverse effects of project facilities in the landscape.

- Using existing vegetation and topographic features to screen wells, facilities, and roads;
- Painting facilities with non-reflective paint that harmonizes with the surrounding landscape;
- Avoiding straight line-of-sight road construction;
- Aligning roads with the contours of the topography rather than cutting straight across contours to well houses, although this method of aligning the roads may result in a greater area of disturbance;
- Constructing clearings to appear as natural clearings by rounding corners and feathering the vegetation interface between the clearing and the surrounding grasses and shrubs (In those areas where the existing vegetation is dense, clearings should be irregular in shape); and

- Removing construction debris immediately because it creates undesirable textural contrasts with the landscape.

In general, resource protection measures proposed for erosion control, road construction, rehabilitation and revegetation, and wildlife protection would mitigate effects to visual quality.

2.4.3 References

Späth, Carl. 2007. *Crow Butte Resources Three Crow Permit Area Class III Cultural Resource Inventory, Dawes and Sioux Counties, Nebraska.* ARCADIS U.S., Inc., Highlands Ranch. Colorado. Prepared for Crow Butte Resources, Inc., Crawford, Nebraska. December 2007.

Steinacher, Terry, and L. Robert Puschendorf. 2007. *Three Crow Permit Area, Crow Butte Resources, Dawes and Sioux Counties, NE, H.P. #0302-033-01.* Letter to Rhonda Grantham, Crow Butte Resources from the Nebraska State Historical Society, 17 December 2007.

U.S.Department of Interior. Bureau of Land Management. (BLM). 1986. *Visual Resource Contrast Rating*. BLM Manual Handbook 8431-1.

U.S. Department of .Interior. Bureau of Land Management (BLM). 1986. *Visual Resource Inventory*. BLM Manual Handbook 8410-1.

Table 2.4-1 Scenic Quality Inventory and Evaluation for the Three Crow Expansion Area

Key Factor	Rating Criteria	Score
Landform	Flat to rolling terrain with no interesting landscape features	1
Vegetation	Some variety of vegetation; cropland, range, riparian	3
Water	Water is present, but not evident as viewed from residences and roads	0
Color	Some variety in colors and contrasts with vegetation and soil.	3
Influence of adjacent scenery	Buttes of Fort Robinson State Park provide a scenic backdrop	5
Scarcity	Landscape is common for the region	1
Cultural modifications	Existing modifications are agricultural, and introduce no discordant elements.	0
	Total Score	13

Table 2.4-2 Determining BLM Visual Resource Inventory Classes

Visual Sensitivity		High			Medium			Low
Special Areas		I	I	I	I	I	I	I
Scenic Quality	A	II	II	II	II	II	II	II
	B	II	III	III/IV	III	IV	IV	IV
	C	III	IV	IV	IV	IV	IV	IV
Distance Zones		f/m	b	ss	f/m	b	ss	ss

f/m = foreground-middleground
b = background
ss = seldom seen

2.5 Climate and Meteorology

The TCEA is located in the north central portion of the Nebraska panhandle, with weather patterns being typical of a semi-arid, continental climate. This climate is characterized by warm summers, cold winters, light precipitation, and frequent changes in the weather. The area is subject to wide seasonal and day-to-day variations in temperature and precipitation. Dawes County is usually warm in the summer, with frequent spells of hot weather and occasional cool days interspersed, although sporadically, throughout the summer. These changes in weather can generate thunderstorms, which deliver a majority of the total annual precipitation.

The Rocky Mountains, located to the west of the site, and the Black Hills, located to the north, effectively block moisture from these directions, while moisture from the south is directed eastward by a plateau south of the region. As a result of this topography, the project area is generally drier than the rest of the panhandle.

This section provides meteorological data that characterizes the TCEA area, providing historical information for temperature, precipitation, relative humidity, mean sea level pressure, and wind speed and wind direction.

2.5.1 Sources of Meteorological Data

Data sources for the meteorological conditions used for this report come from three major sources:

2.5.1.1 High Plains Regional Climatic Center

The High Plains Regional Climatic Center (HPRCC) is located in Lincoln, Nebraska. The partners of this organization consist of National Climatic Data Center, Regional Climatic Centers and State Climate Offices. The mission of the HPRCC is to increase the use and availability of climate data in the High Plains Region of the U.S (HPRCC 2010). The HPRCC maintains historical climate data, archiving all relevant data from National Weather Service surface weather networks.

Historical data for temperature and precipitation were obtained from the HPRCC website for the Chadron National Weather Station (NWS). The period of record for the Chadron NWS covers data for over 100 years of observations between 1894 to the present. Summaries of historical data of temperature and precipitation for the Chadron NWS were collected and used in this is section.

2.5.1.2 Chadron National Weather Station (NWS) Data

The HPRCC data were collected at the Chadron 1 NWS site (latitude 42° 50' north, longitude -103° 01' west with a ground elevation of 1021 meters [3350 feet] above mean sea level). The NWS is approximately 8.0 km (5.0 miles) west northwest of the City of Chadron, 32.2 km (20 miles) east northeast of the City of Crawford, and approximately 40.2 km (25 miles) northeast of the proposed satellite facility (**Figure 2.5-1**).

Wind speed and wind direction data were obtained for the Chadron site by purchasing data from the National Climatic Data Center (NCDC), the world's largest archive of weather data, and from the Weather Underground for relative humidity (NCDC 2010).

2.5.1.3 Whitney Coast Guard Station (WHN5)

The Whitney Coast Guard Station (WHN5) (latitude 42° 74' north longitude -103° 33' west with a ground elevation of 1071 meters [3514 feet], above mean sea level) is operated by the U.S. Coast Guard (USCG) on behalf of the U.S. Department of Transportation (DOT). The weather sensors at the site are owned by National Oceanic and Atmospheric Administration (NOAA). The Whitney station is located between the City of Chadron and the TCEA site, being located approximately 16.1 kilometers (10 miles) northeast of the proposed TCEA site (**Figure 2.5-1**).

Weather data for the Whitney station were obtained from the Earth Systems Research Laboratory (ESRL 2010). Meteorological data obtained for this site for use in this section consisted of hourly relative humidity and barometric pressure (no precipitation, winds speed or direction). Data for 2002 through 2009 was obtained for this station for relative humidity and barometric pressure (adjusted to mean sea level pressure).

2.5.1.4 CBR Onsite Meteorological Station

An onsite meteorological (MET) station was operated at the nearby current operating Crow Butte Project. This MET station was operating from May 1982 to April 1984. The MET Station is located approximately 3.7 miles northeast of the northeast corner of the TCEA license boundary (1093605 Easting 503789 Northing) (**Figure 2.5-1**). Wind speed and direction measurements at this location were used for inclusion in this section.

2.5.2 Temperature

2.5.2.1 Chadron NWS

Annual mean minimum and maximum temperatures for the Chadron NWS are 1.6° C and 16.5° C, respectively, with a mean average of 9.1° C (**Table 2.5-1**) (HPRCC 2010). The number of days of maximum and minimum temperatures is presented in **Table 2.5-2**. Temperatures at or greater than 0° C and 32.2° C, have been recorded for an average of 44.1 and 38.7 days, respectively, while temperatures at or less than 0° C and 17.8° C have been recorded for an average of 165.6 and 18.5 days, respectively. For the time-period between 1894 and 2009, the lowest recorded mean monthly average temperature was -11.3° C for the month of January and the highest recorded mean monthly average temperature was 31.9° C for the month of July (**Table 2.5-1**). July is the average warmest month and January is the average coolest month of the year.

2.5.2.2 Whitney WHN5 Station

Monthly average temperature measures for WHN5 station for 2002 through 2009 ranged from a minimum of -26.7 °C in 2009 to a maximum of 39.2 °C in 2003 (**Table 2.5-4**). Minimum temperatures ranged from -15.6 °C in 2003 to a maximum of -26.7 °C in 2009, while maximum temperatures ranged from 29.2 °C in 2004 to a maximum of 37.8 °C in 2009.

2.5.3 Precipitation

2.5.3.1 Chadron NWS

Precipitation occurs throughout the year (mean annual total of 41.9 centimeters), with yearly averages ranging from a monthly low of 1.2 centimeters in December through February with highs of 7.3 and 7.1 centimeters in May and June, respectively (**Table 2.5-3**). The highest maximum 24-hour event was 26.4 centimeters in the June time-frame and the lowest 24-hour event of 4.8 centimeters being for the month of December. The area has any average annual mean of 111.3 centimeters of snowfall, with annual amounts of snow events ranging from 14 to 22.6 centimeters for the months of November through April. The months of January, March and April had the highest maximum monthly snow fall amounts, i.e., 88.1, 88.1, and 84.8 centimeters, respectively. Historically, the most precipitation on average occurs in May.

2.5.4 Relative Humidity

2.5.4.1 Whitney WNH5 Station

Relative humidity measurements were taken from the Whitney WHN5 station for the years 2002 – 2009 (**Table 2.5-4**). The range of the average relative humidity (RH) measurements ranged from 54.2 to 63.7 percent. The range of the average minimum RH values ranged from 11.4 to 20.5 percent, and the average maximum values ranged from 94.0 to 98.5 percent.

2.5.5 Sea Level Pressure

2.5.5.1 Whitney WNH5 Station

Sea level pressure (SLP) for the City of Crawford area is calculated by using the site station pressure measurements and then correcting for the difference in elevation from sea level. Station pressure measurements were taken from the Whitney WHN5 station for the years 2002 – 2009 (**Table 2.5-4**).

The SLP data for eight years showed a range of 1015.0 to 1016.1 millibars (mb) for the average of measurements, a range of 946.3 to 1001.3 mb for the average minimum measurements, and a range of 1030.0 to 1044.7 mb for the average maximum measurements.

2.5.6 Mixing Height

The nearest national weather station to the TCEA that reports mixing height values is located at North Platte, Nebraska. This station is location approximately 170 miles southeast of the City of Crawford. Due to the distance, the data are not considered representative of the City of Crawford area. Default mixing height values can be obtained from different atmospheric stability classes. The U.S. Environmental Protection Agency (EPA) also provides a default value for calculating the mixing layer height. The default method for calculating mixing height is to use the interpolation scheme employed in the PCRAMMET meteorological processor, which uses the twice-daily mixing heights from the nearest NWS upper observation site, coupled with the stability category determined for the hour. The NRC MILDOS-AREA, a computer program for calculating radiation doses from uranium recovery operations, allows for the use of a default value of 1000 meters (NRC 1981).

2.5.7 Wind Speed and Direction

2.5.7.1 CBR Onsite MET Station and Chadron NWS

Wind speed and direction are key factors affecting the movement of air and other gases in the atmosphere. The wind speed and direction at a location directly affect how emissions are dispersed (affecting concentration and plume dimensions) and in which directions emissions will be conveyed from a source. A wind rose is developed from these data and depicts pictorially the frequency of occurrence of winds in each of the specified wind direction sectors and wind speed classes for a given location and time period.

CBR has used wind speed and direction data from the nearby CBR onsite meteorological data records for the preparation of the onsite wind rose (**Figure 2.5-1**). The results of this monitoring were compared to the data available for the Chadron NWS station, which is located at the airport.

Figure 2.5-2 shows the wind rose for the CBR onsite data from May 1982 to April 1984. **Figures 2.5-3** and **2.5-4** show the wind rose for Chadron NWS data from April 1982 to May 1984 and 2000 to 2009, respectively. A comparison of these three figures shows that the wind predominantly blows from the third quarter quadrant (S, SSW, WS, WS, WSW and W) of the wind rose for both CBR and the Chadron NWS site, with the Chadron NWS data showing a more predominant westerly wind direction. Both locations also show a minor trend of wind blowing from the NNE and NE.

For the CBR Onsite MET Station, **Table 2.5-5 - 2.5-11** shows the frequency of winds by direction and speed for the six stability classes. **Table 2.5-12** shows the annual relative joint frequency distribution. **Tables 2.5-13** and **2.5-14** present the wind direction and speed frequency distribution for the Chadron NWS for the time periods April 1982 – May 1983 and 2000 – 2009, respectively. The Chadron NWS had similar wind speed frequency distribution as that of the CBR Onsite MET Station data. The CBR Onsite MET Station data showed slightly higher frequencies of low wind speeds in the range of 1 – 4 knots than that of the Chadron NWS.

CBR will be installing an onsite meteorological station at or near the TCEA site at the outset of operations to verify specific site meteorological conditions. This station will provide measurements of wind speed, wind direction, relative humidity, barometric pressure, precipitation, temperature, evaporation rates and solar radiation. The station will be operated to collect 12 months of data acceptable to the regulatory agencies. These data will then be compared to the Chadron NWS data to ensure the data is considered representative of the TCEA area.

2.5.8 Air Quality

2.5.8.1 National Ambient Air Quality Standards

The NDEQ regulations are based on federal and/or state law, with the primary source of the authority for air quality regulations being the federal Clean Air Act (NDEQ 2010). The NDEQ adopts the majority of these federal regulations into Title 129 (Nebraska Air Quality of the Nebraska Administrative Code). The basic foundation of the NDEQ air program is the National Ambient Air Quality Standards (NAAQS), which are concentrations of pollutants the EPA has established (and adopted by the NDEQ) as being protective of human health and the environment. The standards are established for six "criteria" pollutants: particulate matter, sulfur dioxide, nitrogen oxides, carbon monoxide, ozone and lead (**Table 2.5-15**). The state of Nebraska is required to keep areas in compliance with the standards and restoring compliance in any areas out of compliance. The NDEQ has several ambient air monitors located throughout the state to measure the concentrations of pollutants in the ambient air (NDEQ 2010). An area may be classified as nonattainment if the concentration of one or more criteria pollutants in an area is found to exceed the regulated or "threshold" level for one or more of the NAAQS. Those areas with concentrations of criteria pollutants that are below the levels established by the NAAQS are considered in attainment or unclassifiable.

The overall air quality of the State of Nebraska is considered to be good. Nebraska is located in a part of US that is largely attainment with NAAQS, thereby minimizing the impact of pollutant transport from other states on Nebraska air quality (NDEQ 2009). All areas within the state are in attainment with state and federal air quality standards (i.e., NAAQS) (NDEQ 2009). The City of Omaha previously had a nonattainment designation for lead, but due to actions by Omaha Air Quality Control, NDEQ, EPA and local industries, the area is now classified as attainment. The City of Omaha is located over 375 miles from the TCEA area. The EPA proposed a new (and lower) ozone standard in the Jan. 19, 2010 Federal Register. When the rule is finalized, the Omaha/Council Bluffs area may be significantly impacted if its levels of ozone pollution are above the regulatory limits.

There are no ambient air quality monitoring data for criteria pollutants in the proposed TCEA license boundary. However, there are a limited amount of state (Nebraska and South Dakota) and federal monitoring sites in the region of the TCEA that can be used as levels representative of the region for the monitored parameters. These monitoring sites are maintained for a variety of purposes, including for regional background purposes by the NDEQ and South Dakota Department of Environment & Natural Resources (SD DENR), as per Appendix D of 40 CFR Part 58.

Regional monitoring sites and parameters measured are presented in **Table 2.5-16**. The locations of the monitor sites are shown in **Figure 2.5-5**. Sites are located in western Nebraska and western South Dakota. The summary of the data available at the time of preparation of this section are presented in **Tables 2.5-17** through **2.5-23**. The results of this monitoring indicates the regions being monitored, included the TCEA area, are well within compliance of NAAQS standards.

2.5.8.2 Prevention of Significant Deterioration

In addition to the ambient air quality standards, there are national standards for the Prevention of Significant Deterioration (PSD) of air quality (40 CFR 51.166). The PSD program is administered by the State of Nebraska and South Dakota, with their programs designed to protect the air quality in area that are in attainment with the NAAQS and to prevent degradation of air quality in areas below the standard (designed as clean air areas). PSD differs from the NAAQS in that the NAAQS provides for maximum allowable concentrations of pollutants, while PSD requirements provide maximum allowable increases in concentrations of pollutants for areas already in compliance with the NAAQS. The PSD requirements establish allowable pollution "increments" that may be added to the air in each area while still protecting air quality. The increment is the maximum allowable deterioration of air quality. The maximum allowable increments applicable to Nebraska and South Dakota are shown in **Table 2.5-24.**

The allowable increments vary by location across the states. Those areas characterized as Class I (i.e., National Parks and Wilderness Areas) allow for less incremental pollution increase. Class III areas are planning areas set aside for industrial growth. The areas classified as Class II are essentially all other areas of the state not designated as Class I or Class III. There are no Class I National Park and Wilderness Areas in Nebraska. The Soldier Creek Wilderness Area located north of Fort Robinson is not designated as Class I. The State of South Dakota has two Class I

Areas: Badlands and Wind Cave National Parks. The Wind Caves National Park is closer to the TCEA, at a distance of approximately 63 miles.

No potential impacts to NAAQS parameters or PSD Class I, II or III areas are expected to occur as the result of the TCEA operations. The primary emissions from the proposed TCEA will be tailpipe emissions of nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), non-methane-ethane volatile organic compounds (VOC and particulate matter with a diameter less than ten micrometers (PM_{10}) resulting from vehicle traffic within the TCEA. The majority of the emissions generated during construction will be fugitive dust and vehicle combustion emissions. Effects of air emissions and impacts associated with construction and operations are discussed in Section 7.2.1.

2.5.9 References

Earth Systems Research Laboratory. (ESRL). 2010. Meteorological Data 2000 – 2009 (Whitney, Nebraska). [Web Page]. Located at: http://www.esrl.noaa.gov/index.html. Accessed on: March 01, 2010.

High Plains Regional Climate Center. (HPRCC). [Web Page]. Located at: http://www.hprcc.unl.edu/. Accessed on: March 19, 2010.

Nebraska Department of Environmental Quality. (NDEQ). 2010. *Environmental Fact Sheet: Establishing Air Quality Regulations in Nebraska.* [Web Page]. Located at: http://www.deq.state.ne.us/. Accessed on: March 18, 2010.

Nebraska Department of Environmental Quality. (NDEQ). 2009. *NDEQ 2009 Ambient Air Monitoring Network Plan.* [Web Page]. Located at: http://www.deq.state.ne.us/. Accessed on: March 18, 2010.

U.S. Nuclear Regulatory Commission, (NRC). 1981. MILDOS – A Computer Program for Calculating Environmental Radiation Doses from Uranium Recovery Operations. NUREG/CR-2011 PNL-3767. April 1981.

South Dakota Department of Environment & Natural Resources (SD DENR). 2009. South Dakota Ambient Air Monitoring Annual Network Plan 2009. [Web Page]. Located at: http://denr.sd.gov/des/aq/aqnews/South%20Dakota%20AP2009.pdf. Accessed on: March 17, 2010.

U.S. Environmental Protection Agency. (USEPA). 2010a. *Airdata: Access to Air Pollution Data. Monitor Values Report - Criteria Air Pollutants – South Dakota.* [Web Page]. Located at: http://epa.gov/air/data/monvals.html?st~SD~South%20Dakota. Accessed on: March 19, 2010.

U.S. Environmental Protection Agency. (USEPA). 2010b. *Airdata: Access to Air Pollution Data. Monitor Values Report - Criteria Air Pollutants – Nebraska.* [Web Page]. Located at: http://epa.gov/air/data/monvals.html?st~SD~South%20Dakota. Accessed on: March 19, 2010.

U.S. Nuclear Regulatory Commission, (NRC). 1981. MILDOS – A Computer Program for Calculating Environmental Radiation Doses from Uranium Recovery Operations. NUREG/CR-2011 PNL-3767. April 1981.

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Table 2.5-1 Chadron NWS Monthly Averages and Monthly Extremes Temperature Data (1894 to 2009)

Month	Monthly Averages			Monthly Extremes Record High		Monthly Extremes Record Low	
	Maximum	Minimum	Mean				
	(°C)	(°C)	(°C)	(°C)	Year	(°C)	Year
Jan	2.1	-11.3	-4.6	1.3	2006	-13.7	1949
Feb	4.7	-9.0	-2.2	5.3	1954	-13.8	1936
Mar	9.0	-5.0	2.0	7.2	1918	-4.8	1965
Apr	15.1	0.7	7.9	12.5	1930	-2.8	1920
May	20.7	6.4	13.6	19.8	1934	10.2	1995
June	26.9	11.7	19.3	24.6	1933	14.7	1945
July	31.9	15.6	23.8	29.1	1936	19.4	1915
Aug	31.2	14.4	22.8	26.2	1937	19.0	1927
Sept	25.3	8.4	16.9	20.9	1931	-10.9	1965
Oct	18.0	1.8	9.9	14.4	1963	-3.0	1925
Nov	9.1	-9.6	2.2	8.3	1999	-7.2	1985
Dec	3.7	-10.1	-2.9	3.6	1939	-13.7	1983
Year	16.5	1.6	9.1	11.5	1934	6.8	1951

Source: HPRCC 2010
Note: For months and annual means, thresholds and sums: months with 5 or more missing days are not considered; years with 1 or more missing months are not considered.

Table 2.5-2 Chadron NWS Temperature Occurrences (1894 to 2009)

Month	Mean Number of Days with Maximum Temperatures		Mean Number of Days with Minimum Temperatures	
	>= 32.2°C	>= 0°C	< =0°C	<= -17.8°C
Jan	0.0	11.2	29.9	7.1
Feb	0.0	7.9	26.2	4.0
Mar	0.0	4.8	25.4	1.6
Apr	0.0	0.9	14.2	0.0
May	1.0	0.0	2.8	0.0
June	6.1	0.0	0.1	0.0
July	16.3	0.0	-.0	0.0
Aug	15.0	0.0	0.0	0.0
Sept	5.5	0.0	1.7	0.0
Oct	0.2	0.5	11.7	0.0
Nov	0.0	4.0	24.6	0.9
Dec	0.0	9.4	29.1	4.8
Year	**44.1**	**38.7**	**165.6**	**18.5**

Source: HPRCC 2010 (Chadron NWS)

Table 2.5-3 Chadron NWS Mean and Maximum Precipitation Data (1894 to 2009)

Month	Water Equivalent		Snow Fall	
	Mean (cm)	Maximum 24-Hour (cm)	Mean (cm)	Maximum Monthly (cm)
Jan	1.2	6.8	16.8	88.1
Feb	1.2	6.2	16.3	59.7
Mar	2.4	8.2	22.6	88.1
Apr	4.9	13.9	15.2	84.8
May	7.3	17.3	2.0	23.6
June	7.1	26.4	0.0	3.0
July	5.3	14.0	00	0.0
Aug	3.5	13.0	0.0	0.0
Sept	3.6	14.8	0.8	25.4
Oct	2.7	9.2	6.4	58.4
Nov	1.4	9.4	14.0	65.8
Dec	1.2	4.8	17.0	61.1
Year	**41.9**	**67.2**	**111.3**	**206.5**

Source: HPRCC 2010 (Chadron NWS)

Table 2.5-4 Whitney WHN5 Sea Level Pressure and Relative Humidity Measurements (2002 to 2009)

Year	Temperature °C			Relative Humidity (Percent)			Sea Level Pressure (mb)		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
2002	-18.2	--	32.4	16.3	55.6	95.3	946.3	1015.7	1036.3
2003	-15.6	--	39.2	13.5	58.8	98.5	997.3	1015.4	1030.0
2004	-19.3	--	29.2	20.3	59.9	94.6	1001.3	1016.1	1031.8
2005	-20.1	--	32.9	18.6	58.8	94.0	998.5	1015.6	1030.1
2006	-25.8	--	34.9	14.6	55.5	94.6	998.2	1015.6	1032.4
2007	-18.7	--	31.8	20.5	54.2	95.1	995.5	1015.5	1030.6
2008	-22.8	--	35.0	19.5	60.1	95.3	994.9	1015.0	1034.8
2009	-26.7	--	37.8	11.4	63.7	97.7	985.1	1015.8	1044.7

Source: WHN5 2010
mb = millibar
RH (Percent) = percent of saturation humidity.

Table 2.5-5 Frequency of Winds by Direction and Speed (Stability Class A)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.98	8.63	2.62	0.11	0.00	0.00	12.34	4.90
NNE	2.61	8.74	2.95	0.11	0.00	0.00	14.31	4.60
NE	1.64	8.52	1.31	0.00	0.00	0.00	11.47	4.50
ENE	0.66	4.37	0.55	0.00	0.00	0.00	5.58	4.40
E	1.20	1.97	0.77	0.00	0.00	0.00	3.94	4.40
ESE	0.33	0.87	0.22	0.00	0.00	0.00	1.42	4.00
SE	0.98	1.75	1.64	0.00	0.00	0.00	4.37	5.10
SSE	0.44	2.61	1.64	0.11	0.00	0.00	4.70	5.30
S	0.98	3.72	1.53	0.00	0.00	0.00	6.23	5.00
SSW	0.55	1.97	2.08	0.22	0.00	0.00	4.82	6.00
SW	0.77	3.72	1.53	0.00	0.00	0.00	6.02	5.00
WSW	0.66	2.08	1.53	0.00	0.00	0.00	4.27	5.30
W	0.66	1.75	1.75	0.11	0.00	0.00	4.27	5.50
WNW	0.77	1.42	0.98	0.44	0.00	0.00	3.61	5.70
NW	0.66	2.30	1.53	0.11	0.00	0.00	4.60	5.50
NNW	1.53	3.93	1.86	0.44	0.00	0.00	7.76	5.30
ALL	15.32	58.25	24.49	1.65	0.00	0.00	99.71	5.00

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.3%
Period mean wind speed = 5.0 knots
Percent occurrence for A stability class = 5.6%

Table 2.5-6 Frequency of Winds by Direction And Speed (Stability Class B)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	1.01	2.68	5.53	0.67	0.00	0.00	9.89	6.40
NNE	1.34	3.52	3.77	0.34	0.00	0.00	8.97	5.70
NE	0.92	5.28	5.45	0.50	0.00	0.00	12.15	6.00
ENE	0.84	1.76	2.85	0.25	0.00	0.00	5.70	6.00
E	0.17	0.84	0.75	0.08	0.00	0.00	1.84	6.00
ESE	0.59	0.59	1.09	0.00	0.00	0.00	2.27	5.80
SE	0.08	1.26	2.26	0.25	0.00	0.00	3.85	6.90
SSE	0.67	1.17	2.43	0.50	0.00	0.00	4.77	6.50
S	1.09	1.01	4.02	0.92	0.00	0.00	7.04	7.00
SSW	1.01	2.01	2.26	0.75	0.00	0.00	6.03	6.30
SW	0.92	3.19	2.61	0.59	0.00	0.00	7.21	6.10
WSW	0.59	2.01	2.60	0.84	0.08	0.00	6.12	6.90
W	0.42	1.34	2.35	0.42	0.08	0.00	4.61	7.20
WNW	0.67	1.09	2.10	0.34	0.00	0.00	4.20	6.60
NW	0.25	1.09	4.02	1.09	0.08	0.00	6.53	7.80
NNW	0.42	1.51	4.95	1.68	0.08	0.00	8.64	7.80
ALL	10.99	30.35	48.94	9.22	0.32	0.00	99.82	6.60

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.2%
Period mean wind speed = 6.5 knots
Percent occurrence for B stability class = 7.4%

Table 2.5-7 Frequency of Winds by Direction and Speed (Stability Class C)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.74	1.54	2.68	0.74	0.00	0.00	5.70	6.70
NNE	0.63	2.62	2.90	0.85	0.00	0.00	7.00	6.60
NE	0.91	2.28	5.69	1.20	0.00	0.00	10.08	7.00
ENE	0.46	1.03	2.96	0.97	0.00	0.00	5.42	7.30
E	0.00	0.57	0.74	0.28	0.00	0.00	1.59	7.60
ESE	0.23	0.34	0.91	0.23	0.00	0.00	1.71	7.00
SE	0.17	0.68	1.82	0.74	0.00	0.00	3.41	7.70
SSE	0.46	0.74	2.22	1.48	0.00	0.00	4.90	8.00
S	0.97	1.65	5.30	2.28	0.00	0.00	10.20	7.70
SSW	1.14	3.02	3.93	0.97	0.00	0.00	9.06	6.60
SW	1.03	3.36	4.67	1.14	0.11	0.00	10.31	6.80
WSW	0.97	3.02	3.59	1.14	0.06	0.06	8.84	6.80
W	0.11	0.91	1.99	1.03	0.11	0.00	4.15	8.40
WNW	0.17	0.51	1.03	1.25	0.06	0.00	3.02	9.10
NW	0.40	0.74	3.70	2.22	0.06	0.00	7.12	8.70
NNW	0.40	1.42	3.42	2.11	0.00	0.00	7.35	8.20
ALL	8.79	24.43	47.55	18.63	0.40	0.06	99.86	7.40

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.2%
Period mean wind speed = 7.4 knots
Percent occurrence for C stability class = 10.8%

Table 2.5-8 Frequency of Winds by Direction And Speed (Stability Class D)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.17	0.52	1.14	0.83	0.20	0.02	2.88	9.20
NNE	0.16	1.12	2.34	2.90	0.89	0.19	7.60	10.70
NE	0.13	1.53	2.65	2.72	0.46	0.08	7.47	9.80
ENE	0.04	0.47	0.79	0.50	0.06	0.00	1.86	8.30
E	0.02	0.06	0.28	0.22	0.04	0.00	0.62	9.50
ESE	0.01	0.25	0.35	0.13	0.00	0.00	0.74	7.40
SE	0.06	0.42	0.71	0.52	0.18	0.01	1.90	9.50
SSE	0.13	1.78	1.50	2.60	1.21	0.34	7.56	11.10
S	0.34	1.67	3.58	7.77	3.57	0.58	17.51	12.40
SSW	0.22	1.37	3.82	3.60	0.76	0.12	9.89	10.00
SW	0.17	2.11	5.80	3.80	0.29	0.02	12.19	8.80
WSW	0.17	0.61	2.28	2.74	0.54	0.16	6.50	10.70
W	0.10	0.20	0.64	1.03	0.47	0.19	2.63	12.60
WNW	0.05	0.17	0.91	1.39	0.66	0.28	3.46	13.20
NW	0.05	0.31	1.60	5.13	2.68	1.55	11.32	15.00
NNW	0.04	0.49	1.80	2.34	0.90	0.20	5.77	11.90
ALL	1.86	13.08	30.09	38.22	12.91	3.74	99.90	11.20

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.1%
Period mean wind speed = 11.2 knots
Percent occurrence for D stability class = 51.3%

Table 2.5-9 Frequency Of Winds By Direction And Speed (Stability Class E)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.85	2.92	0.65	0.04	0.00	0.00	4.46	4.60
NNE	0.97	2.80	1.82	0.00	0.00	0.00	5.59	5.20
NE	0.97	3.32	1.90	0.08	0.00	0.00	6.27	5.10
ENE	0.45	1.26	0.73	0.00	0.00	0.00	2.44	5.10
E	0.16	0.73	0.20	0.00	0.00	0.00	1.09	4.70
ESE	0.28	0.65	0.45	0.00	0.00	0.00	1.38	4.80
SE	0.49	1.82	0.85	0.12	0.00	0.00	3.28	5.10
SSE	1.70	7.62	1.05	0.08	0.00	0.00	10.45	4.40
S	2.23	11.06	4.34	0.16	0.00	0.00	17.79	5.00
SSW	2.11	10.53	2.80	0.04	0.00	0.00	15.48	4.70
SW	1.78	8.18	5.67	0.12	0.04	0.00	15.79	5.50
WSW	1.05	2.88	2.47	0.04	0.00	0.00	6.44	5.40
W	0.65	0.97	0.36	0.04	0.00	0.00	2.02	4.30
WNW	0.36	0.97	0.81	0.00	0.00	0.00	2.14	5.50
NW	0.45	1.18	0.85	0.20	0.00	0.00	2.68	5.70
NNW	0.61	1.34	0.49	0.00	0.00	0.00	2.44	4.50
ALL	15.11	58.23	25.44	0.92	0.04	0.00	99.74	5.00

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.2%
Period mean wind speed = 5.0 knots
Percent occurrence for E stability class = 15.2%

Table 2.5-10 Frequency Of Winds By Direction And Speed (Stability Class F)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	3.30	1.65	0.00	0.00	0.00	0.00	4.95	2.80
NNE	1.65	1.33	0.00	0.00	0.00	0.00	2.98	3.00
NE	0.95	1.40	0.00	0.00	0.00	0.00	2.35	3.10
ENE	1.40	0.76	0.00	0.00	0.00	0.00	2.16	2.80
E	1.27	0.44	0.00	0.00	0.00	0.00	1.71	2.80
ESE	1.78	1.02	0.00	0.00	0.00	0.00	2.80	2.60
SE	1.72	1.78	0.00	0.00	0.00	0.00	3.50	3.00
SSE	3.75	4.76	0.00	0.00	0.00	0.00	8.51	3.10
S	7.50	12.07	0.00	0.00	0.00	0.00	19.57	3.30
SSW	7.24	13.15	0.00	0.00	0.00	0.00	20.39	3.30
SW	6.48	8.01	0.00	0.00	0.00	0.00	14.49	3.20
WSW	2.73	2.60	0.00	0.00	0.00	0.00	5.33	3.00
W	1.78	1.46	0.00	0.00	0.00	0.00	3.24	2.90
WNW	0.83	0.95	0.00	0.00	0.00	0.00	1.78	3.00
NW	1.33	1.21	0.00	0.00	0.00	0.00	2.64	3.00
NNW	1.33	0.51	0.00	0.00	0.00	0.00	1.84	2.60
ALL	45.04	53.10	0.00	0.00	0.00	0.00	98.14	3.10

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 1.8%
Period mean wind speed = 3.1 knots
Percent occurrence for F stability class = 9.7%

Table 2.5-11 Frequency of Winds by Direction and Speed (All Stability Classes)

Wind Direction	Speed Class Intervals (Knots)							
	1 – 3	3 – 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.75	1.72	1.53	0.57	0.10	0.01	4.68	6.50
NNE	0.70	2.16	2.24	1.61	0.46	0.10	7.27	8.20
NE	0.57	2.64	2.69	1.57	0.23	0.04	7.64	7.70
ENE	0.37	0.99	1.08	0.38	0.03	0.00	2.85	6.50
E	0.24	0.42	0.35	0.15	0.02	0.00	1.18	6.20
ESE	0.31	0.46	0.44	0.09	0.00	0.00	1.30	5.50
SE	0.35	0.93	0.95	0.38	0.09	0.01	2.71	7.00
SSE	0.81	2.84	1.44	1.55	0.62	0.17	7.43	8.20
S	1.48	4.17	3.45	4.33	1.83	0.30	15.56	9.30
SSW	1.36	4.17	3.09	2.03	0.39	0.06	11.10	7.20
SW	1.21	3.91	4.62	2.13	0.17	0.01	12.05	7.10
WSW	0.70	1.60	2.21	1.60	0.29	0.09	6.49	8.20
W	0.40	0.69	0.87	0.68	0.26	0.10	3.00	8.90
WNW	0.27	0.54	0.91	0.90	0.35	0.14	3.11	10.20
NW	0.32	0.75	1.73	2.99	1.39	0.79	7.97	12.80
NNW	0.40	0.99	1.84	1.58	0.47	0.10	5.38	9.50
ALL	10.24	28.88	29.44	22.64	6.70	1.92	99.72	8.40

Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.3%
Period mean wind speed = 8.4 knots
Percent occurrence for A stability class = 100.0%

Table 2.5-12 CBR Onsite MET Station Joint Frequency Distribution

Stability Class A					
0.00056	0.00488	0.00148	0.00006	0.00000	0.00000
0.00142	0.00495	0.00167	0.00006	0.00000	0.00000
0.00093	0.00482	0.00074	0.00000	0.00000	0.00000
0.00037	0.00247	0.00031	0.00000	0.00000	0.00000
0.00068	0.00111	0.00043	0.00000	0.00000	0.00000
0.00019	0.00049	0.00012	0.00000	0.00000	0.00000
0.00056	0.00099	0.00093	0.00000	0.00000	0.00000
0.00025	0.00142	0.00093	0.00006	0.00000	0.00000
0.00056	0.00210	0.00087	0.00000	0.00000	0.00000
0.00031	0.00111	0.00117	0.00012	0.00000	0.00000
0.00043	0.00210	0.00087	0.00000	0.00000	0.00000
0.00037	0.00117	0.00087	0.00000	0.00000	0.00000
0.00037	0.00099	0.00099	0.00006	0.00000	0.00000
0.00043	0.00080	0.00056	0.00025	0.00000	0.00000
0.00037	0.00130	0.00087	0.00006	0.00000	0.00000
0.00087	0.00223	0.00105	0.00025	0.00000	0.00000
Stability Class B					
0.00074	0.00198	0.00408	0.00049	0.00000	0.00000
0.00099	0.00260	0.00278	0.00025	0.00000	0.00000
0.00068	0.00389	0.00402	0.00037	0.00000	0.00000
0.00062	0.00130	0.00210	0.00019	0.00000	0.00000
0.00012	0.00062	0.00056	0.00006	0.00000	0.00000
0.00043	0.00043	0.00080	0.00000	0.00000	0.00000
0.00006	0.00093	0.00167	0.00019	0.00000	0.00000
0.00049	0.00087	0.00179	0.00037	0.00000	0.00000
0.00080	0.00074	0.00297	0.00068	0.00000	0.00000
0.00074	0.00148	0.00167	0.00056	0.00000	0.00000
0.00068	0.00235	0.00185	0.00043	0.00000	0.00000
0.00043	0.00148	0.00192	0.00062	0.00006	0.00000
0.00031	0.00099	0.00173	0.00031	0.00006	0.00000
0.00049	0.00080	0.00155	0.00025	0.00000	0.00000
0.00019	0.00080	0.00297	0.00080	0.00006	0.00000
0.00031	0.00111	0.00365	0.00124	0.00006	0.00000

Table 2.5-12 CBR Onsite MET Station Joint Frequency Distribution

Stability Class C					
0.00080	0.00167	0.00291	0.00080	0.00080	0.00000
0.00068	0.00284	0.00315	0.00093	0.00093	0.00000
0.00099	0.00247	0.00618	0.00130	0.00130	0.00000
0.00049	0.00111	0.00321	0.00105	0.00105	0.00000
0.00000	0.00062	0.00080	0.00031	0.00031	0.00000
0.00025	0.00037	0.00099	0.00025	0.00025	0.00000
0.00019	0.00074	0.00198	0.00080	0.00080	0.00000
0.00049	0.00080	0.00241	0.00161	0.00161	0.00000
0.00105	0.00179	0.00575	0.00080	0.00000	0.00000
0.00124	0.00328	0.00427	0.00093	0.00000	0.00000
0.00111	0.00365	0.00507	0.00130	0.00012	0.00000
0.00105	0.00328	0.00389	0.00105	0.00006	0.00006
0.00012	0.00099	0.00216	0.00031	0.00012	0.00000
0.00019	0.00056	0.00111	0.00025	0.00006	0.00000
0.00043	0.00080	0.00402	0.00080	0.00006	0.00000
0.00043	0.00155	0.00371	0.00161	0.00000	0.00000
Stability Class D					
0.00087	0.00266	0.00587	0.00427	0.00105	0.00012
0.0008	0.00575	0.01205	0.0149	0.00457	0.00099
0.00068	0.00785	0.01311	0.01397	0.00235	0.00043
0.00019	0.00241	0.00408	0.0026	0.00031	0.00000
0.00012	0.00031	0.00142	0.00111	0.00019	0.00000
0.00006	0.0013	0.00179	0.00068	0.00000	0.00000
0.00031	0.00216	0.00365	0.00266	0.00093	0.00006
0.00068	0.00915	0.00773	0.01335	0.00624	0.00173
0.00173	0.00859	0.01842	0.04	0.01836	0.00297
0.00111	0.00705	0.01966	0.01854	0.00389	0.00062
0.00087	0.01088	0.02986	0.01953	0.00148	0.00012
0.00087	0.00315	0.01175	0.01409	0.00278	0.0008
0.00049	0.00105	0.00328	0.00532	0.00241	0.00099
0.00025	0.00087	0.0047	0.00717	0.0034	0.00142
0.00025	0.00161	0.00822	0.0264	0.01379	0.00797
0.00019	0.00253	0.00927	0.01205	0.00464	0.00105

Table 2.5-12 CBR Onsite MET Station Joint Frequency Distribution

Stability Class E					
0.00130	0.00445	0.00099	0.00006	0.00000	0.00000
0.00148	0.00427	0.00278	0.00000	0.00000	0.00000
0.00148	0.00507	0.00291	0.00012	0.00000	0.00000
0.00068	0.00192	0.00111	0.00000	0.00000	0.00000
0.00025	0.00111	0.00031	0.00000	0.00000	0.00000
0.00043	0.00099	0.00068	0.00000	0.00000	0.00000
0.00074	0.00278	0.00130	0.00019	0.00000	0.00000
0.00260	0.01162	0.00161	0.00012	0.00000	0.00000
0.00340	0.01688	0.00661	0.00025	0.00000	0.00000
0.00321	0.01607	0.00427	0.00006	0.00000	0.00000
0.00272	0.01249	0.00865	0.00019	0.00006	0.00000
0.00161	0.00439	0.00377	0.00006	0.00000	0.00000
0.00099	0.00148	0.00056	0.00006	0.00000	0.00000
0.00056	0.00148	0.00124	0.00000	0.00000	0.00000
0.00068	0.00179	0.00130	0.00031	0.00000	0.00000
0.00093	0.00204	0.00074	0.00000	0.00000	0.00000
Stability Class F					
0.00321	0.00161	0.00000	0.00000	0.00000	0.00000
0.00161	0.00130	0.00000	0.00000	0.00000	0.00000
0.00093	0.00136	0.00000	0.00000	0.00000	0.00000
0.00136	0.00074	0.00000	0.00000	0.00000	0.00000
0.00124	0.00043	0.00000	0.00000	0.00000	0.00000
0.00173	0.00099	0.00000	0.00000	0.00000	0.00000
0.00167	0.00173	0.00000	0.00000	0.00000	0.00000
0.00365	0.00464	0.00000	0.00000	0.00000	0.00000
0.00729	0.01175	0.00000	0.00000	0.00000	0.00000
0.00705	0.01280	0.00000	0.00000	0.00000	0.00000
0.00631	0.00779	0.00000	0.00000	0.00000	0.00000
0.00266	0.00253	0.00000	0.00000	0.00000	0.00000
0.00173	0.00142	0.00000	0.00000	0.00000	0.00000
0.00080	0.00093	0.00000	0.00000	0.00000	0.00000
0.00130	0.00117	0.00000	0.00000	0.00000	0.00000
0.00130	0.00049	0.00000	0.00000	0.00000	0.00000

Table 2.5-13 Chadron NWS Wind Speed Frequency Distribution (April 1982 – May 1984)

Direction (Degrees)	Wind Speed (Knots)						
	1-4	4-7	7-11	11-17	17-21	>=22	Total
348.75 - 11.25	0.132	1.406	1.515	1.818	1.204	0.249	6.324
11.25 - 33.75	0.202	1.6	2.214	2.75	1.002	0.163	7.931
33.75 - 56.25	0.179	1.445	1.81	2.105	0.396	0.07	6.005
56.25 - 78.75	0.109	0.831	0.909	0.676	0.085	0.008	2.618
78.75 - 101.25	0.155	0.924	0.909	0.73	0.093	0.031	2.842
101.25 - 123.75	0.101	0.777	0.785	0.404	0.07	0.023	2.16
123.75 - 146.25	0.023	0.505	0.761	0.66	0.194	0.016	2.159
146.25 - 168.75	0.109	0.792	1.111	2.004	0.699	0.194	4.909
168.75 - 191.25	0.311	1.896	2.284	4.086	2.051	0.777	11.405
191.25 - 213.75	0.218	1.655	1.67	1.562	0.373	0.093	5.571
213.75 - 236.25	0.28	2.222	2.074	1.445	0.202	0.062	6.285
236.25 - 258.75	0.311	2.54	1.973	1.274	0.218	0.062	6.378
258.75 - 281.25	0.287	2.843	2.96	3.488	1.616	0.396	11.59
281.25 - 303.75	0.163	1.095	1.554	2.564	1.981	1.352	8.709
303.75 - 326.25	0.14	0.606	0.707	1.08	0.552	0.722	3.807
326.25 - 348.75	0.109	0.645	0.637	0.567	0.218	0.078	2.254
Total	2.829	21.782	23.873	27.213	10.954	4.296	90.947
						Calms	0
						Missing/Incomplete	0.1
						Total	1

Table 2.5-14 Chadron NWS Wind Speed Frequency Distribution (2000 - 2009)

Direction (Degrees)	Wind Speed (Knots)						
	1-4	4-7	7-11	11-17	17-21	>=22	Total
348.75 - 11.25	0.389	1.535	0.821	0.854	0.113	0.091	3.802
11.25 - 33.75	0.315	1.964	1.399	1.983	0.301	0.109	6.07
33.75 - 56.25	0.303	2.174	1.807	1.851	0.163	0.032	6.33
56.25 - 78.75	0.25	1.5	0.938	0.553	0.035	0.005	3.281
78.75 - 101.25	0.25	1.446	0.723	0.344	0.032	0.005	2.801
101.25 - 123.75	0.175	0.81	0.374	0.296	0.027	0.008	1.69
123.75 - 146.25	0.23	1.041	0.554	0.465	0.054	0.032	2.376
146.25 - 168.75	0.26	1.1	0.933	1.432	0.367	0.266	4.359
168.75 - 191.25	0.442	1.802	1.546	3.035	1.021	0.663	8.51
191.25 - 213.75	0.52	1.7	0.928	1.048	0.118	0.032	4.346
213.75 - 236.25	0.885	3.662	1.293	0.774	0.036	0.012	6.661
236.25 - 258.75	1.048	6.801	2.689	1.029	0.116	0.045	11.729
258.75 - 281.25	0.992	4.804	2.2	2.348	0.37	0.183	10.897
281.25 - 303.75	0.291	1.16	1.217	3.351	1.041	0.625	7.684
303.75 - 326.25	0.211	1.057	0.986	2.092	0.772	0.719	5.837
326.25 - 348.75	0.177	0.869	0.458	0.439	0.077	0.027	2.047
Total	6.738	33.425	18.866	21.894	4.643	2.854	88.42
						Calms	0.11
						Missing/Incomplete	0.05
						Total	1

Table 2.5-15 National Ambient Air Standards (NAAQS) Primary and Secondary Limits and State of South Dakota

Pollutant	National			State of Nebraska			State of South Dakota		
	Primary Standards	**Averaging Standards**	**Secondary Standards**	**Primary Standards**	**Averaging Times**	**Secondary Standards**	**Primary Standards**	**Averaging Times**	**Secondary Standards**
Particulate Matter (PM_{10})	Revoked[1]	Annual[1] (Arithmetic Mean)	Same as Primary	Revoked	Annual[1] (Arithmetic Mean)	Same as Primary	Revoked	Annual[1] (Arithmetic Mean)	Same as Primary
	150 ug/m^3	24-Hour[2]		150 ug/m^3	24-Hour[2]		150 ug/m^3	24-Hour[2]	
Particulate Matter ($PM_{2.5}$)	15.0 ug/m3	Annual[3] (Arithmetic Mean)	Same as Primary	15.0 ug/m^3	Annual[3] (Arithmetic Mean)	Same as Primary	15 ug/m^3	Annual[3] (Arithmetic Mean)	Same as Primary
	35 ug/m^3	24-Hour[4]	--	35 ug/m^3	24-Hour[4]	--	35 ug/m^3	24-Hour[4]	--
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Mean)	--	0.03 ppm	Annual (Arithmetic Mean)	--	0.03 ppm	Annual[4] (Arithmetic Mean)	--
	0.14 ppm	24-Hour[5]	--	0.14 ppm	24-Hour[5]	--	0.14 ppm	24-Hour[5]	--
	--	3-Hour[5]	0.50 ppm (1300 ug/m^3)	--	3-Hour[5]	0.50 ppm (1300 ug/m^3)	--	3-Hour[5]	0.50 ppm (1300 ug/m^3)
Nitrogen Dioxide	0.053 ppm (100 ug/m^3)	Annual (Arithmetic Mean)	Same as Primary	0.050 ppm (100 ug/m^3)	Annual (Arithmetic Mean)	Same as Primary	0.053 ppm (100 ug/m^3)	Annual (Arithmetic Mean)	Same as Primary
Ozone	0.08 ppm	8-Hour[6]	Same as Primary	0.08 ppm	8-Hour[6]	Same as Primary	0.08 ppm	8-Hour[6]	Same as Primary
	0.12 ppm	1-Hour[7] (Limited Areas)	Same as Primary	0.12 ppm	1-Hour[7] (Limited Areas)	Same as Primary	--	--	--
Carbon Monoxide	9 ppm (10 mg/m^3)	8-Hour[5]	None	9 ppm (10 mg/m^3)	8-Hour[5]	None	9 ppm (10 mg/m^3)	8-Hour[5]	None
	35 ppm (40 mg/m^3)	1-Hour[5]	None	35 ppm (40 mg/m^3)	1-Hour[5]	None	35 ppm (40 mg/m^3)	1-Hour[5]	None
Lead	1.5 ug/m3	Quarterly Average	Same as Primary	1.5 ug/m3	Quarterly Average	Same as Primary	1.5 ug/m3	Quarterly Average	Same as Primary

[1]Annual PM_{10} standard evoked due to lack of evidence linking health problems to long-term exposure to coarse particle pollution.
[2]Not to be exceeded more than once per year on average over 3 years.
[3]To attain this standard, the 3-year average of the weighted annual mean PM_{25} concentrations from single or multiple community-oriented monitors must not exceed 15.0 ug/m^3.
[4]To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 ug/m^3 (effective December 17, 2006).5[4] Not to be exceeded more than once per year. The 98th percentile value is higher than 98 percent of 24-hour values for the year.
[5]Not to be exceeded more than once per year.
[6]To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm .
[7]The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is <1.

Table 2.5-16 Nebraska and South Dakota Ambient Air Monitoring Network in Region of Three Crow Expansion Area

Site	Operating Agency	Location			Parameters Monitored	Monitoring Objective	Distance from TCEA
		State	County	Coordinates			
Wind Cave National Park	SD DENR	SD	Custer	43.557800 -103.483900	PM_{10} $PM_{2.5}$ SO_2 NO_2 Ozone	Background (Regional) Pollutant Transport	63 Miles
Badlands National Park	SD DENR	SD	Jackson	43.745610 -101.941218	PM_{10} $PM_{2.5}$ SO_2 NO_2 Ozone	PM2.5: Regional Others: Background (Regional) & Pollutant Transport	90 Miles
Black Hawk	SDDENR	D	Meade	44.155636 -103.315765	PM_{10} Ozone	PM10: Population & Urban Background Ozone: Population & High Concentration	73 miles
Agate Fossil Beds	National Park Service	NE	Sioux	42.429300 -103.729400	Ozone	Background (regional)	16 miles
Scottsbluff	NDEQ	NE	Scotts Bluff	41.865000 -103.664444	$PM_{2.5}$	Background (Regional) Population	55 miles
Rapid City National Guard	SD DENR	SD	Pennington	44.083489 -103.269603	PM_{10}	Population High Concentration	96 miles

Sources: NDEQ 2009; SD DENR 2009
Note: Clarification of mining objectives:

- **Background Level** monitoring is used to determine general background levels of air pollutants. This can be applied to areas such as regions, neighborhoods, and urban areas.
- **High Concentration** monitoring is conducted at sites to find the highest concentration of an air pollutant in an area within a given monitoring network. A monitoring network may have multiple high concentration sites as a result of varying meteorology, source area variability, etc.
- **Population Exposure** monitoring is conducted to represent the air pollutant concentrations to which a populated area is exposed.
- **Pollutant Transport** is the movement of pollutant(s) between air basins or areas within an air basin. Pollutant transport monitoring is used to assess and address sources from upwind areas when those transported pollutant(s) affect neighboring downwind areas. Transport monitoring can also be used to determine the extent of regional pollutant transport.

Table 2.5-17 PM_{10} Annual Average Monitoring Data for South Dakota Monitoring Sites

Year	Wind Cave		Badlands		Black Hawk		Rapid City (Natl. Guard)	
	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average
	ug/m^3							
1992	--	--	--	--	--	--	37	No Data
1993	--	--	--	--	--	--	34	No Data
1994	--	--	--	--	--	--	39	No Data
1995	--	--	--	--	--	--	33	No Data
1996	--	--	--	--	--	--	35	No Data
1997	--	--	--	--	--	--	41	No Date
1998	--	--	--	--	--	--	31	87
1999	--	--	--	--	--	--	28	117
2000	--	--	12	39	--	--	32	97
2001	--	--	12	48	21	70	35	82
2002	--	--	10	26	19	77	34	105
2003	--	--	16	74	21	77	36	92
2004	--	--	10	24	20	42	35	72
2005	7	32	9	40	15	52	27	94
2006	7	28	9	30	16	50	29	124
2007	10	44	12	50	18	42	32	93
2008	9	51	11	85	16	70	26	89

Standard of 150 ug/m^3 is not to be exceeded more than once per year on average over 3 years.
Source: USEPA 2010a; SD DENR 2009.

Table 2.5-18 Comparison Of Ambient Particulate Matter (PM_{10}) Monitoring Data For Regional Monitoring Sites

Site	2006	2007	2008	3-Year Average	Attainment with NAAQS[2]
	ug/m³				
PM_{10} Annual Averages for Monitoring Sites					
Wind Cave, SD	7	7	10	9	1
Bad Lands, SD	9	9	12	11	1
Black Hawk	15	16	18	16	1
Rapid City, SD. (Natl. Guard)	27	29	32	28	1
Second Highest 24-Hour Concentration					
Wind Cave, SD	26	43	47	39	Yes
Bad Lands, SD	30	40	56	42	Yes
Black Hawk	47	42	36	42	Yes
Rapid City, SD. (Natl. Guard)	91	89	84	88	Yes

[1] Annual PM_{10} standard was revoked by the USEPA in 2006 and later removed by the states of Nebraska and South Dakota.

[2] Standard of 150 ug/m^3 is not to be exceeded more than once per year on average over 3 years.

Table 2.5-19 $PM_{2.5}$ Annual Average Monitoring Data for Regional Monitoring Sites

Year	Wind Cave		Badlands		Black Hawk		Rapid City (Natl. Guard)		Scottsbluff	
	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average	Annual Average	Maximum 24-Hr Average
	ug/m³									
1998	--	--	--	--	--	--	--	--	--	--
1999	--	--	--	--	--	--	--	--	8.17	32.0
2000	--	--	5.38	13.9	--	--	7.94	29.5	6.31	21.8
2001	--	--	5.60	12.7	6.09	23.2	8.44	24.5	6.21	16.9
2002	--	--	5.15	15.1	6.29	35.5	7.73	26.7	5.69	19.8
2003	--	--	5.77	24.0	6.38	26.6	7.71	21.2	6.10	23.0
2004	--	--	5.25	13.5	6.29	24.4	8.09	13.6	5.69	15.4
2005	5.39	16.2	5.35	15.4	--	--	--	--	5.28	20.1
2006	5.34	16.5	5.38	15.7	--	--	--	--	5.76	27.3
2007	6.21	22.4	5.49	18.7	--	--	--	--	7.10	19.8
2008	5.55	41.6	5.80	51.2	--	--	--	--	7.17	31.1

Source: NDEQ 2009; SD DENR 2009; USEPA 2010a and b

[1] To determine attainment status, the 3-year average of the annual 98th percentile value is compared to the 35 ug/m^3 NAAQS. The 98th percentile value is higher than 98 percent of 24-hour values for the year.

[2] To determine attainment status, the 3-year average of the annual averages is compared to the 15 ug/m^3 NAAQS.

Table 2.5-20 Comparison of Ambient Particulate Matter ($PM_{2.5}$) Monitoring Data for Regional Monitoring Sites

Site	2006	2007	2008	3-Year Average	Attainment with NAAQS
	ug/m³				
Comparison of 98th Percentile, 24-Hour Concentrations for $PM_{2.5}$ to NAAQS[1]					
Wind Cave, SD	12.2	17.5	10.8	14.0	Yes
Bad Lands, SD	12.2	12.4	12.8	13.0	Yes
Scottsbluff, NE	19.0	17.7	19.3	19.8	Yes
Rapid City, SD. (Natl. Guard)	--	--	--	--	--
Comparison of 3-Year Annual Averages for $PM_{2.5}$ to NAAQS[2]					
Wind Cave, SD	5.3	6.2	4.9	5.5	Yes
Bad Lands, SD	5.3	5.5	5.2	5.3	Yes
Scottsbluff, NE	5.76	7.10	6.77	6.68	Yes
Rapid City, SD (Natl. Guard_	--	--	--	--	--

[1] To determine attainment status, the 3-year average of the annual 98th percentile value is compared to the 35 ug/m³ NAAQS. The 98th percentile value is higher than 98 percent of 24-hour values for the year.

[2] To determine attainment status, the 3-year average of the annual averages is compared to the 15 ug/m³ NAAQS.

Table 2.5-21 Comparison of Sulfur Dioxide Values for Wind Cave and Badlands Monitor Sites

Monitor Site	SO_2 Annual Average Concentration (2008)	SO_2 24-Hr 2nd Maximum Concentration (2008)	SO_2 3-Hr Average 2nd Maximum Concentration (2008)
Wind Cave	0.001	0.001	0.002
Badlands	0.002	0.005	0.006

SD DENR Standards: 0.5 ppm (3-hour average), 0.14 ppm (24-hour average), 0.030 ppm (annual mean)
Note: The 3 –year averages shown above are used to evaluate compliance with the sulfur dioxide standard.

Table 2.5-22 Comparison of Nitrogen Dioxide Annual Average Values for Wind Cave and Badlands Monitor Sites

Monitoring Site	2005	2006	2007	2008
	ppm			
Wind Cave	0.001	0.001	0.001	0.001
Badlands	0.001	0.001	0.001	0.001

SD DENR Standards: Nitrogen Dioxide: 0.053 ppm (annual mean)

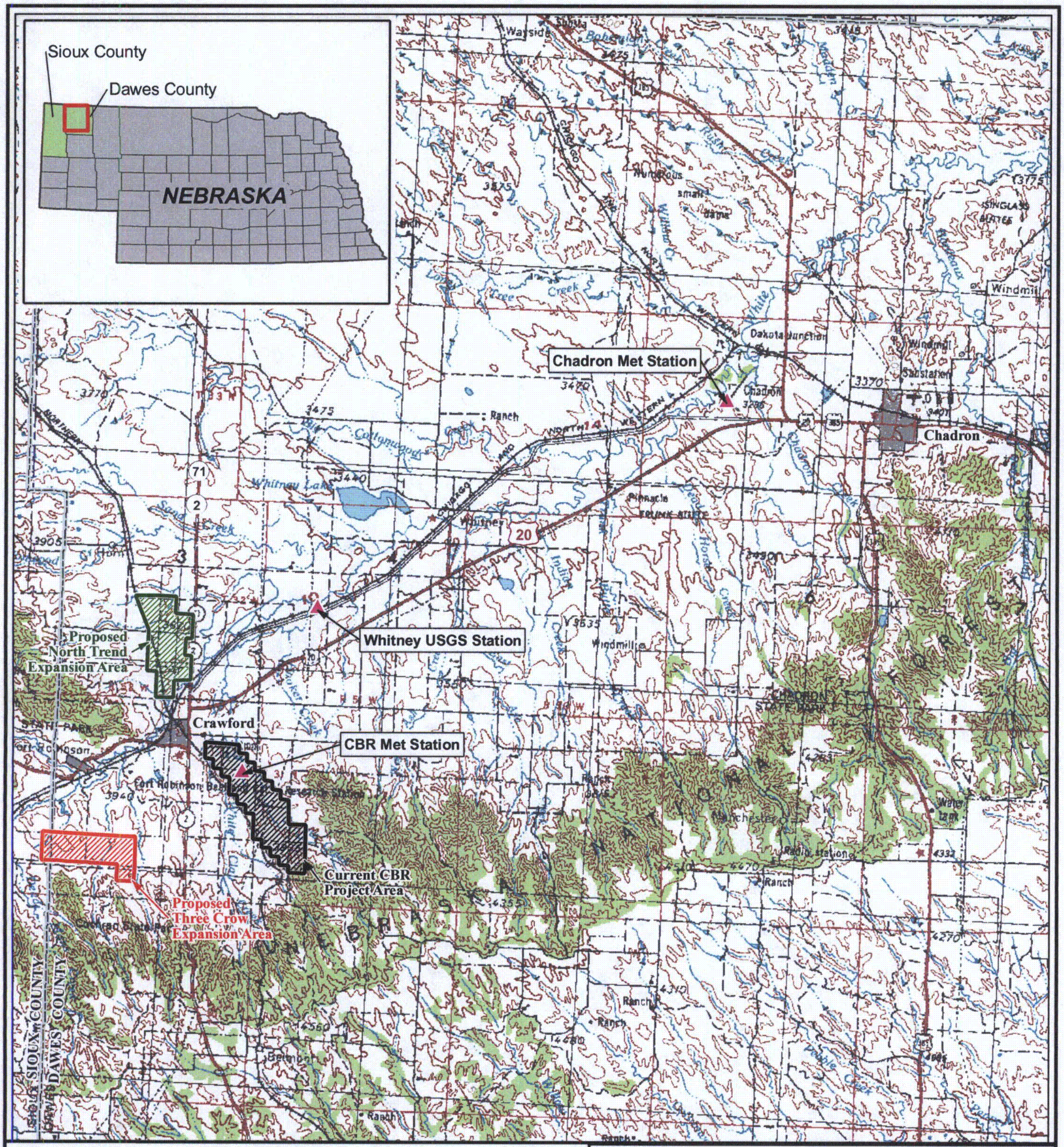
Table 2.5-23 Ozone Yearly 4th Highest 8-Hour Averages for Regional Monitoring Sites [1, 2]

Location	2003	2004	2005	2006	2007	2008	3-Year Average (2006-2008)	Percent NAAQS
	ppm							
Wind Cave, SD	No Data	No Data	0.070	0.073	0.069	0.059	0.067	89%
Bad Lands, SD	0.067	0.063	0.069	0.071	0.064	0.053	0.063	84%
Black Hawk	No Data	No Data	No Data	No Data	0.053	0.060	0.056[6]	75%
Agate Fossil Beds[1, 2]	No Data	No Data	No Data	No Data	0.066	0.067	0.0665[3, 4]	88%[5]

[1] The design value is the 3-year average of the 4th highest maximum for each year. The 4th highest 8-hour average is used to evaluated compliance with the ozone standard.
[2] NAAQS = 0.075 ppm (8-hour average). Standard promulgated 3/27/2008.
[3] The ozone monitor at the Agate Fossil beds was operated by the National park Service. It operated from mid-July 2007 through September 2008 with some down-time in July and August 2008. Approximately one year of data was collected from the site over the 2007 and 2008 monitoring period. The 4th highest maximum value over the 2007 through 2008 time frame was 0.069 ppm. The highest value was 0.072 ppm.
[4] The monitoring method used was not a Federal Reference or Equivalent Method (FRM/FEM). This, it cannot be used to evaluate attainment with the NAAQS. Method comparison work conducted by the National Park Service indicates the results should compare closely to FRM/FEM results.
[5] The two-year average of the 4th highest maximums was 0.0665 ppm or 88% of the 3-year average NAAQS.
[6] The two-year average of the 4th highest maximums was 0.056 ppm or 75% of the 3-year average NAAQS.

Table 2.5-24 Prevention of Significant Deterioration (PSD) of Air Quality Allowable Increments

Pollutant	Averaging Time	PSD Increment ug/m3	
		Class I	Class II
Particulate Matter (PM_{10})	24-Hour Maximum	8	30
	Annual Arithmetic Mean	4	17
Sulfur Dioxide (SO^2)	24-Hour Maximum	5	91
	3-Hour Maximum	25	512
	Annual Arithmetic Mean	2	20
Nitrogen Dioxide (NO^2)	Annual Arithmetic Mean	2.5	25



LEGEND

- ▲ Meteorological Station
- Proposed Three Crow Expansion Area
- Proposed North Trend Expansion Area
- Current CBR Project Area
- County Boundary

N
W — E

0 1.5 3
Miles

PROJECTION: NAD_1927_STATE_PLANE_ NEBRASKA_NORTH_FIPS_2601

SOURCE: USGS 1:250K DRG - ALLIANCE (1980), NE

CROW BUTTE RESOURCES, INC.

FIGURE 2.5-1
LOCATION OF
REGIONAL METEOROLOGICAL STATIONS

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: JEC

ARCADIS
630 Plaza Drive, Ste. 100
Highlands Ranch, CO 80129
P: 720-344-3500 F: 720-344-3535
www.arcadis-us.com

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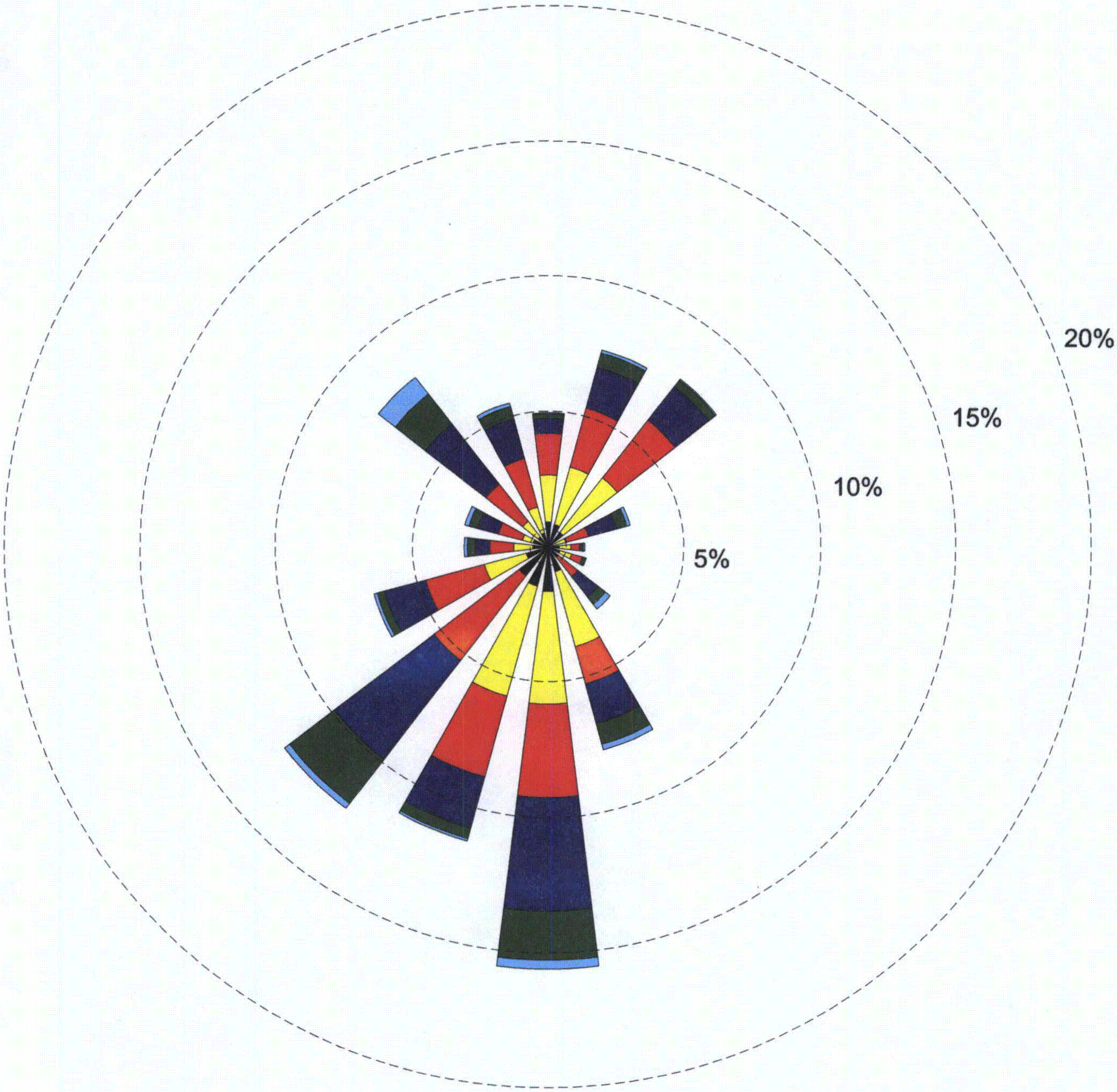


Wind Speed (knots)

- >21
- 17-21
- 11-16
- 7-10
- 4-6
- 1-3

Average Wind Speed: 8.40 knots
Percent Calm Winds: 0.3 percent
Wind Direction: Blowing from
Data Period: May 1982 - April 1984

N
W E

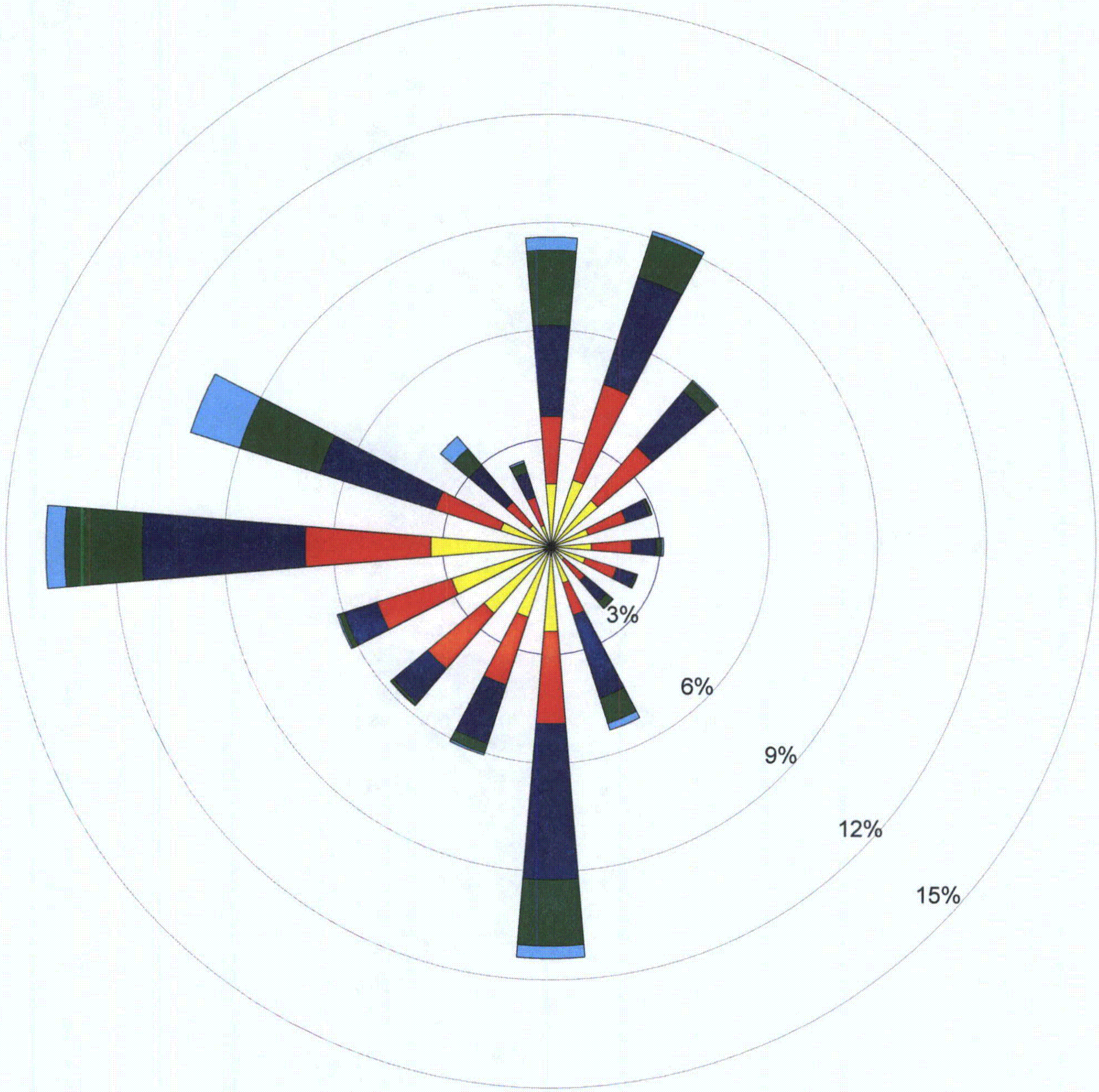
CROW BUTTE RESOURCES, INC.

FIGURE 2.5-2
WIND ROSE PLOT
CROW BUTTE

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: JEC

ARCADIS 630 Plaza Drive, Ste. 100 Highlands Ranch, CO 80129 P: 720-344-3500 F: 720-344-3535 www.arcadis-us.com

K:\CBR_Projects\CO001396_ThreeCrow\3_IMAGES\Illustrator\TR Fig_2_5-2 Wind Rose for Crow Butte.ai @ 05/17/2010



Wind Speed
(knots)

- >21
- 17-21
- 11-16
- 7-10
- 4-6
- 1-3

Average Wind Speed: 11.49 knots
Percent Calm Winds: 0.00 percent
Wind Direction: Blowing from
Data Period: April 1982 - May 1984

N
W — E

CROW BUTTE RESOURCES, INC.

FIGURE 2.5-3
WIND ROSE PLOT
CHADRON NE - STATION No.24017
1982 - 1984

PROJECT: CO001396.00001 | MAPPED BY: JC | CHECKED BY: JEC

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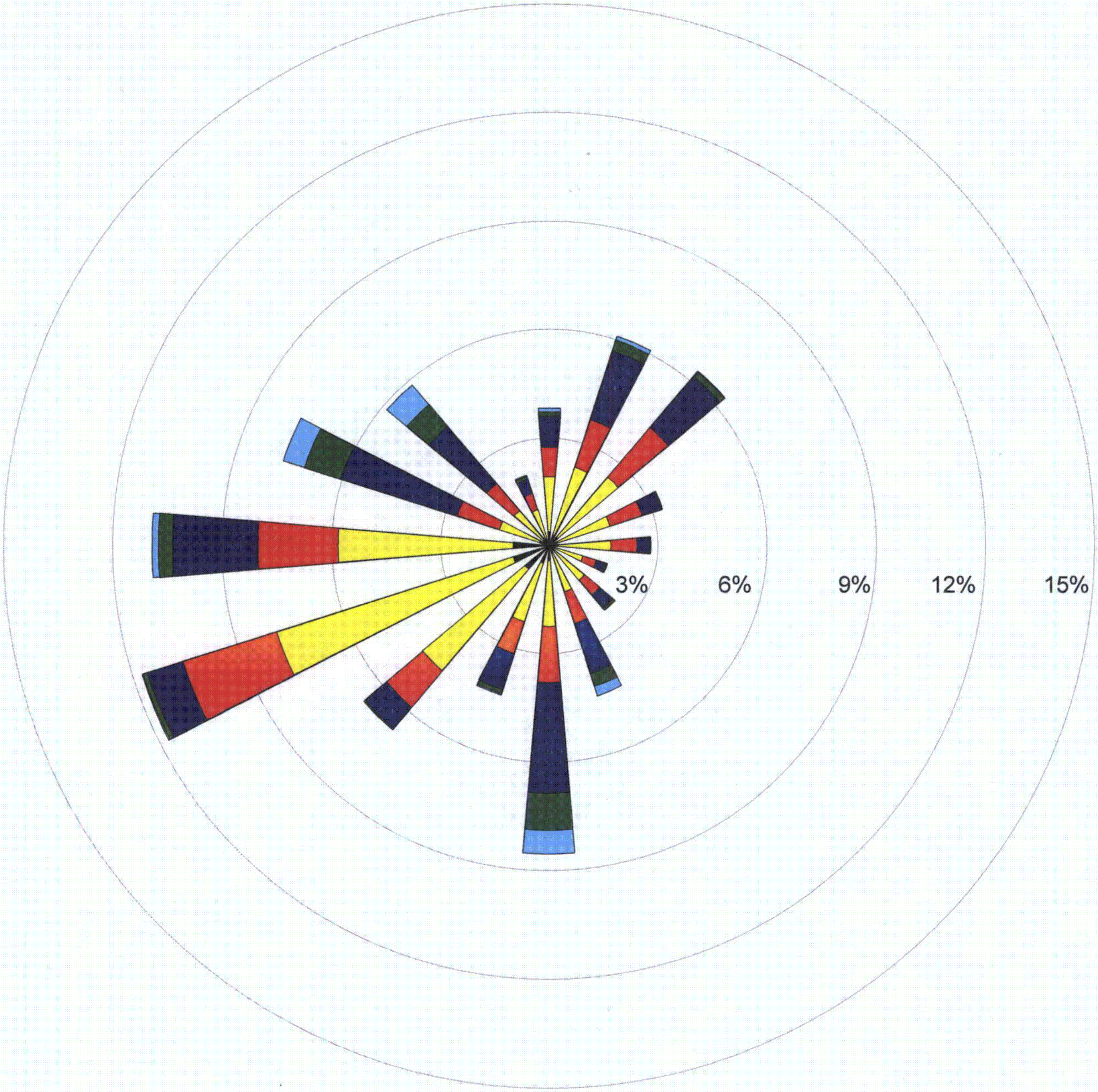
K:\CBR_Projects\CO001396_ThreeCrow\3_IMAGES\Illustrator\TR Fig_2_5-3 Wind Rose for Charon 1982-1984.ai @ 05/18/2010



Wind Speed (knots)

- >21
- 17-21
- 11-16
- 7-10
- 4-6
- 1-3

Average Wind Speed: 8.22 knots
Percent Calm Winds: 11.58 percent
Wind Direction: Blowing from
Data Period: 2000 - 2004, 2005-2009

N
W E

CROW BUTTE RESOURCES, INC.

FIGURE 2.5-4
WIND ROSE PLOT
CHADRON NE - STATION No.24017
2000 - 2009

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: JEC

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K:\CBR_Projects\CO001396_ThreeCrow\3_IMAGES\Illustrator\TR Fig_2_5-4 Wind Rose for Chadron 2000-2009.ai @ 05/17/2010

LEGEND

- Regional Ambient Air Monitoring Site
- City of Crawford
- National Park/Monument
- Proposed Three Crow Expansion Area (TCEA)
- Interstate Highway
- U.S. Route
- State Highway

0 10 20
Miles

PROJECTION:
NAD 1927 STATE PLANE
NEBRASKA NORTH FIPS 2601

N W E

CROW BUTTE RESOURCES, INC.

FIGURE 2.5-5
LOCATION OF REGIONAL AMBIENT AIR MONITORING SITES

PROJECT: CO001396.00001 MAPPED BY: JC CHECKED BY: JEC

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2.6 Geology and Seismology

2.6.1 Regional Setting

As shown on **Figure 1.3-1**, the proposed TCEA is located approximately 3.5 miles southwest of the City of Crawford, Nebraska in Sections 28, 29, 30, and 33 of Township 31 North, Range 52 West and in Section 25 of Township 31 North, Range 53 West. The City of Crawford is 25 miles west of Chadron, Nebraska and 70 miles north of Scottsbluff, Nebraska. The City of Crawford is 21 miles south of the South Dakota state line and 33 miles east of the Wyoming state line. The Crow Butte area is located near the northern limits of the High Plains section of the Great Plains physiographic province. Topography of the Crow Butte area includes gently sloping, rolling hills with outlying, broad ridges which are dissected by intermittent and perennial streams. The most prominent physiographic feature in the region is the Pine Ridge Escarpment, which rises roughly 300 to 900 feet above the basal plain. The escarpment bounds three sides of the Crawford Basin. Colluvial and alluvial deposits originating from this escarpment cover the permit area. The elevation of the Crow Butte area ranges from 3,880 to 4,100 feet above mean sea level (amsl).

2.6.1.1 Regional Stratigraphy

Table 2.6-1 summarizes the regional stratigraphic section for northwest Nebraska that includes the White River Group (Brule Formation through Basal Chadron Sandstone). A geologic map of bedrock in northwest Nebraska is shown on **Figure 2.6-1**. The bedrock map depicts the occurrence in northwest Nebraska of the Miocene Ogallala Group, Miocene Arikaree Group, the Eocene-Oligocene White River Group, and Upper Cretaceous strata belonging to the Montana Group and Colorado Group. The Upper Cretaceous Pierre Shale, the unconformably overlying White River Group (i.e, Brule Formation, Chadron Formation, and Chamberlain Pass Formation), and the Arikaree Group outcrop in the vicinity of the City of Crawford and TCEA (**Figure 2.6-1**, see inset).

2.6.1.2 TCEA Stratigraphy

The local stratigraphy present within the TCEA consists of the following geological units in descending order: alluvial sediments, Brule Formation, Chadron Formation, Basal Chadron Sandstone and Pierre Shale. The channel sandstone facies of the Chamberlain Pass Formation, informally referred to herein as the Basal Chadron Sandstone, represents the production zone and target of solution mining in the TCEA. The general stratigraphic section for the TCEA is summarized in **Table 2.6-2**. **Figure 2.6-2** illustrates the locations of five north-south and east-west cross-sections through the TCEA depicted on **Figures 2.6-3a through 2.6-3e**.

Though a thick (approximately 1,200 to 1,500 feet), regionally extensive stratigraphic section of sedimentary units underlies the Pierre Shale, those units are not relevant to this proposal. The absence of sandstone units for more than 1,000 feet below the top of the Pierre Shale precludes the need for monitoring zones below the surface of the Pierre Shale. Discussion in this report is limited to those formations immediately above and below the Basal Chadron Sandstone (Petrotek 2004; Wyoming Fuel Company 1983).

This section provides a detailed description of the stratigraphy of the TCEA based on an extensive review of existing site-specific drilling logs and published literature. Geological units are described from stratigraphically youngest to stratigraphically oldest. Revised nomenclature for these stratigraphic units is discussed, where applicable, and referred to throughout this application. To be consistent with historical permitting, the stratigraphic nomenclature used in previous submittals to the NRC and the NDEQ has been preserved.

Alluvium

Alluvial deposits occur between the surface and the top of the Brule Formation and vary in thickness (depending upon topography) from 0 to 30 feet. In general, the alluvium consists of Miocene age rock fragments, sand, gravel and sandy soil horizons, and may include weathered portions of the Brule Formation. Because alluvium is generally unconsolidated and contains either shallow groundwater or is within the vadose zone, log signatures within this unit may vary significantly when compared to signatures for underlying units. On most TCEA logs, resistivity is very high (beyond the log scale), indicating the presence of either soil vapor or fresh water. In general, shallow zones with elevated resistivity also indicated a negatively deflected SP curve, suggesting the presence of a permeable zone and formation fluid with lower resistivity than the fluid within the borehole. Although these log signatures suggest the base of the alluvium can be interpreted, this relationship has not been verified and the Alluvium-Brule Formation contact is not depicted on cross-sections included with this application.

White River Group

The Eocene-Oligocene White River Group consists of the Chamberlain Pass Formation overlain by the Chadron Formation, which is, in turn, overlain by the Brule Formation (**Table 2.6-2**). Strata assigned to this group were deposited within fluvial, lacustrine, and eolian environments (Terry and LaGarry 1998). In northwest Nebraska, it rests unconformably on pedogenically modified Pierre Shale. The bulk of the White River Group is composed of airfall and reworked volcaniclastics derived from sources in Nevada and Utah (Larson and Evanoff 1998; Terry and LaGarry 1998).

The history of stratigraphic nomenclature for the White River Group of Nebraska and South Dakota has had various interpretations as described by Harksen and Macdonald (1969). The following stratigraphic nomenclature represents a preservation of formal and informal members based on nomenclature by Schultz and Stout (1955) with representation of more recent nomenclature (Terry and LaGarry 1998; Terry 1998; LaGarry 1998; Hoganson et al. 1998).

Brule Formation

The Oligocene Brule Formation represents the youngest unit within the White River Group which outcrops throughout most of the Crow Butte area. The unit conformably overlies the Chadron Formation and is unconformably overlain by sandstones of the Arikaree Group (**Figure 2.6-1**). The White River Group was originally subdivided by Swinehart et al. (1985) and later revised by LaGarry (1998) into three members, from youngest to oldest: the "brown siltstone" member, the Whitney Member, and underlying Orella Member (**Table 2.6-2**). The "brown siltstone" member consists of pale brown and brown, nodular, cross-bedded eolian volcaniclastic siltstones and sandy siltstones. The contact with the underlying Whitney Member varies from gradational to a sharp unconformity where the brown siltstone fills valleys and depressions. The Whitney Member consists of pale brown, massive, typically nodular eolian siltstones with occasional thin interbeds of brown and bluish-green sandstone, and volcanic ash. In contrast, the lowest 10 meters consist of white or green laminated fluvial siltstones, sheet sandstones, and channel sandstones. The contact between the Whitney Member and the underlying Orella Member is intertonguing. The Orella Member consists of pale brown, brown, and brownish-orange volcaniclastic overbank clayey siltstones and silty claystones, brown and bluish-green overbank sheet sandstones, and volcanic ash. Occasional thick, fine- to medium-grained, channelized sandstones occur throughout the Orella Member. These sandstones appear to have very limited lateral extent. The overall thickness of the Brule Formation within the TCEA is generally less than 200 feet and ranges from approximately 120 to 180 feet. The majority of the Brule Formation present at the TCEA consists of the Orella Member, as the entire "brown siltstone" member and most of the Whitney Member have been eroded.

The contact between the Brule Formation and underlying Chadron Formation is sometimes difficult to ascertain, as the contact between the two formations is inter-tonguing (LaGarry 1998). Regionally, the contact is recognized as the lithologic change from thinly interbedded and less pedogenically-modified brown, orange, and tan volcaniclastic clayey siltstones and sheet sandstones of the Orella Member to pedogenically-modified green, red, and pink volcaniclastic silty claystones of the Upper Chadron (Big Cottonwood Creek Member) (Terry and LaGarry 1998). On geophysical logs, the Brule Formation is characterized by rapidly fluctuating log curves, or "log chatter" (**Figure 2.6-4**). This response is recognized in resistivity curves, and to a lesser extent SP curves, throughout the TCEA. The fluctuations are produced by resistivity contrasts between the thinly interbedded siltstones and sandstones of the Orella Member. Because the sandstones are porous and part of the regional aquifer, the contacts with the interbedded, dry siltstones are sharp and easily recognized on logs. Lateral correlation of beds within the Brule Formation is very difficult due to generally thin bed thicknesses and limited lateral extent.

The contact between the interbedded siltstones and sandstone of the Brule Formation and the silty claystones of the Upper Chadron Formation is distinguished by a drop off of "log chatter" and establishment of relatively flat or straight curves (i.e., the shale baseline) on both resistivity and SP logs (**Figure 2.6-4**). Because of the intertonguing nature of the Lower Brule and Upper Chadron Formations, thin, isolated sandstones and siltstones may be present in the Upper Chadron, making it appear that the formation contact is deeper in some wells.

Chadron Formation

The Eocene-Oligocene Chadron Formation is a member of the lower White River Group (**Table 2.6-2**). The Chadron Formation conformably overlies the Basal Chadron Sandstone and is conformably overlain by the Brule Formation. From top to bottom, the Chadron Formation historically consists of the following stratigraphic units: Big Cottonwood Creek Member (herein referred to as the Upper Chadron and Upper/Middle Chadron to be consistent with historical permitting), Peanut Peak Member (herein referred to as the Middle Chadron to also be consistent with historical permitting), and Basal Chadron Sandstone. The Basal Chadron Sandstone represents the production zone and target of ISL mining within the TCEA. **Figures 2.6-3a** through **2.6-3e** depict the subsurface geology of the Chadron Formation within the TCEA.

Upper Chadron and Upper/Middle Chadron

The Upper Chadron and Upper/Middle Chadron are composed primarily of volcaniclastic overbank silty claystones interbedded with tabular and lenticular channel sandstones, lacustrine limestones, pedogenic calcretes, marls, volcanic ashes, and gypsum (Terry and LaGarry 1998). Tuffs in the Toadstool Park area that occur in the Upper Chadron were dated by $^{40}Ar/^{39}Ar$ methods as late Eocene (~34 Ma) in age (Terry and LaGarry 1998). The lower boundary of this member is an intertonguing contact with the underlying Middle Chadron of the Chadron Formation, or is a local unconformity where the Upper/Middle Chadron fills valleys and depressions (Terry and LaGarry 1998) (**Table 2.6-2**). The upper boundary is recognized by a lithologic change from pedogenically modified green, red, and pink volcaniclastic silty claystones of the Upper Chadron to thinly interbedded and less pedogenically modified brown, orange, and tan volcaniclastic clayey siltstones and sheet sandstones of the Orella Member of the Brule Formation (Terry and LaGarry 1998) (**Table 2.6-2**).

The Upper Chadron is the youngest member of the Chadron Formation (**Table 2.6-2**). The upper part of the Upper Chadron is light green-gray bentonitic clay grading downward to green and frequently red clay, though interbedded sandstones also occur. Based on the predominance of fine-grained lithologies that comprise the Upper Chadron, this unit represents a distinct and rapid facies change from the coarse-grained lithologies present in the underlying Upper/Middle Chadron and Basal Chadron Sandstone. Based on available well control data, the Upper Chadron is continuous across the TCEA. The Upper Chadron ranges in stratigraphic thickness from approximately 270 to 380 feet in the TCEA (**Figures 2.6-3a** through **2.6-3e**).

Four core samples (T-1050c Run 1, T-1050c Run 2, T-1051c Run1, and T-1051c Run 2) were collected from the Upper Chadron by CBR at boreholes T-1050c and T-1051c in Section 30 of the TCEA (**Figure 2.6-2**). X-ray diffraction analyses of both the T-1050c Run 1 and T-1050c Run 2 samples indicate compositions of primarily montmorillonite with minor amounts of calcite, quartz, plagioclase, K-feldspar, and illite/mica. Particle grain size distribution analyses of the T-1050c Run 1 and T-1050c Run 2 samples indicate silts composed of approximately 82 percent silt and clay particles (i.e., approximately 70 percent silt and 12 percent clay particles) and approximately 73 percent silt and clay particles (i.e., approximately 56 percent silt and 16 percent clay particles), respectively. X-ray diffraction analysis of the T-1051c Run 1 sample indicates a composition of primarily montmorillonite with minor amounts of quartz, plagioclase, K-feldspar, and illite/mica. Particle grain size distribution analysis of the T-1051c Run 1 sample indicates a sandy silt composed of approximately 72 percent silt and clay particles (i.e., approximately 58 percent silt and 14 percent clay particles). X-ray diffraction analysis of the T-1051c Run 2 sample indicates a composition of primarily montmorillonite with minor amounts of gypsum, calcite, quartz, plagioclase, K-feldspar, and illite/mica. Particle grain size distribution analysis of the T-1051c Run 2 sample indicates a clayey silt composed of approximately 95 percent silt and clay particles (i.e., approximately 66 percent silt and 29 percent clay particles).

Typical gamma ray (GR), spontaneous potential (SP), and resistivity log signatures for the Upper Chadron exhibit curves representative of the relatively flat shale baseline (**Figure 2.6-4**). Fluctuations are present among Upper Chadron log curves, representing interbedded siltstones, sandstones, limestones, and volcanic ash deposits that occur less commonly than in the overlying Brule Formation.

The Upper/Middle Chadron is directly overlain by the Upper Chadron (**Table 2.6-2**). At some locations, the Upper/Middle Chadron is similar in appearance to the channel sandstone facies of the upper portion of the Basal Chadron Sandstone (described later in this section) and is typically a very fine to fine grained, well-sorted, poorly cemented sandstone. An isopach map of the Upper/Middle Chadron is shown on **Figure 2.6-5**. Extensive review of available data from the TCEA and vicinity strongly indicates that the extent of the sandstone is limited to the southern half of the central and eastern portions of the TCEA (**Figure 2.6-3a through 2.6-3e and Figure 2.6-5**). The unit is completely absent in the western, northern, and southernmost portions of the TCEA (**Figure 2.6-5**). The available data suggest that the Upper/Middle Chadron, where present, typically ranges in thickness from approximately 0 to 50 feet across the TCEA.

The GR curve distinctly marks the top and bottom of the Upper/Middle Chadron (**Figure 2.6-4**). The curve responses of the logs are not as large as those seen in the Basal Chadron Sandstone (discussed below), indicating lower concentrations of radioactive materials. The GR shifts distinctly to the right at the lower boundary, most likely indicating a sandstone containing uranium. The GR curve can also shift to the left within this unit, indicating sandstone with no uranium. The resistivity curve shift described for the Upper/Middle Chadron at the NTEA is not recognized at the TCEA.

For unknown reasons, possibly the continued or renewed uplift of the Black Hills or Chadron Dome, reworked sediment and fluvial deposits of the Upper and Upper/Middle Chadron were concentrated in northwestern Nebraska (Terry and LaGarry 1998). At some locations, initial deposition of the Upper/Middle Chadron occurred within paleovalleys incised into the underlying Middle Chadron (Terry and LaGarry 1998). At other locations (e.g., Toadstool Park), the lower boundary is intertonguing (Terry and LaGarry 1998).

<u>Middle Chadron</u>

The Middle Chadron is described as a clay-rich interval that grades from brick red to grey in color with interbedded bentonitic clay and sands. A light green-gray "sticky" clay within this unit serves as an excellent marker bed in drill cuttings and has been observed in virtually all regional test holes both within the TCEA, NTEA and the CPF license area. The Middle Chadron unconformably overlies the Basal Chadron Sandstone (Chamberlain Pass Formation) in South Dakota and Nebraska (Terry 1998) (**Table 2.6-2**). As described above, the upper boundary is variable and is overlain either by the Upper/Middle Chadron, where present, or by the Upper Chadron (**Table 2.6-2**). The Middle Chadron differs from the overlying Upper/Middle and Upper Chadron in that the Middle Chadron is composed of bluish-green, smectite-rich mudstone and claystone, weathers into hummocky, "haystack-shaped" hills and slopes with a popcorn-like surface, is less variegated in color, and has less silt (Terry 1998). The predominantly clay lithology of the Middle Chadron represents a distinct and rapid facies change from the underlying Basal Chadron Sandstone. Within the TCEA, the unit ranges in stratigraphic thickness from about 130 to 190 feet. A "red clay" horizon that occurs at the base of the Middle Chadron is indicated on more than half of the geophysical logs and driller notes that were reviewed and is discussed in more detail below (Appendix D). This "red clay" is formally referred to as the Upper Interior Paleosol and is discussed in more detail below.

Two core samples (T-1050c Run 3 and T-1051c Run 3) were collected from the Middle Chadron by CBR at boreholes T-1050c and T-1051c in Section 30 of the TCEA (**Figure 2.6-2**). X-ray diffraction analysis of the T-1050c sample indicates a composition of primarily mixed-layered illite/smectite with minor amounts of quartz plagioclase, K-feldspar, gypsum and illite/mica. Particle grain size distribution analysis indicates a clayey silt composed of approximately 85 percent silt and clay particles (i.e., approximately 58 percent silt and 27 percent clay particles). X-ray diffraction analysis of the T-1051c sample indicates a composition of primarily montmorillonite with minor amounts of quartz, plagioclase, and K-feldspar. Particle grain size distribution analysis indicates a silty clay composed of 100 percent silt and clay particles (i.e., approximately 62 percent clay and 38 percent silt particles).

Typical GR, SP, and resistivity log signatures for the Middle Chadron exhibit curves representative of the shale baseline (**Figure 2.6-4**). The top of the Middle Chadron is noted where the curves break either distinctly to the left or to the right, representing the sandstone of the Upper/Middle Chadron, where present. Where overlain by the Upper Chadron, the contact between units is very difficult to ascertain due to similarities in grain size.

The Upper, Upper/Middle and Middle Chadron units represent the upper confining zone for the Basal Chadron Sandstone within the TCEA (see detailed discussion in Section 2.7.4). An isopach map of the upper confining zone is shown in **Figure 2.6-6**. The thickness of the upper confining zone ranges from approximately 400 to 560 feet in the vicinity of the TCEA. The zone appears to generally thicken toward the south and southwest across the permit boundary with a narrow northwest-trending high ridge in the central northern portion of the TCEA.

Basal Chadron Sandstone – Mining Unit

The Basal Chadron Sandstone is the oldest unit in the White River Group. The lower section is a coarse-grained, arkosic sandstone with frequent interbedded thin silt and clay lenses of varying thickness and continuity that lies on a marked regional unconformity with the underlying Yellow Mounds Paleosol (Terry 1998). The lower contact is easily recognized by a change in color and lithology from the underlying black or bright yellow, pedogenically modified surface of the Pierre Shale (i.e., the Yellow Mounds Paleosol) to white channel sandstone. Occasionally, the Basal Chadron Sandstone grades upward to fine-grained sandstone containing varying amounts of interstitial clay material and persistent clay interbeds. Vertebrate fossils from the Basal Chadron Sandstone in northwestern Nebraska and South Dakota indicate a late Eocene age (Chadronian) (Clark et al. 1967; LaGarry 1996; Lillegraven 1970; Vondra 1958).The Upper Interior Paleosol, occurring as a persistent clay horizon, typically brick red in color, developed on top of the Basal Chadron Sandstone and generally marks the upper limit of the Basal Chadron Sandstone (**Table 2.6-2**).

The Basal Chadron Sandstone occurs at depths ranging from about 580 to 940 feet bgs and was encountered at all exploration holes. An isopach map of the Basal Chadron Sandstone in the vicinity of the TCEA is presented on **Figure 2.6-7**. Stratigraphic thickness of the unit within the TCEA ranges from approximately 70 to 250 feet. The thickest sections of the unit occur in the central and western portions of the TCEA (**Figure 2.6-8**). Up to four distinct sandstone units are present in the thickest portions of this unit and are separated by variable amounts of interbedded clay. The Basal Chadron Sandstone thins significantly to the north and east where only two sandstone units appear to be present on the outermost edges of the TCEA. This observation is consistent with the occurrence of only two distinct channel sandstone intervals at the CPF license area located approximately 3 miles to the east. Structure contour maps of the top of the Basal

Chadron Sandstone indicate that the unit dips slightly to the west-northwest across the TCEA (**Figures 2.6-7** and **2.6-11**). This shallow dip is also depicted on selected cross sections (**Figures 2.6-3a, 3b, and 3d**). Regionally, the unit ranges in thickness from 0 to 250 feet (**Figure 2.6-12**).

The greenish-white channel sandstones of the Basal Chadron Sandstone that overlie the Yellow Mounds Paleosol are the target of ISL mining activities in the TCEA. Regionally, deposition of the Basal Chadron Sandstone has been attributed to large, high-energy braided streams. In this regard, the Basal Chadron Sandstone is lenticular with numerous facies changes occurring within short distances. The interbedded thin silt and clay lenses most likely represent flood plain or low velocity deposits normally associated with fluvial sedimentation.

Mineralogical investigations within the TCEA indicate that the Basal Chadron Sandstone is comprised of 50 to 95 percent clear quartz and minor chert, 2 to 15 percent variably-colored (white, green and pink) feldspars, trace to 30 percent lithics (primarily mudstone and shale fragments), and trace weakly altered to fresh pyrite. An increase in organic matter and pyrite appears to be associated with mineralization. A change was noted in overall composition of the sandstones from arkosic in oxidized or unaltered sandstones to a notably less feldspathic, cleaner sandstone in the mineralized intervals, which may indicate better permeability and porosity that was favorable for transport of mineralizing fluids and deposition of uranium. The sandstones that comprise the Basal Chadron Sandstone within the CPF license area are dominated by quartz (50% monocrystalline) and feldspar (30-40% undifferentiated feldspar) with the remainder made up of chert, pyrite, and various heavy metals and polycrystalline and chalcedonic quartz (Collings and Knode, 1984). X-ray diffraction analyses indicate that the Basal Chadron Sandstone within the CPF license area is 75 percent quartz with the remaining composition composed of potassium feldspar and plagioclase and the following clay minerals: illite, smectite, expandable mixed layer illite-smectite, and minor amounts of kaolinite (Collings and Knode, 1984).

Geophysical logs record a unique signature for the Basal Chadron Sandstone (**Figure 2.6-4**). A distinct GR spike is present at the base of the unit in most of the TCEA exploration boreholes, indicating an abundance of radioactive material. Increased resistivity (i.e., log curve shift to the right), decreased N-N count (i.e., log curve shift to the left), and decreased SP (i.e., log curve shift to the left) are typically associated with GR spikes. These log signatures support interpretations of a uranium-bearing, fluid-filled sandstone interval. Overlying channel sandstone intervals that are present in the middle and upper portions of the unit typically have lower GR readings, indicative of both lower amounts of radioactive materials and potentially non-uranium bearing intervals. Such intervals are typically marked by increased resistivity (i.e., higher porosity and fluid-filled) and lower N-N counts and, in contrast to the uranium-bearing units, typically have positive SP curve deviations. This log response indicates that within the higher uranium-bearing units, mud filtrate resistivity is higher than formation water resistivity, which may be the result of the presence of higher salinity waters in uranium-bearing units. Pervasive interbedded clay intervals are indicated by high GR responses accompanied by lower resistivity (i.e., reduced porosity and decrease in water content), an interpretation that is further supported by driller or geologist notes. The high radioactivity of these clay units likely suggests the presence of rhyolitic ash. The top of the formation is marked by a gradual return of SP and resistivity curves to the shale baseline.

Montana Group

Interior Paleosol (Upper Interior Paleosol and Yellow Mounds Paleosol)

The Interior Paleosol of Schultz and Stout (1955) was subsequently divided into the younger Eocene Upper Interior Paleosol and the Cretaceous Yellow Mounds Paleosol (Pierre Shale) (Terry 1991; Evans and Terry 1994; Terry and Evans 1994; Terry 1998) (**Table 2.6-2**). The Upper Interior Paleosol represents pedogenically modified distal overbank deposits of a distinct fluvial system developed on the surface of the Basal Chadron Sandstone which predates deposition of the Chadron Formation. The Yellow Mounds Paleosol developed on the Cretaceous Pierre Shale and altered the normally black marine shale to bright yellow, purple, lavender, and orange.

Review of available data for the TCEA indicates that neither of the two paleosol units could be consistently interpreted based solely on geophysical logs. For simplicity, these units are not represented on the type log or cross-sections.

Pierre Shale

The Cretaceous Interior Seaway resulted in the offshore deposits of the late Cretaceous Pierre Shale (**Table 2.6-2**). The Pierre Shale is a thick, homogenous black marine shale with low permeability that represents one of the most laterally extensive formations of northwest Nebraska. Regional geologic data indicate that this formation can be up to 1,500 feet thick in the Dawes County area (Wyoming Fuel Company 1983; Petrotek 2004). The southward retreat of the Cretaceous Interior Seaway resulted in the subaerial exposure and weathering of rock units from Early Cretaceous to Eocene age across the northern Great Plains (Lisenbee 1988). This event resulted in the erosion and pedogenic modification of the surface of the Pierre Shale to form the brightly-colored Yellow Mounds Paleosol (Terry and LaGarry 1998) (**Table 2.6-2**). Consequently, the pedogenically modified surface of the Pierre Shale marks a major unconformity with the overlying White River Group and exhibits a paleotopography with considerable relief (DeGraw 1969). The Pierre Shale is underlain by organic-rich shale and marl with minor amounts of sandstone, siltstone, limestone, and chalk of the Niobrara Formation (**Table 2.6-1**). Structure contour maps of the top of the Pierre Shale indicate that the unit dips slightly to the west across the TCEA (**Figures 2.6-9 and 2.6-13**). This shallow dip is also depicted on selected cross sections (**Figures 2.6-3a and 3b**).

Two core samples (T-1050c Run 5 and T-1051c Run 5) were collected from the Pierre Shale by CBR at boreholes T-1050c and T-1051c in Section 30 of the TCEA (**Figure 2.6-2**). X-ray diffraction analysis of the T-1050c sample indicates a composition of primarily quartz and mixed-layered illite/smectite with minor amounts of illite/mica, K-feldspar, kaolinite, and chlorite. Particle grain size distribution analysis indicates a silty clay composed of approximately 99 percent silt and clay particles (i.e., approximately 58 percent clay and 42 percent silt particles). X-ray diffraction analysis of the T-1051c sample indicates a composition of primarily quartz and montmorillonite with minor amounts of plagioclase, K-feldspar, dolomite, chlorite, and illite/mica. Particle grain size distribution analysis indicates a clayey silt composed of approximately 97 percent silt and clay-sized particles (i.e., approximately 57 percent silt and 40 percent clay particles).

Typical geophysical log responses for the Pierre Shale exhibit curves that are relatively flat or straight and represent the shale/clay log signature (**Figure 2.6-4**; **Appendix D**). The GR has established the shale/clay baseline. The top of the Pierre Shale is noted where the curves break either sharply to the left or to the right and represent the occurrence of the Basal Chadron Sandstone. Spontaneous potential and resistivity curves qualitatively indicate a lack of permeable, water-bearing zones within the Pierre Shale.

Eight deep oil and gas exploration wells were drilled in the vicinity of the TCEA (Farner 1, Federal 1, Hamaker, Heath 1, Heckman 1, Homrighausen, Roby 3, and Sikorski) (**Figure 2.2-3, Appendix D**). Well abandonment records are shown in **Appendix B**. Oil and gas exploration wells have typically been drilled to depths much greater than on-lease uranium exploration wells. The character of the entire Pierre Shale in the vicinity of the TCEA can best be observed in geophysical logs from five of the eight nearby abandoned oil and gas wells (Federal, Heath 1, Homrighausen, Roby 3, and Sikorski), and the CBR deep disposal well (CBR UCI #1), as these logs were completed through the entire thickness of the unit. Based on observations from logging, the thickness of the Pierre Shale in the vicinity of the TCEA ranges from approximately 600 to 740 feet. The top of the Pierre Shale was encountered in all wells at depths ranging from approximately 600 to 1,300 feet bgs. The Farner 1 well is located approximately 2 miles east of the TCEA permit boundary (T31N, R52W, Section 26) and has a total depth of 3,463 feet bgs. The Federal 1 well (W030995) is located approximately 2 miles north of the TCEA permit boundary (T31N, R52W, Section 17) and has a total depth of 3,818 feet bgs. The Hamaker well is located approximately 5 miles south of the TCEA permit boundary and has a total depth of 4,037 feet bgs. The Heath 1 well is located within approximately 1 mile of the southeastern corner of the TCEA permit boundary (T30N, R52W, Section 26) with a total depth of 3,348 feet bgs. The Heckman 1 well is located approximately 3 miles northeast of the TCEA permit boundary (T31N, R52W, Section 24) and has a total depth of 4,590 feet bgs. The Homrighausen well is location approximately 2.5 miles southeast of the TCEA permit boundary (T30N, R52W, Section 10) and has a total depth of 2,749 feet bgs. The Roby 3 well is located approximately 4 miles east of the TCEA permit boundary (T31N, R51W, Section 31) and has a total depth of 3,399 feet bgs. The Sikorski 1 well is located approximately 2 miles southeast of the TCE permit boundary (T30N, R52W, Section 10) and has a total depth of 3,626 feet bgs. Deep disposal well CBR UIC #1 is located approximatle 4.5 miles east of the TCEA permit boundary (T31N R52W Section 19) and has a total depth of 3,910 feet bgs. At UIC #1, the Pierre Shale was encountered from 925 to 1,560 feet bgs, where the base of the Pierre Shale is indicated by an increase in resitivity at the contact with the underlying Niobrara Formation (**Appendix D**).

Pre-Pierre Shale Stratigraphy

Underlying the Pierre Shale is a thick sequence of Mississippian through Cretaceous age strata that unconformably overlie pre-Cambrian granite (**Table 2.6-1**). Together with the Pierre Shale, the underlying Niobrara Formation, Carlile Shale, Greenhorn Limestone, and Graneros Shale compose a composite lower confining interval approximately 2,500 feet thick which immediately underlies the Basal Chadron Sandstone. There do not appear to be significant sandstone units within this thick sequence of low-permeability strata.

All geologic units encountered during the drilling of oil and gas exploration wells in the vicinity of the TCEA appear to be consistent with known regional stratigraphy. Geologic units that are consistently identified in all wells include the Niobrara Formation, Carlile Shale, Greenhorn

Limestone, "D" and "J" sands of the Dakota Group, and the Skull Creek Formation (**Table 2.6-1**).

2.6.2 Geochemical Description of the Mineralized Zone

The depth to the ore body within the Basal Chadron Sandstone in the TCEA ranges from approximately 580 to 940 feet below ground surface (bgs) (**Table 2.6-2**). The width of the ore body varies from approximately 2,100 to 4,000 feet. Indicated ore resources as U_3O_8 for the TCEA are 3,750,481 pounds (lbs) with an additional inferred estimate of 1,135,452 lbs. Total reserves are estimated at 4,900,000 lbs. The ore grade as U_3O_8 ranges from 0.05 to 0.5 percent with an average ore grade of 0.22 percent.

Hansley et al (1989) conducted detailed geochemical analysis of the Crow Butte uranium ore to assess both ore genesis and composition. The Crow Butte deposits, including Three Crow, are roll-type deposits with coffinite being the predominant uranium mineral species present. The origin of the uranium is rhyolitic ash, which is abundant within the matrix of the Basal Chadron. Coffinite is associated with pyrite, and high silica activity due to dissolution of the rhyolitic ash which favored formation of coffinite over uraninite in most parts of this sandstone. In addition, smectite is present in the samples examined, with the most common minerals in the sandstone being quartz, plagioclase, K-feldspar, coffinite, pyrite, marcasite, calcite, illite/smectite and tyuyamunite. The heavy mineral portion of the samples contained several minerals including those above as well as garnet, magnetite, marcasite, and illmenite. Vanadium was detected in the samples primarily as an amorphous species presumed to have originated from the in-situ ash. Hansley et al state that at least some uranium and vanadium remain bound to amorphous volcanic material and/or smectite rather than as discrete mineral phases.

Petrographic data obtained and examined by Hansley et al (1989) suggest that uranium mineralization occurred before lithification of the Basal Chadron. Hansley states: *"Dissolution of abundant rhyolitic volcanic ash produced uranium (U)- and silicone (Si)- rich ground waters that were channeled through permeable sandstone at the base of the Chadron by relatively impermeable overlying and underlying beds. The precipitation of early authigenic pyrite created a reducing environment favorable for precipitation and accumulation of U in the basal sandstone. The U has remained in a reduced state, as evidenced by the fact that the unoxidized minerals, coffinite and uraninite, comprise the bulk of the ore."*

Based on similar regional deposition, the TCEA ore body is expected to be similar mineralogically and geochemically to that of the CPF license area. The ore bodies in the two areas are within the same geologic unit (the Basal Chadron Sandstone) and have the same mineralization source. The sites are separated by only a few miles, and the cause of mineral deposition in the two areas appears to be similar. Neither site is anticipated to be significantly affected by recharge or other processes.

2.6.3 Structural Geology

Regional uplift during the Laramide Orogeny forced the southward retreat of the Cretaceous Interior Seaway, resulting in the subaerial exposure and weathering of rock units from Early Cretaceous to Eocene age across the northern Great Plains (including the Pierre Shale). The depositional basin associated with deformation of the Wyoming thrust belt and initial Laramide uplifts to the west of Nebraska, represented a structural foredeep. The greatest uplift occurred in the Black Hills, which lie north of Sioux and Dawes Counties in southwestern South Dakota. Lisenbee (1988) provides a comprehensive summary of the tectonic history of the Black Hills uplift. The pre-Oligocene Black Hills uplift (<37 Ma) occurred prior to the deposition of the Eocene-Oligocene strata of the White River Group. Strata of the White River Group cover most of the eroded roots of the Black Hills uplift as well as the syntectonic sedimentary rocks in the Powder River and Williston basins. The Hartville, Laramie, and Black Hills uplifts supplied sediment for rivers that flowed east-southeast across the study area (Clark 1975; Stanley and Benson 1979; Swinehart et al. 1985).

The most prominent structural expression in northwest Nebraska is the Chadron Arch (**Figure 2.6-10, Figure 2.6-13a**). Together with the Chadron Arch, the Black Hills Uplift produced many of the prominent structural features presently observed in the region. The Chadron Arch represents an anticlinal feature that strikes roughly northwest-southeast along the northeastern boundary of Dawes County. Swinehart et al. (1985) suggested multiple phases of probable uplift in northwestern Nebraska near the Chadron Arch between c.a. 28 Ma and <5 Ma. The only known surficial expressions of the Chadron Arch are outcroppings of Cretaceous rocks that predate deposition of the Pierre Shale in the northeastern corner of Dawes County, as well as in small portions of Sheridan County, Nebraska and Shannon County, South Dakota. The general locations of faults in northwest Nebraska are depicted on the State Geologic Map shown on **Figure 2.6-1**.

The Crow Butte area, including the CPF license area, North Trend, and TCEA, lie in what has been named the Crawford Basin (DeGraw, 1969). DeGraw (1969) substantiated known structural features and proposed several previously unrecognized structures in western Nebraska based on detailed studies of primarily deep, oil test hole data collected from pre-Tertiary subsurface geology. The Crawford Basin was defined by DeGraw (1969) as a triangular asymmetrical basin about 50 miles long in an east-west direction and 25 to 30 miles wide. The basin is bounded by the Toadstool Park Fault on the northwest, the Chadron Arch and Bordeaux Fault to the east, and the Cochran Arch and Pine Ridge Fault to the south (**Figure 2.6-10**). The Crawford Basin is structurally folded into a westward-plunging syncline that trends roughly east-west. Note that the Bordeaux Fault, Pine Ridge Fault, and Toadstool Park Fault proposed by DeGraw (1969) are not presented on the State Geologic Map (**Figure 2.6-1**). The Toadstool Park Fault has been mapped at one location (T33N, R53W) and is estimated to have had approximately 60 feet of displacement (Singler and Picard 1980). The City of Crawford is located near the axis of the Crawford Basin. More recent fault interpretations by Hunt (1990) for northwest Nebraska are also shown on **Figure 2.6-10**, which include the Whetstone Fault, Eagle Crag Fault, Niobrara Canyon Fault and Ranch 33 Fault in the vicinity of the City of Harrison in Sioux County. The faults identified by Hunt (1990) all trend to the northeast-southwest, sub-parallel to the Pine Ridge Fault (**Figure 2.6-10**).

Former drilling activities at the CPF license area identified a structural feature referred to as the White River Fault located between the CPF Class III permit area and the NTEA (**Figure 2.6-10**). Evidence of a fault was identified during the exploration drilling phase of the CPF license area (Collings and Knode 1984). The fault is manifested in the vicinity of the NTEA as a significant northeast-trending, subsurface fold. The detailed kinematics of the White River Fault were investigated during preparation of the NTEA Petition for Aquifer Exemption. Based on an extensive review of drilling and logging data, it was determined that while the White River Fault may cut the Pierre Shale at depth along with stratigraphically lower units, there is no evidence that a fault offsets the geologic contact between the Pierre Shale and overlying White River Group nor individual members of the White River Group. This fault does not appear to be present in the vicinity of the TCEA.

2.6.3.1 Pine Ridge Fault

Approximately one mile south of the TCEA is the inferred Pine Ridge Fault, located along the northern edge of the Pine Ridge escarpment (**Figure 2.6-10**). The 230-mile long Pine Ridge escarpment exhibits an average of 1,200 feet of topographic relief (Nixon 1995). The Pine Ridge is an arc roughly concentric to the Black Hills Dome, which suggests an apparent structural relationship. The escarpment has been interpreted to represent the southern outermost cuesta of the Black Hills Dome (Nixon 1995). The escarpment is capped by sandstone of the Arikaree Group with exposed deposits of the White River Group mapped along the topographically lower, northern side of the escarpment.

The Pine Ridge Fault is inferred from several lines of evidence, though detailed studies are currently unavailable. The fault was initially proposed by DeGraw (1969) based on subsurface data. The fault trends east to west across both Sioux and Dawes Counties, is sub-parallel to the Cochran Arch, and has a reported north side down displacement of roughly 300 feet (**Figure 2.6-10**). Swinehart and others (1985) reported normal faulting along the feature that post-dates the deposition of the Upper Harrison beds of the Arikaree Group. This interpretation would confine that age of inferred fault slip to post-early Miocene.

Diffendal (1994) performed lineament analyses based on a mosaic of synthetic-aperture radar data of the Alliance, Nebraska area prepared by the USGS. Observed landforms and lineaments were reported to align well with known faults in the vicinity of Chadron. Lineaments in the radar image along Pine Ridge, located to the south of Chadron, are attributed to jointing or faulting and trend N40E and N50W (Diffendal 1982). Similar features are also noted west of Fort Robinson. Swinehart and others (1985) report that these features are likely an extension of the Whalen trend in Wyoming (Hunt 1981).

The Pine Ridge Fault, as inferred by DeGraw (1969), trends across the southeast corner of the 2.25-mile AOR at approximately 1.5 miles south of the TCEA permit boundary (**Figure 2.6-14**). Borehole data is sparse in the southern third of the AOR, making identification and characterization of the fault difficult. CBR geologists have reviewed the available drill data to determine the extent and impact of this fault on operations. Using the single point resistance on geophysical logs, the depth to the contact between the Pierre Shale and overlying Chadron Formation was determined. Cross sections have been prepared using this data to show the contact surface elevations.

Cross sections which transect the inferred location of the Pine Ridge Fault are shown in **Figure 2.6-14**. Because of the limited amount of drill data, four of the cross sections are located to the east of the TCEA boundary, but are significant in that they provide the closest spaced drill data available for fault characterization. Sections F-F', G-G', H-H' and I-I' are located approximately 5 miles, 2 miles, 1 mile and 0.5 miles east of the TCEA boundary respectively. Section J-J' along the western side of the TCEA, consists of boreholes that are widely spaced, particularly in the area of the proposed fault. Such widely spaced data makes definitive interpretation in this area difficult.

Cross section F-F' shown in **Figure 2.6-15a** provides the most reliable close spaced data for interpreting the fault. Located approximately five miles east of the TCEA, cross section F-F' consists of 20 boreholes along a 6.3-mile trend. The drill holes that comprise this cross section are located along the main axis of the current license area. Moving southward along F-F', this section shows a gentle rise in elevation from R-831 to E-19 that is likely a result of the presence of the Cochran Arch to the south (DeGraw, 1969). From E-19 to Wa-5, a decline of 63 feet is observed over a distance of approximately three quarters of a mile that is roughly in line with the Pine Ridge Fault inferred by DeGraw (1969). The 63 feet of potential displacement is well short of DeGraw's reported 300-feet. It is plausible that this decline may represent the eroded surface of the Pierre Formation prior to deposition of the overlying units. The top surface of the Pierre Shale rises southward from Wa-5 towards the Cochran arch.

Cross section G-G' shown in **Figure 2.6-15a** is located approximately 2 miles east of the TCEA and is comprised of nine drill holes along an approximately 9-mile traverse. Cross section G-G' shows a structural low at drill hole RSm-2 that is in line with the westward-plunging synclinal axis of the Inner Crawford Basin (Collings and Knode 1983). Similar structural lows have been observed in cross sections within the TCEA, which coincide with the thickest intervals of Basal Chadron Sandstone. Cross section G-G' does not show definitive evidence of faulting; however, the south end of the cross section does show a slight increase in elevation that is likely due to the presence of the Cochran Arch to the south.

Cross sections H-H' and I-I' shown in **Figure 2.6-15b** are located approximately 1.0 miles and 0.5 miles east of the TCEA boundary, respectively. These two sections show the Inner Crawford Basin structural low in the northern portions of the cross sections. The top surface of the Pierre Shale rises out of the basin at the northern end of the cross section and then decreases in elevation southward. The observed southward decrease in the top surface of the Pierre Shale does not match well with observations from cross sections to the east and west or with the concept of north side down displacement along the inferred Pine Ridge Fault. Due to the distance between drill locations along the southern extent of cross sections H-H' and I-I', potential errors in estimates of the top surface of the Pierre Shale, topographic lows on the eroded surface of the Pierre Shale, or flexing related to the Crawford Basin may account for the observed southward decrease in elevation. The Pine Ridge Fault, as inferred by DeGraw (1969), would be located in the vicinity of borehole C-7; however, there is no observed displacement in this location on the order of magnitude suggested by DeGraw (1969) (**Figure 2.6-14**).

Cross section J-J' shown in **Figure 2.6-15b** is the westernmost cross section that transects the inferred fault. This cross section is located along the western edge of the TCEA and extends nearly six miles southward. Similar to previously described cross sections, the north end of cross section J-J' shows the synclinal axis of the Inner Crawford Basin and the gradual rise in elevation southward. Due to sparse drilling data and distance between drill locations, the interpreted cause for the approximately 200 feet of elevation change between C-14 and C-27 is speculative. The elevation change may be due to the presence of the Pine Ridge Fault, the Cochran Arch, or both.

Based on the available information, the existence the Pine Ridge Fault within the AOR, as inferred by DeGraw (1969), cannot be confirmed. Furthermore, cross sections F-F' through J-J' do not substantiate the reported vertical displacement of 300 feet within the AOR. It is possible, however, that the displacement within the AOR was significantly less than reported. In general, available information for the top surface of the Pierre Shale in the vicinity of the inferred fault does indicate a rise in elevation to the south of the AOR. Given the magnitude of folding observed elsewhere in the Crawford Basin, it is entirely feasible that displacement along an inferred fault would not be required to explain these observations. In addition, the inferred fault, if present, is located well to the south of the TCEA permit boundary and would have minimal impact upon mining activities.

2.6.4 Seismology

2.6.4.1 National Seismic Hazard Maps and Risks

The USGS finalized an update of the National Seismic Hazard Maps in 2008, which includes changes to the methodology and mathematical equations it uses to model future earthquakes (Petersen 2008). The revised maps incorporate new seismic, geologic, and geodetic information on earthquake rates and associated ground shaking. The maps supersede versions released in 1996 and 2002. The National Hazard Maps show the distribution of earthquake shaking levels that have a certain probability of occurring in the U.S. (**Figure 2.6-16**). The hazard ranking ranges from the lowest hazard (0.4 %g) to the highest (64+ %g), with the City of Crawford area and the majority of Nebraska being located in a low hazard ranking level of 4 to 8 %g. The term "%g" is a unit of acceleration (movement of earth) measured in terms of gravity (g), i.e., acceleration due to gravity. Peak acceleration refers to the maximum acceleration (movement) experienced during a non-uniform earthquake event (i.e., starts off small, achieves a maximum and then decreases).

The seismic hazard map for Nebraska is shown in **Figure 2.6-17**, which shows the peak acceleration (%g) with a 2% probability of exceedance in 50 years for the State of Nebraska (USGS 2009a). The time of 50 years is the time interval for during which all possible earthquakes may occur to determine the shaking hazard. **Figure 2.6-17** also shows that the peak acceleration in the City of Crawford area of 6 to 8 %g for the majority of the immediate area, with some isolated areas of 8 to 10 %g. The 2% probability value means that there would be a 92% to 94% chance that shaking would not exceed the 6 to 8 %g values over a 50 year period, and a 90% to 92% chance that shaking would not exceed the 8 to 10 %g values over fifty years. Although this measurement is somewhat complex, it demonstrates that the Three Crow and City of Crawford area are at the low end of the USGS hazard ranking system for earthquake risks. Note that the difference between **Figure 2.6-16** and **2.6-17** as to the hazard ranking values are due to the use of different scales, i.e., 4 to 8 versus 6 to 8, respectively.

2.6.5 Earthquake Magnitude and Intensity

Earthquakes release different amounts of energy and the strength of this energy can be measured by *magnitude* and *intensity* (CDERA 2009). A comparison of the magnitude and intensity scales is shown in **Table 2.6-3** as well as the USGS abbreviated descriptions of the twelve levels on the Modified Mercalli (MM) scale. The Richter Scale is used to measure the *magnitude* of an earthquake and is a measure of the physical energy released or the vibrational energy associated with the earthquake. In general, earthquakes below 4.0 on the Richter scale do not cause damage, and earthquakes below 2.0 usually can't be felt. However, earthquakes over 5.0 on the Richter scale can cause damage. An earthquake of a magnitude 6.0 is considered strong and a magnitude of 7.0 is considered a major earthquake.

The MM scale measures the *intensity* and consists of twelve increasing levels of intensity that range from imperceptible shaking to catastrophic destruction (USGS 2009b). It is an arbitrary ranking by the USGS based on observed effects rather than a mathematical basis.

For states in the U.S. that had reported earthquakes with a magnitude of 3.5 or greater from 1974 to 2003, the State of Nebraska had a total of 8 (less than 0.05 % of the total of 21,080 earthquakes occurring in the U.S) (USGS 2009d). **Figure 2.6-17** is a seismic hazard map of Nebraska (USGS 2009e). A seismicity map of Nebraska that shows the distribution of earthquakes from 1990 to 2006 is shown in **Figure 2.6-18**.

The first significant earthquake recorded in Nebraska occurred on April 24, 1867, apparently centered near Lawrence, Kansas. It affected an estimated area of 780,000 square kilometers including much of Nebraska. Since 1867 there have been at least seven earthquakes of Intensity V or greater originating within Nebraska boundaries. It is thought that the strongest earthquake in Nebraska occurred on November 15, 1877. The total area affected was approximately 360,000 square kilometers including most of Nebraska. The most recent earthquake occurred on March 20, 2010 (depth of 5 km), approximately 20 miles north of Ainsworth, NE in Brown County, north central Nebraska (lat. 42.83N long. 99.78W). The magnitude of this earthquake was 2.7 with an Intensity of I. The epicenter was approximately 180 miles east southeast of the City of Crawford.

Earthquakes along the Chadron and Cambridge Arches in Western Nebraska

The locations of the Chadron and Cambridge Arches in Nebraska are shown in **Figure 2.6-13a** (Stix 1982). Earthquakes that have occurred in Nebraska in the vicinity of the Chadron and Cambridge Arches from 1884 to 2009 are shown in **Table 2.6-4**. The MM Intensity of these earthquakes ranged from I to VI, with the majority between I and III. The strongest of these earthquakes centered in Dawes County occurred July 30, 1934 with an intensity of VI and was centered near Chadron. It affected an estimated area of approximately 60,000 square kilometers in Nebraska, South Dakota and Wyoming. This earthquake resulted in damaged chimneys, plaster, and china. An earthquake occurred on March 24, 1938 near Fort Robinson. This earthquake had an intensity of IV; no additional information is available. An Intensity IV earthquake should be felt indoors by many and cause dishes, windows, and doors to be disturbed. An earthquake occurred on March 9, 1963 near Chadron. This earthquake was reported to last about a second and was not accompanied by any damage or noise and was not even noticed by many of the residents of Chadron. An earthquake occurred on March 28, 1964 near Merriman. The vibrations from this earthquake lasted about a minute and caused much alarm but no major damage occurred. Books were knocked off shelves and closet and cupboard doors swung open. On May 7, 1978 an earthquake with Intensity V occurred in southwestern Cherry County, also near the Chadron Arch. No major damage was reported from this earthquake.

Earthquakes occurring from 1992 through 2009 within 125 miles of the City of Crawford, in Wyoming and South Dakota are shown in **Table 2.6-5**. The Richter Magnitude measurements ranged from 3.0 to 3.8 for Wyoming and 2.5 to 4.0 for South Dakota. The Modified Mercalli Intensity values for Wyoming ranged from II to IV, with all but one of the total 9 observations ranging from II to III. The Modified Mercalli Intensity values for South Dakota ranged from I to IV, with all but one of the total observations ranging from I to III.

Although the risk of major earthquakes in Dawes County and the State of Nebraska is low (Burchett 1990), some low to moderate tectonic activity has occurred (Rothe 1981). This tectonic movement is also suggested by geomorphic and sedimentation patterns during the Pleistocene (Rothe 1981), which reflect such movement. Previous seismic activity along the Cambridge Arch has been reported as possibly related secondary recovery of oil in the Sleepy Hollow oil field located in Red Willow County in southwest Nebraska (Rothe et al 1981). However, deeper events suggest more recent low level tectonic activity on the Chadron and Cambridge Arches.

Based on information discussed above, and the historical records for the proposed TCEA in northwest Nebraska, no major effects would be expected from earthquakes on in situ mining within the TCEA area.

2.6.6 Inventory of Economically Significant Deposits and Paleontological Resources

According to the Nebraska Oil and Gas Conservation Commission (NOGCC) there was no oil and gas production in Dawes County between 2004 and 2009. There are also no current applications for permits to drill in Dawes County. Two wells are currently producing in Sioux County, but are located at a significant distance southwest of TCEA in T25N, R55W and R56W (NOGCC 2010). The only non-fuel mineral produced in Dawes County is sand and gravel. Coal is not produced anywhere in Nebraska (Nebraska 2010), nor are coal beds expected to be encountered during drilling within the TCEA.

Significant fossil resources, particularly mammalian, are recognized from the Arikaree Group and White River Group in northwestern Nebraska (e.g., Hunt 1981, Terry and LaGarry 1998, Tedford et al. 2004). However, within the TCEA, the Arikaree Group is not present and sediments of the White River Group are typically buried by alluvium.

2.6.7 Soils

The CPF current license area and the TCEA are located in the semiarid northwest region of Nebraska. The majority of the proposed TCEA lies within Dawes County. The western-most portion of the TCEA is located in Sioux County. To the south lies the Pine Ridge, an area of rough steep terrain dissected by steep drainage ways. Vegetative cover in the Pine Ridge region is typically mixed grass and Ponderosa pine trees. South of the Pine Ridge is the Niobrara River drainage basin.

The TCEA is located within the White River watershed in an area dominated by flat or rolling topography – the Cherry Creek drainage is the most distinct topographic feature. Project area elevation is generally just below 4,000 feet above mean sea level. Climate is semiarid (precipitation averages from 16 to 18 inches per year), and natural vegetation is dominated by drought-tolerant short-grass prairie and areas of mixed-grass prairie, which have been replaced by agricultural crops across much of the project area.

An investigation of the TCEA soils included review of available published soils data and field sampling for radionuclide properties. Soils data for the TCEA was obtained from the United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS) Web Soil Survey. The sources for the Dawes County soils data available from the Web Soil Survey includes the Soil Survey of Dawes County, Nebraska, published in February 1977 (NRCS 1977), and updated unpublished materials derived from remote sensing images and other digitized soils mapping of Dawes County. The sources for the Sioux County soils available on the Web Soil Survey include the Soil Survey of Dawes County, Nebraska, published in 1998, and updated unpublished materials derived from remote sensing images and other digitized soils mapping of Sioux County. The following descriptions and classifications for soils in the TCEA were extracted from NRCS Web Soil Survey, which provided the results of a search for soils in the TCEA with a custom Soil Resource Report (NRCS 2010). Twenty-eight soil map units are identified in the project area. Their spatial distributions are illustrated in **Figure 2.6-19**, and their aerial extents summarized in **Table 2.6-6.**

Soils in the project area formed through the weathering of Tertiary bedrock material, loess (windblown silt), or unconsolidated alluvium. Most of the soils in the Three Crow area are weathered from the massive sandstones and interbedded siltstones and mudstones of the Miocene Arikaree Group, or a mixture of Arikaree sandstone and loess (NRCS 2009). Texturally, most soils in the project area are silt loams and very fine sand loams. Soils are generally deep or moderately deep, moderately well or well drained, and have a moderate rate of water transmission (SSS 2010).

Due to the silty or loamy texture of most soils in the TCEA, wind and water erosion pose the most significant risks to soil health and productivity. These soil textures also dictate the good drainage and high infiltration rates characteristic of most soils in the TCEA.

The Canyon-Bridget-Oglala soil association is the most extensive within the TCEA, making up approximately 35% of all soils and is found throughout the project area. Bridget series silt loams and very fine sandy loams make up about 70% of this association (25% of the total project area). The Canyon-Bridget-Oglala association contains "deep and shallow, moderately steep to very steep, well-drained loamy and silty soils that formed in colluvium and in material weathered from sandstone, on uplands and foot slopes". Areas of this association are mostly south of the TCEA along the Pine Ridge.

The second-most extensive soil unit is the Duroc very fine sandy loam (1 to 3 percent slopes; approximately 20% of the project area). The Duroc soil unit dominates the western portion of the project area. The Busher-Tassel-Vetal association makes up approximately 15% of the project area and is mainly found east of Cherry Creek and in the Sioux County portion of the project area. Alliance series silt loams also comprise approximately 15% of the project area and are mostly found in the central and eastern portions of the project area.

In certain areas, the soil material is so rocky, so shallow, so severely eroded or so variable that it has not been classified by soil series. These areas are called land types and are given descriptive names. An example of this is "sandy alluvial land" found within the Busher-Tassel-Vetal association.

One other minor soil association is found in the TCEA. The Kadoka-Keith-Mitchell association contains "deep, nearly level to steep, well drained silty soils that formed in loess and in material weathered from siltstones, on uplands and foot slopes". Typically this association consists of undulating to rolling uplands that are dissected by many spring-fed creeks. Areas of this association are mostly north of the TCEA near the White River.

2.6.7.1 Soil Limitations

The NRCS characterizes soil mapping units and their limitations for a variety of uses based on a wide range of properties such as soil texture, slope, clay content. In general, TCEA soils are moderately susceptible to water erosion, with K-factors of dominant soil map units ranging from 0.32 to 0.43. Hazards for wind erosion vary throughout the TCEA, but are generally moderate to moderately-high in the vicinity of Mine Units 1-4, high to moderate in Mine Units 5-9 and moderate to moderately low elsewhere. Almost all soils in the TCEA have severe or moderate limitations to their suitability as natural road surfaces and potential for rutting and compaction. However, all TCEA soils that are likely to be disturbed by project activities, except those in the immediate vicinity of Cherry Creek, are also considered to have high soil resiliency (i.e., inherent ability to recover degradation) and have high potential for successful restoration. The Tassel soils near Cherry Creek have moderate, or generally favorable, characteristics for restoration. Soils in the area proposed for evaporation ponds are moderately to severely limited in their suitability as pond reservoirs, due to seepage potential (SSS 2010).

2.6.7.2 Soils Range Classifications

Plant cover of soils in the TCEA depends upon the site condition. There are three major soils range classifications in the TCEA: limy range, sandy range, and silty range. Sites that are the most productive for forage are silty range.

The shallow limy range site classification in which Tassel (map units 5118, 6028 and 6036) and Canyon (map units 1742 and 5211) soils fall contains more alkaline soils as the name implies. Approximately 75 percent of climax plant cover is a mixture of decreaser grasses such as little bluestem, sand bluestem, side-oats grama, needle-and-thread, prairie sandreed, plains muhly and western wheatgrass. Perennial grasses, forbs and shrubs make up the remaining 25 percent. These increasers include blue grama, hairy grama, threadleaf sedge, fringed sagewort, common prickly pear, broom snakeweed, skunkbush sumac, and western snowberry.

Map units 5124, 5128, 5129, 5964, 6109, 6090, 5291, and 5292 are classified as sandy range sites. Moderately rapid to rapid permeability of the soils heavily influences vegetation types on these soils. A typical climax plant community is about 50 percent a mixture of decreaser plants such as sand bluestem, little bluestem, and prairie junegrass. The remaining 50 percent is perennial grass, forbs and shrubs. The principal increasers are blue grama, threadleaf sedge, prairie sandreed, needle-and-thread, sand dropseed, western wheatgrass, fringed sagewort and small soapweed. A site in poor condition will commonly have blue grama, threadleaf sage, sand dropseed and western ragweed.

Map units 5105, 5106, 5107, 1356, 1357, 1363, 1364, 5947, 1618, 1620, 1631, 5200, and 1862 are classified as silty range sites. The vegetation which grows on these sites is influenced mainly by the moderately slow or moderate permeability of the soils and by their moderate to high available water capacity. About 50 percent of the climax plant cover is a mixture of such decreaser grasses as big bluestem, little bluestem, side-oats grama, western wheatgrass, and prairie junegrass. About 50 percent consists of other perennial grasses, forbs, and shrubs. Blue grama, buffalograss, threadleaf sedge, needle-and-thread, Arkansas rose, and numerous forbs such as dotted gayfeather, false boneset, heath aster, skeletonplant, and scarlet globemallow are the principal increasers. A site in poor condition will typically have blue grama, buffalograss, threadleaf sedge, and sand dropseed.

2.6.7.3 Soil Mapping Units

As defined by the NRCS, a map unit is identified and named according to the taxonomic classification of the dominant soils. A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. **Table 2.6-6** summarizes the soils in map units found within the TCEA. The table provides the map unit symbols, map unit names, and estimated acres of the dominant soils in the TCEA. The descriptions of each soil mapping unit includes the potential for wind erosion, water erosion, the farmland classification, and the hydric rating. The farmland classification identifies map units as prime farmland, farmland of statewide importance, farmland of local importance, or unique farmland. The classification identifies the soils that are best suited to food, feed, fiber, forage, and oilseed crops. The hydric rating indicates the proportion of the map units that meets the criteria for hydric soils, which are an indicator for wetlands. The soils in the TCEA are also shown as soil map units in **Figure 2.6-19**.

Certain mapping units are composed of soil complexes or undifferentiated soil groups. A soil complex consists of areas of two or more soils so intricately mixed or so small in size that they cannot be shown separately on the soil map. Undifferentiated soil groups are made up of two or more soils that could be delineated individually but are shown as one unit because, for the purpose of the soil survey, there is little value in separating them. The name states the two dominant soil series represented in the group. Two of the mapping units within the TCEA belong to this category, where the names of dominant soils are joined by "and".

The following section describes the soil series and mapping units for those soils in Dawes and Sioux Counties, which occur within the TCEA as shown in **Figure 2.6-19**. The descriptions of soil map units that occur within the TCEA, as shown in **Figure 2.6-19** and listed in **Table 2.6-6** are extracted from the NRCS custom Soil Resource Report as provided by the NRCS Web Soil Survey.

<u>Glenberg Series Soils</u>

The Glenberg series consists of very deep, well drained soils that formed in stratified calcareous alluvium from mixed sources. Glenberg soils are on flood plains and low terraces. Slopes range from 0 to 8 percent. Organic content is moderate to low. Glenberg series soils are suitable for dry-farming and irrigated farming. Because they are restricted to steeper areas near drainages, only portions of the Glenberg soils within the TECA are currently cultivated. Glenberg soils found in the TCEA include the following:

1031 - Glenberg fine sandy loam, channeled, frequently flooded

This map unit is on flood plains on valleys and is dissected by meandering stream channels. The Glenberg, channeled, frequently flooded component makes up 100 percent of the map unit. Slopes are 0 to 2 percent.

The parent material consists of stratified calcareous alluvium. Depth to a root-restrictive layer is greater than 60 inches. It has a fine sandy loam surface layer and moderately rapidly permeable fine sandy loam underlying material. This soil is frequently flooded. It is not a hydric soil.

If the surface is not protected, the hazards of soil blowing and water erosion are slight on this soil. Runoff is negligible to low.

Alliance Series Soils

These soils are used primarily as pastureland and irrigated cropland. Nearly all the acreage for this soil is in native grass and is used for grazing. Because of the moderately steep slopes, this soil is better suited to grass than other uses. The soil is not considered prime farmland. Ecological classification is sandy lowland site.

The Alliance series consists of deep, well-drained soils that formed in material weathered from sandstone. The soils are on upland. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. About half the Alliance soils are cultivated and are suited to dry-farming and irrigation. Alliance soils found in the TCEA include the following:

5105 - Alliance silt loam, 1 to 3 percent slopes

This soil is mainly on smooth upland areas that are as large as 500 acres. This soil has the profile described as representative for the Alliance series. In some areas, lime is below a depth of 30 inches. The soil is partially hydric.

Included with this soil during mapping were small areas of Rosebud soils on high elevations, Duroc soils in swales, and Richfield soils.

If the surface is not protected, the hazards of soil blowing and water erosion are moderate on this soil. Runoff is slow.

Most areas of this soil are cultivated. Wheat, oats, and alfalfa are the principal crops. Wheat is the main cash crop. Nearly all the cropland is dry-farmed, but a few small areas are irrigated. Corn is the main irrigated crop. Areas in native grasses or areas that have been reseeded to tame grasses are used for grazing or for hay. This soil is prime farmland if irrigated. Range classification is silty range site.

5106 - Alliance silt loam, 3 to 9 percent slopes

This soil is located on upland areas that are as large as 300 acres. This soil has a profile similar to the one described for the Alliance series, but its surface layer is slightly thinner. In places a few small areas have a surface layer of very fine sandy loam, a few areas have a surface layer less than 7 inches thick, and in some areas lime is below a depth of 30 inches. The soil is partially hydric.

Included with this soil during mapping were a few areas of soils that have a surface layer of fine sandy loam. Areas of Rosebud soils that occupy higher positions on the landscape than this Alliance soil, Duroc soils in swales, and Keith soils were included, and they make up as much as 15 percent of some mapped areas.

Water erosion and soil blowing are the main hazards in cultivated areas. Runoff is medium.

Most of the acreage of this soil is in native grass, which is used for grazing or hay. This soil is suited to cultivation, but suitable management practices and cropping systems are needed to help control erosion. The soil is prime farmland if irrigated. Range classification is silty range site.

5107 - Alliance silt loam, 3 to 9 percent slopes, eroded

This soil is located on upland areas that are as large as 300 acres. This soil has a profile similar to the one described for the Alliance series, but about 50 percent of the area has a surface layer less than 7 inches thick. In places where the surface layer and the upper part of the subsoil have been mixed by cultivation, the surface layer is light silty clay loam. This soil includes areas where lime is at or near the surface, areas where the subsoil is thinner and less clayey than in the representative profile, and areas where the surface layer is light brownish gray or very pale brown. The soil is partially hydric.

Included with this soil in mapping were small areas of Duroc soils in swales and Rosebud, Oglala, Keith, and Bridget soils. In some areas outcrops of rock are common on knolls.

Water erosion and soil blowing are hazards if the soil surface is not protected. Runoff is medium.

Nearly all the acreage of this soil is cultivated. Winter wheat, alfalfa, and oats are the main crops. Areas of this soil are suited to irrigation, but steepness of slopes and a lack of irrigation water limit the development of irrigation. Some areas are seeded to native or tame grasses and are used for grazing or hay. The soil is prime farmland if irrigated. Range classification is silty range site.

<u>Bridget Series Soils</u>

The Bridget series consists of deep, well-drained soils that formed in loamy colluvial and alluvial sediment on foot slopes and on stream terraces. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. In areas where slopes are less than 9 percent, these soils are used mostly for cultivated dry-farmed crops. Bridget soils found in the TCEA include the following:

1356 - Bridget silt loam, 1 to 3 percent slopes

This soil is on foot slopes and stream terraces near large drainages. Areas are as much as 500 acres in size. This soil has the profile described as representative for the Bridget series. In places the surface layer is light brownish gray; in other places lime is at a depth of 20 to 42 inches; and in still other places buried soils are below a depth of 24 inches.

Included with the soil in mapping were areas of soils that occupy slightly higher positions than this Bridget soil. The soils have a surface layer or transitional layer of fine sandy loam. Bayard soils, mainly at higher elevations, were included, and they maker up as much as 15 percent of some mapped areas. The soil is partially hydric.

Water erosion or gullying are hazards in areas that receive runoff from adjacent slopes. Soil blowing is a hazard if soil surface is unprotected. Runoff is slow to medium.

Nearly all areas of this soil are dry-farmed to wheat, oats, or alfalfa. Areas in native grass are used for grazing or hay. The soil is prime farmland if irrigated. Range classification is silty range site.

1357 - Bridget silt loam, 3 to 9 percent slopes

This soil is on colluvial foot slopes on upland areas that are up to 200 acres in size. This soil has a profile similar to the one described as representative for the Bridget series, but its surface layer is slightly thinner. In some areas the surface layer is more than 20 inches thick; in other areas the surface layer is very fine sandy loam; and in still other areas the surface layer is light brownish gray to pale brown. In places lime is below a depth of 20 inches. The soil is partially hydric.

Included with this soil in mapping were soils in higher areas than this Bridget soil that have a surface layer of fine sandy loam. Some areas of Bayard, Keith or Rosebud soils in the Pine Ridge make up as much as 25 percent of the mapped areas. A few areas of Rock outcrop were also included.

Water erosion is a hazard because of runoff received from adjacent higher areas. Soil blowing is a hazard if the soil surface is unprotected. Runoff is medium.

About half of the acreage of this soil is in native grass and is used for range. Cultivated areas are dry-farmed to wheat, oats, or alfalfa. A small acreage is seeded to tame grasses and is used for grazing and hay. The soil is prime farmland if irrigated. Range classification is silty range site.

1363 - Bridget very fine sandy loam, 3 to 6 percent slopes

This mapping unit is found in the Sioux County portion of the TCEA. This unit is on hillslopes or uplands. The Bridget component makes up 100 percent of the map unit. Slopes are 3 to 6 percent. The parent material consists of loamy colluvium. Depth to a root-restrictive layer is greater than 60 inches. The soil is well drained. Runoff is slow to rapid depending on the degree of slope. Permeability is moderate. Shrink-swell potential is low. This very deep, gently sloping, well drained soil has a very fine sandy loam surface layer and moderately permeable, calcareous very fine sandy loam underlying material. The soil is not hydric.

The soil has a very high potential for water erosion. Soil blowing is a hazard if the soil surface is unprotected. Runoff is medium.

Most Bridget soils are produce winter wheat. Some areas are irrigated corn, sugar beets, potatoes, dry beans and alfalfa. The soil is prime farmland if irrigated. The steeper areas are in native grasses used for grazing. Range classification is silty range site.

1364 - Bridget very fine sandy loam, 6 to 9 percent slopes

This mapping unit is found only in the Sioux County portion of the TCEA. Detailed information for the mapping unit was not available to CBR, but the soil series information should provide adequate information for the purposes of this amendment application.

Busher Series Soils

The Busher series consists of deep, well-drained to somewhat excessively drained soils that formed in material weathered from sandstone. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium to low, and organic matter content is moderate. Busher soils are mostly in native grasses. Busher soils found in the TCEA include the following:

5124 - Busher loamy very fine sand, 1 to 6 percent slopes, eroded

This soil is on uplands. Areas are as much as 200 acres in size. This oil has a profile similar to the one described as representative for the Busher series, but its surface layer is 4 to 7 inches thick and is light brown to light brownish gray. In places lime is at a depth of 12 to 18 inches. The soil is partially hydric.

Included with this soil in mapping were areas of soils that have a surface layer if fine sandy loam and areas where bedrock is at a depth of 20 to 36 inches. Also included were areas of Bridget, Jayem, or Vetal soils, which make up as much as 15 percent of the mapped areas. Tassel soils, on ridgetops and knolls, were included, and they make up as much as 35 percent of the mapped areas.

Water erosion and soil blowing are severe hazards on this soil. Moderately rapid permeability and moderate available water capacity make this soil droughty. Runoff is slow.

Nearly all areas of this soil are cultivated and dry-farmed. Wheat, alfalfa, and oats are the principal crops. The soil is designated as farmland of statewide importance. A few areas are seeded to grass, which is used for grazing or hay. Range classification is sandy range site.

5128 - Busher loamy very fine sand, 6 to 9 percent slopes, eroded

This soil is on uplands. Areas are as much as 100 acres in size. This soil has a profile similar to the one described as representative of the Busher series, but its surface layer is 4 to 7 inches thick. In areas of this soil on middle and upper parts of slopes the surface layer is brown to light brownish gray. In places lime is at a depth of 10 to 18 inches. The soil is partially hydric.

Included with this soil in mapping were areas of soils that have a surface layer of fine sandy loam and areas where bedrock is at a depth of 20 to 36 inches. Jayem, Bridget, and Vetal soils were included, and they make up as much as 15 percent of some mapped areas. Small areas of Rock outcrop and Tassel soils on high elevations were also included.

Soil blowing and water erosion are serious hazards. Fertility is low. This soil is somewhat droughty. Runoff is medium.

Nearly all areas of this soil are dry-farmed. Wheat, alfalfa, and oats are the main crops. The soil is not prime farmland. A few areas are seeded to grass, which is used for grazing or hay. Range classification is sandy range site.

5129 - Busher loamy very fine sand, 9 to 20 percent slopes

This soil is on uplands. Areas are as much as 200 acres in size. This soil has the profile described as representative of the Busher series. In some areas the surface layer is 3 to 7 inches thick and lime is at a depth of less than 18 inches. The soil is not hydric.

Included with this soil in mapping were areas of soils that have a surface layer of fine sandy loam; areas of soils that have a surface layer of fine sandy loam; and areas where bedrock is at a depth of 20 to 36 inches. Jayem, Bridget, Tassel or Vetal soils make up as much as 15 percent of some mapped areas. Small areas of Rock outcrop and Tassel soils on high elevations were also included.

Soil blowing and water erosion are serious hazards if the native grass cover is removed from this soil. Conserving soil moisture is a major concern of management. Runoff is medium.

Nearly all areas of this soil are in native grass, which is sued for grazing or for hay. A small acreage is cultivated along with areas of less sloping soils. The hazard of erosion and steepness of slope make this soil unsuited to cultivation. The soil is not prime farmland. Most areas that were once cultivated have been seeded to native or tame grasses and are now used for grazing or hay. Range classification is sandy range site.

5118 - Busher and Tassel loamy very fine sands, 6 to 20 percent slopes

This mapping unit is on uplands. Slopes are mostly 9 to 20 percent, but range from 6 to 20 percent. Areas are as much as 100 acres in size. Busher loamy very fine sand makes up about 60 percent of this unit, and Tassel loamy very fine sand makes up about 40 percent. A delineated area, however, can contain either one or both of these soils. Busher soils are on the middle and lower part of the slopes, and Tassel soils are on ridgetops, knolls, and sides of small drainages. The soil is not hydric.

In places Busher soils have a surface layer that is less than 7 inches thick and that is brown to light gray. Included in mapping were areas where bedrock is at a depth of 20 to 36 inches. Bridget, Jayem, and Vetal soils and small outcrops of sandstone were included, and they make up as much as 15 percent of some mapped areas.

Soil blowing and water erosion are serious hazards if the native grass cover is removed from this soil. Runoff is medium.

Some areas of this mapping unit are in native grass. Most are used for grazing, and some are cut for hay. The soils are generally not suited to cultivation. The soil is not prime farmland. Classification of Busher soil is sandy range site and Tassel soil is shallow loamy range site.

<u>Duroc Series Soils</u>

The Duroc series consists of deep, well-drained soils that formed in colluvial or alluvial materials derived mostly from loess and weathered sandstone. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Duroc soils are well suited to cultivation and irrigation. Duroc soils found in the TCEA include the following:

5947 - Duroc very fine sandy loam, 1 to 3 percent slopes

This map unit is found in upland swales and on stream terraces. Areas are as much as 300 acres in size. In some areas the surface layer is silt loam. Included in mapping were areas of soils that have a surface layer of fine sandy loam or loamy very fine sand. Also included were small areas of Alliance, Bridget, Keith, Richfield, and Rosebud soils, all generally on slightly higher elevations. Inclusions make up less than 15 percent of the mapped areas. The soil is partially hydric.

In some places, this soil receives additional moisture from adjacent areas. Runoff is slow.

Much of the acreage of this soil is cultivated. It is suited to irrigation but is mostly dry-farmed to wheat, oats, and alfalfa. The soil is prime farmland if irrigated. The rest of the acreage is in native and tame grasses, which are used for grazing or for hay. Range classification is silty range site.

<u>Jayem Series Soils</u>

The Jayem series consists of deep, well-drained to somewhat excessively drained soils that formed in eolian sands. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium, and organic matter content is moderate. Jayem soils are suited to both dry-farmed and irrigated crops. Jayem soils found in the TCEA include the following:

5964 - Jayem and Vetal loamy very fine sands, 6 to 9 percent slopes

This mapping unit is on uplands and foot slopes. The areas are as much as 300 acres in size. Jayem and Vetal soils each make up about 50 percent of the acreage of this mapping unit. The areas, however, can contain either one or both of the soils. Jayem soils are on the upper part of side slopes and on ridgetops. Vetal soils are on the lower part of side slopes and in swales. The soil is not hydric.

Included with this mapping unit were areas of soils that have a surface layer of loamy fine sand and areas where lime is at a depth of 10 to 36 inches. Also included and making up as much as 15 percent of some mapped areas were Busher and Tassel soils and Sarben soils that occupy high positions.

Water erosion is a hazard in cultivated areas. Soil blowing is a hazard if the soil surface is not protected. These soils are easy to work. Runoff is slow to medium.

Most areas of these soils are in native grasses, which are used for grazing and for hay. A small acreage is cultivated to wheat, alfalfa, and oats. These soils are suited to irrigation. The soil is not prime farmland. Range classification is sandy range site.

<u>Keith Series Soils</u>

The Keith series consists of deep, well-drained soils that formed in loess. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Keith soils are suited to both dry-farmed and irrigated crops. Keith soils found in the TCEA include the following:

1618 - Keith silt loam, 1 to 3 percent slopes

This soil is on uplands. Areas are as much as 500 acres in size. This soil has a profile similar to the one described as representative for the Keith series, but its subsoil is thicker. In some places the A horizon is loam or very fine sandy loam and is 3 to 7 inches thick. In places lime is at a depth of 12 to 18 inches. Dark-colored buried soils are common. The soil is no hydric.

Included with this soil in mapping were areas of soils that have a surface layer of fine sandy loam. Also included were small areas of Alliance soils, Duroc soils in swales, and Richfield soils.

Water erosion is a hazard in some areas, but soil blowing is the main hazard. These soils are easy to work. Runoff is slow.

This soil is used for both crops and range. Winter wheat, alfalfa, and oats are the principal dry-farmed crops. A few small areas of alfalfa are irrigated. The soil is prime farmland if irrigated. Some areas are in grass, which is used for hay or for grazing. Range classification is silty range site.

1631 - Keith silt loam, 3 to 9 percent slopes

This soil is on ridges and side slopes. Areas are as much as 300 acres in size. This soil has the profile described as representative for the Keith series. In some areas the surface layer is loam of very fine sandy loam. The soil is partially hydric.

Included with this soil in mapping are areas of higher soils that have a surface layer of fine sandy loam. Also included were areas of Duroc soils in swales and Kadoka variant, Richfield, and Ulysses soils, which generally make up less than 20 percent of the mapped area.

Water erosion is a hazard in cultivated areas. Soil blowing is a concern in management. Runoff is medium.

A small acreage of this soil is used for crops, but most areas are in native grass and are used for grazing or hay. Wheat and alfalfa are the main cultivated crops, and some oats are grown. The soil is prime farmland if irrigated. Range classification is silty range site.

Oglala Series Soils

The Oglala series consists of deep, well-drained soils that formed in material weathered from fine-grained sandstone. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Oglala soils are suited to native grasses. Oglala soils found in the TCEA include the following:

5200 - Oglala loam, 9 to 30 percent slopes

This soil is on hillsides. Areas are as much as 200 acres in size. This soil has the profile described as representative for the Oglala series. Included in the mapping were areas of soils that have a surface layer 3 to 6 inches thick; areas of soils that have a surface layer of fine sandy loam to loamy very fine sand; and areas where lime is at a depth of less than 20 inches. The soil is not hydric. Also included were areas of eroded soils that have a pale brown to very pale brown surface layer. Areas of Bridget, Canyon, and Rosebud and Ulysses soils were also included and make up as much as 15 percent of some mapped areas.

Soil blowing and water erosion are hazards if the soil surface is not protected. Runoff is medium to rapid, depending on the gradient of the slope and the kind and amount of cover.

Nearly all the acreage off this soil is in native grass. A few areas are seeded to tame grasses. This soil is unsuited to cultivation because of steepness of slopes. The soil is no designated prime farmland. Range classification is silty range site.

5211 - Oglala-Canyon loams, 9 to 20 percent slopes

The soils in this unit are on the side slopes and on ridges and knolls. Each area is about 60 to 75 percent Oglala soils and 25 to 40 percent Canyon soils. The areas are as much as 1,000 acres in size. The Oglala soils are on the middle and lower part of the side slopes, and the Canyon soils are on the tops of ridges and knolls.

In some areas the soils have a light brownish-gray surface layer, and in other layers lime is at a depth of less than 20 inches. The soils is not hydric. Included in mapping were small areas of Bridget, Duroc, Keith, Rosebud, and Ulysses soils, which make up less than 25 percent of the mapped areas. Fragments of sandstone are on the surface in some areas.

Water erosion is a hazard if the cover of native grass is removed from these soils. Wind erosion presents a moderately load hazard. Runoff is medium to rapid, depending on the gradient of the slope and the kind and amount of vegetation.

Nearly all the acreage of this unit is in native grass and is used mostly for grazing. Nearly all of the areas that were cultivated have been seeded to grass. These soils are not suited to cultivation. They are not designated prime farmland. Classification of Oglala soil is silty range site and Canyon soil is shallow limy range site.

Rosebud Series Soils

The Rosebud series consists of moderately deep, well-drained soils that formed in material weathered from sandstone. Permeability is moderate, and available water capacity is moderate. Natural fertility is medium, and organic matter content is moderate. Rosebud soils are suited to both dry-farmed and irrigated crops. Rosebud soils found in the TCEA include the following:

1.3.1.1.1.1 1742 - Rosebud-Canyon loams, 3 to 9 percent slopes

This mapping unit is on gently rolling and rolling uplands. Areas are as much as 500 acres in size. Rosebud loam makes up about 50 to 70 percent of each mapped area. Canyon loam 15 to 30 percent, and other soils 10 t0 25 percent. The Rosebud soils are on side slopes, and the

Canyon soils are on ridgetops and knolls. The Rosebud soils have a profile similar to the one described as representative for the Rosebud series, but their surface layer is loam. The soils are partially hydric. The Canyon soils have a profile similar to the one described as representative for the Canyon series. Included in the mapping were areas of Alliance, Bridget, Duroc, Keith, and Oglala soils.

If the soils are cultivated, water erosion and soil blowing are hazards. In some places erosion has removed a part of the surface layer, and tillage has mixed the material remaining in the surface layer with that from the subsoil. In places small areas of Canyon soils on low ridgetops and knolls are cultivated along with deeper soils. In such areas the Canyon soils are easily recognized because of their whitish color and sandstone fragments on the surface. Runoff is medium.

A large acreage of this mapping unit is cultivated. Dry-farmed wheat, alfalfa and oats are the principal crops. The soils are not designated prime farmland. The rest of the areas are in native grass, which is used for grazing or hay. Classification of Rosebud soils is silty range site and Canyon soils are shallow limy range site.

Sarben Series Soils

The Sarben series consists of deep, well-drained soils that formed in wind-deposited sands. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium to low, and organic matter content is low. Sarben soils are suited to both dry-farmed and irrigated crops. Sarben soils found in the TCEA include the following:

6109 - Sarben loamy very fine sand, 9 to 30 percent slopes

This mapping unit is found only in the Sioux County portion of the TCEA. The Sarben component makes up 100 percent of the map unit. Slopes are 9 to 30 percent. This component is on hillslopes on uplands.

The parent material consists of sandy and loamy eolian deposits. Depth to a root-restrictive layer is greater than 60 inches. The soil is well drained, and has a low shrink-swell potential. The soil is not hydric.

Soil blowing and water erosion are serious hazards if the soil surface is not protected. Runoff is low to rapid, depending on the gradient of the slope and the kind and amount of cover.

Nearly all the acreage of this unit is in native grass and is used mostly for grazing. These soils are suited to cultivation of wheat crops. They are not designated prime farmland soils. Range classification is sandy range site.

Tassel Series Soils

The Tassel series consists of shallow, well-drained soils that formed in material weathered from fine-grained sandstone. Permeability is moderately rapid, and available water capacity is very low. Natural fertility and organic matter content are low. Tassel soils are suited to range and to habitat for wildlife. Tassel soils found in the TCEA include the following:

6028 - Tassel soils, 3 to 30 percent slopes

These soils are on ridges and knolls and the sides of upland drainages. Areas are as much as 500 acres in size. These soils have a profile similar to the one described as representative for the Tassel series, but the surface layer is fine sandy loam, loamy very fine sand, or loamy sand. Included in the mapping were areas where sandstone is at a depth of 20 to 40 inches, areas where sandstone is at a depth of 4 to 10 inches, and areas of soils that have a surface layer of loam and very fine sandy loam. Small outcrops of sandstone are included. Also included were areas of Bayard, Busher, Canyon, Jayem, and Sarben soils, which make up as much as 20 percent of some mapped areas. Tassel soils are not hydric.

Soil blowing is a hazard if the grass cover is destroyed. These soils tend to be droughty because the available moisture capacity is low. Conserving moisture is a concern of management. Runoff is slow to rapid, depending on the degree of slope and the kind and amount of vegetation.

Nearly all the acreage of this mapping unit is in native grass and is used for grazing. Steepness of slope and shallow depth to bedrock make Tassel soils unsuited to cultivation. Where these soils occur in areas of deeper soils, they are cultivated along with those soils. Areas of Tassel soils in cultivated areas are easily recognizable by their light color and coarse sandstone fragments on the surface. The soils are not designated prime farmland. Range classification is shallow limy range site.

6036 - Tassel-Busher-Rock outcrop complex, 6 to 30 percent slopes

This mapping unit is found only in the Sioux County portion of the TCEA. Tassel soils are shallow, strongly sloping to very steep, somewhat excessively drained, loamy soils formed in weathered sandstone and eolian material on uplands. Busher soils are deep, strongly sloping to steep, well- to somewhat excessively drained, loamy soils formed in eolian material and weathered sandstone on uplands;. Rock outcrops are very shallow, very steep, excessively drained, weathered sandstone on uplands. All soils in the complex are well drained; with a low shrink-swell potential.

The soils have a very high potential for wind and water erosion. Runoff is medium to rapid, depending on the gradient of the slope and the kind and amount of cover.

This soil is unsuited to cultivation because of steepness of slopes. The soil is not designated prime farmland. Range classification is shallow limy range site.

Ulysses Series Soils

The Ulysses series consists of deep, well-drained soils that formed in loess on uplands. Permeability is moderate, and available water capacity is high. Natural fertility is medium, and organic matter content is moderate. Where slopes are less than 9 percent, Ulysses soils are suited to both dry-farmed and irrigated crops. Ulysses soils found in the TCEA include the following:

1862 - Ulysses silt loam, 9 to 20 percent slopes

This soil is on uplands. Areas are as much as 200 acres in size. This soil has the profile described as representative for the Ulysses series. In some areas the surface layer is loam or very fine sandy loam, in other areas lime is below a depth of 16 inches, and in still other areas the surface layer is less than 7 inches thick. The soil is not hydric

Included with this soil in mapping were areas of soils that occupy slightly higher positions on the landscape than this Ulysses soil. The soils have a surface layer of fine sandy loam. Duroc soils in swales and Oglala, Bridget, and Mitchell soils were included. These areas make up as much as 15 percent of some mapping areas.

Water erosion is a very severe hazard if the grass cover is destroyed. Wind erosion presents a moderately low hazard. Runoff is medium.

Nearly all the acreage for this soil is in native grass and is used for grazing. In a few places, the grass is cut for hay. Because of the moderately steep slopes, this soil is better suited to grass than other uses. The soil is not designated prime farmland. Range classification is silty range site.

Vetal Series Soils

The Vetal series consists of deep, well-drained soils that formed in sandy alluvium and colluvium on foot slopes in upland swales. Permeability is moderately rapid, and available water capacity is moderate. Natural fertility is medium, and organic matter content is moderate. Where slopes are less than 9 percent, Vetal soils are suited to both dry-farmed and irrigated crops. Vetal soils found in the TCEA include the following:

5291 - Vetal very fine sandy loam, 1 to 3 percent slopes

This mapping unit is found in the Sioux County portion of the TCEA on upland swales. The Vetal component makes up 99 percent of the map unit. Slopes are 1 to 3 percent. The parent material consists of loamy alluvium over eolian deposits. Depth to a root-restrictive layer is greater than 60 inches. These soils well drained. Permeability is moderately rapid. Shrink-swell potential is low. The soil is partially hydric.

The potential for water erosion is very low. Soil blowing potential is high if the soil surface is not protected. Surface runoff is slow to medium.

These soils are primarily used as native rangeland and hayland. Some areas produce small grains, corn, alfalfa, and sorghum. The soils are designated as prime farmland if irrigated. Native vegetation includes blue grama, needle-and-thread, prairie sandreed, big bluestem, little bluestem, and western wheatgrass.

5292 - Vetal very fine sandy loam, 3 to 6 percent slopes

This mapping unit is found in the Sioux County portion of the TCEA. This unit is on hillslopes on uplands. The Vetal component makes up 99 percent of the map unit. Slopes are 3 to 6 percent. The parent material consists of loamy alluvium over eolian deposits. These soils well drained. Surface runoff is medium. Permeability is moderately rapid. Shrink-swell potential is low. The soil is partially hydric.

The potential for water erosion is very low. Soil blowing potential is high if the soil surface is not protected.

These soils are primarily used as native rangeland and hayland. Some areas produce small grains, corn, alfalfa, and sorghum. These soils are designated as prime farmland if irrigated. Native vegetation includes blue grama, needle-and-thread, prairie sandreed, big bluestem, little bluestem, and western wheatgrass.

9903 – Fluvaquents, sandy, frequently flooded

The Fluvaquents, frequently flooded component makes up 100 percent of the map unit. Slopes are 0 to 1 percent. This component is on flood plains on valleys. The parent material consists of silty alluvium. The soil is very poorly drained, and is frequently flooded and ponded. These soils are hydric.

The potential for water erosion is very low. Soil blowing potential is moderate if the soil surface is not protected.

The soils are not designated as prime farmland. As hydric soils, Fluvaquents typically support a mix of floating (when submerged) and emergent hydrophytic vegetation such as cattails, sedges, rushes, and algae. Due to frequent flooding, these soils are not utilized for agriculture.

2.6.8 References

Burchett, R.R. 1990. Earthquakes in Nebraska. University of Nebraska-Lincoln, Educational Circular No. 4a, 20pp.

Caribbean Disaster Emergency Response Agency. (CDERA). CDERA Virtual Disaster Library – *Earthquakes and Seismic Activity*. [Web Page]. Located at: http://www.cdera.org/doccentre/fs_earthquakes.php. Accessed on: December 30, 2009.

Clark, J. 1975. Controls of sedimentation and provenance of sediments in the Oligocene of the central Rocky Mountains *In:* Curtis, B.F., ed., Cenozoic history of the southern Rocky Mountains. Geological Society of America Memoir 144, p. 95-117.

Clark, J., Beerbower, J.R. and Kietzke, K.K. 1967. Oligocene sedimentation, stratigraphy, paleoecology and paleoclimatology in the Big Badlands of South Dakota. Field Museum of Natural History, Fieldiana Geology Memoirs, v. 5, p. 158.

Collings, S.P. and Knode, R.H. 1984. . Practical Hydromet '83; 7th Annual Symposium on Uranium and Precious Metals, American Institute of Metallurgical Engineers.

DeGraw, H.M. 1969. Subsurface Relations of the Cretaceous and Tertiary in Western Nebraska. University of Nebraska, MS Thesis, 137pp.

Diffendal, R.F., Jr. 1982. Regional implications of the geology of the Ogallala Group (Upper Tertiary) of southwestern Morrill County, Nebraska. Geological Society of America Bulletin, v. 93, p. 964-976.

Diffendal, R.F., Jr. 1994. Geomorphic and structural features of the Alliance 1 degree X 2 degree Quadrangle, western Nebraska, discernible from synthetic-aperature radar imagery and digital shaded-relief maps. Rocky Mountain Geology; October 1994; v. 30; no. 2; p. 137-147.

Doeckel, J. 1970. Earthquakes of the Stable Interior with Emphasis on the Mid-Continent. University of Nebraska. PhD Thesis.

Evans, J.E. and Terry, D.O., Jr. 1994. The significance of incision and fluvial sedimentation in the Basal White River Group (Eocene-Oligocene), badlands of South Dakota, U.S.A. Sedimentary Geology, v. 90, p. 137-152.

Ferret Exploration Company of Nebraska, Inc. 1987. Application and Supporting Environmental Report for USNRC Commercial Source Material License. September, 1987.

Florida Oceanographic Online. (FOO). 2002. Earthquake Magnitude and Intensity Information. [Web Page]. Located at: http://www.floridaoceanographic.org/reference/earthquake.htm. Accessed on: December 30, 2009.

Hansley, P.L., S.P. Collings, I.K. Brownfield, and G.L. Skipp. 1989. Mineralogy of Uranium Ore from the Crow Butte Uranium Deposit, Oligocene Chadron Formation, Northwestern Nebraska. USGS Open File Report 89-225.

Harksen, J.C. and Macdonald, J.R. 1969. Type sections for the Chadron and Brule Formations of the White River Oligocene in the Big Badlands of South Dakota. South Dakota Geological Survey Report of Investigations #99, p. 23.

Hoganson, J.W., Murphy, E.C. and Forsman, N.F. 1998. Lithostratigraphy, paleontology, and biochronology of the Chadron, Brule, and Arikaree Formations in North Dakota. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 185-196.

Hunt, R.M., Jr. 1981. Geology and vertebrate paleontology of the Agate Fossil Beds National Monument and surrounding region, Sioux County, Nebraska (1972-1978). National Geographic Society Research Reports, v. 13, p. 263-285.

Hunt, R.M., Jr. 1990. Taphonomy and sedimentology of Arikaree (lower Miocene) fluvial, eolian, and lacustrine paleoenvironments, Nebraska and Wyoming: A paleobiota entombed in fine-grained volcaniclastic rocks. *In:* Lockley, M.G., and Rice, A., eds., Volcanism and fossil biotas: Geological Society of America Special Paper 244, p. 69-111.

LaGarry, H.E. 1996. New vertebrate fauna from the Chamberlain Pass Fm (Eocene), Sioux City, Nebraska. Proceedings, 106th Annual Nebraska Academy of Sciences, Earth Science Section, p. 45.

LaGarry, H.E. 1998. Lithostratigraphic revision and rediscription of the Brule Formation (White River Group) of northwestern Nebraska. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 63-91.

Larson, E.E. and Evanoff, E. 1998. Tephrostratigraphy and source of the tuffs of the White River sequence. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 1-14.

Lilligraven, J.A. 1970. Stratigraphy, structure, and vertebrate fossils of the Oligocene Brule Formation, Slim Buttress, northwestern South Dakota. Geological Society of America Bulletin, v. 81, p. 831-850.

Lisenbee, A.L. 1988. Tectonic history of the Black Hills uplift. *In:* Wyoming Geological Association Guidebook, 39th Field Conference, pp. 45–52.

National Earthquake Information Service. (NEIS). Date unknown. [Web Page]. Located at: http://earthwuate.usgs.gov/regional/states/nebraska/seismicity.php. Accessed on: Unknown.

National Resource Conservation Service (NRCS). 1977. USDA, NRCS, in cooperation with University of Nebraska Conservation and Survey Division, Soil Survey of Dawes County Nebraska, Issued February 1977.

NRCS. 2009. Soil Survey Geographic (SSURGO) database for Dawes County, Nebraska. Published: November 21, 2006. Located at: http://SoilDataMart.nrcs.usda.gov. Accessed on: December 30, 2009.

State of Nebraska (Nebraska). 2010. Nebraska Energy Statistics – Energy Production in Btu. [Web Page]. Located at:
http://www.eia.doe.gov/emeu/states/sep_prod/P2/PDF/P2.pdf.
Accessed on: February 23, 2010.

Nebraska Oil and Gas Conservation Commission (NOGCC). 2010. Annual Activity Summaries 2004-2008. [Web Page]. Located at:
http://www.nogcc.ne.gov/NOGCCPublications.aspx. Accessed on: February 23, 2010.

Neuzil, C.E. and Bredehoeft, J.D. 1980. Measurement of In-Situ Hydraulic Conductivity in the Cretaceous Pierre Shale. 3rd Invitational Well-Testing Symposium, Well Testing in Low Permeability Environments, Proceedings March 26-28, 1908, Berkeley, California, p. 96-102.

Neuzil, C.E., Bredehoeft, J.D. and Wolff, R.G. 1984. Leakage and fracture permeability in the Cretaceous shales confining the Dakota aquifer in South Dakota. *In:* Jorgensen, D.G. and Signor, D.C., eds., Geohydrology of the Dakota aquifer-Proceedings of the First C.V.

Theis Conference on Geohydrology, October 5-6, 1982: National Water Well Association, p. 113-120.

Neuzil, C.E. 1993. Low Fluid Pressure within the Pierre Shale: A Transient Response to Erosion. Water Resour. Res., *29*(7), 2007–2020.

Nixon, D.A.. 1995. The structure of the Pine Ridge of the tri-state region of Wyoming, Nebraska, and South Dakota and its relationship to the Black Hills Dome. Geological Society of America Abstracts with Programs, 29th annual meeting, p.77.

Petersen, M.D. et al. 2008. Documentation for the 2008 Update of the United States National Seismic Hazard Maps. United States Geological Survey. Reston, Virginia. Open-File Report 2008 – 1128.

Petrotek. 2004. Class I UIC Permit Re-Application, Class I Non-Hazardous Deepwell. Prepared for Crow Butte Resources, Inc. and submitted to the Nebraska Department of Environmental Quality, March 15, 2004.

Rothe, G.H. 1981. Earthquakes in Nebraska through 1979. Earthquake Notes, V.52, No. 2, pp.59-65.

Rothe, G.H., Lui, C.V., and Steeples, D.W. 1981. Recent Seismicity on the Chadron- Cambridge Arch, South-Central Nebraska. Earthquake Notes, V.52, No. 1, p.61.

Schultz, C.B. and Stout, T.M. 1955. *Classification* of Oligocene sediments of Nebraska. Bulletin of the University of Nebraska State Museum, v. 4, p 17-52.

Singler, C.R. and Picard, M.D. 1980. Stratigraphic Review of Oligocene Beds in Northern Great Plains Earth Science Bul., WGA,. V.13, No.1, p.1-18.

Stanley, K.O. and Bensen, L.V. 1979. Early diagenesis of High Plains Tertiary vitric and arkosic sandstone, Wyoming and Nebraska. *In:* Scholle, P.A., and Schluger, P.R., eds., *Aspects of diagenesis*: Society of Economic Geologists and Paleotonologists Special Publication 26, p. 401-423.

Stix, J. U.S. Department of Energy.1982. Seasat-Satellitte Investigation of the Structure of Western Nebraska and Its Application to the Evaluation of Geothermal Resources. U.S. Department of Energy Publications. University of Nebraska – Lincoln.

Soil Survey Staff (SSS), Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. [Web Page]. Located at: http://websoilsurvey.nrcs.usda.gov. Accessed on: February 16, 2010.

Swinehart, J.B., Souders, V.L., DeGraw, H.M. and Diffendal, R.F. Jr. 1985. Cenozoic Paleography of Western Nebraska. *In:* Flores, R.M. and Kaplan, S.S., eds., Cenzoic Paleogeography of the West-Central United States: Rocky Mountain Section, SEPM, p.187-206.

Tedford, R.H., Albright, L.B., III, Barnosky, A.D., Ferrusquia-Villafranca, I., Hunt, R. M. Jr., Storer, J.E., Swisher, C.C., Voorhies, M.R., Webb, S.D., and Whistler, D.P. 2004. Mammalian biochronology of the Arikareean through Hemphilian interval (Late Oligocene through Early Pliocene epochs). *In:* Woodburne, M.O. ed., Late Cretaceous and Cenozoic Mammals of North America: Columbia University Press. P. 169-231.

Terry, D. O., Jr. 1991. The study and implications of comparative pedogenesis of sediments from the base of the White River Group, South Dakota [M.S. thesis]: Bowling Green, Ohio, Bowling Green State University, p. 184.

Terry, D. O., Jr. 1998. Lithostratigraphic Revision and Correlation of the Lower Part of the White River Group: South Dakota to Nebraska. *In:* Terry, D. O., Jr., LaGarry, H. E. and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 15-37.

Terry, D.O., Jr. and J.E. Evans. 1994. Pedogenesis and paleoclimatic implications of the Chamberlain Pass Formation, Basal White River Group, Badlands of South Dakota. Paleogeography, Paleoclimatology, Paleoecology. v. 110, p. 197-215.

Terry, D. O., Jr., and LaGarry, H. E. 1998. The Big Cottonwood Creek Member: A New Member of the Chadron Formation in Northwestern Nebraska; in Terry, D. O., Jr., LaGarry, H. E., and Hunt, R. M., eds., Depositional Environments, Lithostratigraphy, and Biostratigraphy of the White River and Arikaree Groups (Late Eocene to Early Miocene, North America): Geological Society of America Special Paper #325, p. 117-141.

U.S. Geological Survey (USGS). 2009a. [Web Page]. Located at: http://earthquake.usgs.gov/earthquakes/states/nebraska/hazards.php. Accessed on: December 30, 2009.

U.S. Geological Survey (USGS). 2009b. The Modified Mercalli Intensity Sale. [Web Page]. Located at: http://earthquake.usgs.gov/learn/topics/mercalli.php. Accessed on: December 30, 2009.

U.S. Geological Survey (USGS). 2009c. [Web Page]. Located at: http://earthquake.usgs.gov/earthquakes/. Accessed on: December 30, 2009.

U.S. Geological Survey (USGS). 2009d. *Top Earthquake States.* [Web Page]. Located at: U.S. Geological Survey (USGS). 2009a. [Web Page]. Accessed on: December 29, 2009.

U.S. Geological Survey (USGS). 2009e. [Web Page]. Located at: http://earthquake.usgs.gov/earthquakes/states/nebraska/seismicity.php. Accessed on: December 29, 2009.

U.S. Geological Survey (USGS). 2009f. *Google Earth Files for Earthquake Catalogs.* [Web Page]. Located at: http://neic.usgs.gov/neis/epic/kml/. Accessed on: December 30, 2009.

Vondra, C. F. 1958. Depositional history of the Chadron Formation in northwestern Nebraska: Proceedings, 68th Annual Meeting, Nebraska Academy of Sciences Abstracts with Programs, p. 16.

Wyoming Fuel Company. 1983. Crow Butte Project, Dawes County, Nebraska, Application and Supporting Environmental Report for State of Nebraska. Submitted to Nebraska Dept. of Environmental Control.

Table 2.6-1 General Stratigraphic Chart for Northwest Nebraska

Geologic Period	Series	Formation or Group	Rock Types[1]	Thickness (ft)
Tertiary	Miocene	Ogallala	SS, Slt	1560*
	Oligocene/Eocene	Arikaree	SS, Slt	1070*
		White River	SS, Slt, Cly	1450*
Cretaceous	Upper	Pierre	Sh	1500
		Niobrara	Chalk, Ls, Sh	300
		Carlile	Sh	200-250
		Greenhorn	Ls	30
		Graneros	Sh	250-280
		D Sand	SS	5-30
		D Shale	Sh	60
		G Sand	SS	10-45
		Huntsman	Sh	60-80
	Lower	J Sand	SS	10-30
		Skull Creek	Sh	220
		Dakota	SS, Sh	180
Jurassic	Upper	Morrison	Sh, SS	300
		Sundance	SS, Sh, Ls	300
Permian	Guadalupe	Satanka	Ls, Sh, Anhy	450
	Leonard	Upper	Ls, Anhy	150
		Lower	Sh	150
	Wolfcamp	Chase	Anhy	80
		Council Grove	Anhy, Sh	300
		Admire	Dolo, Ls	70
Pennsylvanian	Virgil	Shawnee	Ls	80
	Missouri	Kansas City	Ls, Sh	80
	Des Moines	Marmaton/ Cherokee	Ls, Sh	130
	Atoka	Upper/Lower	Ls, Sh	200
Mississippian	Lower	Lower	Ls, Sh	30
Pre-Cambrian			Granite	

[1] Rock Type Abbreviations: Anhy: Anhydrate; Cly: claystone; Dolo: Dolomite; Ls: limestone; Sh: shale; Slt: siltstone; SS: sandstone,

* Maximum thickness based on Swinehart, et. al, 1985.

Table 2.6-2 Representative Stratigraphic Section – Three Crow Expansion Area

ELEVATION (FT-AMSL)	GROUP	FORMATION & MEMBER (SCHULTZ AND STOUT, 1955)			FORMATION & MEMBER (REVISED)		REFERENCES (REVISED)
Varying - 3725	White River Group	Brule Formation	Whitney Member		Brule Formation	"Brown Siltstones"	LaGarry (1998)
						Whitney Member	
			Orella Member	Orella D		Orella Member	
				Orella C			
				Orella B			
				Orella A			
3725 - 3425		Chadron Formation	Upper Chadron	Chadron C	Chadron Formation	Big Cottonwood Creek Member	Terry (1998) Terry & LaGarry (1998)
3475 - 3425			Upper/Middle Chadron	Chadron B			
3425 - 3275			Middle Chadron			Peanut Peak Member	Terry (1998) Terry & LaGarry (1998)
3275-3100			Red Clay Horizon	Chadron A	Chamberlain Pass Formation	Upper Interior Paleosol	Terry (1998)
			Basal Chadron Sandstone			Channel Sandstone	Terry (1998)
Varying	Montana Group	Pierre Shale	Interior Paleosol		Pierre Shale	Yellow Mounds Paleosol	Retallack (1983) Terry (1998)
3100 - ~2400			Pierre Shale			Pierre Shale	Terry (1998)

Notes:
1. The Shultz and Stout conventions for Formation & Member are utilized throughout this document.
2. Topsoil, colluvial and alluvial deposits are not shown, but are Quaternary in age and range in thickness from 0 to 30 ft-bgs.
3. FT-AMSL = feet above mean sea level
4. Elevations are representative averages for TCEA only.

Table 2.6-3 USGS Abbreviated Modified Mercalli (MM) Intensity Scale

Richter Magnitude	Modified Mercalli Scale	Description of MM Scale
1.0 – 3.0	I	Not felt except by a very few under especially favorable conditions.
3.0 – 3.9	II	Felt only by a few persons at rest, especially on upper floors of buildings.
	III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
4.0 – 4.9	IV	Felt indoors by many, outdoors by a few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
	V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
5.0 – 5.9	VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
	VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
6.0 – 6.9	VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
	IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
7.0 and higher	X	Some well-built wooded structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
	XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
	XII	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: FOO 2002

Table 2.6-4 Historical Earthquakes in Northwestern Nebraska in Close Proximity to the Chadron and Cambridge Arches (1884 – 2009)

Date	Location	Latitude	Longitude	Depth (km)[1]	Richter Magnitude[2]	Modified Mercalli Intensity[2]	Source
3/17/1884	North Platte, NE	41.133	100.75	--	--	IV	D
12/16/1916	Stapleton, NE	41.55	100.467	--	--	II-III	D
9/24/1924	Gothenberg, NE	40.95	100.133	--	--	IV	D
8/08/1933	Scottsbluff, NE	41.867	103.667	--	--	IV-V	D
7/30/1934	Chadron, NE	42.85	103	--	--	VI	D
3/24/1938	Fort Robinson, NE	42.683	103.417	--	--	IV	D
3/09/1963	Chadron, NE	42.85	103	--	--	II-III	D
3/28/1964	Merriman, NE	42.8	101.667	--	--	VII	D
5/7/1978	SW Cherry County, NE	42.26	101.95	--	--	V	E
3/06/1983	NE Sheridan, NE	42.96	102.2	--	--	III	E
1/01/1987	Crawford, NE	42.79	103.48	--	--	III	E
2/08/1989	Merriman, NE	42.8	101.6	--	--	IV	E
2/09/1989	39 Miles SE of Whiteclay, NE	42 41 21 38	101 54 00 32	5 (3.21 miles)	3.8	III	A

Table 2.6-4 Historical Earthquakes in Northwestern Nebraska in Close Proximity to the Chadron and Cambridge Arches (1884 – 2009)

Date	Location	Latitude	Longitude	Depth (km)[1]	Richter Magnitude[2]	Modified Mercalli Intensity[2]	Source
7/18/1990	7 miles SSE of Ord, NE	41 30 16 72 N	98 57 39 74 W	5 (3.21 miles)	3.0	II	A
9/30/1990	18 miles SE of Hyanus, NE	41 48 52 97 N	101 30 12 67 W	5 (3.21 miles)	3.0	II	A
8/26/1991	10 miles SE of Brownlee, NE	42 09 46 40 N	100 32 03 25 W	5 (3.21 miles)	3.4	II	A
2/20/1993	14 miles SE of Merriman, NE	42 49 48 00 N	101 27 44 36 W	5 (3.21 miles)	3.5	II - III	A
1/25/1994	5 miles ESE of Wood Lake, NE	42 37 36 39 N	100 08 25 90 W	5 (3.21 miles)	3.3	II	A
2/06/1996	1 mile N of Wausa, NE	42 30 47 42 N	97 32 35 99 W	5 (3.21 miles)	3.6	III	A
8/09/1997	5.5 miles NW of Chadron, NE	41 47 43 66 N	98 11 08 76 W	5 (3.21 miles)	3.4	II	A
6/18/1998	21 miles SE of Crawford, NE	42 37 23 70 N	103 00 16 58 W	5 (3.21 miles)	3.4	II	A
6/20/2002	5 miles NE of Scotia, NE	41 30 35 65 N	98 37 15 12 W	5 (3.21 miles)	3.5	II - III	A
11/03/2002	4 miles NW of Bassett, NE	42 46 02 38 N	98 54 10 63 W	5 (3.21 miles)	4.0	IV	A
2/14/2003	8 miles SE of Cambridge, NE	40 14 39 46 N	100 01 14 97 W	5 (3.21 miles)	2.9	I	A
2/01/2006	4 miles NE of Bassett, NE	42 36 55 52 N	99 28 23 72 W	5 (3.21 miles)	2.9	I	A
9/07/2006	16 miles SE of Whiteclay, NE	42 58 32 63 N	102 14 15 90	5 (3.21 miles)	3.1	II	A

Table 2.6-4 **Historical Earthquakes in Northwestern Nebraska in Close Proximity to the Chadron and Cambridge Arches (1884 – 2009)**

Date	Location	Latitude	Longitude	Depth (km)[1]	Richter Magnitude[2]	Modified Mercalli Intensity[2]	Source
4/16/2007	61 miles SE of Ogallala	40 36 40 42 N	100 44 50 99 W	5 (3.21 miles)	3.0	II	A
4/24/2007	25 miles SE of Crawford, NE	40 35 04 82 N	102 56 13 78 W	5 (3.21 miles)	2.7	I	A
12/16/2009	7 miles E of Johnson, NE	40 24 N	95.857 W	5 (3.21 Miles)	3.5	II - III	B

Source: A USGS 2009e [Note: Locations (lat and long) based on using USGS Google Earth Files for USGS/NEIC Catalog, so locations are approximate].
Source: B USGS 2009c
Source: C USGS 2010
Source: D Docekal 1970
Source: E National Earthquake Information Service
[1] Depth where the earthquake begins to rupture (Default values used).
[2] Ratings as per Table 2.6-3
--No data

Table 2.6-5 Earthquakes in Wyoming and South Dakota Within 125 miles of City of Crawford, NE (1992 – 2009)

Date	Location	Latitude	Longitude	Depth (km)[1]	Richter Magnitude[2]	Modified Mercalli Intensity[2]	Source
WYOMING							
8/29/2004	10 miles NW of Douglas, WY	42 54 05 38 N	105 30 33 39 W	5 (3.1 miles)	3.8	III	A
2/15/2004	12 miles N of Douglas, WY	42 56 27 51 N	105 24 12 32 W	10 (6.2 miles)	3.5	II - III	A
4/09/1996	5 miles SE of Redbird, WY	43 03 43 28 N	104 05 54 17 W	5 (3.1 miles)	3.7	III	A
12/13/1993	9 miles SW of Esterbrook, WY	42 20 11 47 N	105 30 04 15 W	5 (3.1 miles)	3.5	II - III	A
10/10/1993	26 miles W of Esterbrook, WY	42 25 25 99 N	105 52 21 90 W	5 (3.1 miles)	3.7	III	A
7/23/1993	18 miles WNW of Esterbrook, WY	42 28 34 03 N	105 42 18 29 W	5 (3.1 miles)	3.7	III	A
6/30/1993	15 miles N of Douglas, WY	42 59 02 58 N	105 22 48 50 W	5 (3.1 miles)	3.0	II	A
2/24/1993	11 miles SE of Wright, WY	43 42 46 50	105 17 20 18 W	0	3.6	III	A
11/02/1992	3 miles SE of Lusk, WY	42 44 49 37 N	104 53 22 98 W	5 (3.1 miles)	3.0	II	A
SOUTH DAKOTA							
2/07/2007	1 mile SW of Owanka, SD	44 01 56 13 N	102 34 47 35 W	5 (3.1 miles)	3.1	II	A
5/25/2003	35 miles E of Pine Ridge, SD	43.08 N	101.84 W	5 (3.1 miles)	4.0	IV	B

Table 2.6-5 Earthquakes in Wyoming and South Dakota Within 125 miles of City of Crawford, NE (1992 – 2009)

Date	Location	Latitude	Longitude	Depth (km)[1]	Richter Magnitude[2]	Modified Mercalli Intensity[2]	Source
5/03/1996	18 miles NW of Ardmore, SD	43 02 32 88 N	104 01 11 30 W	5 (3.1 miles)	3.1	II	A
2/06/1996	8.3 miles NW of Hill City, SD	43 58 52 67 N	103 43 41 52 W	5 (3.1 miles)	3.7	III	A
3/20/1994	3 miles SW of Hot Springs, SD	43 23 51 02 N	103 29 57 16 W	5 (3.1 miles)	2.3	I	A
3/18/1994	3 miles SW of Hot Springs, SD	43 23 51 02 N	103 29 57 16 W	5 (3.1 miles)	2.8	I	A
9/05/1993	2.5 miles NW of Central City, SD	44 24 11 63 N	103 48 07 76 W	5 (3.1 miles)	2.7	I	A
11/05/1991	1.5 miles SE of Central City, SD	44 21 10 54 N	103 45 01 27 W	0	2.5	I	A
3/02/1990	13 miles NW of Wounded Knee, SD	43 19 00 23 N	102 30 04 97 W	5 (3.1 miles)	3.2	II	A
1/28/1990	13 miles NW of Wounded Knee, SD	43 19 00 23 N	102 30 04 97 W	5 (3.1 miles)	4.0	IV	A

Source: A USGS 2009f [Note: Locations (lat and long) based on using USGS Google Earth Files for USGS/NEIC Catalog, so locations are approximate].
Source: B USGS 2009c
[1] D: Depth where the earthquake begins to rupture (Default values used).
[2] Rating as per Table 2.6-3

Table 2.6-6 Summary of Soil Resources Within the TCEA

Map Unit	Map Unit Name	Acres	Percent of Project Area
1031	Glenberg fine sandy loam, channeled, frequently flooded	10.0	0.6
1180	Las Animas fine sandy loam, occasionally flooded	9.3	0.6
1356	Bridget silt loam, 1 to 3 percent slopes	239.8	14.6
1357	Bridget silt loam, 3 to 6 percent slopes	91.1	5.5
1363	Bridget very fine sandy loam, 3 to 6 percent slopes	9.6	0.6
1364	Bridget very fine sandy loam, 6 to 9 percent slopes	67.6	4.1
1618	Keith loam, 1 to 3 percent slopes	11.6	0.7
1620	Keith silt loam, 1 to 3 percent slopes	61.1	3.7
1631	Keith silt loam, 3 to 9 percent slopes	24.3	1.5
1742	Rosebud-Canyon loams, 3 to 9 percent slopes	7.7	0.5
1862	Ulysses silt loam, 9 to 20 percent slopes	55.5	3.4
5105	Alliance silt loam, 1 to 3 percent slopes	89.0	5.4
5106	Alliance silt loam, 3 to 9 percent slopes	7.5	0.5
5107	Alliance silt loam, 3 to 9 percent slopes, eroded	150.1	9.1
5118	Busher and tassel loamy very fine sands, 6 to 20 percent slopes	93.5	5.7
5124	Busher loamy very fine sand, 1 to 6 percent slopes, eroded	17.5	1.1
5128	Busher loamy very fine sand, 6 to 9 percent slopes, eroded	56.6	3.4
5129	Busher loamy very fine sand, 9 to 20 percent slopes	23.0	1.4
5200	Oglala loam, 9 to 30 percent slopes	69.8	4.2
5211	Oglala-Canyon loams, 9 to 20 percent slopes	93.1	5.7
5291	Vetal very fine sandy loam, 1 to 3 percent slopes	0.8	0.0
5292	Vetal very fine sandy loam, 3 to 6 percent slopes	55.4	3.4
5947	Duroc very fine sandy loam, 1 to 3 percent slopes	330.1	20.1
5964	Jayem and Vetal loamy very fine sands, 6 to 9 percent slopes	1.3	0.1
6028	Tassel soils, 3 to 30 percent slopes	44.2	2.7
6036	Tassel-Busher-Rock outcrop complex, 6 to 30 percent slopes	11.3	0.7
6109	Sarben loamy very fine sand, 9 to 30 percent slopes	8.5	0.5
9903	Fluvaquents, sandy, frequently flooded	4.0	0.2
TOTAL		**1643.4**	**100.0**

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