UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

In the Matter of CROW BUTTE RESOURCES, INC. (Marsland Expansion Area)	Docket No. 40-8943-MLA-2 ASLBP No. 13-926-01-MLA-BD01

Hearing Exhibit

Exhibit Number: CBR018

Exhibit Title: Appendix HH - Deep Brule Monitor Well Installation Program

Final Report
Deep Brule Monitor Well Installation Program
Marsland Expansion Area
Dawes County, Nebraska

Prepared for:

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May 3, 2017

Reported by:

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1.0 EXECUTIVE SUMMARY

Crow Butte Resources Inc. (CBR) conducted the first phase of a monitor well installation program in 2016 at the Marsland Expansion Area (MEA), located in Dawes County, Nebraska. Ten wells were installed in the lower (deep) Brule Formation with completion depths ranging from 450 to 630 feet. The well completions and well development were the first phase of the monitor well program and are the subject of this report. Additional program phases, if warranted are to monitor water quality and water levels for one year and to conduct pumping tests to assess any hydrologic connections between the MEA mining zone and the lower Brule.

The monitor well program was proposed by CBR as a result of its revision of the boundary between the Brule and Chadron Formations; the formational boundary was lowered by approximately 280 feet at MEA. Additional characterization of the lower Brule was necessary to address open issues in permitting including potential reclassification of the first overlying aquifer to the mining zone at MEA, and other related regulatory requirements and subsequent revisions to permit applications.

The first phase of the MEA monitor well program resulted in the following conclusions regarding the characterization of the lower Brule Formation:

- Geophysical and geologic sample logging and well development results demonstrate that the lower Brule Formation is composed of non-aquifer sediments and that it does not produce water in usable, significant or economic amounts and cannot be classified as an aquifer.
- Additional testing which includes water quality, water level measurements and pumping tests is not recommended.
- The first overlying aquifer to the mining zone at MEA should remain the Brown Siltstone Member of the upper Brule Formation.

2.0 PROGRAM BACKGROUND

The Marsland Expansion Area (MEA) project is in the permitting stage of development. CBR currently has an application to the U.S. Nuclear Regulatory Commission (NRC) for the MEA license amendment, an Aquifer Exemption Permit (AEP) application to the Nebraska Department of Environmental Quality (NDEQ) and various other required permit applications. CBR revised the Marsland AEP application with changes to the Brule and Chadron Formation geology after reviewing work completed by Swinehart et al. (1985) and LaGarry (1998). The revised AEP reflected changes in the boundary between the Brule and Chadron Formations which was lowered by approximately 280 feet. Along with the revisions to the AEP, CBR proposed to install monitor wells in the lower portion of the Brule, monitor water quality and water levels for one year and to conduct pumping tests to assess any hydrologic connections between the mining zone and the lower Brule (CBR 2016).

Discussions between CBR and the NRC regarding open issues with the MEA license amendment application Technical Report included the topic of additional characterization of the lower Brule Formation (NRC 2016). The NRC summarized, that if an *aquifer* (defined in 10 CFR 40 Appendix A as "...a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of ground water to wells or springs.") deeper than the previously identified aquifer in the Brown Siltstone Member, is determined to represent the first overlying aquifer of the Brule Formation, additional testing and characterization would be required and incorporated into the license application.

CBR implemented the MEA lower (deep) Brule monitor well program with the installation phase being the subject of this report. The field results in this report are to provide additional information about the newly recognized portion of the Brule, and to address the NRC open issue and its potential regulatory requirements. If the lower Brule is determined to be an aquifer by regulatory agency definition, recommendations would be made to conduct the next phase of the program of additional testing.

3.0 PROGRAM DESCRIPTION

Location and General Geology

Situated in northwest Nebraska in the southern portion of Dawes County, the MEA is approximately 11.1 miles south-southeast of the CBR Central Processing Facility and approximately 4.6 miles northeast of the community of Marsland (Figure 1).

Figure 2 presents the bedrock geology at Marsland and a site specific representative stratigraphic column. The stratigraphic sequence at MEA in descending order is alluvial sediments; the Arikaree Group consisting of the Upper Harrison Beds, Harrison-Monroe Creek Formation and Gering Formation; the Brule Formation (which includes the Brown Siltstone, Whitney and Orella Members) the Upper Chadron Formation, Middle Chadron Formation and basal sandstone of the Chadron Formation. The Orella Member of the Brule Formation may have only minimal presence at the MEA as it is not clearly distinguished by drill cuttings or by geophysical log signature. The basal sandstone of the Chadron Formation is the mining zone aquifer at MEA and is underlain by the Pierre Shale. Regional and site specific subsurface geology and stratigraphy is detailed in Section 2.5 of the Technical Report as part of the NRC license amendment (CBR 2015).

As previously described, the boundary between the Brule and the underlying Chadron Formation was lowered by approximately 280 feet at MEA. The revised bottom of the Brule Formation is based on literature review which identifies volcanic ash marker beds (Upper and Lower Whitney Ash) noted in geophysical logs at Marsland, and lithologic changes observed in drill cuttings below the Lower Whitney Ash where the brown and tan siltstones of the lower Brule show a color change towards the brown and green claystones of the Upper Chadron Formation.

The targeted interval to be screened in the monitor well program is the lower portion of the Brule Formation which includes the Whitney Member and the Orella Member, although the Orella may be only minimally present at the MEA. Previously installed Brule monitor wells were screened within sandstone lenses of the Brown Siltstone Member of the upper Brule Formation.

As shown in Figure 3, the MEA stratigraphic column includes the initial interpreted base of the Brule Formation where a distinct grain size change occurs, and the revised base of the Brule occurring below the Lower Whitney Ash. Figure 3 also includes an illustration of the target formation depths of the lower (deep) Brule monitor wells (DBOW), the previously installed shallow Arikaree wells (AOW), the BOW wells which were screened in water bearing sand horizons of the upper Brule, and the monitor wells which were installed and screened in the mining zone aquifer in the basal sandstone of the Chadron Formation.

Well Planning and Installation

Ten DBOW monitor wells were to be drilled (piloted), geophysically logged, reamed, cased, cemented, screens installed and developed by airlifting; monitor well names were designated DBOW1 through DBOW10 (Deep Brule Observation Well). Wells were to be constructed, tested and initially developed using methods described in Sections 3.1.2 of the MEA Technical Report (TR), (CBR 2015).

Monitor well locations were staked in close proximity to BOW wells; target total depths (TD's) were based on revised MEA regional cross sections (TR Figures 2.6-3a through 2.6-3n), interpretation of geophysical logs from nearby exploration drill holes and monitor wells and by

description of cuttings sampled during the drilling of the pilot hole. Screen intervals were to be set in the newly recognized portions of the lower Brule.

The well installation program started on August 11, 2016. During the initial pilot drilling of the DBOW wells, drill cuttings were sampled every 5 feet and laid out for description. Lithologic changes were noted to occur below the Lower Whitney Ash at base of the Brule, where the brown and tan clay rich siltstones change toward the tan/brown and green claystones of the Upper Chadron Formation. The boundary between the Lower Whitney and the underlying Orella Member was not distinguishable by log signature or drill cuttings as they are similar in nature, however the overall lithology change occurring at the Upper Chadron was evident. An example is shown in Figure 4; photographs of the drill cuttings from well DBOW4 show a lithologic change around 510 feet in depth where green clay is noted to occur. The lithologic change is consistent with the interpreted revised base of the Brule shown in revised cross sections in the MEA TR.

The pilot holes were then geophysically logged, reamed, cased and cemented, cement was drilled out and screen assemblies were set. The drill rig was utilized to airlift the wells using an air compressor for a minimum of 3.5 hours and water volumes were measured at the surface to estimate rate of flow from the well. The last DBOW well was installed and initially developed on September 15, 2016. All well sites were reclaimed and seeded during the fall of 2016.

Well locations were resurveyed by GPS, registration forms were completed and submitted to the Nebraska Department of Natural Resources (Attachment A) and well completion reports were sent to the NDEQ.

4.0 PROGRAM RESULTS

The completed DBOW well locations are shown in Figure 5. The completed well depths range from 450 to 630 feet and a summary of the DBOW well information including location data and screened intervals is presented in Table 1.

A structural north-south cross section across the MEA project area includes 8 of the 10 newly installed DBOW wells, selected basal Chadron sandstone monitor (Monitor) wells, exploration drill hole and upper Brule (BOW) monitor wells (Figures 6 and 7). The cross section shows the consistency of the presence of the Upper and Lower Whitney Ash marker beds across the MEA and confirm the placement of the DBOW wells in lower Brule.

Diagrams comparing geophysical logs of all DBOW wells, their associated BOW wells and nearby basal Chadron sandstone monitor wells or exploration drill holes (which were used to help determine the target depth of the DBOW wells) are shown in Figures 8 through 11.

Geophysical and Drill Cuttings Logs

The geophysical logs shown in the cross sections and in the well cluster diagrams indicate a lack of aquifer potential in the lower Brule. The resistivity and SP curves throughout the lower Brule have relatively low activity with little character and do not demonstrate the presence of sandstones such as the log signatures in the overlying Arikaree Group sandstones, the sandstone horizons in the upper Brule and the basal sandstone of the Chadron Formation. The small and thin resistivity / SP gamma kicks that do occur in the lower Brule are associated with the Upper and Lower Whitney Ash beds, which are composed of silt & clay size particles.

Drill cuttings samples recovered from the lower Brule consist predominantly of siltstone, silty claystone and clay rich siltstone but only occasionally possess small amounts of sand sized material. This is in contrast to drill cuttings from the Arikaree Group, the upper Brule sandstones and the basal sandstone of the Chadron which do reveal the presence of sand bodies and are consistent with the interpretation of the geophysical logs.

The poor water-bearing potential of the lower Brule as observed in drill cuttings is consistent with the results of core material testing. Laboratory grain size analysis conducted on 2 core samples within the lower Brule, M-1956C Run 5 Samples 1 and 2 (PTS 2013) resulted in average grain size of 0.052 and 0.029 mm (both classified as silt).

Well Development

Initial well capacities measured during development by airlifting of the DBOW wells further validate the poor water-bearing potential of the lower Brule Formation. Initial well development on the drill rig by airlifting using compressed air was conducted on all wells for a minimum of 3.5 hours following installation of each screen assembly. The initial flow rate / well capacity estimates made during airlifting resulted in a maximum of 0.15 gallons per minute (gpm) (reported as <0.2 gpm to the Nebraska Department of Natural Resources) for wells DBOW2 and DBOW3. Photographs extracted from videos taken during well airlifting are presented in Figures 12 through 15 and display the insignificant amounts of water availability at the time of well development.

The small amounts of water produced from the wells during airlifting demonstrate that no usable quantities exist within the lower Brule.

Following mechanical integrity testing, the DBOW wells were evacuated of water using a wireline / slimline pump assembly. Field conductivity / pH measurements were taken on the extracted water and the elevated readings indicated the presence of drilling mud filtrate and cement thus requiring further well development. Submersible pumps were then installed in each of the wells and static water levels were measured in December 2016. Water levels for each of the DBOW wells are shown in Table 2. The wells were pumped until dry (approximately one casing volume) on several occasions from December 2016 through April, 2017 in an attempt to continue well development. The results of continued conductivity and pH measurements of the extracted water

revealed that the values were slowly dropping but were still elevated and had yet to stabilize several months after well completion.

Two wells (DBOW 3 and DBOW 6) were evacuated and water levels were measured during the recovery cycle for each well. The maximum recovery rate calculated was 0.08 gpm for DBOW 3 and 0.28 gpm for DBOW6; both wells took more than 1 week to return to initial water level.

The extremely low well recovery rates further indicate a formation with very low hydraulic conductivity, which is consistent with previous lab testing. Falling Head Permeameter testing of a core sample from the lower Brule (M-2169c Run 5 sample 1) measured hydraulic conductivity of 1.31×10^{-7} cm/sec. (PTS 2014).

The low recovery rates confirm that the DBOW monitor wells completed in the lower Brule Formation do not produce water in usable, significant or economic quantities and therefore the lower Brule cannot be determined to be an aquifer at the MEA.

Summary

- Geophysical and geologic sample logging and well development results of the DBOW monitor well installation program demonstrate that the lower Brule Formation is not an aquifer and additional testing and characterization is not recommended.
- The first overlying aquifer of the mining zone at the MEA should remain the Brown Siltstone Member of the upper Brule Formation.

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PTS, 2013. PTS Laboratories, Inc., File No. 43570 Physical Properties Data - Marsland Core, 10/10/2013.

PTS, 2014. PTS Laboratories, Inc., File No. 44735 Physical Properties Data - Hydraulic Conductivity, 12/11/2014.

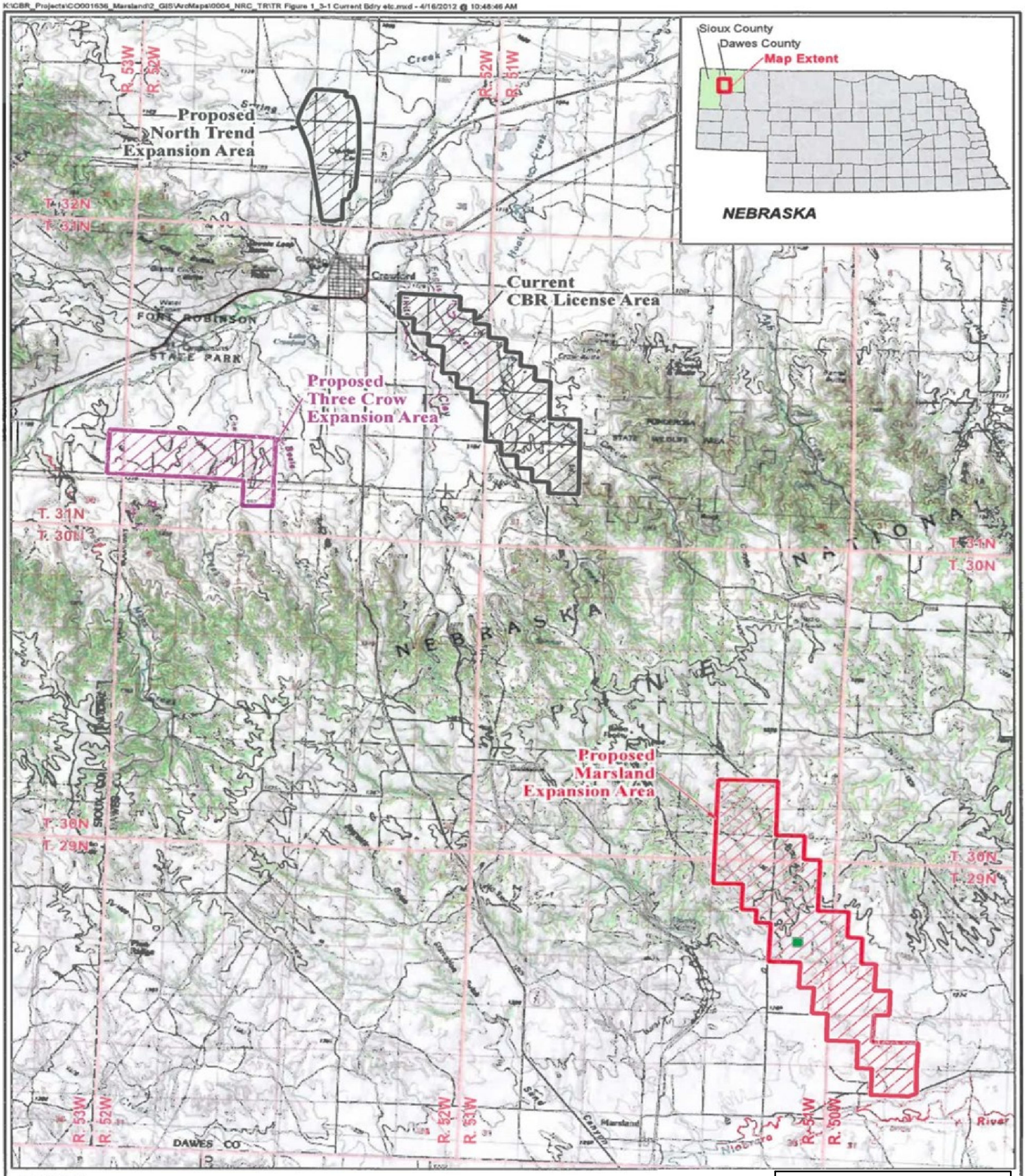
Swinehart James B., Souders Vernon L., Degraw, Harold M., Diffendal Jr., Robert F., 1985. Cenozoic Paleogeography of Western Nebraska in Rocky Mountain SEPM Rocky Mountain Paleogeography Symposium 3, Cenozoic Paleogeography of West-central United States. Denver, Colorado.

Tables

Figures

Attachment A

Deep Brule Well Registration Forms - Nebraska Department of Natural Resources



LEGEND

- Proposed Marsland Satellite Facility Site
- Proposed Marsland Expansion Area
- Proposed Three Crow Expansion Area
- Proposed North Trend Expansion Area
- Current CBR License Area

N

0 1 2

Miles

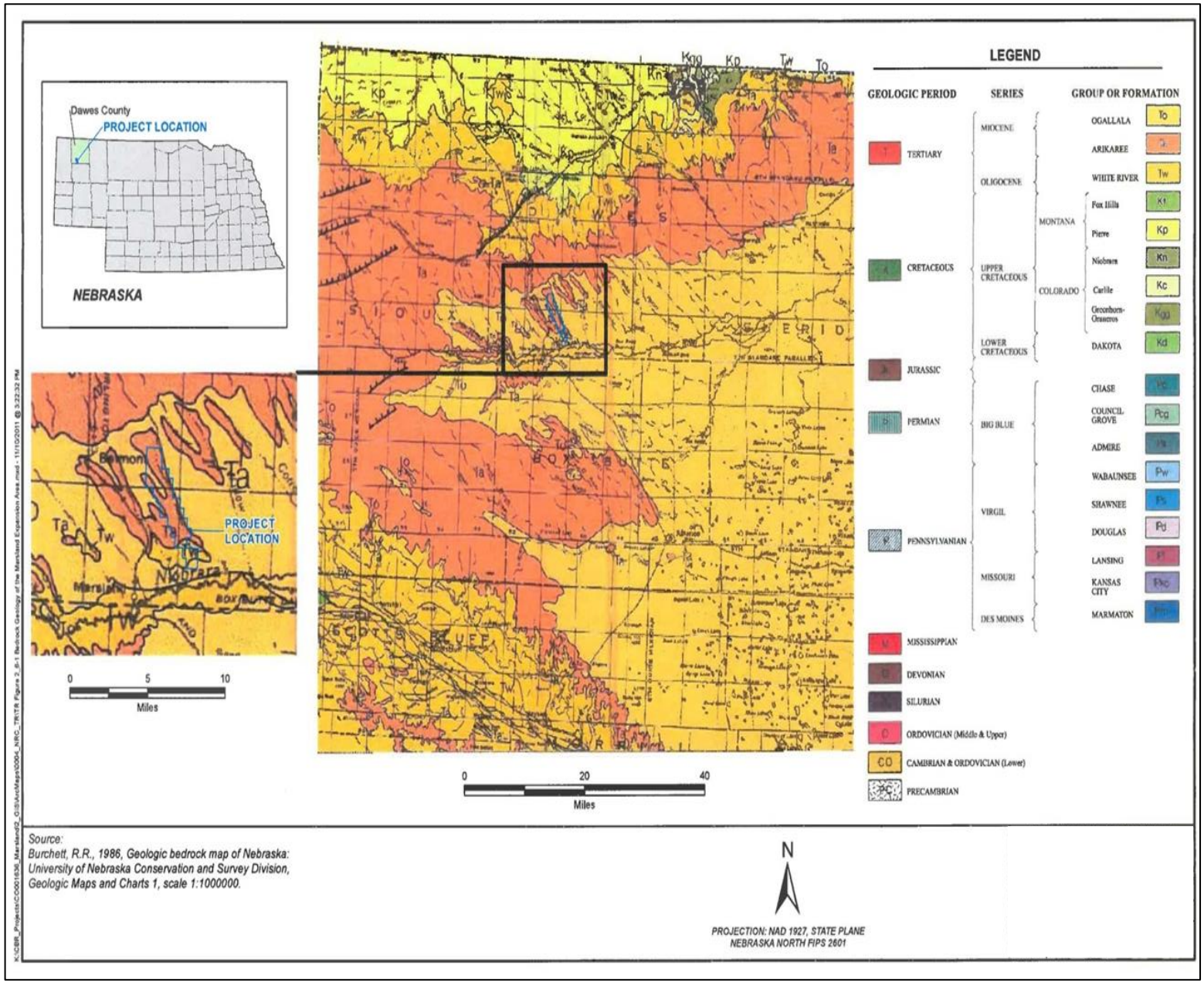
PROJECTION: NAD 1927,
STATE PLANE NEBRASKA NORTH, FIPS 2601
SOURCES: US TOPO MAPS, SERVICED
BY ESRI ARCGIS ONLINE

Crow Butte Resources, Inc

Figure 1
Marsland Expansion Area
Location Map

Scale: See Scale Bar	Date: 12/30/2016

Figure 2 Bedrock Geology and Representative Stratigraphic Section – Marsland Expansion Area



Group	Formation & Member (MEA)	
Arikaree Group		Upper Harrison Beds
		Harrison – Monroe Creek Formation
		Gering Formation
White River Group	Brule Formation	Brown Siltstone Member
		Whitney Member
		Orella Member
	Chadron Formation	Upper Chadron
		Middle Chadron
		basal sandstone of the Chadron Formation
Montana Group	Pierre Shale	

Figure 3 Marsland Expansion Area Stratigraphic Column and Monitor Well Formation Targets

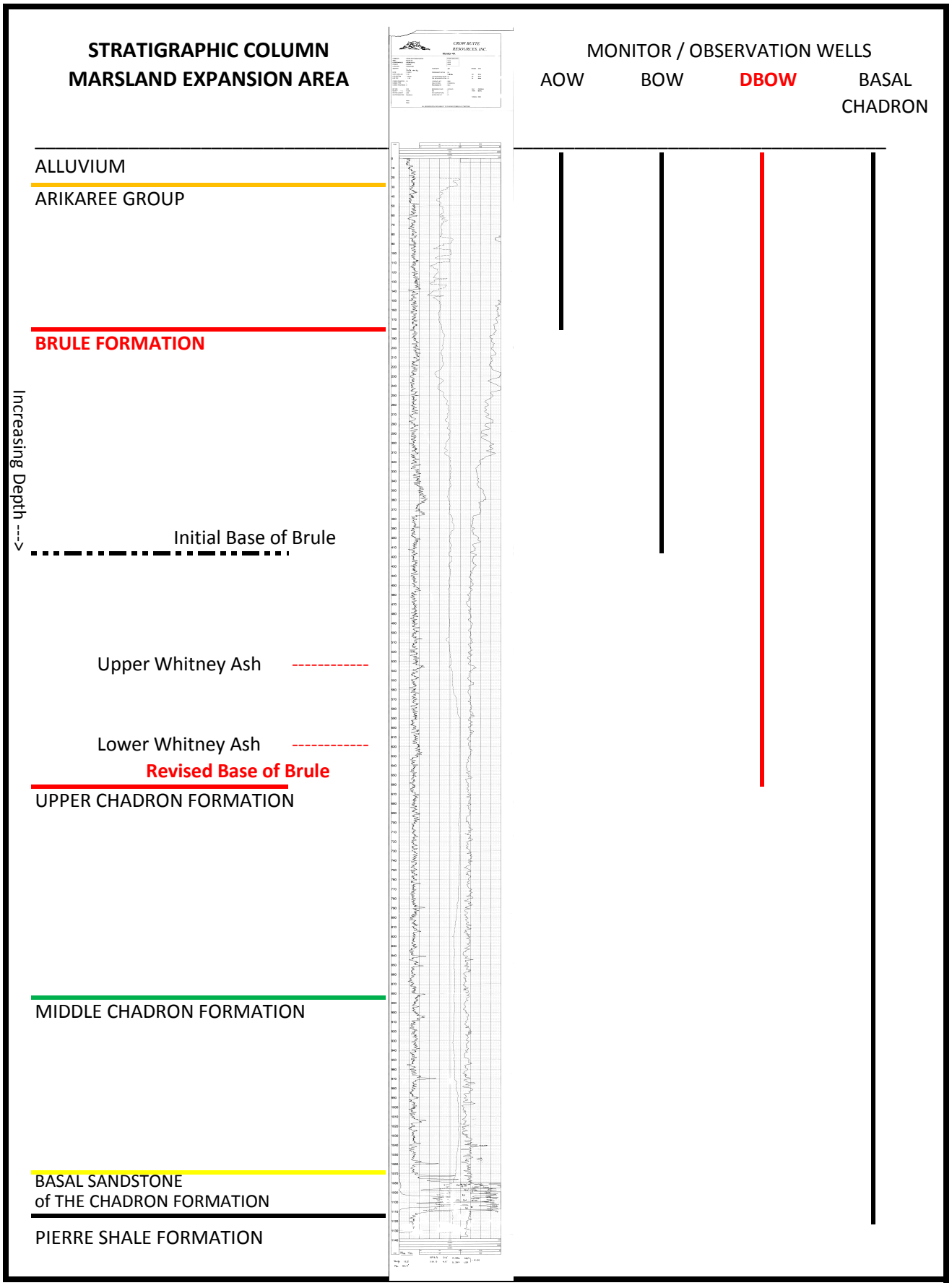


Figure 4
Drill Cuttings Samples: DBOW4 Well

Cuttings Sampled every 5 Feet

Sample Depth

0-100'

100-200'

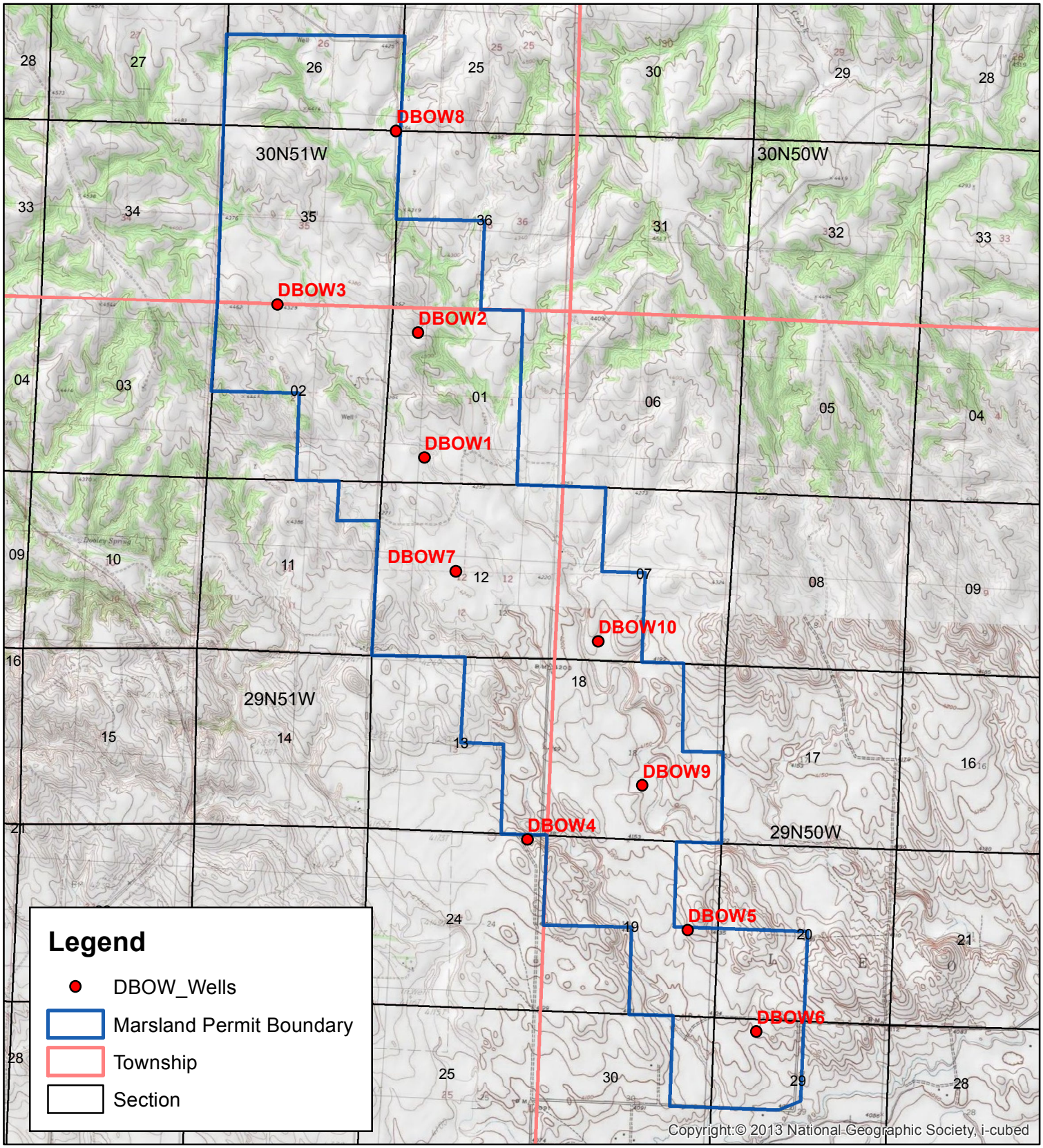
200-300'

300-400'

400-500'

500-520'

510-520'
Green Clay Observed:
Upper Chadron Formation



REVISIONS		
NO.	DATE	BY

Crow Butte Resources, Inc.

Figure 5
Marsland Expansion Area
DBOW Well Locations

N

SIZE:	DATE: 12/30/2016	DEPARTMENT:	COORDINATE SYSTEM: NAD27 State Plane Nebraska North FIPS 2601
GEOL. BY: JS	DATE: XXXX		
ENG. BY: XXXX	DATE: XXXX		
DRAFT BY: XXXX	DATE: XXXX		

DRAWING LOCATION: C:\Users\ca041426\Desktop\DBOW TEMP\X-Sections\Marsland DBOW Monitor wells 2016.mxd

Miles
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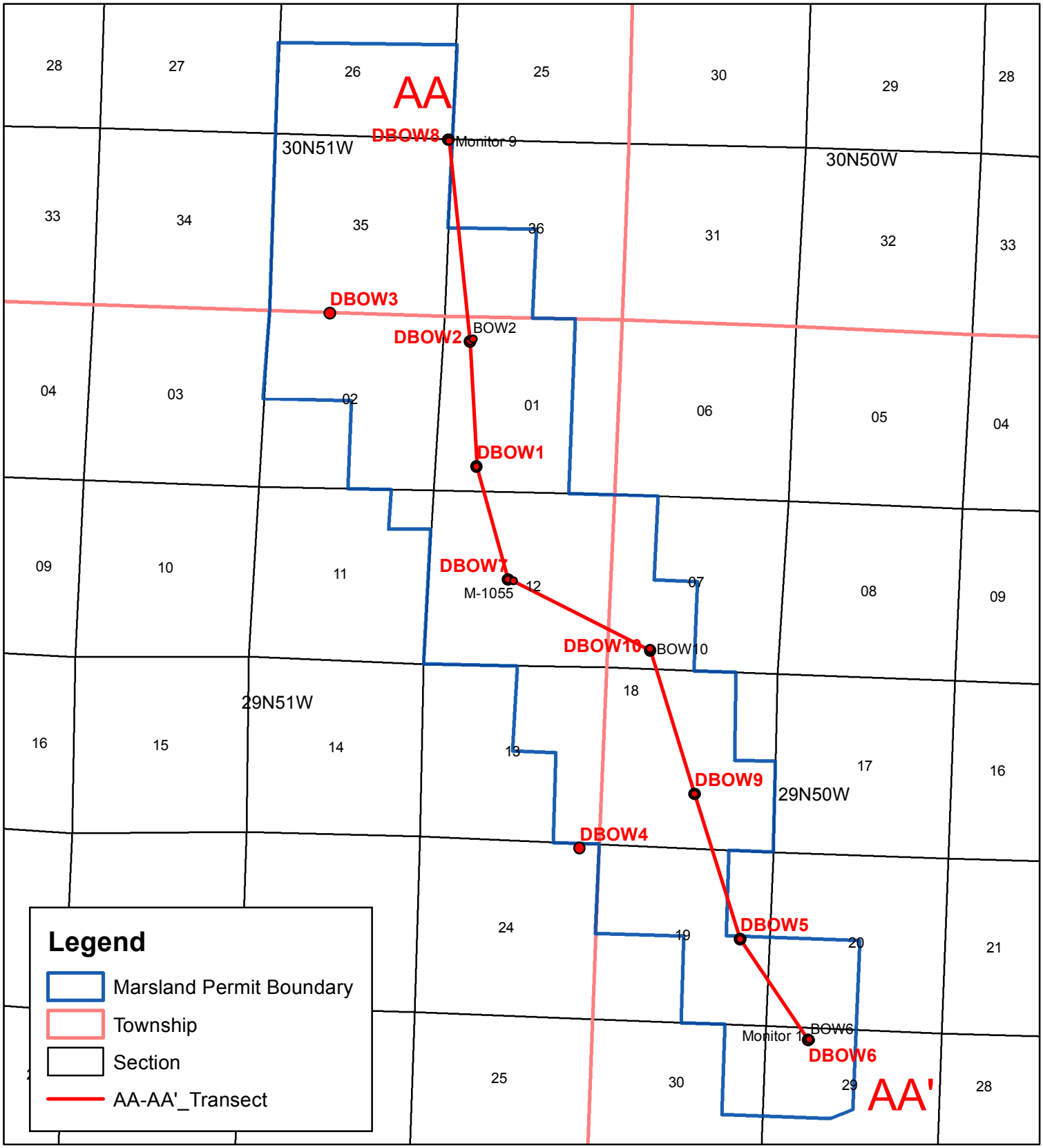

REVISIONS		
NO.	DATE	BY

Crow Butte Resources, Inc.

Figure 6
Marsland Expansion Area
DBOW Well Locations
Cross Section AA-AA'

N

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DATE: 12/30/2016
DEPARTMENT:
COORDINATE SYSTEM: NAD27 State Plane Nebraska North FIPS 2601
REV:

GEOL. BY: XXX DATE: XXX
ENG. BY: XXX DATE: XXX
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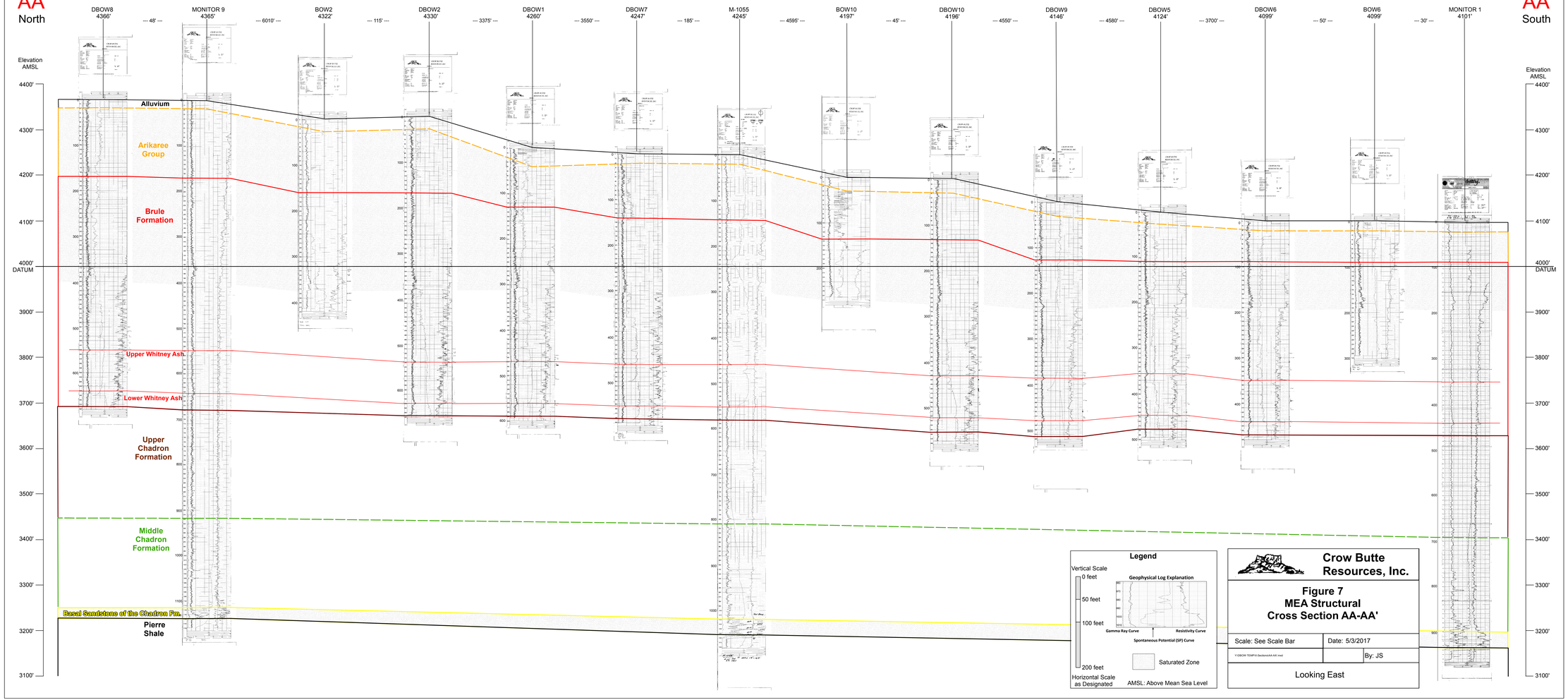

AA
North
AA'
South
DBOW8
4366'
--- 48' ---
MONITOR 9
4365'
--- 6010' ---
BOW2
4322'
--- 115' ---
DBOW2
4330'
--- 3375' ---
DBOW1
4260'
--- 3550' ---
DBOW7
4247'
--- 185' ---
M-1055
4245'
--- 4595' ---
BOW10
4197'
--- 45' ---
DBOW10
4196'
--- 4550' ---
DBOW9
4146'
--- 4580' ---
DBOW5
4124'
--- 3700' ---
DBOW6
4099'
--- 50' ---
BOW6
4099'
--- 30' ---
MONITOR 1
4101'
Elevation
AMSL
4400'
4300'
4200'
4100'
4000'
DATUM
3900'
3800'
3700'
3600'
3500'
3400'
3300'
3200'
3100'
Alluvium
Arikaree
Group
Brule
Formation
Upper Whitney Ash
Lower Whitney Ash
Upper
Chadron
Formation
Middle
Chadron
Formation
Basal Sandstone of the Chadron Fm.
Pierre
Shale
Legend
Vertical Scale
0 feet
50 feet
100 feet
200 feet
Horizontal Scale
as Designated
Geophysical Log Explanation
Gamma Ray Curve
Resistivity Curve
Spontaneous Potential (SP) Curve
Saturated Zone
AMSL: Above Mean Sea Level
Crow Butte
Resources, Inc.
Figure 7
MEA Structural
Cross Section AA-AA'
Scale: See Scale Bar
Date: 5/3/2017
Y:\DBOW TEMP\X-Sections\AA-AA'.mxd
By: JS
Looking East

M-347C | BOW1 | DBOW1 | AOW1 | MONITOR 4A | BOW2 | DBOW2 | MONITOR 8 | BOW3 | DBOW3 | AOW3

Depth Feet

0 Alluvium

Arikaree Group

100

Brule Fm.

200

300

400

Upper Whitney Ash

500

Lower Whitney Ash

600

Upper Chadron Fm.

700

800

Middle Chadron Fm.

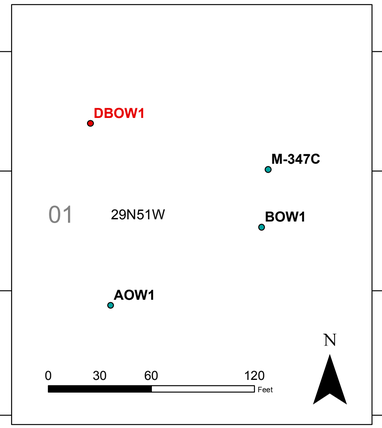
900

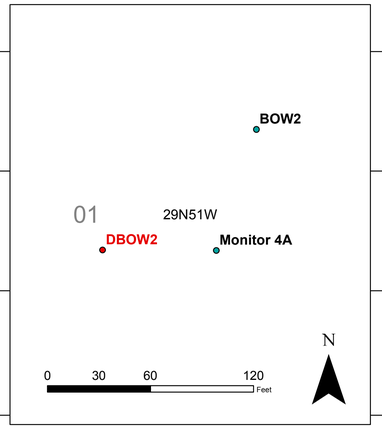
1000

Basal SS of the Chadron Fm.

1100

Pierre Shale





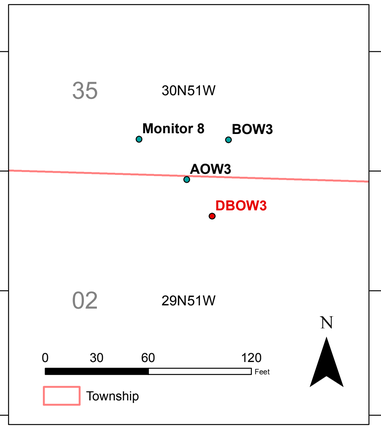


Figure 8 Well Log Comparison Diagrams DBOW1 - DBOW3

MONITOR 10 | BOW4A | DBOW4 | AOW4

MONITOR 11 | BOW5 | DBOW5 | AOW5

MONITOR 1 | BOW6 | DBOW6 | AOW6

Depth Feet

0
100
200
300
400
500
600
700
800
900
1000
1100

Alluvium

Arikaree Group

Brule Fm.

Upper Whitney Ash

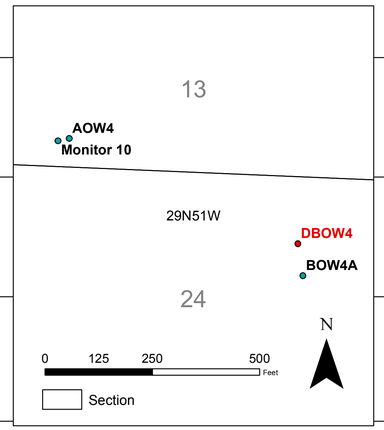
Lower Whitney Ash

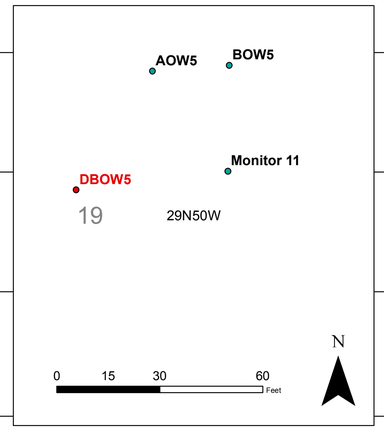
Upper Chadron Fm.

Middle Chadron Fm.

Basal SS of the Chadron Fm.

Pierre Shale





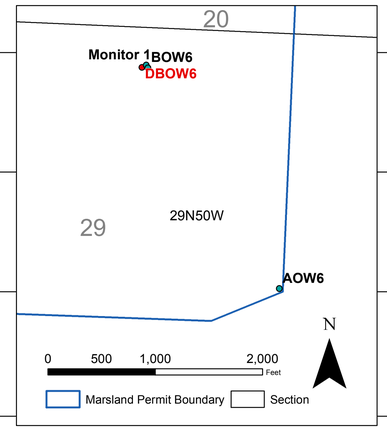


Figure 9 Well Log Comparison Diagrams DBOW4 - DBOW6

M-1055 | BOW7 | DBOW7 | AOW7 | MONITOR 9 | BOW8 | DBOW8 | AOW8 | M-888 | BOW9 | DBOW9 | AOW9

Depth Feet

0 Alluvium

Arikaree Group

100

Brule Fm.

200

300

400

Upper Whitney Ash

500

Lower Whitney Ash

600

Upper Chadron Fm.

700

800

Middle Chadron Fm.

900

1000

Basal SS of the Chadron Fm.

1100

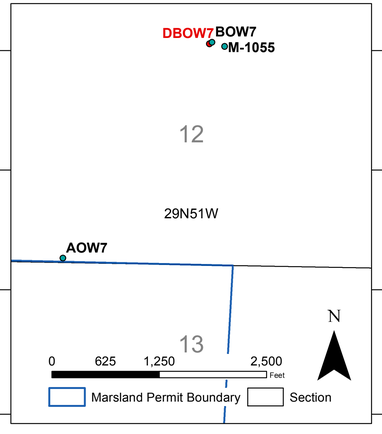
Pierre Shale

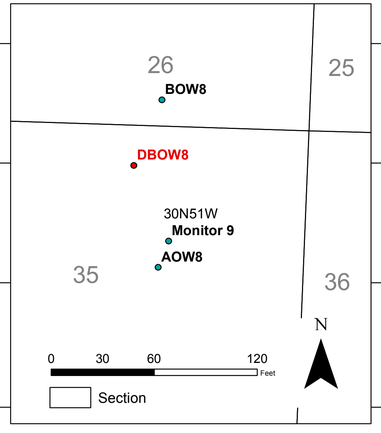
Upper Whitney Ash

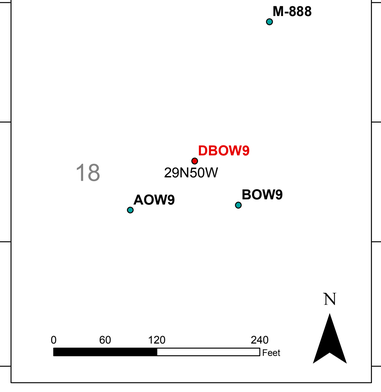
Lower Whitney Ash

Upper Whitney Ash

Lower Whitney Ash







Depth Feet

0

100

200

300

400

500

600

700

800

900

1000

1100

Figure 10 Well Log Comparison Diagrams DBOW7 - DBOW9

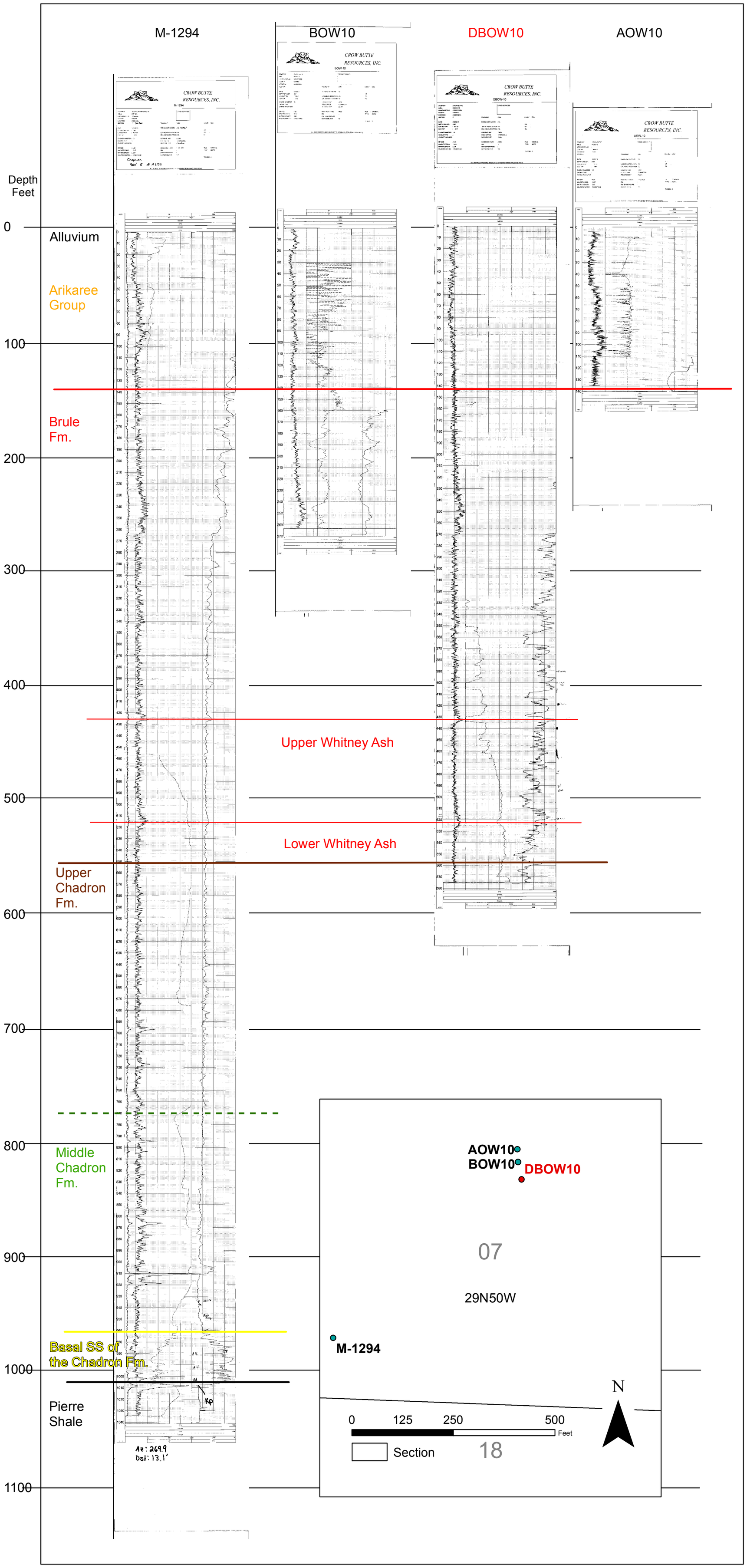


Figure 11 Well Log Comparison Diagram DBOW10

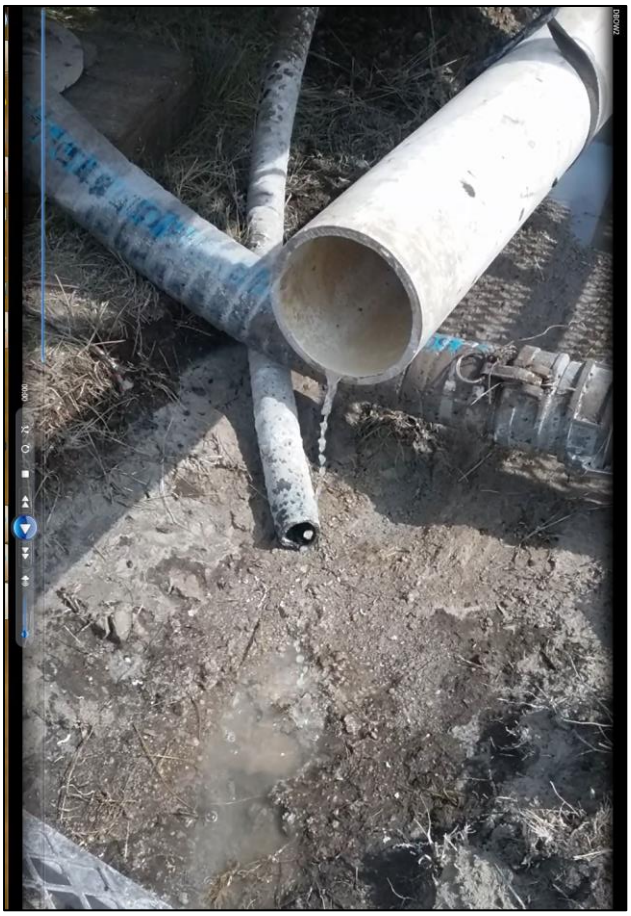


Figure 12 DBOW2 Airlifting @ <0.2 GPM

Figure 13 DBOW3 Airlifting @ <0.2 GPM

Figure 14 DBOW8 Airlifting @ <0.1 GPM

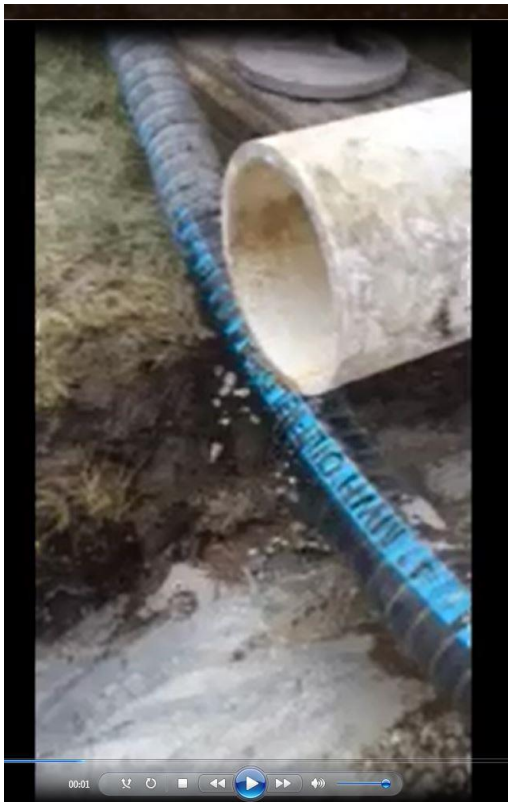


Figure 15 DBOW10 Airlifting @ <0.1 GPM

Table 1

Deep Brule Observation / Monitor Well Summary

Marsland Expansion Area

Dawes County, Nebraska

Well ID	Easting*	Northing	Elevation GL	TOC Height	TOC Elevation	Qtr-Qtr	Section	Township (N)	Range (W)	Formation	Date Completed	Casing Depth	K-Packer Depth	Top of Screen	Bottom of Screen	Top of Screen	Bottom of Screen	Top of Screen	Bottom of Screen
DBOW1	1,121,472	446,312	4259.7	0.7	4260.4	SWSW	1	29	51	Lower Brule	8/24/2016	459	455	465	505	555	565		
DBOW2	1,121,278	450,084	4330.3	0.6	4330.9	NWNW	1	29	51	Lower Brule	8/25/2016	519	510	530	550	620	630		
DBOW3	1,117,047	450,929	4350.3	0.7	4351.0	NENW	2	29	51	Lower Brule	9/1/2016	499	490	500	520	530	570	610	630
DBOW4	1,124,577	434,792	4161.0	0.7	4161.7	NENE	24	29	51	Lower Brule	9/9/2016	379	370	380	440	450	490		
DBOW5	1,129,422	432,057	4123.7	0.9	4124.6	NESE	19	29	50	Lower Brule	9/15/2016	319	315	325	385	435	460		
DBOW6	1,131,480	429,004	4098.8	0.9	4099.7	NENW	29	29	50	Lower Brule	9/14/2016	299	290	300	350	380	400	430	450
DBOW7	1,122,420	442,889	4246.9	0.6	4247.5	NESW	12	29	51	Lower Brule	8/19/2016	479	470	480	500	510	540	550	580
DBOW8	1,120,622	456,167	4365.6	0.5	4366.1	NENE	35	30	51	Lower Brule	8/30/2016	509	501	511	531	541	561	581	601
DBOW9	1,128,050	436,427	4146.1	0.6	4146.7	NWSE	18	29	50	Lower Brule	9/13/2016	379	375	385	405	455	480		
DBOW10	1,126,717	440,765	4195.9	0.6	4196.5	SWSW	7	29	50	Lower Brule	9/12/2016	399	390	400	480	510	530		

* NAD27 State Plane Nebraska North FIPS 2601

Elevations and surface coordinates are measured in feet.

TOC: Top of Casing

Table 2

Deep Brule Observation / Monitor Well Water Levels

Marsland Expansion Area

Dawes County, Nebraska

Well ID	Elevation GL	Date	Water Level	Water Level Elevation
DBOW1	4259.7	12/8/2016	120.5	4139.3
DBOW2	4330.3	12/8/2016	156.7	4173.7
DBOW3	4350.3	12/7/2016	136.6	4213.8
DBOW4	4161.0	12/8/2016	91.6	4069.4
DBOW5	4123.7	12/8/2016	69.6	4054.1
DBOW6	4098.8	12/8/2016	46.0	4052.8
DBOW7	4246.9	12/8/2016	151.9	4095.0
DBOW8	4365.6	12/7/2016	72.1	4293.5
DBOW9	4146.1	12/6/2016	70.8	4075.3
DBOW10	4195.9	12/6/2016	111.9	4084.1

Levels are measured in feet.