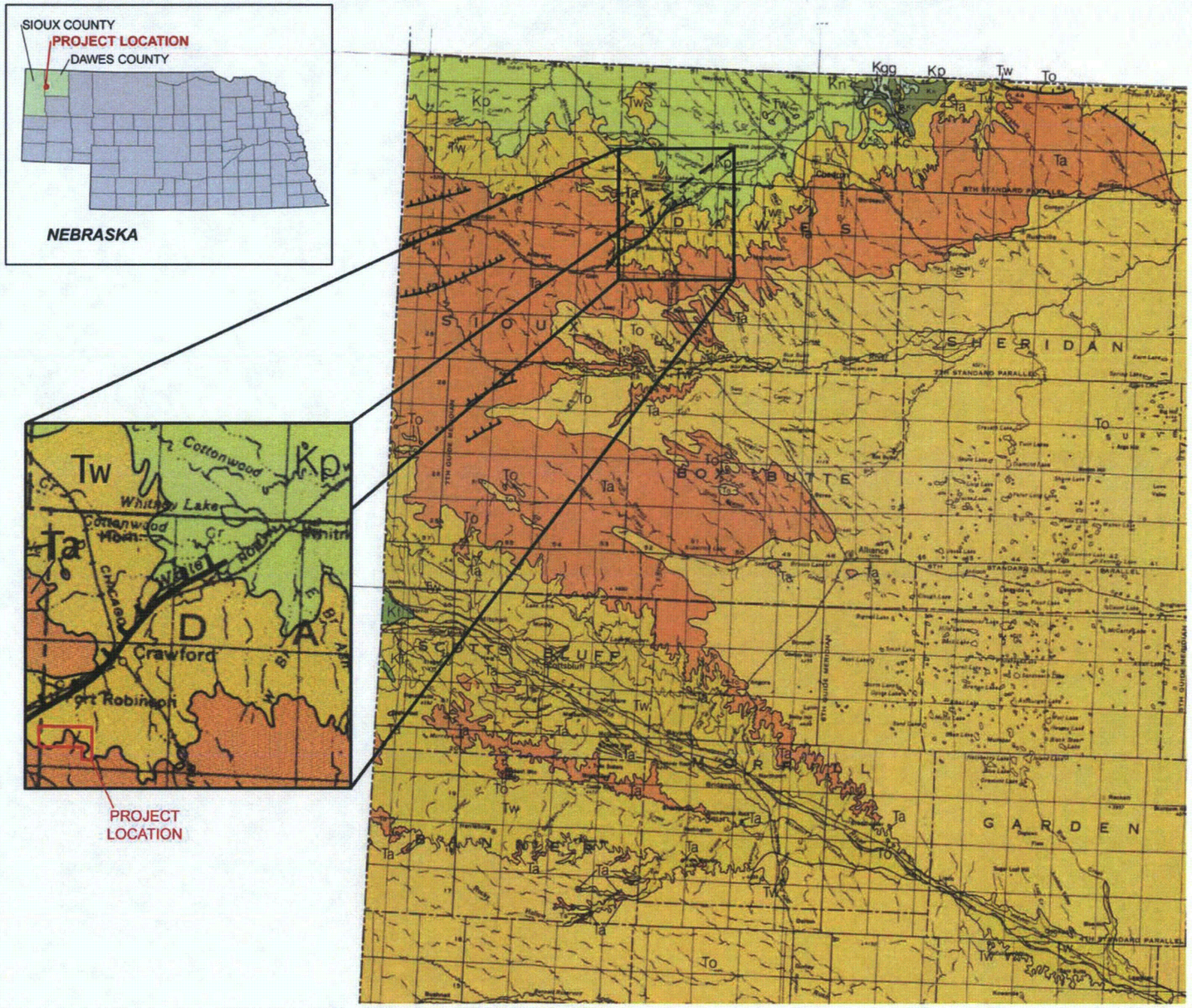

LEGEND

GEOLOGIC PERIOD	SERIES	GROUP OR FORMATION	
T TERTIARY	MIOCENE	OGALLALA	To
		ARIKAREE	Ta
	OLIGOCENE	WHITE RIVER	Tw
K CRETACEOUS	UPPER CRETACEOUS	MONTANA — Fox Hills	Kf
		MONTANA — Pierre	Kp
		COLORADO — Niobrara	Kn
		COLORADO — Carlile	Kc
		COLORADO — Greenhorn-Graneros	Kgg
	LOWER CRETACEOUS	DAKOTA	Kd
J JURASSIC			
P PERMIAN	BIG BLUE	CHASE	Pc
		COUNCIL GROVE	Pcg
		ADMIRE	Pa
IP PENNSYLVANIAN	VIRGIL	WABAUNSEE	IPw
		SHAWNEE	IPs
		DOUGLAS	IPd
	MISSOURI	LANSING	IPl
		KANSAS CITY	IPkc
	DES MOINES	MARMATON	IPm

M MISSISSIPPIAN

D DEVONIAN

S SILURIAN

O ORDOVICIAN (Middle & Upper)

CO CAMBRIAN & ORDOVICIAN (Lower)

PC PRECAMBRIAN

(PLIOCENE AND QUATERNARY deposits not shown)

Source: Nebraska Geological Survey

N
W E

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-1
BEDROCK GEOLOGY OF
THE THREE CROW EXPANSION AREA

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

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K:\CBR_Projects\CO001396_ThreeCrow\3_IMAGES\PhotoshopIAE_Figure6_Bedrock Geology.psd

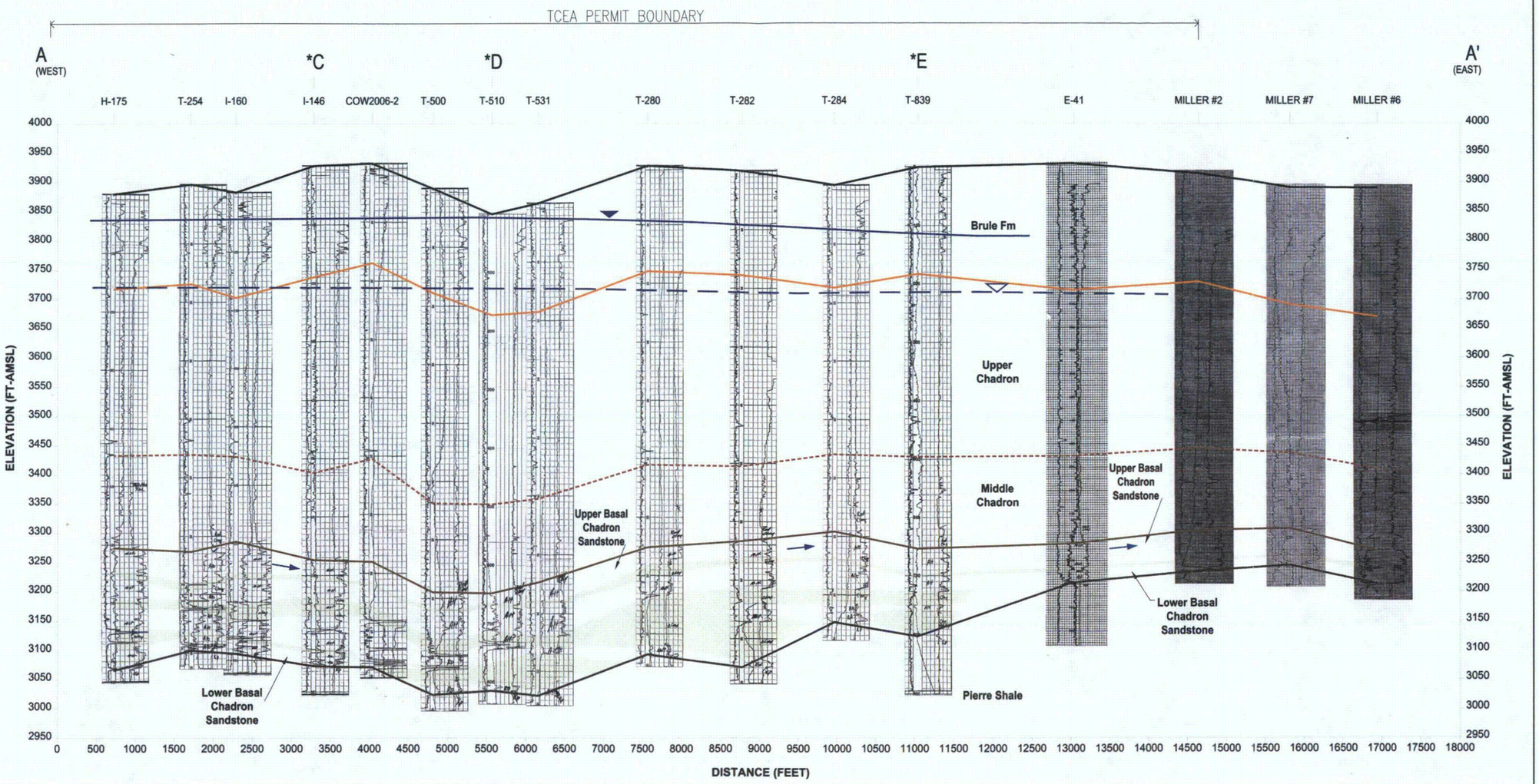
THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

"FIGURE 2.6-2 THREE CROW CROSS-SECTION LOCATION MAP"

WITHIN THIS PACKAGE...OR BY SEARCHING USING THE DOCUMENT/REPORT NO.

D-01



Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in elogs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 4.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10 & 2/08/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10
- Groundwater Flow Direction

0 100' 200'
VERTICAL GRAPHIC SCALE

0 750' 1,500'
HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-3a
THREE CROW STRUCTURAL CROSS-SECTION: A-A'

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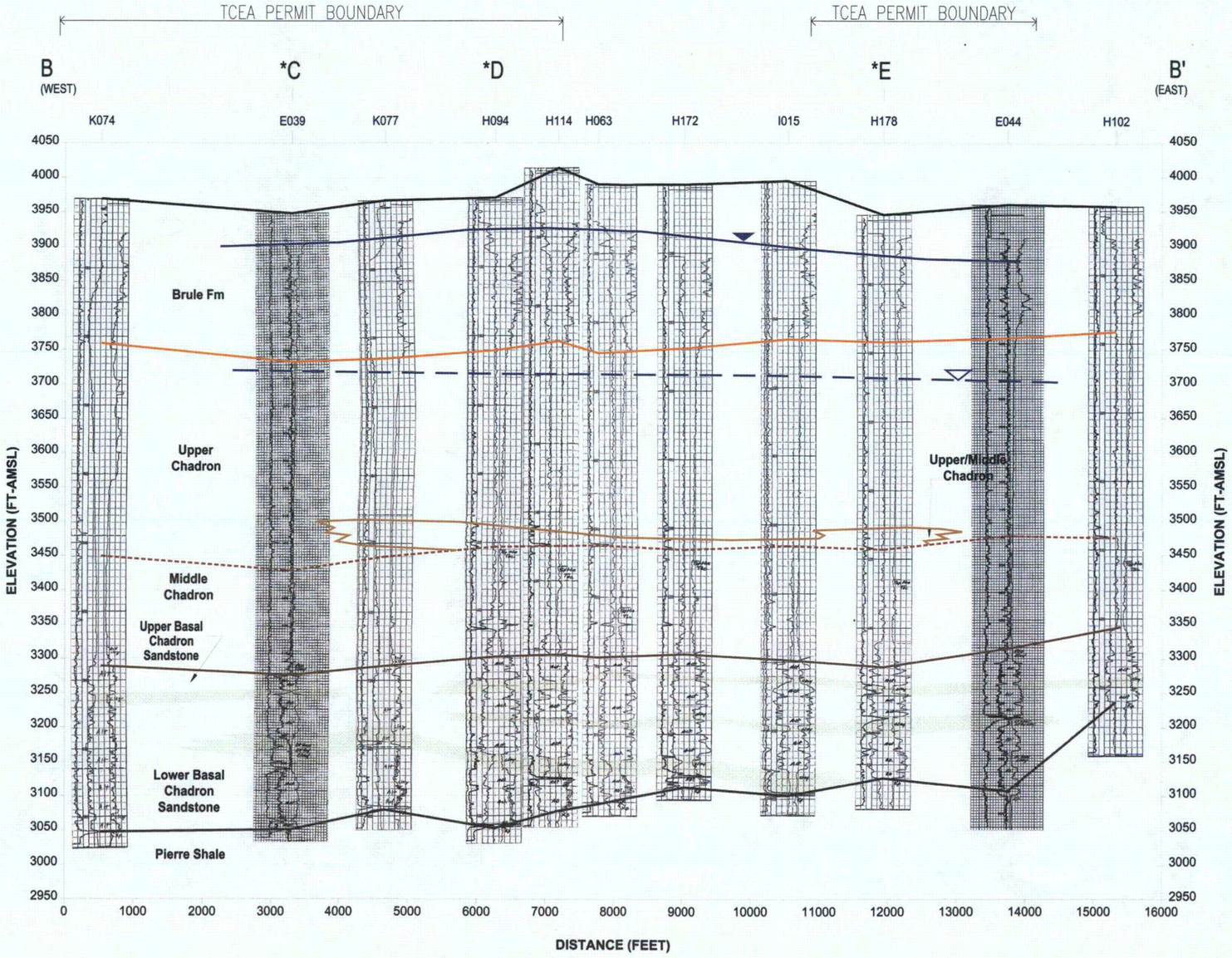

Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in elogs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 4.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Upper/Middle Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10 & 2/08/10
- Groundwater Flow Direction

0 100' 200'
VERTICAL GRAPHIC SCALE

0 1,000' 2,000'
HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-3b
THREE CROW STRUCTURAL CROSS-SECTION: B-B'

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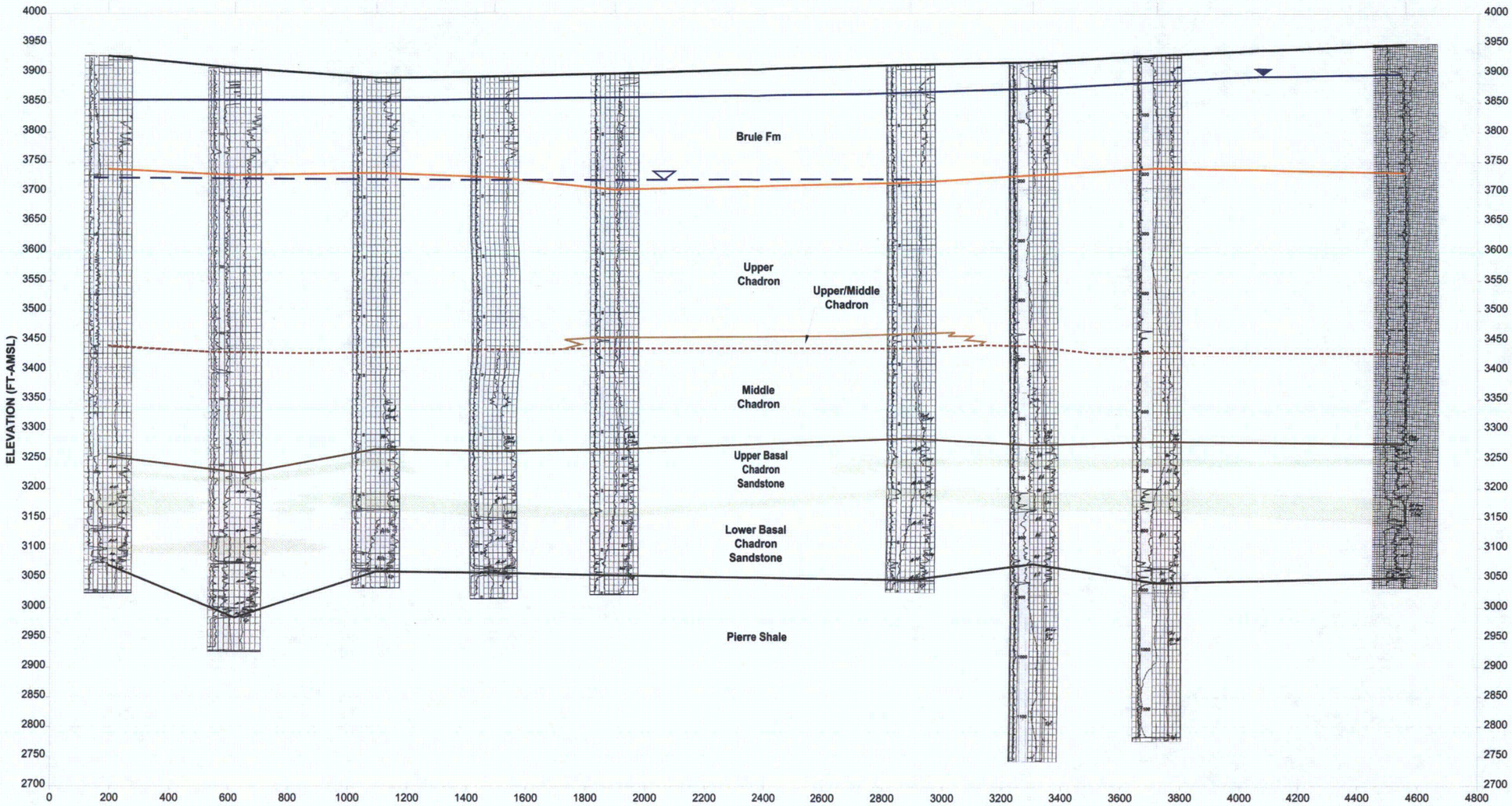
PATH: C:\working\3CROW\3S_BB.dwg, LAYOUT: AE_BB SAVED DATE/TIME: 2/19/2010 2:42 PM

TCEA PERMIT BOUNDARY

C (NORTH) *A *B C' (SOUTH)

I146 I165 T258 T257 T317 T320 T817 T828 E039



Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in elogs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 4.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Upper/Middle Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10 & 2/08/10

0 100' 200' VERTICAL GRAPHIC SCALE

0 200' 400' HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-3c
THREE CROW STRUCTURAL CROSS-SECTION: C-C'

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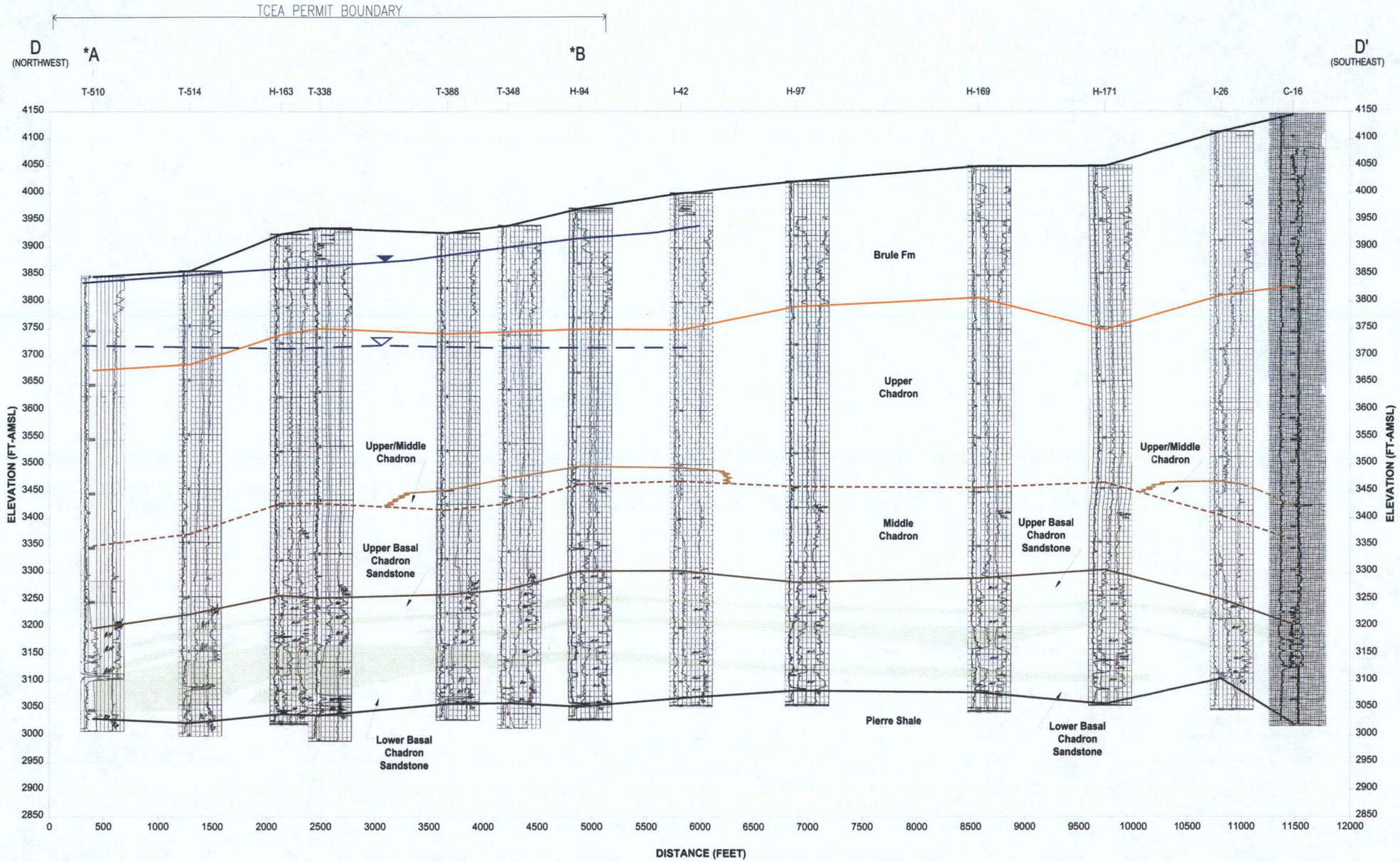

Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in elogs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 4.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Upper/Middle Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10 & 2/08/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10
- Groundwater Flow Direction

0 100' 200'
VERTICAL GRAPHIC SCALE

0 500' 1,000'
HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-3d
THREE CROW STRUCTURAL CROSS-SECTION: D-D'

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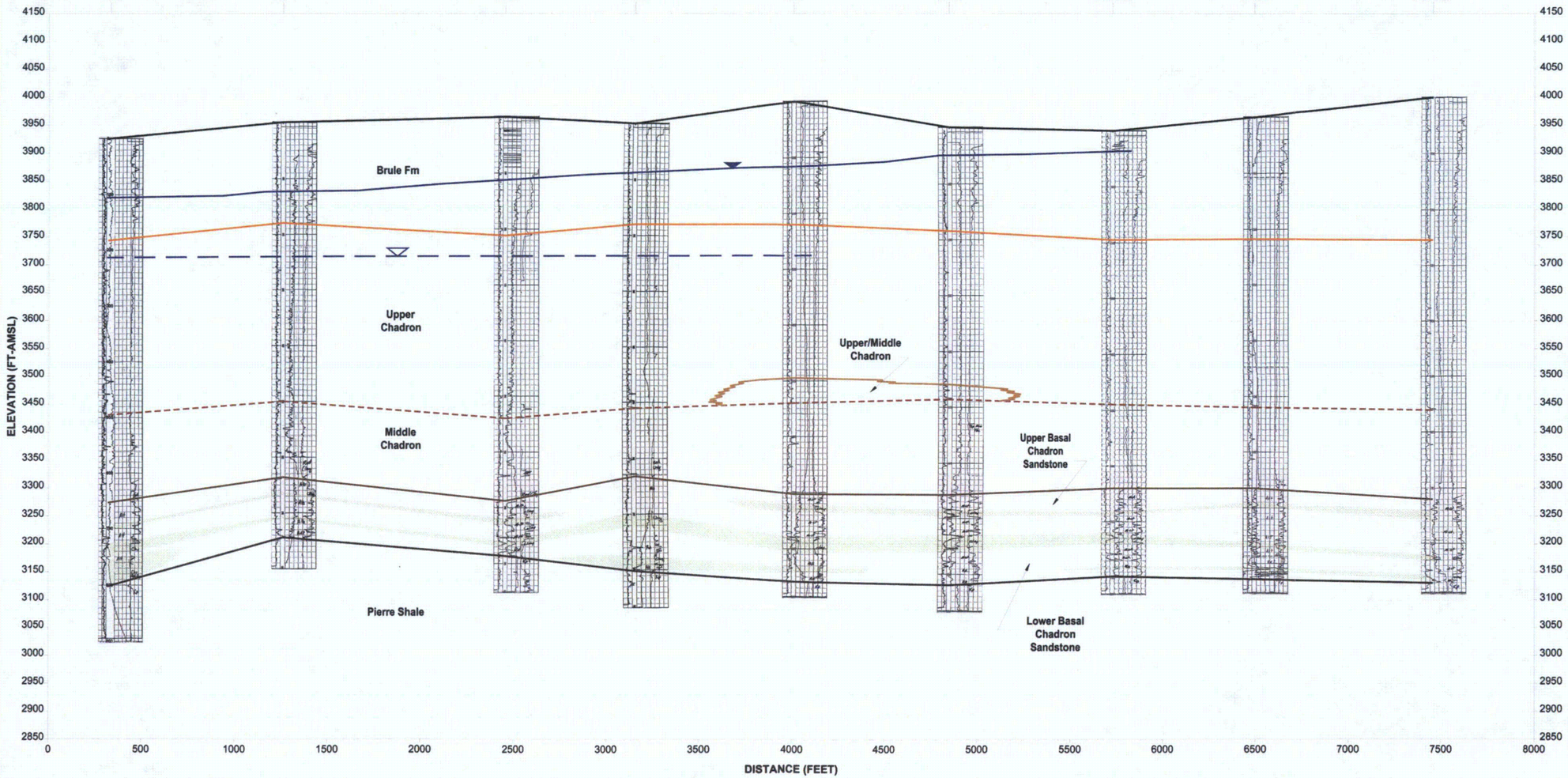
TCEA PERMIT BOUNDARY

E (NORTHWEST) *A *B E' (SOUTHEAST)

T-839 T-274 T-294 T-297 I-64 H-178 I-45 EST K-105 I-54 EST



Notes:

1) Geologic units that underlie the Pierre Shale are not shown.

2) For locations where the Upper/Middle Chadron Fm was not observed in elogs, the contact between the Upper Chadron Fm and the Middle Chadron Fm was extrapolated based on known occurrence, and is shown as dashed lines.

* Letter indicates location of intersecting cross-section lines shown on Figure 4.

Legend:

- Topographic Surface
- Top of Upper Chadron
- Top of Upper/Middle Chadron
- Top of Middle Chadron
- Top of Basal Chadron Sandstone
- Interbedded Clay
- Top of Pierre Shale
- Water Table (Brule Fm) - 1/22/10
- Potentiometric Surface (Basal Chadron Sandstone) - 1/22/10 & 2/08/10

0 100' 200'
VERTICAL GRAPHIC SCALE

0 500' 1,000'
HORIZONTAL GRAPHIC SCALE

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-3e
THREE CROW STRUCTURAL CROSS-SECTION: E-E'

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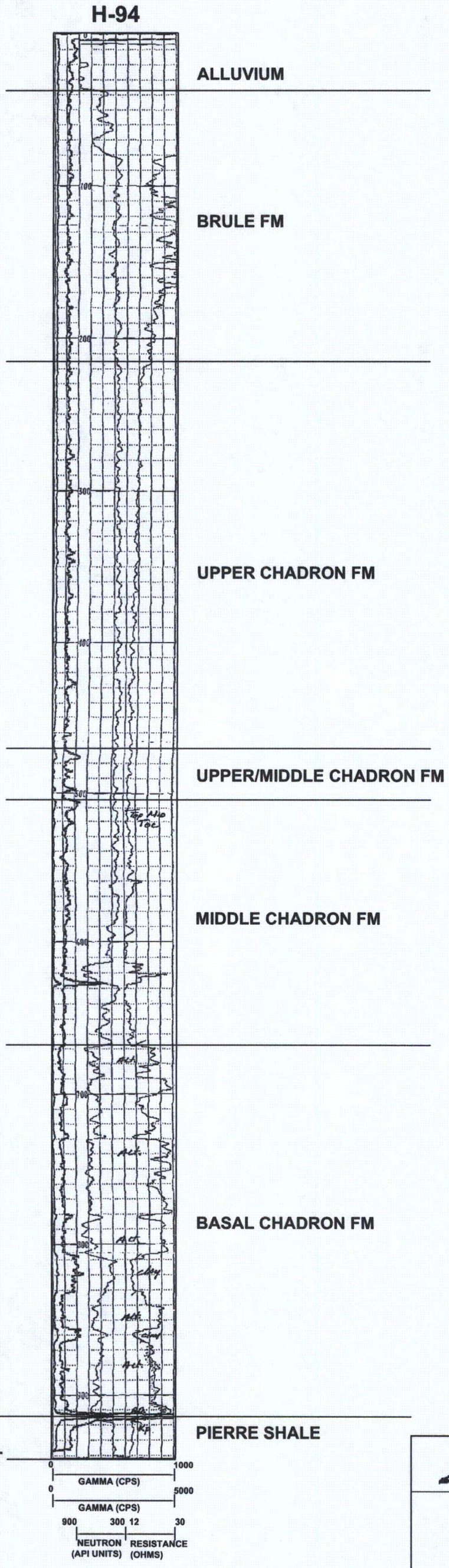

NOTE:
1). E-LOGS NEWER THAN 1990 USE SP RATHER THAN NUETRON LOGGING.

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-4
THREE CROW EXPANSION AREA
TYPE LOG (H-94)

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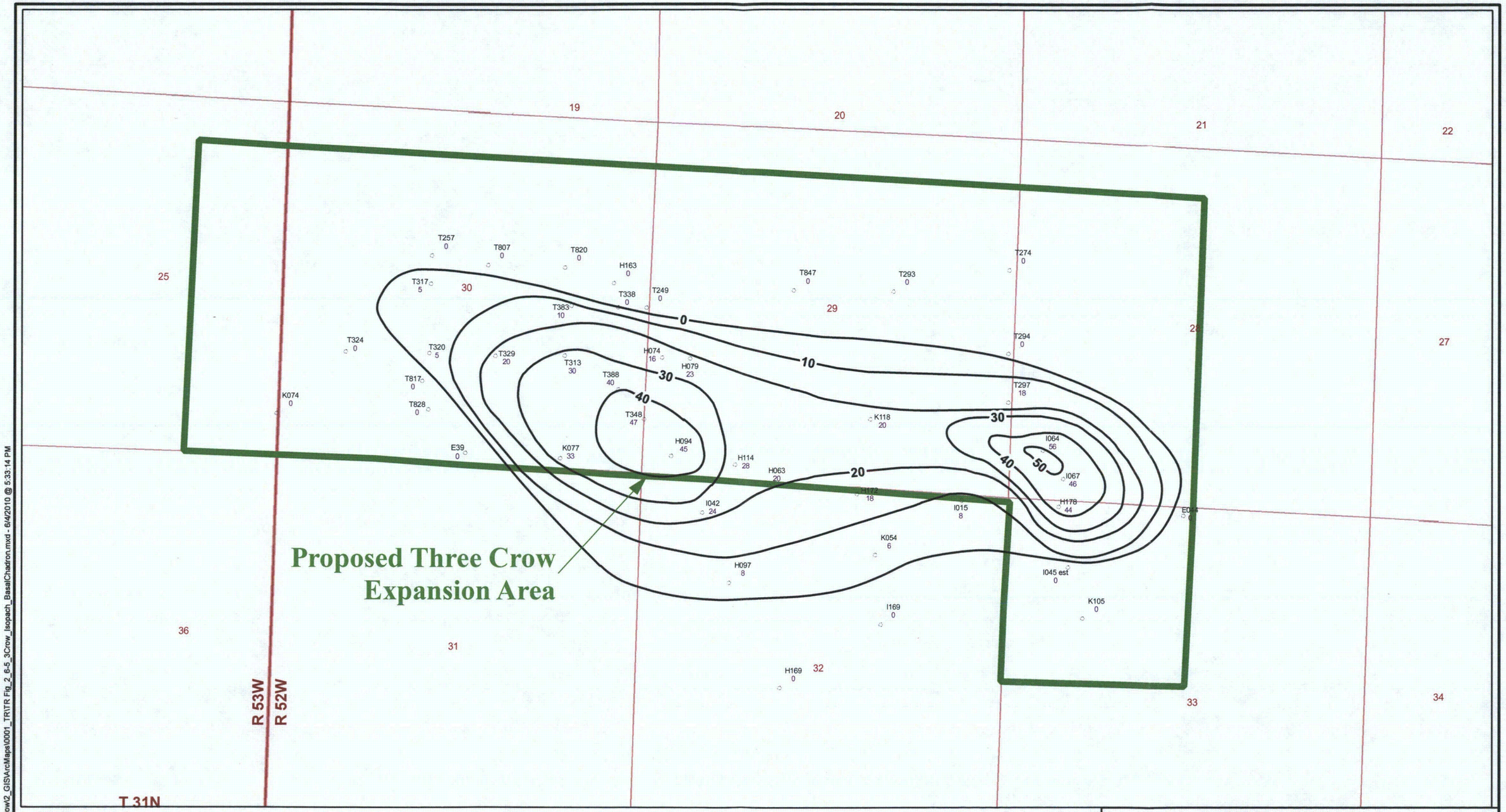

LEGEND

- Exploration Borehole
- Isopach Contour (Feet)
- Proposed Three Crow Expansion Area
- T828 / 238 — Borehole/Well ID / Unit Thickness (Feet)

0 1,000 2,000
Scale in Feet

PROJECTION:
NAD 1927, STATE PLANE
NEBRASKA NORTH FIPS 2601

N
W E

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-5
THREE CROW ISOPACH MAP -
UPPER/MIDDLE CHADRON FORMATION

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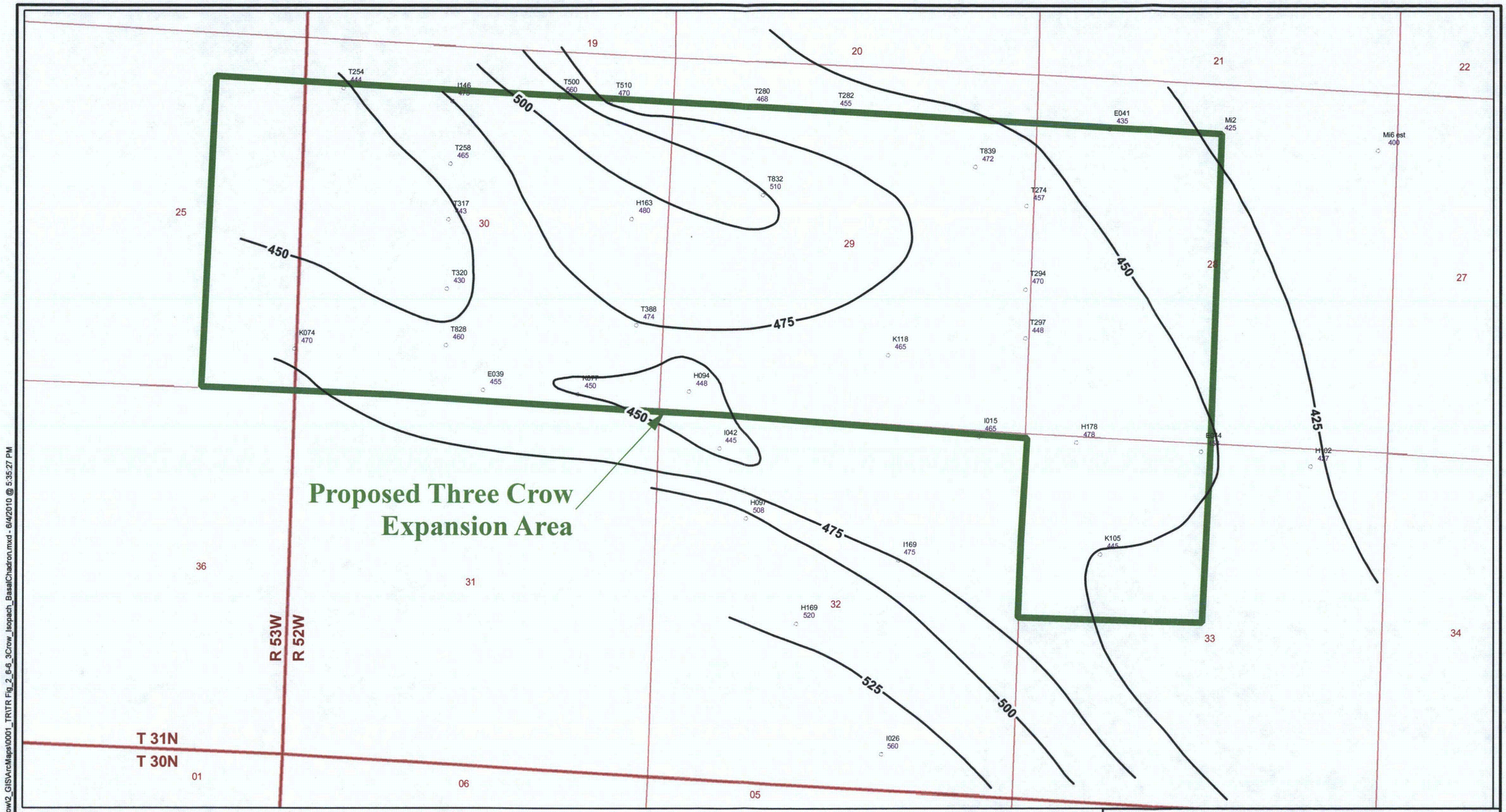
K:\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0001_TR\TR Fig_2_6-5_3Crow_Isopach_BasalChadron.mxd - 6/4/2010 @ 5:33:14 PM



LEGEND

- Exploration Borehole
- Thickness Contour (Upper Confining Zone)
- Proposed Three Crow Expansion Area
- T828 / 238 — Borehole/Well ID / Unit Thickness (Feet)

Note: 1) The upper confining zone represents the interval between the base of the Brule Formation and the top of the underlying Basal Chadron Sandstone.

0 1,000 2,000
Scale in Feet

PROJECTION:
NAD 1927, STATE PLANE
NEBRASKA NORTH FIPS 2601

N
W E

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FIGURE 2.6-6
THREE CROW ISOPACH MAP - UPPER CONFINING ZONE

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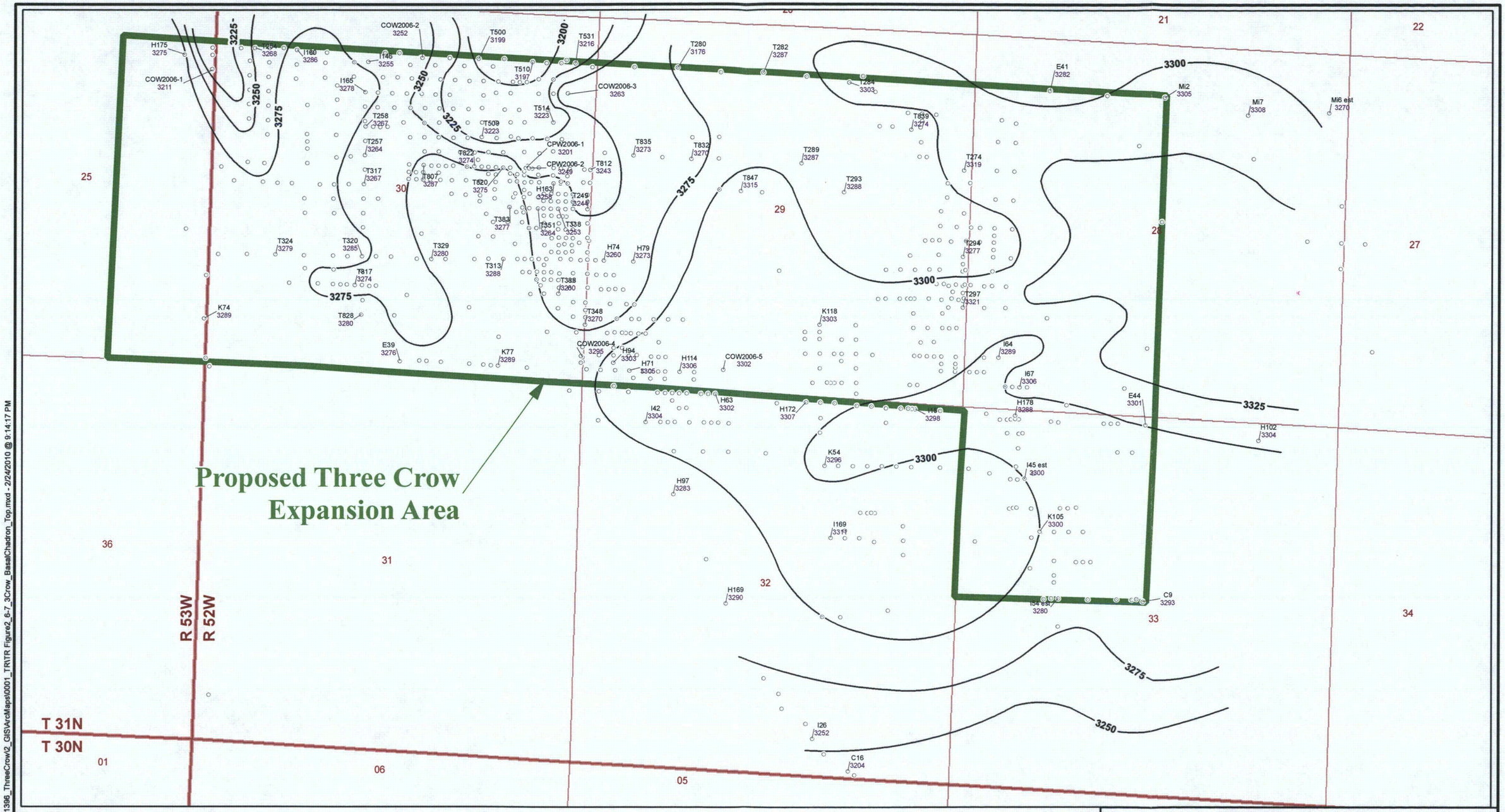

LEGEND

- Exploration Borehole
- Top of Basal Chadron Contour (FT-AMSL)
- Proposed Three Crow Expansion Area
- Borehole/Well ID (e.g. T329 / 3280 = Top of Basal Chadron (FT-AMSL))

0 1,000 2,000
Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_ NEBRASKA_NORTH_FIPS_2601

N / W — E

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-7
THREE CROW STRUCTURE CONTOUR MAP
TOP OF BASAL CHADRON SANDSTONE

PROJECT: CO001396.0003 MAPPED BY: JC CHECKED BY: MS

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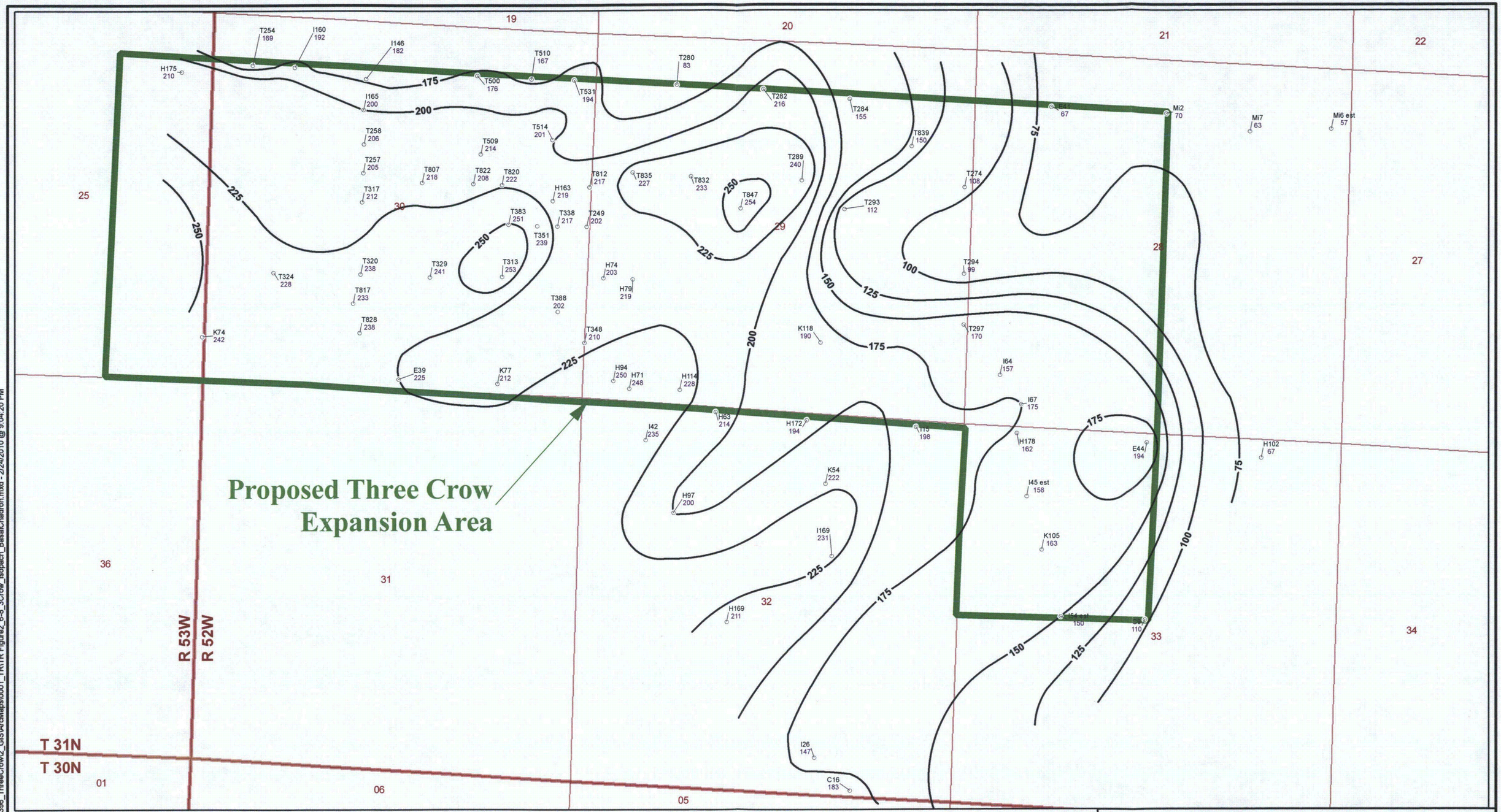
\\Co3fp\gis-cadd\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\00001_TRTR Figure\2_6-7_3Crow_BasalChadron_Top.mxd - 2/24/2010 @ 9:14:17 PM



LEGEND

- Exploration Borehole
- Isopach Contour (Feet)
- Proposed Three Crow Expansion Area
- T828 / 238 — Borehole/Well ID / Unit Thickness (Feet)

0 1,000 2,000
Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601

N
W E

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-8
THREE CROW ISOPACH MAP - UPPER AND LOWER BASAL CHADRON SANDSTONE

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

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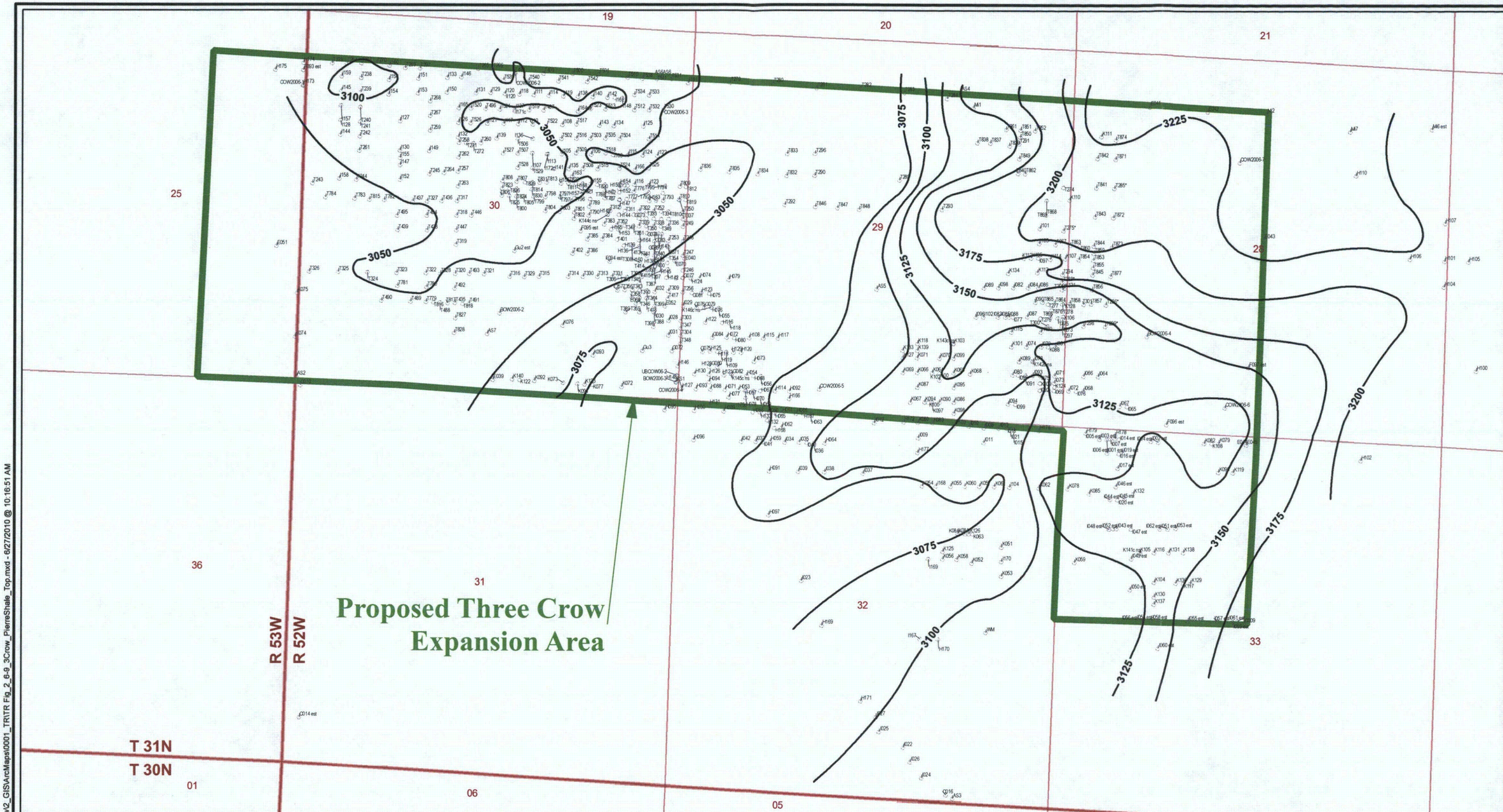
\\Co3fpgis-cadd\CHR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0001_TR\TR Figure2_6-8_3Crow_Isopach_BasalChadron.mxd - 2/24/2010 @ 9:04:20 PM



LEGEND

- Exploration Borehole
- Top of Pierre Shale Contour (FT-AMSL)
- Proposed Three Crow Expansion Area

0 1,000 2,000
Scale in Feet

PROJECTION:
NAD_1927_STATEPLANE_
NEBRASKA_NORTH_FIPS_2601

N
W E

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-9
THREE CROW STRUCTURE CONTOUR MAP - TOP OF PIERRE SHALE

PROJECT: CO001396.0003 | MAPPED BY: JC | CHECKED BY: MS

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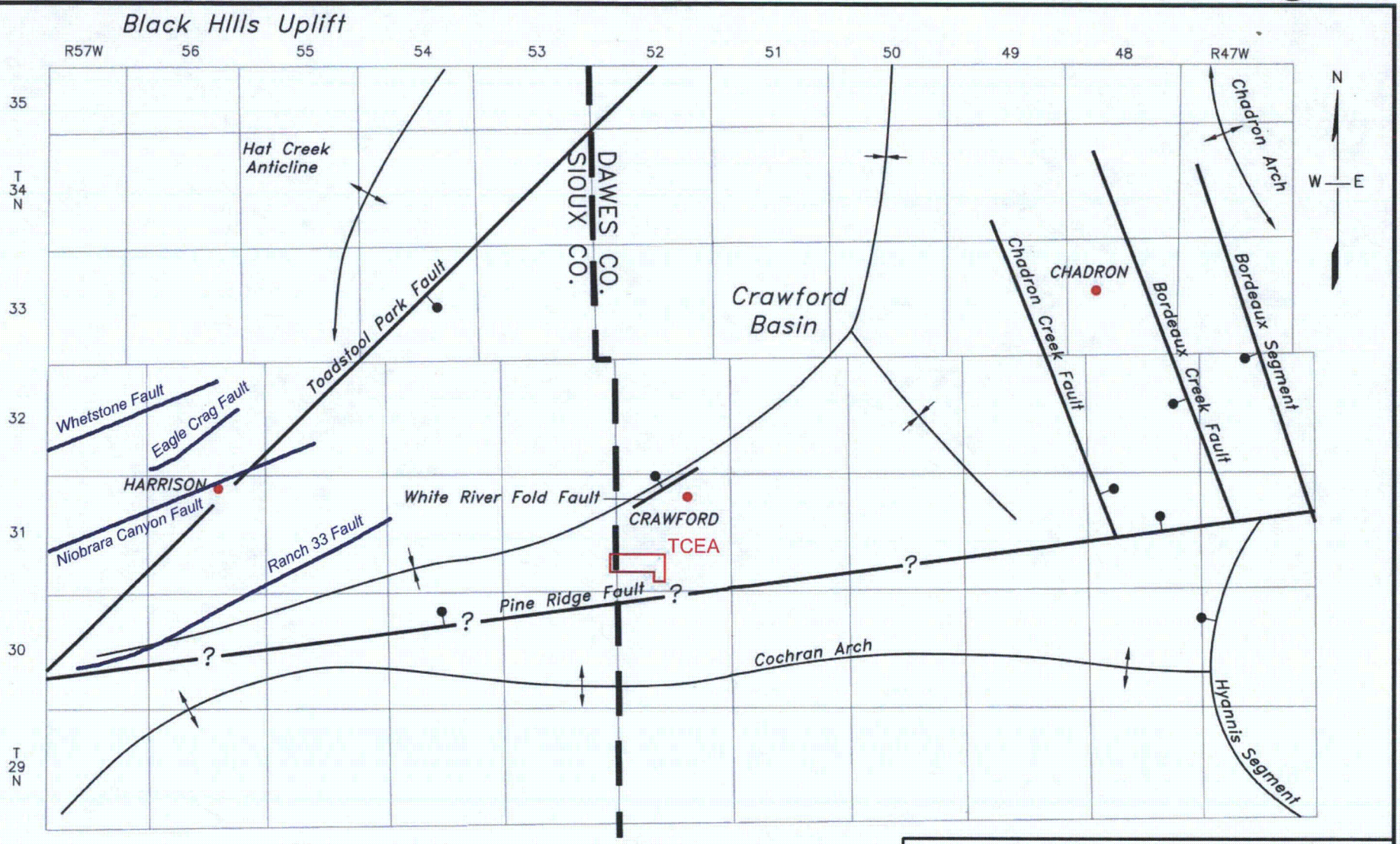
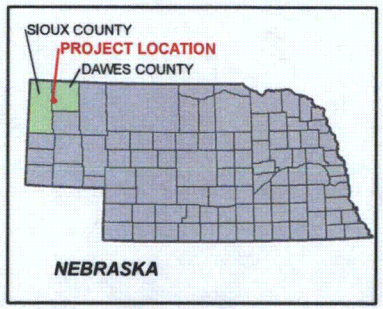


LEGEND

- Fault (Ball on downthrown side)
- Anticline
- Syncline
- Proposed Three Crow Expansion Area (TCEA)
- Fault interpretations by Hunt (1990)

0 5 10
SCALE IN MILES

Modified from DeGraw, 1969;
WFC-White River Fault only (Collings & Knode, 1984)



CROW BUTTE RESOURCES, INC.

FIGURE 2.6-10
STRUCTURAL FEATURES MAP OF THE CRAWFORD BASIN

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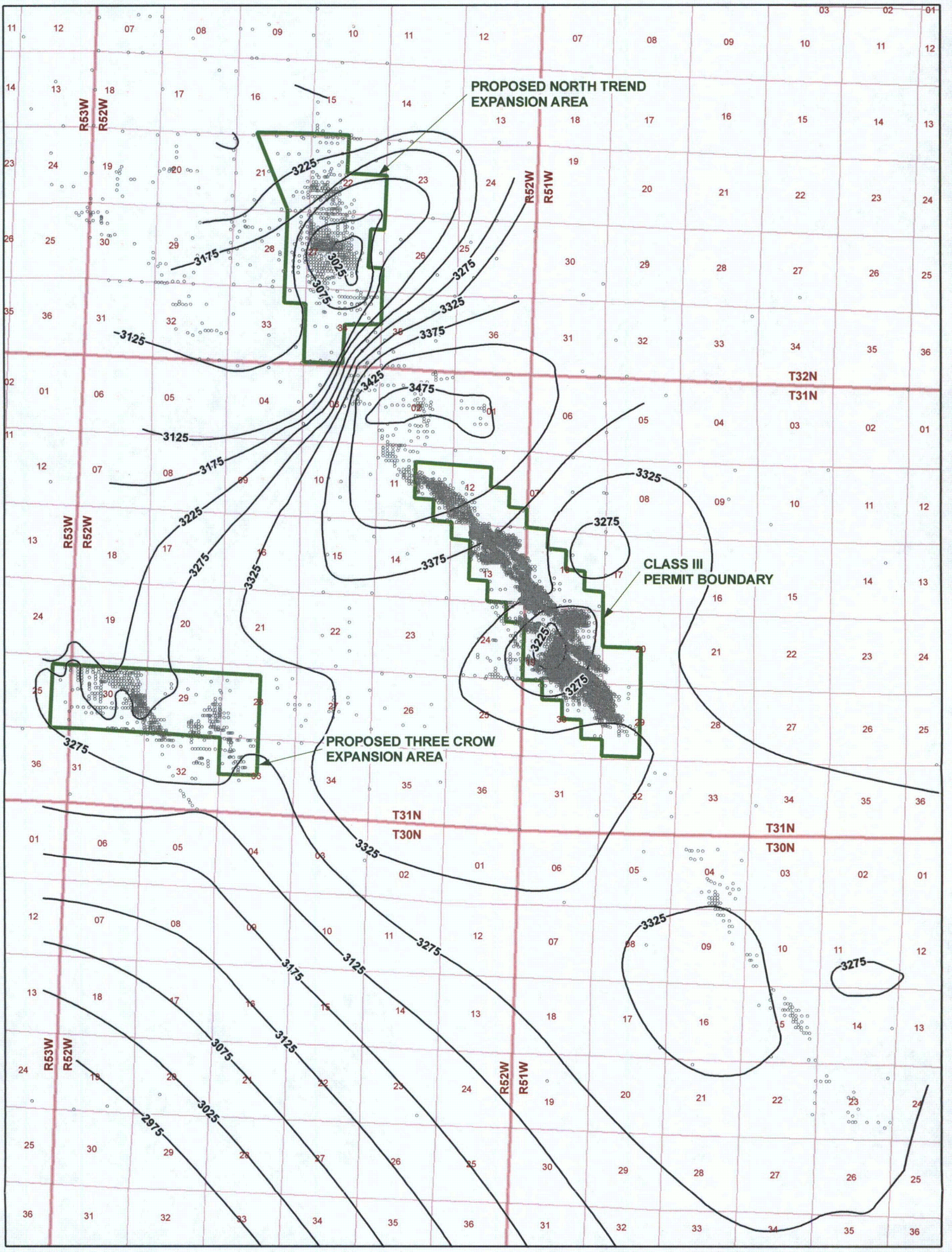
K:\CBR_Projects\CO001396_ThreeCrow\3_IMAGES\Illustrator\TR Fig_2_6-10 Regional Structural Features.ai @ 03/27/2010



LEGEND

- Exploration Borehole
- Groundwater Potentiometric Surface (FT-AMSL)

N
W — E

0 5,000 10,000

Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_ NEBRASKA_NORTH_FIPS_2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-11
REGIONAL STRUCTURE CONTOUR MAP - TOP OF BASAL CHADRON SANDSTONE

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\\Co3fp\gis-cadd\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0001_TR\TR Figure2_6-11_Regional_Structure_Contour_Map_Top_of_BasalChadron.mxd - 2/24/2010 @ 9:37:47 PM

PROPOSED NORTH TREND EXPANSION AREA

CLASS III PERMIT BOUNDARY

PROPOSED THREE CROW EXPANSION AREA

R53W R52W R52W R51W

T32N T31N T31N T30N T31N T30N

LEGEND

Unit Thickness (Feet)

Exploration Borehole

N W E

0 5,000 10,000

Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_ NEBRASKA_NORTH_FIPS_2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-12
REGIONAL ISOPACH MAP - BASAL CHADRON SANDSTONE

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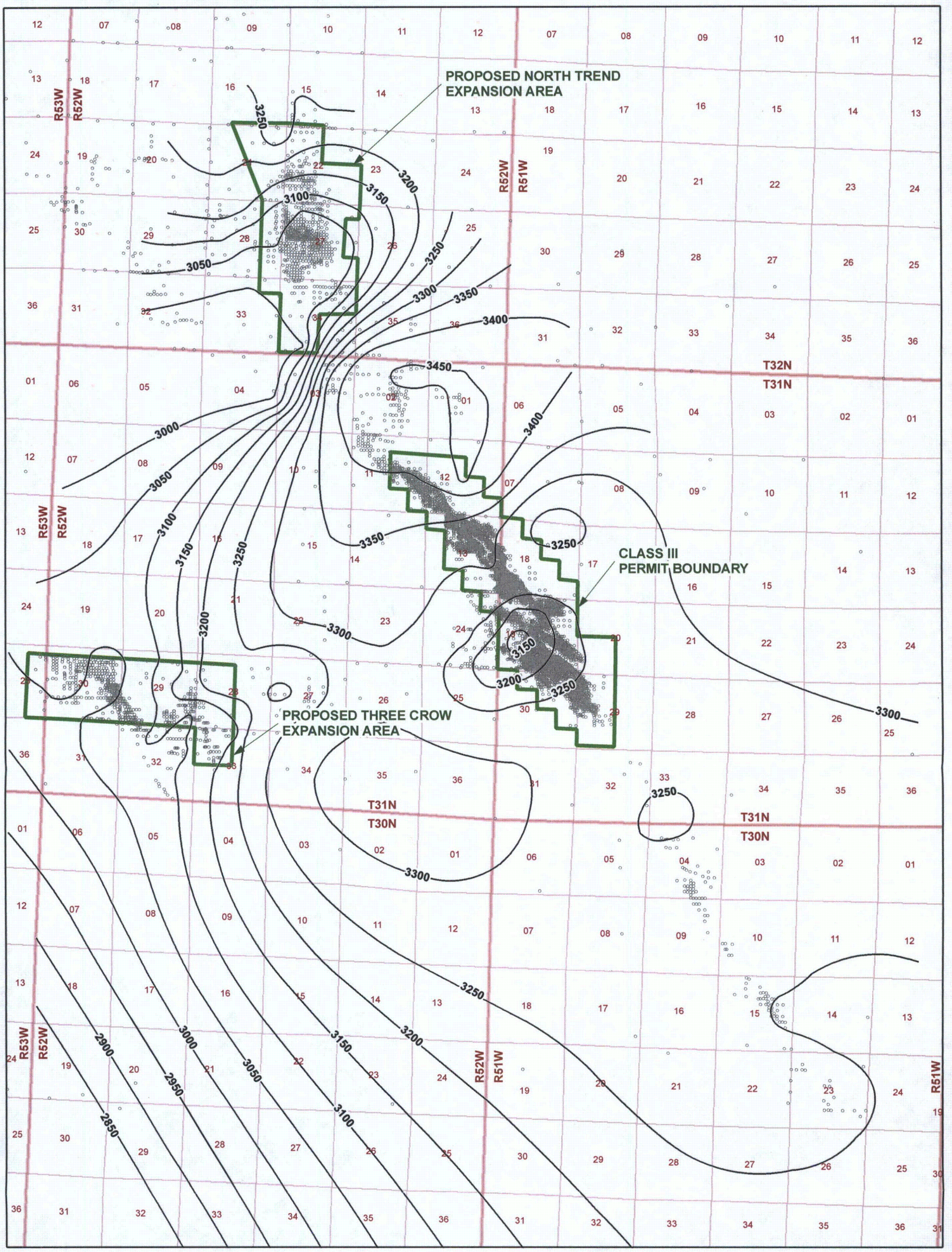
\\Co3fplgis-cadd\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0001_TRITR Figure2_6-12_Regional_Isopach_Map_BasalChadron.mxd - 2/24/2010 @ 9:42:33 PM



LEGEND

- Elevation Contour (FT-AMSL)
- Exploration Borehole

N
W — E

0 5,000 10,000
Scale in Feet

PROJECTION: NAD_1927_STATEPLANE_ NEBRASKA_NORTH_FIPS_2601

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-13
REGIONAL STRUCTURE CONTOUR MAP - TOP OF PIERRE SHALE

PROJECT: CO001396.0003 MAPPED BY: JC CHECKED BY: MS

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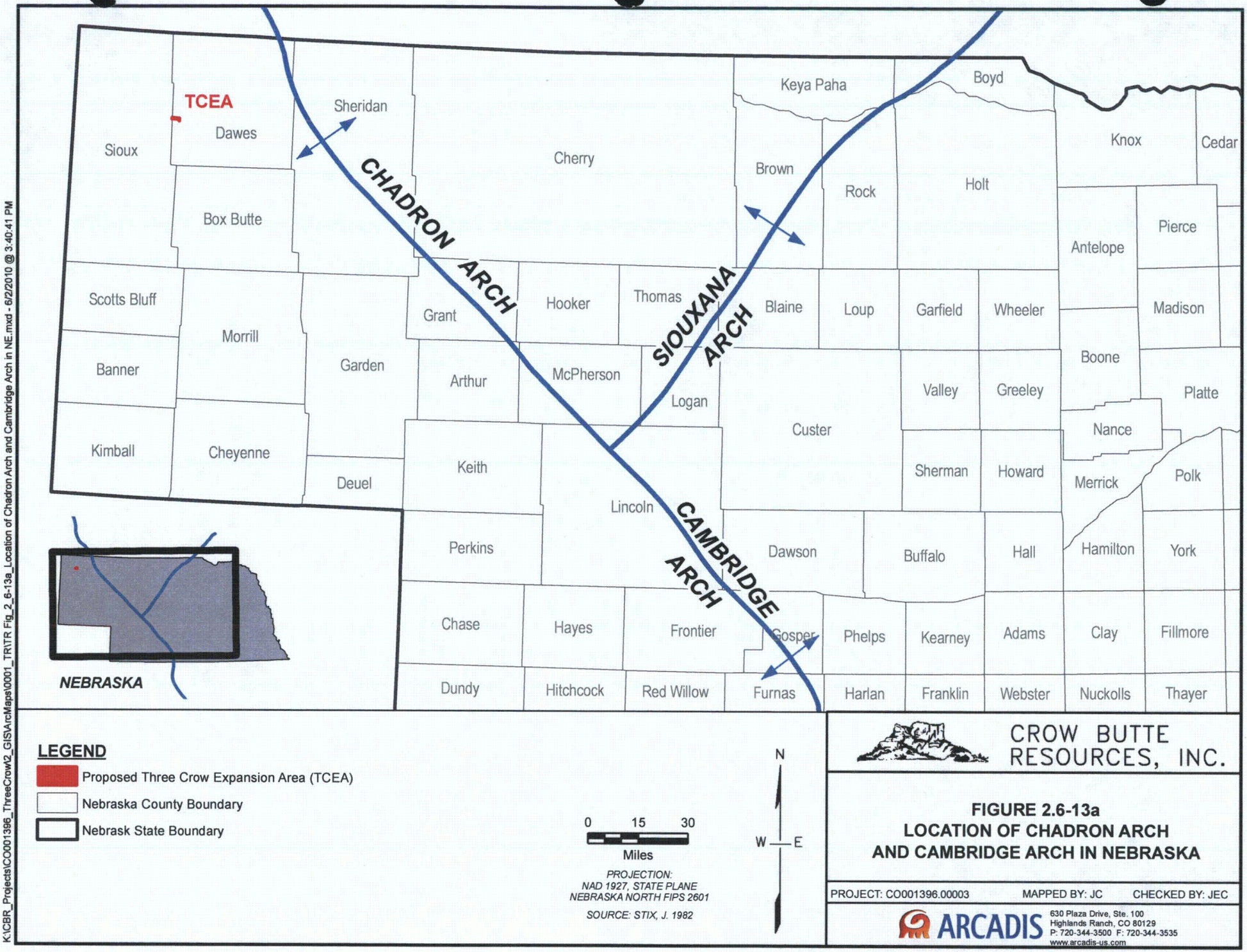
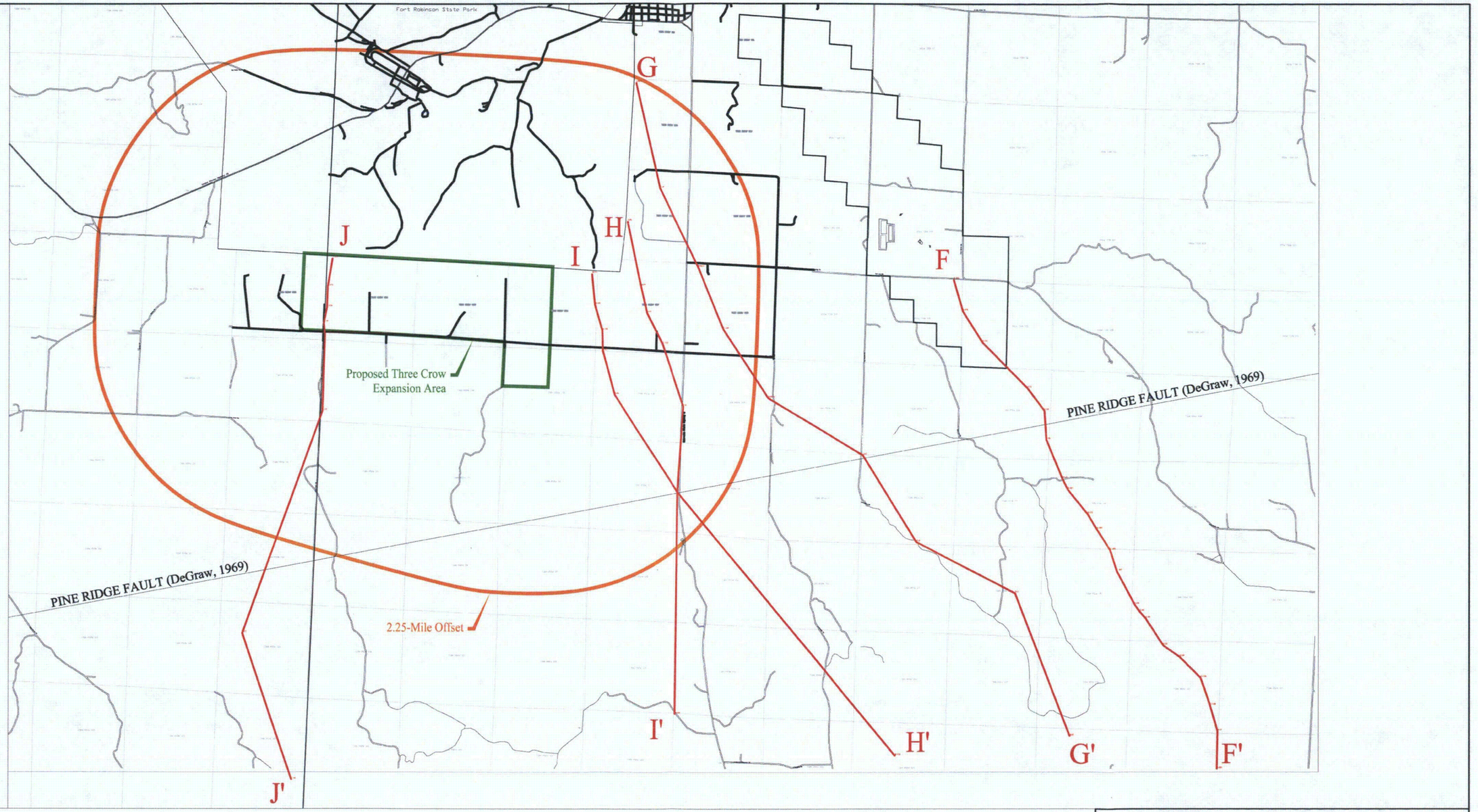
\\Co3fpigis-cadd\CBR_Projects\CO001396_ThreeCrowV2_GIS\ArcMaps\10003_AEPITR Figure2_6-13_Regional_Structure_Contour_Map_Top_of_PierreShale.mxd - 2/24/2010 @ 9:45:56 PM



K:\CBR_Projects\CO001396_ThreeCrow\2_GIS\ArcMaps\0001_TR\TR Fig_2_6-13a_Location of Chadron Arch and Cambridge Arch in NE.mxd - 6/2/2010 @ 3:40:41 PM



2000 0 2000 4000 6000 8000 Feet

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-14
THREE CROW SECTION LOCATION MAP

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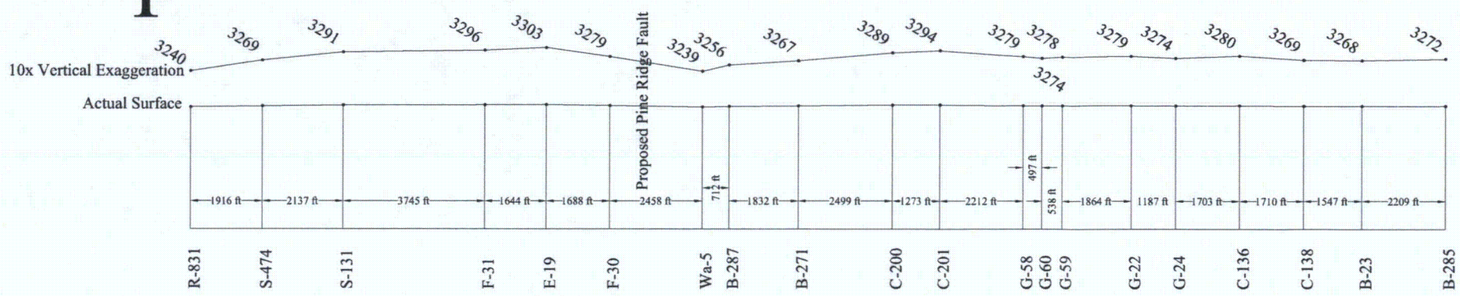
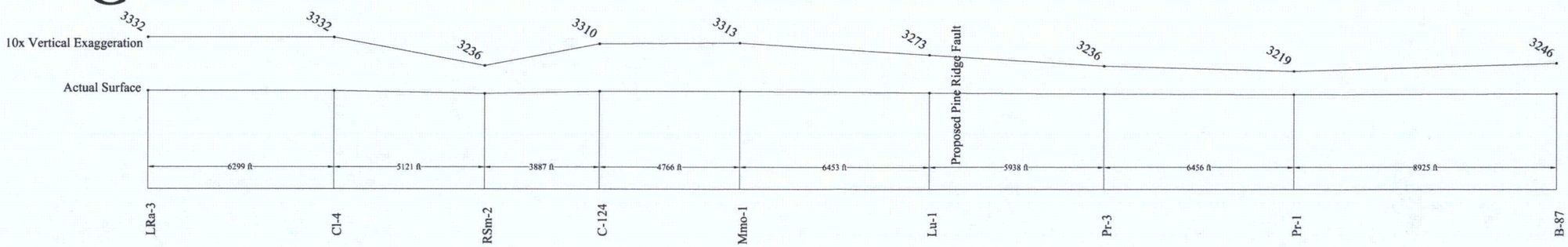
North **F** **F'** South



North **G** **G'** South



2000 0 2000 4000 6000 8000 Feet

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-15a
THREE CROW STRUCTURAL CROSS-SECTIONS F-F' AND G-G'
(TOP OF PIERRE SHALE)

PROJECT: CO001396 MAPPED BY: JC CHECKED BY: MS

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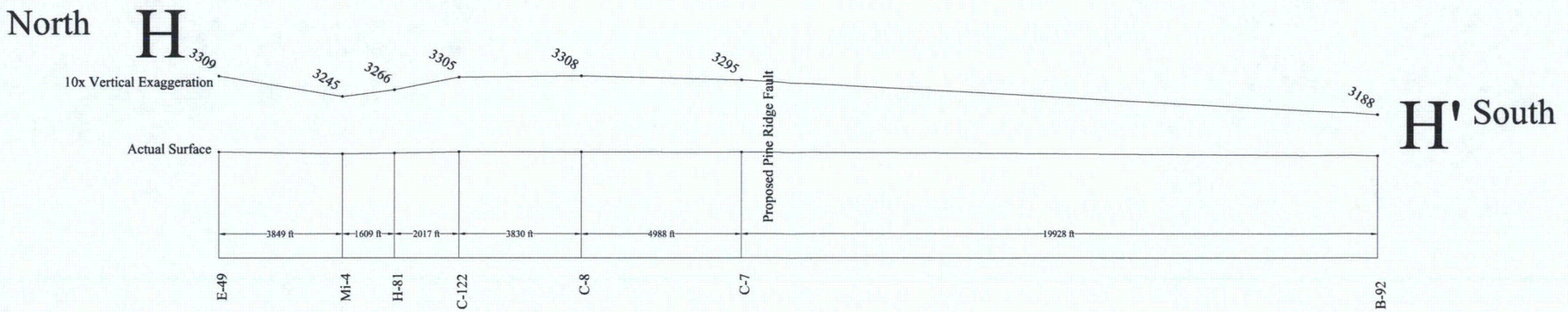
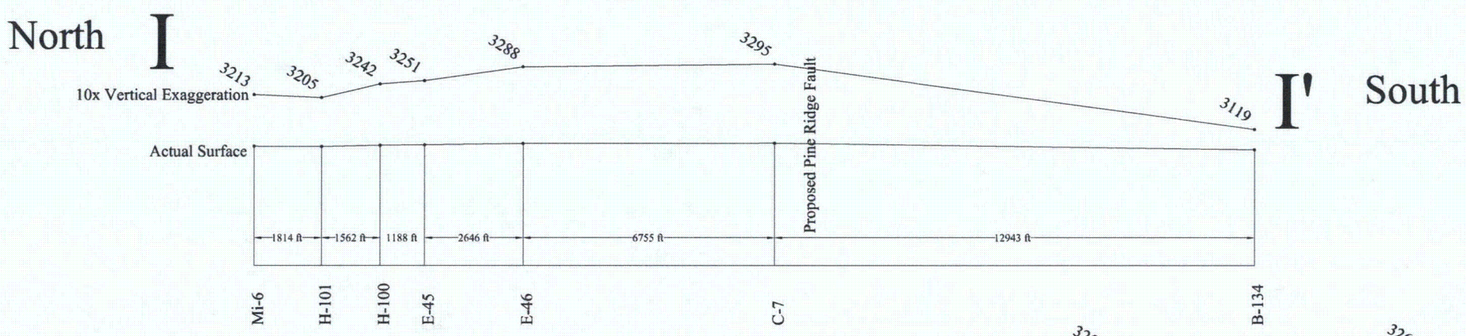
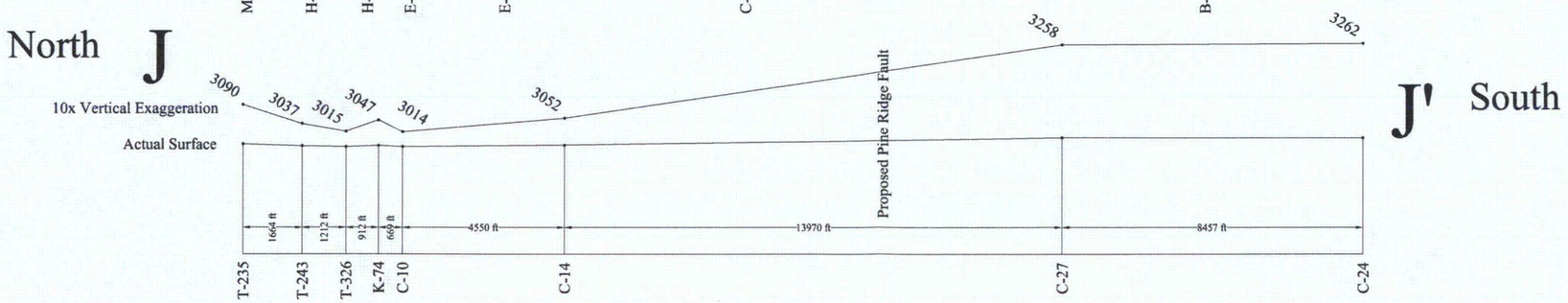
PATH: K:\CBR_Projects\CO001396_ThreeCrow\1_ACAD\e-transmit\Hydro-XS.dwg LAYOUT: TR-a SAVED DATE/TIME: 6/4/2010 12:39 AM







2000 0 2000 4000 6000 8000 Feet

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FIGURE 2.6-15b
THREE CROW STRUCTURAL CROSS-SECTIONS H-H', I-I', AND J-J' (TOP OF PIERRE SHALE)

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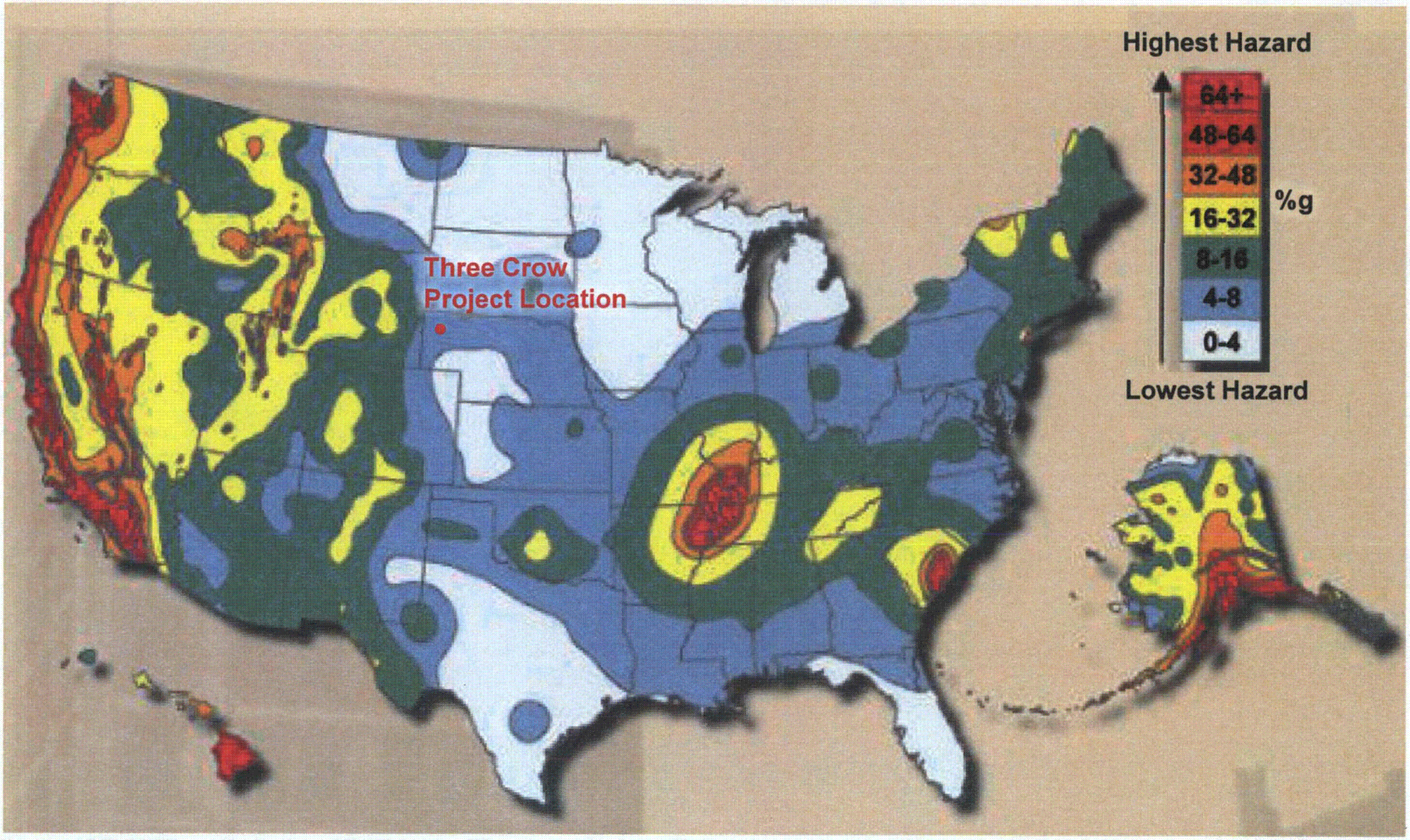

Source: SD 2008.

N
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FIGURE 2.6-16
EARTHQUAKE HAZARD RANKING IN THE U.S.

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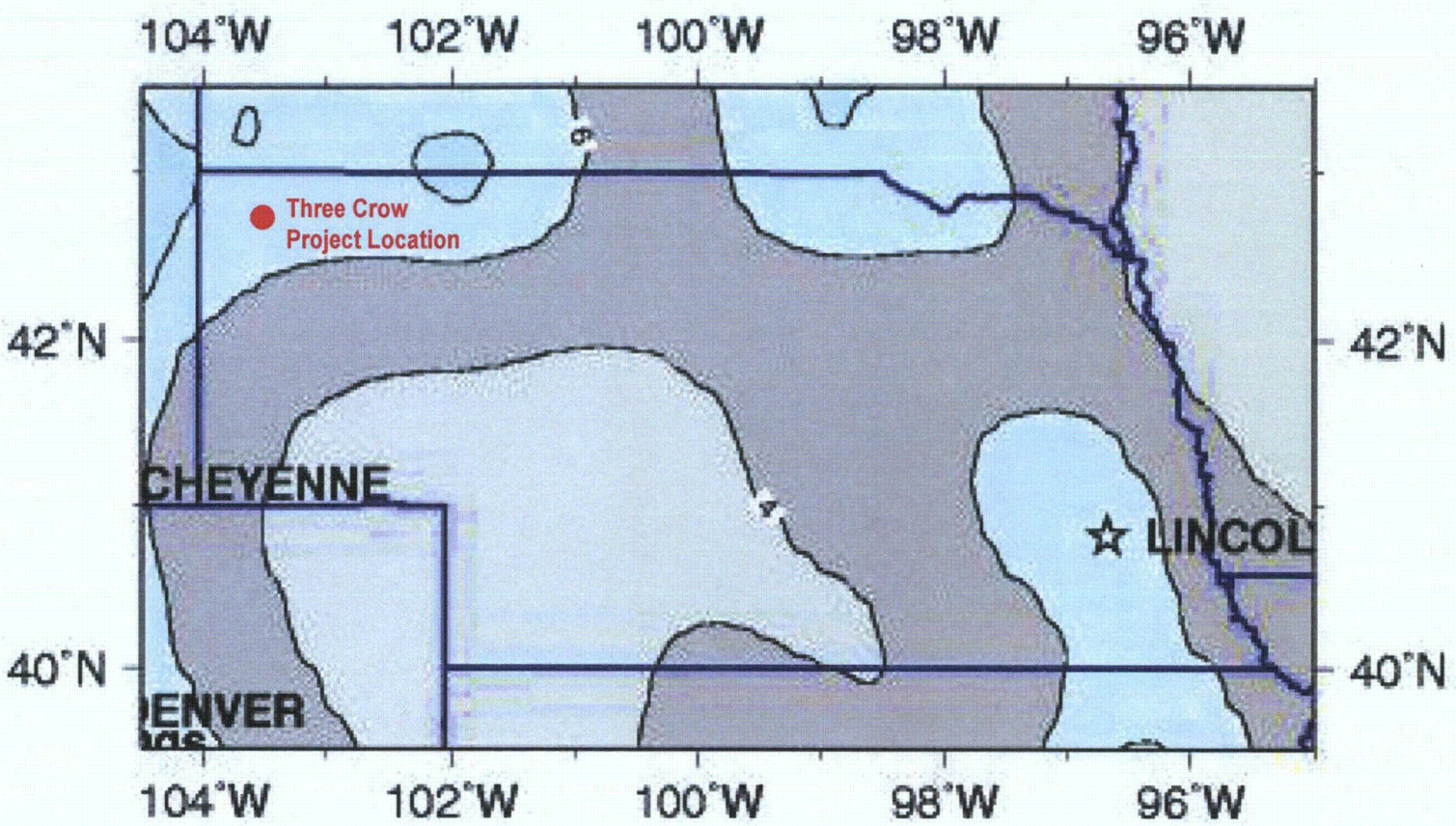
SOURCE: SD 2008

K:\CBR_Projects\CO001396_ThreeCrow\3_IMAGES\IllustratorTR Fig_2_6-27 Earthquake Hazard Ranking in the US.ai @ 01/13/2010



Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
Site: NEHRP B-C boundary
National Seismic Hazard Mapping Project (Peterson, M.D. 2008)

SOURCE: USGS 20009a

N
W E

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FIGURE 2.6-17
SEISMIC HAZARD MAP
FOR NEBRASKA (2008)

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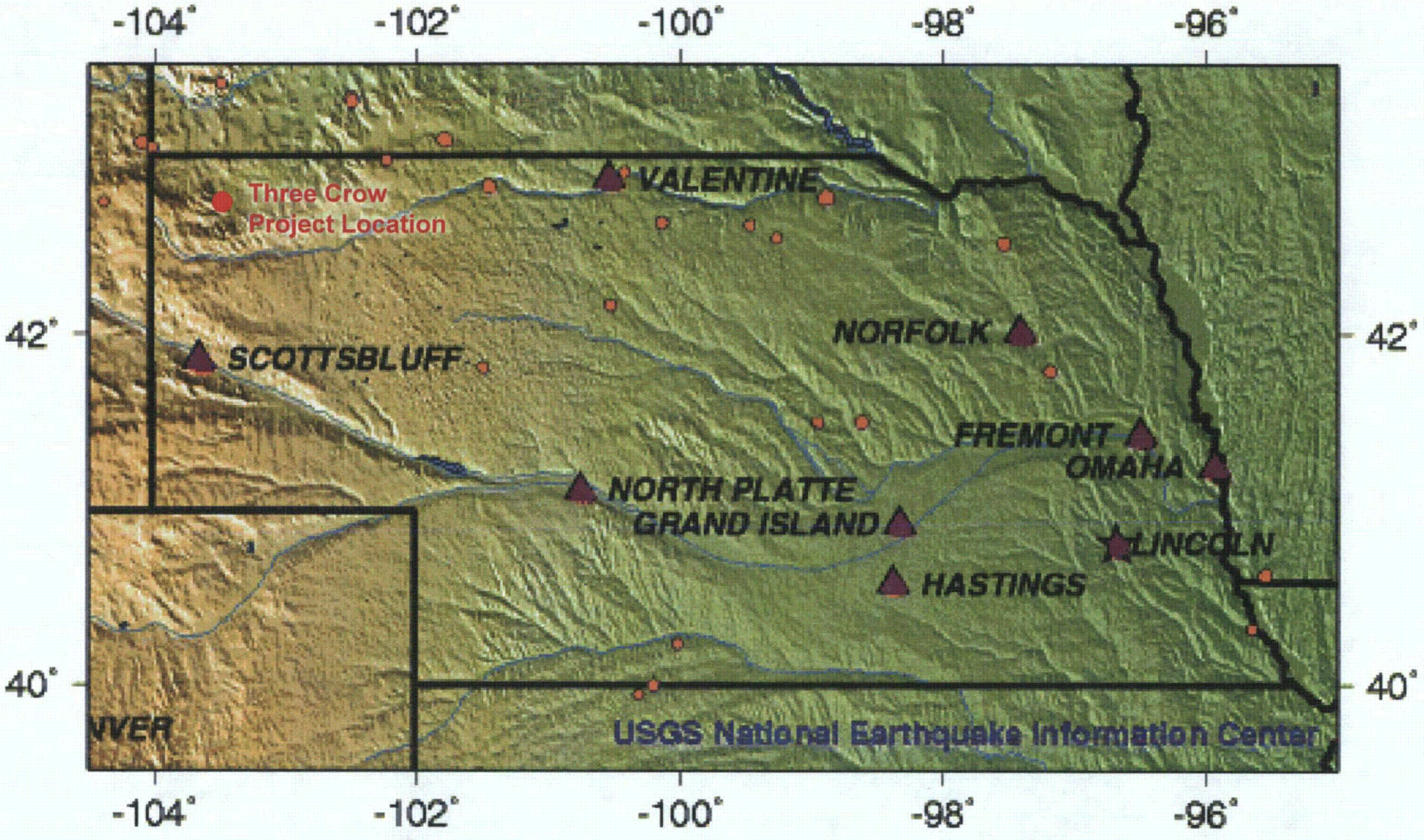
K:\CBR_Projects\CO001396_ThreeCrow\3_IMAGES\Illustrator\TR Fig_2_6-28 Seismic Hazard Map for Nebraska.ai @ 01/08/2010



-151 -71 -33 0

DEPTH

Depth is in kilometers.
Purple Triangles: Cities
Purple Star: Capital City
Circles: Earthquakes (color represents depth range)
Earthquake locations are from the USGS/NEIC PDE catalog

SOURCE: USGS 2009e

N
W E

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FIGURE 2.6-18
SEISMICITY OF NEBRASKA
1990-2006

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

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K:\CBR_Projects\CO001396_ThreeCrow\3_IMAGES\Illustrator\TR Fig_2_6-29 Seismicity of Nebraska 1990-2006.ai @ 01/13/2010

T. 31N R. 53W | T. 31N R. 52W

19 | 20 | 21

25 | 30 | 29 | 28 | 32 | 33

SIOUX COUNTY | DAWES COUNTY

Cherry Creek | Bozle Creek

Proposed Three Crow Expansion Area

LEGEND: Soils

- 1031, Glenberg fine sandy loam, channeled, frequently flooded
- 1180, Las Animas fine sandy loam, occasionally flooded
- 1356, Bridget silt loam, 1 to 3 percent slopes
- 1357, Bridget silt loam, 3 to 6 percent slopes
- 1363, Bridget very fine sandy loam, 3 to 6 percent slopes
- 1364, Bridget very fine sandy loam, 6 to 9 percent slopes
- 1618, Keith loam, 1 to 3 percent slopes
- 1620, Keith silt loam, 1 to 3 percent slopes
- 1631, Keith silt loam, 3 to 9 percent slopes
- 1742, Rosebud-Canyon loams, 3 to 9 percent slopes
- 1862, Ulysses silt loam, 9 to 20 percent slopes
- 5105, Alliance silt loam, 1 to 3 percent slopes
- 5106, Alliance silt loam, 3 to 9 percent slopes
- 5107, Alliance silt loam, 3 to 9 percent slopes, eroded
- 5118, Busher and tassel loamy very fine sands, 6 to 20 percent slopes
- 5124, Busher loamy very fine sand, 1 to 6 percent slopes, eroded
- 5128, Busher loamy very fine sand, 6 to 9 percent slopes, eroded
- 5129, Busher loamy very fine sand, 9 to 20 percent slopes
- 5200, Oglala loam, 9 to 30 percent slopes
- 5211, Oglala-Canyon loams, 9 to 20 percent slopes
- 5291, Vetal very fine sandy loam, 1 to 3 percent slopes
- 5292, Vetal very fine sandy loam, 3 to 6 percent slopes
- 5947, Duroc very fine sandy loam, 1 to 3 percent slopes
- 5964, Jayem and Vetal loamy very fine sands, 6 to 9 percent slopes
- 6028, Tassel soils, 3 to 30 percent slopes
- 6036, Tassel-Busher-Rock outcrop complex, 6 to 30 percent slopes
- 6109, Sarben loamy very fine sand, 9 to 30 percent slopes
- 9903, Fluvaquents, sandy, frequently flooded

0 500 1,000

Scale in Feet

N

W — E

PROJECTION:
NAD_1927_STATEPLANE_NEBRASKA_NORTH_FIPS_2601
SOURCE:
AERIAL - NAIP 2006, SIOUX COUNTY & DAWES COUNTY, NEBRASKA;
SOILS - NRCS SOIL MART, NE045, NE165

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-19
THREE CROW EXPANSION AREA
SOILS MAP

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

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