BEFORE THE OIL AND GAS CONSERVATION COMMISSION

OF THE STATE OF WYOMING

RECEIVED

AUG 14 2020

WYOMING OIL & GAS CONSERVATION COMMISSION

IN THE MATTER OF THE APPLICATION OF AETHON ENERGY OPERATING LLC FOR AN ORDER FROM THE WYOMING OIL AND GAS CONSERVATION COMMISSION UNDER CHAPTER 4, SECTION 5 AND SECTION 12 OF THE RULES AND REGULATIONS OF THE UNDERGROUND INJECTION CONTROL PROGRAM AND AQUIFER EXEMPTION REGULATIONS TO APPROVE THE DISPOSAL OF WATER INTO THE AMSDEN AND MADISON FORMATIONS FROM THE MARLIN 29-21WDW WELL (API NO. 49-013-23374) AND TO TAKE WHATEVER OTHER ACTION WHICH IS DEEMED APPROPRIATE, *FREMONT COUNTY, WYOMING.*	)	DOCKET NO. 1711-2020

APPLICATION

COMES NOW, the Applicant, Aethon Energy Operating LLC (Aethon), 12377 Merit Drive, Suite 1200, Dallas, TX 75251, by and through its attorneys, S. Thomas Throne, Jacob T. Haseman, and Alexis A. Townsley, Throne Law Office, P.C., and respectfully presents this Application to the Wyoming Oil and Gas Conservation Commission (Commission) for approval of an injection program pursuant to Chapter 4, Section 5 and Section 12 of the Rules and Regulations of the Commission. In support of its Application, Aethon alleges as follows:

1. The Marlin 29-21WDW well (API No. 49-013-23374) located in the NENW of Section 29, Township 35 North, Range 90 West, 6th P.M., is currently shut-in disposal well approved for the Tensleep Formation.

2. Attached to this Application as Exhibit "A" is a report prepared by Bonnie S. Percy, a registered professional engineer in Wyoming and Lynette D. W. George, a registered professional geologist in Wyoming. The report contains all the information to support this Application, both as to the request for underground disposal of water under Chapter 4, Section 5 and the request for aquifer exemption under Chapter 4, Section 12. The requested aquifer exemption for the Amsden and Madison Formations is a 3-mile radius from the Marlin 29-21WDW well.

3. Throne Law Office, P.C. will send notice to all necessary parties once identified as soon as possible after a notice list becomes available and Throne Law Office, P.C. will furnish an Affidavit of Mailing showing that all necessary parties were mailed a copy of this Application. Aethon is requesting an enlarged three (3) mile exemption so notice will be sent to necessary parties within three and one quarter (3¼) miles of the Marlin 29-21WDW well.

WHEREFORE, Applicant requests that the Commission find as follows:

A. That proper notice of the filing of this Application and the time and place of hearing was given pursuant to Chapter 4, Section 5 and Section 12 of the Commission.

B. That the requirements of Chapter 4, Section 5 and Section 12 have been satisfied.

C. That the Amsden and Madison Formations through the Marlin 29-21WDW well located in the NENW of Section 29, Township 35 North, Range 90 West, 6th P.M. produces at a depth or location which makes recovery of fresh and potable water economically or technologically impractical. The Amsden and Madison Formations are very deep, and the well is located large distances from population centers. In addition to depth and distance, the water produced from the Madison Formation contains Benzene at concentrations that exceed the EPA established maximum contaminant levels (MCLs) for drinking water, and thus, economically or technologically impractical to render the water fit for use as fresh and potable water.

D. That the Amsden and Madison Formations underlie the following lands associated with the Marlin 29-21WDW well and the surrounding three (3) mile exemption:

<u>Township 35 North, Range 90 West, 6th P.M.</u>
Sections 7-11, 14-23, 26-35

<u>Township 35 North, Range 91 West, 6th P.M.</u>
Sections 11-14, 23-26, 35-36

<u>Township 34 North, Range 90 West, 6th P.M.</u>
Sections 2-11

<u>Township 34 North, Range 91 West, 6th P.M.</u>
Sections 1-2, 11-12

THEREFORE, based upon the findings of fact, the Commission should enter its order as follows:

I. Approving the disposal of water in the Marlin 29-21WDW well (API No. 49-013-23374) located in the NENW of Section 29, Township 35 North, Range 90 West, 6th P.M. for purposes of produced water disposal in the Amsden and Madison Formations.

II. Granting such other relief as may be just and proper after a hearing on the matter has been held in accordance with the statutes of Wyoming.

DATED this 13th day of August 2020.

AETHON ENERGY OPERATING LLC

By: ______________________________
S. Thomas Throne, WY #5-1602
Jacob T. Haseman, WY #6-4238
Alexis A. Townsley, WY #7-4973
Throne Law Office, P.C.
P.O. Drawer 6590
Sheridan, WY 82801
(307) 672-5858

Attorneys for
Aethon Energy Operating LLC

VERIFICATION

STATE OF WYOMING)
) ss.
COUNTY OF SHERIDAN)

I, S. Thomas Throne, being of lawful age, and being first duly sworn upon his oath, states and declares:

That he is the attorney for Aethon Energy Operating LLC, Applicant herein; that he has read the above and foregoing Application by him subscribed, knows the contents thereof, and that the allegations and matters therein state are true and correct as he verily believes.

____
S. Thomas Throne

Subscribed and sworn to before me this 13th day of August 2020 by S. Thomas Throne.

MICHELLE LAWSON - NOTARY PUBLIC
County of Sheridan
State of Wyoming
My Commission Expires July 27, 2024

____
Notary Public

BEFORE THE OIL AND GAS CONSERVATION COMMISSION

OF THE STATE OF WYOMING

IN THE MATTER OF THE APPLICATION OF AETHON ENERGY OPERATING LLC FOR AN ORDER FROM THE WYOMING OIL AND GAS CONSERVATION COMMISSION UNDER CHAPTER 4, SECTION 5 AND SECTION 12 OF THE RULES AND REGULATIONS OF THE UNDERGROUND INJECTION CONTROL PROGRAM AND AQUIFER EXEMPTION REGULATIONS TO APPROVE THE DISPOSAL OF WATER INTO THE AMSDEN AND MADISON FORMATIONS FROM THE MARLIN 29-21WDW WELL (API NO. 49-013-23374) AND TO TAKE WHATEVER OTHER ACTION WHICH IS DEEMED APPROPRIATE, *FREMONT COUNTY, WYOMING.*	)))))))))))))	DOCKET NO.

AFFIDAVIT OF MAILING

STATE OF WYOMING)
)ss.
CITY AND COUNTY OF SHERIDAN)

I, S. Thomas Throne, of lawful age, and being first duly sworn upon her oath, hereby state and declare:

On August 13 17, 2020, I caused to be mailed by certified postage prepaid, return receipt requested, a copy of the above captioned Application to the following interest holders:

Aethon United BR LP
12377 Merit Drive, Suite 1200
Dallas, TX 75251

Albert J Herbst and Deborah A. Herbst
PO Box 3
Lysite, WY 82642

Albert J Herbst and Deborah Ann Herbst
PO Box 3
Lysite, WY 82642

Benjamin Cilensek
412 North Main St, Suite 100
Buffalo, WY 82834

Bureau of Land Management
5353 Yellowstone Road
Cheyenne, WY 82009

Constance M. Horton
817 Cheryl Sue Drive
Riverton, WY 82501

EOG A Resources, Inc.
PO Box 4362
Houston, TX 77210

Key Ranches, LLC
19566 North Highway 59
Garrison, TX 75946

Kirkwood Oil & Gas LLC
PO Box 2850
Casper, WY 82602

Michael and Katherine Ruby
20 Ocean Lane Road
Riverton, WY 82501

Oxy Y-1 Company
PO Box 27570
Houston, TX 77227

PEO Wyoming, LLC
16400 Dallas Parkway, Suite 400
Dallas, TX 75248

State of Wyoming
Herschler Building
122 W. 25th Street
Cheyenne, WY 82002

XTO Energy Inc.
22777 Springwoods Village Parkway
Spring, TX 77389

Ramona M. Thompson Survivor Trust
dated 1/14/2014
Mary Margaret Miles, James Noah Miles and
Charles S. Miles
220 Hudson Avenue
Alliance, NE 69301

Thoren Enterprises, LP
1145 Arapahoe Street
Thermopolis, WY 82443

Return receipts are maintained at Throne Law Office, P.C.

S. Thomas Throne

Subscribed and sworn to before me on this 13th day of August 2020.

MICHELLE LAWSON - NOTARY PUBLIC
County of Sheridan
State of Wyoming
My Commission Expires July 27, 2024

Michelle Lawson
Notary Public

AETHON ENERGY OPERATING LLC

Amended Application for Aquifer Exemption and Underground Disposal of Water in Accordance with the Wyoming Oil & Gas Conservation Commission Rules & Regulations Chapter 4, Sections 5 and 12

Applicant:	**Aethon Energy Operating LLC** **12377 Merit Drive, Suite 1200** **Dallas, TX 75251** **Contact: Tom Nelson** **Phone: 214-750-4321**
Subject Well Location:	**Marlin No 29-21 WDW API # 49-013-23374** **SHL: NE NW 660' FNL 1977' FWL; Section 29 T35N R90W** **BHL: NE NW 1328' FNL 1779' FWL; Section 29 T35N R90W** **Fremont County, Wyoming**
Formation:	**Madison and Amsden**

Application Contributors:

Bonnie Percy, PE 6360, GGA Inc., Casper, WY 307-265-9199
Lynette George, PG 1004, Casper, WY 307-265-6338
Josh Talbert, Sr Geological Advisor, Aethon Energy Operating LLC
Andrea Taylor, HSE Manager, Aethon Energy Operating LLC

Professional Engineer (Chemical)
BONNIE S. PERCY
6360
Date 8/12/2020
WYOMING

PROFESSIONAL GEOLOGIST
LYNETTE D.W. GEORGE
PG-1004
8-13-2020
WYOMING

TABLE OF CONTENTS

Amended Application for Aquifer Exemption and Underground Disposal of Water in Accordance with the Wyoming Oil & Gas Conservation Commission Rules & Regulations Chapter 4 Sections 5 and 12

Marlin 29-21 WDW API # 49-013-23374
SHL: NE NW 660' FNL 1977' FWL; Section 29 T35N R90W
BHL: NE NW 1328' FNL 1779' FWL; Section 29 T35N R90W
Fremont County, Wyoming

INTRODUCTION AND PROJECT DESCRIPTION

This application is being amended to add the Amsden so that both the Madison and the Amsden are proposed as receiving formations.

Aethon desires to increase their disposal capacity for oil and gas associated produced water from wells in the Wind River Basin in Fremont and Natrona County, Wyoming. In Docket 438-2011, Encana received authorization for disposal into the Nugget, Tensleep and Madison Formations into the proposed Marlin 29-21 with the stipulation that those formations exhibit a TDS in excess of 5000 mg/l in water samples to be collected after the well was drilled.

Encana drilled the Marlin 29-21 as a new WDW; it reached TD in May 2012. A map of the well location is shown in Attachment R-1. The Nugget was not prospective as a disposal interval; Encana perforated both the Tensleep and the Madison. The Tensleep TDS is 6900 mg/l; a step rate test and injectivity test was conducted on the Tensleep, but disposal capacity was not at the desired volume. The Tensleep was fracture stimulated and injection rates increased but remain below the desired disposal capacity. The order for Docket 3-2013 dated June 11, 2013 reaffirmed the aquifer exemption for the Nugget and Tensleep formations. The well is currently shut-in with the Madison perforations squeezed under a cement retainer and the Tensleep perforations open.

Water analysis of the Madison obtained from samples collected after the Marlin 29-21 was drilled indicates that Madison water quality ranges from 910 to 1200 mg/l TDS. With this low TDS, the criteria to obtain an aquifer exemption becomes more complex requiring analysis of the economic suitability and use of the Madison waters. Aethon purchased the Encana properties in the area in April 2015. Aethon continued to pursue use of the Madison as a disposal formation. The application in WOGCC Docket 3-2013 resulted in multiple hearings from 2013 to 2015 which primarily addressed the Madison disposal interval. Initially the commission ruled to approve the Madison Aquifer Exemption but held the record open to allow WDEQ and EPA further time for review and Encana further time for additional geologic and hydrologic analysis. Additional analysis provided to the WOGCC in 2015 included a regional groundwater flow and transport model study prepared by Tetra Tech which was calibrated against step rate test data and utilized to predict injectate plume migration. Tetra Tech also conducted age dating of the Madison Water from the Marlin 29-21. Ultimately, after input from the WDEQ and EPA, the commission ruled in the November 2015 hearing to deny the Madison Aquifer Exemption. The orders indicate that the commission concerns were related to migration of the injected fluids to shallower depths and the influence of structure.

Aethon has conducted additional geologic and hydrologic analysis in support of using the Madison and Amsden as a water disposal interval. The groundwater flow and transport model study prepared by Tetra Tech was expanded to include the Darwin Sandstone member of the Amsden as a separate model layer. The Marlin 29-21 Reservoir Saturation Sigma Log was reprocessed to provide more accurate porosity values for the Amsden and Madison lithologies. 2D Seismic data was acquired and utilized to refine local structure mapping. The Amsden is being added as a receiving zone for operational efficiency, as the lower member (Darwin Sandstone) is porous and immediately overlies the Madison. The following application is for an Aquifer Exemption and Authorization to Dispose under WOGCC Rules and Regulations Chapter 4, Section 12 and 5 for the Madison and Amsden Formation in the Marlin 29-21 WDW operated by Aethon.

Source wells will be Aethon operated wells in the project vicinity that produce primarily from the Lower Fort Union and Lance. The requested area of the aquifer exemption has been enlarged to 3 miles due to anticipated high injection rates and the long life of the disposal well.

APPLICATION FOR AQUIFER EXEMPTION

Chapter 4, Section 12(a)

An aquifer which contains fresh and potable water may be exempt from the definition in Chapter 1, Section 2 (a), if the Commission by order, after due and legal notice and public hearing, determines any of the following criteria exists:

(i) The Aquifer Is Mineral, Hydrocarbon, Or Geothermal Energy Producing.

The Marlin 29-21 WDW was drilled for disposal purposes and has not produced hydrocarbons on an economic basis. However, the water analysis from three samples from the Madison do contain hydrocarbons (See Attachment R-2 and Appendix A). Among other parameters, Benzene is present at concentrations of 18 to 110 ug/l; these are in excess of the MCL for drinking water of 5 ug/l of Benzene. No representative water analysis from the Amsden is available at this time.

(ii) The Aquifer Is Situated At A Depth Or Location Which Makes Recovery Of Fresh And Potable Water Economically Or Technologically Impractical.

The proposed Marlin 29-21WDW is located at a depth or location which makes recovery of fresh and potable water economically or technologically impractical. A detailed analysis of the "Economic Practicality of Potable Water Use – Amsden and Madison Formations" is contained in Appendix B. This analysis discusses water use for the nearby population centers: Shoshoni, Riverton, Thermopolis and Casper. It concludes that these population centers are unlikely to utilize the Madison or Amsden at the subject site for water supply.

(iii) The Aquifer Is So Contaminated That It Would Be Economically Or Technologically Impractical To Render The Water Fit For Use As Fresh And Potable Water.

The formation water in the Madison is not contaminated in that it has not been impacted by man-made chemicals or activities. It does contain non-anthropogenic hydrocarbons as discussed in Chapter 4, Section 12(a)(i) above.

(iv) The Aquifer Is Located Over A Mining Area Subject To Subsidence Or Catastrophic Collapse.

Not applicable. The proposed location is not in a mining or subsidence area.

(v) The Aquifer Has A Total Dissolved Solids (TDS) Concentration Of More Than Five Thousand Milligrams Per Liter (5,000 mg/L) And Less Than Ten Thousand Milligrams Per Liter (10,000 mg/L) And Is Not Reasonably Expected To Be Used As Fresh Or Potable Water.

Analysis of formation water from the three samples from the Madison collected from the Marlin 29-21 exhibit a TDS ranging from 910 to 1200 mg/l. The laboratory report is included as Attachment R-2.

Amsden water quality information is sparse and distant; Aethon is planning to perforate the Amsden and collect a swabbed water sample for analysis. The initial perforations will be in the upper portion of the Amsden at depths of approximately 14,860 to 14,875 ft. This upper portion of the Amsden is tight. It serves as a confining unit between the Tensleep and the Darwin Member. Even if there is enough fluid entry to obtain a water sample, there will unlikely be enough fluid entry to purge three tubing volumes. Documentation of sampling efforts and results of water analyses, if a sample can be collected, will be provided to the WOGCC as it becomes available. It is anticipated that the Amsden will either 1) swab dry in which case the formation is not classified as a USDW or 2) the water yield from the Amsden will be too low for use as a public water supply. In the latter case, "Appendix B - Economic Practicality of Potable Water Use" will be supplemented to include details supporting this conclusion. Due to lithologic similarities, the Amsden water quality is anticipated to be more similar to the Tensleep TDS of 6900 mg/l.

A second set of perforations in the Amsden within the Darwin Sandstone Member at 14,975 to 14,995 ft may be tested. This porous sand sits directly on top of the Madison Limestone. Since the Madison and Darwin perforations were step rate tested together, these intervals are most likely in communication, or at the least, were in communication during the step rate test. Further, there was no flowback after the test was conducted, so any water sample collected at this point in time may not be representative of the formation. If required by the WOGCC, Aethon will collect and analyze the Darwin water sample.

Chapter 4, Section 12(b)

Interested Parties Wishing To Have An Aquifer Exempted Must Submit To The Commission An Application Which Includes Sufficient Data To Justify The Proposal. At A Minimum A Structure Or Isopach Map, Geologic Description, And Legal Description Of The Area To Be Exempted Needs To Be Filed. The Commission Will Provide Thirty (30) Days Legal Notice Prior To A Public Hearing On The Matter.

GEOLOGIC DESCRIPTION

See Attachment G-1 through G-11.

LEGAL DESCRIPTION OF THE AREA TO BE EXEMPTED

The requested aquifer exemption area is a 3 mile radius from the BHL of the proposed Marlin 29-21 WDW located at:

SHL: NE NW 660' FNL 1977' FWL; Section 29 T35N R90W
BHL: NE NW 1328' FNL 1779' FWL; Section 29 T35N R90W
Fremont County, Wyoming

Justification for a 3-mile aquifer exemption is further discussed in the section for Chapter 4, Section 5 (c) (vi) below.

APPLICATION FOR AUTHORIZATION TO DISPOSE
Chapter 4, Section 5(a)

The underground disposal of <u>fresh water</u> or of salt water, brackish water, or other water unfit for domestic, livestock, irrigation, or other general uses, is permitted only upon order of the <u>Commission</u> or approval of the <u>Supervisor</u>, obtained pursuant to an application therefore filed in accordance with the Rules of Practice and Procedure, as amended herein. Orders authorizing <u>disposal wells</u> shall remain valid unless revoked by the Commission for just cause. In addition, there is assessed a seventy five dollar ($75.00) annual fee on all new and old disposal wells.

A check for the amount of $250.00 is attached as an application fee.

Chapter 4, Section 5(b)

<u>Disposal Well Permits</u>. The applicant shall have the burden of demonstrating that the proposed disposal operation will not endanger fresh water sources. Disposal wells shall be cased and the casing cemented in such a manner that damage will not be caused to oil, gas, or fresh water sources.

<u>Description of the Casing and Cementing of the Disposal Well(s):</u>
As shown on Attachment E-1, the Marlin 29-21WDW well has 9 5/8" 40# N-80 surface casing set at 2,541' cemented to surface, 7" 26# N-80 intermediate casing set at 9666' cemented to surface, and a 5" T-95 and HT liner set from 9475 to 15,405' and cemented to the top of the liner. Cement bond logs are on file with the WOGCC. An injection packer is set at 14,446' though there is no tubing in the well currently. The Madison perforations have been squeezed and are under a cement retainer. The Tensleep perforations are open.

Attachment E-2 shows the proposed completion with the Tensleep, Amsden and Madison commingled as receiving zones. The Tensleep has been previously authorized for injection under Dockets 438-2011 and 3-2013. The packer is within 100' of the top perforation at 14,448 ft. To accomplish this configuration, Aethon will pull the existing packer, drill out the cement plug and cement retainer to the PBTD of approximately 15,355 ft, perforate the Amsden and/or Darwin Sandstone and re-perforate the Madison from 15,011 to 15,312 ft. The procedure to isolate the Amsden interval(s) to collect water samples for analysis are detailed in Attachment E-5. Since water samples were previously collected and step rate tests have been conducted on both the Tensleep and the Madison, there is no need to isolate the Madison or Tensleep. The well will then be rigged for injection with a packer set within 100 ft of the top perforation.

<u>Proposed Method for Testing the Casing Before Use of the Disposal Well:</u>
Mechanical integrity of the tubing-casing annulus will be verified by pressure testing to 1000 psi for 30 minutes. The Commission staff will be notified in advance of the test. The CBL, injection temperature survey and mechanical integrity test should provide definitive information to show that injection fluid will not enter oil, gas or fresh water sources.

Chapter 4, Section 5 (c) (i)

Applicant shall include a plat showing the location of the disposal well or wells, including abandoned and drilling wells and dry holes, and the names of all lease Operators or Owners and surface owners within a one-half (1/2) mile radius from the proposed disposal well or wells.

Attachment R-1 is a map showing the location of the proposed disposal well and other oil and gas wells in the area, including a designation for a three (3) mile and a 3.25 mile radius around the well. The names of all mineral owners, surface owners, and working interest owners within a 3.25 mile radius from the proposed injection wells are listed in Appendix C.

Chapter 4, Section 5 (c) (ii)

Applicant shall include an affidavit showing that said lease Operators or Owners and surface owners within a one-half (1/2) mile radius have been provided a copy of the application for disposal.

An affidavit of mailing stating that all surface owners, working interest owners, and royalty interest owners listed in Appendix C have been mailed a notice of this application will be supplied by the filing attorney.

Chapter 4, Section 5 (c) (iii)

Applicant shall include the names, description, and depth of the formation into which water is to be injected, including a mechanical log of the proposed disposal well or wells if one is available.

Name of the Formation Into Which Water is to be Injected – Amsden Formation and Madison Limestone.

Description of the Formation Into Which Water is to be Injected - See Chapter 4 Section 12 (a)(b) above and Attachments G-1 through G-11.

Depth of the Formation Into Which Water is to be Injected - The Madison Formation top occurs at a depth of 15,003 ft MD. Anticipated Madison perforations will be from 15,011 to 15,312 ft. The Amsden Formation top occurs at 14,795 ft MD, the Darwin Sandstone Member top occurs at 14,974 ft MD, and the base of the Amsden is the top of the Madison at 15,003 ft.

Log of the Proposed Disposal Well - See Attachment G-3

Chapter 4, Section 5 (c) (iv)

Applicant shall include a description of the casing in the disposal well or wells, or the proposed casing program and the proposed method for testing casing before use of the disposal well or wells.

See the casing and testing description under Chapter 4, Section 5 (b).

Chapter 4, Section 5 (c) (v)

Applicant shall include a statement specifying the source of water to be injected.

Source wells will be Aethon operated wells in the project vicinity that produce primarily from the Lower Fort Union and Lance. A list of the source wells identifying the producing formation is contained in Appendix D. Several existing wells listed in Appendix D do not have water analyses on record with the WOGCC and Aethon is in the process of sampling these wells and will provide analyses to the WOGCC.

Chapter 4, Section 5 (c) (vi)

Applicant shall include the estimated minimum and maximum amount of water to be injected daily.

Madison:
The estimated minimum and maximum daily volumes to be injected into the proposed Marlin 29-21 WDW disposal well are 1,000 and 30,000 barrels per day, respectively. Average injection into the Madison is anticipated to be in the range of 4,500 to 9,900 BWPD, depending on the formation permeability as reported in the simulation by Tetra Tech.

Radius of emplaced fluid calculations are shown for each of the three Tetra Tech permeability cases for the Madison in Attachment E-3. Net Pay and porosity are based on the log analysis using a 2% porosity cutoff. These results are compared to Encana simulation results and Tetra Tech simulation results. The long life (50 years) for the disposal well contributes significantly to the large radius of emplaced fluid that ranges from 0.9 to 1.8 miles. Tetra Tech simulation results for the most likely cases yield similar radii; the radius of salinity increase (~ equivalent to a radius of emplaced fluid) is 0.9 to 1.7 miles. However, some simulation cases exhibit radii of 4.5 miles after 50 years of injection and up to 6.8 miles of migration after 10,000 years of aquifer movement.

Darwin Sandstone:
Average injection rates into the Amsden are anticipated to be low, though the Darwin Sandstone interval may accept fluid at measurable rates. The phiH of the Darwin is approximately 20% of the Madison therefore anticipated injection rates in the Darwin are estimated to be 20% of the Madison rates. Minimum and Maximum rates are 200 and 6,000 BWPD, respectively. Average

injection rate is anticipated to be 900 BWPD. The radius of emplaced fluid for the Darwin is estimated to be 0.8 miles.

A radius of 3.0 miles for an Aquifer Exemption is being requested by Aethon at this time. After a few years of historical injection data have been gathered and provide a basis for a simulation history match; the radius of emplaced fluid may be determined with a higher accuracy and the aquifer exemption may be enlarged at that time if needed.

Chapter 4, Section 5 (c) (vii)

Applicant shall include the average and maximum disposal pressure.

A step rate test has been conducted in the Madison in the Marlin 29-21. Analysis of that data is presented in Attachment E-4 and results in a fracture gradient of 0.644 psi/ft. Using a fracture gradient of 0.644, the top of the Madison proposed perforations, and a 90% safety factor, calculations result in a calculated maximum injection pressure of 2850 psi. (See Attachment E-3) For the Amsden, The Hamilton Dome and Horse Trap Fields document fracture gradients of 0.70 to 0.87 psi/ft. Conservatively using the Madison fracture gradient of 0.644, the top of the Amsden (Darwin) proposed perforations, and a 90% safety factor, calculations result in a calculated maximum injection pressure of 2840 psi which is the requested maximum surface injection pressure. Average injection pressure will be very near the maximum pressure. Additionally, an injectivity test may be conducted to demonstrate that injection will remain in zone at injection pressures higher than the fracture pressure. If perforation and water sampling from the Amsden indicate that it will be a viable disposal interval, then a step rate test will be conducted in the Amsden as well (See Attachment E-5).

The Tensleep is currently authorized with a temporary maximum injection pressure of 3,500 psi.

Chapter 4, Section 5 (c) (viii)

Applicant shall include evidence and data to support a Commission finding that the proposed disposal well will not initiate fractures through the overlying strata or confining zone which could enable the injection fluid or formation fluid to enter the fresh water strata.

- See the step rate test and injectivity test descriptions described under Chapter 4, Section 5 (c) (vii) above. Disposal into the Amsden and Madison will not initiate fractures through the overlying strata because the maximum injection pressure will either be limited to less than 90% of the fracture pressure or injectivity testing will be conducted to show that higher injection pressures do not exceed the fracture pressure of the confining units thus containing injection within the receiving formation.

- The existing cementing program also provides containment of the injected fluids.

- Thick confining units will prevent communication from the receiving zone to shallower intervals. The Tensleep, Darwin and Madison are isolated above and below from aquifers and hydrocarbon producing zones (Attachment G-7). Above the Tensleep Sandstone there are numerous confining units, including the Cody Shale which is over 4,000 feet thick at the Marlin well. Below the Madison, the Galatin Limestone and Gros Ventre Formation are confining units that isolate the Madison from the Flathead Sandstone and Precambrian below. At Madden field the Gallatin is about 300 feet thick and the Gros Ventre is about 450 feet thick. Density logs show these formations to have low porosity and significant amounts of shale (Brown and Shannon, 1989).

The bounding shales and a maximum disposal pressure below the formation fracture pressure will prevent the initiation and propagation of fractures through the overlying strata to any fresh water zones.

Chapter 4, Section 5 (c) (ix)

Applicant shall include standard laboratory analyses of the water to be disposed and the water in the formation into which disposal is taking place. The method of water analysis is subject to review by the Commission or the Supervisor.

See Chapter 4, Section 12(a) (v) above which discusses the analysis of the receiving formation. See Chapter 4, Section 5(c) (v) above which discusses the analysis of the source wells.

Chapter 4, Section 5 (c) (x)

Applicant shall include a reference to the Commission order exempting the aquifer that is to receive the injected fluid.

A concurrent application for a 3-mile radius aquifer exemption is being submitted with this application.

Chapter 4, Section 5 (c) (xi)

The applicant shall provide for a one-quarter (1/4) mile radius of investigation for mechanical conditions of all wells which have penetrated the disposal zone surrounding a proposed disposal well. Specifically known and documented geological features may limit the need to review all wells within a one-quarter (1/4) mile radius.

Attachment R-1 shows six wells within a 3.25-mile radius of the Marlin 29-21. All six wells have been P&A and have depths less than 8957 ft, thus these wells have not penetrated the Nugget, Tensleep, Amsden or Madison formations or their confining units. No further analysis of these wells is necessary.

Chapter 4, Section 5 (c) (xii)

Applicant shall include the depth and areal extent of all usable fresh and potable water (USDW) underlying the area proposed for exemption.

Wyoming State Engineer's Office (SEO) records indicate that groundwater being utilized for domestic or stock purposes in the project vicinity is very sparse; in a 144 mile (4 Township) search area, only 3 domestic water wells were identified and these wells exhibited depths of 138 to 148 feet. There were 44 wells for stock use ranging up to 560 feet in depth (See Attachment R-3).

The Wind River Formation is the bedrock at the surface around the Marlin 29-21 WDW. It consists of a thin series of coarse-grained sandstone and conglomerate at the base overlain by varicolored siltstone and claystone interbedded with white, gray and tan lenticular sandstone. Maximum thickness at surface outcrops is approximately 1,000 feet (Keefer, 1965, page A49). The water wells in this vicinity are in the Wind River Formation.

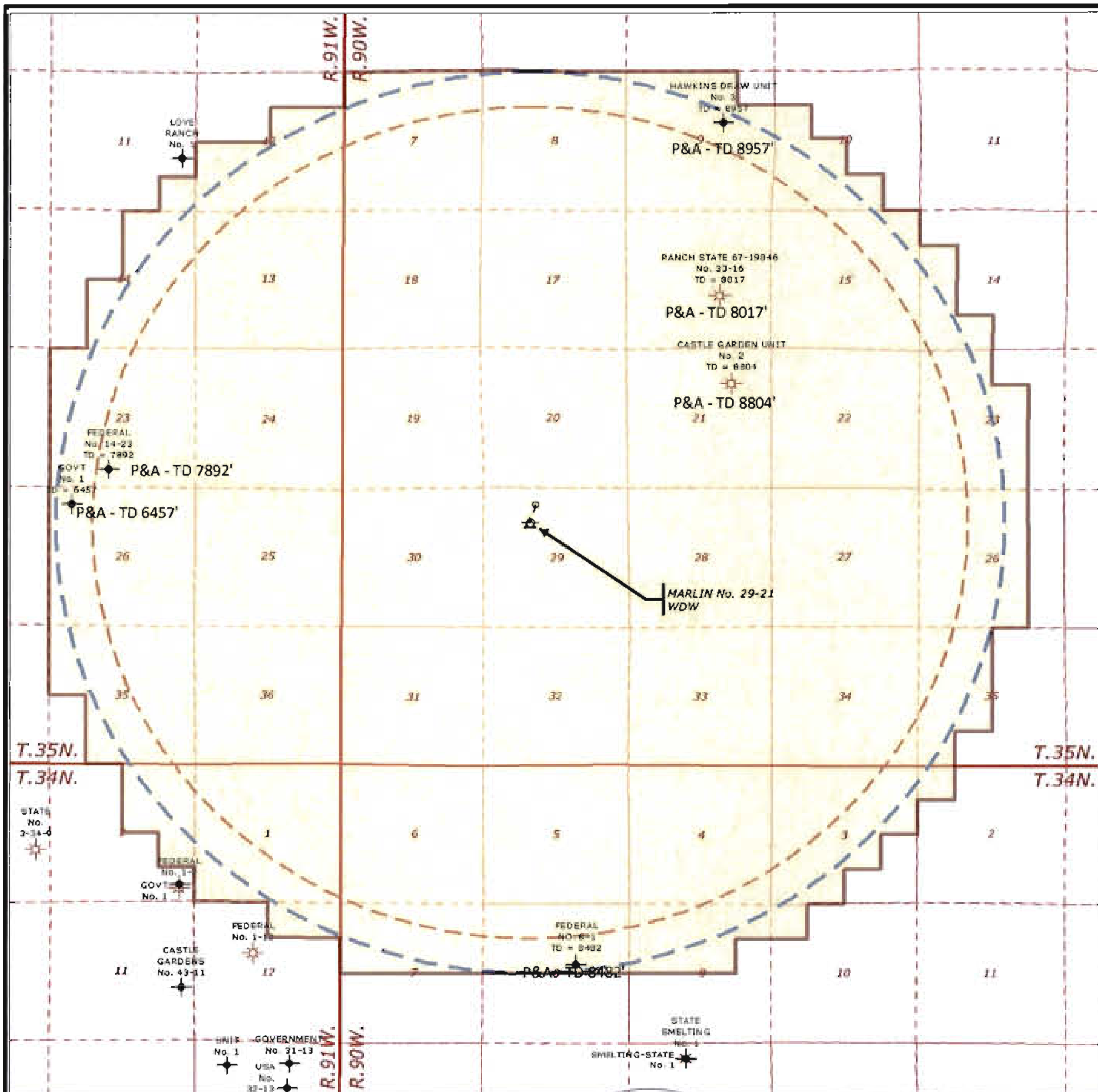
Reference:

Keefer, W. R., 1965, Stratigraphy and geologic history of the uppermost Cretaceous, Paleocene, and Lower Eocene rocks in the Wind River basin, Wyoming, USGS Professional Paper 495-A. 77 p.

Chapter 4, Section 5 (c) (xiii)

An Operator or Owner who files an application for approval of a disposal well which is within a one-half (1/2) mile radius of a well producing from the proposed disposal zone shall give notice of the application to the royalty and overriding royalty interest owners within said radius unless the wells are located within a unit.

There are no wells that produce from the Madison or Amsden within the 3.25-mile radius of the proposed disposal well, thus no ORRI owners were noticed.



LEGEND

- GAS WELL, P&A
- OIL WELL, P&A
- DISPOSAL WELL, SHUT IN
- SURFACE HOLE LOCATION
- 3 MILE RADIUS
- 3.25 MILE RADIUS
- NOTIFIED OWNERS & OPERATORS LOCATED WITHIN ½ MILE OF PROPOSED DISPOSAL WELL

N

5,000 0 5,000 10,000

SCALE: 1"=5000'

Professional Engineer (Chemical)
BONNIE S. PERCY
6360
WYOMING
Date 8/12/2020

ATTACHMENT R-1

AETHON ENERGY
APPLICATION FOR
CLASS II WATER DISPOSAL WELL
MARLIN No. 29-21 WDW

APPLICATION PLAT

SECTION 29, T.35N., R.90W.
FREMONT COUNTY, WYOMING

GENE R. GEORGE & ASSOCIATES, INC.

Map Document: (O:\ESRI\AETHON\2020\MARLIN2921WDWLRG.mxd) 1/7/2020 -- 9:35:48 AM

Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. _____-2020

Attachment R-2 - Water Quality Analysis Summarry from Madison Perforation Set #1 (15,110 - 15,180 ft)

PRECISION ANALYSIS

29 Country Acres Rd.
Riverton, WY 82501
Phone (307) 856-0866
Toll Free: (866) 985-0866
Cell: (307) 851-7046

Full Service Lab • Gas Measurement • Emissions Testing • Sample Collection • Custom Fabrication Shop

NELAP Accredited • A2LA Accredited • EPA Certified • HubZone Certified • Women Owned

Visit our Website www.Precision-Labs.com

MADISON FORMATION ANALYSIS

http://water.epa.gov/drink/contaminants/index.cfm#List

Analyses	Units	7/3/2012	7/5/2012	7/9/2012	EPA Drinking Water Limit
General Parameters					
Alkalinity as HCO3	mg/L	190	120	56	
Alkalinity as CO3	mg/L	<2	<2	<2	
Alkalinity as OH	mg/L	<2	<2	<2	
Total Hardness as CaCO3	mg/L	660	750	610	
Radium 226	pCi/L	2.4 +/- 0.9	5.9 +/- 1.4	2.5 +/- 0.9	5
Radium 228	pCi/L	.662 +/- 0.506	.879 +/- 0.45	12.0 +/- 5.86	5
Major Ions					
Ammonia as N	mg/L	1.2	0.1	0.2	
Calcium	mg/L	220	250	200	
Chloride	mg/L	35	36	32	
Fluoride	mg/L	4.4	4.4	2.3	4
Magnesium	mg/L	24	30	28	
Nitrate	mg/L	<1	<1	<1	
Nitrate as N	mg/L		<1	<1	10
Potassium	mg/L	30	28	30	
Sodium	mg/L	69	63	82	
Sulfate	mg/L	670	630	550	
Orthophosphate	mg/L	<.09	<.09		
Physical Properties					
Conductivity	uS/cm	1660	1410	1240	
pH	s.u.	6.63	7.01	7.05	
Total Dissolved Solids (TDS)	mg/L	1200	960	910	
Total Suspended Solids (TSS)	mg/L	360	37	730	
Temperature	C	9.6	16.8	5.4	
Dissolved Organic Carbon (DOC)	mg/L	67.9		2.6	
TOC	mg/L	108	9	3.6	
BOD	mg/L	2.1	<2	300	
Sulfide	mg/L		0.01	0.01	
Dissolved Metals					
Aluminum	ug/L	5.2	7.2	<1	
Arsenic	ug/L	<0.5	<0.5	<1	
Barium	mg/L	83.9	81.7	69	
Beryllium	ug/L	<0.2	<0.2	<1	
Boron	ug/L	333	236	389	
Cadmium	ug/L	0.086	<0.08	<1	
Chromium	ug/L	0.6	0.78	<1	
Copper	ug/L	118	11	4.64	
Iron	ug/L	1810	745	594	
Lead	ug/L	0.12	<0.1	<1	
Manganese	ug/L	682	487	1000	
Mercury	ug/L	<0.2	<0.2	<0.2	
Nickel	ug/L	99.4	14.2	28.1	
Selenium	ug/L	<0.5	<0.5	<1	
Silica	ug/L	41100	74900	23800	
Silver	ug/L	0.75	<0.5	<1	
Strontium	ug/L	3430	3290	2930	
Thallium	ug/L	0.16	<0.1	<1	
Zinc	ug/L	13.5	14.5	7.06	
Total Metals					
Aluminum	ug/L	357	15.8	<1	

Arsenic	ug/L	14.5	2.4	16.7	10
Barium	ug/L	1390	171	240	2000
Beryllium	ug/L	<0 2	<0.2	<1	4
Boron	ug/L	321	256	422	
Cadmium	ug/L	<0.08	<0.08	<1	5
Chromium	ug/L	181	6.9	116	100
Copper	ug/L	656	80.9	307	1300
Iron	ug/L	108000	37500	119000	
Lead	ug/L	297	7	38.4	15
Manganese	ug/L	1590	764	2920	
Mercury	ug/L	3	0.88	1.2	2
Nickel	ug/L	205	27	126	
Selenium	ug/L	0.68 mg/L	<0.5	<1	50
Silica	ug/L	32100	40100	27100	
Silver	ug/L	0.8	<0.5	<1	
Strontium	ug/L	1720	1660	3060	
Thallium	ug/L	0.52 mg/L	<0.1	<1	2
Zinc	ug/L	1060	83	806	

Hydrocarbons

TPH	mg/L	120	37	17	
Benzene	ug/L	110	22	18	5
Toluene	ug/L	140	120	230	1000
Ethyl Benzene	ug/L	83	56	160	700
m,p-Xylene	ug/L	250	280	620	10000 (Total Xylene)
o-Xylene	ug/L	210	440	400	
Napthalene	ug/L	<4	83	96	
GRO	ug/L	5300	12000	5000	
DRO	ug/L	160000	48000	17000	
Methanol	ug/L	<400	<400	<5 mg/L	

Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. _____-2020

Attachment R-3 - State Engineers Office - Water Rights Search in 4 Township Area T34-35N R90-91W (144 Square miles)

SEO data download date: 5/22/2018

WR Number	Priority Date	WaterRight Status	Company	Facility Name	Uses	Twn	Rng	Sec	Qtr-Qtr	Appropriation (GPM)	Total depth (Ft)	StaticWaterLevel (Ft)
P6773.0P	06/21/1940	Fully Adjudi		KIMBALL WELL #3	DOM_GW; STK	035N	090W	22	SW1/4NE1/4	6	148.00	90
P6778.0W	10/19/1970	Fully Adjudi		EAST PASTURE WELL #8	DOM_GW; STK	035N	090W	15	SW1/4NW1/4	22	145.00	60
P6775.0P	04/30/1944	Fully Adjudi		NORTH SHED WELL #5	DOM_GW; STK	035N	090W	10	SW1/4SW1/4	10	138.00	100
P51982.0W	04/28/1980	Cancelled	W. E. AUER OIL & GAS COMPANY	#1 ROBERTS W W	MIS	034N	091W	13	NE1/4SW1/4	30		
P83935.0W	10/24/1990	Cancelled	ALPAR RESOURCES INC.	ALPAR #0290	MIS	035N	090W	31	SW1/4NW1/4	60		
P197891.0W	09/12/2011	Cancelled	ENCANA OIL & GAS USA INC.	MARLIN #29-21 WSW	MIS; STK	035N	090W	29	NE1/4NW1/4	140		
P71116.0W	09/09/1985	Cancelled	USDI - BLM	JUMPING OFF #1	STK	034N	091W	06	SE1/4SE1/4	12		
P169586.0W	08/25/2005	Cancelled		LIAM	STK	034N	090W	36	NE1/4NE1/4	25		
P109754.0W	04/27/1998	Incomplete		SHERRY #1	STK	035N	090W	34	SW1/4SW1/4	25		
P109756.0W	04/27/1998	Incomplete		JOHNNY #1	STK	035N	090W	36	SE1/4NW1/4	25		
P114262.0W	01/28/1999	Complete		JOHNNY #2	STK	035N	090W	28	SW1/4NW1/4	25	560.00	90
P24148.0P	08/13/1973	Fully Adjudi	Matador Cattle Co.	LOVE RANCH #10-5	STK	035N	090W	30	SW1/4NE1/4	5	550.00	-4
P24147.0P	08/13/1973	Fully Adjudi	Matador Cattle Co.	LOVE RANCH #10-4	STK	035N	091W	35	NE1/4SW1/4	5	500.00	-4
P109755.0W	04/27/1998	Cancelled		MORGAN #1	STK	035N	090W	16	NW1/4SW1/4	25	500.00	90
P127419.0W	08/01/2000	Complete	Wyo State Board of Land Commissioners	Morgan #1	STK	035N	090W	16	NW1/4SW1/4	25	500.00	90
P114261.0W	01/28/1999	Complete		TOMPSON #2	STK	035N	090W	01	SW1/4SW1/4	3	480.00	280
P116939.0W	07/15/1999	Complete		CONNAGER #1	STK	035N	090W	21	NE1/4NE1/4	25	460.00	90
P114263.0W	01/28/1999	Complete		CANYON WELL	STK	035N	090W	03	SW1/4SW1/4	5	405.00	-4
P6779.0P	04/30/1969	Fully Adjudi		BLACK ROCK #9	STK	035N	090W	10	NW1/4SW1/4	0.3	400.00	-4
P6780.0P	06/30/1968	Fully Adjudi		NORTH WELL #10	STK	035N	090W	03	SW1/4SW1/4	1	400.00	-4
P109753.0W	04/27/1998	Complete		JUSTIN NO. 1	STK	035N	090W	26	SW1/4NE1/4	25	380.00	80
P116940.0W	07/15/1999	Complete		FLASH #1	STK	035N	090W	14	SW1/4SW1/4	25	380.00	90
P18293.0P	04/20/1967	Fully Adjudi		MILES #2	STK	035N	090W	24	NE1/4NW1/4	10	375.00	325
C89727.0W	09/01/1982	Fully Adjudi	USDI BLM	DEER CREEK WELL	STK	035N	090W	12	SE1/4NE1/4	10	332.00	285
P12424.0P	04/10/1968	Fully Adjudi	USDI BLM	DEER CREEK WELL #0881	STK	035N	090W	12	SE1/4NE1/4	10	332.00	285
P2706.0P	04/10/1968	Fully Adjudi	DEER CREEK RANCH INC.	DEER CREEK WELL #14	STK	035N	090W	12	SE1/4NE1/4	10	332.00	285
P2642.0P	04/10/1967	Fully Adjudi	DEER CREEK RANCH INC.	DEER CREEK #3	STK	035N	090W	02	SE1/4SE1/4	10	320.00	260
C89652.0W	11/01/1982	Fully Adjudi	USDI BLM	FISH DRAW WELL SD	STK	035N	090W	19	SW1/4SE1/4	1	305.00	-1
P63190.0W	02/01/1983	Complete	USDI - BLM	FISH DRAW WELL PROJECT #504	STK	035N	090W	19	SW1/4SE1/4	10	305.00	-4
P6771.0P	05/31/1938	Fully Adjudi		LANE #1	STK	035N	090W	27	SE1/4NW1/4	5	304.00	90
P62513.0W	11/05/1982	Fully Adjudi		LYNN #3 STOCK	STK	034N	091W	16	NE1/4SE1/4	15	245.00	200
C89653.0W	11/01/1982	Fully Adjudi	USDI BLM	ROB #2 WELL SD	STK	034N	091W	13	NW1/4NW1/4	5	232.00	15
P64104.0W	05/18/1983	Fully Adjudi	USDI BLM	ROB #2 #2238	STK	034N	091W	13	NW1/4NW1/4	10	232.00	15
P24151.0P	08/13/1973	Fully Adjudi	Matador Cattle Co.	BUTTE WELL #9-2	STK	034N	091W	32	NE1/4NE1/4	5	170.00	40
P12586.0P	10/01/1940	Fully Adjudi	USDI BLM	BUTTE WELL #0033	STK	035N	091W	30	NW1/4SE1/4	7.5	165.00	-6
P6776.0P	06/30/1957	Fully Adjudi		SHEARING SHED WELL #6	STK	035N	090W	23	NE1/4NE1/4	6	164.00	100
P24153.0P	08/13/1973	Fully Adjudi	Matador Cattle Co.	ROBERTS #10-3	STK	034N	091W	13	NE1/4SW1/4	5	160.00	40
P24142.0P	08/13/1973	Fully Adjudi	Matador Cattle Co.	SEVENTY-ONE #7-4	STK	035N	091W	01	NW1/4NE1/4	5	160.00	35
P6774.0P	12/31/1940	Fully Adjudi		SOUTH #4	STK	034N	090W	11	NE1/4NW1/4	20	160.00	50
P24152.0P	08/13/1973	Fully Adjudi	Matador Cattle Co.	LOVE RANCH #10-2	STK	035N	091W	24	SW1/4SE1/4	5	155.00	35
P6772.0P	05/31/1938	Fully Adjudi		OLSON #2	STK	035N	090W	03	NW1/4NW1/4	1.39	150.00	90
P24146.0P	08/13/1973	Fully Adjudi	Matador Cattle Co.	LOVE RANCH #10-1	STK	035N	091W	34	NE1/4NW1/4	5	125.00	35
P6777.0P	05/31/1965	Fully Adjudi		COLE WELL #7	STK	035N	090W	10	NW1/4SW1/4	10	120.00	80
P174547.0W	05/04/2006	Complete		BURGETT #2	STK	034N	091W	26	NW1/4SW1/4	10	80.00	40
C93894.0W	04/17/1926	Fully Adjudi	USDI BLM	PWR #107(149)	STK	034N	091W	23	NW1/4NW1/4	1	-1.00	-1
C93892.0W	04/17/1926	Fully Adjudi	USDI BLM	SULPHER SPRINGS	STK	034N	091W	01	NE1/4NW1/4	2	-1.00	-1
C93893.0W	04/17/1926	Fully Adjudi	USDI BLM	NO NAME SPRING #9	STK	034N	091W	15	NW1/4NE1/4	2	-1.00	-1
C89725.0W	09/01/1982	Fully Adjudi	USDI BLM	CANYON WELL	STK	035N	090W	03	NW1/4SE1/4	5	-1.00	-1
C89726.0W	09/01/1982	Fully Adjudi	USDI BLM	BLACK ROCK WELL	STK	035N	090W	03	SW1/4SE1/4	10	-1.00	-1

3 Domestic Wells - 138 to 148' in Depth
44 Stock Wells - surface to 560' in Depth
2 Miscelaneous Wells - no reported depth

Professional ... (Chemical)
BONNIE S. PERCY
6360
Date 8/12/2020
WYOMING

Aethon Energy Operating LLC

Aquifer Exemption/Water Disposal Application
Marlin 29-21 WDW

G-1
Geologic Description of Amsden Formation and Madison Limestone

Marlin 29-21 WDW
API 49-013-23374
SHL: NE¼NW¼ Section 29, T35N, R90W
BHL: NE¼NW¼ Section 29, T35N, R90W
Fremont County, Wyoming

Aethon Energy Operating LLC proposes the underground disposal of water into the Amsden Formation and the Madison Limestone in Marlin 29-21 WDW (*NE¼NW¼ Section 29, T35N, R90W*) (G-2).

LOCATION

The Marlin 29-21 well is in the southern Wind River basin in a remote area about 5 miles west of the geographic center of Wyoming in Fremont County. The well is located about 45 miles east of Riverton, 30 miles southeast of Shoshoni, 65 miles west of Casper, and 45 miles north of Muddy Gap. Gas production occurs 4.5 miles to the south in Castle Gardens field from sandstones in the Cody Shale. Oil is produced from sandstones in the Cody at Raderville field 10 miles to the east. The Gun Barrel Unit has gas production from the Fort Union and Lance about 13 miles to the north. The water produced from Gun Barrel Unit will be the main source of water for disposal.

WELL

The Marlin 29-21 WDW was spud on November 30, 2011 and drilled to a measured depth of 15,405 feet in the Gallatin Limestone. The completion report indicates a bottom hole in the Gros Ventre, but correlation to deep wells in the Madden field indicate that the TD is in the Gallatin, which overlies the Gros Ventre. Open hole logs were run in the well from measured depths of 2,540 to 9,650 feet on March 5, 2012 and from 9,994 to 10,402 feet on March 26, 2012. Cased hole Reservoir Saturation logs were run from 3,440 to 15,335 feet measured depth on June 14, 2012. These logs are displayed on G-3 with tops shown. The Tensleep is perforated from 14,448 to 14,766 feet. The Madison was perforated from 14,972 to 15,312 feet. This perforated interval extended up into the Darwin Sandstone Member of the Amsden Formation above the Madison. The entire interval was later squeezed.

STRUCTURE

The Marlin 29-21 WDW is in the southern Wind River basin. The southern flank of the basin is rippled by several asymmetric, faulted anticlines that plunge into the basin. The well is on the less steeply dipping northeast flank of one of these anticlines where dip is about 15° to the northeast (G-2 and G-4).

The Marlin 29-21 WDW is about 13 miles south of the Gun Barrel Unit, which will be the source for most of the water for disposal. The Madden field, which produces gas from the Madison, is located about 20 miles to the north of the Marlin on the north side of the basin axis. The regional structure of the Madison is shown on G-4. Cross-section F to F' illustrates structure from the Owl Creek Mountains to Granite Mountains and the position of the Marlin (G-5). Madison data control is limited in the area (G-2). Structural mapping was provided by Encana and is shown on G-2 overlain with township and range and well control for the area around the ground water modeling done by Tetra Tech (Tetra Tech, 2015 and 2020).

To investigate the local structure around the Marlin 29-21 WDW with minimal well control available, Aethon has acquired two seismic lines of 2D data crossing the Marlin 29-21 WDW (G-6). These lines provide no evidence of faulting at the Madison level.

SEISMICITY

The "Basic Seismological Characterization", for both Fremont and Natrona counties, indicates that probability-based or fault activation-based worst-case scenario for this area would be a VII intensity earthquake in which damage is negligible in buildings of good design and construction, slight-to-moderate in well-built ordinary structures, considerable in poorly built or badly designed structures (Case, et al., 2002 and Case, et al. 2003). The Wyoming Geological Survey report on earthquakes and injection/disposal well activities found no indication of induced seismicity in this area (Larsen and Wittke, 2014). The depth to basement in this area is estimated at about 16,250 feet (Blackstone, 1993). Basement is estimated to be about 900 feet below the base of the Madison. The risk of damage from earthquakes or the occurrence of induced seismicity is low.

STRATIGRAPHY

A stratigraphic chart for the area of the Marlin 29-21 WDW is shown as G-7. It is modified from Table 4-1 Lithostratigraphic and Hydrogeologic Units of the Wind River Basin in the Tetra Tech report of "Performance and Influence of the Marlin 29-21 WDW" (Tetra Tech, 2015 and 2020) and sourced from the "Wind/Bighorn River Basin Water Plan Update Groundwater Study Available Groundwater Determination Technical Memorandum" (Taucher et al., 2012). Lithostratigraphic units and hydrogeologic units are shown with the addition of depths for the formations encountered in the Marlin 29-21 WDW.

The Wind River Formation is the bedrock at the Marlin well. The Wind River is composed of variegated basin fill sediments that accumulated in the Wind River Basin during early Eocene time to a thickness of almost 8,000 feet (Finn, 2007). It is the major source of ground water for Riverton. Quaternary alluvium, dune sand and loess deposits are present at the surface in the surrounding township (G-8). The Fort Union outcrop that outlines the anticline south of the Marlin is about 1.5 miles to the southwest.

At the Marlin location the Cenozoic section is over 3,200 feet of continental sediments. The Mesozoic section is almost 11,000 feet thick and composed predominately of shales, shaley sandstones and sandstones. The thickest deposits were laid down in the Cretaceous Western Interior Seaway and Triassic red beds are the oldest Mesozoic rocks. The Paleozoic section is estimated at over 2,000 feet and composed of sandstone and carbonates, limestones and dolomites, and shales.

DISPOSAL ZONE

The Madison is Mississippian in age and was deposited on a shallow-marine shelf that extended from New Mexico to western Canada. It is predominantly limestone and dolomite. At the Marlin 29-21 WDW, it is about 359 feet thick with the top of the Madison at a measured depth of 15,003 feet (-9,071, ssTVD) and the base of the Madison (top of Gallatin Limestone) at 15,365 feet, measured depth (-9,430 ssTVD). At Madden field to the north, the Madison is composed of four depositional sequences (IV, III, II, and I, shallower to deeper) that are laterally extensive (Westphal et al., 2004). These sequences are correlated in the Marlin well and indicated that porosity and permeability at Madden are analogous to that in the Marlin (G-9). Pore types include interparticle, moldic, intercrystalline and fracture porosity. Sequences III, II, and I are highly dolomitized and have higher porosity than IV. The Madden area had a porosity range of 0 to 35%. The Reservoir Saturation Sigma Log run in the Marlin 29-21 WDW was reprocessed on 4/13/2020 to provide more accurate porosity values for the Amsden and Madison lithologies (G-11). Those porosity values for Tensleep, Amsden, Darwin Sandstone Member of the Amsden, and Madison are tabulated in Table 1 below, using a 70 API gamma ray cutoff. Permeability from core in Madden field ranges from .09 to 16 millidarcies (Brown and Shannon, 1989). Testing of the Marlin 29-21 WDW indicates a horizontal permeability to water of 3.5 millidarcies.

The Amsden Formation is Mississippian to Pennsylvanian in age and a predominantly carbonate and shale sequence. It was deposited during a west-to-east transgression of the Amsden sea across the post-Madison erosional surface. The Amsden is subdivided into three members in central Wyoming, from top to bottom, the Ranchester Limestone Member, the Horseshoe Shale Member, and the Darwin Sandstone Member (G-10). In the Marlin 29-21 WDW, the Ranchester is correlated between 14,795 and 14,884 feet measured depth and described in samples as light tan dolomite, off white limestone and brick red

API #	49-013-23374
State	Wyoming
County	Fremont
Sec-Twp-Rng	29-35N-90W
Qtr-Qtr	NENW
Historical Operator	Encana Oil & Gas
Current Operator	Aethon Energy
Well Name & #	Marlin 29-21WDW
Spud Date	11/30/2011
TD (MD ft)	15405
KB (ft)	5894

Table 1. Depths, Thicknesses and Porosity *(reprocessed Schumberger RST log, Table 3-2, Tetra Tech, 2020)*

Notes:
Phi cutoffs include a gamma ray cutoff of <70 API
MD = Measured Depth
TVD = True Vertical Depth
SSTVD = Subsea True Vertical Depth
NPHI = Neutron Porosity
H = Thickness
Phi = Porosity
ft. = Feet

Formation	Top (MD ft)	Top (TVD ft)	Top (SSTVD ft)	Base (MD ft)	Base (TVD ft)	Base (SSTVD ft)	Gross H (MD ft)	Gross H (TVD ft)
Tensleep	14434	14403	-8509	14795	14760	-8866	361	357
Amsden	14795	14760	-8866	14974	14937	-9043	179	177
Darwin	14974	14937	-9043	15003	14965	-9071	29	28
Madison Seq 4	15003	14965	-9071	15145	15106	-9212	142	141
Madison Seq 3	15145	15106	-9212	15216	15176	-9282	71	70
Madison Seq 2	15216	15176	-9282	15306	15265	-9371	90	89
Madison Seq 1	15306	15265	-9371	15365	15324	-9430	59	59

Formation	NPHI Matrix Setting	5% phi cutoff			4% phi cutoff		
		Net H (ft)	Avg phi	PhiH	Net H (ft)	Avg phi	PhiH
Tensleep	Sandstone	35.539	0.076	2.701	61.209	0.063	3.856
Amsden	Sandstone	36.488	0.082	2.992	39.952	0.079	3.156
Darwin	Sandstone	19.592	0.078	1.528	23.555	0.073	1.720
Madison Seq 4	Limestone	21.029	0.076	1.598	25.488	0.071	1.810
Madison Seq 3	Dolomite	21.307	0.100	2.131	26.262	0.089	2.337
Madison Seq 2	Dolomite	2.479	0.054	0.134	12.152	0.046	0.559
Madison Seq 1	Dolomite	15.365	0.090	1.383	22.050	0.077	1.698

Formation	NPHI Matrix Setting	3% phi cutoff			2% phi cutoff		
		Net H (ft)	Avg phi	PhiH	Net H (ft)	Avg phi	PhiH
Tensleep	Sandstone	117.474	0.050	5.874	154.98	0.044	6.819
Amsden	Sandstone	43.911	0.075	3.293	51.831	0.068	3.525
Darwin	Sandstone	25.041	0.071	1.778	25.041	0.071	1.778
Madison Seq 4	Limestone	27.469	0.069	1.895	32.424	0.062	2.010
Madison Seq 3	Dolomite	32.705	0.079	2.584	38.156	0.071	2.709
Madison Seq 2	Dolomite	16.613	0.043	0.714	41.895	0.031	1.299
Madison Seq 1	Dolomite	49.807	0.053	2.640	49.807	0.053	2.640

shale. The Horseshoe is correlated between 14,884 and 14,974 feet measured depth and described in samples as tan dolomite, siltstone, red shale and off-white limestone. The porosity shown in Table 1 for the Amsden, which covers the Ranchester Limestone and Horseshoe Shale members, does not correct for the shale content of those lithologies and the indicated porosity is erroneously high. The Darwin is correlated at 14,974 to 15,003 feet measured depth and described in samples as tan to light purple, very-fine-grained, sandstone. Table 1 shows porosity and thickness for the Darwin.

CONFINING ZONES

The Madison is isolated above and below from shallower aquifers and hydrocarbon producing zones (G-7). The Amsden Formation separates the Madison from the Tensleep Sandstone, which is approved for water disposal and aquifer exemption in the Marlin 29-21 WDW. In the Wind River Basin, the Amsden commonly separates Tensleep producing zones from Madison water-bearing or hydrocarbon-producing zones. The Ranchester Limestone and Horseshoe Shale Members are shaley with no permeability and act as the confining beds between the Tensleep and Madison. The Darwin Sandstone Member has low porosity but may receive some water from disposal activities. It is included in the proposed disposal zone mainly for operational simplicity. Above the Tensleep Sandstone there are numerous confining units, including the Cody Shale which is over 4,000 feet thick at the Marlin well. Below the Madison, the Gallatin Limestone and Gros Ventre Formation are confining units that isolate the Madison from the Flathead Sandstone and Precambrian below. At Madden field the Gallatin is about 300 feet thick and the Gros Ventre is about 450 feet thick. Density logs show these formations to have low porosity and significant amounts of shale (Brown and Shannon, 1989).

TETRA TECH REPORT

Tetra Tech at the behest of Encana Oil & Gas (USA) Inc. prepared a report, "Performance and Influence of the Marlin 29-21 Water Disposal Well on the Madison Formation in Fremont County, Wyoming", to provide additional information for the assessment of the aquifer exemption of the Madison. This report was dated January 27, 2015 and revised September 22, 2015. Concerns addressed in the report include a hydrogeologic model for the region around the Marlin 29-21 WDW, probable flow pathway from recharge areas to the Marlin, age of Madison water, analysis of step-rate test of the Madison, and predictions of later injectate migration. In 2020, Aethon Energy Operating LLC requested and received an update of the report.

The report concluded that data for the Madison is very sparse in the central portion of the Wind River Basin. Groundwater flow in the Wind River Basin is from recharge areas along the southern, western and northwestern perimeter of the basin toward the center of the basin and toward oil and gas producing fields in the center and western parts of the basin. The age of Madison water in the Marlin 29-21 WDW is about 37,000 ybp. The recharge to the Marlin area is from Madison outcrops and subcrops about 14 miles to the south and southeast. The velocity of this recharge is about 3 feet per year. Upward discharge of water from the Madison along faults is unlikely, and large faults compartmentalize groundwater flow. Long-term predictions of injectate movement indicate that the water injected will remain within the Madison and move downdip toward the north. Vertical migration into the Tensleep Formation will not occur. Under the worst-case conditions the waste plume will not migrate up-dip into areas where the top of the Madison Formation is less than about 12,000 feet, nor would it move closer than 12 miles from the nearest Madison outcrop.

Attachments:
G-2: Madison Structure Map
G-3: Marlin 29-21 WDW logs
G-4: Madison Regional Structure Map
G-5: Madison Regional Structural Cross-section F-F'
G-6: Seismic Line Locations
G-7: Lithostratigraphic and Hydrogeologic Units of the Wind River Basin with tops picked in the Marlin 29- 21 WDW
G-8: Surface Geologic Map
G-9: Madison Stratigraphic Cross-section A-A'
G-10: Amsden Stratigraphic Cross-section A-A'
G-11: RST Advisor Log – Processed 4/13/2020 -- Marline 29-21WDW

References:

Blackstone, D. L., Jr., 1993, Basement map of Wyoming State Geological Survey, Map Series 43, scale 1:1,000,000.

Brown, R. G. and L. T. Shannon, 1989, Madden (greater) – Long Butte, IN D. F. Cardinal, T.S. Miller, W. W. Stewart, and J. F. Trotter, eds., Wyoming oil and gas fields symposium, Bighorn and Wind River Basins, p. 293 -295 with map.

Case, J. C., R. N. Toner and R. Kirkwood, 2002, Basic Seismological Characterization for Fremont County, Wyoming, Wyoming State Geological Survey, online at http://www.wrds.uwyo.edu/wrds/wsgs/hazards/quakes/seischar/Fremont.pdf.

Case, J. C., R. N. Toner and R. Kirkwood, 2003, Basic Seismological Characterization for Natrona County, Wyoming, Wyoming State Geological Survey, online at http://www.wrds.uwyo.edu/wrds/wsgs/hazards/quakes/seischar/Natrona.pdf

Finn, T. M., 2007, Subsurface stratigraphic cross sections of Cretaceous and Lower Tertiary rocks in the Wind River Basin, central Wyoming, IN USGS Wind River Basin Province assessment team, Petroleum systems and geologic assessment of oil and gas in the Wind River Basin Province, Wyoming: U.S. Geological Survey Digital Data Series DDS–69–J, ch.9, 32 p.

Larsen, M. C. and S. J. Wittke, 2014, Relationships between injection and disposal well activities and known earthquakes in Wyoming, from 1984 to 2013, Wyoming State Geological Survey, open file report 2014-05, 11 p.

Taucher, P., T. T. Bartos, S. A. Quillianan, L. L. Hallberg, M. L. Clark, M. Thompson, N. Gribb, B. Worman and T. Gracias, 2012, Wind/Bighorn River Basin Water Plan Update, Groundwater Study, Level I (2008-2011), Available Groundwater Determination, Technical Memorandum, D. Copeland, editor, Wyoming State Geological Survey, p. 338. This publication is also available online at http://waterplan.state.wy.us/plan/bighorn/bighorn-plan.html

Tetra Tech, 2015, Performance and Influence of the Marlin 29-21 Water Disposal Well on the Madison Formation in Fremont County, Wyoming, prepared for Encana Oil & Gas (USA) Inc., signed by Keith S. Thompson, 52 p.

Tetra Tech, 2020, Performance and Influence of the Marlin 29-21 Water Disposal Well on the Madison Formation in Fremont and Natrona Counties, Wyoming, prepared for Aethon Energy Operating LLC. signed by Keith S. Thompson.

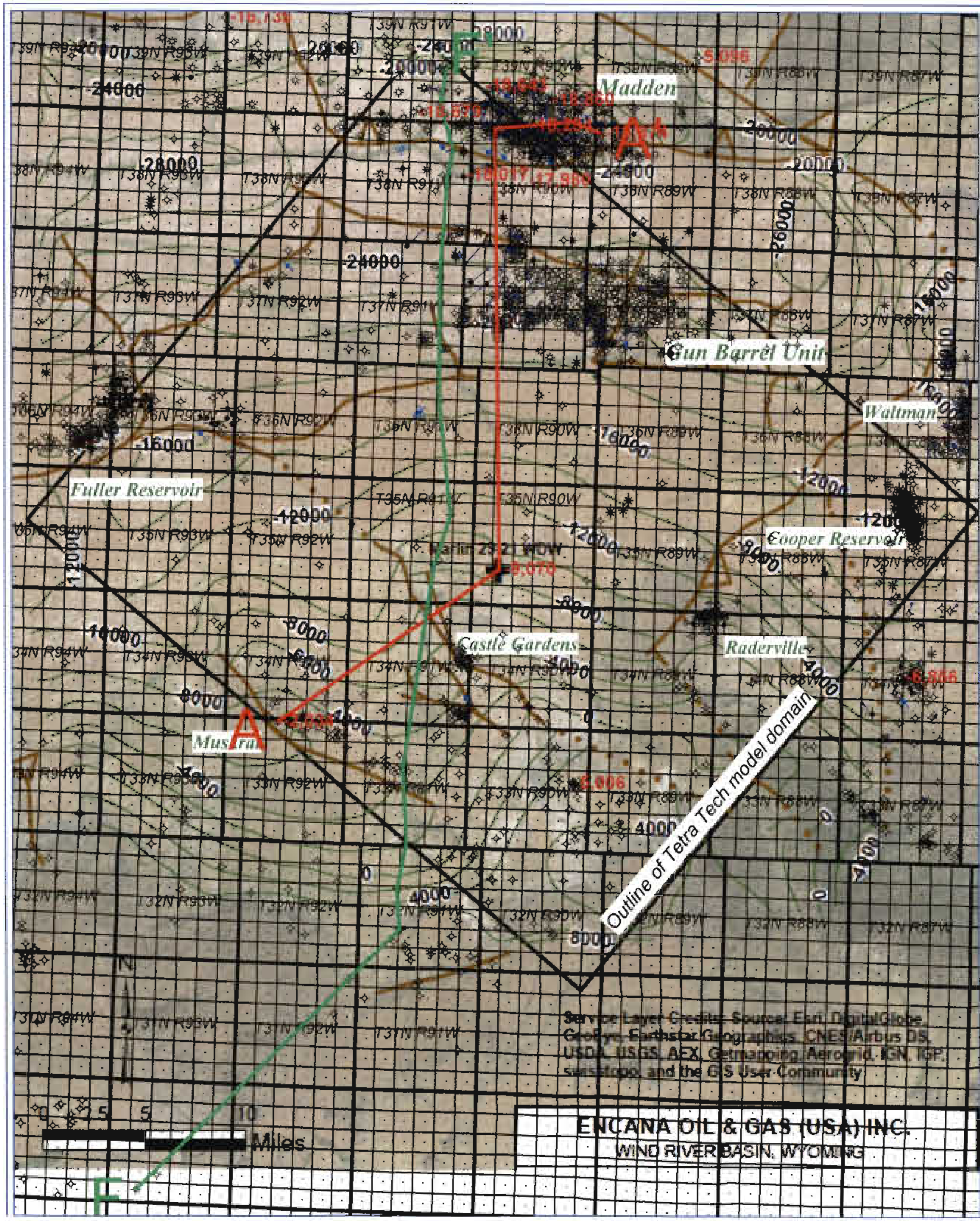
Westphal, H., G. P. Eberli, L. B. Smith, G. M. Grammar, and J. Kislak, 2004, Reservoir characterization of the Mississippian Madison Formation, Wind River basin, Wyoming, AAPG Bulletin, v. 88, no. 4, pp. 405-432.

Josh Talbert
Aethon Energy Operating LLC

Lynette D. W. George
WYPG #1004
August 14, 2020

PROFESSIONAL GEOLOGIST
LYNETTE D.W. GEORGE
PG-1004
WYOMING

Lynette D.W. George
8-13-2020



PROFESSIONAL GEOLOGIST
LYNETTE D.W. GEORGE
PG-1004
8-13-2020
WYOMING

Aethon Energy Operating LLC

Aquifer Exemption/Water Disposal

Marlin 29-21 WDW

T35N R90W S29, Fremont County

G-2: Madison Structure

POSTED WELL DATA

Madison Ls (SS) (FEET)

WELL SYMBOLS

- Location Only
- Oil - active permit
- Oil - Confidential
- Oil - dry and abandoned
- Oil - producing oil
- Oil - producing gas
- Oil - shut-in
- Oil - temporarily abandoned
- Oil - plugged and abandoned
- Gas - waiting on permit
- Gas- active permit
- Gas - spud
- Gas - dry and abandoned
- Gas - producing gas
- Gas - producing oil
- Gas - shut-in
- Gas - temporarily abandoned
- Gas - plugged and abandoned
- Inj - plugged and abandoned
- Disposal - Class 1
- Disposal - active
- Disposal - shut-in
- Water supply
- Strat test - plugged and abandoned

REMARKS

Faults in brown. Dotted where inferred.
Structure contours in green.
CI = 2000 feet
From Figure 4-10, "Performance and Influence of Marlin 29-21" (Tetra Tech, 2015)

By: Lyn George, Consulting Geologist

July 24, 2020

Aethon Energy Operating LLC

Aquifer Exemption/Water Disposal

Marlin 29-21 WDW

T35N R90W S29, Fremont County

G-3: Logs from Marlin 29-21 WDW

Log display isTVD enabled

By: Lyn George, Consulting Geologist

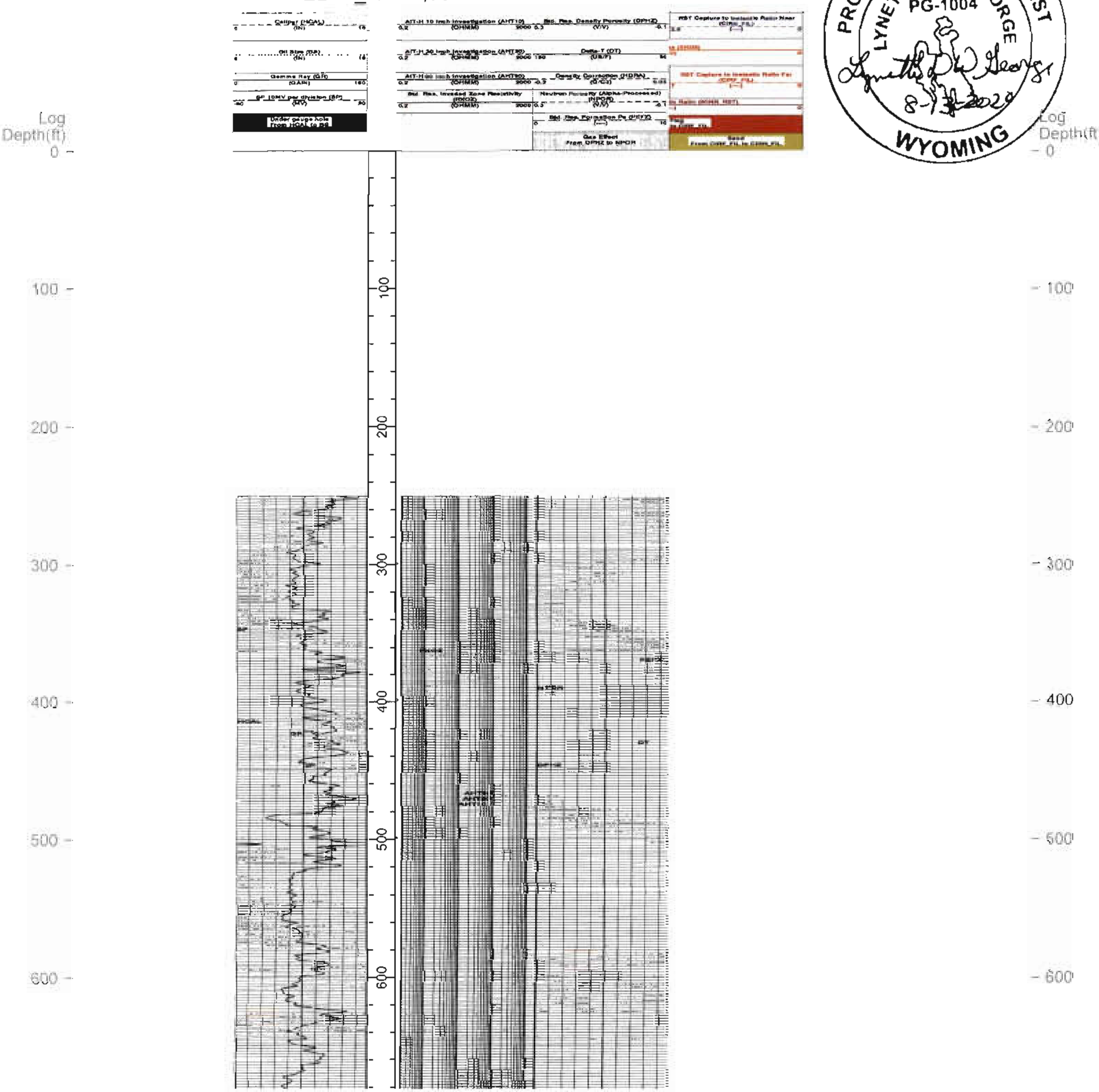
July 27,2020 1:31 PM

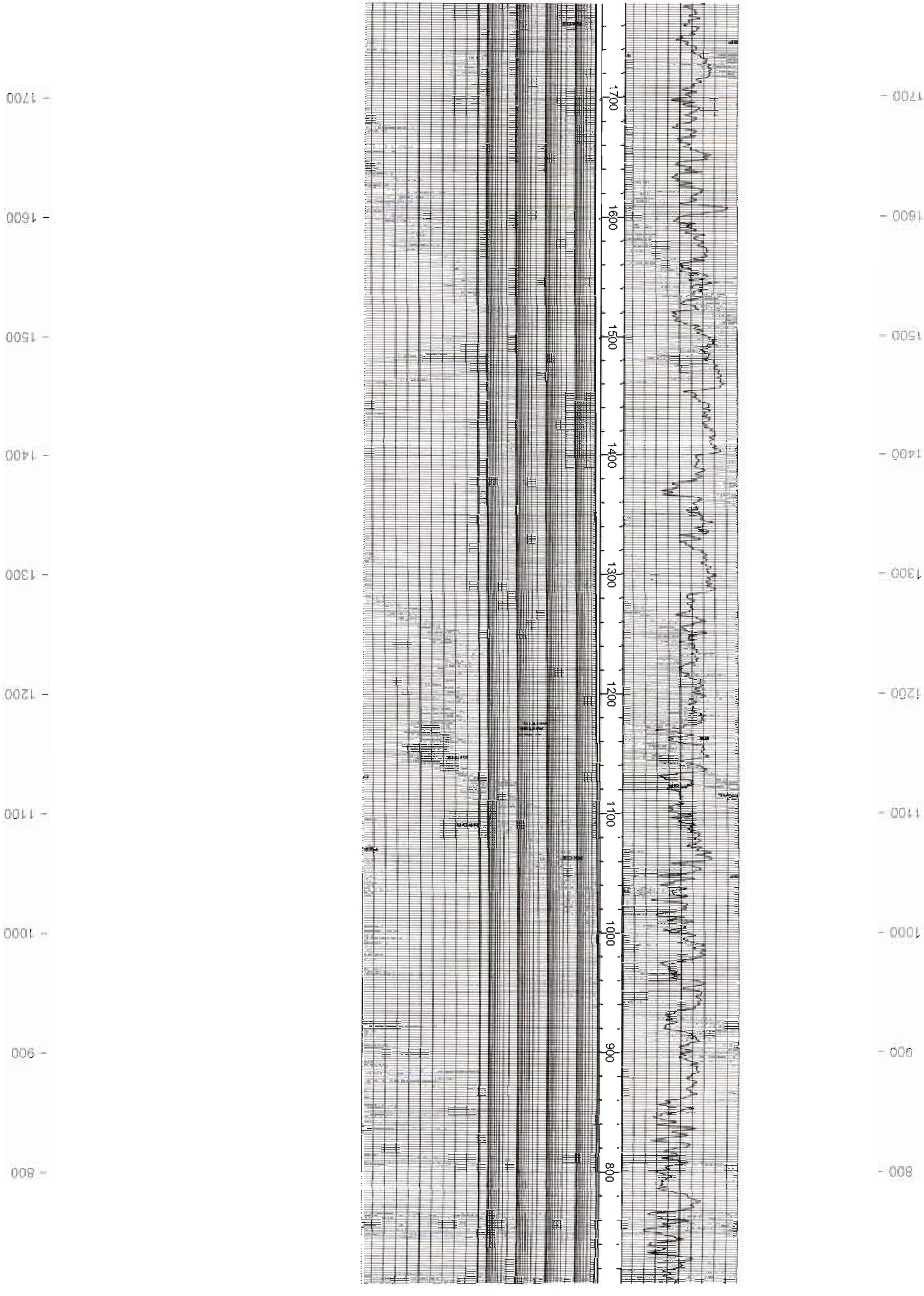
1323374
AETHON ENERGY OPERATING LLC
29-21WDW
MARLIN
660 FNL 1977 FWL

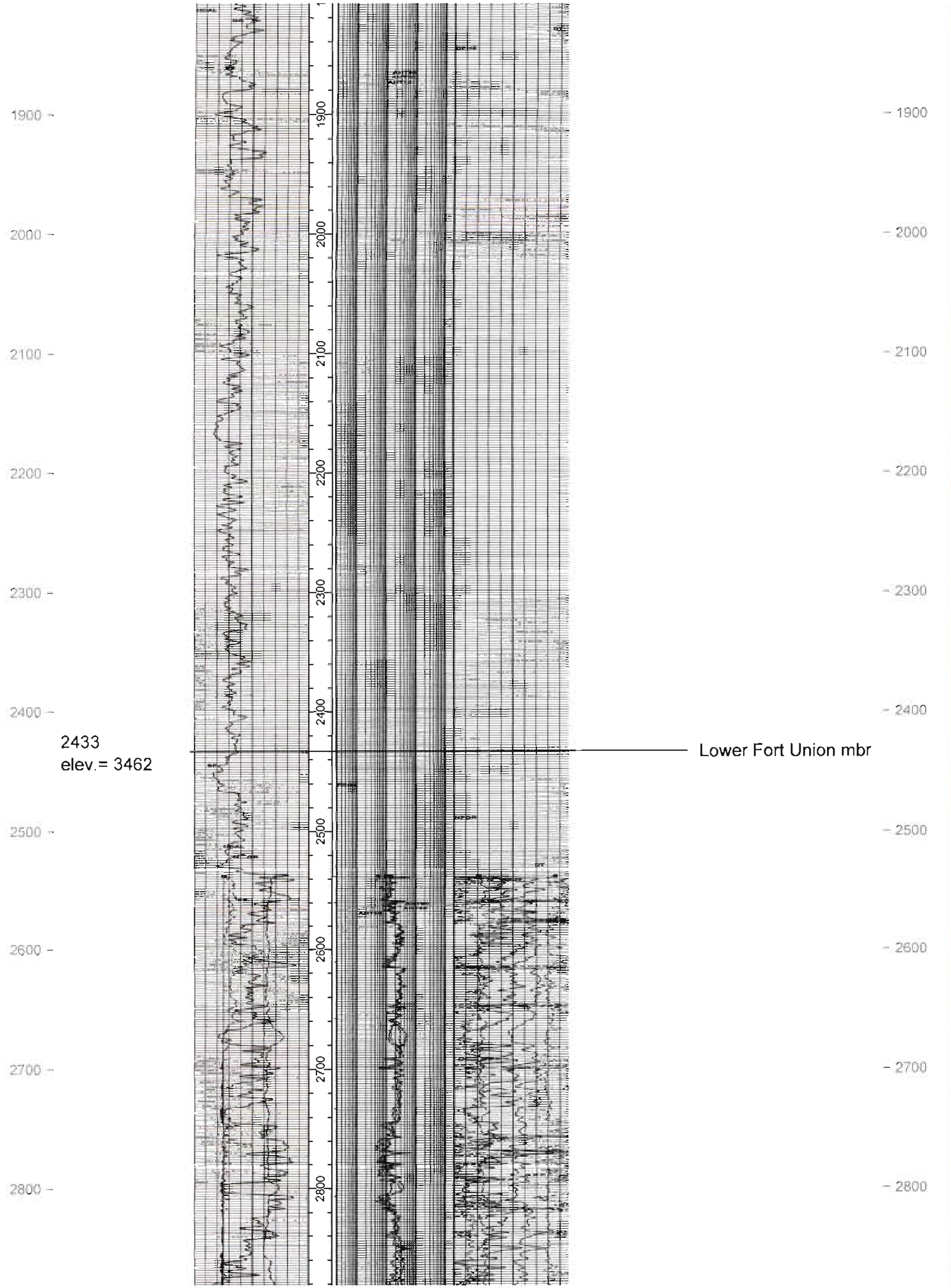
T35N R90W S29
NENW
ELEV_KB : 5,895

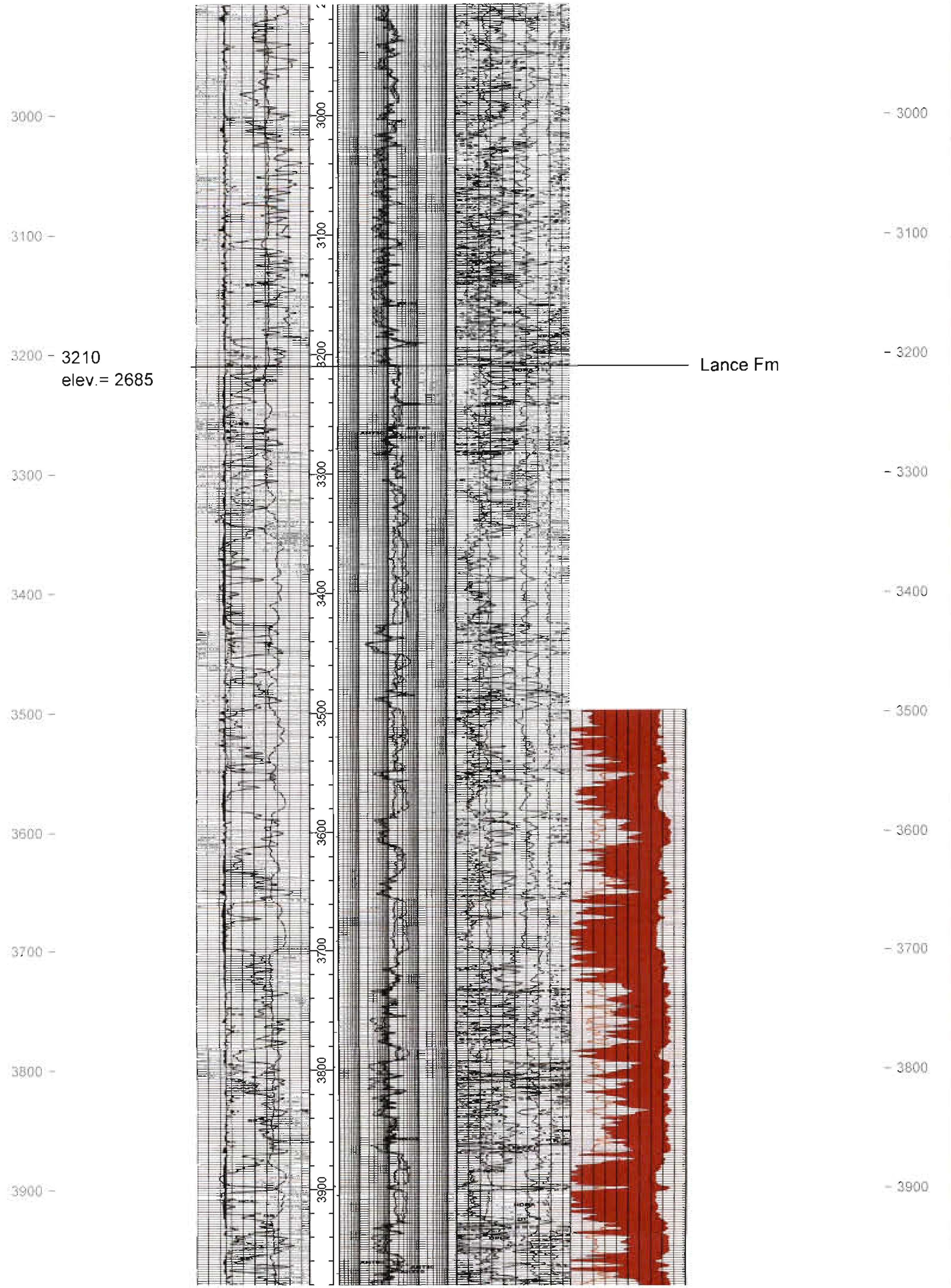
PROFESSIONAL GEOLOGIST
LYNETTE D.W. GEORGE
PG-1004
WYOMING

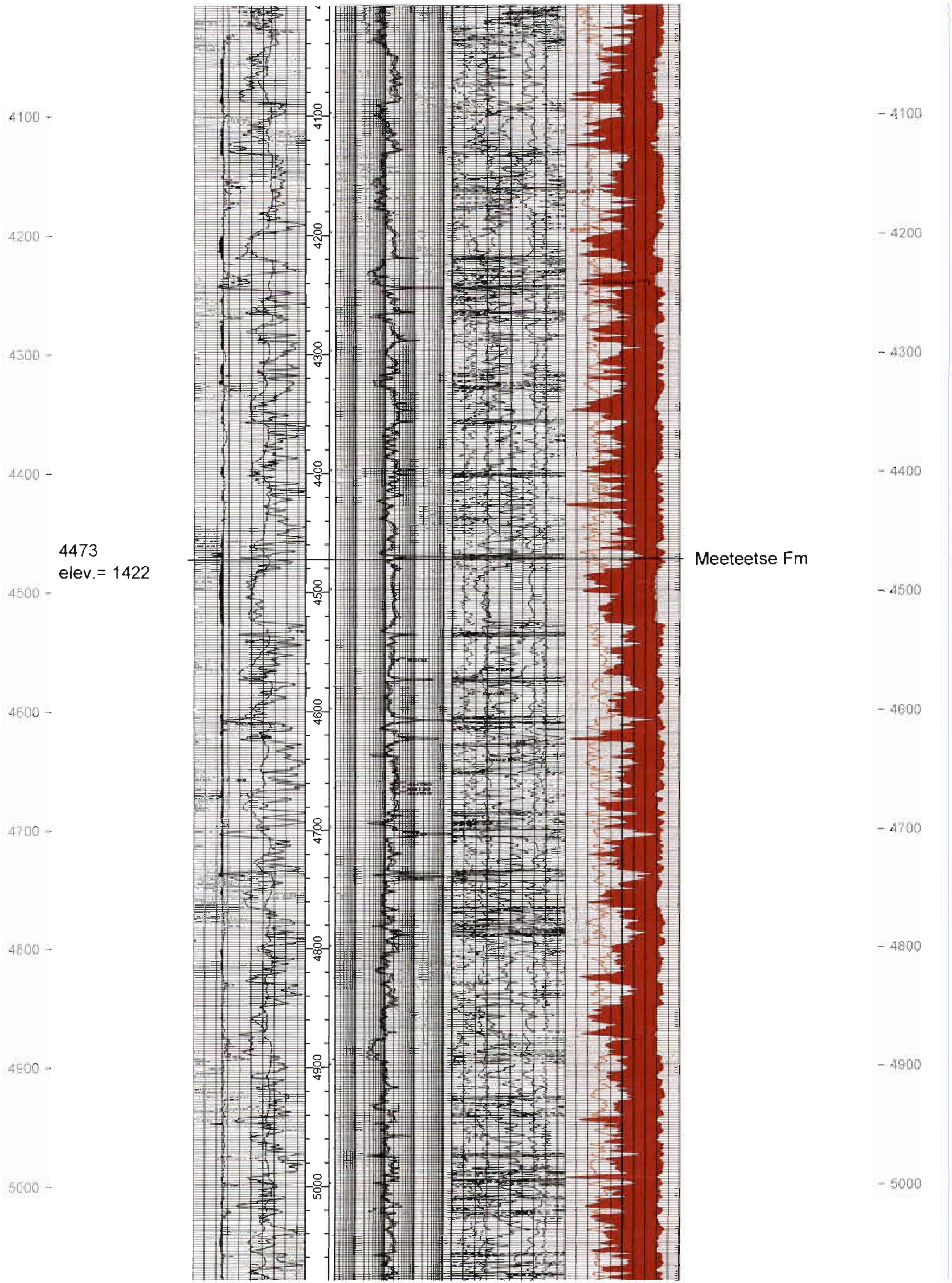
Lynette D.W. George
8-13-2020



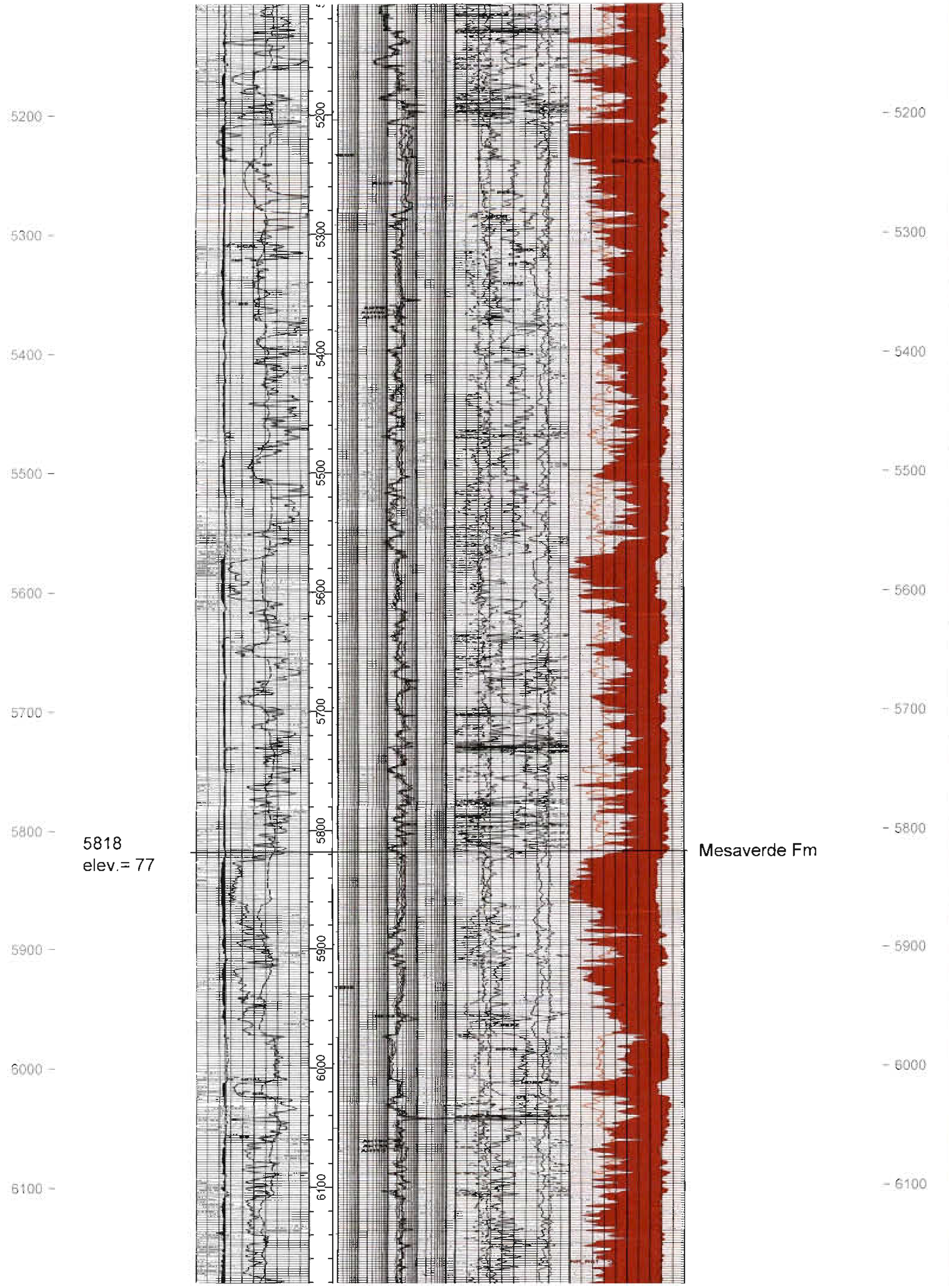

1700
1600
1500
1400
1300
1200
1100
1000
900
800


1900
2000
2100
2200
2300
2400
2433
elev.= 3462
Lower Fort Union mbr
2500
2600
2700
2800

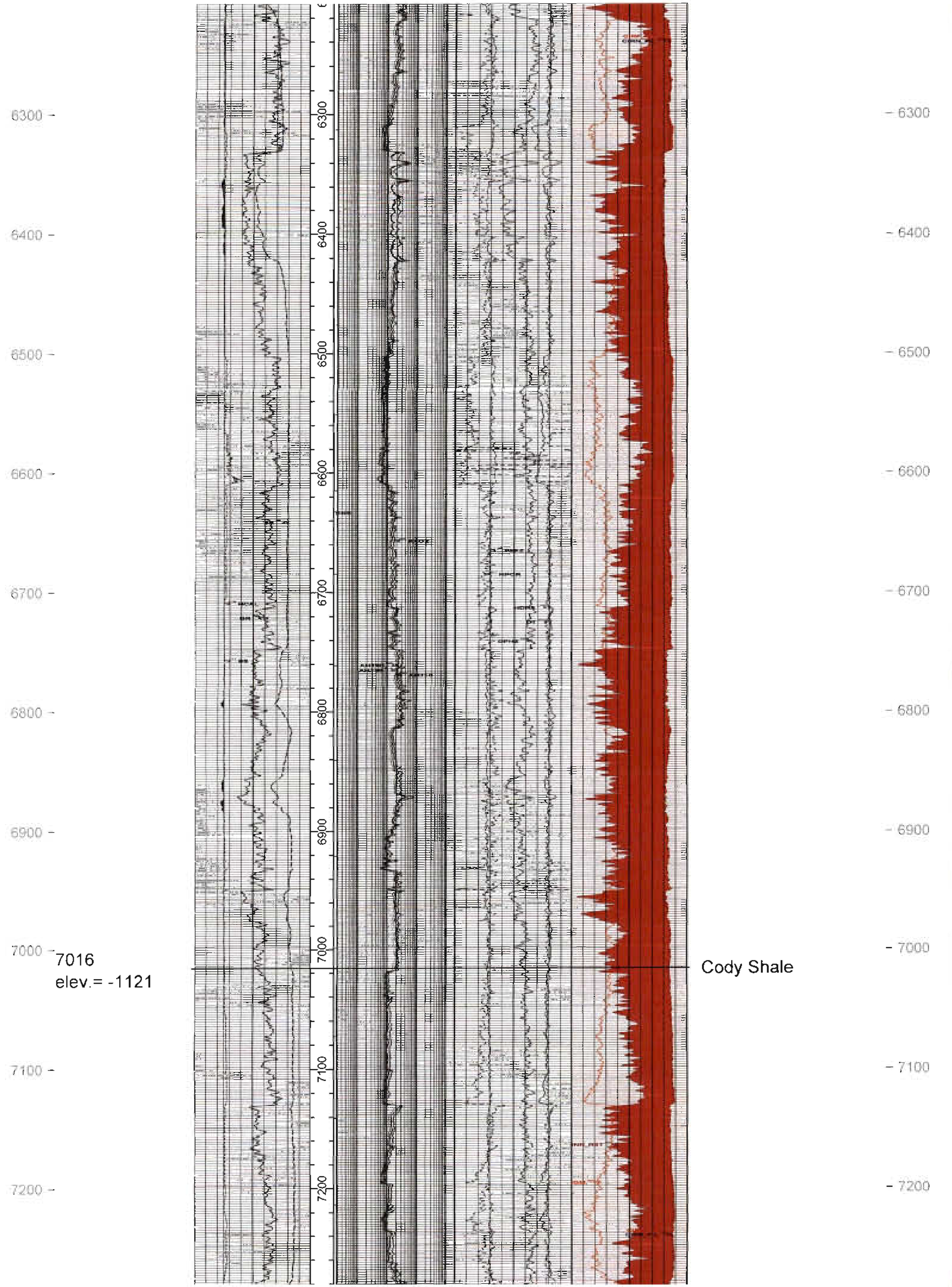

3000
3100
3200
3210
elev.= 2685
3300
3400
3500
3600
3700
3800
3900
Lance Fm

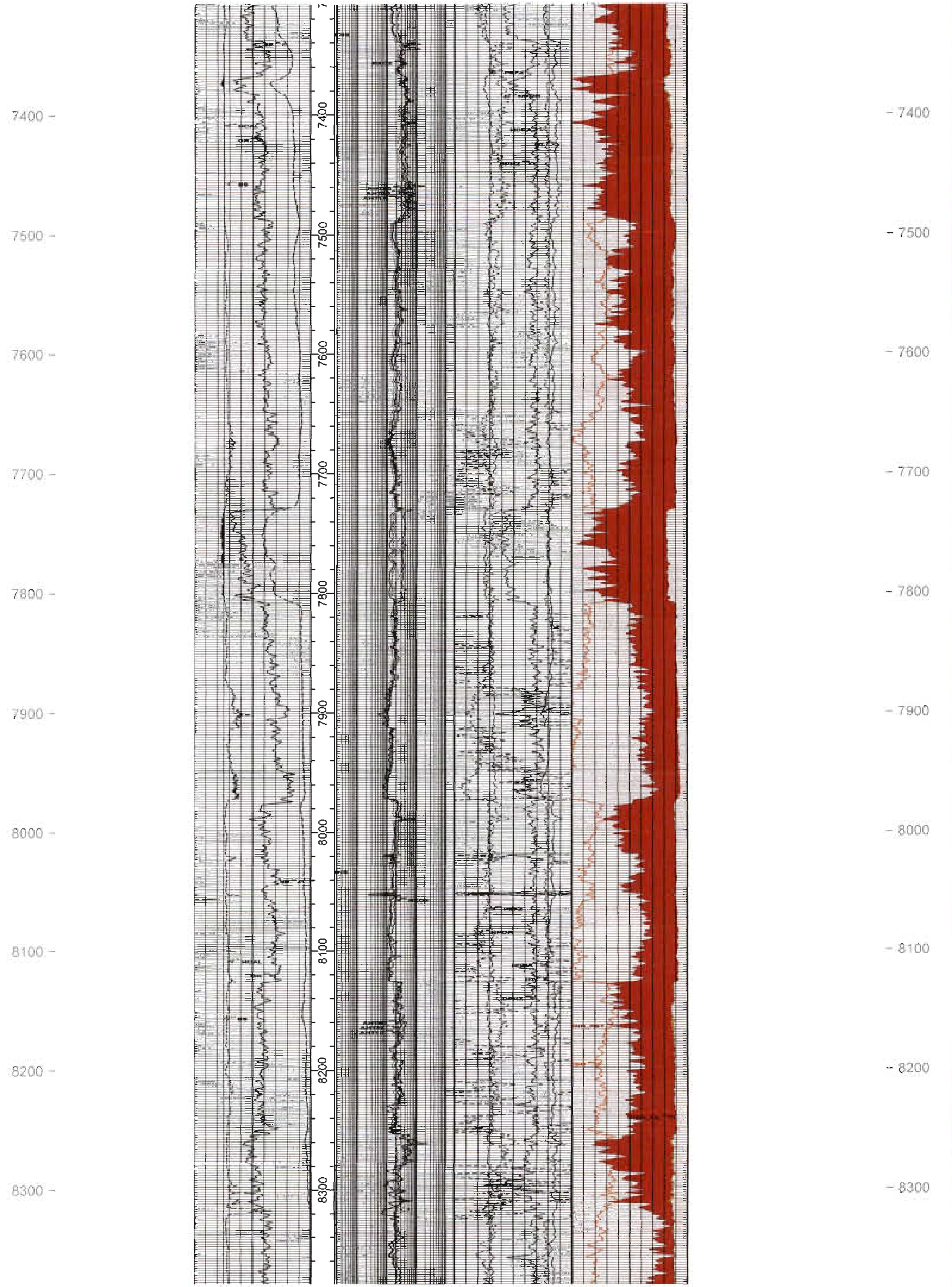


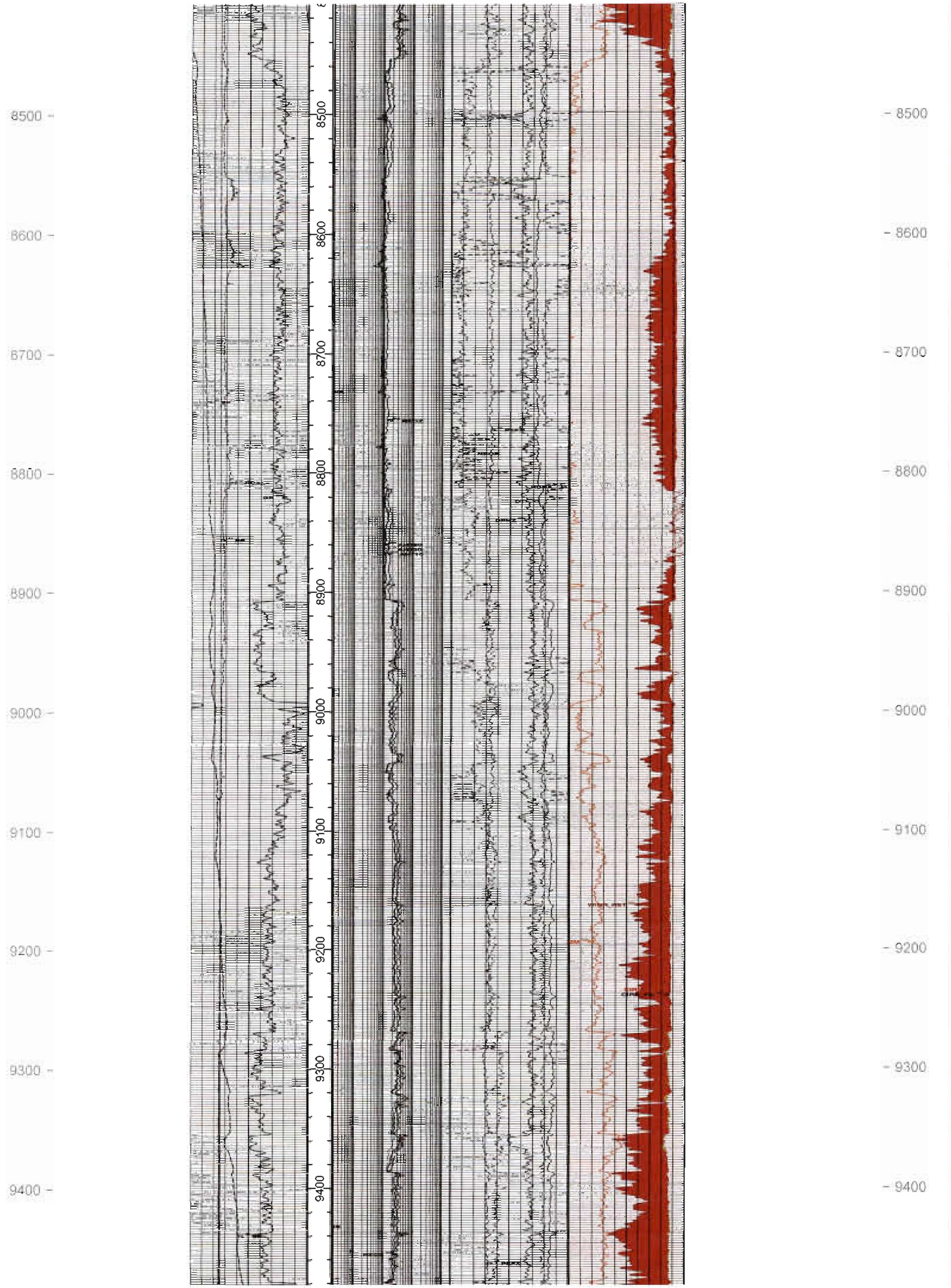
4100
4200
4300
4400
4473
elev.= 1422
Meeteetse Fm
4500
4600
4700
4800
4900
5000

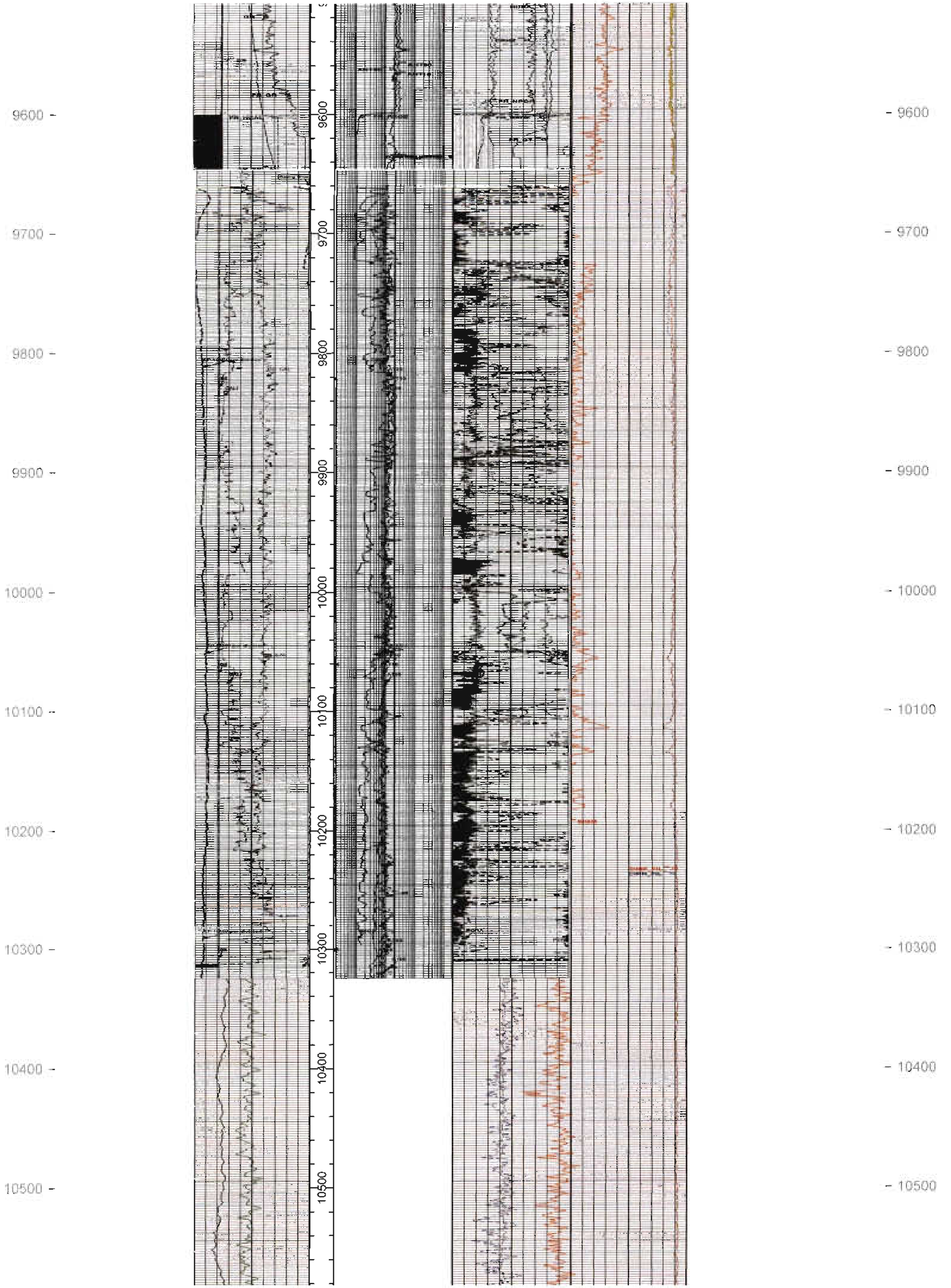


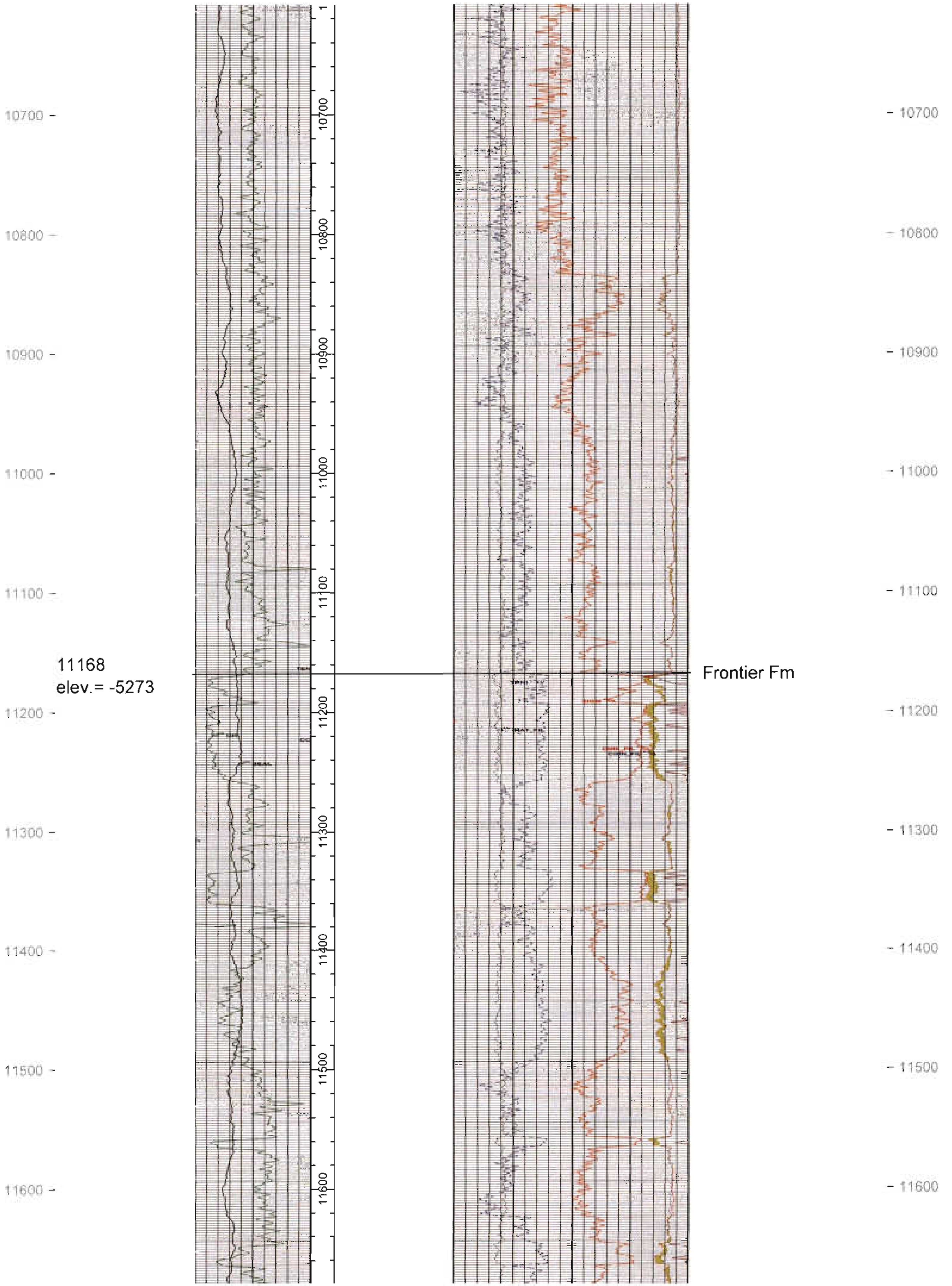
5200
5300
5400
5500
5600
5700
5800
5900
6000
6100
5818
elev.= 77
Mesaverde Fm

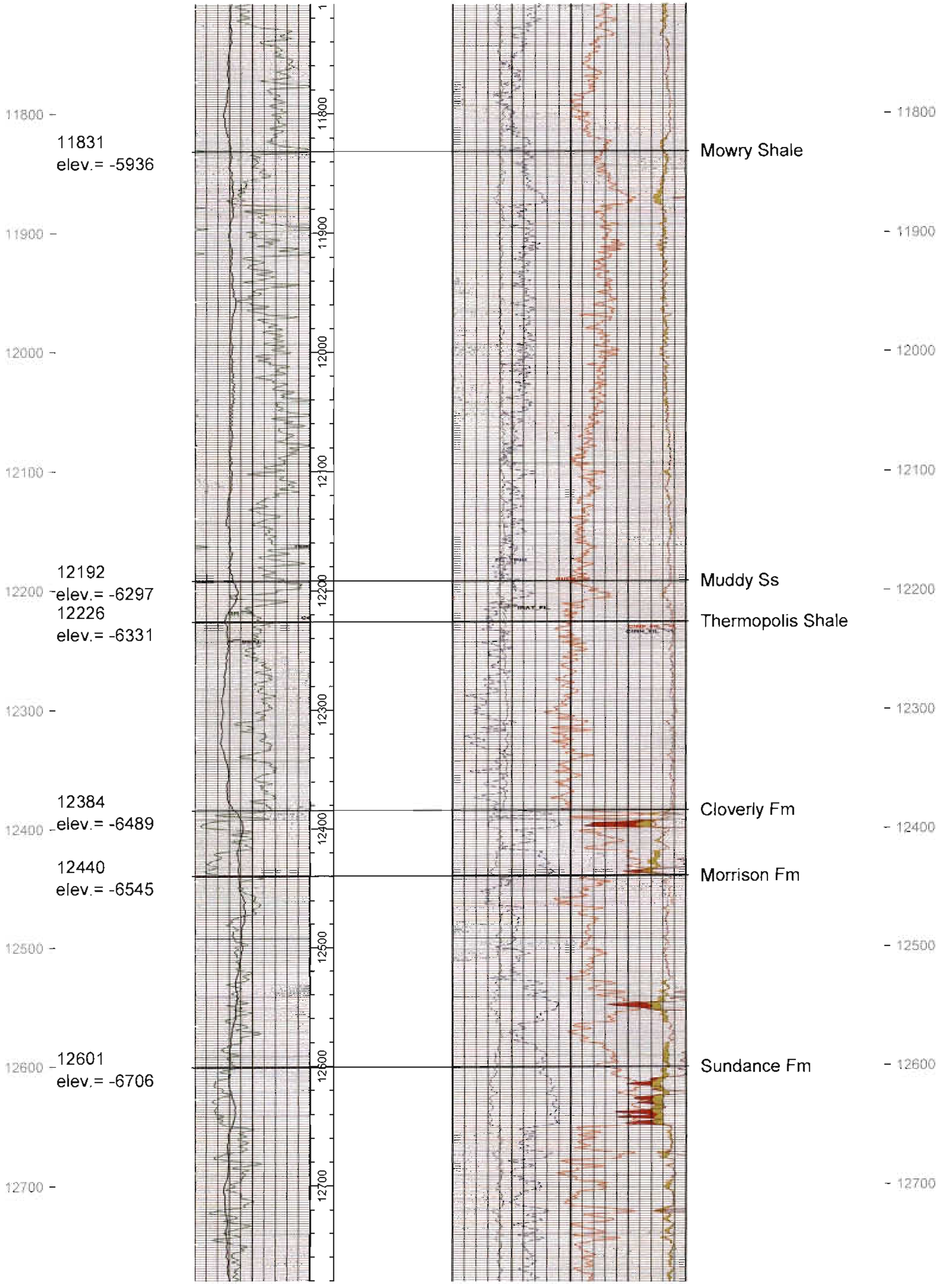

6300
6400
6500
6600
6700
6800
6900
7000
7016
elev.= -1121
Cody Shale
7100
7200

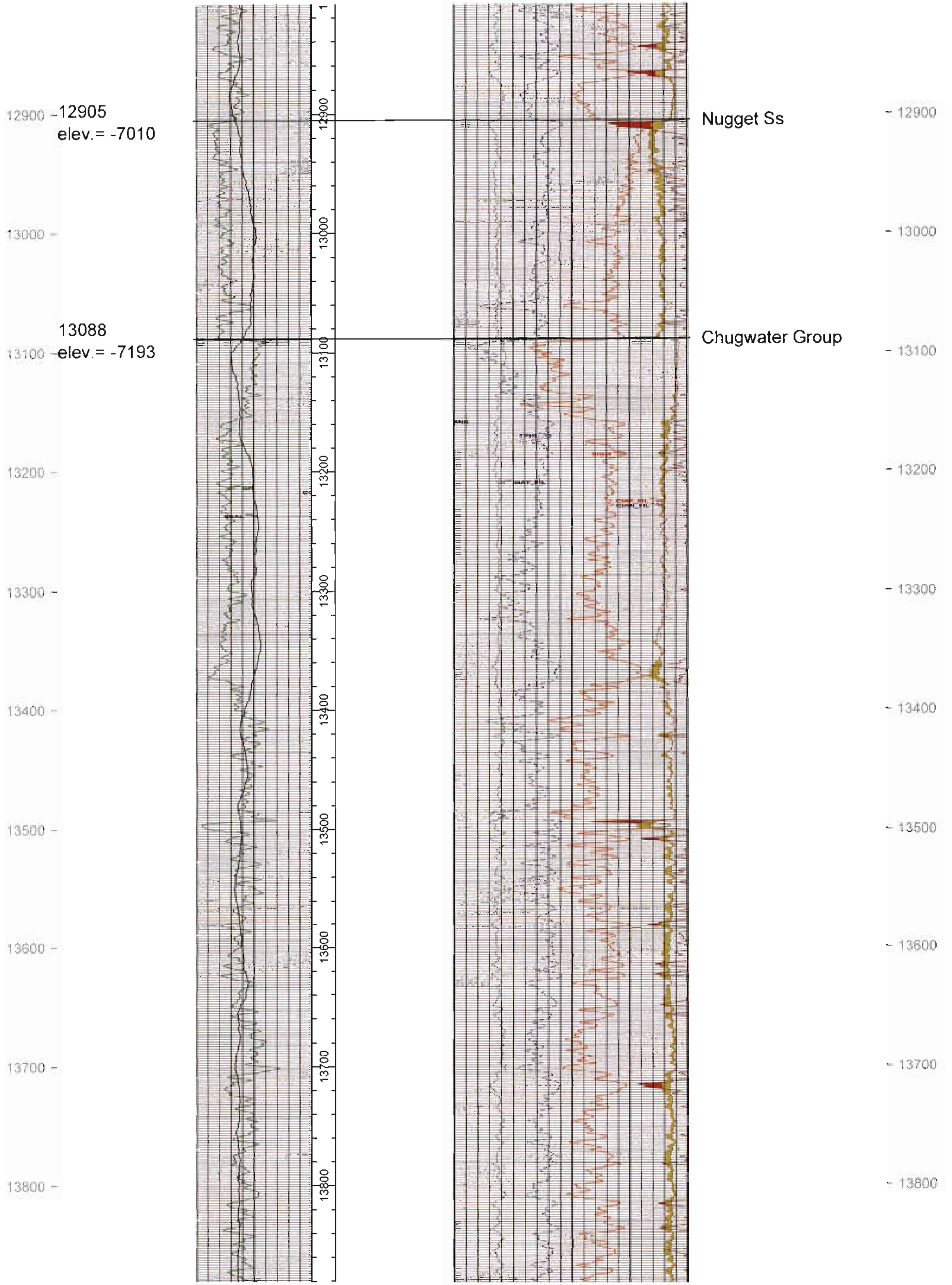

7400
7500
7600
7700
7800
7900
8000
8100
8200
8300

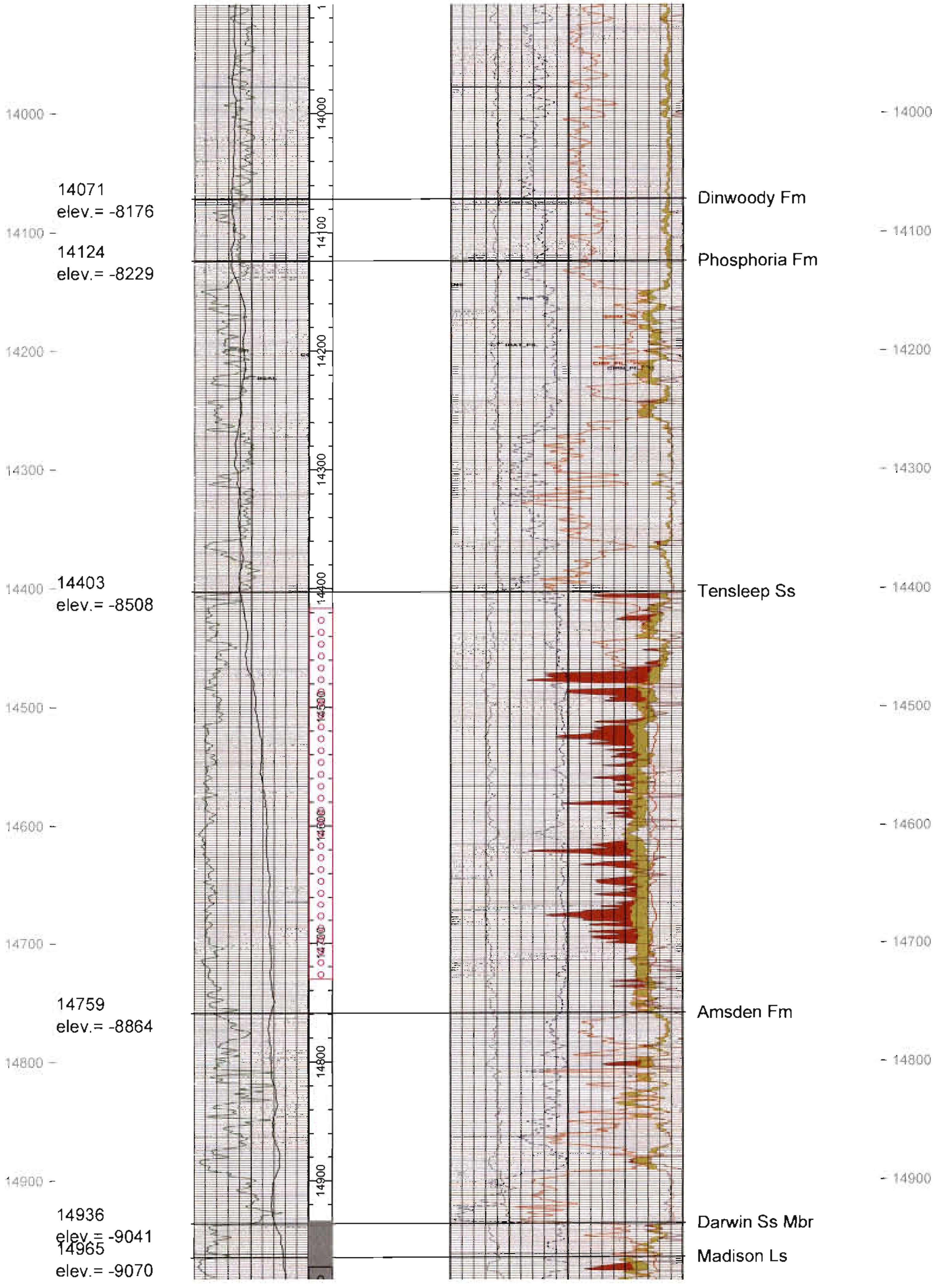

8500
8600
8700
8800
8900
9000
9100
9200
9300
9400


9600
9700
9800
9900
10000
10100
10200
10300
10400
10500

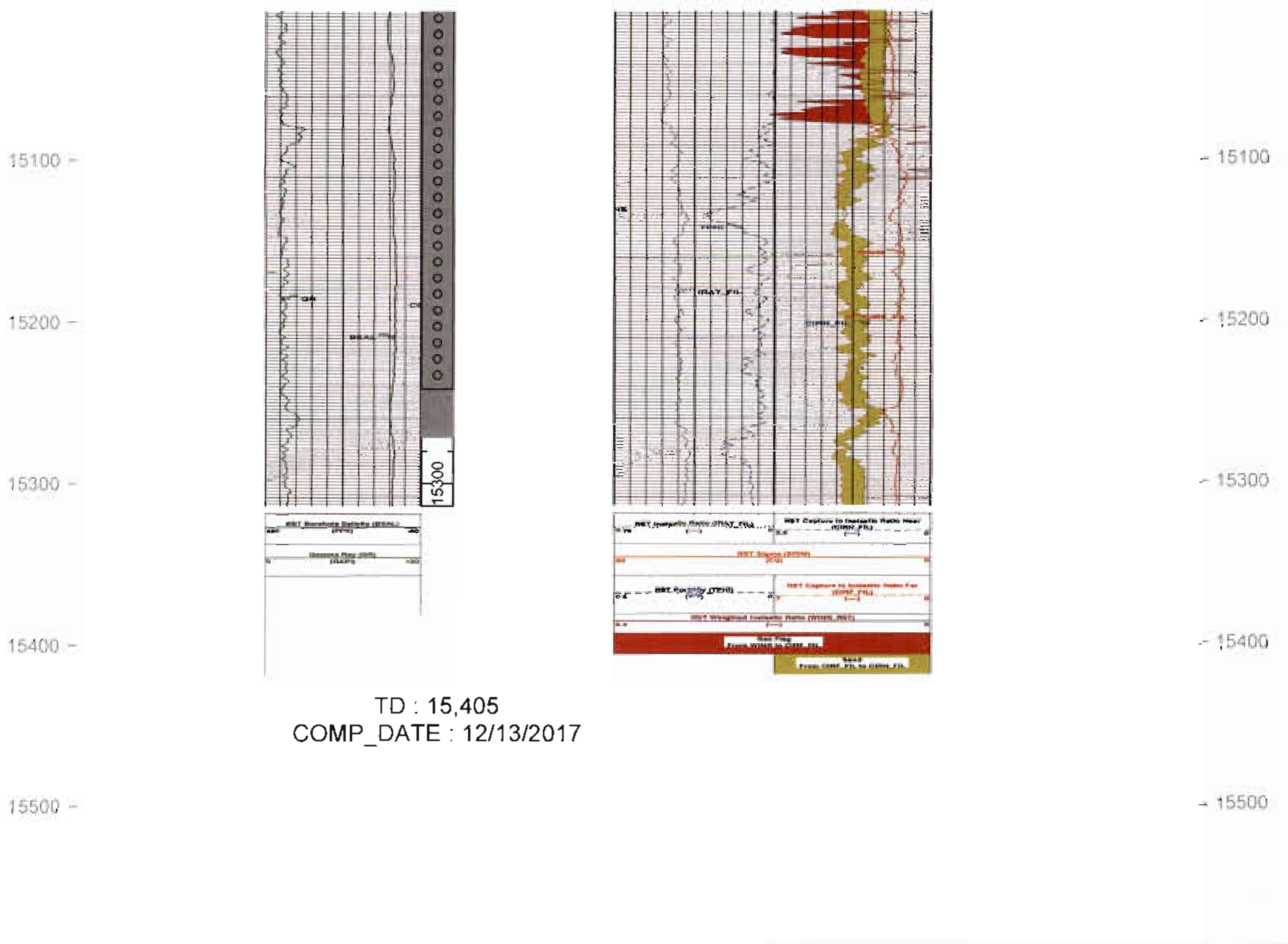

10700
10800
10900
11000
11100
11168
elev.= -5273
11200
11300
11400
11500
11600
Frontier Fm

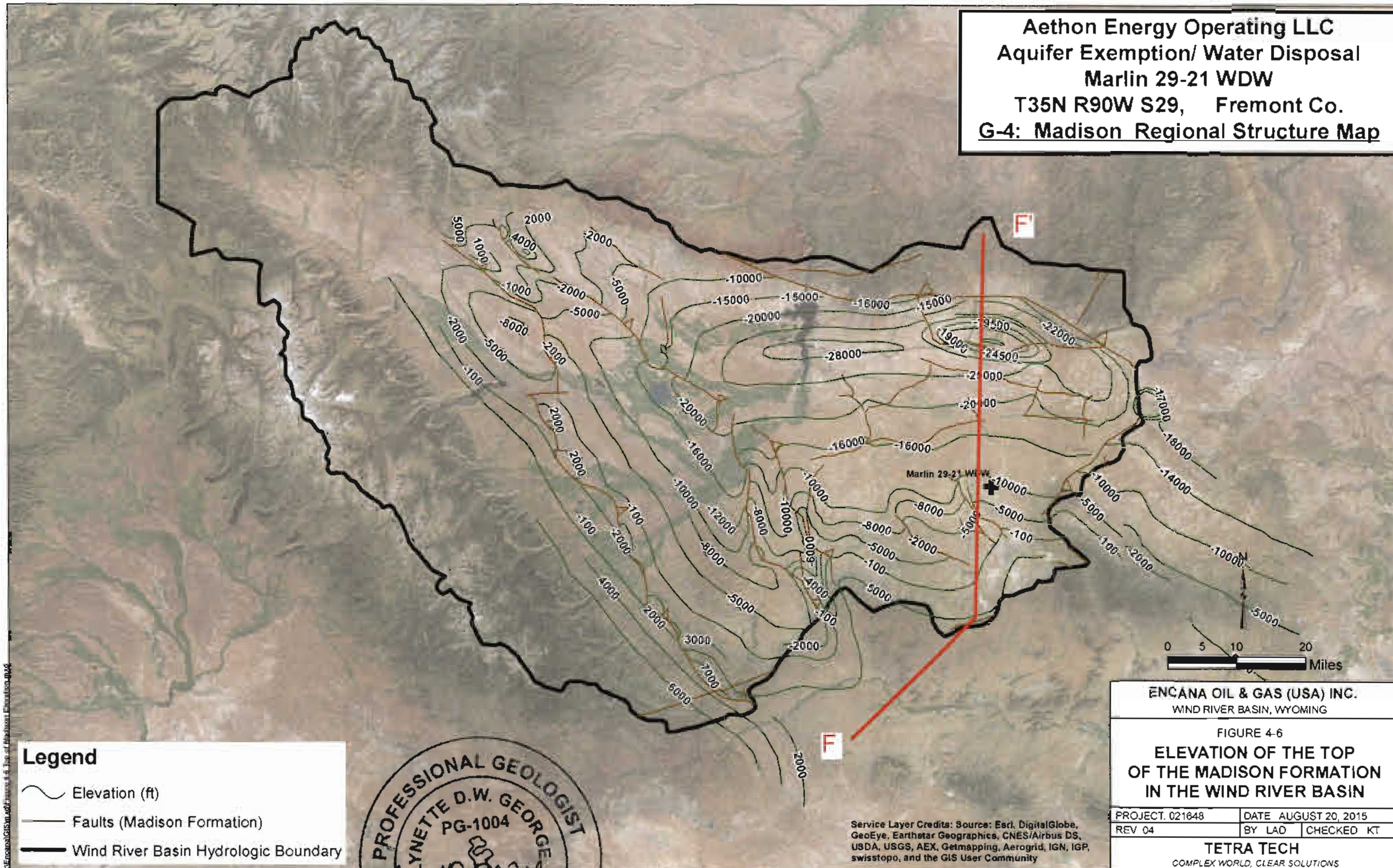

11800
11831
elev.= -5936
Mowry Shale
11900
12000
12100
12192
elev.= -6297
Muddy Ss
12200
12226
elev.= -6331
Thermopolis Shale
12300
12384
elev.= -6489
Cloverly Fm
12400
12440
elev.= -6545
Morrison Fm
12500
12601
elev.= -6706
Sundance Fm
12600
12700


12905
elev.= -7010
13088
elev.= -7193
Nugget Ss
Chugwater Group
12900
13000
13100
13200
13300
13400
13500
13600
13700
13800



14000
14071
elev.= -8176
Dinwoody Fm
14100
14124
elev.= -8229
Phosphoria Fm
14200
14300
14403
elev.= -8508
Tensleep Ss
14400
14500
14600
14700
14759
elev.= -8864
Amsden Fm
14800
14900
14936
elev.= -9041
Darwin Ss Mbr
14965
elev.= -9070
Madison Ls


15100
15200
15300
15400
15500
15300
TD : 15,405
COMP_DATE : 12/13/2017
15100
15200
15300
15400
15500

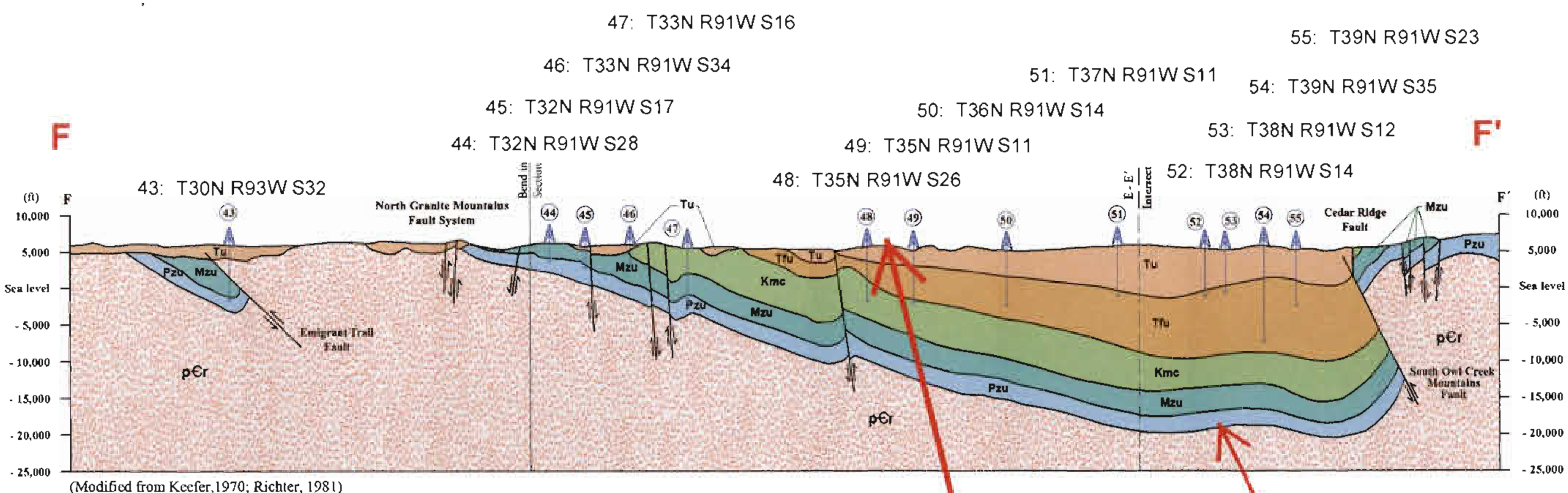


PROFESSIONAL GEOLOGIST
LYNETTE D.W. GEORGE
PG-1004
WYOMING

Lynette D.W. George
8-13-2020

Aethon Energy Operating LLC
Aquifer Exemption/Water Disposal
Marlin 29-21 WDW, Fremont Co.

G-5: Cross Section F-F'



(Modified from Keefer,1970; Richter, 1981)

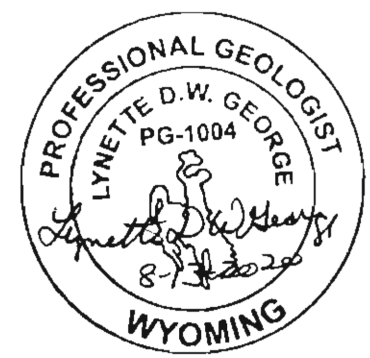
from Geologic cross sections, Wind/Bighorn River Basin, Wyoming
Complied by S. Quillianan, J. Rodgers, and D. Copeland, 2012,
Wyoming State Geological Survey

Approximate location of the Marlin 29-21 WDW

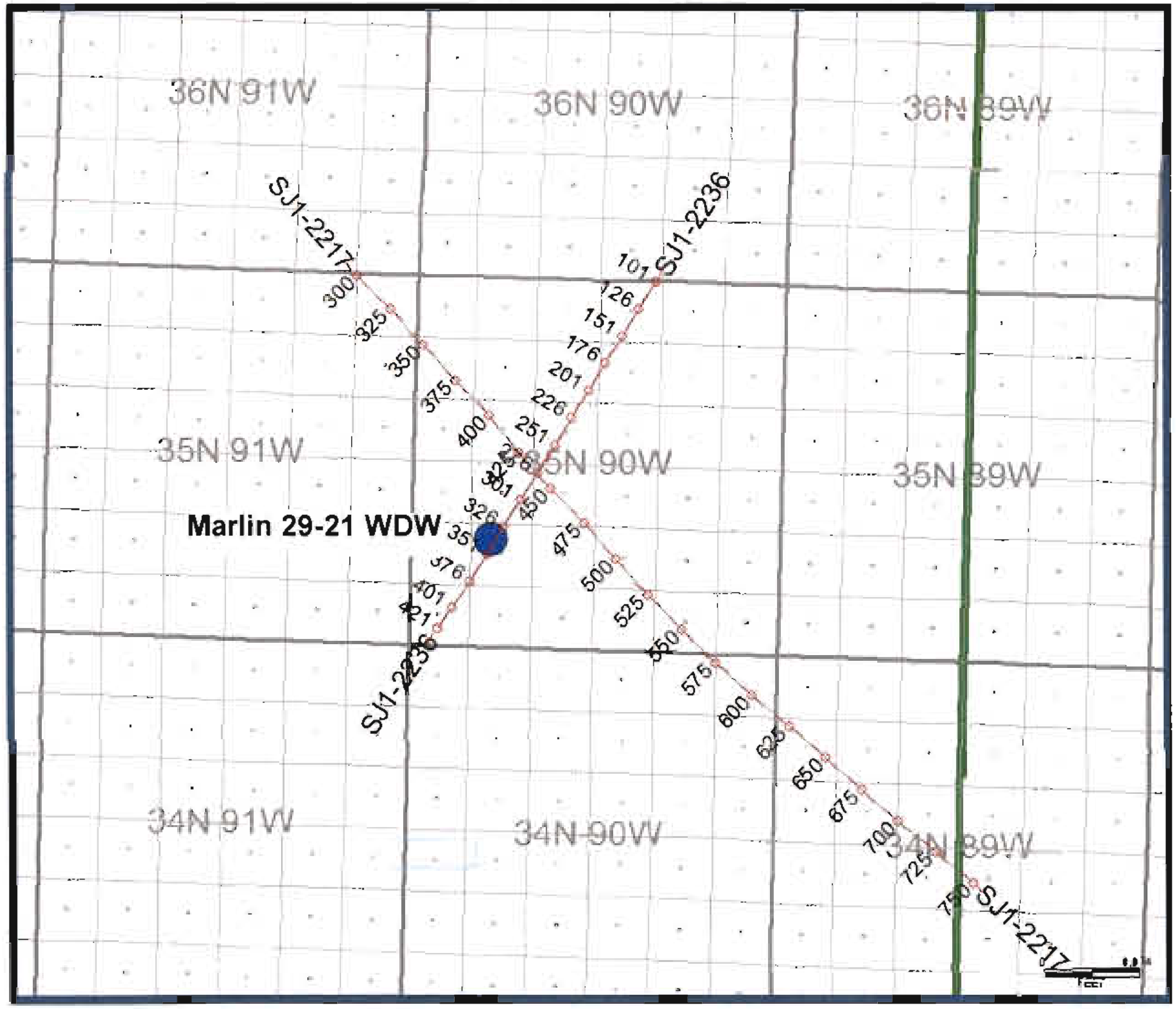
Madison Fm. is included in the blue unit, Pzu

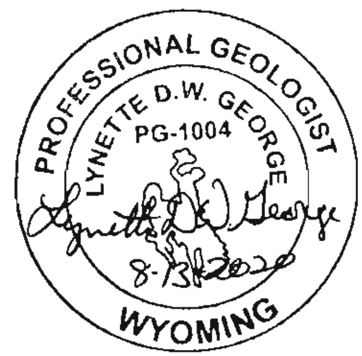
KEY

Tu -- Tertiary rocks undivided
Tfu -- Fort Union Fm.
Kmc -- Meeteetse, Mesaverde and Cody Fm. undivided
Mzu -- Mesozoic rocks undivided
Pzu -- Paleozoic rocks undivided
pCr -- Precambrian igneous and metamorphic rocks



Aethon Energy Operating LLC
Aquifer Exemption/ Water Disposal
Marlin 29-21 WDW
T35N R90W S29, Fremont Co.
G-6: Seismic Line Locations



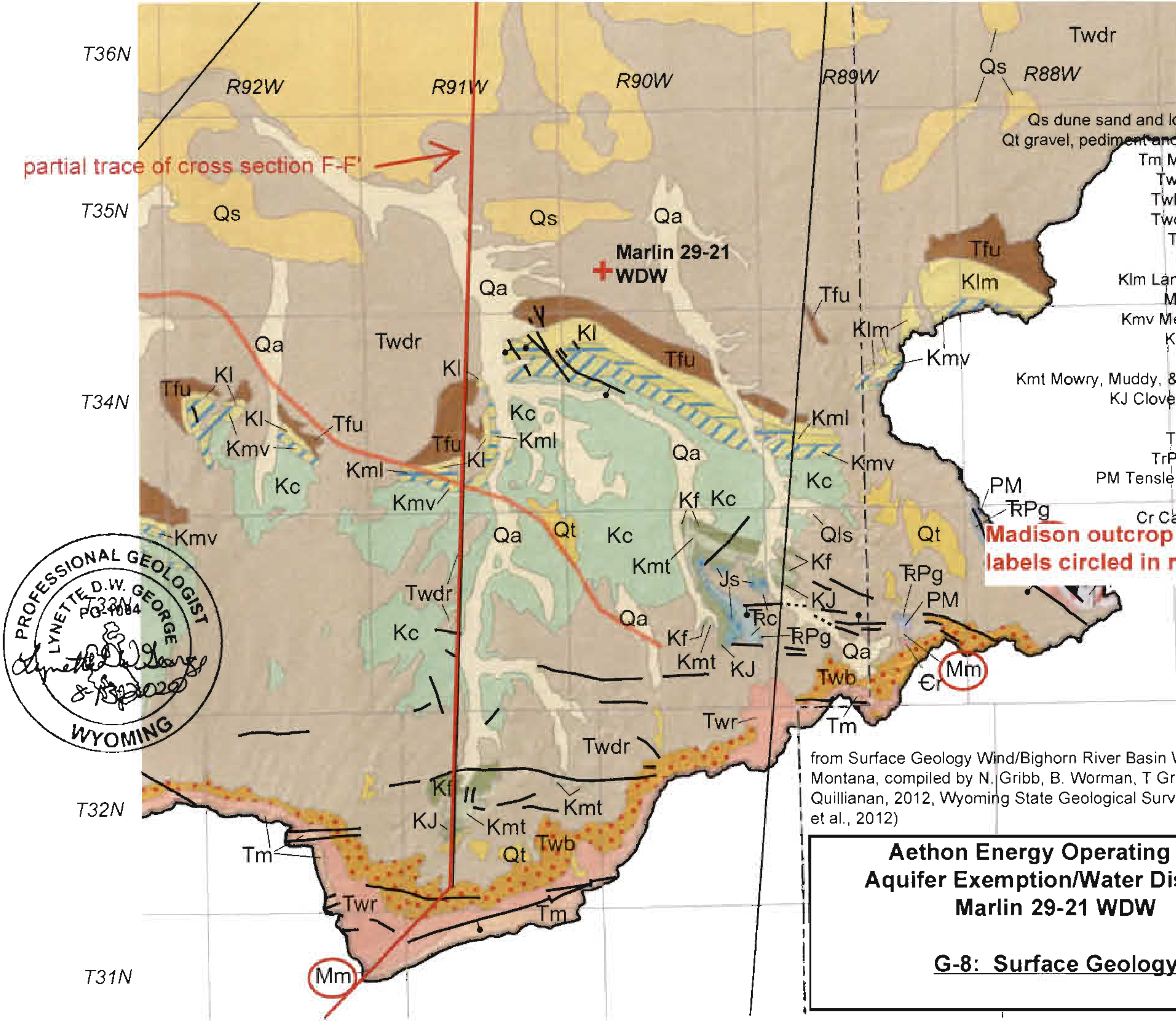


Lithostratigraphic and Hydrogeologic Units of the Wind River Basin plus Tops Picked in the Marlin 29-21 WDW

ERA	System	Series	Lithostratigraphic Units of Love et al. (1993)	Thickness (ft.)	Hydrogeologic Units	Depths at Marlin 29-21: depth (TVD)	elevation	thick-ness	formation
CENOZOIC	Quaternary	Holocene and Pleistocene	Alluvium, terrace deposits, landslide deposits, dune sand (eolian) deposits, and glacial deposits	0 – 10+	Quaternary unconsolidated- deposit aquifers				
	Tertiary	Miocene	Split Rock Formation	0 – 3,000	Split Rock aquifer	*absent*			
		Oligocene							
			White River Formation	0 – 800	White River aquifer	*absent*			
		Eocene	Tepee Trail Fm / Wagon Bed Fm	0 – 2,500 / 0 – 700	Aycross–Wagon Bed confining unit	*absent*			
			Aycross Fm			*absent*			
			Wind River Formation	0 – 9,000	Wind River aquifer	at surface	5,881		5,895 KB
			Indian Meadows Fm		Indian Meadows confining unit				
		Paleocene	Fort Union Fm: Shotgun Mbr / Waltman Shale Mbr	0 – 8,000	Fort Union aquifer; Fort Union – Lance aquifer	top of Fort Union not picked			
			Fort Union Fm: Lower unnamed mbr			2,433	3,462	777	Lower Fort Union
MESOZOIC	Cretaceous	Upper Cretaceous	Lance Formation	0 – 6,000	Lance aquifer	3,210	2,685	1,263	Lance
			Meeteetse Fm / Lewis Shale	0 – 1,335 / 0 - 550	Meeteetse–Lewis confining unit	4,473	1,422	1,345	Meeteetse
			Mesaverde Fm: Teapot Sandstone Mbr	700 – 2,000	Teapot Sandstone aquifer; Mesaverde aquifer	5,818	77	1,198	Mesaverde
			Mesaverde Fm: Middle unnamed mbr		Middle confining unit				
			Mesaverde Fm: Parkman Ss Mbr		Parkman Ss aquifer				
			Mesaverde Fm: Wallace Creek Tongue of Cody Shale		Confining unit				
			Mesaverde Fm: Fales Ss Member		Fales Ss aquifer				
			Cody Shale	3,000 – 5,000	Cody confining unit	7,016	-1,121	4,152	Cody
			Frontier Formation	600 – 1,000	Frontier aquifer; Basal regional confining unit; Lower and middle Mesozoic aquifers and confining units	11,168	-5,273	663	Frontier
			Mowry Shale	250 – 700	Mowry confining unit; Mowry–Thermopolis confining unit	11,831	-5,936	361	Mowry
		Lower Cretaceous	Muddy Sandstone	125 – 250	Muddy Ss aquifer	12,192	-6,297	34	Muddy
			Thermopolis Shale		Thermopolis confining unit	12,226	-6,331	158	Thermopolis
			"Dakota Sandstone" Cloverly Formation "Fuson Shale" "Lakota Sandstone"	200 - 700	Cloverly aquifer	12,384	-6,489	56	Cloverly
	Jurassic	Upper Jurassic	Morrison Formation		Morrison confining unit	12,440	-6,545	161	Morrison
			Sundance Formation	200 – 550	Sundance aquifer; Sundance–Nugget aquifer	12,601	-6,706	304	Sundance
		Middle Jurassic	Gypsum Spring Formation	0 – 250	Gypsum Spring confining unit	absent			Gypsum Spring
	Jurassic(?) and Triassic(?)		Nugget Sandstone	0 – 500	Nugget aquifer	12,905	-7,010	183	Nugget

ERA	System and Series		Lithostratigraphic Units of Love et al. (1993)			Thickness (ft.)		Hydrogeologic Units			Depths at Marlin 29-21			
	Triassic	Upper Triassic	Chugwater Grp or Fm	Popo Agie Fm or Mbr		1,000 – 1,300		Popo Agie confining unit	Chugwater aquifer and confining unit	Lower and middle Mesozoic aquifers and confining units	13,088	-7,193	983	Chugwater
				Crow Mountain Ss or Ss Mbr				Crow Mountain aquifer						
		Lower Triassic		Alcova Ls or Ls Mbr				Alcova confining unit						
				Red Peak Fm or Mbr				Red Peak aquifer						
			Dinwoody Formation		Goose Egg Formation	50 – 200	350 - 380	Dinwoody confining unit	Goose Egg aquifer and confining unit	Goose Egg – Phosphoria aquifer and confining unit	14,071	-8,176	53	Dinwoody
PALEOZOIC	Permian		Phosphoria Formation			200 – 400		Phosphoria aquifer and confining unit			14,124	-8,229	279	Phosphoria
	Pennsylvanian	Upper Pennsylvanian	Tensleep Sandstone			200 – 600		Tensleep aquifer	Paleozoic aquifer system		14,403	-8,508	356	Tensleep
		Middle Pennsylvanian												
		Lower Pennsylvanian	Amsden Formation		Ranchester Ls Mbr	0 – 400		Amsden aquifer			14,759	-8,864	88	Amsden
					Horseshoe Shale Mbr						14,847	-8,952	89	
	Mississippian	Upper Mississippian			Darwin Ss Mbr						14,936	-9,041	30	
		Lower Mississippian	Madison Limestone			300 – 700		Madison aquifer			14,965	-9,071	359	Madison
	Devonian	Upper Devonian	Darby Formation			0 – 300		Darby aquifer			*absent*			
	Ordovician	Upper Ordovician	Bighorn Dolomite			0 – 300		Bighorn aquifer			*absent*			
		Middle Ordovician												
	Cambrian	Upper Cambrian	Gallatin Limestone			0 – 365		Gallatin confining unit	Gallatin–Gros Ventre confining unit		15,324	-9430		Gallatin
		Middle Cambrian	Gros Ventre Formation			0 – 700		Gros Ventre confining unit			*not penetrated*			
			Flathead Sandstone			50 – 500		Flathead aquifer						
	Precambrian		Precambrian rocks					Precambrian basal confining unit						

PROFESSIONAL GEOLOGIST
LYNETTE D.W. GEORGE
PG-1004
WYOMING
Lynette D.W. George
8-13-2020



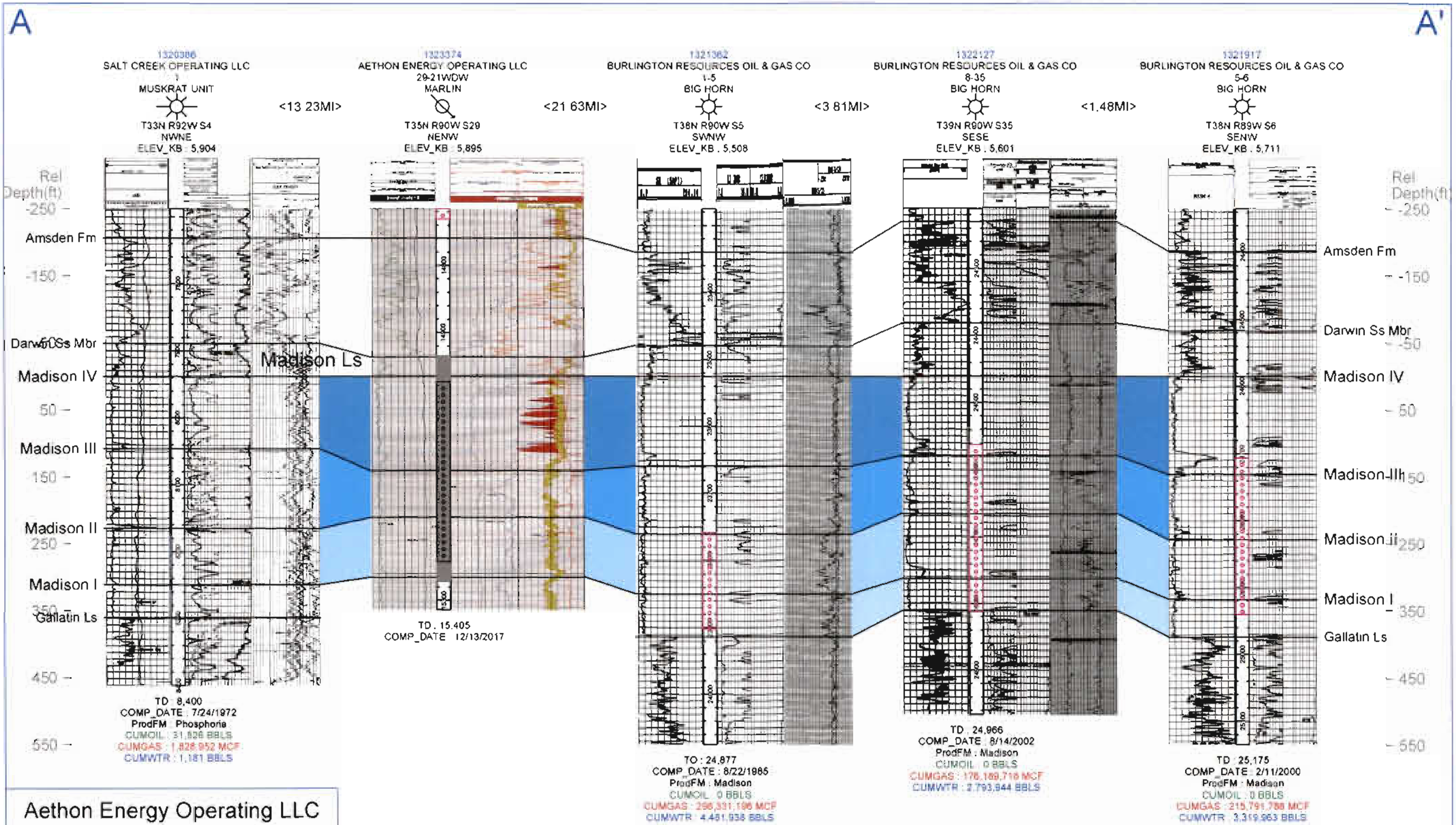
Key

Qa alluvium
Qs dune sand and loess deposits
Qt gravel, pediment and fan deposits
Tm Miocene rocks
Twr White River
Twb Wagon Bed
Twdr Wind River
Tfu Fort Union
Kl Lance Fm.
Klm Lance, Fox Hills, Meeteetse Fm.
Kmv Mesaverde Fm.
Kc Cody Shale
Kf Frontier
Kmt Mowry, Muddy, & Thermopolis
KJ Clovery & Morrison
Js Sundance
Trc Chugwater
TrPg Goose Egg
PM Tensleep & Amsden
Mm Madison
Cr Cambrian rocks

from Surface Geology Wind/Bighorn River Basin Wyoming and Montana, compiled by N. Gribb, B. Worman, T Gracias, and S. Quillianan, 2012, Wyoming State Geological Survey (Taucher, P., et al., 2012)

Aethon Energy Operating LLC
Aquifer Exemption/Water Disposal
Marlin 29-21 WDW

G-8: Surface Geology



Aethon Energy Operating LLC

Aquifer Exemption/Water Disposal

Marlin 29-21 WDW

T35N R90W S29, Fremont County

G-9: Madison Cross-section A-A'

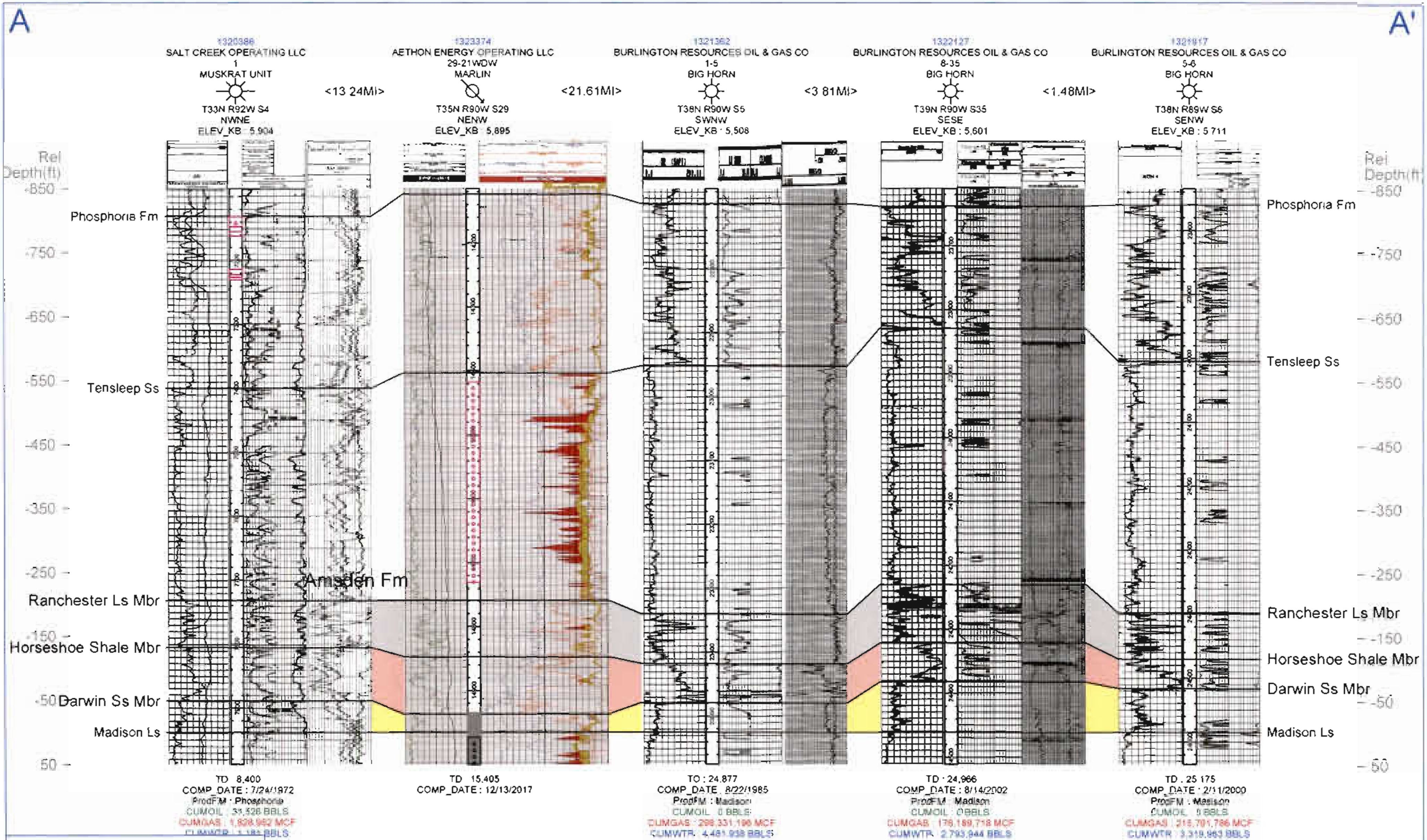
Datum: top of Madison
Logs displayed with TVD
Madison subdivisions from Westphal et al., 2004

By: Lyn George, Consulting Geologist

July 27,2020 1:25 PM

PETRA 7/27/2020 1:25:44 PM (MadisonCorr.CSP)

PROFESSIONAL GEOLOGIST
LYNETTE D.W. GEORGE
PG-1004
Lynette D.W. George
8-7-2020
WYOMING



Aethon Energy Operating LLC

Aquifer Exemption/Water Disposal

Marlin 29-21 WDW

T35N R90W S29, Fremont County

G-10: Amsden Cross-section A-A'

Datum: top of Madison
Logs displays as TVD

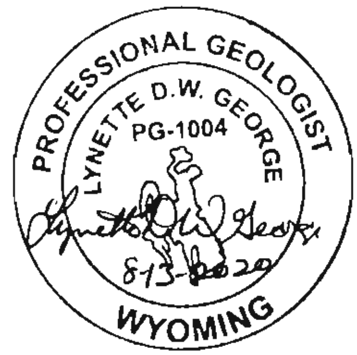
By: Lyn George, Consulting Geologist

July 27, 2020 1:21 PM

PETRA 7/27/2020 1:21:58 PM (AmsdenCon.CSP)

PROFESSIONAL GEOLOGIST
LYNETTE D.W. GEORGE
PG-1004
WYOMING
8-3-2020

Aethon Energy Operating LLC
Aquifer Exemption/ Water Disposal
Marlin 29-21 WDW
T35N R90W S29, Fremont Co.
G-11 RST Advisor Log



Schlumberger RST Advisor

COMPANY:	Encana Oil & Gas	COMPANY:	Encana Oil & Gas
WELL:	Marlin 29-21 WDW	WELL:	Marlin 29-21 WDW
FIELD:	Frenchie Draw	FIELD:	Frenchie Draw
COUNTY:	Fremont	COUNTY	Fremont
STATE:	Wyoming	STATE:	Wyoming
COUNTRY:	USA	COUNTRY:	USA

Location: API No: 49-013-233374
Field: SHL 660' FNL & 1980' FEL
Section: 29 Township: 35 N Range: 90 W
Latitude: 42 Longitude: -107

Other Services: SLIM CEMENT MAPPING TOOL

Permanent Datum:	GL	Elev.: 5880.6 ft	Elevations:
Log Measured From:	KB	% Well.APD% ft above Perm. Datum	K.B. 5894 ft
Drilling Measured from:	KB		D.F. 5894 ft
			G.L. 5880.6 ft

Date	26-Mar-2012	Type of fluid in hole	WATER
Run no.	Two	Dens. / Visc.	10.9 lbm/gal / -999.25 s
Depth Driller	11091 ft	pH / Fluid Loss	9.1 / -999.25
Depth Logger (Schl)	10400 ft	Source of Sample	Active Tank
Bottom Log Interval	10402 ft	Rm @ Meas. Temp.	0.2 ohm.m @ 68 degF
Top Log Interval	9664 ft	Rmf @ Meas. Temp.	0.15 ohm.m @ 68 degF
Casing Size	7 in	Rmc @ Meas. Temp.	
Casing Logger	9666 ft	Rm @ BHT	0.0683549 ohm.m @ -999.25 degF
Bit Size	6.125 in	Recorded by	
Maximum recorded temperature	-999.25 degF	Witnessed by	Victor Steier/ Phil Littlefield
Circulation Stopped	18:30:00	Logger on bottom	09:30:16

FOLD HERE. The well name, location and borehole reference data were furnished by the customer.

Svc. Order #: BJJ8-00125 Location: Midland	DP Vers: 20C0-999 Baseline: Techlog 2013.1	Processed by: LUJAN	Process Date: 4/13/2020

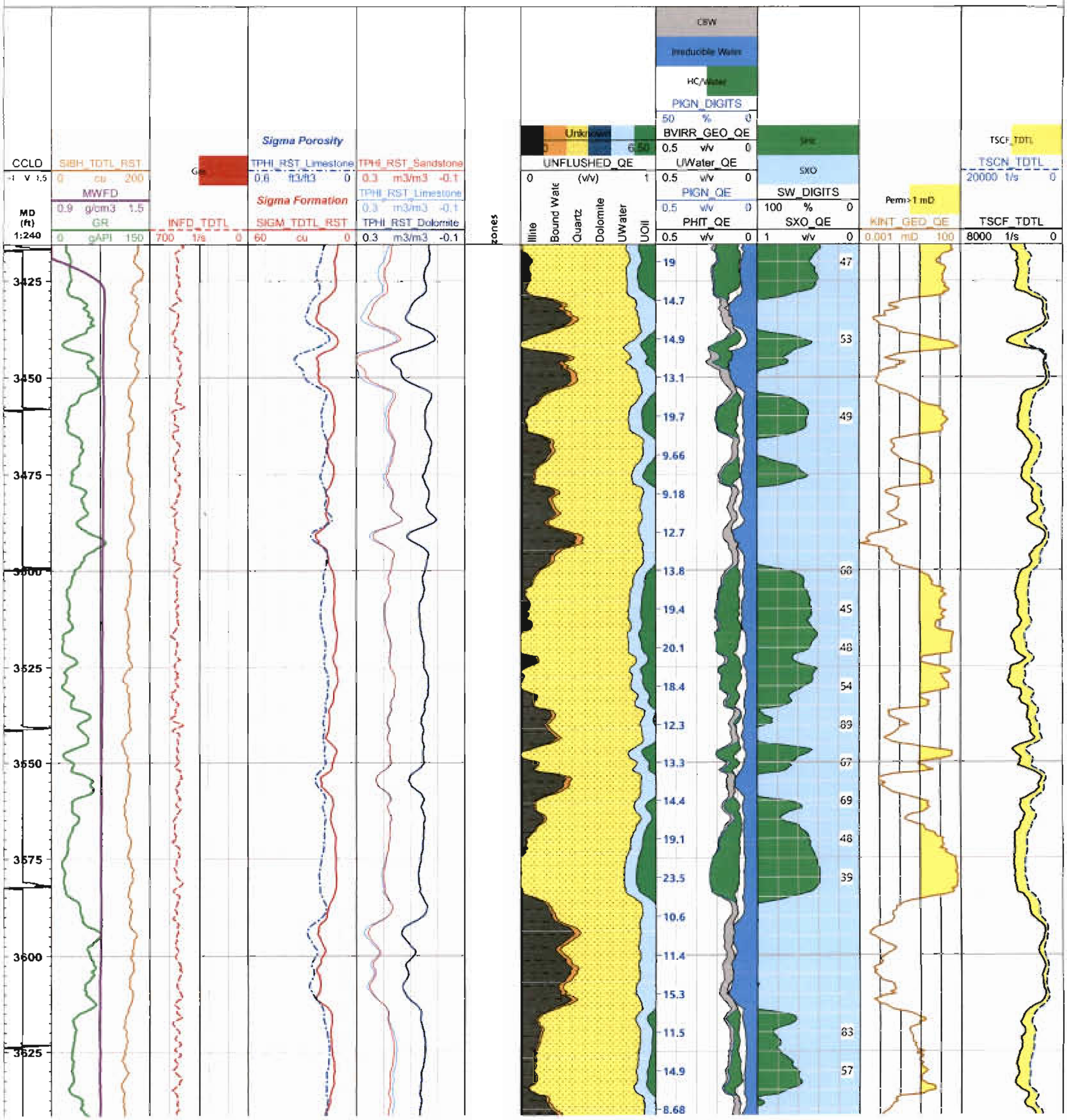
Remarks:

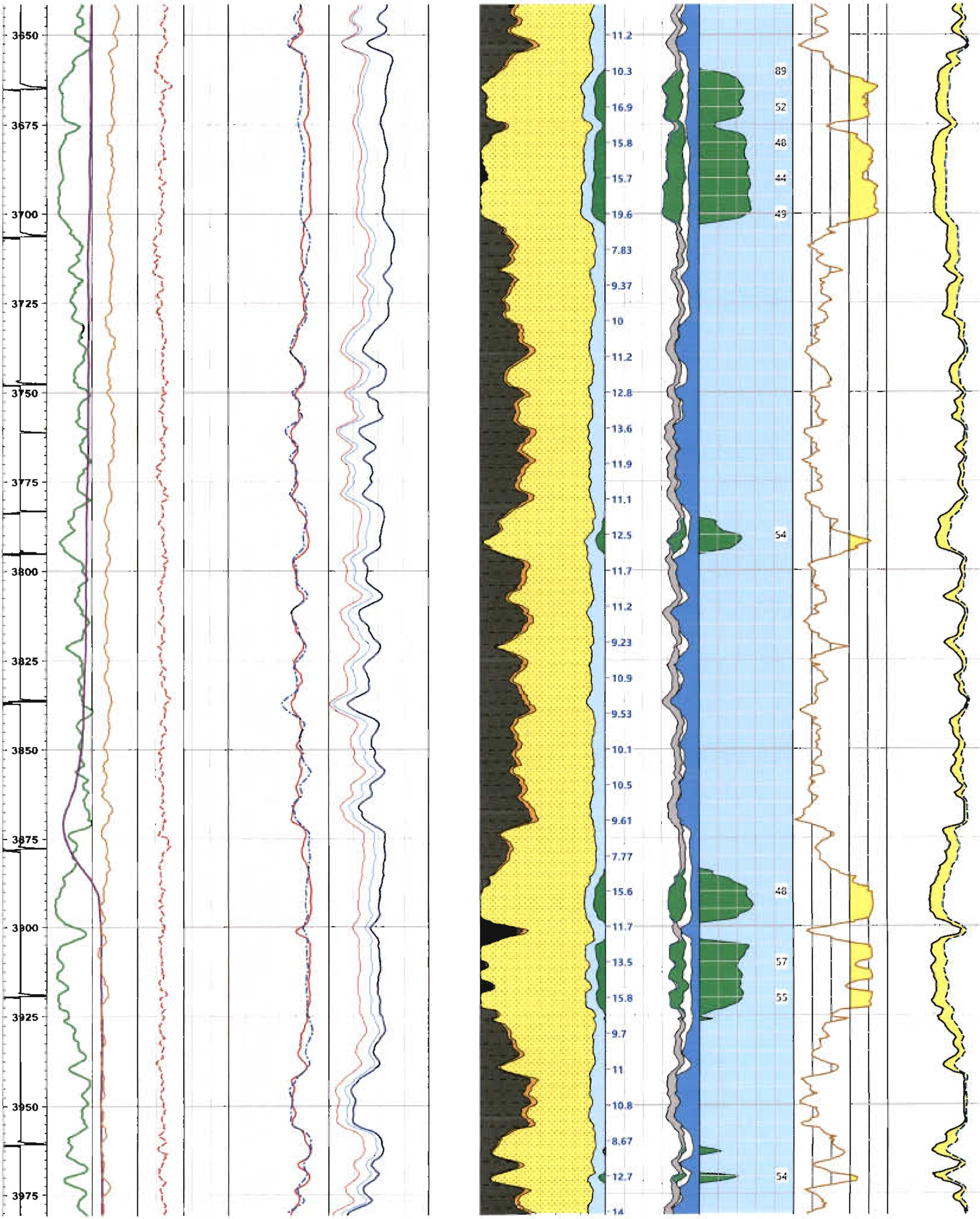
Sigma Water= 80
Sigma HC=17

Well: **Marlin 29-21 WDW**

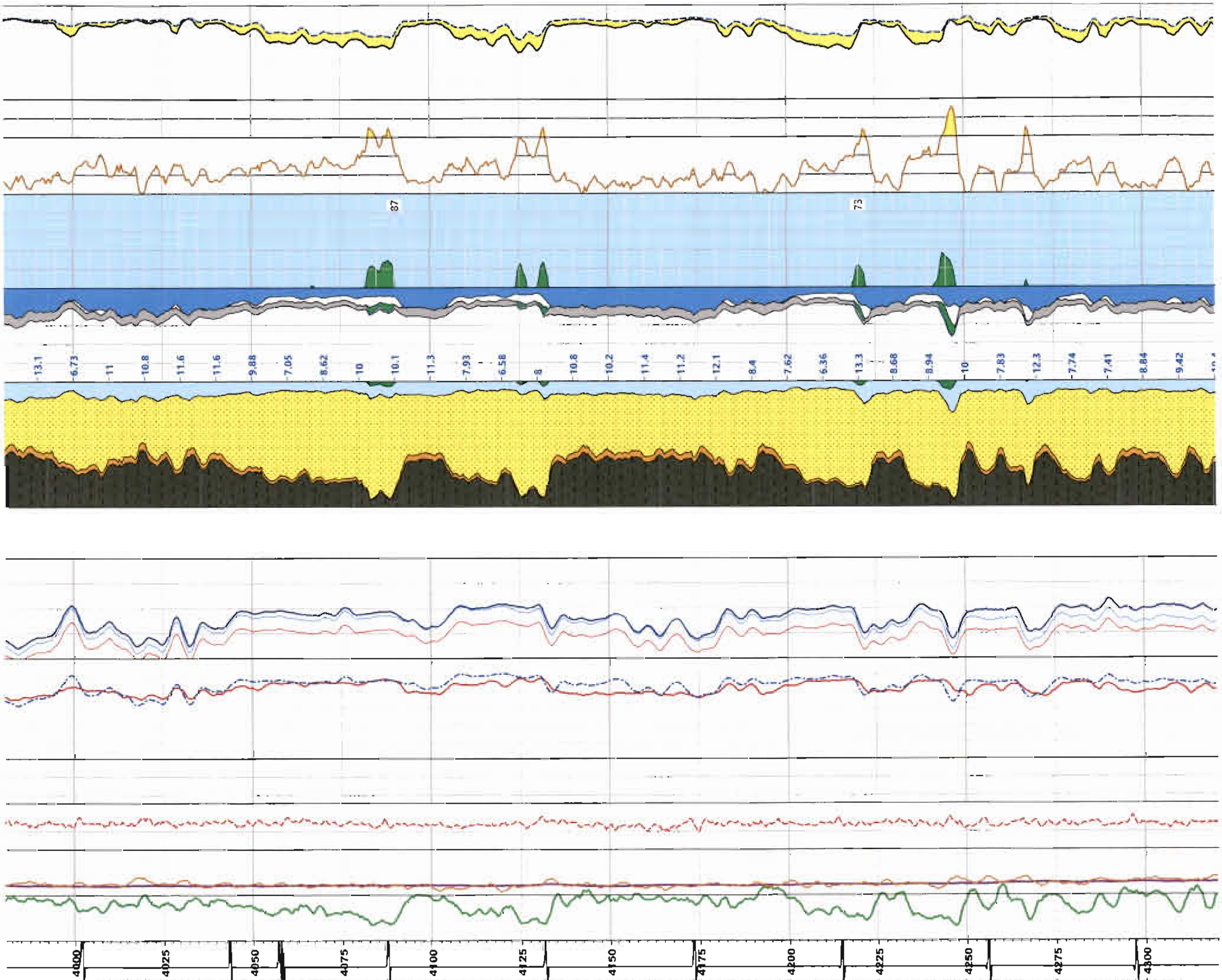
UWI:	Elevation:	X:	SPUD date:	Country: **USA**
Short name:	Elevation datum:	Y:	Completion date:	Field: **Frenchie Draw**
Long name:	Total depth: **11091**	Longitude: **-107.00000 degrees**	Status:	State: **Wyoming**
	Coordinate system:	Latitude: **42.000000 degrees**	Operator:	Company: **Encana Oil & Gas**

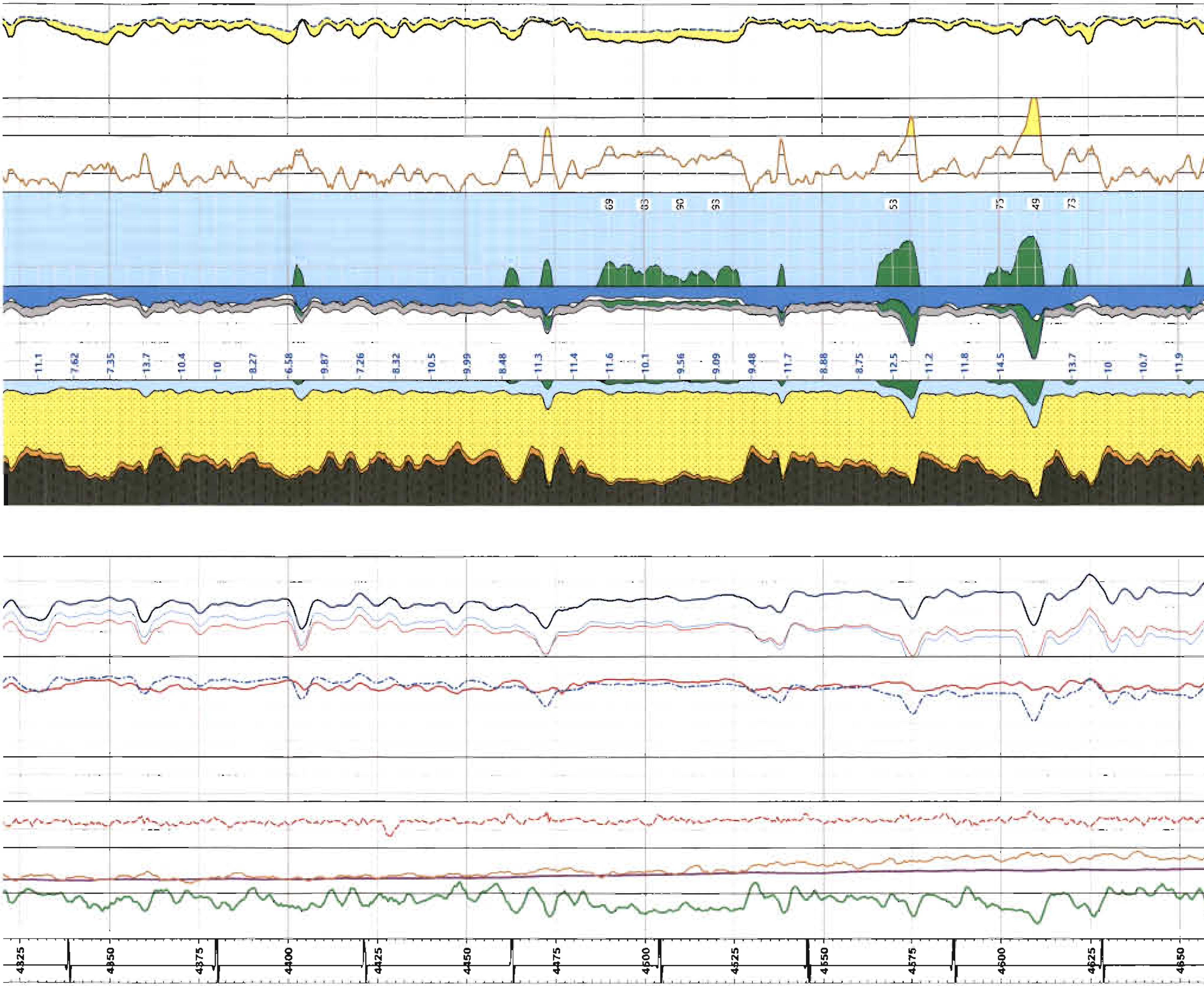
Mnemonic	Unit	Description
MD	.ft	:
BHPR	.psi	: Borehole Pressure
Bound_Water_QE	.v/v	: Bound Water Volume Fraction
BSAL_TDTL_RST	.ppk	: Borehole Salinity
BVIRR_GEO_QE	.v/v	: Bulk volume irreducible
CCLD	.V	: CCL Discriminated Amplitude
CS	.ft/h	: Cable Speed
Dolomite_QE	.v/v	: Dolomite Volume Fraction
Dry_Weight_Dolomite_QE	.w/w	: Dry Weight Fraction From Quanti.Elan
Dry_Weight_Illite_QE	.w/w	: Dry Weight Fraction From Quanti.Elan
Dry_Weight_Quartz_QE	.w/w	: Dry Weight Fraction From Quanti.Elan
GR	.gAPI	: Gamma Ray
GTEM	.degF	: Generalized Borehole Temperature
Illite_QE	.v/v	: Illite Volume Fraction
INFD_TDTL_RST	.1/s	: Far Inelastic Count Rate
KINT_GEO_QE	.mD	: Permeability (Juhasz 1979)
MWFD	g/cm3	: Manometer Well Fluid Density
PHIT_QE	v/v	: Total Porosity
PIGN_QE	.v/v	: Effective porosity (with irreducible water)
Quartz_QE	.v/v	: Quartz Volume Fraction
RHGA_GEO_QE	.g/cm3	: Apparent grain density
SIBH_TDTL_RST	.cu	: Sigma Borehole Corrected
SIGM_RST	.cu	: Formation Sigma
SUWI_QE	.v/v	: Water saturation virgin zone
SW_QE	.v/v	: Undisturbed Zone Water Saturation
TENS	.lbf	: Cable Tension
TPHI_RST	.m3/m3	: Formation Porosity
TPHI_RST_Dolomite	.m3/m3	: Formation Porosity, dolomite matrix
TPHI_RST_Limestone	.m3/m3	: Formation Porosity, limestone matrix
TPHI_RST_Sandstone	.m3/m3	: Formation Porosity, sandstone matrix
TSCF_TDTL_RST	.1/s	: Total Selected Count Rate Far Detector
TSCN_TDTL_RST	.1/s	: Total Selected Count Rate Near Detector
VCL_GEO_QE	.v/v	: Clay fraction
XOil_QE	.v/v	: Flushed Zone Oil Volume Fraction
XWater_QE	.v/v	: Flushed Zone Water Volume Fraction


CCLD
MD (ft)
1:240
SIBH_TDTL_RST
0 cu 200
MWFD
0.9 g/cm3 1.5
GR
0 gAPI 150
INFD_TDTL
700 1/s 0
Gas
Sigma Porosity
TPHI_RST_Limestone
0.6 ft3/ft3 0
Sigma Formation
SIGM_TDTL_RST
60 cu 0
TPHI_RST_Sandstone
0.3 m3/m3 -0.1
TPHI_RST_Limestone
0.3 m3/m3 -0.1
TPHI_RST_Dolomite
0.3 m3/m3 -0.1
zones
Unknown
UNFLUSHED_QE
0 (v/v) 1
Illite
Bound Water
Quartz
Dolomite
UWater
UOil
CBW
Irreducible Water
HC/Water
PIGN_DIGITS
50 % 0
BVIRR_GEO_QE
0.5 v/v 0
UWater_QE
0.5 v/v 0
PIGN_QE
0.5 v/v 0
PHIT_QE
0.5 v/v 0
SXO
SW_DIGITS
100 % 0
SXO_QE
1 v/v 0
Perm>1 mD
KINT_GEO_QE
0.001 mD 100
TSCF_TDTL
TSCN_TDTL
20000 1/s 0
TSCF_TDTL
8000 1/s 0
3425
3450
3475
3500
3525
3550
3575
3600
3625
19
14.7
14.9
13.1
19.7
9.66
9.18
12.7
13.8
19.4
20.1
18.4
12.3
13.3
14.4
19.1
23.5
10.6
11.4
15.3
11.5
14.9
8.68
47
53
49
68
45
48
54
89
67
69
48
39
83
57

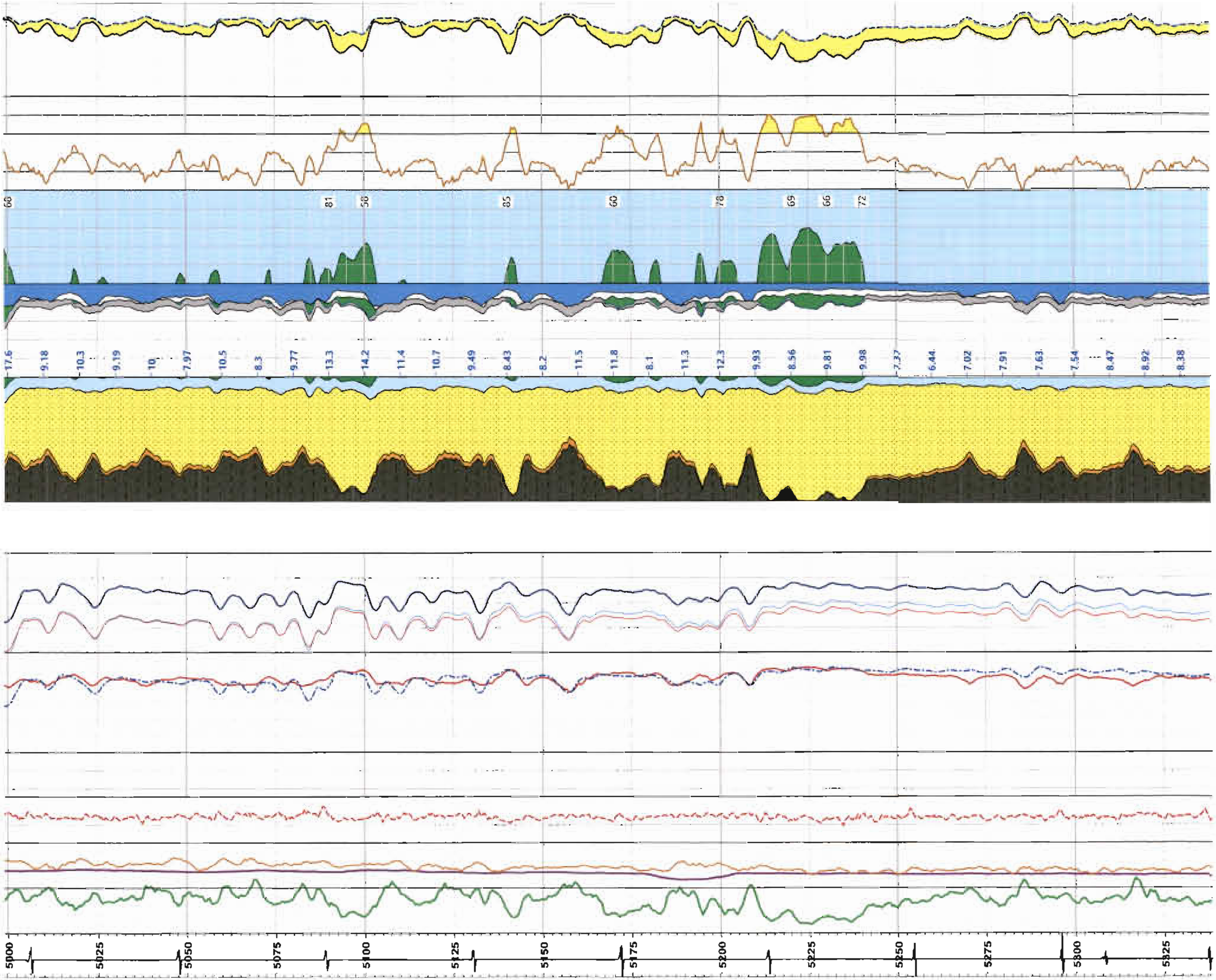


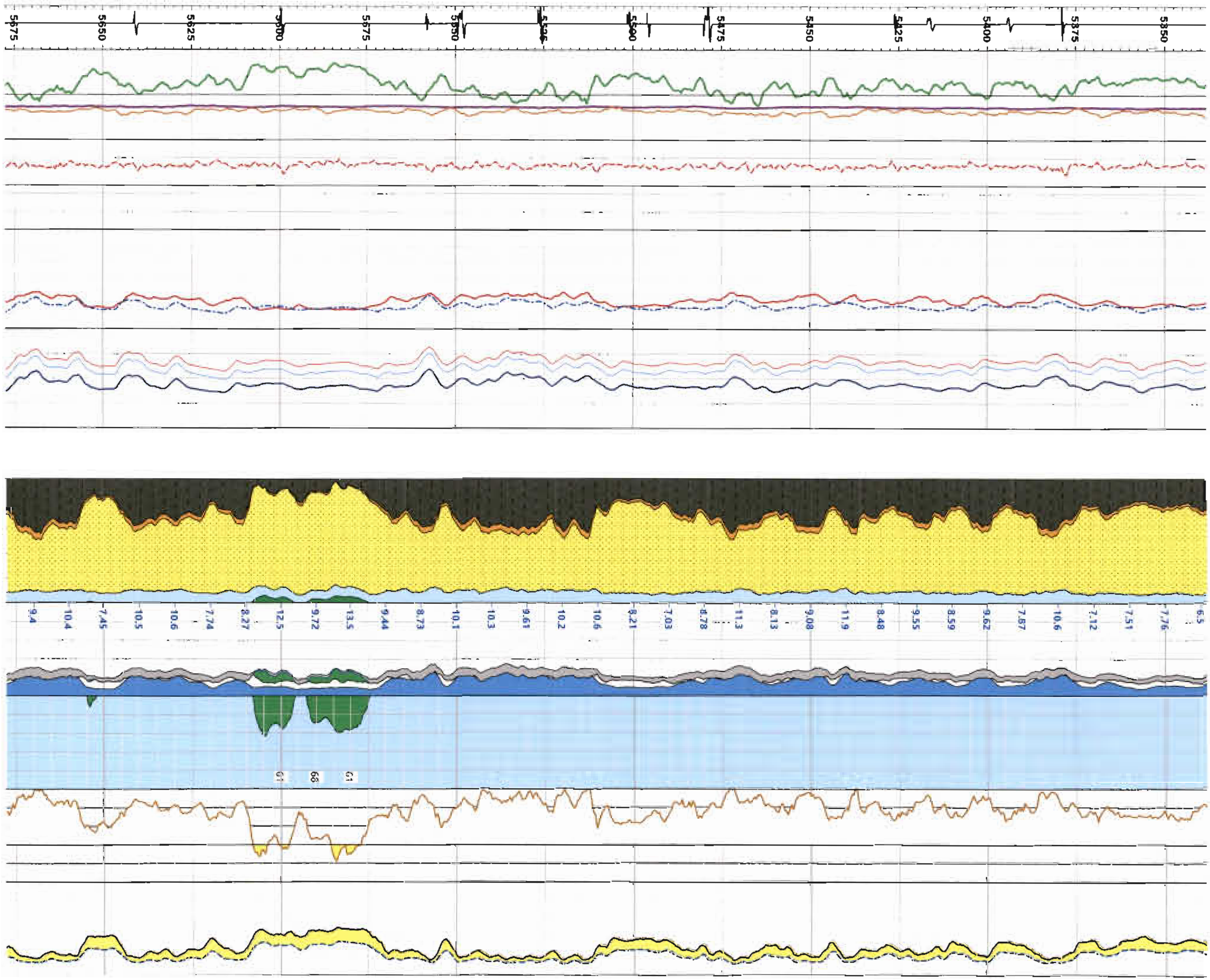
3650
3675
3700
3725
3750
3775
3800
3825
3850
3875
3900
3925
3950
3975
11.2
10.3
16.9
15.8
15.7
19.6
7.83
9.37
10
11.2
12.8
13.6
11.9
11.1
12.5
11.7
11.2
9.23
10.9
9.53
10.1
10.5
9.61
7.77
15.6
11.7
13.5
15.8
9.7
11
10.8
8.67
12.7
14
89
52
48
44
49
54
48
57
55
54

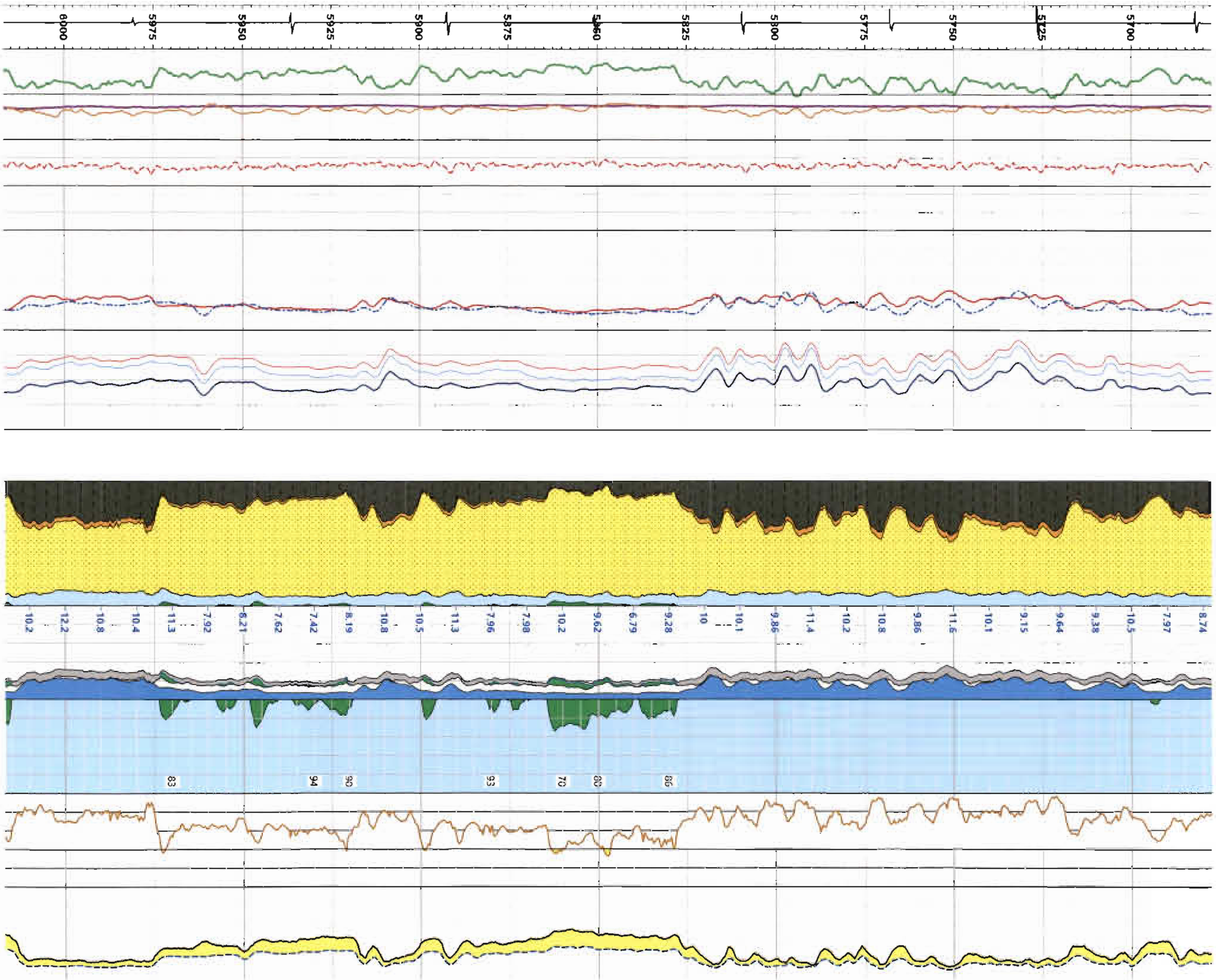

37
73
13.1
6.73
11
10.8
11.6
11.6
9.88
7.05
8.62
10
10.1
11.3
7.93
6.58
8
10.8
10.2
11.4
11.2
12.1
8.4
7.62
6.36
13.3
8.68
8.94
10
7.83
12.3
7.74
7.41
8.84
9.42
4000
4025
4050
4075
4100
4125
4150
4175
4200
4225
4250
4275
4300

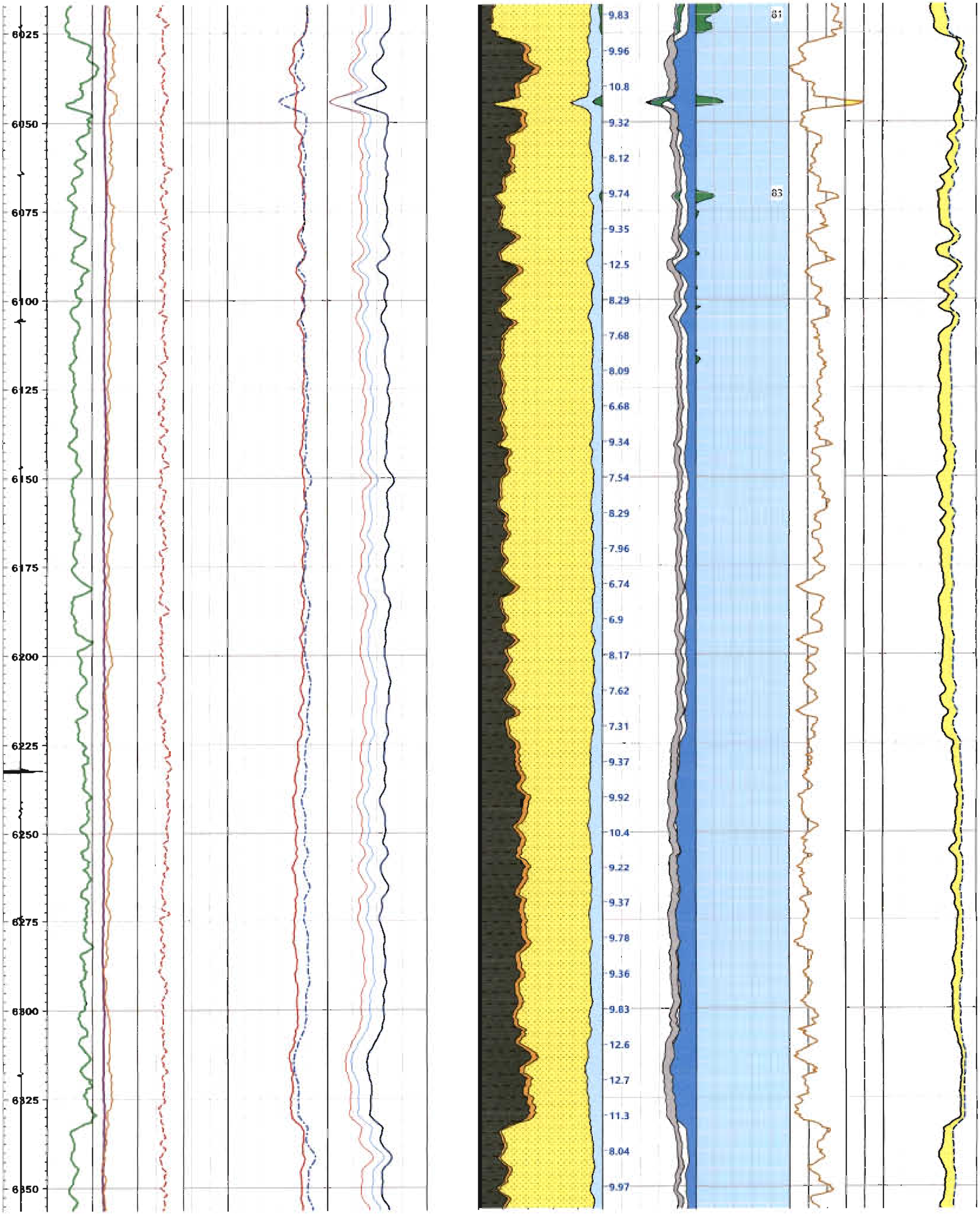

69
83
90
93
53
75
49
73
11.1
7.62
7.35
13.7
10.4
10
8.27
6.58
9.87
7.26
8.32
10.5
9.99
8.48
11.3
11.4
11.6
10.1
9.56
9.09
9.48
11.7
8.88
8.75
12.5
11.2
11.8
14.5
13.7
10
10.7
11.9
4325
4350
4375
4400
4425
4450
4475
4500
4525
4550
4575
4600
4625
4650

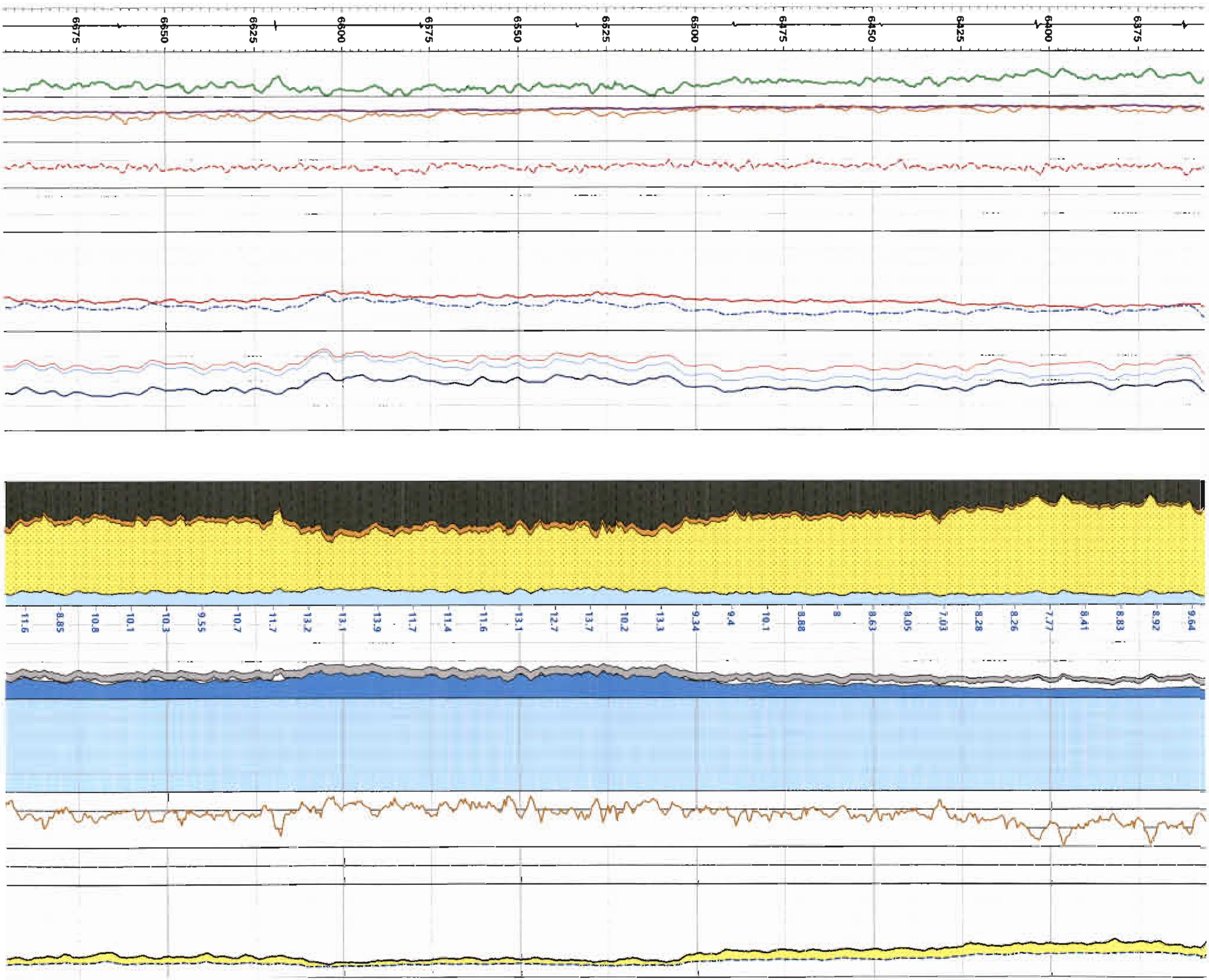
51
75
66
67
77
61
46
65
54
58
67
71
94
65
69
67
76
10
16.2
12.7
12.5
11.9
13.5
10.4
11.6
8.04
15.1
19.4
11.4
18.5
11.7
11.3
10
12.8
10.4
10.6
11.4
8.36
13.9
14.5
10.3
14
11.4
14.6
10.7
9.86
10.1
9.64
10.3
9.99
4675
4700
4725
4750
4775
4800
4825
4850
4875
4900
4925
4950
4975

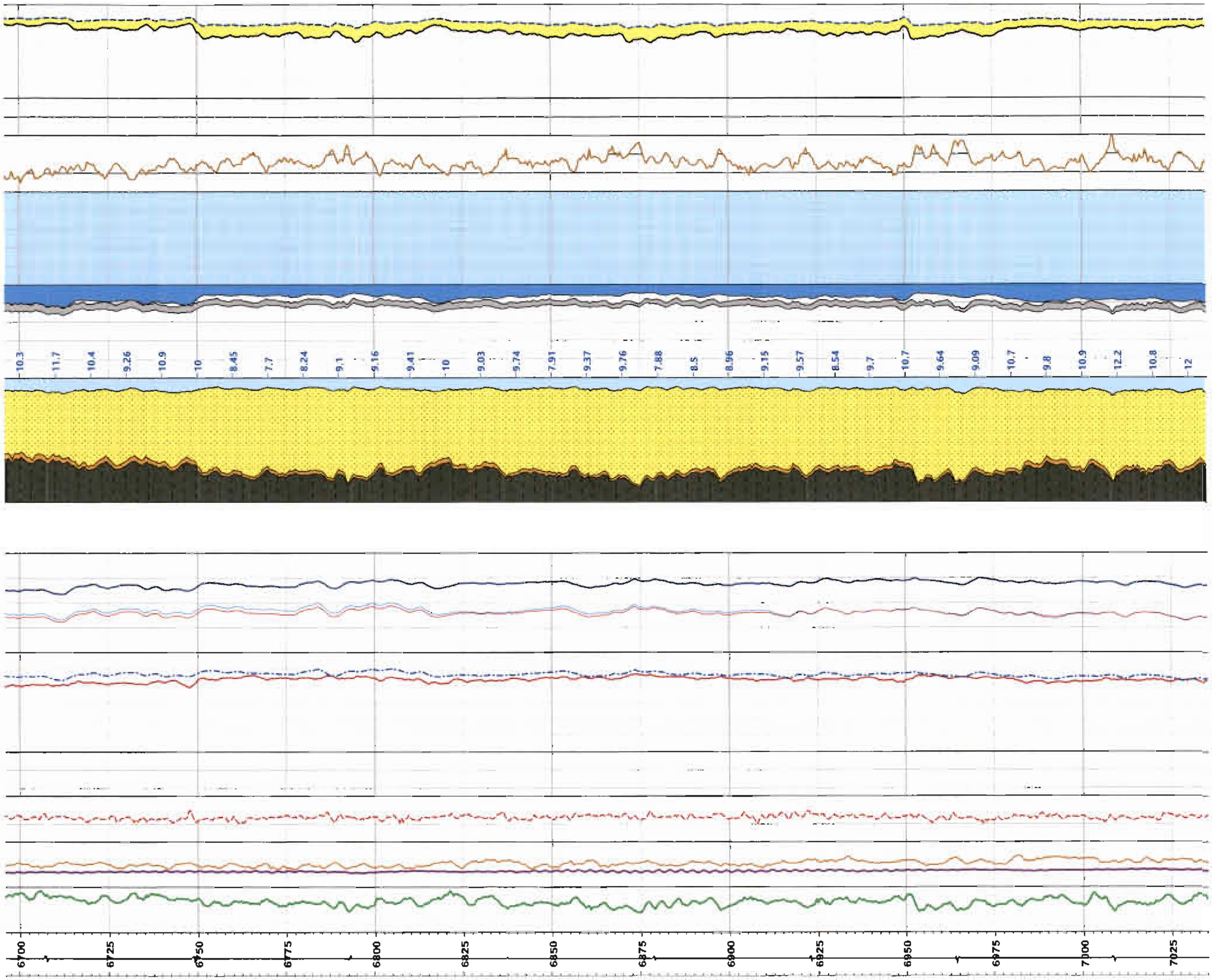

68
81
58
85
60
78
69
66
72
17.6
9.18
10.3
9.19
10
7.97
10.5
8.3
9.77
13.3
14.2
11.4
10.7
9.49
8.43
8.2
11.5
11.8
8.1
11.3
12.3
9.93
8.56
9.81
9.98
7.37
6.44
7.02
7.91
7.63
7.54
8.47
8.92
8.38
5000
5025
5050
5075
5100
5125
5150
5175
5200
5225
5250
5275
5300
5325


5675
5650
5625
5600
5575
5550
5525
5500
5475
5450
5425
5400
5375
5350
9.4
10.4
7.45
10.5
10.6
7.74
8.27
12.5
9.72
13.5
9.44
8.73
10.1
10.3
9.61
10.2
10.6
8.21
7.03
8.78
11.3
8.13
9.08
11.9
8.48
9.55
8.59
9.62
7.87
10.6
7.12
7.51
7.76
6.5
G1
66
G1

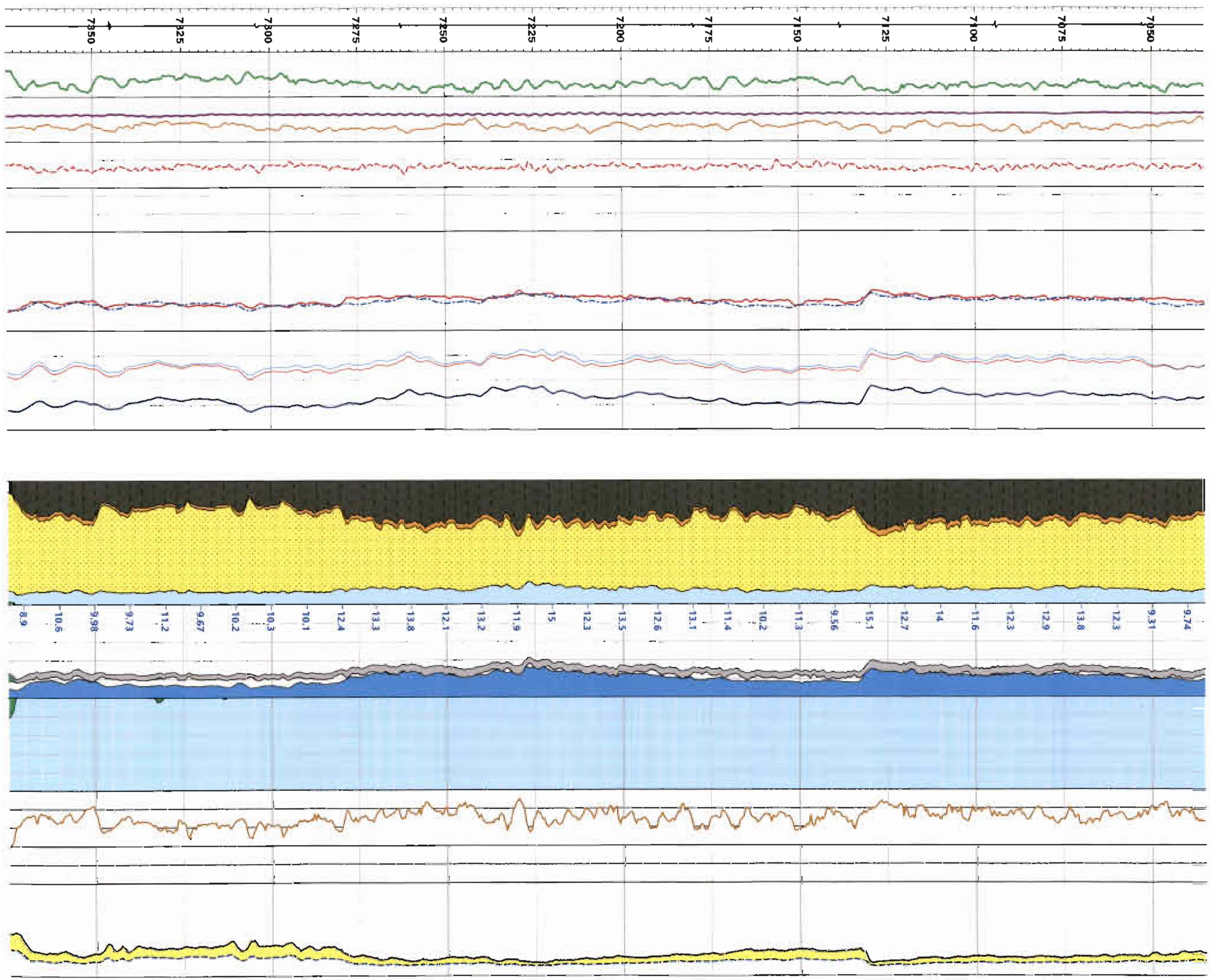

6000
5975
5950
5925
5900
5875
5850
5825
5800
5775
5750
5725
5700
10.2
12.2
10.8
10.4
11.3
7.92
8.21
7.62
7.42
8.19
10.8
10.5
11.3
7.96
7.98
10.2
9.62
6.79
9.28
10
10.1
9.86
11.4
10.2
10.8
9.86
11.6
10.1
9.15
9.64
9.38
10.5
7.97
8.74

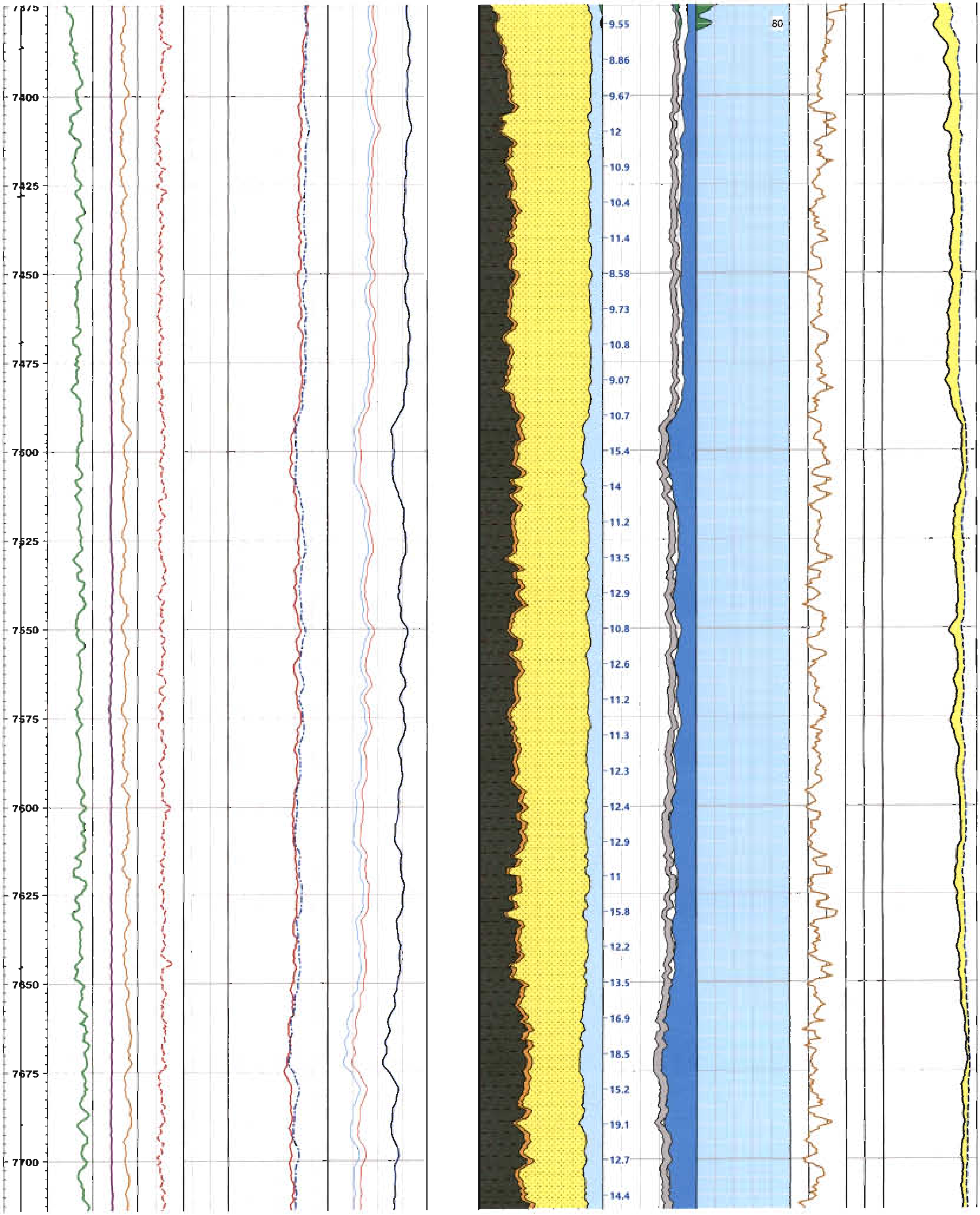

6025
6050
6075
6100
6125
6150
6175
6200
6225
6250
6275
6300
6325
6350
9.83
9.96
10.8
9.32
8.12
9.74
9.35
12.5
8.29
7.68
8.09
6.68
9.34
7.54
8.29
7.96
6.74
6.9
8.17
7.62
7.31
9.37
9.92
10.4
9.22
9.37
9.78
9.36
9.83
12.6
12.7
11.3
8.04
9.97
81
83


6675
6650
6625
6600
6575
6550
6525
6500
6475
6450
6425
6400
6375
11.6
8.85
10.8
10.1
10.3
9.55
10.7
11.7
13.2
13.1
13.9
11.7
11.4
11.6
13.1
12.7
13.7
10.2
13.3
9.34
9.4
10.1
8.88
8
8.63
8.05
7.03
8.28
8.26
7.77
8.41
8.83
8.92
9.64

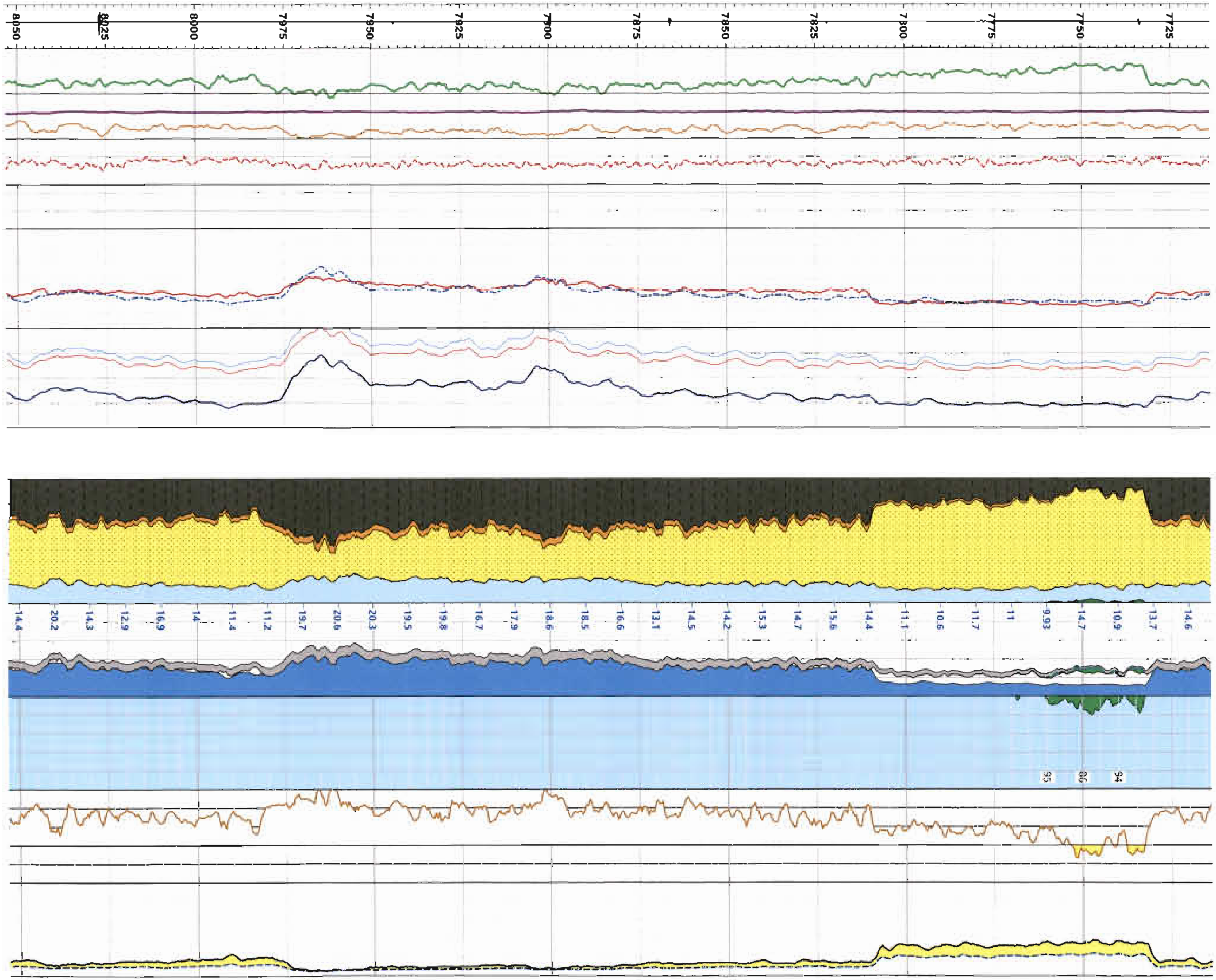


10.3
11.7
10.4
9.26
10.9
10
8.45
7.7
8.24
9.1
9.16
9.41
10
9.03
9.74
7.91
9.37
9.76
7.88
8.5
8.96
9.15
9.57
8.54
9.7
10.7
9.64
9.09
10.7
9.8
10.9
12.2
10.8
12
6700
6725
6750
6775
6800
6825
6850
6875
6900
6925
6950
6975
7000
7025

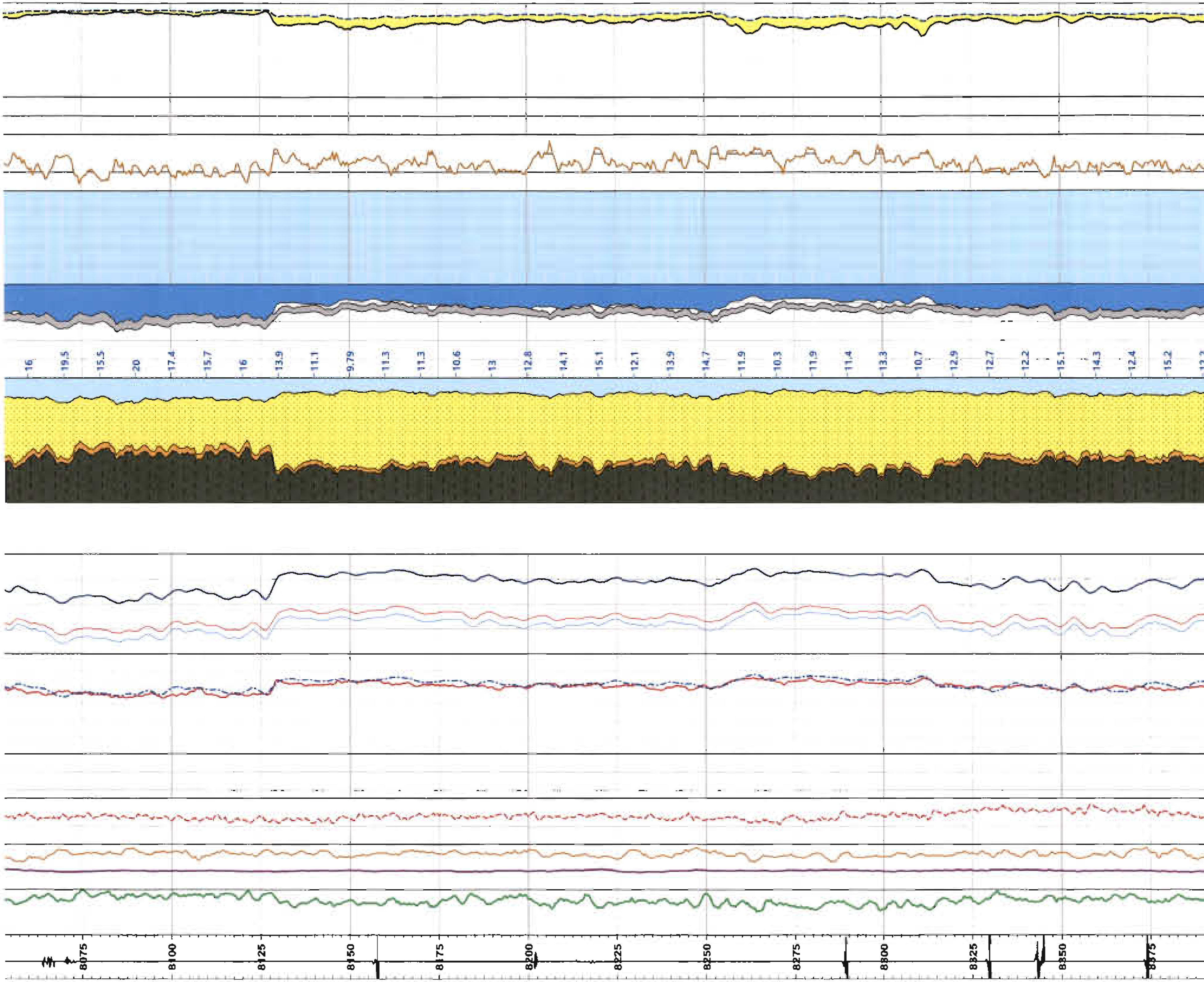

7350
7325
7300
7275
7250
7225
7200
7175
7150
7125
7100
7075
7050
8.9
10.6
9.98
9.73
11.2
9.67
10.2
10.3
10.1
12.4
13.3
13.8
12.1
13.2
11.9
15
12.3
13.5
12.6
13.1
11.4
10.2
11.3
9.56
15.1
12.7
14
11.6
12.3
12.9
13.8
12.3
9.31
9.74

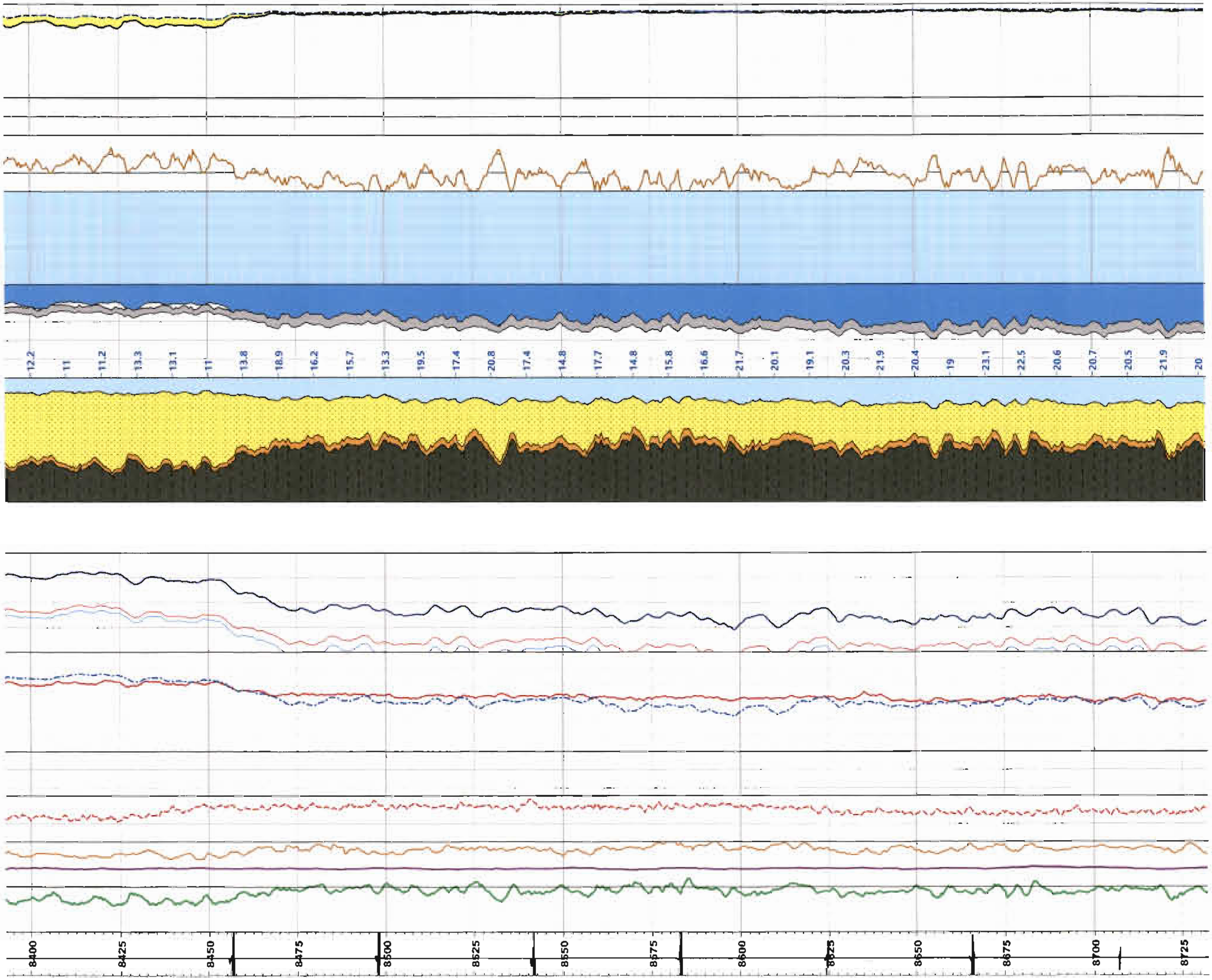


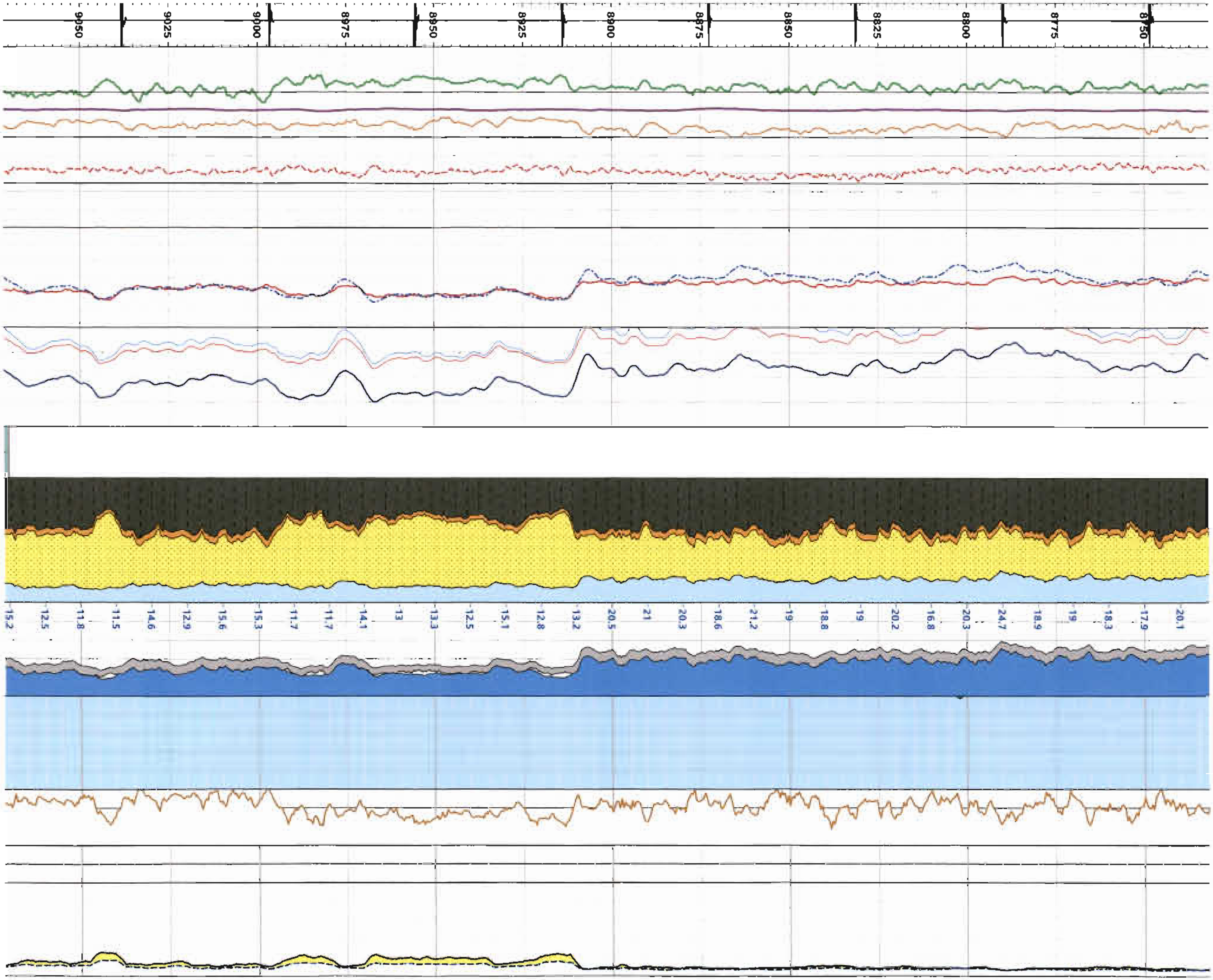
7375
7400
7425
7450
7475
7500
7525
7550
7575
7600
7625
7650
7675
7700
9.55
8.86
9.67
12
10.9
10.4
11.4
8.58
9.73
10.8
9.07
10.7
15.4
14
11.2
13.5
12.9
10.8
12.6
11.2
11.3
12.3
12.4
12.9
11
15.8
12.2
13.5
16.9
18.5
15.2
19.1
12.7
14.4
60

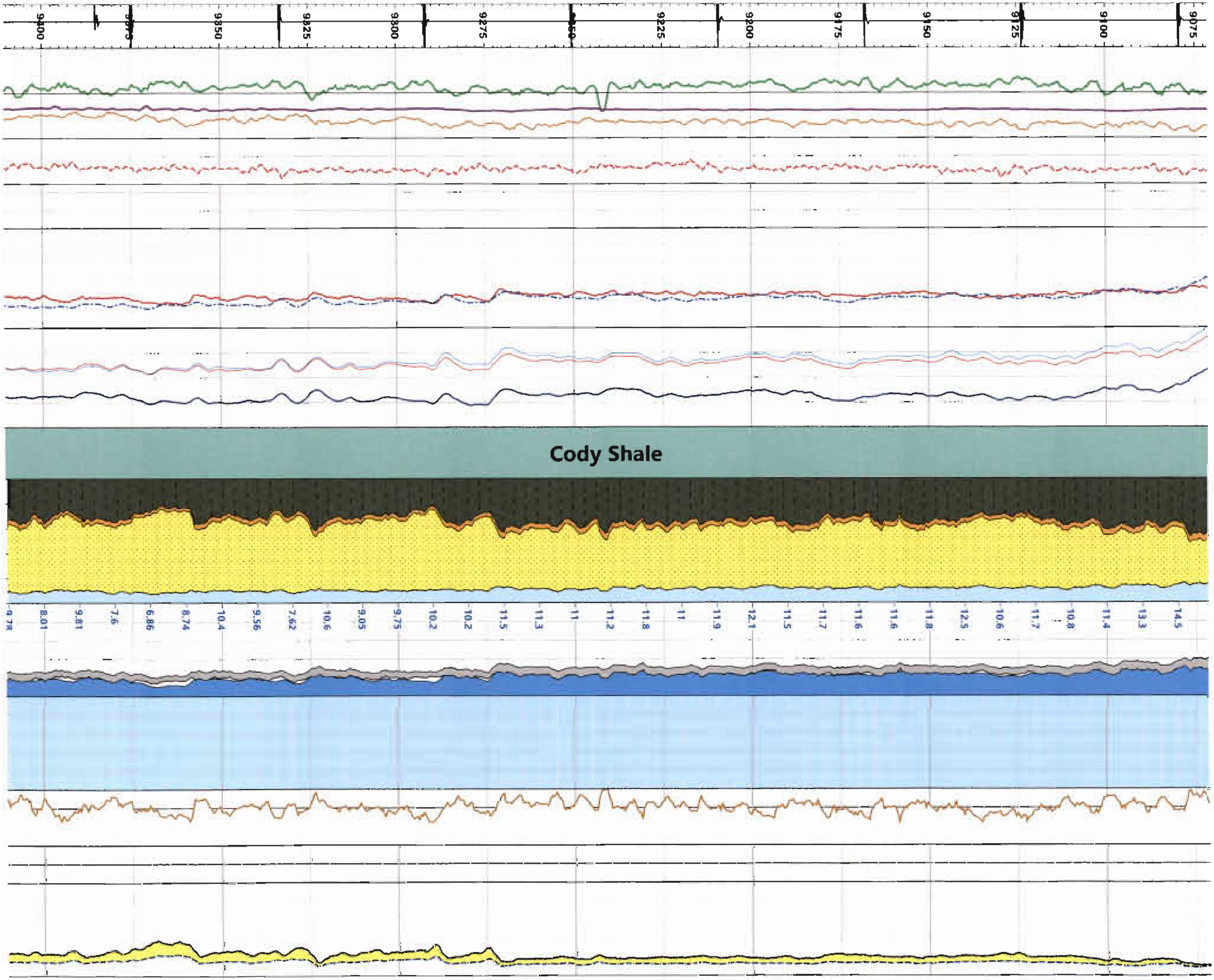


8050
8025
8000
7975
7950
7925
7900
7875
7850
7825
7800
7775
7750
7725
14.4
20.2
14.3
12.9
16.9
14
11.4
11.2
19.7
20.6
20.3
19.5
19.8
16.7
17.9
18.6
18.5
16.6
13.1
14.5
14.2
15.3
14.7
15.6
14.4
11.1
10.6
11.7
11
9.93
14.7
10.9
13.7
14.6

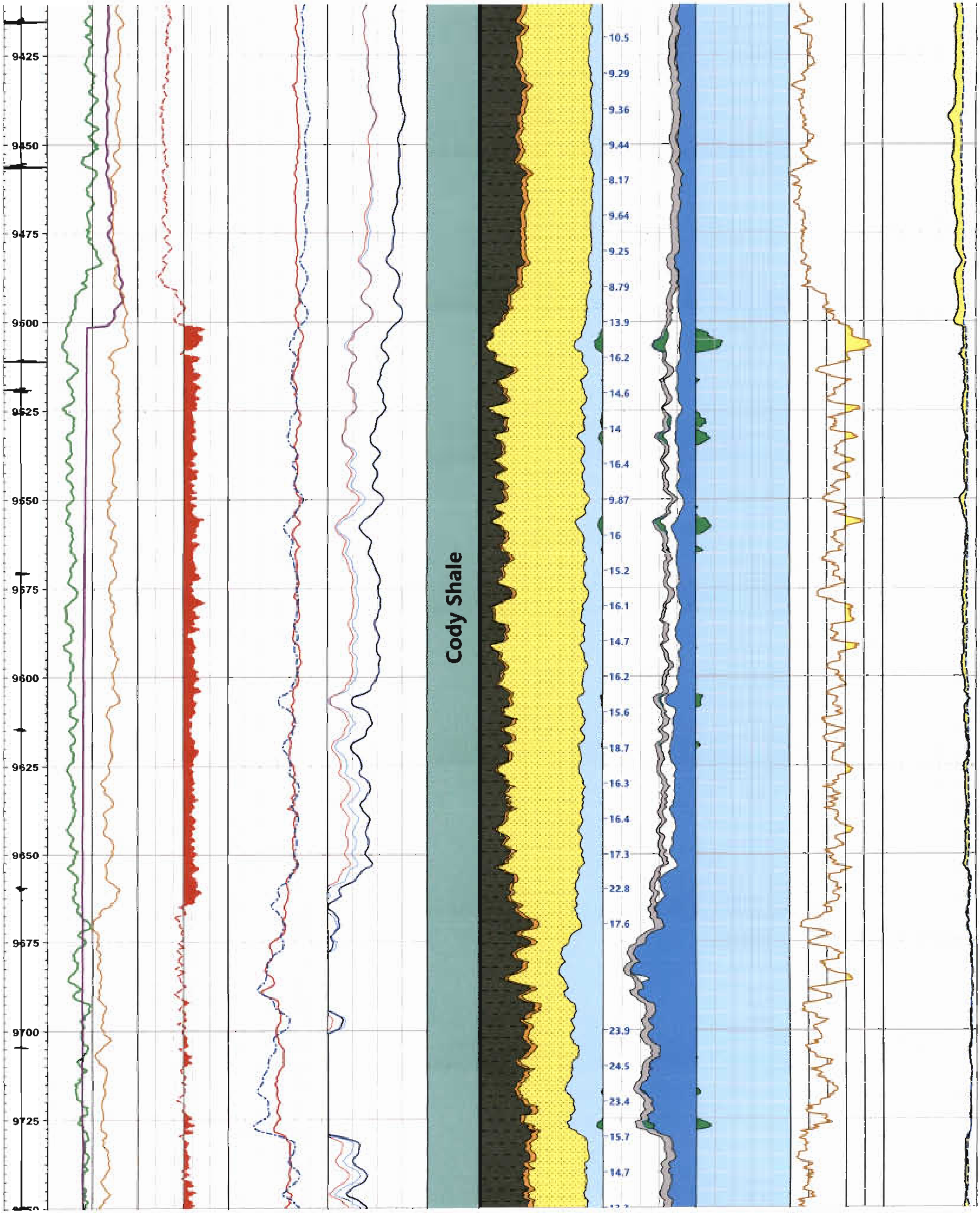

16
19.5
15.5
20
17.4
15.7
16
13.9
11.1
9.79
11.3
11.3
10.6
13
12.8
14.1
15.1
12.1
13.9
14.7
11.9
10.3
11.9
11.4
13.3
10.7
12.9
12.7
12.2
15.1
14.3
12.4
15.2
12.2
8075
8100
8125
8150
8175
8200
8225
8250
8275
8300
8325
8350
8375


12.2
11
11.2
13.3
13.1
11
13.8
18.9
16.2
15.7
13.3
19.5
17.4
20.8
17.4
14.8
17.7
14.8
15.8
16.6
21.7
20.1
19.1
20.3
21.9
20.4
19
23.1
22.5
20.6
20.7
20.5
21.9
20
8400
8425
8450
8475
8500
8525
8550
8575
8600
8625
8650
8675
8700
8725

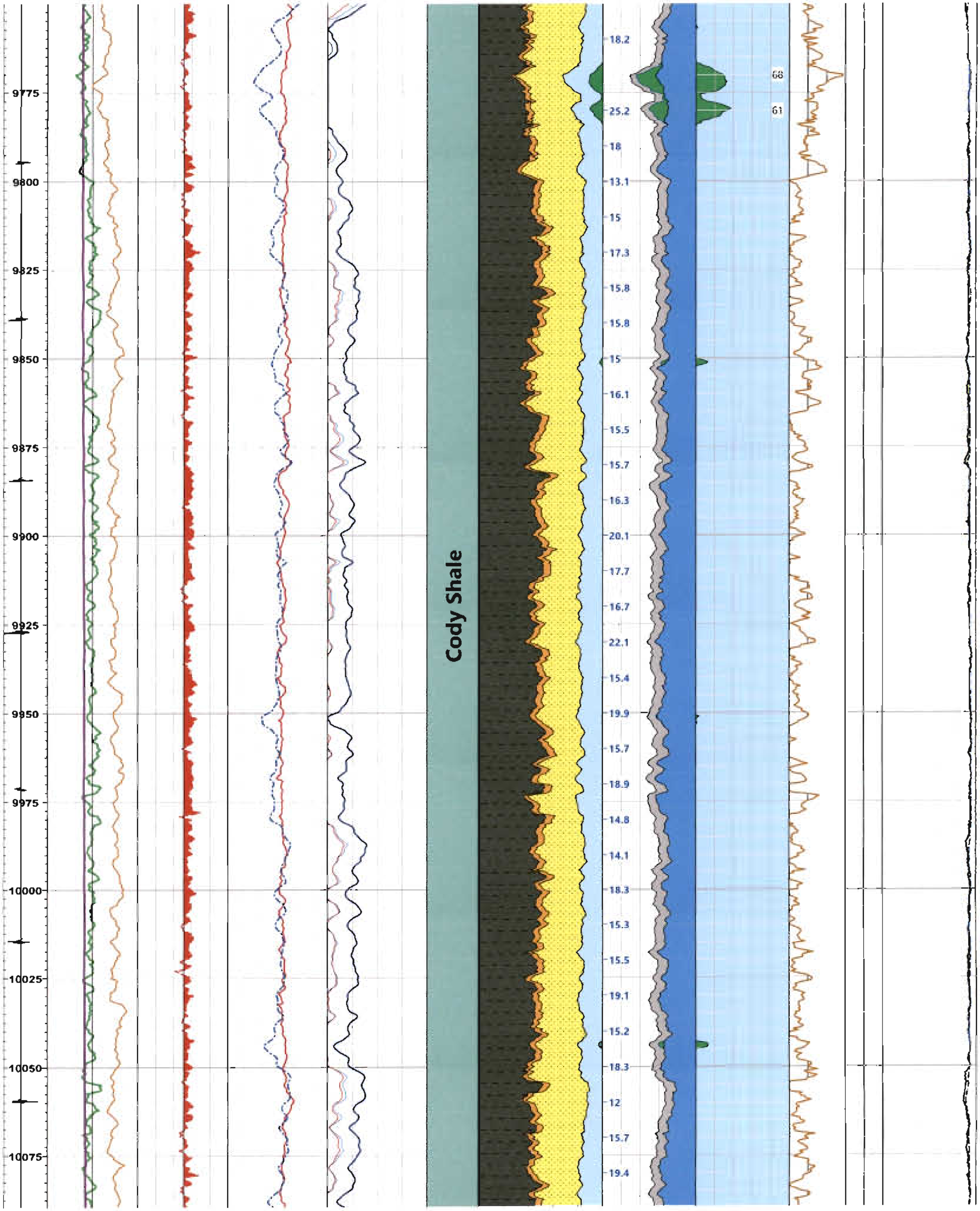

9050
9025
9000
8975
8950
8925
8900
8875
8850
8825
8800
8775
8750
15.2
12.5
11.8
11.5
14.6
12.9
15.6
15.3
11.7
11.7
14.1
13
13.3
12.5
15.1
12.8
13.2
20.5
21
20.3
18.6
21.2
19
18.8
19
20.2
16.8
20.3
24.7
18.9
19
18.3
17.9
20.1

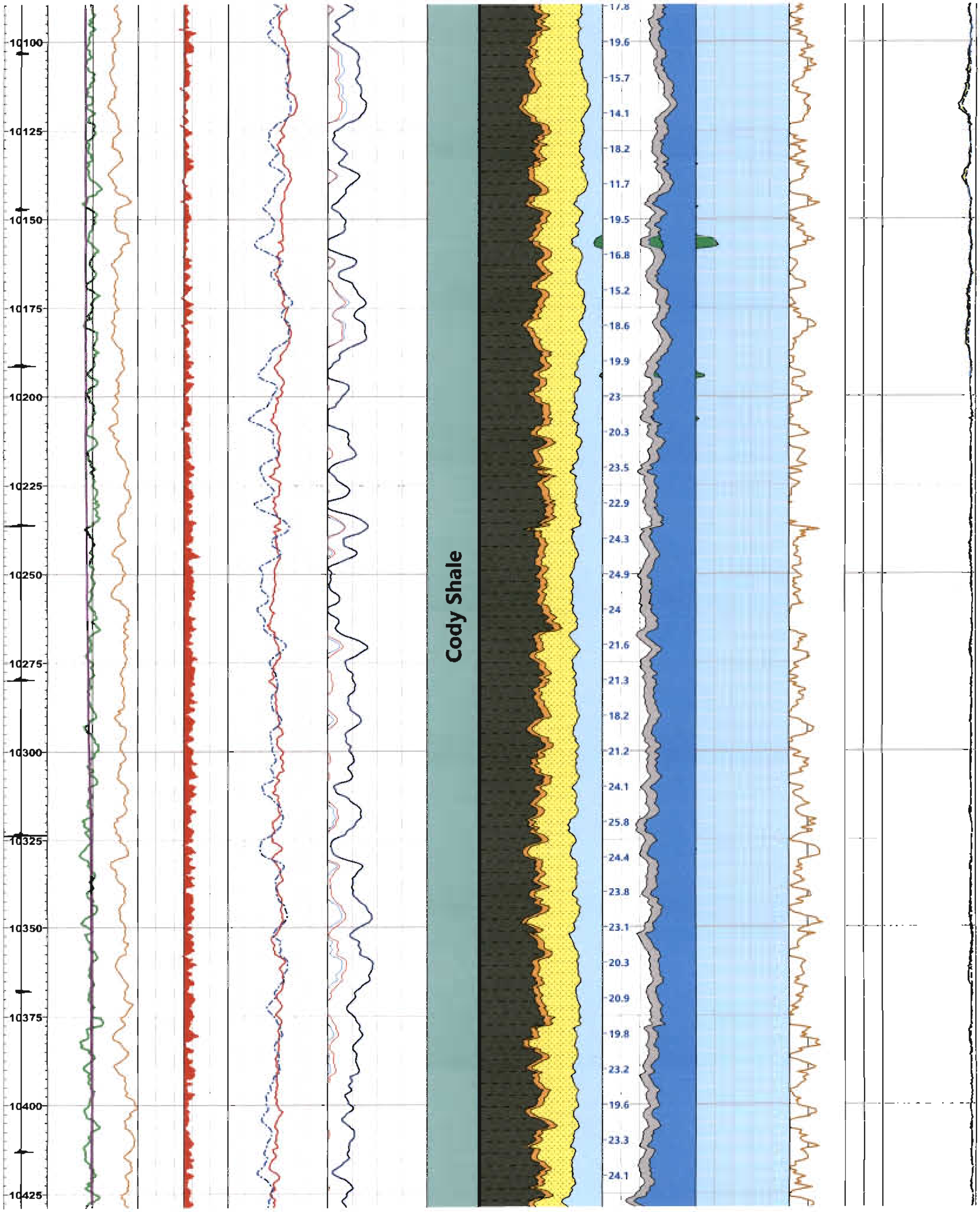


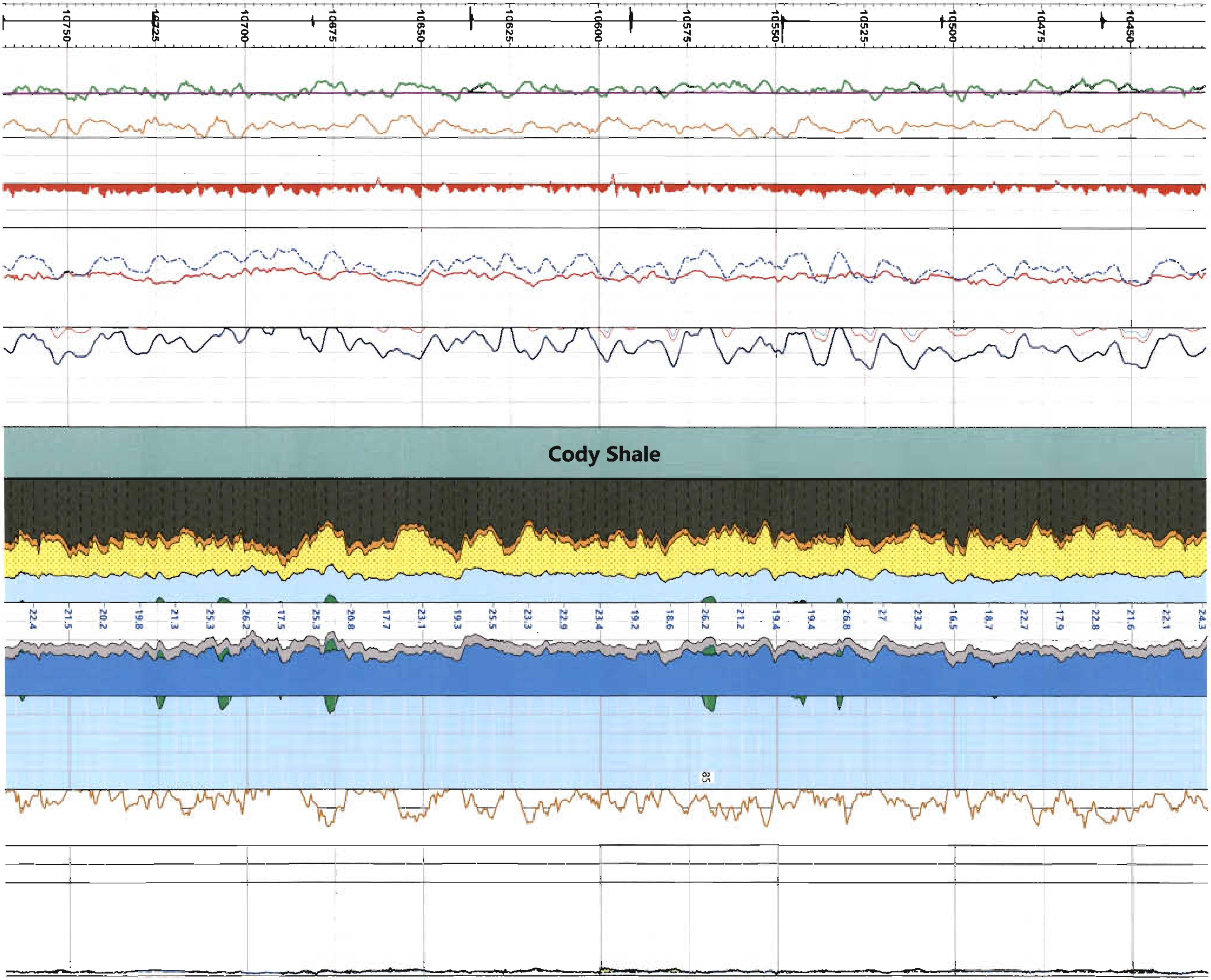
9400
9375
9350
9325
9300
9275
9250
9225
9200
9175
9150
9125
9100
9075
Cody Shale
8.01
9.81
7.6
6.86
8.74
10.4
9.56
7.62
10.6
9.05
9.75
10.2
10.2
11.5
11.3
11
11.2
11.8
11
11.9
12.1
11.5
11.7
11.6
11.6
11.8
12.5
10.6
11.7
10.8
11.4
13.3
14.5



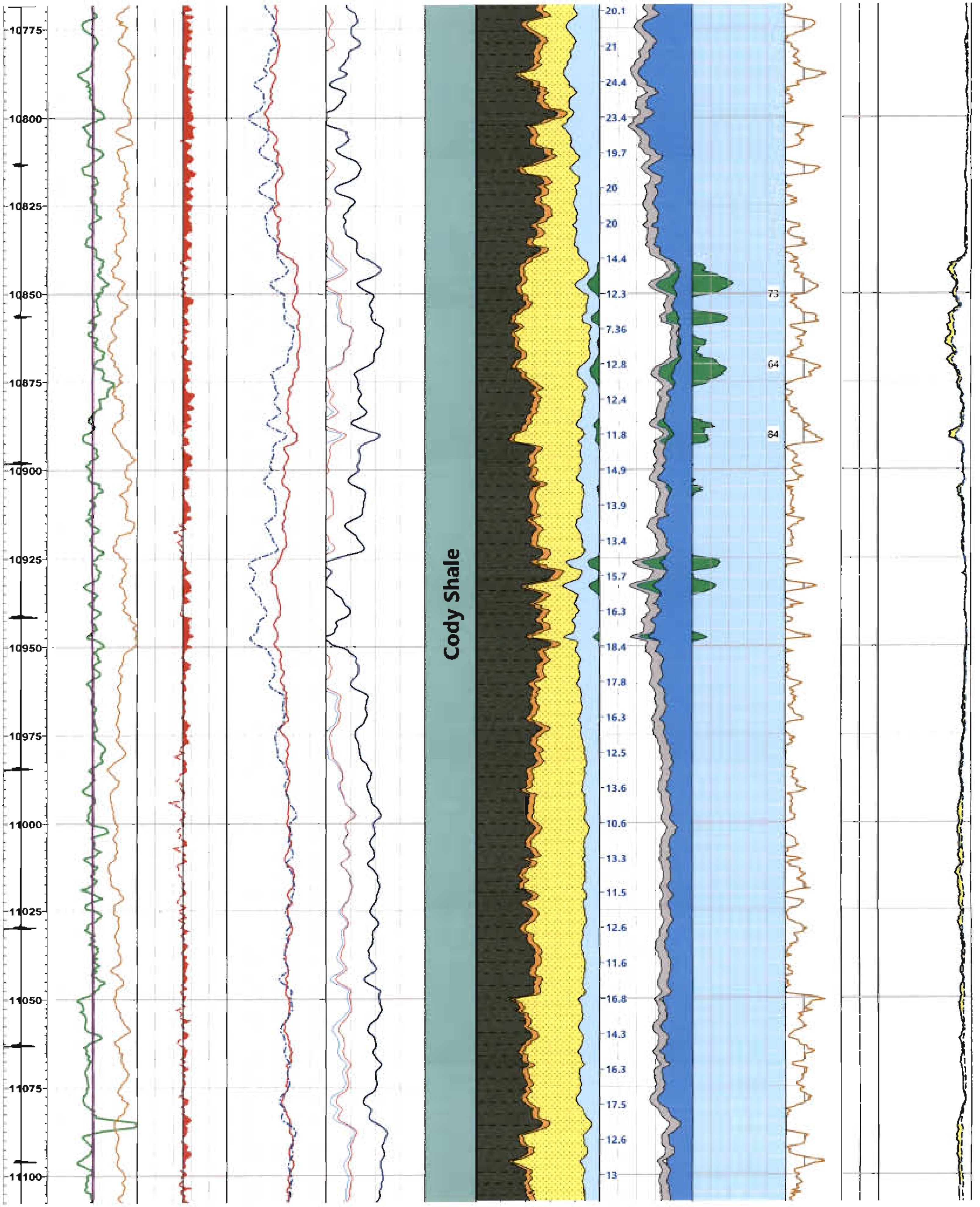
9425
9450
9475
9525
9550
9625
9650
9675
9700
9725
Cody Shale
10.5
9.29
9.36
9.44
8.17
9.64
9.25
8.79
13.9
16.2
14.6
14
16.4
9.87
16
15.2
16.1
14.7
16.2
15.6
18.7
16.3
16.4
17.3
22.8
17.6
23.9
24.5
23.4
15.7
14.7

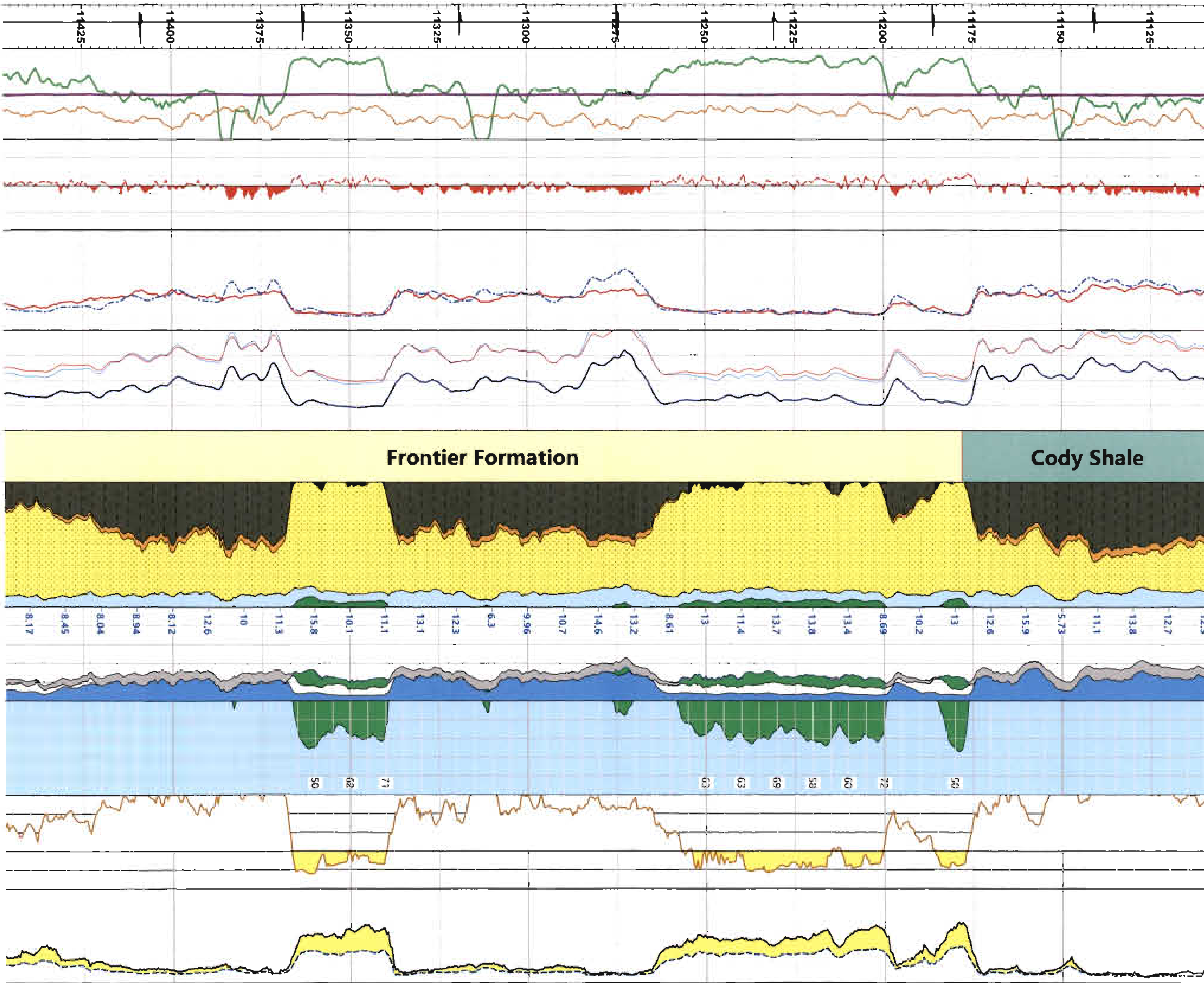

9775
9800
9825
9850
9875
9900
9925
9950
9975
10000
10025
10050
10075
Cody Shale
18.2
25.2
18
13.1
15
17.3
15.8
15.8
15
16.1
15.5
15.7
16.3
20.1
17.7
16.7
22.1
15.4
19.9
15.7
18.9
14.8
14.1
18.3
15.3
15.5
19.1
15.2
18.3
12
15.7
19.4
68
61


10100
10125
10150
10175
10200
10225
10250
10275
10300
10325
10350
10375
10400
10425
Cody Shale
19.6
15.7
14.1
18.2
11.7
19.5
16.8
15.2
18.6
19.9
23
20.3
23.5
22.9
24.3
24.9
24
21.6
21.3
18.2
21.2
24.1
25.8
24.4
23.8
23.1
20.3
20.9
19.8
23.2
19.6
23.3
24.1

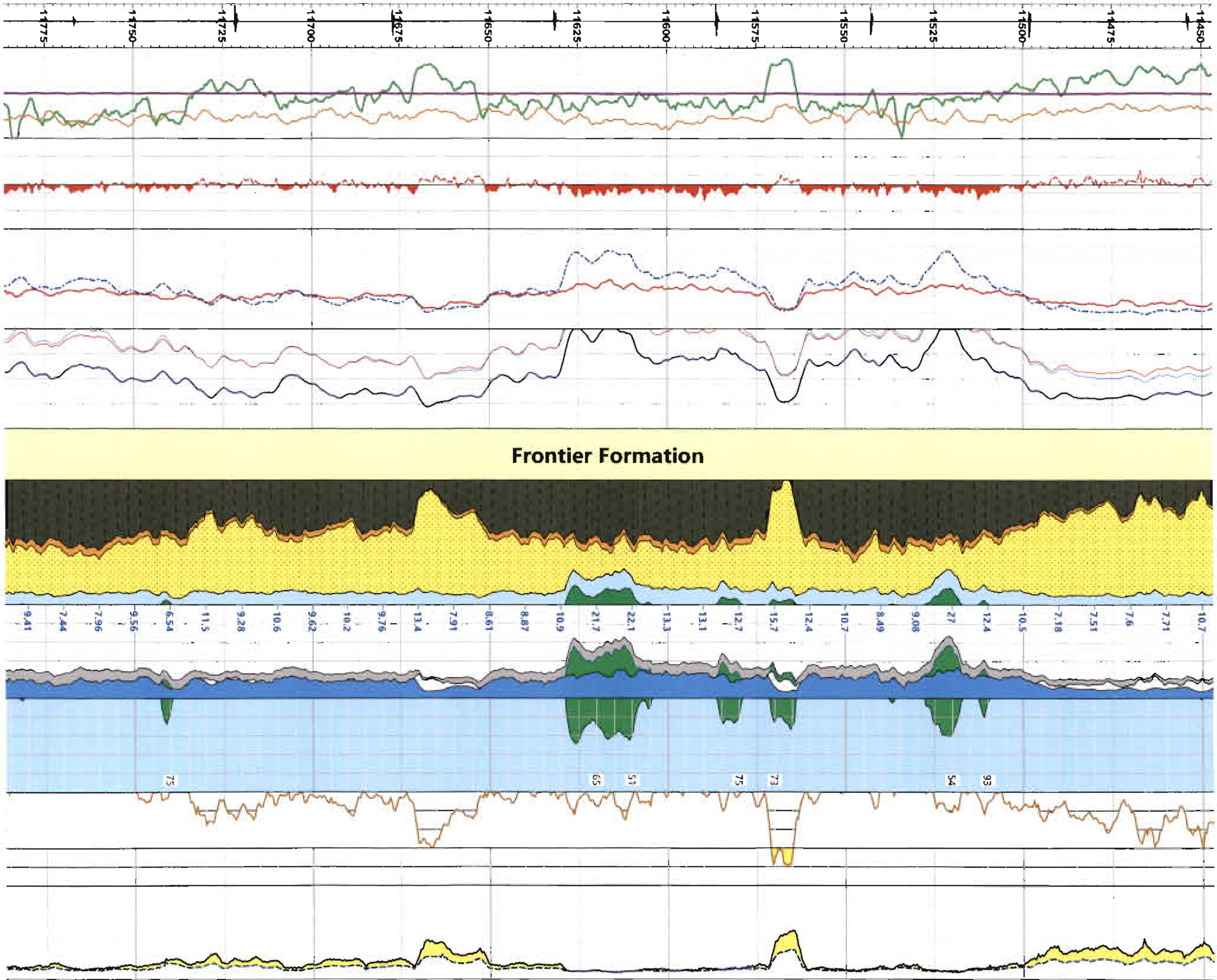


10750
10725
10700
10675
10650
10625
10600
10575
10550
10525
10500
10475
10450
Cody Shale
22.4
21.5
20.2
19.8
21.3
25.3
26.2
17.5
25.3
20.8
17.7
23.1
19.3
25.5
23.3
22.9
23.4
19.2
18.6
26.2
21.2
19.4
19.4
26.8
27
23.2
16.5
18.7
22.7
17.9
22.8
21.6
22.1
24.3
85

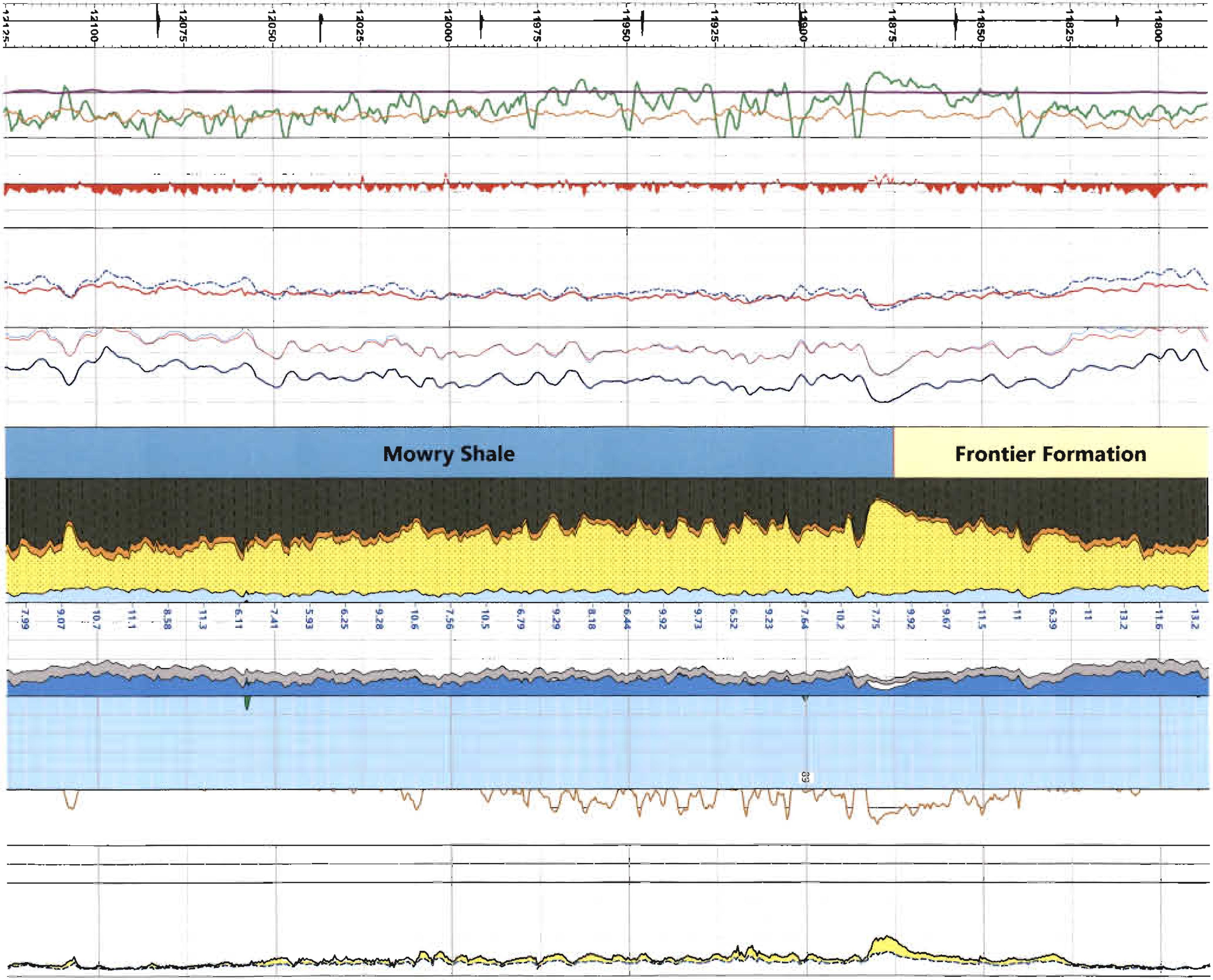

10775
10800
10825
10850
10875
10900
10925
10950
10975
11000
11025
11050
11075
11100
Cody Shale
20.1
21
24.4
23.4
19.7
20
20
14.4
12.3
7.36
12.8
12.4
11.8
14.9
13.9
13.4
15.7
16.3
18.4
17.8
16.3
12.5
13.6
10.6
13.3
11.5
12.6
11.6
16.8
14.3
16.3
17.5
12.6
13
73
64
84

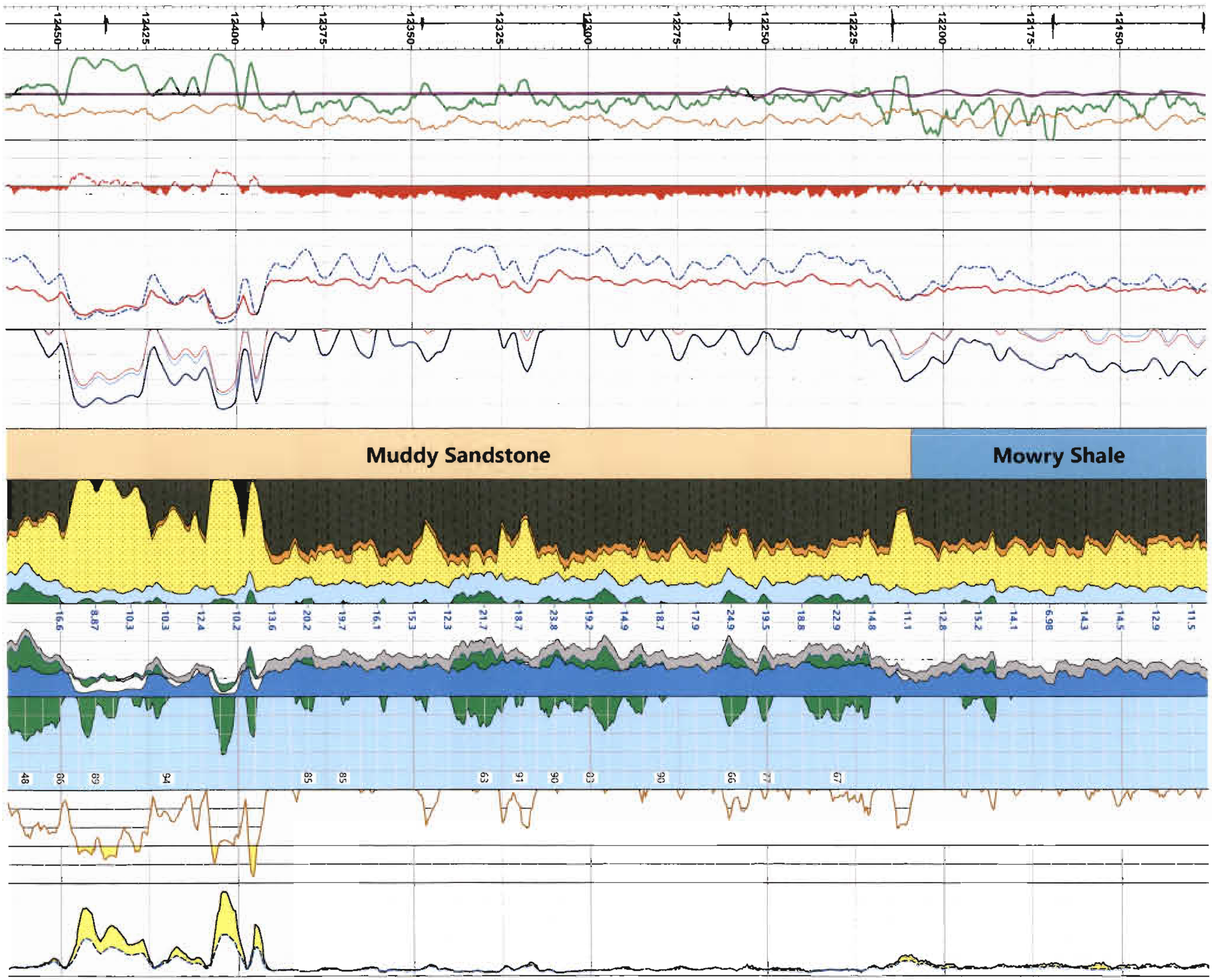


11425
11400
11375
11350
11325
11300
11275
11250
11225
11200
11175
11150
11125
Frontier Formation
Cody Shale

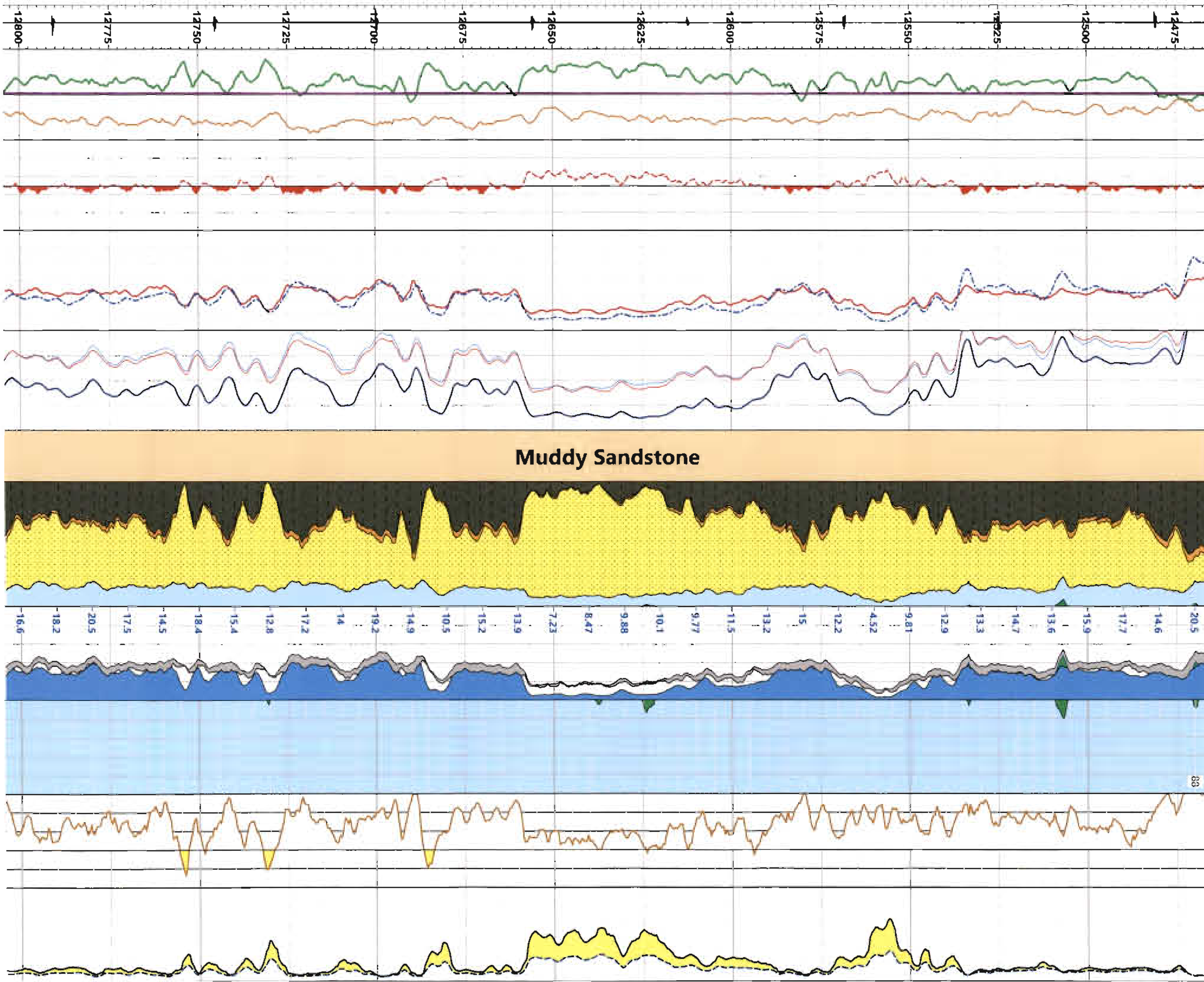


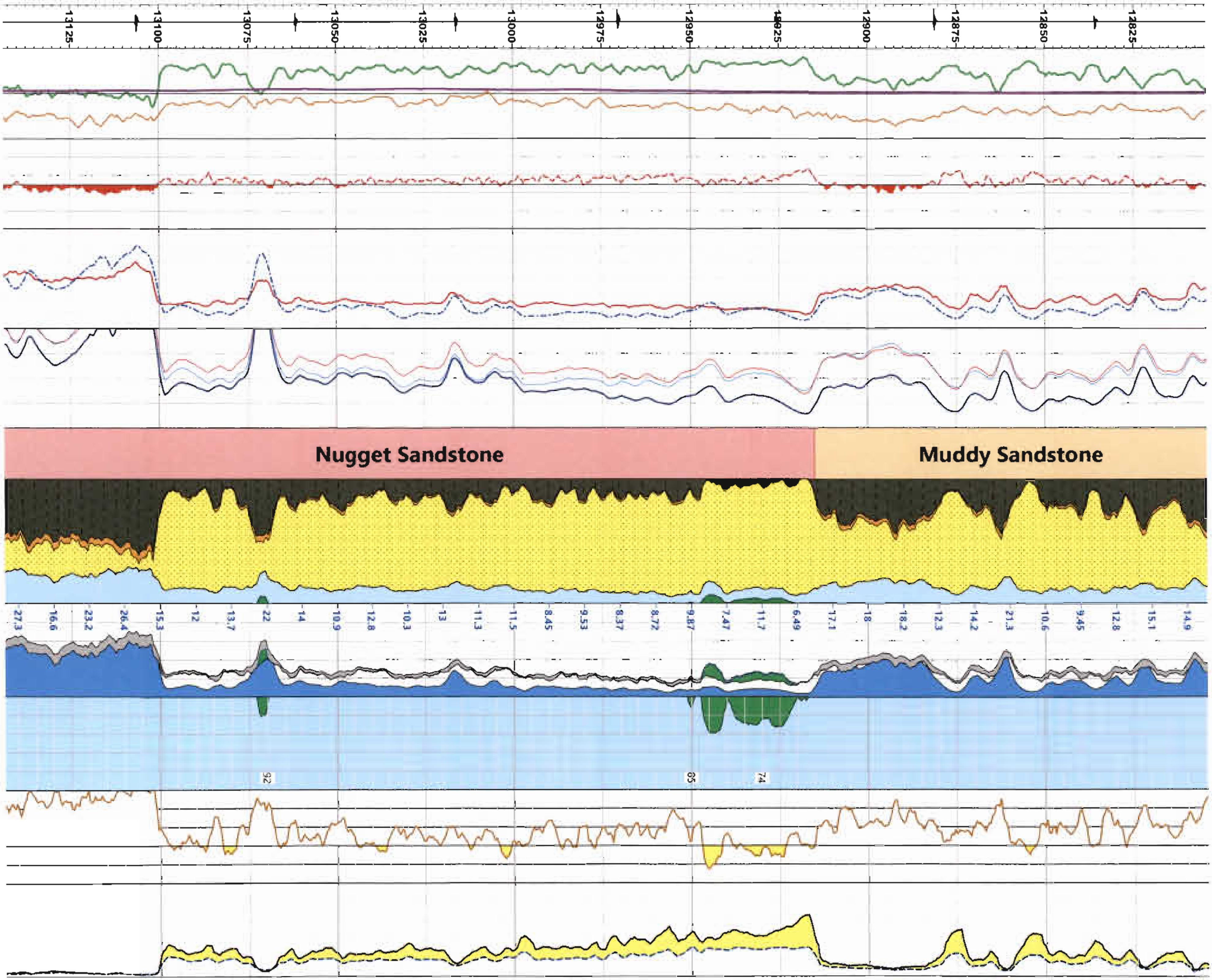
11775
11750
11725
11700
11675
11650
11625
11600
11575
11550
11525
11500
11475
11450
Frontier Formation
9.41
7.44
7.96
9.56
6.54
11.5
9.28
10.6
9.62
10.2
9.76
13.4
7.91
8.61
8.87
10.9
21.7
22.1
13.3
13.1
12.7
15.7
12.4
10.7
8.49
9.08
27
12.4
10.5
7.18
7.51
7.6
7.71
10.7

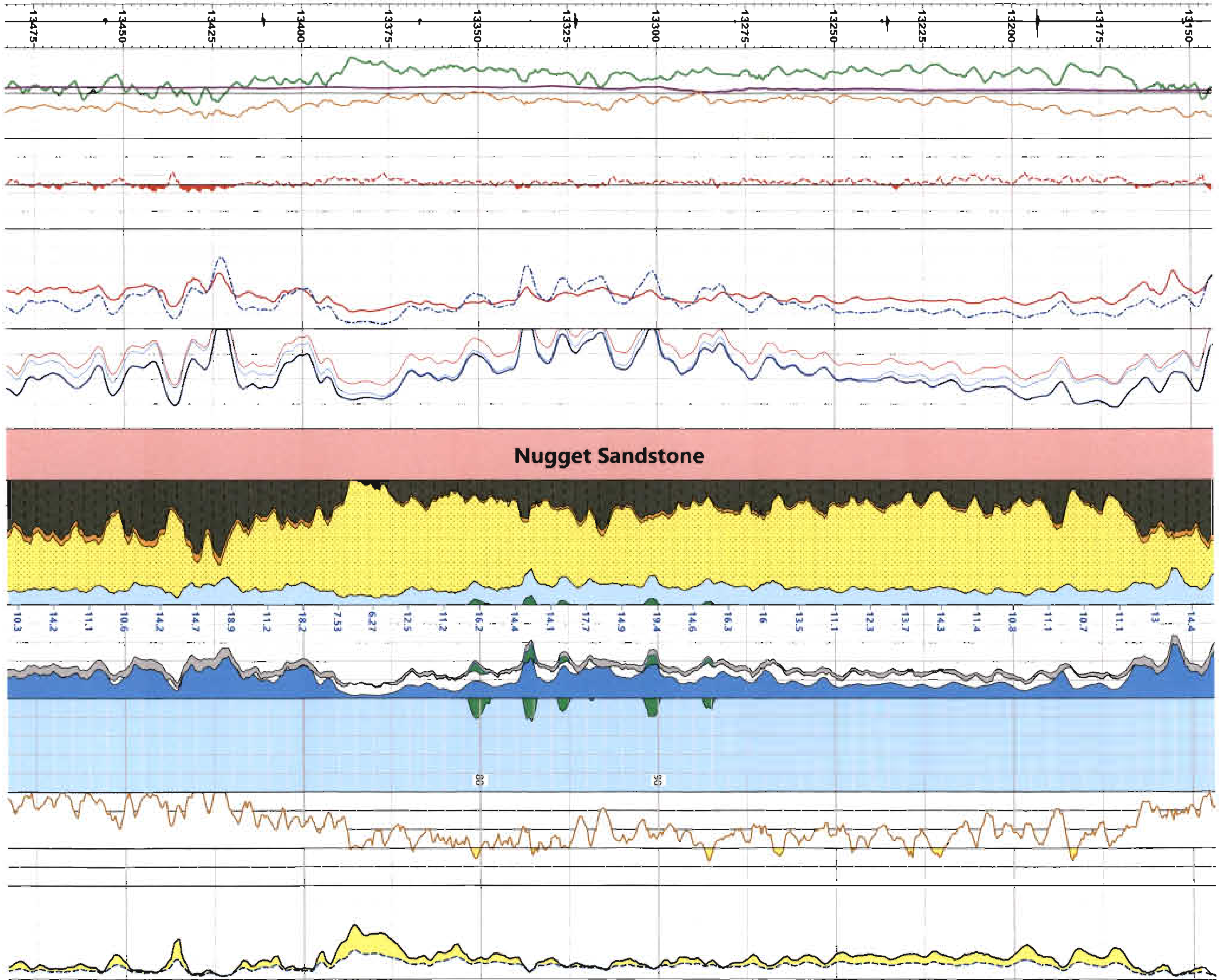

12125
12100
12075
12050
12025
12000
11975
11950
11925
11900
11875
11850
11825
11800
Mowry Shale
Frontier Formation

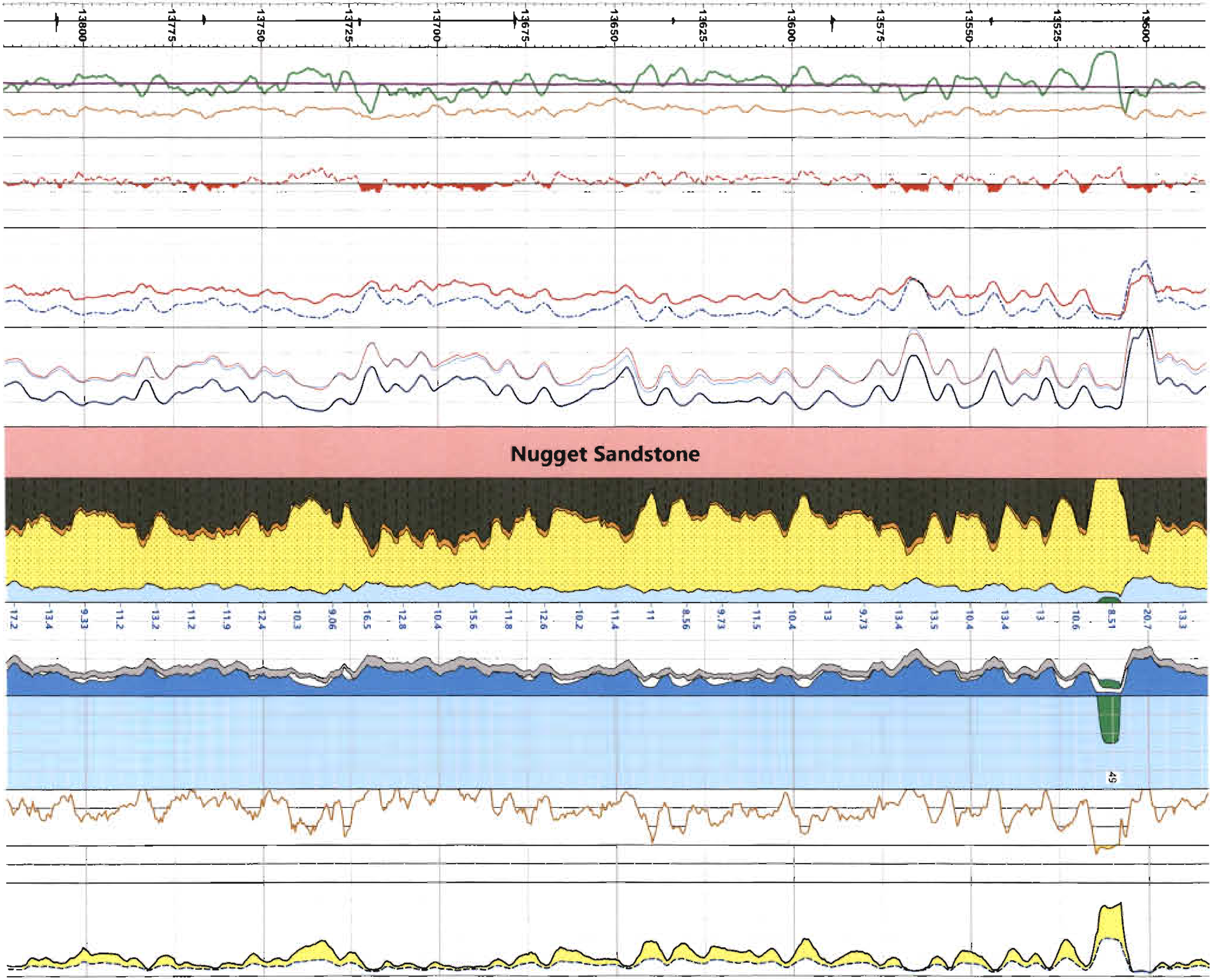


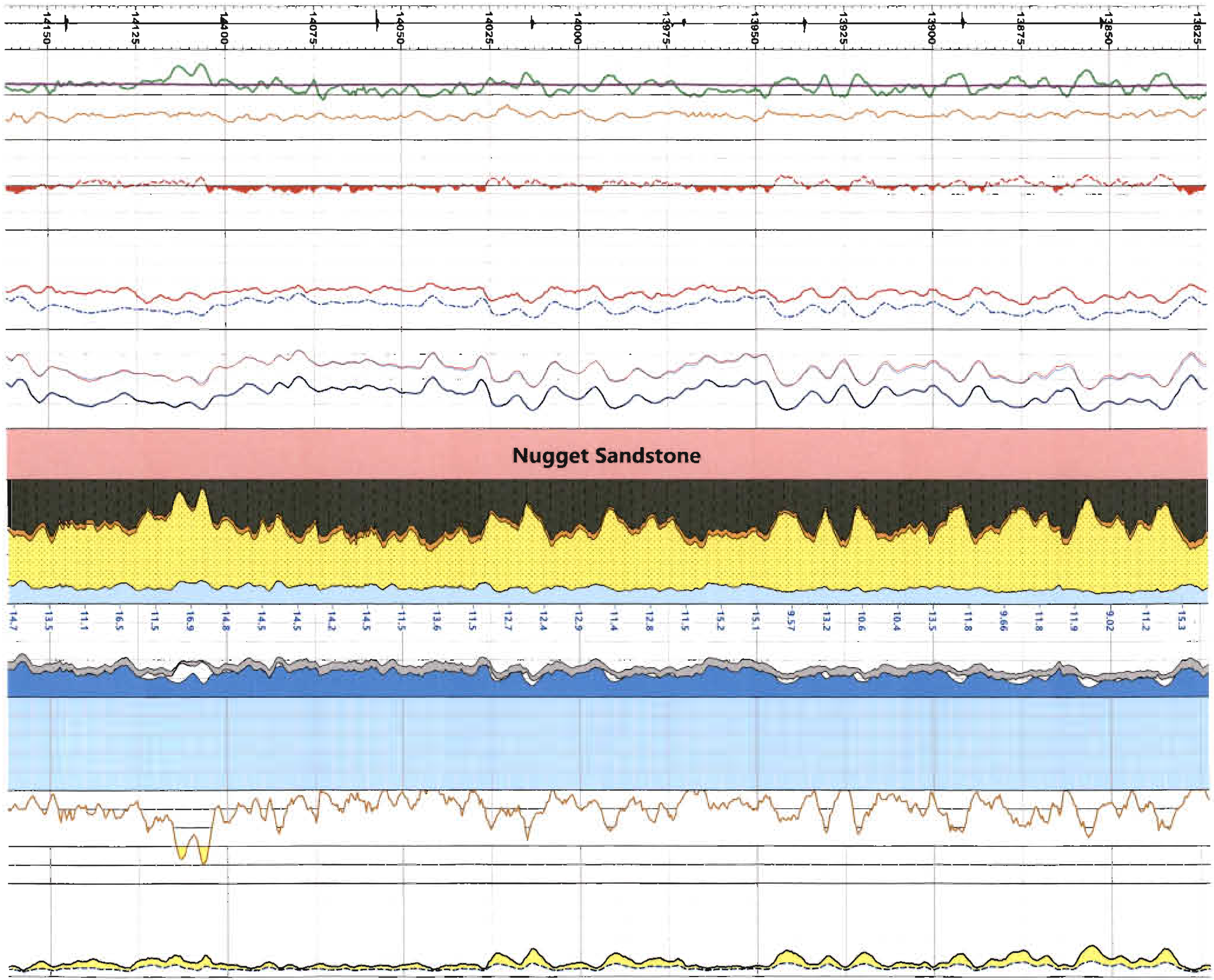
Muddy Sandstone
Mowry Shale


12800
12775
12750
12725
12700
12675
12650
12625
12600
12575
12550
12525
12500
12475
Muddy Sandstone
16.6
18.2
20.5
17.5
14.5
18.4
15.4
12.8
17.2
14
19.2
14.9
10.5
15.2
13.9
7.23
8.47
9.88
10.1
9.77
11.5
13.2
15
12.2
4.52
9.81
12.9
13.3
14.7
13.6
15.9
17.7
14.6
20.5

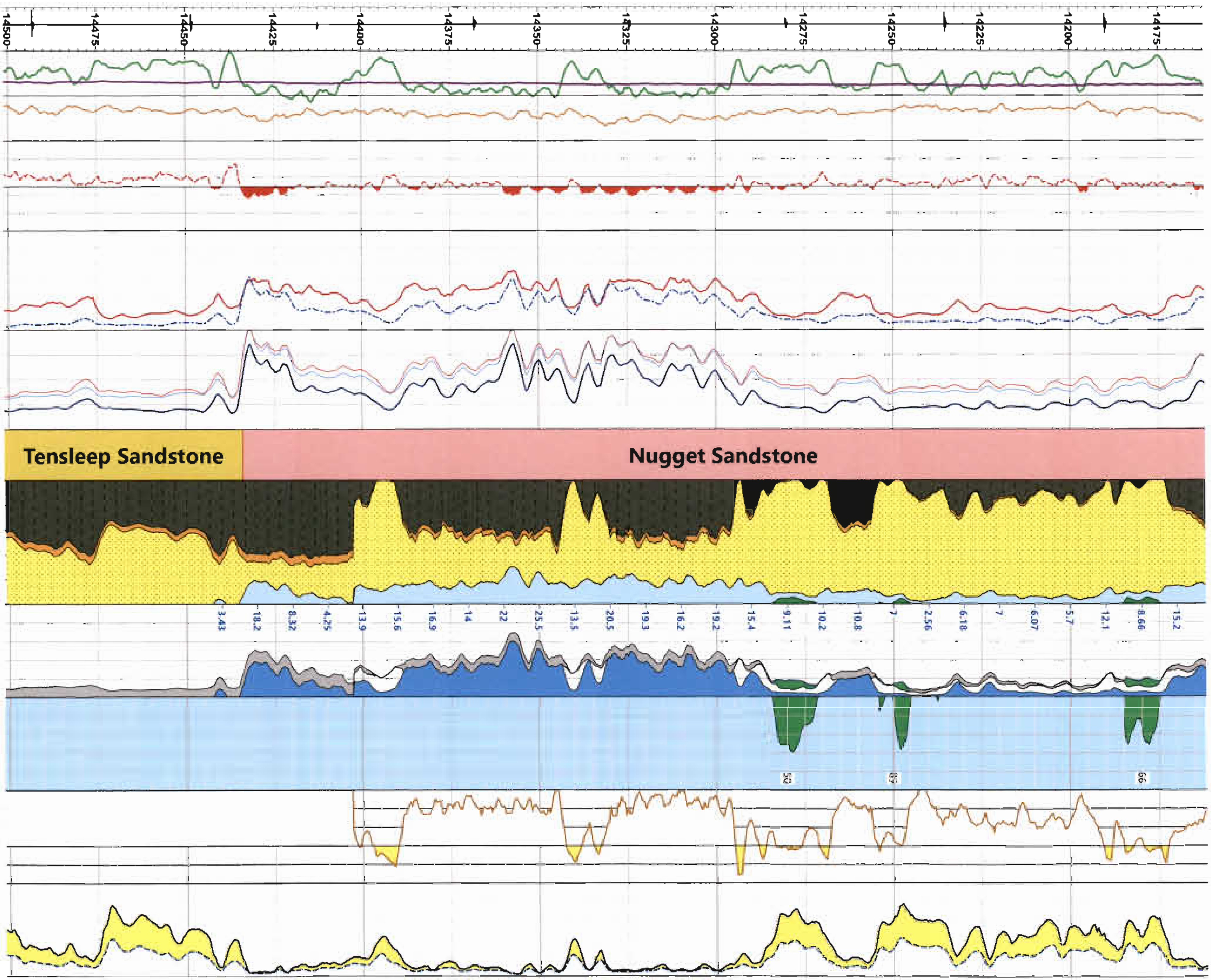

13125
13100
13075
13050
13025
13000
12975
12950
12925
12900
12875
12850
12825
Nugget Sandstone
Muddy Sandstone


13475
13450
13425
13400
13375
13350
13325
13300
13275
13250
13225
13200
13175
13150
Nugget Sandstone
10.3
14.2
11.1
10.6
14.2
14.7
18.9
11.2
18.2
7.53
6.27
12.5
11.2
16.2
14.4
14.1
17.7
14.9
19.4
14.6
16.3
16
13.5
11.1
12.3
13.7
14.3
11.4
10.8
11.1
10.7
11.1
13
14.4
90
90

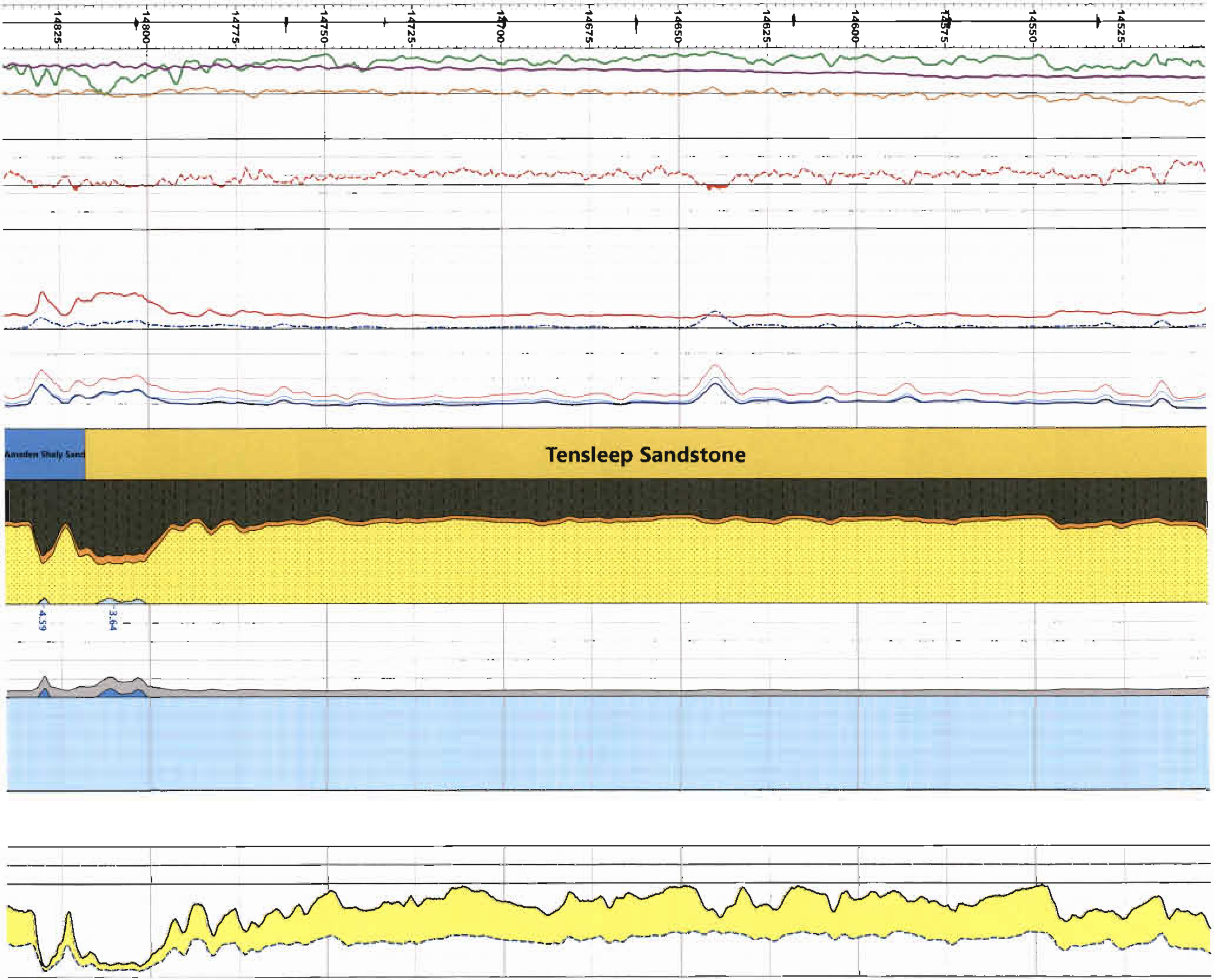

13800
13775
13750
13725
13700
13675
13650
13625
13600
13575
13550
13525
13500
Nugget Sandstone

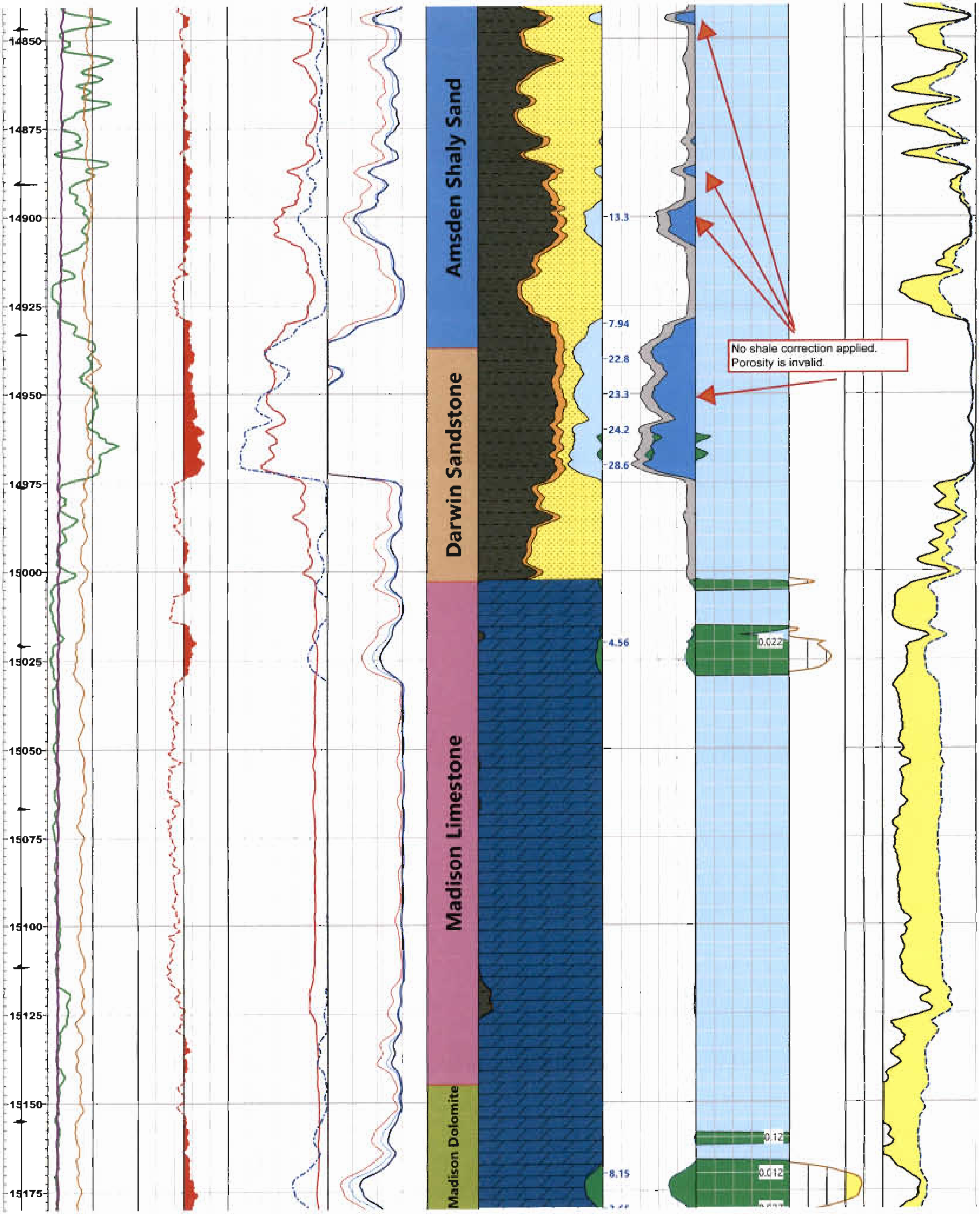


14150
14125
14100
14075
14050
14025
14000
13975
13950
13925
13900
13875
13850
13825
Nugget Sandstone
14.7
13.5
11.1
16.5
11.5
16.9
14.8
14.5
14.5
14.2
14.5
11.5
13.6
11.5
12.7
12.4
12.9
11.4
12.8
11.5
15.2
15.1
9.57
13.2
10.6
10.4
13.5
11.8
9.66
11.8
11.9
9.02
11.2
15.3

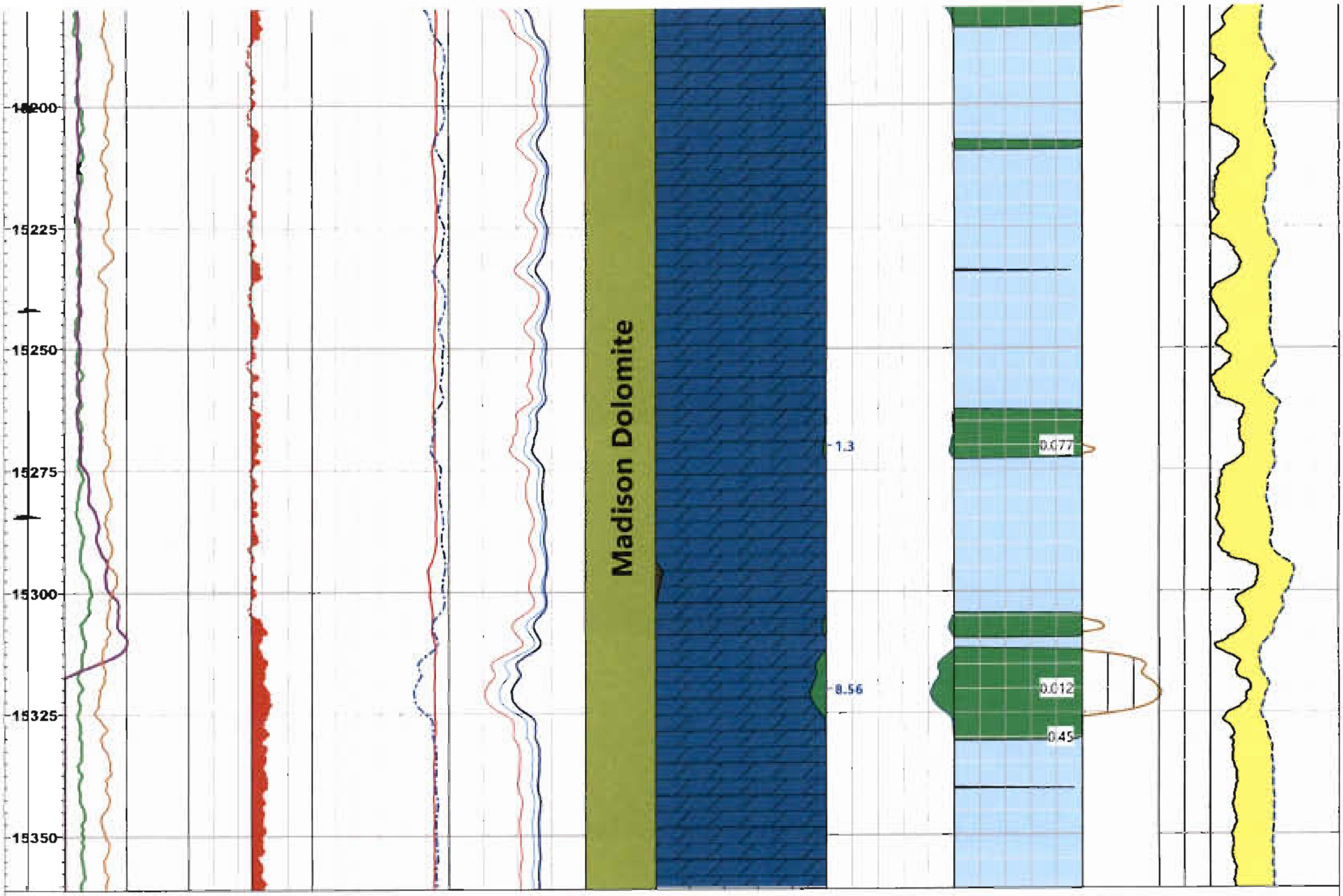


14500
14475
14450
14425
14400
14375
14350
14325
14300
14275
14250
14225
14200
14175
Tensleep Sandstone
Nugget Sandstone
3.43
18.2
8.32
4.25
13.9
15.6
16.9
14
22
25.5
13.5
20.5
19.3
16.2
19.2
15.4
9.11
10.2
10.8
7
2.56
6.18
7
6.07
5.7
12.1
8.66
15.2


14825
14800
14775
14750
14725
14700
14675
14650
14625
14600
14575
14550
14525
Amsden Shaly Sand
Tensleep Sandstone
4.59
3.64



14850
14875
14900
14925
14950
14975
15000
15025
15050
15075
15100
15125
15150
15175
Amsden Shaly Sand
Darwin Sandstone
Madison Limestone
Madison Dolomite
13.3
7.94
22.8
23.3
24.2
28.6
4.56
8.15
0.022
0.12
0.012
No shale correction applied.
Porosity is invalid.



Well: **Marlin 29-21 WDW**

UWI:
Short name:
Long name:

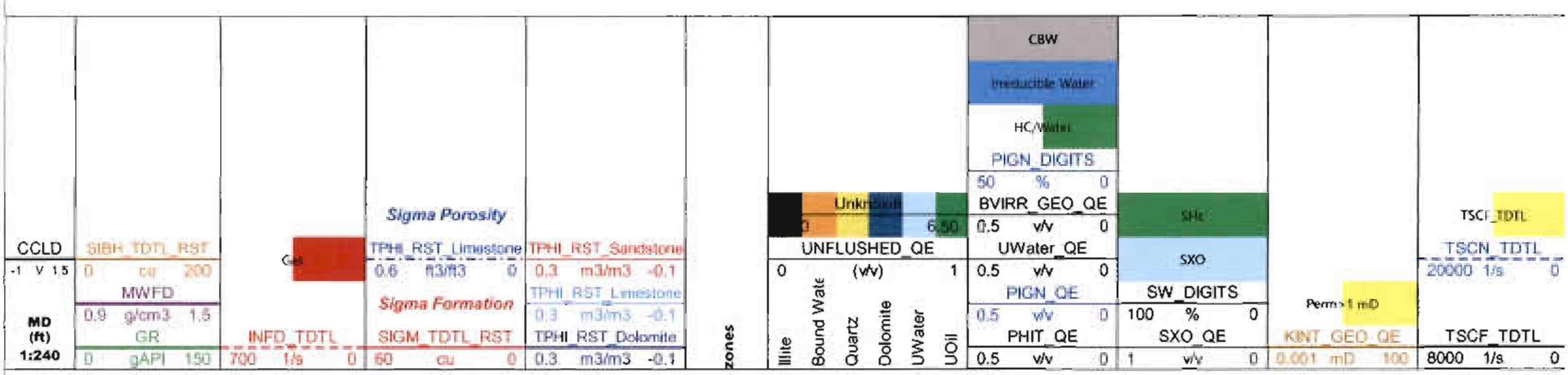
Elevation:
Elevation datum:
Total depth: **11091**
Coordinate system:

X:
Y:
Longitude: **-107.00000 degrees**
Latitude: **42.000000 degrees**

SPUD date:
Completion date:
Status:
Operator:

Country: **USA**
Field: **Frenchie Draw**
State: **Wyoming**
Company: **Encana Oil & Gas**

MD	.ft	:
BHPR	.psi	:Borehole Pressure
Bound_Water_QE	.v/v	: Bound Water Volume Fraction
BSAL_TDTL_RST	.ppk	: Borehole Salinity
BVIRR_GEO_QE	.v/v	: Bulk volume irreducible
CCLD	V	: CCL Discriminated Amplitude
CS	.ft/h	: Cable Speed
Dolomite_QE	.v/v	: Dolomite Volume Fraction
Dry_Weight_Dolomite_QE	.w/w	: Dry Weight Fraction From Quanti.Elan
Dry_Weight_Illite_QE	.w/w	: Dry Weight Fraction From Quanti.Elan
Dry_Weight_Quartz_QE	.w/w	: Dry Weight Fraction From Quanti Elan
GR	.gAPI	: Gamma Ray
GTEM	.degF	: Generalized Borehole Temperature
Illite_QE	.v/v	: Illite Volume Fraction
INFO_TDTL_RST	.1/s	: Far Inelastic Count Rate
KINT_GEO_QE	.mD	: Permeability (Juhasz 1979)
MWFD	.g/cm3	Manometer Well Fluid Density
PHIT_QE	.v/v	: Total Porosity
PIGN_QE	.v/v	: Effective porosity (with irreducible water)
Quartz_QE	.v/v	Quartz Volume Fraction
RHGA_GEO_QE	.g/cm3	: Apparent grain density
SIBH_TDTL_RST	.cu	: Sigma Borehole Corrected
SIGM_RST	.cu	: Formation Sigma
SUWI_QE	.v/v	: Water saturation virgin zone
SW_QE	.v/v	: Undisturbed Zone Water Saturation
TENS	lbf	:Cable Tension
TPHI_RST	.m3/m3	Formation Porosity
TPHI_RST_Dolomite	.m3/m3	: Formation Porosity, dolomite matrix
TPHI_RST_Limestone	.m3/m3	: Formation Porosity, limestone matrix
TPHI_RST_Sandstone	.m3/m3	: Formation Porosity, sandstone matrix
TSCF_TDTL_RST	.1/s	: Total Selected Count Rate Far Detector
TSCN_TDTL_RST	.1/s	: Total Selected Count Rate Near Detector
VCL_GEO_QE	.v/v	: Clay fraction
XOil_QE	.v/v	: Flushed Zone Oil Volume Fraction
XWater_QE	.v/v	: Flushed Zone Water Volume Fraction



COMPANY: Encana Oil & Gas

WELL: Marlin 29-21 WDW
FIELD: Frenchie Draw
COUNTY: Fremont
STATE: Wyoming
COUNTRY: USA

Schlumberger

API No.: 49-013-233374 Date Processed: 4/13/2020

Parameters

DLIS Name	Description	Value	
	RST-C: Reservoir Saturation Pro Tool C		
AIRB	RST Air Borehole	No	
BHS	Borehole Status	CASED	
BSALOPT	RST Borehole Salinity Option	Unknown	
BSFL	RST Borehole Salinity Filter Length	51	
DFPC	RST Depth Filter Processing Constant	One	
DFPC_TDTL	RST Depth Filter Processing Constant (TDT-like)	Two	
MATR	Rock Matrix for Neutron Porosity Corrections	SANDSTONE	
NORM_IRAT_RST	RST Normalized Inelastic Ratio	0.48	
NORM_SIGM_RST	RST Normalized Sigma	30	CU
RGAI	Near/Far Gain Calibration Ratio	1	
TIER_SIGM	RST Sigma Acquisition Mode	0_RST_Sigma	
	PSPT: Production Services Logging Platform		
BHS	Borehole Status	CASED	
MATR	Rock Matrix for Neutron Porosity Corrections	SANDSTONE	
	System and Miscellaneous		
BS	Bit Size	8.000	IN
BSAL	Borehole Salinity	-50000.00	PPM
CSIZ	Current Casing Size	5.000	IN
CWEI	Casing Weight	23.20	LB/F
DO	Depth Offset for Playback	0.0	FT
PP	Playback Processing	OFF	

Parameters from original log on June 14, 2012.

Attachment E-1 - Existing Completion

AETHON

Downhole Well Profile

Well Name: MARLIN 29-21 WDW (W002481-1)

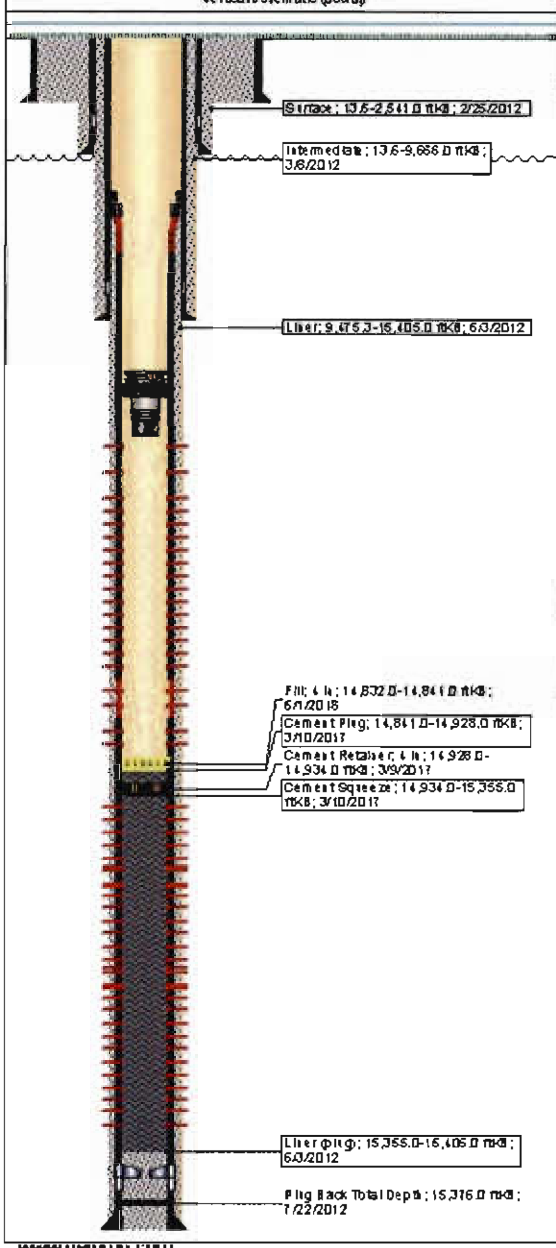
API/UWI	Surface Legal Location	Field Name	Basin	State/Province	Well Configuration Type
49013233740100	S29-T35N-R90W	Wildcat	Wind River	Wyoming	Vertical
Original KB Elevation (ft)	**KB-Ground Distance (ft)**	**Spud Date**	**Rig Release Date**	**PBTD (All) (ftKB)**	**Total Depth (ftKB)**
5,894.60	13.60	2/23/2012 23:30	5/6/2012 00:00	Original Hole - 15,375.0	15,405.0

Casing Strings

Csg Des	OD (in)	ID (in)	Wt/Len (lb/ft)	Grade	Top Thread	Set Depth (ftKB)
Conductor	20	19.00	106.50	J-55		74.0
Surface	9 5/8	8.84	40.00	N-80	LT&C	2,541.0
Intermediate	7	6.28	26.00	N-80	LT&C	9,666.0
Liner	5	4.13	21.40	T95	ST&C	15,405.0

Vertical, Original Hole, 12/26/2019 11:52:26 AM

Vertical schematic (actual)



Perforations

Date	Type	Top (ftKB)	Btm (ftKB)	Top (TVD) (ftKB)	Btm (TVD) (ftKB)
10/10/2012	Tensleep	14,448.0	14,474.0	14,416.9	14,442.5
10/10/2012	Tensleep	14,502.0	14,522.0	14,470.1	14,489.9
10/10/2012	Tensleep	14,548.0	14,572.0	14,515.5	14,539.2
10/10/2012	Tensleep	14,584.0	14,604.0	14,551.1	14,570.8
10/10/2012	Tensleep	14,610.0	14,620.0	14,576.8	14,586.6
10/10/2012	Tensleep	14,634.0	14,668.0	14,600.5	14,634.0
8/11/2012	Tensleep	14,674.0	14,682.0		
8/11/2012	Tensleep	14,702.0	14,712.0		
8/11/2012	Tensleep	14,722.0	14,730.0		
10/10/2012	Tensleep	14,750.0	14,766.0	14,714.9	14,730.7
5/31/2014	Darwin	14,972.0	14,998.0	14,934.7	14,960.4
5/31/2014	Madison	15,000.0	15,030.0	14,962.4	14,992.1
7/13/2012	Madison	15,012.0	15,080.0	14,974.3	15,041.7
5/31/2014	Madison	15,032.0	15,062.0	14,994.1	15,023.9
5/31/2014	Madison	15,064.0	15,094.0	15,025.8	15,055.6
5/31/2014	Madison	15,096.0	15,126.0	15,057.5	15,087.3
7/2/2012	Madison	15,110.0	15,180.0	15,071.4	15,140.6
5/30/2014	Madison	15,128.0	15,158.0	15,089.2	15,119.0
5/30/2014	Madison	15,160.0	15,190.0	15,121.0	15,150.7
5/30/2014	Madison	15,190.0	15,220.0	15,150.7	15,180.4
5/30/2014	Madison	15,222.0	15,252.0	15,182.4	15,212.2
5/30/2014	Madison	15,254.0	15,284.0	15,214.1	15,243.9
7/23/2012	Madison	15,262.0	15,328.5	15,222.1	15,288.0
5/29/2014	Madison	15,282.0	15,312.0	15,241.9	15,271.6

Tubing Strings

Tubing Description	Run Date	String Length (ft)	Set Depth (ftKB)
Tubing - Packer	6/2/2018	13.76	14,445.6

Item Des	Jts	OD (in)	Wt (lb/ft)	Grade	Len (ft)	Btm (ftKB)	Btm (TVD) (ftKB)	Incl Max (°)
On/Off Tool	1	3 1/2	4.70		1.20	14,433.0	14,402.1	9.75
[illegible]	1	4.126	4.70		7.00	14,440.0	14,409.0	9.74
EPN coated sub	1	2 3/8	4.70		4.10	14,444.1	14,413.0	9.71
BXN Nipple (1.875" ID)	1	2 3/8	4.70		1.05	14,445.2	14,414.1	9.69
Pump Out Plung 4 screws	1	2 3/8	4.70		0.41	14,445.6	14,414.5	9.69

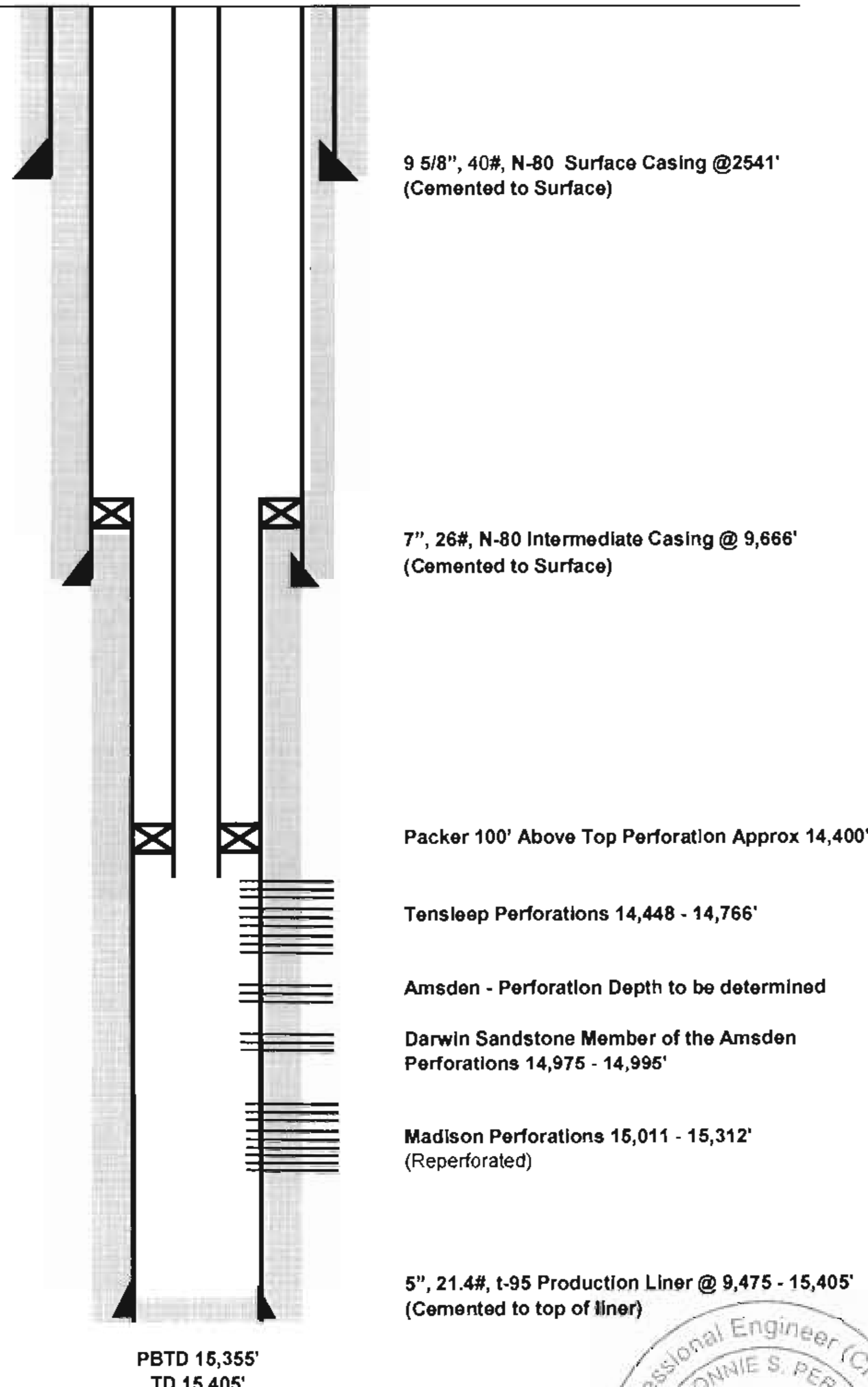
Notes:
Completion reports indicate the 5" liner is set at 9513 to 15405'

Professional Engineer (Chemical)
BONNIE S. PERCY
6360
Bonnie S. Percy
Date 8/12/2020
WYOMING

Aethon Energy Operating LLC– Marlin No 29-21 WDW

Section 29 T35N R90W
Fremont County, Wyoming
Attachment E-2 (Revised) - Proposed Completion

Formation	TVD (FT)	MD (FT)
Wind River	-	-
Lower Fort Union	2,433	2,435
Lance	3,210	3,212
Meeteetse	4,473	4,475
Mesaverde	5,818	5,820
Cody Shale	7,016	7,018
Frontier	11,168	11,174
Mowry	11,831	11,838
Muddy	12,192	12,199
Thermopolis Shale	12,226	12,233
Cloverly	12,384	12,392
Morrison	12,440	12,447
Sundance	12,601	12,609
Nugget	12,905	12,914
Chugwater	13,088	13,099
Dinwoody	14,071	14,096
Phosphoria	14,124	14,150
Tensleep	14,403	14,434
Amsden	14,759	14,795
Darwin SS MBR	14,936	14,974
Madison	14,965	15,003
Gallatin		15,365



Professional Engineer (Chemical)
BONNIE S. PERCY
6360
Date 8/12/2020
WYOMING

Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. ______-2020

Attachment E-3 (Revised)

Professional Engineer (Chemical)
BONNIE S. PERCY
6360
Date 8/12/2020
WYOMING

Water Disposal Plan — **Marlin No 29-21 WDW API # 49-013-23374**

	Tensleep	Amsden (Darwin)	Madison	
Depth to top Perforation		14,975	15,011	FT
Fracture Gradient		0.644	0.644	psi/ft
Fracture Pressure at Top Perforation		9644	9667	psi
Fluid Gradient		0.433	0.433	psi/ft
Fracture Pressure at Surface		3159	3167	psi
Maximum Injection Pressure using 90% safety Factor		**2840**	**2850**	**psi**
Requested Temporary Maximum Injection Pressure		**2840**	**2850**	**psi**
Currently Authorized Maximum Injection Pressure	**3,500**			**psi**

MADISON RADIUS OF EMPLACED FLUID

Case	Amsden (Darwin)	Madison Most Likely	Madison Optimistic	Madison Highly Optimistic	
Permeability		3.5	6.0	17	MD
Minimum Water Injection Rate	**200**	**1000**	**1000**	**1000**	**BWPD**
Average Water Injection Rate	**900**	**4,500**	**9,900**	**20,000**	**BWPD**
Maximum Water Injection Rate	**6,000**	**30,000**	**30,000**	**30,000**	**BWPD**
Receiver Net Thickness (Log Analysis)	25	162	162	162	ft
Injection Period (50 years)	18250	18250	18250	18250	days
Injection Rate	26	131	289	578	gpm
Injection Rate (Tetra Tech) (2020)	900	4500	9900	19800	bwpd
Injection Rate	5054	25268	55589	111177	ft^3/day
Porosity (Log Analysis)	7.1%	5.3%	5.3%	5.3%	phi
Area of Emplaced Fluid (A=rate*time/thicknes/porosity)	1191	1223	2690	5380	Acres
Radius - Emplaced Fluid	4063	4117	6107	8637	feet
Radius - Emplaced Fluid	**0.770**	**0.780**	**1.157**	**1.636**	**miles**
10% increase for Dispersion	**0.8**	**0.9**	**1.3**	**1.8**	**miles**

Comparison of REW calculations to simulation:

Encana CMG Simulation

Perm	4.3	9.3	Perm
Inj Rate @ 10 YRS	28,000	55,000	BWPD
Cone of Influence (Increased P)*	30	30	miles
Radius of Salinity Increase*	4.5	4.5	miles

* *Exhibits do not indicate which of the two possible perm cases are associated with these results*

Tetra Tech SWIFT Simulation	**Most Likely**	**Optimistic**	**Highly Optimistic**	
Perm	3.5	8	17	Perm
Receiver Net Thickness	318	318	318	ft
Porosity	8.4%	8.4%	8.4%	phi
Radius of Salinity Increase(6.9 mg/l)*	**0.9**	**1.2**	**1.7**	miles
Migrated Radius of Salinity Increase (updip/downdip) **	0.6/1.7	0.5/3.3	0.1/6.8	miles
Cone of Influence (Increased P)***	7.0	11.5	13	miles

**based on the 6.9 mg/l contour - radii are from contour maps - Tetra Tech Fig 5-13, 5-16, 5-19*
*** at 10,000 years - from Tetra Tech Fig 5-14, 5-17, 5-20*
**** From Tetra Tech Fig 5-12, 5-15, 5-18 for a 100 psi increase* (TETRA TECH, 2020)

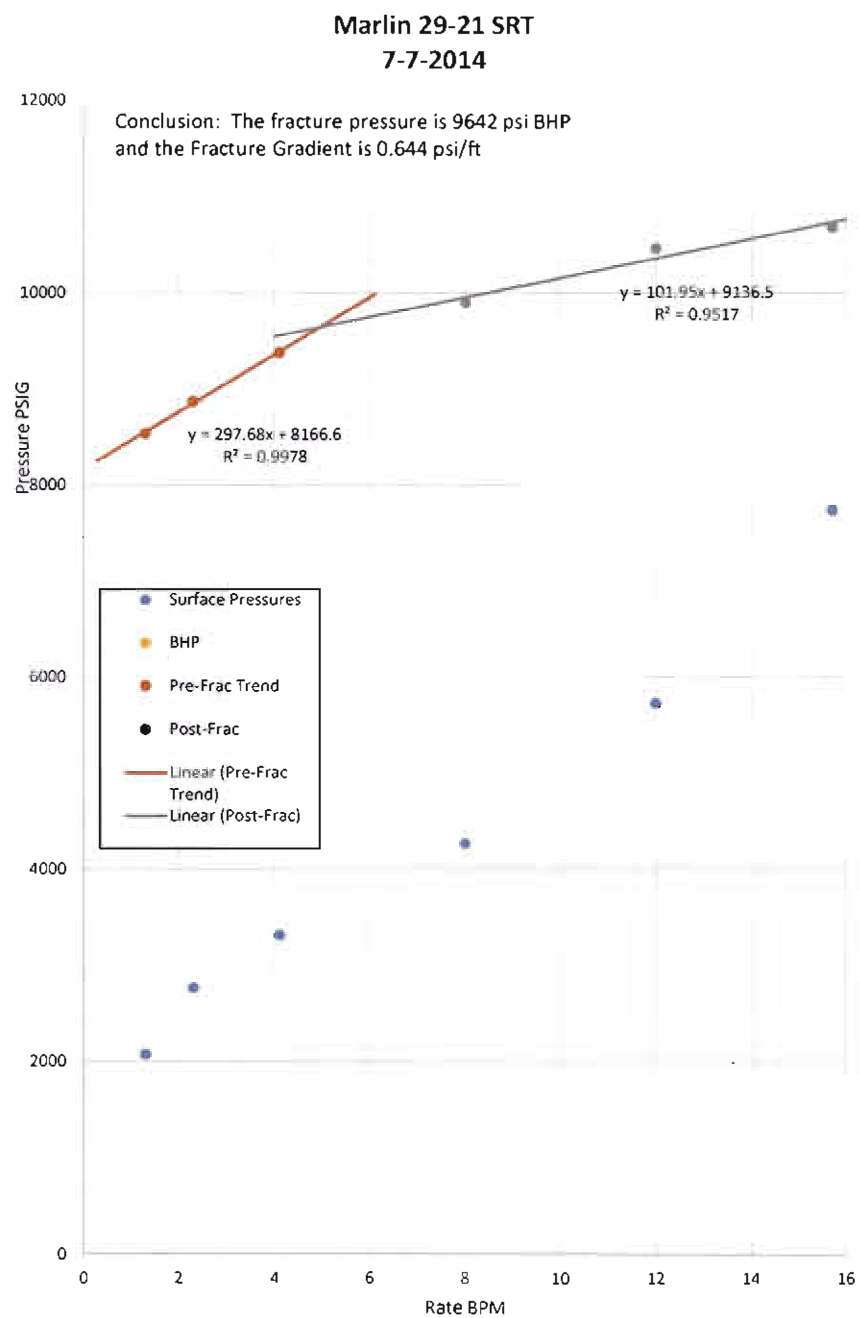
Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. _____-2020

Attachment E-4

Step End Time (hh:mm:ss)	Rate BPM	Rate GPM	Surface Pressure psig	Friction Pressure L psi	BH Pressure psig
	1.3	55	2075		8539
	2.3	97	2764		8874
	4.1	172	3312		9379
	8	336	4265		9903
	12	504	5732		10462
	15.7	659	7747		10684

Top Perf		**14972**	
Injectate Fluid Gradient		0.4330	psi/ft
	m	b	
pre-frac trend line	297.68	8166.6	
post-frac trend line	101.95	9136.5	
Fracture rate (b1-b2)/(m2-m1)		4.96	BPM
Fracture BH Pressure		9642	psi BHP
Fracture Gradient		**0.644**	psi/ft

Professional Engineer (Chemical)
BONNIE S. PERCY
6360
Bonnie S Percy
Date 8/12/2020
WYOMING



Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. _____-2020

Professional Engineer (Chemical)
BONNIE S. PERCY
6360
Date 8/12/2020
WYOMING

Attachment E-5

Recompletion Procedure

<u>PROCEDURE:</u>

1. MIRU workover rig.

2. Release tubing anchor and POOH with tubing.

3. Perf Amsden (Upper portion - depths to be determined, approximately 14,860 - 14,875' MD)

4. RIH with tbg and pkr; isolate Amsden perforations, swab water sample; POOH
   Note: This upper portion of the Amsden is tight. It serves as a confining unit between the Tensleep and the Darwin. Even if there is enough fluid entry to obtain a water sample, there will unlikely be enough fluid entry to purge three tubing volumes.

5. RIH with 4-3/4" bit, bit sub, and SN on tubing. Drill out cement retainer at 14,928'.
   Drill through Darwin Sandstone Member of the Amsden to 15,000'.

6. Optional Darwin Test: Perf Amsden (Darwin Sanstone Member) 14975 to 14995 ft

7. RIH with tbg and pkr; isolate Darwin Sanstone perforations, swab water sample; POOH
   Note: The Darwin Sandstone water will be sampled and analyzed if required by the WOGCC for permitting

8. Evaluate Amsden and/or Darwin injectivity. Stimulate as needed. Conduct Step rate test.

9. RIH with 4-3/4" bit, bit sub, and SN on tubing. Drill out cement to 15,350'.

10. Re-Perf Madison 15,011 to 15,312 ft

11. PU 5-1/2" coated injection packer and RIH on tubing. Set packer at 14,400' +/-.

12. Mix packer fluid and place in annulus

13. Pressure-test to 1000 psi for 30 min. with WOGCC witness.

14. Rig well for Injection.

Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. _____-2020

APPENDIX A

Receiving Formation Water Quality Documentation

29 Country Acres Rd. Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070505
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12070505-02			
Customer Sample ID:	Marlin Well	Collection:	7/3/2012	5:00 PM
Matrix:	Aqueous	Received:	7/5/2012	10:15 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	110	ug/L	1		EPA 8021 B	7/5/2012	15:08	RH
Surr: 4-Bromofluorobenzene	104.2	%	70-130		EPA 8021 B			
Toluene	140	ug/L	1		EPA 8021 B	7/5/2012	15:08	RH
Surr: 4-Bromofluorobenzene	104.2	%	70-130		EPA 8021 B			
Ethyl Benzene	83	ug/L	2		EPA 8021 B	7/5/2012	15:08	RH
Surr: 4-Bromofluorobenzene	104.2	%	70-130		EPA 8021 B			
m,p-Xylene	250	ug/L	5		EPA 8021 B	7/5/2012	15:08	RH
Surr: 4-Bromofluorobenzene	104.2	%	70-130		EPA 8021 B			
o Xylene	210	ug/L	4		EPA 8021 B	7/5/2012	15:08	RH
Surr: 4-Bromofluorobenzene	104.2	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	5300	ug/L	100		EPA 8015 D	7/5/2012	15:08	RH
Surr: 4-Bromofluorobenzene (FID)	99.6	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	160	mg/L	0.05		EPA 8015 D	7/6/2012	18:14	RH
Surr: o-Terphenyl	707.0	%	70-130		EPA 8015 D			
Methanol	< 400	ug/L	400	L	EPA 8015 D	7/9/2012	12:29	CL
Oil and Grease	120	mg/L	1		EPA 1664 A	7/12/2012	11:15	JP

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070505
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12070505-02			
Customer Sample ID:	Marlin Well	Collection:	7/3/2012	5:00 PM
Matrix:	Aqueous	Received:	7/5/2012	10:15 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Total Metals								
Aluminum	357	ug/L	4	L	EPA 200.8	7/23/2012	12:30	CL
Arsenic	14.5	ug/L	0.5	L	EPA 200.8	7/23/2012	12:30	CL
Barium	1390	ug/L	1.5	L	EPA 200.8	7/23/2012	12:34	CL
Beryllium	< 0.2	ug/L	0.2	L	EPA 200.8	7/23/2012	12:30	CL
Boron	321	ug/L	0.04	L	EPA 200.8	7/28/2012	13:35	CL
Cadmium	< 0.08	ug/L	0.08	L	EPA 200.8	7/23/2012	12:30	CL
Chromium	181	ug/L	0.5	L	EPA 200.8	7/12/2012	12:30	CL
Copper	656	ug/L	2.5	L	EPA 200.8	7/23/2012	12:34	CL
Iron	108000	ug/L	2500	L	EPA 200.8	7/23/2012	12:37	CL
Lead	297	ug/L	0.1	L	EPA 200.8	7/23/2012	12:30	CL
Manganese	1590	ug/L	25	L	EPA 200.8	7/23/2012	12:37	CL
Mercury	3.0	ug/L	0.20	L	EPA 7470	7/27/2012	10:10	CL
Nickel	205	ug/L	0.5	L	EPA 200.8	7/23/2012	12:30	CL
Selenium	0.68	mg/L	0.5	L	EPA 200.8	7/23/2012	12:37	CL
Silicon as SiO2	32100	ug/L	1250	L	EPA 200.8	7/23/2012	12:37	CL
Silver	0.80	ug/L	0.5	L	EPA 200.8	7/23/2012	12:30	CL
Strontium	1720	ug/L	25	L	EPA 200.8	7/23/2012	12:37	CL
Thallium	0.52	mg/L	0.1	L	EPA 200.8	7/23/2012	12:34	CL
Zinc	1060	ug/L	25	L	EPA 200.8	7/23/2012	12:34	CL

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070505
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12070505-02			
Customer Sample ID:	Marlin Well	Collection:	7/3/2012	5:00 PM
Matrix:	Aqueous	Received:	7/5/2012	10:15 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Dissolved Metals								
Aluminum	5.2	ug/L	4	L	EPA 200.8	7/23/2012	13:19	CL
Arsenic	< 0.5	ug/L	0.5	L	EPA 200.8	7/23/2012	13:19	CL
Barium	83.9	ug/L	0.3	L	EPA 200.8	7/23/2012	13:19	CL
Beryllium	< 0.2	ug/L	0.2	L	EPA 200.8	7/23/2012	13:19	CL
Boron	333	ug/L	5	L	EPA 200.8	7/23/2012	13:19	CL
Cadmium	0.086	ug/L	0.08	L	EPA 200.8	7/23/2012	13:19	CL
Chromium	0.60	ug/L	0.5	L	EPA 200.8	7/23/2012	13:19	CL
Copper	118	ug/L	0.5	L	EPA 200.8	7/23/2012	13:19	CL
Iron	1810	ug/L	50	L	EPA 200.8	7/23/2012	13:19	CL
Lead	0.12	ug/L	0.1	L	EPA 200.8	7/23/2012	13:19	CL
Manganese	682	ug/L	2.5	L	EPA 200.8	7/23/2012	13:23	CL
Mercury	< 0.2	ug/L	0.2	L	EPA 7470	7/10/2012	13:06	CL
Nickel	99.4	ug/L	0.5	L	EPA 200.8	7/23/2012	13:19	CL
Selenium	< 0.5	ug/L	0.5	L	EPA 200.8	7/23/2012	13:19	CL
Silicon as SiO2	41100	ug/L	535	L	EPA 200.8	7/28/2012	13:53	CL
Silver	0.75	ug/L	0.5	L	EPA 200.8	7/23/2012	13:19	CL
Strontium	3430	ug/L	2.5	L	EPA 200.8	7/23/2012	13:23	CL
Thallium	0.16	ug/L	0.1	L	EPA 200.8	7/23/2012	13:19	CL
Zinc	13.5	ug/L	5	L	EPA 200.8	7/23/2012	13:19	CL

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070505
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12070505-02			
Customer Sample ID:	Marlin Well	Collection:	7/3/2012	5:00 PM
Matrix:	Aqueous	Received:	7/5/2012	10:15 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
General Parameters								
Ammonia as N	1.2	mg/L	0.1		SM 4500-NH3 D	7/5/2012	15:13	CB
Dissolved Organic Carbon (DOC)	67.9	mg/L	1	L	SM 5310C	7/13/2012	10:02	CL
Naphthalene	< 4	ug/L	4	L	EPA 8260	7/9/2012	15:01	CL
Radium-228	0.662 +/- 0.506	pCi/L	1	L	EPA 904.0	7/19/2012	15:40	CL
Radium-226	2.4 +/- 0.9	pCi/L	0.21		SM 7500-Ra	7/11/2012	12:34	MW
Temperature (Thermometric)	9.6	°C			N/A	7/5/2012	16:46	LU
Total Hardness as CaCO3	660	mg/L	6.6		EPA 200.7	7/10/2012	13:27	CV
Total Organic Carbon (purgeable)	108	mg/L	60	L	SM 5310C	7/12/2012	16:55	CL
Major Ions								
Alkalinity, Bicarbonate (HCO3)	190	mg/L	2		SM 2320 B	7/6/2012	14:37	MW
Alkalinity, Carbonate (CO3)	< 2	mg/L	2		SM 2320 B	7/6/2012	14:37	MW
Alkalinity, Hydroxide (OH)	< 2	mg/L	2		SM 2320 B	7/6/2012	14:37	MW
Calcium	220	mg/L	2		EPA 200.7	7/10/2012	13:22	CV
Chloride	35	mg/L	1		EPA 300.0	7/6/2012	19:50	MW
Fluoride	4.4	mg/L	0.2		EPA 300.0	7/6/2012	19:50	MW
Magnesium	24	mg/L	0.02		EPA 200.7	7/10/2012	16:27	MW
Nitrate	< 1	mg/L	1		EPA 300.0	7/6/2012	19:50	MW
Potassium	30	mg/L	0.06		EPA 200.7	7/10/2012	13:27	CV
Sodium	69	mg/L	0.3		EPA 200.7	7/10/2012	16:27	CV
Sulfate	670	mg/L	100		EPA 300.0	7/6/2012	19:11	MW
Orthophosphate	ND	mg/L	0.09		EPA 300.0	7/6/2011	8:03	MW

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070505
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12070505-02			
Customer Sample ID:	Marlin Well	Collection:	7/3/2012	5:00 PM
Matrix:	Aqueous	Received:	7/5/2012	10:15 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Physical Properties								
Biochemical Oxygen Demand (5 day)	2.1	mg/L	2		SM 5210 B	7/11/2012	14:15	LU
Conductivity	1660	µS/cm	5		SM 2510 B	7/5/2012	16:47	MW
pH	6.63	s.u.	0.01		EPA 150.1	7/6/2012	16:37	KF
Total Dissolved Solids (TDS) @ 180 C	1200	mg/L	5		SM 2540 C	7/6/2012	17:08	LU
Total Suspended Solids (TSS)	360	mg/L	1		SM 2540 D	7/6/2012	13:17	LU

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070601
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12070601-02			
Customer Sample ID:	Marlin 29-21	Collection:	7/5/2012	4:30 PM
Matrix:	Aqueous	Received:	7/5/2012	6:28 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	22	ug/L	10		EPA 8021 B	7/11/2012	13:29	RH
Surr: 4-Bromofluorobenzene		%	70-130		EPA 8021 B			
Toluene	120	ug/L	10		EPA 8021 B	7/11/2012	13:29	RH
Surr: 4-Bromofluorobenzene		%	70-130		EPA 8021 B			
Ethyl Benzene	56	ug/L	20		EPA 8021 B	7/11/2012	13:29	RH
Surr: 4-Bromofluorobenzene		%	70-130		EPA 8021 B			
m,p-Xylene	280	ug/L	40		EPA 8021 B	7/11/2012	13:29	RH
Surr: 4-Bromofluorobenzene		%	70-130		EPA 8021 B			
o Xylene	440	ug/L	30		EPA 8021 B	7/11/2012	13:29	RH
Surr: 4-Bromofluorobenzene		%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	12000	ug/L	1000		EPA 8015 D	7/11/2012	13:29	RH
Surr: 4-Bromofluorobenzene (FID)		%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	48	mg/L	0.0051		EPA 8015 D	7/12/2012	21:50	RH
Surr: o-Terphenyl	212.6	%	70-130	D, M	EPA 8015 D			
Methanol	< 400	ug/L	400	L	EPA 8015 D	7/11/2012	13:53	CL
Oil and Grease	37	mg/L	1		EPA 1664 A	7/12/2012	16:20	JP

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070601
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12070601-02			
Customer Sample ID:	Marlin 29-21	Collection:	7/5/2012	4:30 PM
Matrix:	Aqueous	Received:	7/5/2012	6:28 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Total Metals								
Aluminum	15.8	ug/L	4	L	EPA 200.8	7/23/2012	12:41	CL
Arsenic	2.4	ug/L	0.5	L	EPA 200.8	7/23/2012	12:41	CL
Barium	171	ug/L	0.3	L	EPA 200.8	7/23/2012	12:41	CL
Beryllium	<0.2	ug/L	0.2	L	EPA 200.8	7/23/2012	12:41	CL
Boron	256	ug/L	5	L	EPA 200.8	7/23/2012	12:41	CL
Cadmium	<0.08	ug/L	0.08	L	EPA 200.8	7/23/2012	12:41	CL
Chromium	6.9	ug/L	0.5	L	EPA 200.8	7/23/2012	12:41	CL
Copper	80.9	ug/L	0.5	L	EPA 200.8	7/23/2012	12:41	CL
Iron	37500	ug/L	250	L	EPA 200.8	7/23/2012	12:45	CL
Lead	7.0	ug/L	0.1	L	EPA 200.8	7/23/2012	12:41	CL
Manganese	764	ug/L	2.5	L	EPA 200.8	7/23/2012	12:45	CL
Mercury	0.88	ug/L	0.2	L	EPA 7470	7/26/2012	10:17	CL
Nickel	27	ug/L	0.5	L	EPA 200.8	7/23/2012	12:41	CL
Selenium	<0.5	ug/L	0.5	L	EPA 200.8	7/23/2012	12:41	CL
Silicon as SiO2	40100	ug/L	2680	L	EPA 200.8	7/23/2012	12:48	CL
Silver	<0.5	ug/L	0.5	L	EPA 200.8	7/23/2012	12:41	CL
Strontium	1660	ug/L	25	L	EPA 200.8	7/23/2012	12:48	CL
Thallium	<0.1	ug/L	0.1	L	EPA 200.8	7/23/2012	12:41	CL
Zinc	83	ug/L	5	L	EPA 200.8	7/23/2012	12:41	CL

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070601
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12070601-02			
Customer Sample ID:	Marlin 29-21	Collection:	7/5/2012	4:30 PM
Matrix:	Aqueous	Received:	7/5/2012	6:28 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Dissolved Metals								
Aluminum	7.2	ug/L	4	L	EPA 200.8	7/23/2012	13:34	CL
Arsenic	< 0.5	ug/L	0.5	L	EPA 200.8	7/23/2012	13:34	CL
Barium	81.7	ug/L	0.3	L	EPA 200.8	7/23/2012	13:34	CL
Beryllium	< 0.2	ug/L	0.2	L	EPA 200.8	7/23/2012	13:34	CL
Boron	236	ug/L	5	L	EPA 200.8	7/23/2012	13:34	CL
Cadmium	< 0.08	ug/L	0.08	L	EPA 200.8	7/23/2012	13:34	CL
Chromium	0.78	ug/L	0.5	L	EPA 200.8	7/23/2012	13:34	CL
Copper	11	ug/L	0.5	L	EPA 200.8	7/23/2012	13:34	CL
Iron	745	ug/L	50	L	EPA 200.8	7/23/2012	13:34	CL
Lead	< 0.1	ug/L	0.1	L	EPA 200.8	7/23/2012	13:34	CL
Manganese	487	ug/L	2.5	L	EPA 200.8	7/23/2012	13:34	CL
Mercury	< 0.2	ug/L	0.2	L	EPA 7470	7/12/2012	10:01	CL
Nickel	14.2	ug/L	0.5	L	EPA 200.8	7/23/2012	13:34	CL
Selenium	< 0.5	ug/L	0.5	L	EPA 200.8	7/23/2012	13:34	CL
Silicon as SiO2	74900	ug/L	1070	L	EPA 200.8	8/1/2012	15:10	CL
Silver	< 0.5	ug/L	0.5	L	EPA 200.8	7/23/2012	13:34	CL
Strontium	3290	ug/L	2.5	L	EPA 200.8	7/23/2012	13:38	CL
Thallium	< 0.1	ug/L	0.1	L	EPA 200.8	7/23/2012	13:34	CL
Zinc	14.5	ug/L	5	L	EPA 200.8	7/23/2012	13:34	CL

Definitions:

ND-Not Detected at the reporting limit	S-Spike Recovery outside accepted recovery limits	D-Diluted out of recovery limits
RL-Analyte Reporting Limit	J-Analyte detected below quantitation limits	L-Analyzed by a contract laboratory
H-Holding times for preparation or analysis exceeded	M-Matrix Effect	

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070601	
Project ID:	Marlin Well	Report Date:	7/26/2012	
Lab ID:	12070601-02		Date	Time
Customer Sample ID:	Marlin 29-21	Collection:	7/5/2012	4:30 PM
Matrix:	Aqueous	Received:	7/5/2012	6:28 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
General Parameters								
Ammonia as N	0.1	mg/L	0.1		SM 4500-NH3 D	7/10/2012	9:22	KF
Naphthalene	83	ug/L	1	L	EPA 8260	7/11/2012	10:01	CL
Radium-228	.879 +/- 0.45	pCi/L	1	L	EPA 904.0	7/19/2012	11:30	CL
Radium-226	5.9 +/- 1.4	pCi/L	0.21		SM 7500-Ra	7/11/2012	10:36	MW
Temperature (Thermometric)	16.8	°C			N/A	7/6/2012	9:50	LU
Total Hardness as CaCO3	750	mg/L	6.6		EPA 200.7	7/12/2012	14:26	CV
Total Organic Carbon (purgeable)	9.0	mg/L	3	L	SM 5310C	7/11/2012	18:18	CL
Major Ions								
Alkalinity, Bicarbonate (HCO3)	120	mg/L	2		SM 2320 B	7/6/2012	14:22	MW
Alkalinity, Carbonate (CO3)	< 2	mg/L	2		SM 2320 B	7/6/2012	14:22	MW
Alkalinity, Hydroxide (OH)	< 2	mg/L	2		SM 2320 B	7/6/2012	14:22	MW
Calcium	250	mg/L	2		EPA 200.7	7/12/2012	14:26	CV
Chloride	36	mg/L	1		EPA 300.0	7/6/2012	19:50	MW
Fluoride	4.4	mg/L	0.2		EPA 300.0	7/6/2012	19:50	MW
Magnesium	30	mg/L	0.2		EPA 200.7	7/12/2012	14:31	CV
Nitrate	< 1	mg/L	1		EPA 300.0	7/6/2012	19:50	MW
Nitrate as N	< 1	mg/L	1		EPA 300.0	7/6/2012	19:50	MW
Potassium	28	mg/L	0.6		EPA 200.7	7/12/2012	14:31	CV
Sodium	63	mg/L	1		EPA 200.7	7/12/2012	14:31	CV
Sulfate	630	mg/L	100		EPA 300.0	7/6/2012	18:58	MW
Orthophosphate	ND	mg/L	0.09		EPA 300.0	7/6/2012	7:50	MW

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070601
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12070601-02			
Customer Sample ID:	Marlin 29-21	Collection:	7/5/2012	4:30 PM
Matrix:	Aqueous	Received:	7/5/2012	6:28 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Physical Properties								
Biochemical Oxygen Demand (5 day)	< 2	mg/L	2		SM 5210 B	7/10/2012	10:15	LU
Conductivity	1410	µS/cm	5		SM 2510 B	7/6/2012	9:32	LU
pH	7.01	s.u.	0.01		EPA 150.1	7/6/2012	10:46	LU
Sulfide	0.01	mg/L	0.01		EPA 376.2	7/6/2012	11:43	MW
Total Dissolved Solids (TDS) @ 180 C	960	mg/L	5		SM 2540 C	7/9/2012	9:46	LU
Total Suspended Solids (TSS)	37	mg/L	1		SM 2540 D	7/6/2012	12:09	LU

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12071002
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12071002-02			
Customer Sample ID:	Marlin Well	Collection:	7/9/2012	
Matrix:	Aqueous	Received:	7/10/2012	8:45 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	18	ug/L	1		EPA 8021 B	7/10/2012	21:21	RH
Surr: 4-Bromofluorobenzene	100.5	%	70-130		EPA 8021 B			
Toluene	230	ug/L	1		EPA 8021 B	7/10/2012	21:21	RH
Surr: 4-Bromofluorobenzene	100.5	%	70-130		EPA 8021 B			
Ethyl Benzene	160	ug/L	2		EPA 8021 B	7/10/2012	21:21	RH
Surr: 4-Bromofluorobenzene	100.5	%	70-130		EPA 8021 B			
m,p-Xylene	620	ug/L	4		EPA 8021 B	7/10/2012	21:21	RH
Surr: 4-Bromofluorobenzene	100.5	%	70-130		EPA 8021 B			
o Xylene	400	ug/L	3		EPA 8021 B	7/10/2012	21:21	RH
Surr: 4-Bromofluorobenzene	100.5	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	5000	ug/L	100		EPA 8015 D	7/10/2012	21:21	RH
Surr: 4-Bromofluorobenzene (FID)	98.8	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	17	mg/L	0.0056		EPA 8015 D	7/12/2012	22:26	RH
Surr: o-Terphenyl	98.9	%	70-130		EPA 8015 D			
Methanol	< 5	mg/L	5		EPA 8015 D	7/18/2012	9:09	RH
Surr: Ethanol	99.5	%	70-130		EPA 8015 D			
Oil and Grease	17	mg/L	1		EPA 1664 A	7/13/2012	13:00	JP

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12071002
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12071002-02			
Customer Sample ID:	Marlin Well	Collection:	7/9/2012	
Matrix:	Aqueous	Received:	7/10/2012	8:45 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Total Metals								
Aluminum	< 1	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Arsenic	16.7	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Barium	240	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Beryllium	< 1	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Boron	422	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Cadmium	< 1	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Chromium	116	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Copper	307	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Iron	119000	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Lead	38.4	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Manganese	2920	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Mercury	1.2	ug/L	1	L	EPA 200.8	7/16/2012	11:23	CL
Nickel	126	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Selenium	< 1	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Silicon as SiO2	27100	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Silver	< 1	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Strontium	3060	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Thallium	< 1	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL
Zinc	806	ug/L	1	L	EPA 200.8	7/17/2012	10:52	CL

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12071002
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12071002-02			
Customer Sample ID:	Marlin Well	Collection:	7/9/2012	
Matrix:	Aqueous	Received:	7/10/2012	8:45 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Dissolved Metals								
Aluminum	< 1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Arsenic	< 1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Barium	69	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Beryllium	< 1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Boron	389	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Cadmium	< 1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Chromium	< 1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Copper	4.64	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Iron	594	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Lead	< 1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Manganese	1000	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Mercury	< 0.2	ug/L	0.2	L	EPA 200.8	7/16/2012	11:36	CL
Nickel	28.1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Selenium	< 1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Silicon	23800	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Silver	< 1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Strontium	2930	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Thallium	< 1	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL
Zinc	7.06	ug/L	1	L	EPA 200.8	7/17/2012	11:34	CL

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12071002
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12071002-02			
Customer Sample ID:	Marlin Well	Collection:	7/9/2012	
Matrix:	Aqueous	Received:	7/10/2012	8:45 AM

Notes:

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
General Parameters								
Ammonia as N	0.2	mg/L	0.1		SM 4500-NH3 D	7/10/2012	16:30	KF
Dissolved Organic Carbon (DOC)	2.6	mg/L	1	L	SM 5310 B	7/17/2012	9:39	CL
Naphthalene	96	ug/L	20	L	EPA 8021 B	7/13/2012	22:24	CL
Radium-228	12.0 +/- 5.86	pCi/L	1	L	Ra-05	7/20/2012	12:25	CL
Radium-226	2.5 +/- 0.9	pCi/L	0.21		SM 7500-Ra	7/19/2012	10:21	MW
Temperature (Thermometric)	5.4	°C			N/A	7/10/2012	8:45	CRV
Total Hardness as CaCO3	610	mg/L	6.6		EPA 200.7	7/11/2012	11:35	CV
Total Organic Carbon (purgeable)	3.6	mg/L	1	L	SM 5310 B	7/17/2012	15:23	CL
Major Ions								
Alkalinity, Bicarbonate (HCO3)	56	mg/L	2		SM 2320 B	7/16/2012	12:02	MW
Alkalinity, Carbonate (CO3)	< 2	mg/L	2		SM 2320 B	7/16/2012	12:02	MW
Alkalinity, Hydroxide (OH)	< 2	mg/L	2		SM 2320 B	7/16/2012	12:02	MW
Calcium	200	mg/L	2		EPA 200.7	7/11/2012	11:35	CV
Chloride	32	mg/L	1		EPA 300.0	7/11/2012	20:46	MW
Fluoride	2.3	mg/L	0.2		EPA 300.0	7/11/2012	20:46	MW
Magnesium	28	mg/L	0.2		EPA 200.7	7/11/2012	11:40	CV
Nitrate	< 1	mg/L	1		EPA 300.0	7/11/2012	20:46	MW
Nitrate as N	< 1	mg/L	1		EPA 300.0	7/11/2012	20:46	MW
Potassium	30	mg/L	0.6		EPA 200.7	7/11/2012	11:40	CV
Sodium	82	mg/L	1		EPA 200.7	7/11/2012	11:40	CV
Sulfate	550	mg/L	100		EPA 300.0	7/11/2012	20:21	MW

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12071002
Project ID:	Marlin Well	Report Date:	7/26/2012

			Date	Time
Lab ID:	12071002-02			
Customer Sample ID:	Marlin Well	Collection:	7/9/2012	
Matrix:	Aqueous	Received:	7/10/2012	8:45 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Physical Properties								
Biochemical Oxygen Demand (5 day)	300	mg/L	2		SM 5210 B	7/16/2012	16:05	KF
Conductivity	1240	µS/cm	5		SM 2510 B	7/10/2012	14:49	KF
pH	7.05	s.u.	0.01		EPA 150.1	7/10/2012	14:50	CB
Sulfide	0.01	mg/L	0.01		EPA 376.2	7/11/2012	14:40	CV
Total Dissolved Solids (TDS) @ 180 C	910	mg/L	5		SM 2540 C	7/11/2012	15:37	KF
Total Suspended Solids (TSS)	730	mg/L	1		SM 2540 D	7/16/2012	9:35	LU

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12072609
Project ID:	Marlin 29-21 WDW	Report Date:	8/2/2012

			Date	Time
Lab ID:	12072609-01			
Customer Sample ID:	Marlin 29-21	Collection:	7/26/2012	12:42 PM
Matrix:	Aqueous	Received:	7/26/2012	4:35 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	12	ug/L	1		EPA 8021 B	7/27/2012	7:48	RH
Surr: 4-Bromofluorobenzene	112.2	%	70-130		EPA 8021 B			
Toluene	69	ug/L	1		EPA 8021 B	7/27/2012	7:48	RH
Surr: 4-Bromofluorobenzene	112.2	%	70-130		EPA 8021 B			
Ethyl Benzene	110	ug/L	1		EPA 8021 B	7/27/2012	7:48	RH
Surr: 4-Bromofluorobenzene	112.2	%	70-130		EPA 8021 B			
m,p-Xylene	330	ug/L	2		EPA 8021 B	7/27/2012	7:48	RH
Surr: 4-Bromofluorobenzene	112.2	%	70-130		EPA 8021 B			
o Xylene	250	ug/L	1		EPA 8021 B	7/27/2012	7:48	RH
Surr: 4-Bromofluorobenzene	112.2	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	7200	ug/L	146		EPA 8015 D	7/27/2012	7:48	RH
Surr: 4-Bromofluorobenzene (FID)	100.0	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	330	mg/L	50		EPA 8015 D	8/1/2012	18:53	RH
Surr: o-Terphenyl	1,067.0	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12072718
Project ID:	Marlin Well	Report Date:	8/2/2012

			Date	Time
Lab ID:	12072718-01			
Customer Sample ID:	Marlin	Collection:	7/27/2012	10:40 AM
Matrix:	Aqueous	Received:	7/27/2012	3:30 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	14	ug/L	1		EPA 8021 B	7/27/2012	20:52	RH
Surr: 4-Bromofluorobenzene	110.5	%	70-130		EPA 8021 B			
Toluene	140	ug/L	1		EPA 8021 B	7/27/2012	20:52	RH
Surr: 4-Bromofluorobenzene	110.5	%	70-130		EPA 8021 B			
Ethyl Benzene	55	ug/L	1		EPA 8021 B	7/27/2012	20:52	RH
Surr: 4-Bromofluorobenzene	110.5	%	70-130		EPA 8021 B			
m,p-Xylene	180	ug/L	3		EPA 8021 B	7/27/2012	20:52	RH
Surr: 4-Bromofluorobenzene	110.5	%	70-130		EPA 8021 B			
o Xylene	140	ug/L	1		EPA 8021 B	7/27/2012	20:52	RH
Surr: 4-Bromofluorobenzene	110.5	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	4100	ug/L	146		EPA 8015 D	7/27/2012	20:52	RH
Surr: 4-Bromofluorobenzene (FID)	100.0	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	180	mg/L	50		EPA 8015 D	8/1/2012	19:29	RH
Surr: o-Terphenyl	664.0	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12073008
Project ID:	Marlin Well	Report Date:	8/2/2012

			Date	Time
Lab ID:	12073008-01			
Customer Sample ID:	Marlin	Collection:	7/28/2012	11:10 AM
Matrix:	Aqueous	Received:	7/30/2012	2:35 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	4	ug/L	1		EPA 8021 B	7/30/2012	15:35	RH
Surr: 4-Bromofluorobenzene	89.3	%	70-130		EPA 8021 B			
Toluene	39	ug/L	1		EPA 8021 B	7/30/2012	15:35	RH
Surr: 4-Bromofluorobenzene	89.3	%	70-130		EPA 8021 B			
Ethyl Benzene	55	ug/L	1		EPA 8021 B	7/30/2012	15:35	RH
Surr: 4-Bromofluorobenzene	89.3	%	70-130		EPA 8021 B			
m,p-Xylene	170	ug/L	3		EPA 8021 B	7/30/2012	15:35	RH
Surr: 4-Bromofluorobenzene	89.3	%	70-130		EPA 8021 B			
o Xylene	120	ug/L	2		EPA 8021 B	7/30/2012	15:35	RH
Surr: 4-Bromofluorobenzene	89.3	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	3200	ug/L	146		EPA 8015 D	7/30/2012	15:35	RH
Surr: 4-Bromofluorobenzene (FID)	93.6	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	160	mg/L	50		EPA 8015 D	8/1/2012	17:06	RH
Surr: o-Terphenyl	580.2	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit	S-Spike Recovery outside accepted recovery limits	D-Diluted out of recovery limits
RL-Analyte Reporting Limit	J-Analyte detected below quantitation limits	L-Analyzed by a contract laboratory
H-Holding times for preparation or analysis exceeded	M-Matrix Effect	

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12073104
Project ID:	Marlin Well	Report Date:	8/2/2012

			Date	Time
Lab ID:	12073104-01			
Customer Sample ID:	Marlin	Collection:	7/29/2012	10:00 AM
Matrix:	Aqueous	Received:	7/31/2012	2:18 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	6	ug/L	1		EPA 8021 B	7/31/2012	22:40	RH
Surr: 4-Bromofluorobenzene	92.6	%	70-130		EPA 8021 B			
Toluene	100	ug/L	1		EPA 8021 B	7/31/2012	22:40	RH
Surr: 4-Bromofluorobenzene	92.6	%	70-130		EPA 8021 B			
Ethyl Benzene	86	ug/L	1		EPA 8021 B	7/31/2012	22:40	RH
Surr: 4-Bromofluorobenzene	92.6	%	70-130		EPA 8021 B			
m,p-Xylene	340	ug/L	3		EPA 8021 B	7/31/2012	22:40	RH
Surr: 4-Bromofluorobenzene	92.6	%	70-130		EPA 8021 B			
o Xylene	230	ug/L	2		EPA 8021 B	7/31/2012	22:40	RH
Surr: 4-Bromofluorobenzene	92.6	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	2600	ug/L	100		EPA 8015 D	7/31/2012	22:40	RH
Surr: 4-Bromofluorobenzene (FID)	98.7	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	23	mg/L	5		EPA 8015 D	8/2/2012	7:20	RH
Surr: o-Terphenyl	118.9	%	70-130		EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12080116
Project ID:	Marlin Well	Report Date:	8/3/2012

			Date	Time
Lab ID:	12080116-01			
Customer Sample ID:	Marlin	Collection:	8/1/2012	10:05 AM
Matrix:	Aqueous	Received:	8/1/2012	12:35 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	4	ug/L	1		EPA 8021 B	8/2/2012	5:06	RH
Surr: 4-Bromofluorobenzene	97.9	%	70-130		EPA 8021 B			
Toluene	100	ug/L	1		EPA 8021 B	8/2/2012	5:06	RH
Surr: 4-Bromofluorobenzene	97.9	%	70-130		EPA 8021 B			
Ethyl Benzene	82	ug/L	1		EPA 8021 B	8/2/2012	5:06	RH
Surr: 4-Bromofluorobenzene	97.9	%	70-130		EPA 8021 B			
m,p-Xylene	540	ug/L	2		EPA 8021 B	8/2/2012	5:06	RH
Surr: 4-Bromofluorobenzene	97.9	%	70-130		EPA 8021 B			
o Xylene	330	ug/L	1		EPA 8021 B	8/2/2012	5:06	RH
Surr: 4-Bromofluorobenzene	97.9	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	4500	ug/L	100		EPA 8015 D	8/2/2012	5:06	RH
Surr: 4-Bromofluorobenzene (FID)	100.1	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	82	mg/L	50		EPA 8015 D	8/2/2012	19:10	RH
Surr: o-Terphenyl	247.4	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit	S-Spike Recovery outside accepted recovery limits	D-Diluted out of recovery limits
RL-Analyte Reporting Limit	J-Analyte detected below quantitation limits	L-Analyzed by a contract laboratory
H-Holding times for preparation or analysis exceeded	M-Matrix Effect	

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12080205
Project ID:	Marlin Well	Report Date:	8/7/2012

			Date	Time
Lab ID:	12080205-01			
Customer Sample ID:	Marlin	Collection:	8/2/2012	1:55 PM
Matrix:	Aqueous	Received:	8/2/2012	3:52 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	1	ug/L	1		EPA 8021 B	8/2/2012	16:47	RH
Surr: 4-Bromofluorobenzene	99.2	%	70-130		EPA 8021 B			
Toluene	29	ug/L	1		EPA 8021 B	8/2/2012	16:47	RH
Surr: 4-Bromofluorobenzene	99.2	%	70-130		EPA 8021 B			
Ethyl Benzene	76	ug/L	1		EPA 8021 B	8/2/2012	16:47	RH
Surr: 4-Bromofluorobenzene	99.2	%	70-130		EPA 8021 B			
m,p-Xylene	290	ug/L	2		EPA 8021 B	8/2/2012	16:47	RH
Surr: 4-Bromofluorobenzene	99.2	%	70-130		EPA 8021 B			
o Xylene	160	ug/L	1		EPA 8021 B	8/2/2012	16:47	RH
Surr: 4-Bromofluorobenzene	99.2	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	4500	ug/L	100		EPA 8015 D	8/2/2012	16:47	RH
Surr: 4-Bromofluorobenzene (FID)	99.2	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	62	mg/L	5		EPA 8015 D	8/6/2012	16:25	RH
Surr: o-Terphenyl	321.7	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12080601
Project ID:	Marlin Well	Report Date:	8/8/2012

			Date	Time
Lab ID:	12080601-01			
Customer Sample ID:	Marlin 29-21	Collection:	8/3/2012	11:00 AM
Matrix:	Aqueous	Received:	8/1/2012	2:50 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	6	ug/L	1		EPA 8021 B	8/6/2012	18:13	HF
Surr: 4-Bromofluorobenzene	95.6	%	70-130		EPA 8021 B			
Toluene	100	ug/L	3		EPA 8021 B	8/6/2012	18:13	HF
Surr: 4-Bromofluorobenzene	95.6	%	70-130		EPA 8021 B			
Ethyl Benzene	110	ug/L	1		EPA 8021 B	8/6/2012	18:13	HF
Surr: 4-Bromofluorobenzene	95.6	%	70-130		EPA 8021 B			
m,p-Xylene	750	ug/L	5		EPA 8021 B	8/6/2012	18:13	HF
Surr: 4-Bromofluorobenzene	95.6	%	70-130		EPA 8021 B			
o Xylene	390	ug/L	2		EPA 8021 B	8/6/2012	18:13	HF
Surr: 4-Bromofluorobenzene	95.6	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	6700	ug/L	100		EPA 8015 D	8/6/2012	18:13	HF
Surr: 4-Bromofluorobenzene (FID)	97.1	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	65	mg/L	5		EPA 8015 D	8/8/2012	1:13	RH
Surr: o-Terphenyl	236.4	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12080712
Project ID:	Marlin Well	Report Date:	8/8/2012

			Date	Time
Lab ID:	12080712-01			
Customer Sample ID:	Marlin Well	Collection:	8/4/2012	10:45 AM
Matrix:	Aqueous	Received:	8/6/2012	3:00 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	2	ug/L	1		EPA 8021 B	8/7/2012	3:00	RH
Surr: 4-Bromofluorobenzene	92.8	%	70-130		EPA 8021 B			
Toluene	26	ug/L	1		EPA 8021 B	8/7/2012	3:00	RH
Surr: 4-Bromofluorobenzene	92.8	%	70-130		EPA 8021 B			
Ethyl Benzene	57	ug/L	1		EPA 8021 B	8/7/2012	3:00	RH
Surr: 4-Bromofluorobenzene	92.8	%	70-130		EPA 8021 B			
m,p-Xylene	250	ug/L	3		EPA 8021 B	8/7/2012	3:00	RH
Surr: 4-Bromofluorobenzene	92.8	%	70-130		EPA 8021 B			
o Xylene	130	ug/L	2		EPA 8021 B	8/7/2012	3:00	RH
Surr: 4-Bromofluorobenzene	92.8	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	2300	ug/L	110		EPA 8015 D	8/7/2012	3:00	RH
Surr: 4-Bromofluorobenzene (FID)	98.8	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	96	mg/L	50		EPA 8015 D	8/7/2012	21:02	RH
Surr: o-Terphenyl	351.4	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit	S-Spike Recovery outside accepted recovery limits	D-Diluted out of recovery limits
RL-Analyte Reporting Limit	J-Analyte detected below quantitation limits	L-Analyzed by a contract laboratory
H-Holding times for preparation or analysis exceeded	M-Matrix Effect	

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12080712
Project ID:	Marlin Well	Report Date:	8/8/2012

			Date	Time
Lab ID:	12080712-02			
Customer Sample ID:	Marlin Well	Collection:	8/5/2012	10:30 AM
Matrix:	Aqueous	Received:	8/6/2012	3:00 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	2	ug/L	1		EPA 8021 B	8/7/2012	3:32	RH
Surr: 4-Bromofluorobenzene	95.2	%	70-130		EPA 8021 B			
Toluene	24	ug/L	1		EPA 8021 B	8/7/2012	3:32	RH
Surr: 4-Bromofluorobenzene	95.2	%	70-130		EPA 8021 B			
Ethyl Benzene	55	ug/L	1		EPA 8021 B	8/7/2012	3:32	RH
Surr: 4-Bromofluorobenzene	95.2	%	70-130		EPA 8021 B			
m,p-Xylene	220	ug/L	3		EPA 8021 B	8/7/2012	3:32	RH
Surr: 4-Bromofluorobenzene	95.2	%	70-130		EPA 8021 B			
o Xylene	120	ug/L	2		EPA 8021 B	8/7/2012	3:32	RH
Surr: 4-Bromofluorobenzene	95.2	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	2700	ug/L	110		EPA 8015 D	8/7/2012	3:32	RH
Surr: 4-Bromofluorobenzene (FID)	98.2	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	67	mg/L	5		EPA 8015 D	8/8/2012	3:38	RH
Surr: o-Terphenyl	252.9	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12080712	
Project ID:	Marlin Well	Report Date:	8/8/2012	
Lab ID:	12080712-03		Date	Time
Customer Sample ID:	Marlin Well	Collection:	8/6/2012	10:30 AM
Matrix:	Aqueous	Received:	8/6/2012	3:00 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	2	ug/L	1		EPA 8021 B	8/7/2012	4:05	RH
Surr: 4-Bromofluorobenzene	96.0	%	70-130		EPA 8021 B			
Toluene	20	ug/L	1		EPA 8021 B	8/7/2012	4:05	RH
Surr: 4-Bromofluorobenzene	96.0	%	70-130		EPA 8021 B			
Ethyl Benzene	42	ug/L	1		EPA 8021 B	8/7/2012	4:05	RH
Surr: 4-Bromofluorobenzene	96.0	%	70-130		EPA 8021 B			
m,p-Xylene	180	ug/L	3		EPA 8021 B	8/7/2012	4:05	RH
Surr: 4-Bromofluorobenzene	96.0	%	70-130		EPA 8021 B			
o Xylene	93	ug/L	2		EPA 8021 B	8/7/2012	4:05	RH
Surr: 4-Bromofluorobenzene	96.0	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	2000	ug/L	110		EPA 8015 D	8/7/2012	4:05	RH
Surr: 4-Bromofluorobenzene (FID)	100.0	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	46	mg/L	5		EPA 8015 D	8/8/2012	4:11	RH
Surr: o-Terphenyl	230.7	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12080716	
Project ID:	Marlin Well	Report Date:	8/9/2012	
Lab ID:	12080716-01		Date	Time
Customer Sample ID:	Marlin	Collection:	8/7/2012	11:00 AM
Matrix:	Aqueous	Received:	8/7/2012	2:44 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date	Time	Analyst
Organic Compounds								
Benzene	5	ug/L	1		EPA 8021 B	8/7/2012	21:16	RH
Surr: 4-Bromofluorobenzene	96.4	%	70-130		EPA 8021 B			
Toluene	41	ug/L	1		EPA 8021 B	8/7/2012	21:16	RH
Surr: 4-Bromofluorobenzene	96.4	%	70-130		EPA 8021 B			
Ethyl Benzene	87	ug/L	1		EPA 8021 B	8/7/2012	21:16	RH
Surr: 4-Bromofluorobenzene	96.4	%	70-130		EPA 8021 B			
m,p-Xylene	370	ug/L	3		EPA 8021 B	8/7/2012	21:16	RH
Surr: 4-Bromofluorobenzene	96.4	%	70-130		EPA 8021 B			
o Xylene	190	ug/L	2		EPA 8021 B	8/7/2012	21:16	RH
Surr: 4-Bromofluorobenzene	96.4	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	3800	ug/L	100		EPA 8015 D	8/7/2012	21:16	RH
Surr: 4-Bromofluorobenzene (FID)	99.4	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	540	mg/L	50		EPA 8015 D	8/8/2012	16:14	RH
Surr: o-Terphenyl	1,624.3	%	70-130	D, M	EPA 8015 D			

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070201
Project ID:	Marlin Well	Report Date:	7/27/2012

			Date	Time
Lab ID:	12070201-02			
Customer Sample ID:	Marlin Brine	Collection:	6/29/2012	5:00 PM
Matrix:	Aqueous	Received:	7/2/2012	9:43 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Organic Compounds								
Benzene	< 100	ug/L	100		EPA 8021 B	7/5/2012	11:05	RH
Surr: 4-Bromofluorobenzene	103.1	%	70-130		EPA 8021 B			
Toluene	140	ug/L	100		EPA 8021 B	7/5/2012	11:05	RH
Surr: 4-Bromofluorobenzene	103.1	%	70-130		EPA 8021 B			
Ethyl Benzene	270	ug/L	100		EPA 8021 B	7/5/2012	11:05	RH
Surr: 4-Bromofluorobenzene	103.1	%	70-130		EPA 8021 B			
m,p-Xylene	930	ug/L	200		EPA 8021 B	7/5/2012	11:05	RH
Surr: 4-Bromofluorobenzene	103.1	%	70-130		EPA 8021 B			
o Xylene	750	ug/L	100		EPA 8021 B	7/5/2012	11:05	RH
Surr: 4-Bromofluorobenzene	103.1	%	70-130		EPA 8021 B			
Gasoline Range Organics (GRO)	55000	ug/L	10000		EPA 8015 D	7/5/2012	11:05	RH
Surr: 4-Bromofluorobenzene (FID)	98.9	%	70-130		EPA 8015 D			
Diesel Range Organics (DRO)	1500	mg/L	250		EPA 8015 D	7/3/2012	23:41	RH
Surr: o-Terphenyl	1,161.6	%	70-130	D, M	EPA 8015 D			
Methanol	< 400	ug/L	400	L	EPA 8015 D	7/9/2012	12:10	CL
Oil and Grease	1200	mg/L	1		EPA 1664 A	7/5/2012	10:00	JP

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070201	
Project ID:	Marlin Well	Report Date:	7/27/2012	
Lab ID:	12070201-02		Date	Time
Customer Sample ID:	Marlin Brine	Collection:	6/29/2012	5:00 PM
Matrix:	Aqueous	Received:	7/2/2012	9:43 AM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Total Metals								
Aluminum	1500	ug/L	20	L	EPA 200.8	7/12/2012	20:55	CL
Arsenic	59.6	ug/L	2.5	L	EPA 200.8	7/12/2012	20:55	CL
Barium	62400	ug/L	2000	L	EPA 200.8	7/16/2012	10:51	CL
Beryllium	< 1	ug/L	1	L	EPA 200.8	7/12/2012	20:55	CL
Boron	1410	ug/L	25	L	EPA 200.8	7/12/2012	20:55	CL
Cadmium	< 0.4	ug/L	0.4	L	EPA 200.8	7/12/2012	20:55	CL
Chromium	268	ug/L	2.5	L	EPA 200.8	7/12/2012	20:55	CL
Copper	648	ug/L	2.5	L	EPA 200.8	7/12/2012	20:55	CL
Iron	51800	ug/L	250	L	EPA 200.8	7/12/2012	20:55	CL
Lead	7.5	ug/L	0.5	L	EPA 200.8	7/12/2012	20:55	CL
Manganese	1310	ug/L	2.5	L	EPA 200.8	7/12/2012	20:55	CL
Mercury	<0.20	ug/L	0.20	L	EPA 7470	7/27/2012	10:32	CL
Nickel	169	ug/L	2.5	L	EPA 200.8	7/12/2012	20:55	CL
Selenium	< 2.5	ug/L	2.5	L	EPA 200.8	7/12/2012	20:55	CL
Silicon as SiO2	16600	ug/L	268	L	EPA 200.8	7/12/2012	20:55	CL
Silver	2.6	ug/L	2.5	L	EPA 200.8	7/12/2012	20:55	CL
Strontium	322000	ug/L	1000	L	EPA 200.8	7/16/2012	10:51	CL
Thallium	6.3	ug/L	0.5	L	EPA 200.8	7/12/2012	20:55	CL
Zinc	18700	ug/L	250	L	EPA 200.8	7/12/2012	20:59	CL

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070201
Project ID:	Marlin Well	Report Date:	7/27/2012

			Date	Time
Lab ID:	12070201-02			
Customer Sample ID:	Marlin Brine	Collection:	7/2/2012	
Matrix:	Aqueous	Received:	7/2/2012	9:43 AM

Notes:

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Dissolved Metals								
Aluminum	< 20	ug/L	20	L	EPA 200.8	7/23/2012	14:12	CL
Arsenic	28.1	ug/L	2.5	L	EPA 200.8	7/23/2012	14:12	CL
Barium	14500	ug/L	15	L	EPA 200.8	7/23/2012	14:16	CL
Beryllium	< 1	ug/L	1	L	EPA 200.8	7/23/2012	14:12	CL
Boron	1370	ug/L	25	L	EPA 200.8	7/23/2012	14:12	CL
Cadmium	0.88	ug/L	0.4	L	EPA 200.8	7/23/2012	14:12	CL
Chromium	<25.0	ug/L	25	L	EPA 200.8	7/23/2012	14:12	CL
Copper	<1000	ug/L	1000	L	EPA 200.8	7/23/2012	14:12	CL
Iron	< 250	ug/L	250	L	EPA 200.8	7/23/2012	14:12	CL
Lead	24.8	ug/L	0.5	L	EPA 200.8	7/23/2012	14:12	CL
Manganese	1600	ug/L	25	L	EPA 200.8	7/23/2012	14:12	CL
Mercury	< 0.2	ug/L	0.2	L	EPA 7470	7/10/2012	13:04	CL
Nickel	51.1	ug/L	2.5	L	EPA 200.8	7/23/2012	14:12	CL
Selenium	< 2.5	ug/L	2.5	L	EPA 200.8	7/23/2012	14:12	CL
Silicon	2500	ug/L	268	L	EPA 200.8	7/23/2012	14:12	CL
Silver	< 2.5	ug/L	2.5	L	EPA 200.8	7/23/2012	14:12	CL
Strontium	193000	ug/L	1000	L	EPA 200.8	7/24/2012	16:54	CL
Thallium	6.1	ug/L	0.5	L	EPA 200.8	7/23/2012	14:12	CL
Zinc	12000	ug/L	250	L	EPA 200.8	7/23/2012	14:16	CL

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070201
Project ID:	Marlin Well	Report Date:	7/27/2012

			Date	Time
Lab ID:	12070201-02			
Customer Sample ID:	Marlin Brine	Collection:	7/2/2012	
Matrix:	Aqueous	Received:	7/2/2012	9:43 AM

Notes:

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
General Parameters								
Ammonia as N	1.0	mg/L	0.1		SM 4500-NH3 D	7/5/2012	15:13	CB
Naphthalene	16	ug/L	4	L	EPA 8260	7/13/2012	1:07	CL
Radium-228	37.8 +/- 33.4	pCi/L	1	L	EPA 904.0	7/19/2012	11:32	CL
Radium-226	33.5 +/- 22.8	pCi/L	1	L	EPA 903.1	7/24/2012	10:56	CL
Temperature (Thermometric)	6.6	°C	0.01		N/A	7/2/2012	9:43	CRV
Total Hardness as CaCO3	150000	mg/L	6.6		EPA 200.7	7/3/2012	11:10	CV
Total Organic Carbon (purgeable)	< 3	mg/L	3	L	SM 5310C	7/13/2012	9:44	CL
Major Ions								
Alkalinity, Bicarbonate (HCO3)	< 2	mg/L	2		SM 2320 B	7/3/2012	11:22	MW
Alkalinity, Carbonate (CO3)	< 2	mg/L	2		SM 2320 B	7/3/2012	11:22	MW
Alkalinity, Hydroxide (OH)	< 2	mg/L	2		SM 2320 B	7/3/2012	11:22	MW
Calcium	57000	mg/L	200		EPA 200.7	7/3/2012	11:10	CV
Chloride	170000	mg/L	10000		EPA 300.0	7/3/2012	21:52	MW
Fluoride	< 20	mg/L	20		EPA 300.0	7/3/2012	22:17	MW
Magnesium	1900	mg/L	20		EPA 200.7	7/3/2012	11:16	CV
Nitrate	4900	mg/L	100		EPA 300.0	7/3/2012	22:17	MW
Nitrate as N	1100	mg/L	1		EPA 300.0	7/3/2012	22:17	MW
Potassium	2100	mg/L	60		EPA 200.7	7/3/2012	11:16	CV
Sodium	59000	mg/L	1000		EPA 200.7	7/3/2012	11:10	CV
Sulfate	500	mg/L	1		EPA 300.0	7/3/2012	22:17	MW
Orthophosphate	ND	mg/L	9		EPA 300.0	7/3/2012	10:17	MW

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Toll Free: (866) 985-0866 • E-mail: Info@Precision-Labs.com • Online: www.Precision-Labs.com

LABORATORY ANALYTICAL REPORT

Customer Name:	Encana Oil and Gas (USA)	Order ID:	12070201
Project ID:	Marling Well	Report Date:	7/27/2012

			Date	Time
Lab ID:	12070201-02			
Customer Sample ID:	Marlin Brine	Collection:	7/2/2012	
Matrix:	Aqueous	Received:	7/2/2012	9:43 AM

Notes:

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time		Analyst
Physical Properties								
Biochemical Oxygen Demand (5 day)	< 2	mg/L	2		SM 5210 B	7/10/2012	10:15	CB
Conductivity	555000	µS/cm	5		SM 2510 B	7/3/2012	9:50	MW
pH	0.30	s.u.	0.01		EPA 150.1	7/3/2012	11:22	MW
Total Dissolved Solids (TDS) @ 180 C	430000	mg/L	5		SM 2540 C	7/3/2012	17:02	MW
Total Suspended Solids (TSS)	500	mg/L	1		SM 2540 D	7/6/2012	11:00	LU

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW   API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. _____-2020

Appendix B (Revised)

Economic Practicality of Potable Water Use
Amsden and Madison

Appendix B
Economic Practicality of Potable Water Use
Amsden and Madison Formations

The top of the Amsden formation in the project area is located at a depth of approximately 14,774 feet. The base of the Madison formation is about 15,355 ft in the project area. These are depths for which it is not economic or practical for development as a water supply. The following analysis includes a cost estimate for shallow water supply, a cost estimate for deep water supply from the proposed receiving zones, identification of nearby population centers, and estimates of treatment and transportation expenses to supply water to the population center. Finally, a discussion of Amsden yield and potential classification as a USDW is discussed.

Cost of Shallow Water Supply:

Wyoming State Engineer's Office (SEO) records indicate that groundwater in the project vicinity is available at depths of approximately 560 feet (See Attachment R-3). The estimated cost to drill a shallow water supply well is \$50/ft. The cost of a shallow water well to 560 feet at \$50/ft would be \$28,000.

Cost of Deep Water Supply from the Madison and Amsden:

The cost to drill and complete a 15,000-foot vertical well through the Amsden and Madison is approximately \$3.0 million based on a cost of \$200.00/foot. Therefore, at \$3.0 million it would be economically impractical to use a well drilled through the Madison for water supply when shallow water is available at a much lower cost.

Costs to Supply Treated Water to Nearby Population Centers:

The nearest population center, the city of **Shoshoni**, is approximately 30 miles northwest. The city of Shoshoni has a population of 649 based on the 2010 census. The city of Shoshoni utilizes four water source wells. They have a total permitted capacity of 875 gpm and are able to have their capacity enlarged as needed for a minimal cost. Based on a typical household usage of 0.1 gpm/person (USGS Water Science and EPA WaterSense), the city of Shoshoni utilizes 65 gpm or roughly 7% of its current capacity. In comparison, utilizing a usage of 100 gpm, a treatment cost of \$0.50/bbl, a pipeline procurement and installation cost of \$5/inch-ft and a right-of-way procurement cost of \$10,000/mile, an 4-inch pipeline supplying 100 gpm of treated water to Shoshoni would cost \$4.09 million (\$625,000 for one year of treatment, \$3.17 million for 4" pipeline material and installation and \$300,000 to acquire right-of-way). Therefore, it is unlikely that the city of Shoshoni would utilize water from the proposed disposal well given that the city already has existing capacity significantly greater than existing or future usages and the costs associated with supplying treated water from the proposed disposal well would be impractical.

The city of **Riverton** is approximately 45 miles southwest. The city of Riverton has a population of 10,615 people based on the 2010 census. The city of Riverton utilizes thirteen water source wells tapping the Wind River Aquifer. They have a total permitted capacity of 4,750 gpm and are able to have their capacity enlarged as needed for a very minimal cost. Based on a typical household usage of 0.1 gpm/person (USGS Water Science and EPA WaterSense), the city of Riverton utilizes 1,061 gpm or roughly 22% of its current capacity. In comparison, utilizing a treatment cost of \$0.50/bbl, a pipeline procurement and installation cost of \$5/inch-ft and a right-of way procurement cost of \$10,000/mile, a 4-inch pipeline supplying 100 gpm of treated water (which represents a yield of 3400 BWPD from a water supply well) to Riverton would cost $5.83 million ($626,000 for one year of treatment, $4.75 million for 4" pipeline material and installation and $450,000 to acquire right-of-way). Therefore, it is unlikely that the city of Riverton would utilize water from the proposed disposal well given that the city already has existing capacity significantly greater than existing or future usages and the costs associated with supplying treated water from the proposed disposal well would be impractical.

The city of **Thermopolis** is approximately 50 miles northwest. The city of Thermopolis has a population of 3,009 people based on the 2010 census. The city of Thermopolis utilizes three alluvial wells and a diversion from the Big Horn River. They have a total permitted capacity of 1,645 gpm and are able to have their capacity enlarged as needed for a very minimal cost. Based on a typical household usage of 0.1 gpm/person (USGS Water Science and EPA WaterSense), the city of Thermopolis utilizes 300 gpm or roughly 18% of its current capacity. In comparison, utilizing a treatment cost of $0.50/bbl, a pipeline procurement and installation cost of $5/inch-ft and a right-of way procurement cost of $10,000/mile, a 4-inch pipeline supplying 100 gpm of treated water (which represents a yield of 3400 BWPD from a water supply well) to Thermopolis would cost $6.40 million ($625,000 for one year of treatment, $5.28 million for 4" pipeline material and installation and $500,000 to acquire right-of-way). Therefore, it is unlikely that the city of Thermopolis would utilize water from the proposed disposal well given that the city already has existing capacity significantly greater than existing or future usages and the costs associated with supplying treated water from the proposed disposal well would be impractical.

The city of **Casper** is approximately 70 miles east. The city of Casper has a population of 55,316 based on the 2010 census. The city of Casper utilizes twenty-nine North Platte River alluvial aquifer wells and a diversion from the North Platte River. These wells have a capacity in excess of 15,000 gpm and are able to have their capacity enlarged as needed for a very minimal cost. Based on a typical household usage of 0.1 gpm/person (USGS Water Science and EPA WaterSense), the city of Casper utilizes 5,532 gpm or roughly 37% of its current capacity. In comparison, utilizing a usage of 1,000 gpm, a treatment cost of $0.50/bbl, a pipeline procurement and installation cost of $5/inch-ft and a right-of-way procurement cost of $10,000/mile, an 4-inch pipeline supplying 100 gpm of treated water (which represents a yield of 3400 BWPD from a water supply well) to Casper would cost $8.72 million ($625,000 for one year of treatment, $7.39 million for 4" pipeline material and installation and $700,000 to acquire right-of-way). Therefore, it is unlikely that the city of Casper would utilize water from the proposed disposal well given that the city already has existing capacity significantly greater than existing or future usages and the costs associated with supplying treated water from the proposed disposal well would be impractical.

References:

Shoshoni Population: https://en.wikipedia.org/wiki/Shoshoni,_Wyoming
Shoshoni Water Quality Report: http://shoshoniwyoming.org/ArchiveCenter/ViewFile/Item/91

Riverton Population: https://en.wikipedia.org/wiki/Riverton,_Wyoming
Riverton Water Quality Report:
http://www.rivertonwy.gov/departments/public_works/docs/Final%20CCR%20Report%202015.pdf

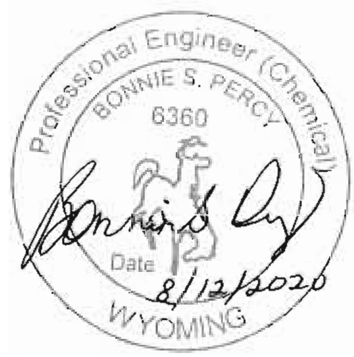
Thennopolis Population: https://en.wikipedia.org/wiki/Thermopolis,_Wyoming
Thermopolis Water Quality Report: http://www.townofthermopolis.com/newsletter.aspx?id=53

Casper Population: https://en.wikipedia.org/wiki/Casper,_Wyoming
Casper Water Quality Report:

http://www.casperwy.gov/UserFiles/Servers/Server_62983/File/Government/Departments/Public%20Services/Public%20Utilities/2016%20City%20of%20Casper%20CCR%20-%20Retail%20Customers.pdf

"Statistics and Facts." EPA, Environmental Protection Agency, 7 Nov. 2018, www.epa.gov/watersense/statistics-and-facts.

Note: Truck-mounted shallow water drilling equipment is much less expensive than deep well drilling rigs which accounts for the difference between $50/ft for shallow wells and the $200/ft for deep wells. These costs are based on actual cost from drilling contractors.



Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW   API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. _____-2020

APPENDIX C

Reserved for:
Notice List - Owners and Operators and Surface Owners Within 3.25 Miles

To Be Supplied with the Affidavit of Mailing

Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. _____-2020

APPENDIX D

Source Wells

Api_Number	Company	Well_NO	Unit_Lease	Q1	Q2	S	T	R	Field	Status	Formation	TDS	On File with WOGCC
49-013-23398	AETHON ENERGY OPERATING LLC	'34-42-3891H	DOUBLE IRON	SE	NE	34	38N	91W	FRENCHIE DRAW	PO	FORT UNION	NA (2)	No
49-013-22893	AETHON ENERGY OPERATING LLC	'31-36-E	IRON HORSE	NW	NE	36	38N	91W	MONETA HILLS	PG	FORT UNION	11,523	Yes
49-013-22570	AETHON ENERGY OPERATING LLC	'22-1-C	IRON HORSE FEDERAL	SE	NW	1	37N	90W	MONETA HILLS	PG	FORT UNION	8,495	Yes
49-013-22984	AETHON ENERGY OPERATING LLC	'44-1-C	IRON HORSE FEDERAL	NE	SE	1	37N	90W	MONETA HILLS	PG	FORT UNION	18,273	Yes
49-013-22993	AETHON ENERGY OPERATING LLC	'42-1-C	IRON HORSE FEDERAL	SE	NE	1	37N	90W	MONETA HILLS	PG	FORT UNION	5,360	Yes
49-013-23175	AETHON ENERGY OPERATING LLC	'33-1-C	IRON HORSE FEDERAL	NW	SE	1	37N	90W	MONETA HILLS	PG	FORT UNION	7,130	Yes
49-013-22571	AETHON ENERGY OPERATING LLC	'23-4	IRON HORSE FEDERAL	NE	SW	4	37N	90W	MONETA HILLS	PG	FORT UNION	10,284	Yes
49-013-23121	AETHON ENERGY OPERATING LLC	'12-4-C	IRON HORSE FEDERAL	NW	NW	4	37N	90W	MONETA HILLS	PG	FORT UNION	8,599	Yes
49-013-23122	AETHON ENERGY OPERATING LLC	'43-4-C	IRON HORSE FEDERAL	SE	NE	4	37N	90W	MONETA HILLS	PG	FORT UNION	7,010	Yes
49-013-22983	AETHON ENERGY OPERATING LLC	'31-4-C	IRON HORSE FEDERAL	NW	NE	4	37N	90W	MONETA HILLS	PG	FORT UNION	8,762	Yes
49-013-23240	AETHON ENERGY OPERATING LLC	'431-5C	IRON HORSE FEDERAL	NW	NW	4	37N	90W	MONETA HILLS	PG	FORT UNION	5,780	Yes
49-013-23241	AETHON ENERGY OPERATING LLC	'414-5-C	IRON HORSE FEDERAL	NW	NW	4	37N	90W	MONETA HILLS	PG	FORT UNION	6,500	Yes
49-013-23242	AETHON ENERGY OPERATING LLC	'232-4-C	IRON HORSE FEDERAL	NW	NW	4	37N	90W	MONETA HILLS	PG	FORT UNION	4,770	Yes
49-013-23243	AETHON ENERGY OPERATING LLC	'143-33-B	IRON HORSE FEDERAL	NW	NW	4	37N	90W	MONETA HILLS	PG	FORT UNION	4,900	Yes
49-013-23244	AETHON ENERGY OPERATING LLC	'214-4-C	IRON HORSE FEDERAL	NW	NW	4	37N	90W	MONETA HILLS	PG	FORT UNION	4,900	Yes
49-013-23245	AETHON ENERGY OPERATING LLC	'112-4-C	IRON HORSE FEDERAL	NW	NW	4	37N	90W	MONETA HILLS	PG	FORT UNION	4,240	Yes
49-013-23246	AETHON ENERGY OPERATING LLC	'341-32-B	IRON HORSE FEDERAL	NW	NW	4	37N	90W	MONETA HILLS	PG	FORT UNION	6,620	Yes
49-013-23174	AETHON ENERGY OPERATING LLC	'33-4-C	IRON HORSE FEDERAL	NW	SE	4	37N	90W	MONETA HILLS	PG	FORT UNION	4,110	Yes
49-013-22959	AETHON ENERGY OPERATING LLC	'44-5-C	IRON HORSE FEDERAL	SE	SE	5	37N	90W	MONETA HILLS	PG	FORT UNION	7,921	Yes
49-013-22908	AETHON ENERGY OPERATING LLC	'13-20-B	IRON HORSE FEDERAL	NW	SW	20	38N	90W	MONETA HILLS	SI	FORT UNION	6,979	Yes
49-013-23120	AETHON ENERGY OPERATING LLC	'34-33-B	IRON HORSE FEDERAL	SW	SE	33	38N	90W	MONETA HILLS	PG	FORT UNION	7,090	Yes
49-013-23267	AETHON ENERGY OPERATING LLC	'421-32-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	5,040	Yes
49-013-23247	AETHON ENERGY OPERATING LLC	'212-33-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	4,200	Yes
49-013-23248	AETHON ENERGY OPERATING LLC	'224-33-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	5,227	Yes
49-013-23249	AETHON ENERGY OPERATING LLC	'131-33-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	11,300	Yes
49-013-23250	AETHON ENERGY OPERATING LLC	'121-33-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	4,760	Yes
49-013-23251	AETHON ENERGY OPERATING LLC	'143-34-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	6,910	Yes
49-013-23252	AETHON ENERGY OPERATING LLC	'324-33-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	6,790	Yes
49-013-23253	AETHON ENERGY OPERATING LLC	'244-33-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	5,460	Yes
49-013-23254	AETHON ENERGY OPERATING LLC	'433-33-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	6,700	Yes
49-013-23182	AETHON ENERGY OPERATING LLC	'23-33-B	IRON HORSE FEDERAL	NE	SW	33	38N	90W	MONETA HILLS	PG	FORT UNION	907	Yes
49-013-22273	AETHON ENERGY OPERATING LLC	'12-36	IRON HORSE STATE	SW	NW	36	38N	90W	WC	PO	FORT UNION	10,553	Yes
49-013-23458	AETHON ENERGY OPERATING LLC	'26-13	PKU	SE	SW	26	37N	91W	KANSON DRAW	WP	NA	NA(1)	No
49-013-23447	AETHON ENERGY OPERATING LLC	'36-22	PKU	SW	NW	36	37N	91W	KANSON DRAW	AP	NA	NA (2)	Not drilled yet
49-013-23448	AETHON ENERGY OPERATING LLC	'36-21	PKU	C	NW	36	37N	91W	KANSON DRAW	AP	NA	NA(1)	No
49-013-23449	AETHON ENERGY OPERATING LLC	'36-12	PKU	SW	NW	36	37N	91W	KANSON DRAW	AP	NA	NA (2)	Not drilled yet
49-013-23450	AETHON ENERGY OPERATING LLC	'36-11	PKU	SW	NW	36	37N	91W	KANSON DRAW	AP	NA	NA(1)	No
49-013-23352	AETHON ENERGY OPERATING LLC	'37-91-26-42	POWDER KEG	SE	NE	26	37N	91W	FRENCHIE DRAW	PG	FORT UNION	NA(1)	No
49-013-23097	AETHON ENERGY OPERATING LLC	'3-24	RESERVOIR CREEK	SE	SW	3	37N	90W	FRENCHIE DRAW	PG	FORT UNION	9,233	Yes
49-013-21820	AETHON ENERGY OPERATING LLC	'44-36	STATE	SE	SE	36	38N	91W	MONETA HILLS	PG	FORT UNION	11,842	Yes
49-013-22643	AETHON ENERGY OPERATING LLC	'13-10-36-90	TALON UNIT	NW	Q2	10	36N	90W	WC	PG	LANCE	13,000	Yes
49-013-22580	AETHON ENERGY OPERATING LLC	'31-31-37-89	TALON UNIT	SW	NE	31	37N	89W	WC	PG	FORT UNION	11,817	Yes
49-013-22581	AETHON ENERGY OPERATING LLC	'11-32-37-89	TALON UNIT	NW	NW	32	37N	89W	WC	PG	FORT UNION	9,798	Yes
49-013-22579	AETHON ENERGY OPERATING LLC	'41-32-37-89	TALON UNIT	NE	NE	32	37N	89W	WC	PG	FORT UNION	11,519	Yes
49-013-22425	AETHON ENERGY OPERATING LLC	'1	TALON UNIT	NE	NE	34	37N	90W	WC	PG	LANCE AND FT UNION	16,800	Yes
49-013-22547	AETHON ENERGY OPERATING LLC	'3-20	WEBB RANCH UNIT	NE	SW	20	37N	90W	KANSON DRAW	PG	FORT UNION	12,350	Yes

NA(1) - A water analysis is not currently available; the well is flowing and Aethon will collect a wellhead sample and provide the analysis to the WOGCC as soon as possible.
NA(2) - A water analysis is not currently available; the well is SI or waiting completion; Aethon will collect a wellhead sample and provide the analysis to the WOGCC when the well is activated.

Aethon Energy Operating LLC
Application for Aquifer Exemption and Authorization to Dispose
Marlin No 29-21 WDW API # 49-013-23374
Section 29 T35N R90W
WOGCC Docket No. _____-2020

APPENDIX E (Revised)

Well Records

Completion Report - 2013
Completion Report -2018
Tensleep Step Rate Test

FORM 3
Dec 2010

OCF DSCF DS

STATE OF WYOMING
OIL AND GAS CONSERVATION COMMISSION
P. O. Box 2640
Casper Wyoming 82602

Apd

WELL COMPLETION OR RECOMPLETION REPORT AND LOG (SUBMIT SINGLE, DUPLICATE ON STATE LAND)

9 API WELL NO: **49-013-23374-0100**
12 COUNTY: FREMONT
13 STATE: Wyoming
5 STATE LEASE SERIAL NO: WYW159681
7. UNIT OR COMMUNITIZATION AGREEMENT: WYW147739X
8 FARM OR LEASE NAME: **MARLIN**
8a WELL No: **No. 29-21WDW**
10 FIELD NAME: Wildcat
11 SEC T, R, M, OR BLOCK AND SURVEY OR AREA: 29 T 35N R 90W
36 MULTIPLE COMPL?
DOCKET OR AA DATE
17. ELEVATIONS (DF, RKB, RT, GR, etc)*: 5881' GL 5894.6' KB

1a. Type of Well: [ ] Oil Well [ ] Gas Well [ ] Dry [ ] CBM Other: WDW
b Type of Completion: [x] New Well [ ] Workover [ ] Deepen [ ] Plug Back [ ] Diff Resvr
[ ] Initial [X] Final
Other

2 Name of Operator: ENCANA OIL AND GAS USA INC

3 Address: 370 17th Street, Suite 1700
Denver, CO. 80202

3a. Phone No (include area code): Jennifer Brown 720-876-3582

4. Location of Well (Report location clearly and in accordance with WOGCC requirements with footages and qtr qtrs.)

At surface	660' FNL	1977' FWL	NE	NW	Lat	42 98281	Long	107 65234
Top prod Int	N/A	N/A			Lat		Long.	
At total depth	1328' FNL	1779' FWL	NE	NW	Lat	42.98098	Long	107.65308

14 Date Spudded: 11/30/2011
15 Date T.D. Reached: 05/30/2012
16 Date Completed: [ ] D & A 07/02/2012 [ ] Ready to Prod

18 Total Depth: MD 15405 TVD 15364'
19 Plug back T D: MD 15330' TVD 15289'
20 Depth Bridge Plug Set: MD 14820' (Requires Prior Approval) TVD

21 Type Electric & other Logs Run (Submit 1 copy and 1 LAS of each). Cased and Open Hole, Btm Hole Press Survey
AIT BHC TLD GR/Temperature/CBL-GR-CCL/RST

22 Was well cored? [x] No [ ] Yes (Submit analysis)
Was DST run? [x] No [ ] Yes (Submit report)
Directional Survey? [ ] No [x] Yes (Submit copy, w/ cert.)

23 Casing and Liner Record (Report all strings set in well)

Hole Size	Size/ Grade	Wt (#/ft)	Top (MD)	Bottom(MD)	Stage Cementer Depth	No of Sks & Type of Cement	Slurry Vol (Bbl)	Cement Top*	Amount Pulled
24			0	74'	Conductor				
12 1/4	9.625 N80	40#	0	2541'	Surface	2013 sks		5881'	
8.5	7 N80	26#	0	9666'	Intermediate	633 sks		5881'	
6.125	5 T95	23.20#	9513'	10197'	Liner	164 sks		9475'	
6.125	5 T95	21.40#	10197'	15376'	Liner				
6.125	5 HT	18#	15376'	15405'	Liner				

24 Tubing Record

Size	Depth Set (MD)	Packer Depth (MD)	Size	Depth Set (MD)	Packer Depth (MD)	Size	Depth Set (MD)	Packer Depth (MD)
2.875"	14650'	14300'	3.96"					

25 Producing Intervals / 26 Perforation Record

	Formation	Top	Bottom	Perforated Interval	Size	No of Holes	Perf Status
A)	N/A						See Perforation Details
B)							
C)							
D)							

27 Acid, Fracture Treatment, Cement Squeeze, Etc. (Each Require Prior Approval)

Depth Interval / Amount and Type of Materials and Chemicals (attach job log if poss)

Top Bottom	Stim Type	Date	Co.	Amt Fluid	Type	2dry Fluid	Type	Prop Vol	Type	Min PSI	Max PSI
N/A											

RECEIVED
APR 22 2013
WYOMING OIL & GAS CONSERVATION COMMISSION

28. Production- Interval A

Date First Produced	Test Date	Hours Tested	Test Production	Oil Bbl	Gas MCF	Water Bbl	Oil Gravity Corr. API	Gas Gravity	Flowback Disposal
N/A	N/A		→						

Choke Size	Tbg Press Flwg.	Csg Press	24 Hr Rate	Oil Bbl	Gas MCF	Water Bbl	Gas Oil Ratio	Res Press	Well Status
	SI		→						

* See instructions and spaces for additional data on page 2

28a Production- Interval B									
Date First Produced	Test Date	Hours Tested	Test Production	Oil Bbl	Gas MCF	Water Bbl	Oil Gravity Corr. API	Gas Gravity	Flowback Disposal
Choke Size	Tbg. Press Flwg SI	Csg Press.	24 Hr Rate	Oil Bbl	Gas MCF	Water Bbl	Gas. Oil Ratio	Res. Press	Well Status

28b Production- Interval C									
Date First Produced	Test Date	Hours Tested	Test Production	Oil Bbl	Gas MCF	Water Bbl	Oil Gravity Corr API	Gas Gravity	Flowback Disposal
Choke Size	Tbg Press Flwg SI	Csg Press	24 Hr Rate	Oil Bbl	Gas MCF	Water Bbl	Gas. Oil Ratio	Res Press	Well Status

28c Production- Interval D									
Date First Produced	Test Date	Hours Tested	Test Production	Oil Bbl	Gas MCF	Water Bbl	Oil Gravity Corr API	Gas Gravity	Flowback Disposal
Choke Size	Tbg Press Flwg SI	Csg Press	24 Hr Rate	Oil Bbl	Gas MCF	Water Bbl	Gas Oil Ratio	Res. Press	Well Status

29. Disposition of Gas *(Sold, used for fuel, vented, etc.)*
N/A

Test Witness.

30. Summary of Porous Zones (include Aquifers):
Show all important zones of porosity and contents thereof. Cored intervals and all drill-stem tests, including depth interval tested, cushion used, time tool open, flowing and shut-in pressures and recoveries.

31. Formation (Log) Markers:

Formation	Top	Bottom	Descriptions Contents, Etc.		Name	
Lance	3212'		Frontier 5	11767'	Phosphoria 14150'	
Cody	5821'		Mowry	11878'	Tensleep 14436'	
Niobrara	9678'		Muddy	12199'	Amsden 14774'	
Carlile	10900'		Lakota	12386'	Madison 15011'	
Frontier 1	11174'		Morrison	12440'	Gros Ventre 15355'	
Frontier 2	11384'		Nugget	12896'		
Frontier 3	11559'		Chugwater	13091'		
Frontier 4	11649'		Dinwoody	14096'		

32. Additional remarks: include plugging procedure (Req. prior approval)

Tubing was landed in this well on 10/4/2012

33. Indicate which items have been attached by placing a check in the appropriate boxes:

- [ ] Electrical/ Mechanical Logs (1 full set) Cased & Open hole
- [ ] Geologic Report
- [ ] DST Report
- [x] Directional Survey
- [ ] Sundry Notice for plugging and cementing
- [ ] Core Analysis
- [ ] Press. Survey
- [x] Other Diagram, Csg/Cmt/Perf details

34. I hereby certify that the foregoing and attached information is complete and correct as determined from all available records (see attached instructions)*

Name (please print) Jennifer A Brown   Title Engineering Technician

Signature Jennifer A. Brown   Date 04/18/2013

INSTRUCTIONS

If not filed prior to the time this summary record is submitted, copies of all currently available logs (drillers, geologists, sample and core analysis, all types electric, etc), formation and pressure tests, and directional surveys should be attached hereto, to the extent required by applicable Federal and or State laws and regulations. All attachments should be listed on this form, see space 33.

Space 4 If there are no applicable State requirements, locations on Federal or Indian land should be described in accordance with Federal requirements. Please note all Lat./ Longs. In NAD 83. Calculate all "Top of Producing Intervals" and "BHL" first as distance from the section corner, second as the Lat. /Long Spacing orders are based on a well location in a section Well locations must match the surveyed footages.

Space 17: Indicate elevation used for depth measurements given in other spaces on this form and in any attachments.

Space 23: " Sacks Cement " : Attached supplemental records for this well should show the details of any multiple stage cementing and the location of the cementing tool. Show how reported top(s) of cement were determined, i.e. circulated (CIR), or calculated (CAL), or cement bond log (CBL), or temperature survey (TS).

Spaces 25 and 28: If this well is completed for commingled production from more than one pool (multiple zone completion), state in space 25 and 26, and in space 25 show the producing interval, or intervals, top(s), bottom(s) and name(s) (if any) for the pools reported in space 28 through 28c. Submit a separate completion report on this form for each pool separately produced, (not commingled).

Space 27: If a well was fracture treated or stimulated, all data required in Chapter 3, Section 45 must be filed with this Completion Report

Space 28: Provide well test data for each interval tested or stimulated and flowed.

Space 28 or 32. Provide frac flowback disposal volumes and handling.

Space 32: Provide final annulus casing pressure.

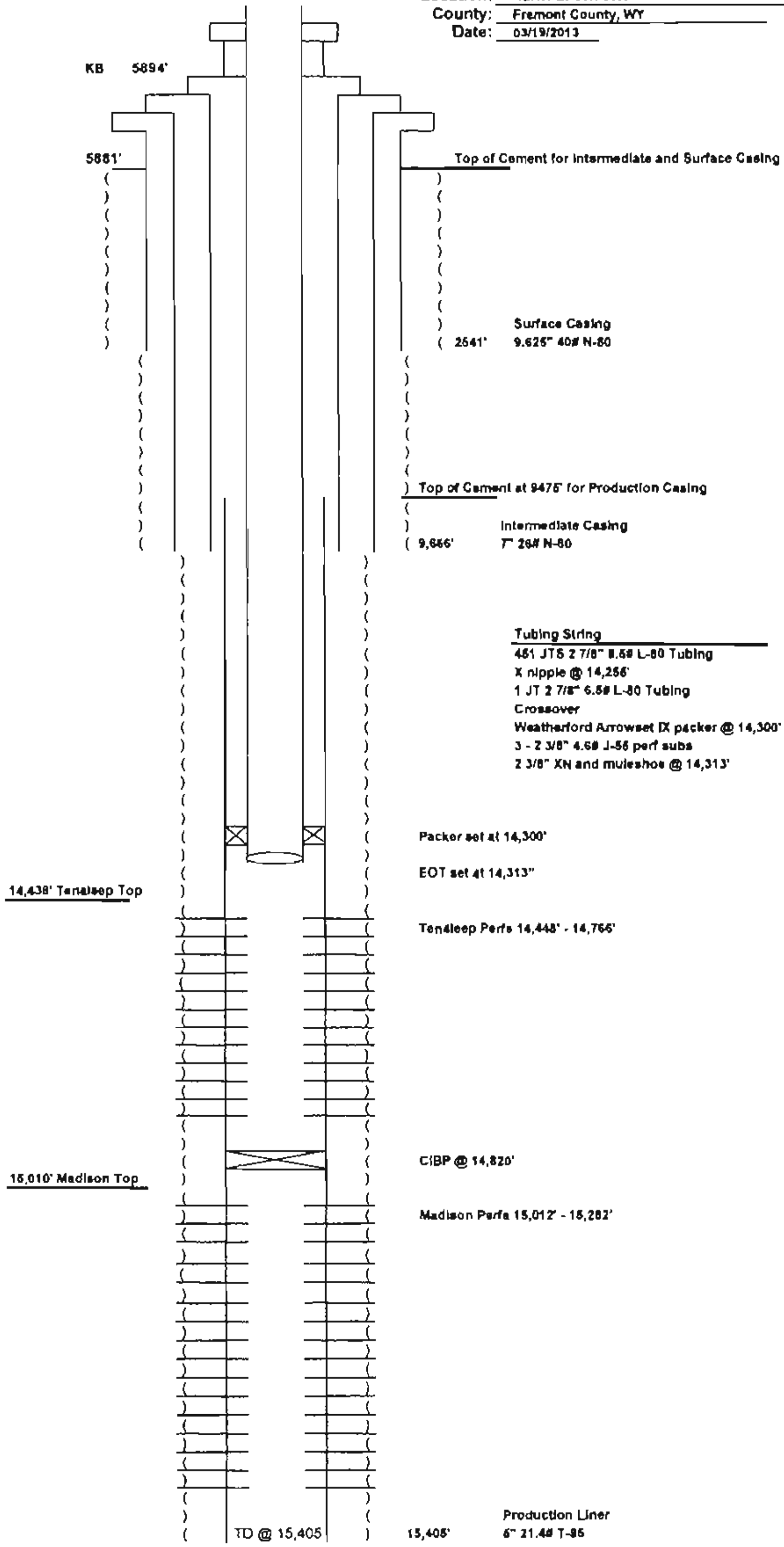
Space 32 or Attachment: Provide all Stimulation Chemicals by Name. Type, Volumes and CAS #s.

Attach a wellbore diagram whenever possible.

WELLBORE DIAGRAM

CURRENT WELLBORE DIAGRAM

Company: EnCana Oil & Gas (USA) Inc
Lease Name: Marlin 29-21 WDW
Location: NENW 29 35N 90W
County: Fremont County, WY
Date: 03/19/2013



FORM 3

STATE OF WYOMING
OIL AND GAS CONSERVATION COMMISSION
P. O. Box 2640
Casper Wyoming 82602

APD

WELL COMPLETION OR RECOMPLETION REPORT AND LOG (SUBMIT SINGLE, DUPLICATE ON STATE LAND)

9 API WELL NO: 49-013-23374

12 COUNTY: FREMONT | 13 STATE: Wyoming

5 STATE LEASE SERIAL NO: WYW 159681

7 UNIT OR COMMUNITIZATION AGREEMENT: WYW147739X

8 FARM OR LEASE NAME: Marlin

8a WELL No: No. 29-21 WDW ✓

10 Field Name: Wildcat ✓

11 SEC T, R, M, OR BLOCK AND SURVEY OR AREA: 29 T 35N R 90W

36 MULTIPLE COMPL? DOCKET OR AA DATE.

17 ELEVATIONS (DF, RKB, RT, GR, etc.)*: 5,717.60 5739.6 KB

1a Type of Well: ☐ Oil Well ☐ Gas Well ☐ Dry ☐ CBM Other: WDW

b Type of Completion: ☐ New Well ☐ Workover ☐ Deepen ☐ Plug Back ☐ Diff Resvr ☐ Initial ☒ Final Other: Fracture Treatment

2 Name of Operator: Aethon Energy Operating LLC

3 Address: 12377 Merit Drive Ste 1200 Dallas, TX 75251

3a Phone No (include area code): 214-750-3834 Email: ddamme@aethonenergy.

4. Location of Well (Report location clearly and in accordance with WOGCC requirements with footages and qtr qtrs. Section, Township and Range)

✓ At surface: 660' FNL & 1977' FWL (NENW) Lat 42.98281 Long 107 65234

Top prod. Int. TVD / MD Lat (MD) Long

At total depth TVD / MD: 1328' FNL and 1779' FWL (NENW) Lat (MD) 42 98098 Long 107.65308

14 Date Spudded: 11/30/2011

15 Date T D. Reached: 5/30/2012

16 Date Completed: D & A ☐ 12/13/2017 ☒ Ready to Prod

18 Total Depth: MD 15405 TVD 15364

19 Plug back T D: MD 14481 TVD 14440

20 Depth Bridge Plug Set: MD (Requires Prior Approval) TVD

21 Type Electric & other Logs Run (Submit 1 copy and 1 LAS of each), Cased and Open Hole, Btm Hole Press Survey

22 Was well cored? ☐ No ☐ Yes (Submit analysis)
Was DST run? ☐ No ☐ Yes (Submit report)
Directional Survey? (Required on all non-vertical) ☐ No ☐ Yes (Submit copy, w/ cert.)

23. Casing and Liner Record (Report all strings set in well)

Hole Size	Size/ Grade	Wt. (#/ft.)	Top (MD)	Bottom(MD)	Stage Cementer Depth	No. of Sks & Type of Cement	Slurry Vol. (Bbl)	Cement Top*	Amount Pulled
24			0	74'	Conductor				
12 1/4	9.625 N80	40#	0	2541'	Surface	2013 sks		5881'	
8.5	7 N80	26#	0	9666'	Intermediate	633 sks		5881'	
6.125	5 T95	23.20#	9513'	10197'	Liner	164 sks		9475'	
6.125	5 T95	21.40#	10197'	15376'	Liner				
6.125	5 HT	18#	15376'	15405'	Liner				

24 Tubing Record:

Size	Depth Set (MD)	Packer Depth (MD)	Size	Depth Set (MD)	Packer Depth (MD)	Size	Depth Set (MD)	Packer Depth (MD)

25 Producing Intervals: ✓ | 26 Perforation Record.

	Formation	Top	Bottom	Perforated Interval		Size	No. of Holes	Perf Status
A)	Tensleep	14448	14766	14448	14766	0.5	652	Open
B)	Madison	14972	15312	14972	15312	0.5	1766	Squeezed
C)								
D)								

27 Acid, Fracture Treatment, Cement Squeeze, Etc (Each Require Prior Approval)

Depth Interval | Amount and Type of Materials and Chemicals (attach job log if poss.)

Top	Bottom	Stim Type	Date	Co	Amt Fluid	Type	Secondary Fluid	Type	Prop Vol	Type	Min PSI	Max PSI
14448	14766	Frac	8/3/17	QES	1,343	Slickwater	2,669	25# Xlink	199,512	20/40 White	0	7500
14448	14766	Frac	12/13/17	SLB	1,473	Slickwater	4,192	YF125FlexD	254,077	20/40 White & 100 Mesh	66	4693

Summary Total Frac Stages: 2 Total Slurry (bbls): 10,466 Total Proppant (lbs): 453,589

28 Production- Interval A | 25 Formation: | Productive Interval: -

Date First Produced	Test Date	Hours Tested	Test Production	Oil Bbl	Gas MCF	Water Bbl	Oil Gravity Corr API	Gas Gravity	Flowback Disposal
			→						

Choke Size	Tbg Press Flwg	Csg Press	24 Hr Rate	Oil Bbl	Gas MCF	Water Bbl	Gas Oil Ratio	Res. Press	Well Status
			→						Shut In ✓

* See instructions and spaces for additional data on page 2

28a Production- Interval B			25. Formation			Productive Interval.			
Date First Produced	Test Date	Hours Tested	Test Production →	Oil Bbl	Gas MCF	Water Bbl	Oil Gravity Corr API	Gas Gravity	Flowback Disposal
Choke Size	Tbg Press Flwg. SI	Csg Press	24 Hr Rate →	Oil Bbl	Gas MCF	Water Bbl	Gas Oil Ratio	Res Press	Well Status
28b Production- Interval C			25 Formation:			Productive Interval:			
Date First Produced	Test Date	Hours Tested	Test Production →	Oil Bbl	Gas MCF	Water Bbl	Oil Gravity Corr. API	Gas Gravity	Flowback Disposal
Choke Size	Tbg Press Flwg SI	Csg Press	24 Hr Rate →	Oil Bbl	Gas MCF	Water Bbl	Gas Oil Ratio	Res Press.	Well Status
28c. Production- Interval D			25 Formation.			Productive Interval			
Date First Produced	Test Date	Hours Tested	Test Production →	Oil Bbl	Gas MCF	Water Bbl	Oil Gravity Corr. API	Gas Gravity	Flowback Disposal
Choke Size	Tbg.Press Flwg. SI	Csg Press	24 Hr Rate →	Oil Bbl	Gas MCF	Water Bbl	Gas Oil Ratio	Res Press	Well Status

29 Disposition of Gas *(Sold, used for fuel, vented, etc.)*

Test Witness.

30 Summary of Porous Zones (include Aquifers)

Show all important zones of porosity and contents thereof. Cored intervals and all drill-stem tests, including depth interval tested, cushion used, time tool open, flowing and shut-in pressures and recoveries

31 Formation (Log) Markers

Formation:	Top	Bottom	Descriptions Contents, Etc	Name:	Depth (Measured):
				Phosphoria	14150
				Tensleep	14436
				Amsden	14724
				Madison	15011
				Gros Ventre	15355

32 Additional remarks; include plugging procedure (Req prior approval)

Please see updated Form 3 for sundry transaction #: 1323374022 along with current wellbore schematic, job timeline, and associated post job reports.

33 Indicate which items have been attached by placing a check in the appropriate boxes:

- [ ] Electrical/ Mechanical Logs (1 full set) Cased & Open hole
- [ ] Geologic Report
- [ ] DST Report
- [ ] Directional Survey w/ Certification
- [ ] Sundry Notice for plugging and cementing
- [ ] Core Analysis
- [ ] Press Survey
- [X] Other Frac Reports

34 I hereby certify that the foregoing and attached information is complete and correct as determined from all available records (see attached instructions)*

Name (please print) Dustin Damme Title Operations Engineer

Signature Dustin D Damme Digitally signed by Dustin D Damme Date: 2018.01.29 12:19:00 -06'00' Date

STATE OF WYOMING
OIL AND GAS CONSERVATION COMMISSION
Office of State Oil and Gas Supervisor
P. O. Box 2640
Casper Wyoming 82602

SUNDRY NOTICES AND REPORTS ON WELLS

(Do not use this form for proposals to drill, or deepen. Form 1 is provided for such proposals.)

12 API No.: 49-013 -23374
13. County: FREMONT
[illegible]
If a Split Estate Location Change Provide Form 1A.
5 Lease No.:
6 Unit Agreement or CA.
7. Farm or Lease Name: MARLIN
8. Well No.: 29-21WDW
9 Reservoir: TENSLEEP-MADISON
10 Field Name: WC
11 Quarter- Quarter, Section, Township and Range: NE NW 29 Township 35 North Range 90 West

1. Type Well:
☐ Oil ☐ Gas ☐ CBM ☐ Dry Hole ☐ Injection ☒ Other Disposal

2 Operator: ENCANA OIL & GAS USA INC
3 Address: 370 17th Street, Suite 1700 Denver, CO 80202
14 Elevation: 5881 GL
4 Phone Number (w/ area code): 720-876-5011
Email: sandra.ocker@encana.com
16 Latitude: 42.98281
15 Footages: SHL 660 FNL 1977 FWL
BHL: 0 T0 R0
17 Longitude: -107.65234

18 CHECK APPROPRIATE BOXES TO INDICATE THE NATURE OF NOTICE, REPORT, OR OTHER DATA

Type of Submission:
☒ Notice of Intent
☐ Subsequent Report
☐ Change of Address. List Old & New Below
Split Estate? Yes ☒ No ☐
If this is a Split Estate location change or Fed Lease owner change file Form 1A.

Type of Action:
☐ Change Plans
☐ Convert to injection
☐ Dormant
☐ Location or Site Change
☐ Federal Lease Owner Change
☐ Fracture Treat/ Enhance
☐ Plug and Abandon
☐ Perforate
☐ Recomplete/ Plugback
☐ Reclaim
☐ Rename
☐ Repair Well
☐ Shut-in
☐ Start / Resume Production
☐ Temporarily Abandoned
☐ Water Shut-Off
☒ Other Water Disposal

19. Describe the proposed or completed operations: Clearly state all pertinent dates and details, including estimated start date of proposed work.
Form 3 is required following completion and recompletion procedures. Attach additional sheets if necessary, referencing API No., Well Name and Legal Location.

Resubmitting notice of intent for Water Disposal into the Tensleep Formation with corrections requested by Tom Kropatsch.

Encana Oil & Gas (USA) Inc. respectfully requests approval to dispose of the produced water into the Tensleep Formation of the Marlin 29-21 WDW at a maximum surface injection pressure of 3,500psi, based on the attached results of the most recent step rate test.
An aquifer exemption has already been granted for the Tensleep formation from the sundry submitted on 9/12/2012 and approved on 9/20/2012. The actual temperature logs will be mailed to the WOGCC office, Attn: Tom Kropatsch. If additional information is needed or any questions come up please contact Steve Greene @ 720-876-5553.

20 I hereby certify that the foregoing as to any work or operation performed is a true and correct report of such work or operations

Name (Printed or Typed): Sandy Ocker
Title: Operations Tech.

21 Signature: Filed Electronically Transaction 1323374015
Date: 12/17/2012

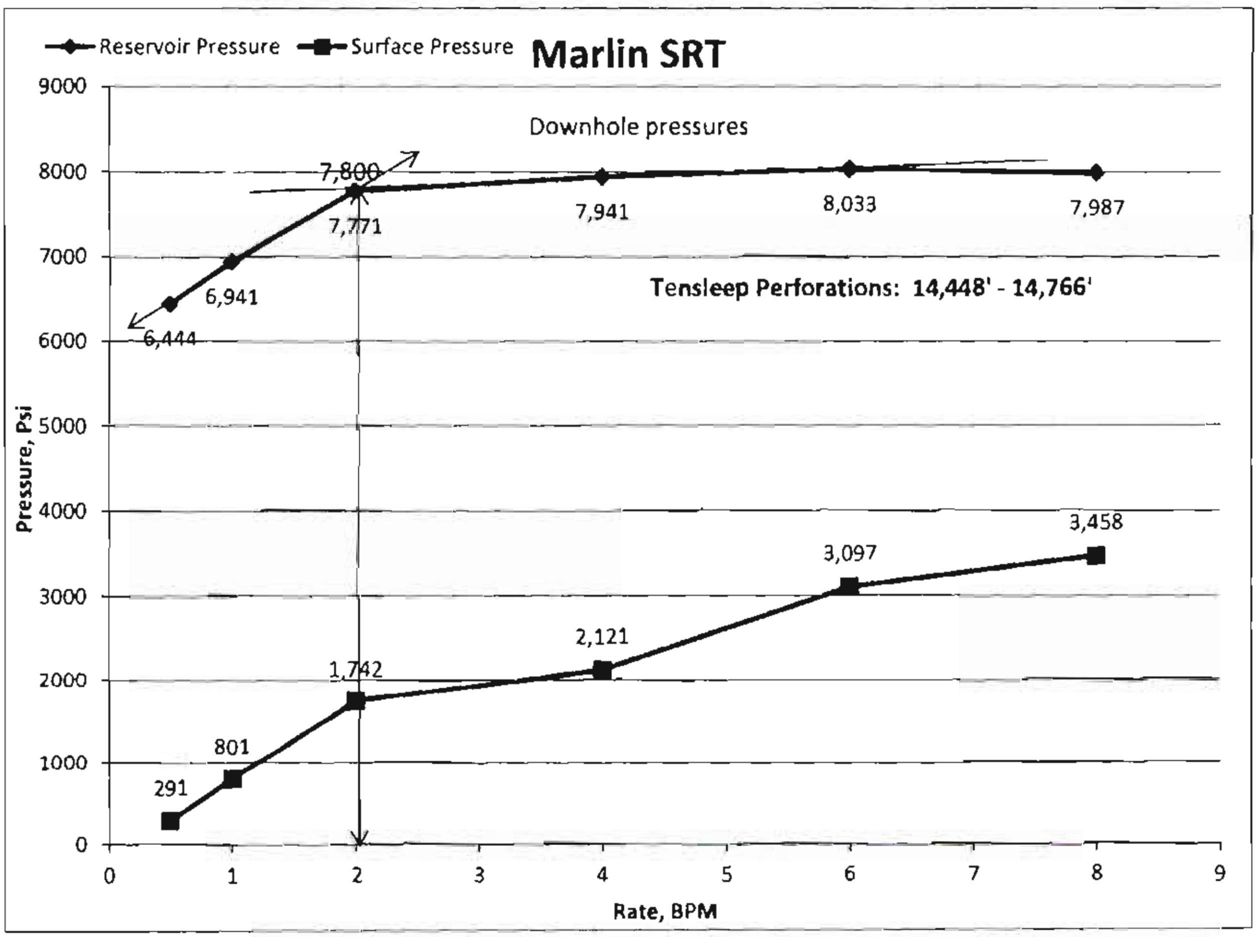
(The space below is for State office use)

Approval Date: FEDERAL
Approved By:
State Oil and Gas Supervisor
Approvals sent: TKK

Conditions of approval, if any:

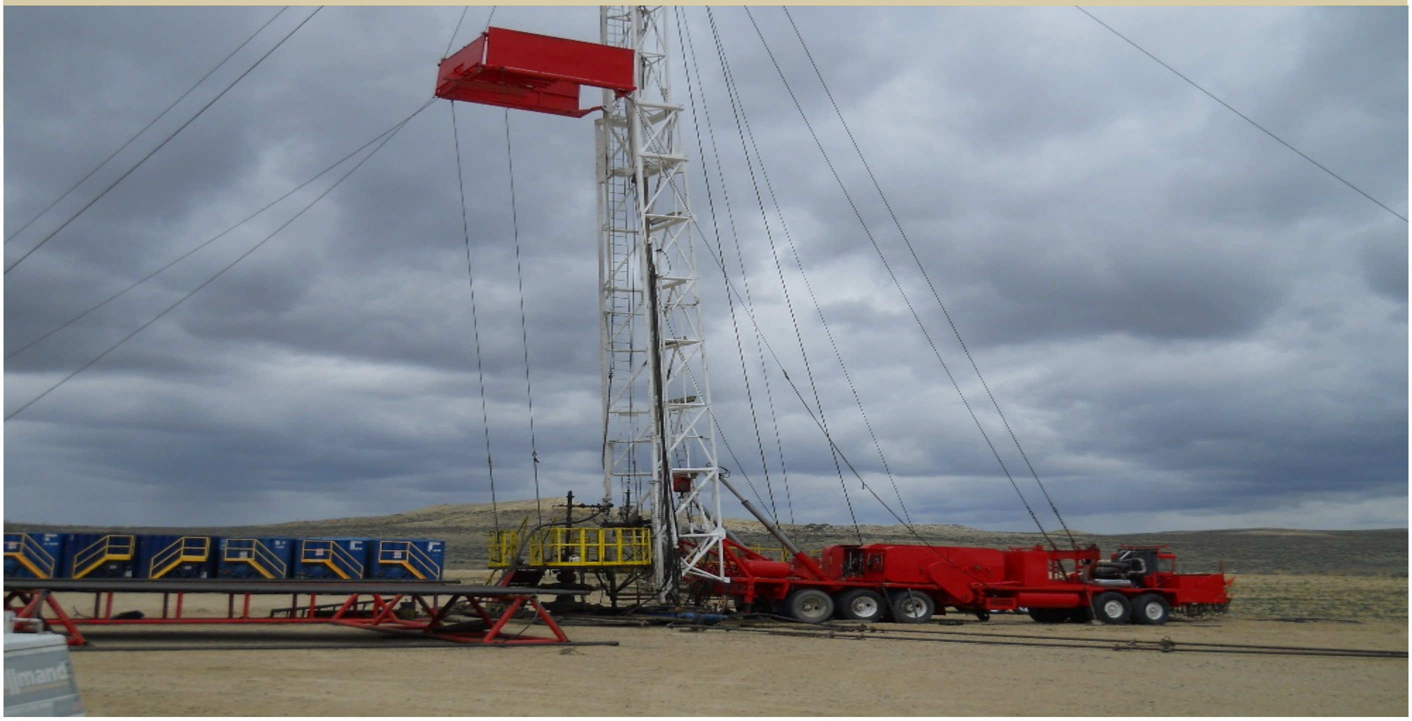
maximum surface injection pressure of 1750psi will be approved. 1750psi corresponds to the bottom hole pressure at which the step rate test indicates the formation fracture pressure was reached. See supplemental order prepared for the Marlin 29-21WDW authorizing max surface injection pressure.

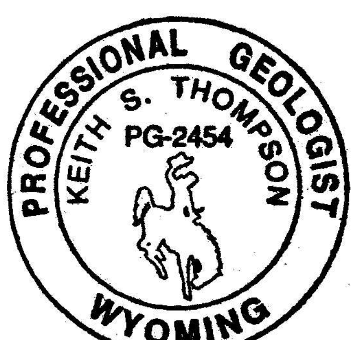
The data associated with the step rate test can be seen below. The graph shows both surface pressures and downhole pressures for each 60 minute injection rate step. The downhole pressures were measured via a downhole pressure gauge set @ 14,310' right below the packer and ~140' above the top perforation in the Tensleep formation (Tensleep perfs = 14,448' to 14,766'). From the data it can be concluded the formation fractured at an approximate surface pressure of 1750 psi with a 2 bbl/min rate. During the test the surface pressure did not exceed a surface pressure of 3500 psi.



Performance and Influence of the Marlin 29-21 Water Disposal Well on the Madison Formation in Fremont County, Wyoming

Aethon Energy Operating LLC





Leading with Science®

August 12, 2020

The seal appearing on this document was authorized by
Keith S. Thompson, P.G. 2454 on August 12, 2020

Performance and Influence of the Marlin 29-21 Water Disposal Well on the Madison Formation in Fremont County, Wyoming

Prepared for:

Aethon Energy Operating LLC

12377 Merit Drive
Suite 120
Dallas, Texas 75251

Prepared by:

Tetra Tech

3801 Automation Way
Suite 100
Fort Collins, Colorado 80525
(970) 223-9600

Tetra Tech Project No. 117-8730001

August 12, 2020

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

%	percent
δ	delta, or del
^{13}C	stable isotope of carbon
^{14}C	radioactive isotope of carbon
Aethon	Aethon Energy Operating LLC
bbl/day	barrels per day
BLM	Bureau of Land Management
Ca	calcium
cm/s	centimeters per second
CH_4	methane
Cl	chloride
CO_2	carbon dioxide
cp	centipoise
C_r	compressibility of rock
C_w	compressibility of water
DIC	dissolved inorganic carbon
DST	drill stem test
ft.	feet
Encana	Encana Oil & Gas (USA) Inc.
EPA	United States Environmental Protection Agency
FEIS	Final Environmental Impact Statement
H_2S	hydrogen sulfide
HCO_3	bicarbonate
K	potassium
K_h	horizontal hydraulic conductivity
K_v	vertical hydraulic conductivity
k_h	horizontal permeability
k_v	vertical permeability
k_x	permeability in the x-direction
k_y	permeability in the y-direction
Na	sodium
MD	measured depth
Mg	magnesium
mg/L	milligrams per liter
md	millidarcies
msl	mean sea level

NPHI	neutron porosity
Phi	porosity
pmc	percent modern carbon
SMCL	secondary maximum contaminant level
SO_4	sulfate
SRT	step-rate test
SSTVD	subsea true vertical depth
SWIP	Survey Waste Injection Program
TDS	total dissolved solids
TVD	True Vertical Depth
USGS	United States Geological Survey
US NRC	United States Nuclear Regulatory Commission
WDW	Water Disposal Well
WDEQ-AML	Wyoming Department of Environmental Quality Abandoned Mine Lands Program
WOGCC	Wyoming Oil and Gas Conservation Commission
WRB	Wind River Basin
WRDS	Wyoming Water Resources Data System
WSEO	Wyoming State Engineer's Office
WSGS	Wyoming State Geological Survey
WRR	Wind River Range
WWDO	Wyoming Water Development Office
ybp	years before present

EXECUTIVE SUMMARY

Tetra Tech's summary and conclusions are presented below.

- Tetra Tech obtained and reviewed published information including geologic and geophysical reports, seismic cross sections, hydrogeological maps, well logs, water quality reports, location and depth of geologic structures and features in the area.
- Tetra Tech completed an assessment of existing and relevant data to verify and validate its use in development of the site conceptual hydrogeologic model and the injection well performance simulations. These data include: downhole geophysical data evaluated for lithology and hydrogeologic properties; water chemistry for general water quality properties and for understanding groundwater flow within the basin; DST for formation pressure and hydraulic properties; core report for porosity and permeability; and original model input files from Encana Oil and Gas (USA) Inc. for applicability to Tetra Tech's injection model.
- In general, the available data were very sparse within the central portion of the WRB which includes the location of the Marlin 29-21 WDW and our simulation model. A majority of the well data were located near the perimeter of the basin where the Madison Formation is closer to the surface than the deeper portions of the basin.
- Tetra Tech estimated potentiometric head elevations for the Madison and Tensleep aquifers from DST shut-in pressures, water-level elevations in water wells, spring elevations, and constraints of outcrop elevations. The potentiometric surface elevation contours indicate that groundwater flow in both aquifers is from recharge areas along the southern, western and northwestern parts of the WRB toward the central parts of the basin and toward producing oil and gas fields in the central and western parts of the basin. Recharge to the Madison aquifer in the Wind River Basin is estimated to be approximately 35,500 acre-ft. per year. Groundwater discharge is to oil and gas wells which produce water (an average of approximately 3,900 acre-ft. per year) in addition to oil and gas and to areally-distributed seepage upward or downward into adjacent aquitards and aquifers.
- Faults with vertical displacement of 1,000 ft. or more compartmentalize groundwater flow within the Madison aquifer and act as barriers to groundwater flow.
- Upward discharge of groundwater from the Madison aquifer via faults with enhanced vertical permeability is not likely, as investigations have shown that the open fractures of fault breccias in the Madison were subsequently filled by calcite. Additionally, there is no evidence of significant upward discharge of groundwater along the trace of the Owl Creek thrust fault that bounds the structurally deep northern side of the basin.
- Based on potentiometric, geochemical, and aquifer property data, the conceptual flow path deemed most probable for flow of groundwater to the vicinity of the Marlin 29-21 well is from the Madison outcrop area in the Rattlesnake Hills 14 miles southeast of the WDW site directly northwest toward the Marlin 29-21 WDW.
- Tetra Tech sampled formation water for chemical composition and for determining the radiocarbon age. In this report the ^{14}C measurements were adjusted by using the geochemical model NETPATH to account for chemical reactions that involve mass transfer of constituents that affect the interpretation of ^{14}C content for determining actual travel time. These corrections indicate the measured ^{14}C result of 37,990 ybp should be minimally adjusted to a more accurate value of from 36,878 to 37,658 ybp, which would

represent the travel time from recharge area on the southern edge of the WRB to the Marlin 29-21 WDW location. A more conservative value of 27,000 years was used in travel time assessments because of the uncertainty in groundwater compositions in the recharge area and the undefined migration pathway from recharge at the land surface to the subcropping Madison aquifer.

- Tetra Tech constructed a regional groundwater flow and transport model using the SWIFT numerical modeling code to simulate pressurization and waste migration from proposed injection operations at the Marlin 29-21 WDW.
- The model includes the Madison Formation (the injection zone) and the overlying Darwin Sandstone, Amsden (confining units) and Tensleep Formations.
- The model covers an area of approximately 1,075 square miles and encompasses recharge areas to the south and discharge areas to north along the Owl Creek fault zone
- Structural contour and isopach data were included for each formation/layer in the model (i.e., there are variable elevation and thickness at every grid block in the model except for the Darwin Sandstone that has variable elevation and a constant thickness of 29 feet).
- The modeling strategy employed in this analysis is based on US EPA Class I hazardous waste injection well standards, which are more stringent and conservative than the standards for a brine disposal well.
- A SRT was conducted at the Marlin 29-21 WDW in the Madison Formation in July 2014. The primary purpose of the SRT was to determine the breakdown pressure of the formation for regulatory agencies.
- To the extent possible, the SWIFT model matched a portion of the SRT before formation fracturing occurred. The permeability used in the model to match that portion of the SRT was 3.5 md, which is consistent with values reported in the literature for the Madison Formation in the WRB.
- Predictive simulations using values of permeability for the Madison Formation of 3.5 and 8 md and a reservoir pressure constraint of 9,850 psi (obtained from the SRT) indicate that the maximum average injection rate that can be sustained for the 50-year operational period ranges between approximately 4,500 to 9,900 bpd. These results are consistent with the data obtained from the SRT.
- An injection rate of approximately 19,800 bpd can be achieved if the permeability of the Madison Formation is 17 md. This value, while within the range of permeability values reported for the Madison Formation, is more likely associated with areas of the formation that have higher porosity and/or at shallower depths.
- The 1 x 10^{-3} normalized concentration contour was used to define the edge of the waste injectate plume representing an increase of 6.9 mg/L, (based on an injectate concentration of 8,000 mg/L) and formation water concentration of 1,100 mg/L).
- Simulations were performed on three permeability values (3.5, 8, and 17 md) as well as a series of sensitivity analyses on key hydraulic parameters affecting waste migration (i.e., porosity in order to simulate net thickness, dispersivity, anisotropy, vertical hydraulic conductivity of the Darwin Sandstone and Amsden Formation).
- Long-term simulations (10,000 years) indicate that the waste plume generated from the three base case permeability values (i.e., 3.5, 8 and 17 md) would remain contained laterally within the deepest portions of the Madison Formation, even under the most

conservative or "worst case" conditions. For the 3.5 md case, the waste plume migrated up-dip and down-dip approximately 0.6 and 1.7 miles, respectively, for the 8 md case, the waste plume migrated up-dip and down-dip approximately 0.5 and 3.3 miles, respectively, and for the 17 md case, the waste plume migrated up-dip and down-dip approximately 0.1 and 6.8 miles, respectively.

- Long-term simulations (10,000 years) indicate that, under the worst-case conditions simulated, the waste plume will not migrate up-dip into areas where the top of the Madison Formation is less than about 12,000 feet below the land surface, nor will it move closer than approximately 12 miles from the nearest outcrop of the formation.
- Long-term simulations (10,000 years) also indicate that no waste injectate will migrate vertically into the Tensleep Formation under base case or net thickness conditions or under any of the sensitivity analyses scenarios.

1.0 INTRODUCTION

On April 10, 2012, the Wyoming Oil and Gas Conservation Commission (WOGCC) approved Encana Oil and Gas (USA), Inc.'s (Encana) disposal well and aquifer exemption application conditioned on a determination that "waters in the disposal intervals are proven to have total dissolved solids concentrations in excess of 5,000 mg/l" (WOGCC Report of Examiners, Doc. No. 438-2011, p. 5). Encana conducted tests of Madison Formation waters and determined the formation contained total dissolved solids (TDS) concentrations less than 5,000 mg/l. On November 19, 2012, Encana filed a second application for a Madison Formation aquifer exemption based on the grounds that the Madison Formation aquifer in the area of the disposal well "is situated at a depth or location which makes recovery of fresh and potable water economically or technologically impractical." (WOGCC Rules, Ch. 4, Sec. 12(a)(ii)). Following an evidentiary hearing before the WOGCC on January 8, 2013, the U.S. Environmental Protection Agency (EPA) and Wyoming Department of Environmental Quality (WDEQ) submitted written comments to the WOGCC and requested additional information from Encana. Encana responded to EPA and WDEQ on February 27, 2013 (to EPA), and March 7, 2013 (to WDEQ). On March 12, 2013, following a second evidentiary hearing, the WOGCC granted Encana's aquifer exemption application. On April 8, 2013, EPA sent a letter to the WOGCC requesting additional information. On December 30, 2013, Encana met with representatives of EPA, WOGCC and other agencies, and on January 16, 2014, WOGCC staff provided Encana with additional comments from EPA.

Aethon Energy Operating LLC (Aethon) acquired the Moneta Divide asset from Encana on April 29, 2015, with an effective date of July 1, 2014. Aethon worked with Tetra Tech to update the hydrogeologic study in September 2015, and then participated in a water exemption hearing for approval of the Madison Formation to be used as a disposal zone on November 10, 2015, docket number 3-2013. On May 14, 2019, the Wyoming Oil and Gas Conservation Commission (WOGCC) issued an order of denial for Aethon's request for a water exemption for the Madison Formation, docket number 3-2013. In the Findings of Fact section, No. 12, commissioners expressed concerns about whether the injected water will stay within a reasonable distance of the wellbore or move up to a depth at which recovery of groundwater as a resource would be more economical depth (5,000 feet or less below ground surface); structural geologic complexity including faults and related fractures; and whether reservoir heterogeneity, compartmentalization, and different pressure regimes were adequately addressed with regard to water movement in preferential directions related to geology.

This report focuses only on the hydrogeology of the region surrounding the Marlin 29-21 water disposal well (WDW), the analysis of injection performance of the well, and the flow and time-related spatial distribution of injected water. Questions related to future well development by Aethon and the alternative uses of the Madison Aquifer are addressed by Encana or Aethon in other documents presented to regulatory agencies and are not discussed in this report. Additionally, the schedule and history of meetings and communications with regulatory agencies regarding the Marlin 29-21 WDW are adequately recorded elsewhere and are beyond the scope of this project.

1.1 Scope of Work

Tetra Tech's scope of work included a review and assessment of baseline data, development of a conceptual site hydrogeologic model, modeling simulations of the Marlin 29-21 WDW injection performance and flow field and addressing the related hydrologic question of travel time from the recharge area to the Marlin 29-21 WDW. The purpose of these tasks is to provide additional information for EPA's assessment of Aethon's aquifer exemption and the WOGCC's approval of the aquifer exemption for the Madison Formation.

Encana previously conducted computer simulations for injection of produced water into the Marlin 29-21 WDW and provided estimates of radius of influence and travel distance for specified injection rates and hydraulic properties. The EPA did not consider the initial model sufficient to answer questions regarding travel distances, and the agency posed several related questions that should be addressed for the aquifer exemption request. In 2014 Encana contracted with Tetra Tech to conduct a third-party, independent simulation of the effects of the injection of produced water and subsequently address some of the concerns presented by the EPA (EPA, 2013). Tetra Tech completed the simulation in 2015 and prepared a report (Tetra Tech 2015b) which was submitted to the WOGCC in 2015. The Tetra Tech (2015b) report was the result of the requested independent, revised modeling project. In 2020, Tetra Tech revised the 2015 groundwater model for Aethon, as described herein. This report is an update of the Tetra tech (2015b) report and has been revised to incorporate new information, updated modeling input, and updated modeling results.

Specific concerns noted by the EPA that are addressed in this report include the following:

1. Evaluate the conceptual hydrogeologic model for the region in the vicinity of the Marlin 29-21 WDW;
2. Examine the regional flow system and determine the most probable flow pathway from recharge location to the Marlin 29-21 WDW;
3. Determine the approximate age and probable source of water produced from the Marlin 29-21 WDW;
4. Review the results of the step-rate test (SRT) conducted in the Madison Formation by Encana;
5. Analyze the results of the SRT;
6. Update the 2015 model by a) separating the Amsden Formation into two layers, one to represent the Darwin Sandstone member and one to represent the rest of the Amsden Formation and b) revise the porosity distribution by model layers, if necessary, based on information provided by Aethon; and
7. Predict the TDS concentrations surrounding the Marlin 29-21 WDW at the end of a 50-year injection period and after subsequent migration under ambient flow conditions.

1.2 Report Outline

This report discusses the results of the project effort in essentially the same sequence as the execution of the project tasks, including: Task 1 – Review and Assessment of Baseline Data; Task 2 – Hydrogeologic Conceptual Model; Task 3 – Disposal Well Performance Modeling; and Task 4 – Additional Hydrogeologic Questions from EPA. The tasks were proposed such that they follow the workflow of qualifying the critical data, and then establishing the regional conceptual hydrologic models to provide the context for the site-specific evaluation of the performance and influence of the Marlin 29-21 WDW on the Madison Formation. Report sections are arranged as follows:

Section 1.0: Introduction

Section 2.0: Brief background statement

Section 3.0: Information and data management: workflow, organization, review, qualification for either the regional conceptual model or for input to the numerical simulation.

Section 4.0: Regional hydrologic conceptual models, geology, hydrology, elimination of flowpaths from consideration that do not reach the Marlin 29-21 WDW location and a description of the most probable flowpath from the recharge area to location of the Marlin 29-21 WDW.

Section 5.0: Description of the selected numerical model, evaluation of the SRT, numerical model construction and calibration, and prediction of pressure changes and injectate migration.

Section 6.0: Geochemical information and use of radiocarbon data to best define groundwater travel time from the recharge location to the Marlin 29-21 WDW.

Section 7.0: Summary and Conclusions

Section 8.0: References

2.0 BACKGROUND INFORMATION

The Marlin 29-21 WDW (API#49013233740100) is located in Fremont County, Wyoming in the Wind River Basin (WRB) at latitude 42.98281° N and longitude 107.65234° W (Figure 2-1). It is located northwest of the Rattlesnake Hills and approximately 37 miles east of Riverton, Wyoming.

The WRB is drained by the Wind River, which exits the basin north of the Boysen Reservoir. The lowest elevation along this reach of the river is approximately 4,600 feet (ft.). Southeast of the Marlin 29-21 WDW, the highest elevation along the topographic divide is approximately 7,600 ft.

The Marlin 29-21 WDW was spudded in the Fort Union Formation at an elevation of 5,881 ft. on April 1, 2014, with the intended use as a wastewater disposal well associated with oil and gas production. The total depth (relative to land surface) of the well is 15,392 ft., within the Gros Ventre Formation. The well was constructed to allow injection into the Tensleep sandstone and/or the Madison limestone/dolomite. The Tensleep and the Madison Formations are separated by the lower-permeability Amsden Formation. The lower part of the well (10,183.8 to 15,357.5 ft.) is cased with 5-inch steel casing with an inside diameter of 4.126 inches. The annular space is cemented from total depth up to approximately 9,458 ft. There are two perforated zones; the upper one, opposite the Tensleep Formation, is between depths of 14,435 and 14,753 ft. and the deeper zone, opposite the Madison Formation, is from 14,959 to 15,315.5 ft. The Madison perforations were cemented off and a cast iron bridge plug and a cement plug were set above the top of the Madison Formation on March 9-10, 2017. The plan to facilitate use of the well as a disposal well is to drill out the cement, remove the plug, and perforate intervals for disposal in Madison sequence III.

Aethon’s intent is to use the Marlin 29-21 WDW to inject wastewater produced from the Moneta Divide area, with a total dissolved solids (TDS) content of approximately 8,000 milligrams per liter (mg/L). The intended injection rate is up to 20,000 barrels per day (bbl/day), but the actual injection rate will depend on the characteristics of the formation. In 2014 Encana performed a SRT of the Madison Formation to provide preliminary information on the permeability of the Madison Formation. Data generated from this test are evaluated in this report.

3.0 REVIEW AND ASSESSMENT OF BASELINE DATA

A desktop study and literature search was conducted by Tetra Tech to understand and assess the known hydrogeologic conditions within the project review area for Aethon's Marlin 29-21 WDW. The project review area includes the extent of the WRB. This information was gathered and reviewed to support development of the site conceptual model which is discussed in detail in Section 4.0 of this report and to provide supporting information in Tetra Tech's injection model discussed in Section 5.0 of this report. Key publications and documents reviewed are cited and included in the list of references (Section 8.0) of this report. Tetra Tech primarily relied on data available from sources listed below.

- Encana – model input, PETRA files, interpreted hydrogeologic data and raw data summaries, presentations, geophysical logs, porosity core test;
- United States Geological Survey (USGS) – Regional geological maps, cross sections, hydrogeologic data, geologic publications;
- Wyoming State Engineer's Office (WSEO) - https://sites.google.com/a/wyo.gov/seo/ - Groundwater Well Locations;
- Bureau of Land Management (BLM) - http://www.blm.gov/wy/st/en.html - BLM land parcels;
- Wyoming State Geological Survey (WSGS)- http://www.wsgs.uwyo.edu/ - Basins, Bedrock Geology, Dikes, Faults, Cross-sections;
- Wyoming Oil & Gas Conservation Commission (WOGCC) - http://wogcc.state.wy.us/ - O&G Well Locations/Logs;
- Fremont County, WY Tax Assessor http://fremontcountywy.org/county-assessor/mapserve/ - Landowner Data;
- Natrona County, WY Tax Assessor - http://www.natronacounty-wy.gov/index.aspx?nid=15 - Landowner Data; and
- Wyoming Water Development Commission – http://wwdc.state.wy.us - Water Plan for the WRB.

The information and data gathered in support of this project are divided into two basic categories. The first represents baseline information consisting of published reports and maps reviewed for general hydrogeological understanding of the project. This first data review category is discussed in the paragraphs below. The second category consists of data obtained by Tetra Tech and assessed to verify whether or not the data would be used in support of the site conceptual hydrogeologic model and the injection model. The second category is discussed in detail in Sections 3.1 and 3.2.

Tetra Tech obtained and reviewed published baseline information including geologic and geophysical reports, hydrogeological maps, well logs, water quality reports, and location and depth of geologic structures and features in the project review area. This information was gathered for use by Tetra Tech in developing the regional hydrogeological profile for use in the site conceptual model. It is assumed that the published data and reports gathered for this work are usable and acceptable information and require no additional data verification.

Lithology and structure information was available from six regional cross-sections which provide two-dimensional presentation of regional lithology and structure. These were obtained from published data (McLaughlin, 2009 and Quillinan, 2012) and reviewed for general understanding of the WRB lithology and structure. Five of these cross-sections are oriented generally southwest to northeast and the sixth one is oriented west to east across the central portion of the WRB. Along with regional structural data provided by Keefer, 1970, Peterson, 1978, and Peterson, 1984, Taucher et al., 2012, and structural map of Madison Formation prepared by Encana, these cross-sections were used for obtaining a baseline understanding of lithology and structure, as discussed in Section 3.2.1.

Tetra Tech reviewed previous works by Thompson and Erslev (2009), Thompson (2010), and Thompson (2015) detailing fracture orientation within the WRB. Regarding fracture orientation within the basin, Thompson (2010) concluded that "two distinct stages of deformation were observed and confirmed by the fracture data. NE-SW compression is consistent with the Laramide while the highly localized NE-SW to NNW-SSE extension is post-Laramide". This information regarding fracture orientation was useful for the preparation of the Injection Model and is also discussed in more detail in Section 4.1.1.The published maps and reports related to hydrogeology of the project review area were obtained and reviewed to assist Tetra Tech in our understanding of the location of key hydrogeologic features like the Madison Formation outcrop/recharge zones (Rahkit, 2006, and USGS, 2014). The identification of Madison Formation outcrop/recharge zones is a key component used in the site conceptual model and understanding groundwater flow within the basin. Hydrogeologic information reviewed included available pumping data from the Marlin 29-21 WDW, SRTs, and published water level measurements and hydraulic data from other wells in the surrounding area to assess aquifer and formation characteristics. The Marlin 29-21 WDW test data and the published hydrogeologic information were also used to make an assessment as to the condition of the aquifer and groundwater flow in the area under Task 2 and Task 3.

Published reports containing a summary and discussion of hydraulic parameters for the Tensleep, Amsden, and Madison Formations were obtained from various sources including, the WSGS, USGS and Wyoming State Water plan for the WRB area (these publications include: Rahkit, 2006; Taucher et al., 2012; Westphal et al., 2004; WWDO, 2010; Anna, 1986; Peterson 1978; Whitcomb and Lowry, 1968). The published hydraulic data from these documents included specific capacity, transmissivity, porosity, hydraulic conductivity or permeability, and storativity values. The published hydraulic data were reviewed for general understanding of the WRB hydrogeology and used to support the conceptual site model and to provide a comparison from a regional perspective to assumptions used in the injection model. Additionally, under Task 3 (Section 5.0) we received and reviewed the input data which included the hydraulic parameters Encana used for their model.

Tetra Tech searched for available groundwater well locations, water chemistry, and well completion information for Madison Formation groundwater wells within the WRB. Databases reviewed by Tetra Tech include:

1. the USGS National Produced Waters Geochemical Database (http://energy.usgs.gov/EnvironmentalAspects/EnvironmentalAspectsofEnergyProductionandUse/ProducedWaters.aspx#3822349-data),
2. the USGS Nation Water Information System website (http://nwis.waterdata.usgs.gov/nwis/qwdata),
3. WOGCC website (http://wogcc.state.wy.us/warchoiceMenu.cfm),
4. the University of Wyoming Water Resources Data System (WRDS), and
5. Published reports.

The searches yielded only depths of wells and minimal information regarding water composition. The available Madison wells data did provide ground water chemistry but with no supporting sampling and analysis information as discussed in Section 3.3. There were no Madison Formation groundwater wells found to be located in the interior of the WRB near the Marlin 29-21 WDW location.

In 2020, the BLM published the Final Environmental Impact Statement (FEIS) for the Moneta Divide Natural Gas and Oil Development Project (BLM, 2020). The report, primarily the Groundwater Modeling Report (Appendix O, BLM, 2020) was reviewed for any new information pertinent to the proposed Marlin 29-21 water disposal. The BLM groundwater model was run for 100 years (50 years operational plus 50 years post-operational), therefore no conclusions can be made for long-term waste migration. The primary conclusion of the BLM groundwater model was that injection would result in head increases of up to 170 feet at depth and head increases extending approximately 3,000 ft. beyond the boundary of the modeled Madison Disposal Area. These results are consistent with results of the Tetra Tech 2015 groundwater model for Encana.

3.1 Hydrogeological Data Evaluation

Tetra Tech completed an assessment of existing and relevant data to verify their use in supporting the site conceptual hydrogeologic model and for use for the injection well performance simulations. Data covered in the assessment included:

- Downhole geophysical data evaluated for tops of key formations;
- Downhole geophysical data evaluated for porosity values for the Madison Formation;
- Drill stem tests (DST) for determining the potentiometric surface;
- Pressure test of the Marlin 29-21 WDW for hydraulic properties including permeability;
- Geotechnical report of core tests for porosity and permeability;
- Original model input data from Encana for applicability to Tetra Tech's injection model; and
- Water chemistry for general water quality properties and for understanding groundwater flow within the basin.

Table 3-1 presents a summary of the data obtained by Tetra Tech and assessed to verify whether or not the data would be used in support of the site conceptual hydrogeologic model and the injection model. This subsection describes the source and type of data gathered and its general applicability to the project.

3.1.1 Geological Lithology and Structure

Available geophysical data were obtained for review and used where applicable in the conceptual site model (Section 4.0) and the injection model (Section 5.0) for the Marlin 29-21 WDW. The geophysical data obtained included downhole geophysical logs from nearby oil and gas wells within the WRB and the geophysical logs from the Marlin 29-21 test well. Aethon re-processed the geophysical log data to better reflect geophysical properties in changing lithologies between formations. Two 2-dimensional interpreted seismic were available; the data confirmed previous mapping used in the Tetra Tech study. In addition, a data file was obtained from Encana which included their identification of formation tops based on their interpretation of borehole geophysical log data for a database of 49 Madison Formation oil and gas well penetrations within the WRB.

A database of over 75 geophysical logs was also obtained from Encana for oil and gas wells located across the WRB. Of particular interest for this study are the 49 wells and related geophysical logs that penetrate the Madison Formation. Most of which are located around or near the perimeter of the basin. The logging suites run for each of these wells varied, but typically included, gamma, electrical, and porosity logs. Other geophysical logs that were run in various well locations included cement bond logs, induction logs, sonic logs, and density logs. A subset of the geophysical logs that penetrate the Madison Formation within the WRB were used by Tetra Tech to evaluate the use of the stratigraphic boundaries mapped by Encana for their model and potential use in our model. These logs and the evaluation of the subsequent stratigraphy are discussed below.

Tetra Tech completed our own interpretation of a select group of these oil and gas well logs. The verification of the data was completed by interpreting for comparison purposes, 7 of the 49 off-set geophysical logs and picking formation tops of the Madison, Amsden, Phosphoria, and Tensleep Formations in these logs, if present. Copies of these geophysical logs were obtained by Tetra Tech from WOGCC. The Marlin 29-21 WDW mud log and geophysical logs were also obtained and reviewed for comparison to the lithologic and geophysical log data in the off-set logs. The seven wells were all within the WRB and were the closest available to the Marlin 29-21 WDW from the WOGCC and at a similar surface elevation as the Marlin 29-21 WDW. The seven wells are as follows:

- MUSKRAT UNIT, #1, 49013203860000
- NEVA-FEDERAL. #44-19, 49013209640000
- SPRING CREEK-FED #1, 49013205640000
- HUNNICUTT-FEDERAL, #1,49013202380000
- HELLS HALF ACRE, #1-K11, 49025208370000
- JAMESON-CITIES, #14-22, 49025212500000
- CROWHEART BUTTE SW, #1-29-3D, 49013213430000

The selected stratigraphic boundaries (formation tops) were compared to the same intervals identified in the Marlin 29-21 WDW by Encana and to stratigraphic zones identified from logs obtained from the WOGCC, for the key formation tops of the Madison, Amsden, and Tensleep Formations. The relative differences from Tetra Tech's pick to Encana's lithologic sections in the off-set logs ranged from one foot to 97 ft., with most being less than 50 ft. The difference in depth may be due to one of several reasons including the subjective nature of interpreting logs or assumptions regarding the starting depths, tool length, and/or specific marker beds used by Encana and unknown to Tetra Tech. Based on this evaluation it is Tetra Tech's opinion that the formation tops selected by Encana in these 49 off-set locations are reasonable and representative of the key formation tops within the WRB. The Madison, Amsden, and Tensleep formation tops identified in the Marlin 29-21 WDW by Encana and verified as described above by Tetra Tech were used in the injection model.

Additionally, the structure (e.g., formation top, fault locations) presented in the published maps and cross-sections support the WRB conceptual structural model of the Madison Formation prepared by Encana for use in their injection model. However, review of Encana's structure map shows the presence of additional faults not identified in the USGS and WSGS structure maps (Keefer, 1970; Taucher et al., 2012). It is our understanding that this additional detail comes from seismic data and basin knowledge unavailable to Tetra Tech. Therefore, we are unable to verify the additional detail in Encana's structure map, but, given the effort expended by Encana in obtaining and interpreting this information, we believe this map to be reliable for the purposes of the present evaluation.

3.1.2 Hydrogeological Characteristics

Hydraulic and well properties related to the Marlin 29-21 WDW and hydraulic properties related other injection wells in the region, where available and relevant, were obtained and reviewed. Encana completed pressure testing and SRTs of the Madison Formation interval for hydraulic characteristics needed to determine the range of potential injection volumes and rates in the Marlin 29-21 WDW. The test data were provided and reviewed for applicability under Task 3 and are discussed in Section 4 and Section 5. The regional published hydrogeological data and specific data from the Marlin 29-21 WDW tests were utilized to support the preparation a hydrogeologic conceptual model of the groundwater flow system described in Task 2 and reviewed under Task 3 for use in the completion of the injection model for the Marlin 29-21 WDW.

A potentiometric surface map of the Madison Formation was received from Encana and reviewed for this effort. This potentiometric map was not verifiable, as no supporting data were available for the origin of this map, and therefore the map was not used in our conceptual model. A database of DST results for the WRB Basin was reviewed as a potential source for pressure data for the Madison Formation. There were not sufficient data to create a potentiometric surface with these data alone. The DST results could not be qualified by Tetra Tech without more specific information regarding the details of the pressure build-up curves. However, potentiometric surface elevation maps were developed by Tetra Tech under Task 2 for the Madison and Tensleep aquifers using DST shut-in pressures from select locations that had been qualified from Rahkit (2006), along with available groundwater well and spring elevations. The use of these data and their qualification for use and application are described and discussed in further detail in Section 4.2 of this report.

Geophysical logs from the Marlin 29-21 WDW and five of the seven oil and gas wells were also utilized to evaluate porosity ranges for the Madison Formation using the available neutron porosity logs for these wells. The neutron logs were digitized for the Madison Formation, and the average porosity was determined by integrating the log response over the depth of the Madison and dividing by the depth range. The porosity information for the Marlin 29-21 WDW was provided by Aethon, using an interpretation of the re-processed Schlumberger RST log, corrected for matrix of each formation. Except for the re-processed Marlin29-21 WDW log, this dataset included negative porosity values; an offset of 2% was added to all data points to correct for this artifact of the data processing. The porosity values from the neutron porosity log of the Marlin 29-21 WDW for the Madison Formation ranged from 0% to 17% and averaged 5.0%. Westphal et al. (2004) discussed four different lithologic sequences in the Madison. Based on lithologic picks provided by Aethon, the average porosities for these sequences, from shallowest to deepest (Sequence IV to Sequence I), are 7.6%, 10.0%, 5.4%, 9.0% using a 5.0% porosity cutoff (Table 3-2).

Table 3-1 Data Review and Evaluation Summary

Data Type	Source	Data Reviewed	Data Verified by Tetra Tech (Y/N)	Data Used in Modeling (Y/N)
LITHOLOGY & STRUCTURE				
Structure Map	Encana Map	Fault Locations - Encana Map vs USGS/WSGS Maps	N	N
Tops of Key Formations	Encana, WOGCC	Geophysical Logs & Top of formation picks from 7 of 49 Madison penetrating Off-set wells	Y	Y
HYDROGEOLOGICAL				
Geophysical Porosity Logs	Encana, WOGCC	Marlin 29-21 WDW and 5 oil and gas well neutron porosity logs for porosity	Y	Y
Drill Stem Tests	Encana, Rahkit	Summary file of WRB basin DSTs. DST shut in pressures from Rahkit report for potentiometric surface map of Madison and Tensleep Formations	N	Y
Water Levels	Rahkit, USGS, WOGCC, WRDD	Available groundwater level data for Madison and Tensleep Formations primarily from wells in the basin perimeter and springs	N	Y
Marlin Pressure Tests	Encana	Marlin 29-21 WDW for hydraulic properties – porosity, permeability, water levels	Y	Y
Model Input Files	Encana	Various files and input parameters for model (structure, groundwater flow, hydraulic parameters)	N	N
Well Design/Construction	Encana	Marlin 29-21 WDW construction design	Y	Y
GEOCHEMISTRY				
Marlin Well	Tetra Tech	Chemical and isotopic composition of water samples	Y	Y
Analogous Well Data	Busby et al., 1991	Chemical and isotopic composition of water samples	Y	N
Produced Water	WOGCC	Chemical composition of water samples, well completion	Y	N
Southwest Recharge Area Groundwater	USGS	Chemical composition of water samples, well completion	Y	N
Southern Recharge Area Groundwater	WRDS, PRI, 1998; Umetco, 2001	Chemical composition of water samples, well completion, local hydrogeology, mining activities	N	N
Southern Recharge Area Groundwater	WDEQ-AML	Chemical composition of water samples, well completion	Y	Y

Neutron porosity logs for nearby wells were also evaluated in a similar manner. These wells are located to the southwest, south, and east-southeast of the Marlin 29-21 WDW and are not believed to penetrate the full thickness of the Madison Formation. In the Muskrat #1 well, the porosities for the Madison ranged from 0 to 18% and averaged 5.4%. The range in the Hunnicutt well was larger (0 to 23%), and the average porosity was 7.9%. The porosities in the Jameson-Cities well were higher, ranging from 0 to 29% and averaging 11.9%. Using a larger dataset, Westphal et.al. (2004) reported that in the WRB, the average porosities for the deeper sequences (I, II, and III) were in the range of 7.3 to 12.1%, but distinctly lower in Sequence IV (2.1%). In general, the average porosity values in these geophysical logs evaluated by Tetra Tech typically ranged from approximately 5% to 12%. These values may be biased low because they include the full thickness of Sequence IV, but the logs may not fully penetrate the more permeable, deeper sequences.

Encana provided a core test report for laboratory porosity and permeability measurements for the Madison Formation from the Bighorn #2-3 oil and gas well located approximately 20 miles north of the Marlin 29-21 WDW in the Madden field. These data are presented and discussed in Section 4.1. The Madison section in the Madden field is thinner than at the Marlin 29-21 WDW, but the data for both porosity and permeability (vertical and horizontal) are within the range of values found in the literature. Further evaluation of these porosity and permeability data is provided in Section 4.1.2.1.

Table 3-2 Aquifer Lithologic Depths, Thicknesses and Porosity Values

Formation	Top (MD ft.)	Top (TVD ft.)	Top (SSTVD ft.)	Base (MD ft.)	Base (TVD ft.)	Base (SSTVD ft.)	Gross H (MD ft.)	Gross H (TVD ft.)	NPHI Matrix Setting
Tensleep	14434	14403	-8509	14795	14760	-8866	361	357	Sandstone
Amsden	14795	14760	-8866	14974	14937	-9043	179	177	Sandstone
Darwin	14974	14937	-9043	15003	14965	-9071	29	28	Sandstone
Madison Seq 4	15003	14965	-9071	15145	15106	-9212	142	141	Limestone
Madison Seq 3	15145	15106	-9212	15216	15176	-9282	71	70	Dolomite
Madison Seq 2	15216	15176	-9282	15306	15265	-9371	90	89	Dolomite
Madison Seq 1	15306	15265	-9371	15365	15324	-9430	59	59	Dolomite

Formation	5% phi cutoff			4% phi cutoff			3% phi cutoff			2% phi cutoff		
	Net H (ft.)	Avg phi	PhiH	Net H (ft.)	Avg phi	PhiH	Net H (ft.)	Avg phi	PhiH	Net H (ft.)	Avg phi	PhiH
Tensleep	35.539	0.076	2.701	61.209	0.063	3.856	117.474	0.050	5.874	154.98	0.044	6.819
Amsden	36.488	0.082	2.992	39.952	0.079	3.156	43.911	0.075	3.293	51.831	0.068	3.525
Darwin	19.592	0.078	1.528	23.555	0.073	1.720	25.041	0.071	1.778	25.041	0.071	1.778
Madison Seq 4	21.029	0.076	1.598	25.488	0.071	1.810	27.469	0.069	1.895	32.424	0.062	2.010
Madison Seq 3	21.307	0.100	2.131	26.262	0.089	2.337	32.705	0.079	2.584	38.156	0.071	2.709
Madison Seq 2	2.479	0.054	0.134	12.152	0.046	0.559	16.613	0.043	0.714	41.895	0.031	1.299
Madison Seq 1	15.365	0.090	1.383	22.050	0.077	1.698	49.807	0.053	2.640	49.807	0.053	2.640

Notes:
MD = Measured Depth
TVD = True Vertical Depth
SSTVD = Subsea True Vertical Depth
NPHI = Neutron Porosity
H = Thickness
Phi = Porosity
ft. = Feet

3.2 Geochemical Baseline Information and Data Evaluation

Literature research was conducted to obtain available chemical data from the Madison Formation groundwater in the southern WRB. Constituents included in the search criteria were general inorganic water chemistry, stable isotopic composition, organic compounds, and radioactive isotopes for groundwater age dating. Tetra Tech searched databases from all identified sources including the USGS, WOGCC, University of Wyoming WRDS, as well published reports in the open literature.

Results of the search yielded relevant analytical data for the southern WRB from three principal sources: 1) the Madison Formation recharge areas on the southwestern margin, 2) producing wells completed in the Madison Formation in the Madden and Beaver Creek Fields, and 3) shallow groundwater from the Wind River Formation in the Gas Hills area that recharges the subcropping Madison Formation on the southern margin.

<u>Southwest Recharge Area</u>. On the southwestern margin of the WRB near Lander, WY, eleven wells and three springs were identified from the USGS National Water Information System database with applicable general and inorganic water chemistry data. No information on the type or use, completion, or ownership of the wells was available in the USGS database. Data from only four wells were used for evaluation of the site conceptual model, data from one well included only pH, specific conductance, and temperature, and no well depth information was available for another well; data from these two wells were not considered applicable for use. It is assumed the data were collected by the USGS using professionally-recognized techniques, data were reviewed for cation-anion balance, and test results are considered valid regarding this criterion. These chemical data are not associated with any description of sampling activities, preservation protocol, or analytical methods. Because the samples were collected by the USGS it is assumed the professional sampling procedures promulgated by the UGGS were employed. Only the general inorganic chemical data are used from these wells in this report for defining water type and establishing potential evolution of general water composition from recharge area into the WRB. The analyses are similar among wells in same proximity and of the same depths, and the change in composition with depth and flow path is altered according to a plausible evolutionary pathway. Consequently, the uncertainty in the quality from lack of sampling detail is not sufficient to prevent the use of these data for purposes of evaluating conceptual models.

<u>Marlin 29-21 WDW.</u> Data collected from the Marlin 29-21 WDW by Tetra Tech were used for evaluation of the site conceptual model summarized in Section 4 and additional geochemical evaluation regarding radiocarbon age corrections summarized in Section 6. These samples were collected using approved sampling and analytical methods according to the Sampling and Analysis Procedure (2013). Analyses performed include general and inorganic water chemistry, stable isotopic composition, organic compounds, and radioactive isotopes for groundwater age dating. The chemical and isotopic composition of water samples collected from the Marlin 29-21 WDW were discussed in another report prepared by Tetra Tech (2015).

<u>Analogous Data</u>. Published geochemical data (Busby, et al., 1991) of Madison Formation groundwater were used for analogy to WRB groundwater chemistry in the site conceptual model and additional chemical evaluations. Procedures of sample collection and analysis are noted in the documents and are the professionally accepted methods used by the USGS (Busby et al., 1991; Plummer et al., 1990).

<u>Producing Field Data</u>. Chemical analyses for the Madison Formation reservoir were obtained for nine oil producing wells located in the Beaver Creek oil field. These data were obtained from the

WOGCC website and included general inorganic water chemistry. Data are similar among wells, and data from seven wells were used in the evaluation of the site conceptual model, in one well the target formation was the Phosphoria Formation, and for another well the completion information was not available on the WOGCC website, data from these two wells were not considered applicable for use. No information is available on methods of sample collection or analysis. Data were checked for cation-anion balance, and test results balance within 10%, which is the acceptance criterion for that test for groundwater. Similarly, chemical data for Madison Formation reservoir water were obtained for two oil producing wells (Bighorn 1-5 and Bighorn 2-3) located in the Madden oil field. These data were obtained from the WOGCC website and included general inorganic water chemistry. Three analyses are provided, and the TDS values are unusually low (1,010, 410, and 370 mg/L). No information is available on how the water samples were collected, whether at depth or land surface, where samples were analyzed or the performing laboratory, or whether well treatments with introduced fluid had preceded the sample collection. The cation-anion balance was greater than 10%, and therefore test result validity is not confirmed for charge balance of the chemical analyses for the Madden Field wells. These data are not used for modeling, and these results are discussed in Section 6 only in terms of their potential contribution to the understanding of deep basin flow. Additional producing field data were obtained from the USGS National Produced Waters Geochemical Database. This included data from produced water, drill-stem testing, swabbing, and unverifiable water types, as well as from producing wells within the Wind River hydrologic basin but outside the WRB structural basin. Chemical data from waters from drill-stem testing, swabbing, or unverifiable water types were reviewed but not included as part of the chemical and isotopic analyses for the Madison Aquifer.

Southern Recharge Area. Groundwater wells completed in the Madison Formation on the southern margin of the southern WRB were not located. Searches of the WRDS, as well as published reports in the open literature were reviewed to determine the availability of Madison Formation groundwater chemical data in potential recharge areas in the Gas Hills and Rattlesnake Hills south and southeast of the Marlin 29-21 WDW. No chemical data of the Madison Formation from this area are available. In this region the shallow groundwater is generally obtained from the wells in the Wind River Formation, which overlies the Madison by less than 200 ft. in areas on the slopes of the Gas Hills and the Rattlesnake Hills but is progressively deeper but not well defined toward the west. Chemical data from saturated zones overlying the subcropping Madison Formation in the Gas Hills area are assumed to represent the water composition recharging the underlying Madison Formation. This region has no identified domestic or stock watering wells completed in the Madison Formation, but wells associated with the uranium mining industry and completed in shallower sediments are numerous. Unfortunately, most of these wells are associated with the extraction process or are monitoring wells located in disturbed areas that negate their use as background wells sufficiently representative of pre-mining recharge water composition. Data from published reports (Power Resources Inc, 1998; Umetco, 2001) associated with in-situ uranium mining and subsequent state-supervised remedial cleanup and monitoring were reviewed to determine the availability and applicability of wells deemed background wells in those reports. The search focused on chemical data from wells deemed as background, located outside of and upgradient to the mining zones that could be assumed to be a representative of recharge into the underlying Madison Formation and assumed to be a composition more representative of historical recharge and not affected by anthropogenic activities. Several wells were identified as background wells; the most southerly background well outside the disturbed zone from mining activity being the LA -7 monitoring well. Analytical results from the September 2014 sampling of LA-7 were obtained for use in the additional chemical evaluation summarized in Section 6.0. The LA-7 sample was collected as a part of the State of Wyoming Gas Hills Abandoned Mine Land remediation and monitoring project and is assumed to have been collected using professionally-recognized techniques. Data were reviewed for cation-anion balance, and test results are considered valid; field collection notes indicate standard practices were employed. Additional analysis for $\delta^{13}C$ of dissolved inorganic carbon (DIC) was obtained by Tetra Tech for the LA-7 sample, results are provided in Section 6.0.

4.0 HYDROGEOLOGIC CONCEPTUAL MODEL

Tetra Tech developed a hydrogeologic conceptual model for the area near the Marlin 29-21 WDW and extending outward to areas hydrogeologically significant to the operation of the well. The hydrogeologic conceptual model describes groundwater flow in the Madison, Amsden and Tensleep Formations in the context of geologic and hydrogeologic conditions identified during this study and in consideration of the operation of the Marlin 29-21 WDW. The hydrogeologic conceptual model is based on the data obtained and reviewed in Task 1 (Section 3.0) and serves as the foundation for the numerical model described in Task 3 (Section 5.0).

4.1 Review and Synthesis of Hydrogeologic Data

Tetra Tech reviewed lithologic, stratigraphic and structural geologic data regarding the WRB and, in particular, the Madison, Amsden and Tensleep Formations, to produce a synthesis of the geologic framework on which the hydrogeologic conceptual model is based. Subsequently, hydrogeologic data were integrated with the geologic data to add the detail necessary to complete the hydrogeologic conceptual model. The hydrogeologic data included information regarding aquifer permeability and porosity, hydrostatic head, groundwater recharge, and groundwater chemistry.

4.1.1 Geologic Framework

The Marlin 29-21 WDW is located in the east-central part of the southern flank of the WRB in central Wyoming (Figure 4-1). The trapezoidal-shaped basin is bounded by compressional uplifts including the Owl Creek Mountains on the north, the Casper Arch on the east, the Granite Mountains on the south, and the Wind River Mountains on the west. The Owl Creek thrust fault extends along the northern and northeastern sides of the basin, the Granite Mountain normal fault extends along the southern side, and the monoclonal flank of the Wind River Mountains extends along the western side. At least 42,000 ft. of structural relief exists between the Precambrian basement rock outcrops in the mountainous areas bordering the basin, at elevations up to 13,800 ft. above mean sea level (msl), and beneath Boysen Reservoir in the deepest part of the basin, more than 28,000 ft. below msl.

The WRB is markedly asymmetric, with the structurally deepest areas close to the northern and eastern margins of the basin. The major axis of the basin trends west-northwest, roughly parallel to and approximately 5 to 10 miles south of the Owl Creek thrust fault at the northern edge of the basin, and the minor axis trends northwest, close to and parallel to the thrust-faulted eastern margin of the basin (Blackstone, 1993).

The Precambrian basement rocks within the basin are overlain by up to 33,000 ft. of sedimentary rocks ranging in age from Cambrian to Miocene. The lowermost sedimentary sequence filling the basin includes approximately 750 to 4,300 ft. of Paleozoic rocks, primarily marine shelf sediments of limestone, dolomite, sandstone, siltstone and shale deposited in shallow seas. The thickness of the Paleozoic sequence increases from the southeast to the northwest. Wide-spread unconformities and changes in depositional patterns are present because of sea-level fluctuations or minor uplift or subsidence, and large areas were periodically exposed above sea level and subjected to erosion. The overlying Mesozoic rocks include approximately 7,000 to 20,000 ft. of primarily sandstone, siltstone, shale and coal deposited in both marine and continental environments. Late-Cretaceous marine shales comprise the greatest part of the Mesozoic sequence. Cenozoic sedimentary rocks range in thickness from zero to about 20,000 ft. and consist mainly of continental sandstone, siltstone, shale and claystone, with significant volcanic-derived sediments ranging from claystone to conglomerate. The late-Cretaceous and early-

Eocene sedimentary units were deposited during the period of most active subsidence within the basin and thicken dramatically in the north-central and northeastern parts of the basin.

The sedimentary rocks exposed at the surface throughout most of WRB are continental sediments of the Wind River Formation. The older sedimentary rocks are exposed at the margins of the basin, principally along the western and northern sides and, to a lesser extent, along the southern side of the basin. Along much of the southern side of the basin, the Paleozoic and Mesozoic rocks are covered by a mantle of late Eocene and younger sediments. Figure 4-2 illustrates the structural and stratigraphic relationships.

The WRB is highly asymmetrical and exhibits a conspicuous northwest structural grain (Keefer, 1970; Drean, 2012). The sedimentary rocks within the basin dip generally toward the basin axis. Moderate dips of 10 to 15 degrees are common in the Paleozoic and lower Mesozoic sequences along the western and southwestern margins, and steeper dips of 25 to 35 degrees are common along the eastern part of the south margin. In contrast, steeply-dipping to overturned beds are frequently present along the northern and eastern margins of the basin and along the numerous faults and folds that extend into the basin from the north and south margins.

Thompson and Erslev (2009) and Thompson (2010) describe the results of detailed study of fault and fracture orientations throughout the WRB. Thompson (2010) summarized data collected on more than 1,000 faults, 600 systematic joints, and 9,100 subsurface fractures. Northwest-trending normal faults and systematic joints are found on the eastern and western margins of the basin and in a swath through the middle of the basin. East-west trending normal faults and systematic joints are more common along the northern and southern margins of the basin. Both studies indicate that the fault and joint orientation tends to parallel the basin margins within about 12 miles of the basin margins (Figure 4-3). Farther into the basin, the predominant trend of faults and fractures is northwest-southeast.

Basement-cored faults, most commonly thrust faults, developed in response to compression during the Laramide orogeny of the latest Cretaceous to early Eocene. Dissipation of the compressive stress after the Laramide orogeny allowed back-sliding along the basin-bounding thrust faults, resulting in listric normal fault movement (Thompson, 2010). Normal and strike-slip faults, including many which trend east-west or northeast-southwest, and shallow-seated grabens are related to later extension during and after the middle Pliocene. The basement-cored compressional faults exhibit vertical offsets up to about 7,000 ft., and offsets in the range of 2,000 to 4,000 ft. are common. The majority of these compressional faults terminate upward in the Cretaceous shale sequence and are not exposed at the land surface. Conversely, the shallow extensional grabens originate high within the sedimentary sequence and terminate downward in the Cretaceous sedimentary sequence. Neither set of faults appears to transect the Cretaceous sedimentary sequence (Thompson and Erslev, 2009). Fault-related anticlinal folds within the basin frequently host oil and gas resources.

4.1.2 Hydrogeologic Setting

The Wind/Bighorn River Basin Water Plan Update Groundwater Study Available Groundwater Determination Technical Memorandum (Taucher et al., 2012) subdivides the lithostratigraphic units of the WRB into hydrogeologic units categorized into aquifers, aquifer systems, and confining units (Table 4-1). An aquifer is defined as “a geologic unit, group of geologic units, or part of a geologic unit that contains sufficient water-saturated and permeable material to yield sufficient quantities of water to wells and springs, with ‘sufficient’ generally defined in terms of use.” An aquifer system is defined as “a heterogeneous body of saturated, interbedded geologic units with variable permeabilities that functions regionally as a major integrated water-bearing hydrogeologic unit; it comprises two or more smaller aquifers separated, at least locally, by strata with low permeability that impede groundwater movement between the component aquifers but do not preclude the regional hydraulic continuity of the system." Aquifer systems generally:

- are regionally extensive
- have common recharge and discharge areas and mechanisms
- have similar hydraulic properties
- have similar water-quality characteristics
- are sealed from younger and older aquifers/aquifer systems by thick and laterally extensive confining units

A confining unit is defined as "a hydrogeologic unit composed of a geologic unit, group of units, or part of a unit with very low hydraulic conductivity that impedes or precludes the movement of groundwater between aquifers that it separates or between an aquifer and the land surface" (Taucher et al., 2012). Confining units are conventionally considered to be impermeable to groundwater flow, but most leak water at low to very low flow rates. Over large areas and extended periods of time, however, confining units can leak large quantities of water.

The hydrogeologic units of primary concern to this report include the Madison, Amsden, and Tensleep aquifers, which comprise the Paleozoic aquifer system in the eastern WRB. The Darby and Bighorn aquifers elsewhere are included in the Paleozoic aquifer system, but they are absent from the eastern part of the basin. Also important to this report are the underlying Gallatin-Gros Ventre confining unit and the overlying Goose Egg-Phosphoria aquifer and confining unit.

4.1.2.1 Madison Aquifer

The Mississippian-age Madison Limestone forms the Madison aquifer, a major aquifer throughout the WRB (Figure 4-4). The Madison Limestone was deposited along a wide, shallow-water marine shelf that extended from New Mexico into western Canada. It consists predominantly of limestone and dolomite but contains shaly strata near the base of the formation and quartzose sediments sporadically throughout. In the WRB, it ranges in thickness from less than 300 ft. in the southwest to more than 700 ft. in the northwest (Figure 4-5). Logs of the Marlin 29-21 WDW show a thickness of 385 ft. in the southeast-central part of the basin. The Madison is separated from the underlying Cambrian-age Gallatin Limestone in the eastern part of the basin or the Ordovician-age Bighorn Dolomite in the western part of the basin by an unconformity representing the Ordovician (in the east only), Silurian, and Devonian ages, a period of 75 to 140 million years. The Madison is bounded at the top by a regional karstified unconformity representing about 20 million years of exposure and erosion (Sando, 1967).

The Madison Formation in the eastern WRB is composed of four depositional sequences (I through IV, from lowest to highest) that can be correlated over many miles. The I, II and III sequences are highly dolomitized (Westphal et al., 2004) and exhibit the high intercrystalline porosity and permeability typical of the more dolomitized sections of the Madison (Peterson, 1984).

Table 4-1 Lithostratigraphic and Hydrogeologic Units of the Wind River Basin

ERA	System and Series		Lithostratigraphic Units of Love et al. (1993)	Thickness (ft.)	Hydrogeologic Units		
CENOZOIC	Quaternary	Holocene and Pleistocene	Alluvium, terrace deposits, landslide deposits, dune sand (eolian) deposits, and glacial deposits	0 – 10+	Quaternary unconsolidated-deposit aquifers		
CENOZOIC		Miocene	Split Rock Formation	0 – 3,000	Split Rock aquifer		
CENOZOIC		Oligocene	Split Rock Formation	0 – 3,000	Split Rock aquifer		
CENOZOIC		Oligocene	White River Formation	0 – 800	White River aquifer		
CENOZOIC		Eocene	Tepee Trail Fm; Aycross Fm / Wagon Bed Fm	0 – 2,500 / 0 – 700	Aycross–Wagon Bed confining unit		
CENOZOIC		Eocene	Wind River Formation	0 – 9,000	Wind River aquifer		
CENOZOIC		Eocene	Indian Meadows Fm	0 – 9,000	Indian Meadows confining unit		
CENOZOIC		Paleocene	Fort Union Fm: Shotgun Mbr / Waltman Shale Mbr; Lower unnamed Member	0 – 8,000	Fort Union aquifer	Fort Union – Lance aquifer	
MESOZOIC	Cretaceous	Upper Cretaceous	Lance Formation	0 – 6,000	Lance aquifer	Fort Union – Lance aquifer	
MESOZOIC	Cretaceous	Upper Cretaceous	Meeteetse Fm / Lewis Shale	0 – 1,335 / 0 - 550	Meeteetse–Lewis confining unit		
MESOZOIC	Cretaceous	Upper Cretaceous	Mesaverde Formation: Teapot Sandstone Member	700 – 2,000	Teapot Sandstone aquifer		Mesaverde aquifer
MESOZOIC	Cretaceous	Upper Cretaceous	Mesaverde Formation: Middle unnamed member	700 – 2,000	Middle confining unit		Mesaverde aquifer
MESOZOIC	Cretaceous	Upper Cretaceous	Mesaverde Formation: Parkman Ss Mbr	700 – 2,000	Parkman Ss aquifer		Mesaverde aquifer
MESOZOIC	Cretaceous	Upper Cretaceous	Mesaverde Formation: Wallace Creek Tongue of Cody Shale	700 – 2,000	Confining unit		Mesaverde aquifer
MESOZOIC	Cretaceous	Upper Cretaceous	Mesaverde Formation: Fales Ss Member	700 – 2,000	Fales Ss aquifer		Mesaverde aquifer
MESOZOIC	Cretaceous	Upper Cretaceous	Cody Shale	3,000 – 5,000	Cody confining unit		
MESOZOIC	Cretaceous	Upper Cretaceous	Frontier Formation	600 – 1000	Frontier aquifer Basal regional confining unit		Lower and middle Mesozoic aquifers and confining units
MESOZOIC	Cretaceous	Upper Cretaceous	Mowry Shale	250 – 700	Mowry confining unit	Mowry–Thermopolis confining unit	Lower and middle Mesozoic aquifers and confining units
MESOZOIC	Cretaceous	Lower Cretaceous	Muddy Sandstone	125 – 250	Muddy Ss aquifer	Mowry–Thermopolis confining unit	Lower and middle Mesozoic aquifers and confining units
MESOZOIC	Cretaceous	Lower Cretaceous	Thermopolis Shale	125 – 250	Thermopolis confining unit	Mowry–Thermopolis confining unit	Lower and middle Mesozoic aquifers and confining units
MESOZOIC	Cretaceous	Lower Cretaceous	"Dakota Sandstone" Cloverly Formation "Fuson Shale" "Lakota Sandstone"	200 - 700	Cloverly aquifer		Lower and middle Mesozoic aquifers and confining units
MESOZOIC	Jurassic	Upper Jurassic	Morrison Formation	200 - 700	Morrison confining unit		Lower and middle Mesozoic aquifers and confining units
MESOZOIC	Jurassic	Upper Jurassic / Middle Jurassic	Sundance Formation	200 – 550	Sundance aquifer	Sundance–Nugget aquifer	Lower and middle Mesozoic aquifers and confining units
MESOZOIC	Jurassic	Middle Jurassic	Gypsum Spring Formation	0 – 250	Gypsum Spring confining unit	Sundance–Nugget aquifer	Lower and middle Mesozoic aquifers and confining units

ERA	System and Series		Lithostratigraphic Units of Love et al. (1993)			Thickness (ft.)		Hydrogeologic Units		
	Jurassic(?) and Triassic(?)			Nugget Sandstone		0 – 500		Nugget aquifer		
	Triassic	Upper Triassic	Chugwater Group or Fm	Popo Agie Formation or Member		1,000 – 1,300		Popo Agie confining unit	Chugwater aquifer and confining unit	
	Triassic	Upper Triassic	Chugwater Group or Fm	Crow Mountain Ss or Sandstone Member		1,000 – 1,300		Crow Mountain aquifer	Chugwater aquifer and confining unit	
	Triassic	Lower Triassic	Chugwater Group or Fm	Alcova Limestone or Limestone Member		1,000 – 1,300		Alcova confining unit	Chugwater aquifer and confining unit	
	Triassic	Lower Triassic	Chugwater Group or Fm	Red Peak Formation or Member		1,000 – 1,300		Red Peak aquifer	Chugwater aquifer and confining unit	
	Triassic	Lower Triassic		Dinwoody Formation	Goose Egg Formation	50 – 200	350 - 380	Dinwoody confining unit	Goose Egg aquifer and confining unit	Goose Egg – Phosphoria aquifer and confining unit
PALEOZOIC	Permian			Phosphoria Formation and Park City Formation	Goose Egg Formation	200 – 400	350 - 380	Phosphoria aquifer and confining unit	Goose Egg aquifer and confining unit	Goose Egg – Phosphoria aquifer and confining unit
PALEOZOIC	Pennsylvanian	Upper Pennsylvanian		Tensleep Sandstone		200 – 600		Tensleep aquifer		Paleozoic aquifer system
PALEOZOIC	Pennsylvanian	Middle Pennsylvanian		Tensleep Sandstone		200 – 600		Tensleep aquifer		Paleozoic aquifer system
PALEOZOIC	Pennsylvanian	Lower Pennsylvanian		Amsden Formation, including Darwin Sandstone Member		0 – 400		Amsden aquifer		Paleozoic aquifer system
PALEOZOIC	Mississippian	Upper Mississippian		Amsden Formation, including Darwin Sandstone Member		0 – 400		Amsden aquifer		Paleozoic aquifer system
PALEOZOIC	Mississippian	Upper Mississippian		Madison Limestone		300 – 700		Madison aquifer		Paleozoic aquifer system
PALEOZOIC	Mississippian	Lower Mississippian		Madison Limestone		300 – 700		Madison aquifer		Paleozoic aquifer system
PALEOZOIC	Devo-nian	Upper Devonian		Darby Formation		0 – 300		Darby aquifer		Paleozoic aquifer system
PALEOZOIC	Silurian			(not present in WRB)		0 – 300		Darby aquifer		Paleozoic aquifer system
PALEOZOIC	Ordovician	Upper Ordovician		Bighorn Dolomite		0 – 300		Bighorn aquifer		Paleozoic aquifer system
PALEOZOIC	Ordovician	Middle Ordovician		Bighorn Dolomite		0 – 300		Bighorn aquifer		Paleozoic aquifer system
PALEOZOIC	Cambrian	Upper Cambrian		Gallatin Limestone		0 – 365		Gallatin confining unit		Gallatin–Gros Ventre confining unit
PALEOZOIC	Cambrian	Middle Cambrian		Gros Ventre Formation		0 – 700		Gros Ventre confining unit		Gallatin–Gros Ventre confining unit
PALEOZOIC	Cambrian	Middle Cambrian		Flathead Sandstone		50 – 500		Flathead aquifer		
Precambrian				Precambrian rocks				Precambrian basal confining unit		

Most of sequence IV is limestone and, due to its lower porosity and permeability, may provide a seal for the underlying dolomitized rocks that comprise the productive part of the Madison Formation in the subsurface. Karst pipes can extend more than 300 ft. down into the formation, but the karst cavities are generally infilled with breccia characterized by massive and laminated mudstones, chert, and a silty matrix. Tectonic and hydrothermal breccias developed in the Madison along the Owl Creek thrust fault that bounds the north side of the basin. The open fractures of the breccias were healed by calcite precipitated from hydrothermal fluids, so fractures that would ordinarily increase the permeability of the formation do not do so, but rather act to compartmentalize the unit (Westphal et al., 2004).

Madison Formation porosities range from 0 to 35%. Westphal et al. (2004) report average porosities of 10.8% to 12.1% in sequences I and II (the deeper sequences), 7.3% to 7.9% in sequence III, and 2.1% in sequence IV (the shallowest sequence), with pore types that include interparticle, moldic, intercrystalline, and fracture porosity. Laboratory data for Madison cores from the #2-3 Bighorn well in the Madden field about 20 miles north of the Marlin 29-21 WDW show porosities ranging from 2.4% to 17.1%, with a median value of 6.0%. Average porosity values determined from neutron porosity logs from wells in the vicinity of the Marlin 29-21 WDW range from 5.4% to 11.9%. The log from the Marlin 29-21 WDW indicated an average porosity of 5.0%, with Sequence IV having the lowest porosity (2.7%) and the deeper sequences having average porosities ranging from 4.4% to 7.6%.

Laboratory measurements on core samples from the #2-3 Bighorn showed air-permeability values that ranged from 0.09 millidarcies (md) to 16 md horizontally and 0.03 md to 26 md vertically. The ratio of horizontal to vertical permeability ranged from 0.14 to 47 and had a median of 1.8. About two-thirds of the values were greater than 1 (horizontal permeability greater than vertical permeability). Testing of the Marlin 29-21 WDW indicated Madison horizontal permeabilities of approximately 3.5 md for water at the ambient down-hole temperature (Section 5.3).

The structural configuration of the top of the Madison Formation (Figure 4-6) was developed using data from several sources:

- Encana provided a file with lithologic contact data from 324 boreholes that penetrated to the top of the Madison Formation. Of those, 28 reached the bottom of the Madison Formation as well, providing data regarding the thickness of the Madison Formation. The Marlin 29-21 ST WDW borehole information was included in the lithologic contact data.
- Encana provided a contour map in shapefile format representing the best current understanding of the elevation of the top of the Madison Formation. The map included the locations of and offset along faults. The fault locations and offsets were also provided in shapefile format.
- A Madison Formation isopach map (Taucher et al., 2012) was available in shapefile format from the Wyoming State Water Plan Wind/Bighorn River Basin Water Plan website (Wyoming Water Development Office, 2010).

The faults with large offsets limit hydraulic communication across the faults and serve to compartmentalize the Madison aquifer. For example, the northeast-trending thrust fault east of the Marlin 29-21 WDW exhibits offsets ranging from about 7,000 ft. near the southwestern end to about 2,000 ft. on the northeastern end and the fault coring the Dutton Creek anticline south and southwest of the Marlin 29-21 WDW exhibits offsets of 1,000 to 2,000 ft. along most of its length. The structural configuration of the Madison Formation is representative of the configuration of the Amsden and Tensleep Formations, as well as the other units of Paleozoic age. Relatively small differences attributable to variations in the thicknesses of the various units are observed, but the overall pattern, as well as the scale of offset along the structures is essentially the same throughout the Paleozoic and lower Mesozoic sections.

Taucher et al. (2012) reported that the chemical composition of groundwater from the Madison aquifer on the basis of water samples from 9 water-supply wells, 5 springs, and 64 produced-water samples. The chemical composition as reported by Taucher et al. (2012) was highly variable, with TDS concentrations ranging from 181 to 920 mg/L, with a median of 216 mg/L, for samples from water-supply wells and ranging from 291 to 30,600 mg/L, with a median of 2,040 mg/L, for produced-water samples. They also reported that concentrations of some properties and constituents approached or exceeded EPA or State of Wyoming water-quality standards and could limit suitability for some uses. Arsenic, radium, manganese, iron, sulfate, and TDS in water-supply wells, and TDS, sulfate, chloride, iron, manganese and pH in produced-water samples exceeded water-quality standards for domestic use. Radium and sulfate occasionally exceeded State of Wyoming standards for agricultural and livestock use, and produced-water samples generally had concentrations of arsenic, sulfate, TDS, and chloride, and occasionally pH, that exceeded standards for agricultural and livestock use. The water chemistry from the more limited data set that was qualified for this study was similar to that reported by Taucher.

4.1.2.2 Amsden Aquifer

The Amsden Formation of late-Mississippian to early-Pennsylvanian age unconformably overlies the Madison Formation. The Amsden in the WRB is classified (Taucher et al., 2012) as a minor aquifer with marginal potential for development. It consists of two distinct stratigraphic sequences up to 400 ft. thick. The upper sequence is made up of shale, dense dolomite, thin, cherty limestone, and thin, fine-grained sandstone. The lower sequence, the Darwin Sandstone, consists of fine- to medium-grained porous sandstone. The permeable parts of the Amsden Formation comprise the aquifer and are separated by consistent, low-permeability shaly sections.

Thicknesses of the Amsden Formation within the area of the numerical model discussed in Section 5 were determined from lithologic contact information provided in well logs. The thickness data were contoured using Surfer 8 (Golden Software, 2002), and elevation contours for the top of the Amsden were then developed by adding the thickness of the Amsden to the elevation of the top of the Madison Formation. Taucher et al. (2012) present an isopach map showing the combined thickness of the Amsden and Tensleep Formations, shown here as Figure 4-7. The structural configuration of the top of the Amsden is very similar to that of the Madison, with minor variation due to the variable thickness of the Amsden.

Taucher et al. (2012) reported the quality of one produced-water sample which had a TDS concentration of 6,100 mg/L; concentrations of TDS, sulfate and chloride exceeded the EPA secondary maximum contaminant level (EPA SMCLs) aesthetic standards for domestic use, as well as standards for agricultural use.

4.1.2.3 Tensleep Aquifer

The Tensleep Sandstone of middle- to late-Pennsylvanian age comprises the Tensleep Aquifer. It consists of 200 to 600 ft. of massive to cross-bedded, well-sorted, fine- to medium-grained sandstone cemented with carbonate and silica. It contains thin layers of chert, limestone, and dolomite. It is classified (Taucher et al., 2012) as a major aquifer and provides water supplies on the margins of the basin, where it is accessible at relatively shallow depths. The Tensleep is a major oil and gas producer throughout the WRB, and large volumes of water are withdrawn from the numerous oil fields in the basin.

Porosity and permeability in the Tensleep aquifer are considered to be primarily intergranular and dependent on the amount of secondary cementation and re-crystallization, both of which limit permeability and both of which increase with burial depth. Secondary porosity and permeability are common along folds and faults, and such structures are noted as more productive than other locations without enhanced secondary porosity and permeability. Permeabilities ranging from approximately 0.2 md to 250 md and porosities ranging from approximately 1% to 25% have been reported (Yin, 2005).

The thickness of the Tensleep structural configuration were determined from lithologic contact information provided in well logs, using a procedure similar to that described above. Thickness data were contoured using Surfer 8 (Golden Software, 2002), and elevation contours for the top of the Tensleep were then developed by adding the combined thickness of the Tensleep and Amsden to the elevation of the top of the Madison Formation. The thickness of the Tensleep Sandstone (combined with that of the Amsden Formation) is shown in Figure 4-7. The configuration of the top of the Amsden is very similar to that of the Madison, with minor variation due to the variable thickness of the Amsden.

The quality of groundwater from the Tensleep aquifer is reported by Taucher et al. (2012) on the basis of water samples from 14 water-supply wells, three springs, and 114 produced-water samples. TDS concentration in samples from water-supply wells and springs ranged from 146 to 1,060 mg/L, with a median of 208 mg/L. Most were suitable for domestic use, but radon, gross alpha, radium, sulfate, and TDS concentrations occasionally exceeded MCLs or health advisory levels for domestic use, and some samples exceeded agricultural- or livestock-use standards for gross alpha, radium, and/or sulfate. Produced-water samples exhibited TDS concentrations ranging from 167 to 25,600 mg/L, with a median of 2,930 mg/L. They generally had concentrations of iron, TDS, sulfate, chloride, and occasionally pH that exceeded standards for domestic use, agricultural use and, less frequently, livestock use.

4.1.3 Structural Contour Maps for Use in the Model

Information on the elevations of the formations is needed for the flow and transport modeling that is described in Section 5. As discussed in that section, the model includes the Tensleep, Amsden, and Madison Formations. Therefore, datasets were developed providing the elevations for 1) top of the Tensleep Formation, 2) top of the Amsden Formation, 3) top of the Madison Formation, and 4) bottom of the Madison Formation.

Several data sources were used to generate the lithologic surfaces used in model development:

- Encana provided a file with lithologic contact data from 324 boreholes that penetrated to the top of the Madison Formation. Of these wells, 28 reached the bottom of the Madison Formation as well, providing data regarding the thickness of the Madison Formation. The Marlin 29-21 ST WDW borehole information was included in the lithologic contact data.
- Encana provided a contour map in shapefile format representing the best current understanding of the elevation of the top of the Madison Formation. The map included the effects of faults, and the locations of the faults were also provided in shapefile format.
- A Madison Formation isopach map was available in shapefile format from the Wyoming State Geological Survey (Wind/Bighorn River Basin Water Plan Update, Groundwater Survey, Level 1 2008-2011, authored by P. Taucher, T. T. Bartos, K. E. Clarey, S. A. Quillinan, L. L. Hallberg, M. L. Clark, M. Thompson, N. Gribb, B. Worman, and T. Garcias, 2012).

The procedure was to first contour the top elevation of the Madison Formation, since this unit was by far the best characterized in the available data. The contours representing the top of the Madison Formation were generated using two main sources: 1) depth contacts from drill holes and 2) existing elevation contours that took into account the structure of the region. Depth contacts provided by Encana for the top of the Madison Formation were converted to elevation by subtracting from the kelly bushing elevation (if available) or the ground surface elevation (if no kelly bushing elevation was available). The shapefile provided by Encana for the top elevation of the Madison Formation was converted to points with x, y, and elevation data using GIS. Next, the elevation contacts from drill logs were combined with the elevation contacts from the shapefile and were contoured using the minimum curvature method in Surfer 8 (Golden Software, 2002). This method allows representation of fault traces so that the faults with significant offset in the model area could be included in contouring. Control points were added as needed to better represent the effects of faults. Finally, the contours were spot-checked for accuracy.

After the top elevation contours for the Madison Formation were finished, isopach maps were created to represent the thickness of the Tensleep, Amsden, and Madison Formations. Isopach maps were chosen because the thickness of the formations was much more consistent than their elevations due to the effects of faulting. For the Tensleep and Amsden Formations, the only available data were the contacts recorded from borelog analysis by Encana. Thickness of the Tensleep Formation was calculated by subtracting the top of the Amsden Formation from the top of the Tensleep Formation. Thickness of the Amsden Formation was calculated by subtracting the top of the Madison Formation from the top of the Amsden Formation. In some cases, the Amsden Formation was logged as the Darwin Formation (a member of the Amsden) by the field geologists, so if no Amsden Formation contact was present, the Darwin Formation was used. For the Madison Formation, an additional source of information was the Madison Formation isopach map from the Wyoming State Geological Survey (2012). The shapefile was converted into points with x, y, and elevation using GIS. These points were combined with the thicknesses calculated by subtracting the top of the Gallatin Formation from the top of the Madison Formation. All the isopachs were contoured in Surfer 8 (Golden Software, 2002) and spot-checked for accuracy.

The isopach maps of the Tensleep, Amsden, and Madison Formations were mathematically added to or subtracted from the Madison Formation top elevation surface using Surfer's Grid Math (Golden Software, 2002) function to generate the other surfaces. First, the Madison Formation isopach was subtracted from the Madison Formation top elevation. This generated the bottom of the Madison Formation. Next, the Amsden Formation isopach was added to the Madison Formation top elevation. This generated the top of the Amsden Formation. Finally, the Tensleep Formation isopach was added to the Amsden Formation top elevation surface to generate the top of the Tensleep Formation.

The results of this process are provided in Figures 4-8 (top of the Tensleep), 4-9 (top of the Amsden, 4-10 (top of the Madison), and 4-11 (bottom of the Madison). Also shown is the outline of the flow and transport model, which is described in Section 5. The elevations of these surfaces were subsequently extracted for the center of each model grid cell using Surfer 8, and incorporated into the modeling datasets.

4.2 Groundwater Flow

Groundwater flow in the Madison, Amsden and Tensleep aquifers within the WRB was interpreted based on a synthesis of lithologic, structural, hydrogeologic, and hydrogeochemical data for the basin. The primary data included the information presented in Section 4.1, shut-in pressures from drill stem test data, elevations of springs, water-level elevations in water wells, outcrop area elevations, geochemical data, and data presented in Taucher et al. (2012). Aspects of groundwater flow considered included recharge mechanisms, areas, and volumes; flow directions; chemical evolution along flow paths; and discharge mechanisms, areas and volumes. Potential flow pathways considered from hydraulic, hydrogeologic, and hydrogeochemical perspectives included those shown in Figure 3-1.

4.2.1 Hydraulic Constraints

Potentiometric surface elevation maps were developed for the Madison and Tensleep aquifers (Figures 4-12 and 4-13, respectively) using shut-in pressures recorded for DST, supplemented with water-level elevations from water wells and spring elevations. Drill stem test shut-in pressure data compiled and supplied by Encana were used to calculate potentiometric head elevations based on the elevation of the mid-point of the tested interval and a pressure gradient of 2.3095 ft. of water head for each pound per square inch (psi) of shut-in pressure. Qualification of more than 15,000 drill stem tests in the WRB was performed by Rakhit Petroleum Consulting Ltd. (Rakhit, 2006). They rated a substantial percentage of the tests as questionable or unusable due to mechanical problems or unfavorable test conditions. Because the Rakhit (2006) ratings were not available to Tetra Tech and qualification of the drill stem test data was beyond Tetra Tech's scope on this project, the shut-in pressure data were used as received by Tetra Tech, and only obviously anomalous data were culled. Considerable variation of shut-in pressure elevation heads was noted in areas where numerous wells had been tested over periods of several decades while oil and gas were being produced from the oil fields in which the tested wells were located. Lowered pressures result from water production ancillary to oil and gas production, and the effects can be significant.

The shut-in pressure elevation head data, combined with water well and spring data, were contoured using Surfer version 9 software (Golden Software, 2010). Allowance was made for contouring breaks where large-displacement faults are known to be present. Because of the sometimes large variations in shut-in pressure elevation head over small distances, contouring of the elevation-head data was performed using 1) all the data, 2) the median shut-in pressure for wells within 10,000 ft. of one another, and 3) the maximum shut-in pressure for wells within 10,000 ft. of one another. Lack of control points in the northern part of the basin hampered contouring in that area. A number of springs issue from the Madison and Tensleep aquifers in the northern part of the Wind River hydrologic basin, but the springs in all but the westernmost part of the basin are on the upthrown block north of the Owl Creek thrust fault and are separated stratigraphically and hydrologically from the Madison and Tensleep aquifers within the Wind River geologic basin by 20,000 to 30,000 ft. of vertical displacement along the fault. Because the fault severs hydrologic communication between the two fault blocks at the level of the Madison and Tensleep aquifers, the springs are not suitable for contouring with the data points south of the fault.

The potentiometric surface elevation maps for both the Madison and Tensleep aquifers indicate flow generally from recharge areas along the margins of the basin toward the central parts of the basin and the oil fields with significant water production. Recharge occurs primarily through infiltration of precipitation in outcrop areas and downward leakage from overlying saturated rocks where the eroded edges of the Madison and Tensleep aquifers subcrop beneath Tertiary-age rocks along the southern side of the basin. Of note to groundwater circulation in the vicinity of the Marlin 29-21 WDW are the recharge areas southeast and south of the well, which are outcrops along the flanks of the Rattlesnake Hills 14 miles southeast of the well and subcrops beneath the White River, Wagon Bed and Wind River Formations south-southeast, south, and southwest of the well. Small outcrops also appear along the subcrop trend where the overlying rocks have been removed by erosion. The Madison aquifer in the subcrop area dips generally northward at about

10 to 15 degrees, so the width of the Madison subcrop would be about 1,500 to 2,300 ft., similar to outcrop widths in the Rattlesnake Hills. The hydraulic gradient in the Madison aquifer between the Rattlesnake Hills outcrop area, where the potentiometric head is about 7,250 ft., and the Marlin 29-21 WDW, where the head is approximately 6,134 ft., is approximately 0.015. On the basis of hydraulic gradients indicated by the potentiometric data and large structural offset that disrupt hydraulic communication across faults, and in particular those trending northwest along the southern side of the WRB, potential groundwater flow pathways 1, 2, and 4 as shown on Figure 3-1 can be ruled out.

Recharge rates were estimated by Taucher et al. (2012) for the combined Paleozoic and Mesozoic aquifers in the WRB. Recharge rates were estimated by Tetra Tech for the Madison and Tensleep aquifers. The estimates were based on recharge areas and the range of recharge values reported by Taucher et al. (2012) for the combined Paleozoic and Mesozoic aquifers, the Madison aquifer outcrop area as a percentage of the combined Paleozoic-Mesozoic outcrop area, and the assumption that the average recharge for the combined outcrop area applies to the Madison aquifer outcrop. The method could underestimate recharge to the Madison aquifer, considering that recharge rates are typically greater at higher elevations and the Madison aquifer outcrop areas are biased toward elevations higher than the median elevations of the combined Paleozoic and Mesozoic outcrop area. However, the potential underestimation is thought to be small relative to the range in recharge volumes reported by Taucher et al. (2012). The estimated recharge volumes are summarized in Table 4-2.

Table 4-2 Groundwater Recharge Estimates

Aquifer	Outcrop Area (acres)	Area Underlain by Aquifer in Wind River Basin (acres)	Annual Recharge Volume (acre-ft. per year)		
			Minimum	Maximum	“Best Value”
Combined Paleozoic and Mesozoic	842,211	3,228,880	217,692	394,095	295,671
Madison	101,031	3,108,294	26,114	47,275	35,469
Tensleep plus Amsden	63,374	2,989,565	16,381	29,655	22,248

Discharge is interpreted to be to the adjacent aquifers or confining units and to producing oil and gas wells within the basin. As a check on the possibility that all recharge to the Madison aquifer could discharge to adjacent aquifers or confining units, Tetra Tech calculated the minimum average vertical hydraulic conductivity that would be necessary to allow the entire volume of average annual recharge to the Madison to discharge vertically from the Madison aquifer to adjacent confining units. The calculated minimum vertical hydraulic conductivities range from 4.4×10^{-9} to 8×10^{-9} centimeters per second (cm/s), which is not unreasonable for the types of lithologies in the units stratigraphically adjacent to the Madison aquifer. That range of vertical hydraulic conductivity is equivalent to vertical permeabilities of 0.008 to 0.01 md.

Although vertical hydraulic conductivities are likely high enough to allow areally-distributed discharge of all the water entering the Madison aquifer as recharge, produced water withdrawal accounts for a significant portion of the discharge from the Madison and Tensleep aquifers. Produced water volumes (WOGCC, 2014) reported for the Madison and Tensleep Formations in the WRB are large compared to the recharge volumes estimated by Taucher et al. (2012). The reported water production between 2010 and 2013 from oil wells completed in the Madison Formation averaged approximately 3,900 acre-ft. per year, about 11% of the total annual recharge to the Madison aquifer and 1.3% of the recharge to the combined Paleozoic and Mesozoic aquifers. For oil wells completed in the Tensleep Formation, reported water production during that period averaged approximately 19,400 acre-ft. per year, about 87% of the total annual recharge to the Tensleep and Amsden aquifers and about 7% of the total recharge to the combined Paleozoic and Mesozoic aquifers.

Evidence of upward discharge of groundwater along the trace of the Owl Creek thrust fault was not identified. Evidence of that type of discharge is typically found in the form of springs, seepage areas, wetlands, and/or surface water bodies oriented along the fault trace or exhibiting increases in flow where the stream crosses the fault trace. Westphal et al. (2004) reported that fractures in breccia along the Owl Creek fault were filled with calcite, which indicates that permeability would not be enhanced along the fault. The combination of the two lines of evidence suggests that vertically upward discharge of deep groundwater along the fault, if it occurs, is not significant.

4.2.2 Geochemical Constraints

Geochemical data from WRB Madison Formation groundwater were evaluated to support interpretation of the basin hydrogeologic conceptual model. Data were evaluated for spatial distribution of water types and potential trends in chemical evolution of groundwater as a function of water-rock interactions. Trends in chemistry in Madison Formation groundwater have previously been noted (Busby et al., 1991) to be indicative of anhydrite and/or halite dissolution, or precipitation and dissolution reactions with calcite and dolomite that are at or near saturation. Cation and anion data from Madison Formation samples were depicted (on a mole percent basis) on the trilinear diagram in Figure 4-14, showing the relative proportions of cations and anions.

Data from one spring issuing from recharge area of Madison Formation in the Wind River Range (USGS WWR Spring) were plotted on Figure 4-14. The spring is of a calcium-magnesium-bicarbonate (Ca-Mg-HCO_3) water type, similar to most recharge waters identified by Busby et al. (1991). Beginning with the Ca-Mg-HCO_3 recharge water, anions in groundwater in downgradient wells (USGS WWR 1,400 ft. bgs through USGS WWR 4,212 ft. bgs) proceed from a predominance of bicarbonate to a predominance of sulfate, with a slight increase in the relative proportion of sodium plus potassium. This evolutionary trend is similar to the trend seen in flow paths 1, 4, 7, and 8 of Busby et al. (1991), which is interpreted as an example of chemical changes caused by anhydrite dissolution and de-dolomitization reactions. The water chemistry of the Marlin 29-21 WDW is indicative of chemical evolution along the reaction path from Ca>Mg: HCO_3 to Ca>Mg:SO_4> HCO_3.

Chemical data from produced water from select Beaver Creek field and Madden field (2-3 Bighorn) wells are also displayed on Figure 4-14. Waters from these wells are distinctly different from the waters in the Wind River Range or the Marlin 29-21 WDW, with cations predominantly sodium and a shift from sulfate to chloride predominance, indicative of halite dissolution.

Also plotted on Figure 4-14 are chemical data from Gas Hills well LA-7, completed in the Wind River Formation. Chemical data from the Wind River Formation overlying the Madison Formation in the Gas Hills area should represent the water composition recharging the immediately underlying Madison Formation. The water type of LA-7 is Ca-Mg-HCO_3-SO_4, enriched in sulfate compared to the WWR recharge but clearly along the evolutionary pathway from bicarbonate to sulfate predominance.

In comparing the chemistry of the water considered to be recharge water (USGS WWR Spring and LA-7) to water from the Marlin 29-21 WDW, not only are there differences in relative concentrations, but there are differences in the absolute concentrations of several cations and anions. Table 4-3 summarizes concentrations of cations and anions in the recharge waters and Marlin 29-21 WDW, and differences are likely attributable to reactions occurring along the flow path between any recharge area and the Marlin 29-21 WDW.

Table 4-3 Cation and Anion Concentrations in Recharge Water and Marlin 29-21 WDW

Location		Concentration (mg/L)							
	Date	Na	K	Ca	Mg	Cl	HCO_3(*)	SO_4	TDS
USGS WWR Spring	6/23/1990	2.1	1.1	57	30	0.9	282	3.6	403
LA-7	6/3/2013	34	18	117	31	9	180	305	734
Marlin 29-21	5/1/2014	78.9	28	197	25.5	37	94	619	1079

Notes:
* HCO_3 reported as $CaCO_3$

4.3 Groundwater Velocity Estimates

Groundwater velocity estimates in the area of primary interest to this study were developed based on age-dating of water samples from the Marlin 29-21 WDW. The age-dating is discussed in detail in Section 6. Analysis of the ^{14}C age-dating data indicated a measured water age of approximately 38,000 years before present (ybp) which is corrected to a slightly younger age to account for aquifer reactions; in this analysis a conservative age of 27,000 years at the Marlin 29-21 WDW is used. The Madison outcrop area to the south-southeast of the well is approximately 14 miles (about 75,000 ft.) from the well. The average macroscopic velocity calculated from the distance and travel time is 75,000 ft. in 25,000 years, or 3 ft. per year.

The velocity estimated from the travel time and distance was compared to estimates of permeability made at the Marlin 29-21 WDW. The comparison used the Darcy equation:

$$v = K \frac{dh}{dl} \frac{1}{\theta},$$

where:

v = macroscopic velocity [LT^{-1}]
K = hydraulic conductivity [L^2T^{-1}]
dh = change in potentiometric head [L]
dl = linear distance over which the change in head occurs [L]
θ = effective porosity [dimensionless]

The equation was re-arranged to solve for hydraulic conductivity:

$$K = \frac{dl}{dh} \theta v$$

The following values were assigned:

v = 2.78 ft./year (0.0082 ft./day)
dh = 1,116 ft.
dl = 75,000 ft.
θ = various values: 0.01, 0.05, 0.08, and 0.1

The results are summarized in Table 4-4. The range of calculated hydraulic conductivities and intrinsic permeabilities is reasonable when compared to permeabilities determined from testing of the Marlin 29-21 WDW and permeabilities measured on core samples from the #2-3 Bighorn well.

Table 4-4 Groundwater Velocity Estimates

Effective Porosity	Calculated Hydraulic Conductivity		Permeability (for water at 60° F) md	Permeability (for water at 220° F) md
	ft/day	cm/sec		
0.1	0.051	1.80×10^{-5}	24	5.2
0.08	0.041	1.44×10^{-5}	19	4.2
0.05	0.026	9.02×10^{-5}	12	2.6
0.01	0.005	1.80×10^{-6}	2.4	0.5

4.4 Conceptual Model

The conceptual model of the groundwater system in the Madison, Amsden and Tensleep aquifers combines the information summarized in Sections 4.1, 4.2 and 4.3. The primary aquifer of interest, the Madison aquifer, comprises the saturated, permeable parts of the Madison Formation. The Madison is divided into four laterally extensive stratigraphic sequences labeled, from lowest to highest, sequence I through sequence IV. Sequences I, II, and III are primarily dolomite, whereas sequence IV is primarily limestone. The total thickness is approximately 385 ft. at the Marlin 29-21 WDW and up to slightly more than 400 ft. within about 20 miles north and west of the well. Thicknesses continue to increase toward the west.

- The structural fabric of the WRB results in fracture distributions trending predominantly northwest-southeast except along the northern and southern margins of the basin, where they trend east-west.
- Madison aquifer permeabilities from tested core samples range from 0.09 millidarcies (md) to 16 md horizontally and 0.03 md to 26 md vertically. The ratio of horizontal to vertical permeability ranged from 0.14 to 47 and had a median of 1.8. About two-thirds of the values were greater than 1 (horizontal permeability greater than vertical permeability). Testing of the Marlin 29-21 WDW indicated Madison horizontal permeabilities of approximately 0.25 md.
- Madison aquifer porosities reportedly decrease upwards, ranging from of 10.8% to 12.1% in sequences I and II, 7.3% to 7.9% in sequence III, and 2.1% in sequence IV, Laboratory data for Madison cores from the #2-3 Bighorn well in the Madden field about 20 miles north of the Marlin 29-21 WDW show porosities ranging from 2.4% to 17.1%, with a median value of 6.0%.

- Recharge of groundwater to the Madison aquifer is primarily from precipitation on outcrop areas and, south of the Marlin 29-21 WDW, from downward seepage from Tertiary-age rocks that overlie the Madison where it subcrops south of the well. Recharge to the Madison aquifer in the WRB is estimated to be approximately 26,000 to 47,000 acre-ft. per year.
- Groundwater discharge from the Madison aquifer in the WRB occurs via seepage upward or downward to adjacent aquitards or aquifers and to oil and gas wells. Water production from wells completed in the Madison averaged about 3,900 acre-ft. per year between 2010 and 2013, about 11% of the total recharge to the aquifer. Discharge via vertical movement along major faults is relatively minor, as tectonic fractures in faulted areas were reported to be filled with calcite, resulting in lowered, rather than increased, permeability.
- Basement-cored faults are typically reverse or thrust faults and terminate upwards in the thick shales of late Mesozoic to early Cenozoic age. Faults in the younger sedimentary strata are typically normal faults, frequently create graben structures, and terminate downwards in the thick shales of late Mesozoic to early Cenozoic age. The two types of faults do not overlap vertically.
- Faults with large vertical displacement (more than about 1,000 ft.) are interpreted as functioning hydrogeologically as barriers to groundwater flow in the WRB. The major faults contribute to compartmentalization of the groundwater flow system.
- Age-dating of water from the Marlin 29-21 WDW suggested a groundwater velocity of approximately 3 ft. per year between the recharge area to the south and the well. Back-calculated hydraulic conductivities and permeabilities that would facilitate that flow rate under the current-day hydraulic gradient fall within the range of values reported from the Marlin 29-21 WDW and from other wells in the WRB.
- Groundwater quality evolves from a low-TDS Ca-Mg-HCO_3 water type in the recharge areas to a higher-TDS, Ca-Mg-SO_4 water type as it travels downgradient along the flow path and finally to a high-TDS, Na-Cl water type as it continues to travel along the flow path. The chemical evolution is interpreted to be the result of anhydrite dissolution followed by halite dissolution. Water quality at the Marlin 29-21 WDW reflects anhydrite dissolution and a slight increase in sulfate and TDS but not halite dissolution and the attendant larger increase in TDS, sodium, and chloride.

5.0 DISPOSAL WELL PERFORMANCE MODELING

Tetra Tech constructed and calibrated a groundwater flow and transport model to assess the extents of injected fluid migration from operations at the Marlin 29-21 WDW. The model developed is based on information and data collected and reviewed in Task 1 and synthesized as part of the conceptual model development in Task 2. The model also considers the effects of pressurization and injectate migration both laterally in the Madison Formation and vertically through the overlying Amsden and Tensleep Formations. A post-operational period of 10,000 years was evaluated. The output files from the computer simulations are provided on CD in the Appendix.

5.1 Description of SWIFT Model

5.1.1 Code Selection and Description

The approach used to determine pressure buildup and waste injectate migration consists of numerical groundwater flow and transport modeling. The computer code selected to simulate groundwater flow and contaminant transport is SWIFT (Sandia Waste Isolation Flow and Transport Model) for Windows, Version 2.61 (GeoTrans, 2000). The SWIFT model was chosen based on the origins of development, continued enhancement and quality assurance, level of verification and validation, and previous use and acceptance by the EPA for deep well waste disposal analysis.

SWIFT for Windows is a fully transient, three-dimensional model which can simulate the flow and transport of fluid, heat (energy), brine, and radionuclide chains in porous and fractured geologic media. The primary equations for fluid, heat, and brine are coupled by fluid density, fluid viscosity, and porosity, all of which are allowed to vary throughout the model domain. Steady-state options are available for fluid and brine equations, and both Cartesian (x-y) and cylindrical (radial) coordinate systems may be used.

5.1.2 Chronology and Evolution of the SWIFT Model

The SWIFT for Windows, Version 2.61, model is the result of work performed over a period of almost 30 years. It was originally developed for use in the analysis of deep geologic facilities for nuclear waste disposal. SWIFT was developed under contract from the United States Nuclear Regulatory Commission (US NRC) at the Sandia National Laboratory. SWIFT evolved from an earlier model known as SWIP (Survey Waste Injection Program), which was developed for the USGS for assessing the effects of deep well injection into saline aquifers. The following summarizes the chronology of the SWIFT model evolution:

Code	Code Developer	Source of Funding	Year
SWIP	Intercomp, Inc.	USGS	1976
SWIFT	Intera, Inc.	NRC	1977
SWIPR	Intera, Inc.	USGS	1978
SWIFT II	GeoTrans, Inc.	NRC	1986
SWIFT III	GeoTrans, Inc.	GeoTrans, Inc.	1987
SWIFT/386	GeoTrans, Inc.	GeoTrans, Inc.	1991
SWIFT/486	GeoTrans, Inc.	GeoTrans, Inc.	1992
SWIFT for Windows	GeoTrans, Inc.	GeoTrans, Inc.	2000

In summary, there have been continuous improvements and maintenance of the SWIFT code since 1977.

5.1.3 Code Verification and Validation

The verification of a groundwater code refers to a testing process whose objectives are to 1) check the accuracy of the computational algorithm used to solve the governing equations, and 2) to assure that the computer code (model) is fully functional. A computer code (model) is said to be verified if sufficient testing has been performed to show that it accurately represents the mathematical model. Verification of a computer code involves 1) comparison with known analytical solutions, and 2) benchmarking with other verified computer codes.

SWIFT has been verified against numerous analytical solutions (Ward et al., 1984). In addition, SWIFT has been compared with numerous field studies. The comparisons provide supporting evidence that the equations solved properly reflect the observed hydrogeologic behavior (Ward et al., 1984). In summary, the SWIFT model has been verified and validated against more than 70 test cases and analytical solutions to ensure that the computer code produces valid and correct results.

5.1.4 Basic Assumptions and Characteristics of the SWIFT Model

The physical processes that are incorporated into the SWIFT model are described by four equations: fluid pressure (head), heat (energy), brine transport, and radionuclide transport. As mentioned earlier, these equations can be solved for both porous and fractured geologic media. Some of the basic assumptions and characteristics of the SWIFT for Windows model include:

1. three-dimensional transport in the global system,
2. single-phase fluid flow governed by Darcy's Law,
3. linear variations in porosity and fluid density with respect to the dependent variables,
4. viscosity is dependent on temperature and/or brine concentrations,
5. isothermal equilibrium adsorption (Freundlich or linear isotherm),
6. injection wastes are miscible with the resident fluid,
7. confined or unconfined reservoir may be simulated,
8. hydraulic conductivities may be heterogeneous and/or anisotropic,
9. longitudinal and transverse dispersivities may vary throughout the domain,
10. molecular diffusion is constant in the model domain,
11. unitless concentrations used where the resident formation fluid ("water") has a concentration of C = 0.0 and the injectate ("brine") has a concentration of C = 1.0,
12. compressibility terms are defined by c_w (compressibility of water) and c_r (compressibility of rock).

5.1.5 Method of Solution

Discretization of the model domain in SWIFT is performed by the block-centered finite-difference method. The solution is obtained using either the centered or backward weighting (upstream) in the time and space domains. Matrix solution is performed either by Gaussian elimination (direct method) or the two-line successive over-relaxation method (L2SOR).

5.1.6 Boundary Conditions

Boundary conditions determine how the model interacts with the "outside" world. They allow for the inflow and/or outflow of water (pressure/head) and mass (brine/waste). A variety of boundary conditions and source terms may be used in SWIFT for both the porous and fractured media. These include:

1. prescribed pressure (head), temperature, and/or brine concentration (first-type or Dirichlet boundary condition),
2. prescribed flux of fluid (water), heat, brine, or radionuclide mass (second-type or Neumann boundary condition),
3. aquifer influence function (i.e., Carter-Tracy infinite aquifer boundary condition),
4. freewater surface (unconfined) with recharge,
5. no-flow (inactive) boundary condition (fluid neither enters or exits the system).

5.2 Model Construction

Model construction involved the translation of the conceptual model into a numerical model within a consistent framework by capturing the relevant geologic, hydrogeologic, and reservoir properties, parameters and assumptions pertaining to the site. The primary phases in the construction of the numerical model included: 1) construction of a grid for the model volume; 2) specification of model layer geometry (i.e., top and bottom elevations); 3) assignment of boundary conditions; 4) specification of hydraulic parameter values (e.g., permeability, porosity); 5) specification of sources and sinks of fluid (i.e., wells); and 6) selection of appropriate site data measurements for calibration of the model. The model was run in a mode to consider the effects of injecting denser water into the Madison Formation, but not to simulate changes in fluid temperatures, because of the significant impact on run times without having much effect on the simulation results.

5.2.1 Model Grid

The model grid used for this analysis is shown in Figure 5-1, and its outline within the WRB was shown on Figure 4-12. The model grid is rotated 50 degrees west of north based on observations that fracture orientation in the Madison Formation in the WRB is primarily in the northwest direction (between 45 and 55 degrees west of north) (Thompson, 2010), thus orienting the grid with the principal permeability directions. The grid is finite-difference and consists of 296 rows, 279 columns, and six model layers. The grid spacing is variable and consists of fine grid spacing (100 x 100 ft.) in and around the vicinity of the Marlin 29-21 WDW (approximate 2 mile radius around the well), with increasing grid spacing (to 3000 x 3000 ft.) along the model edges. The length of the model grid in the X direction is approximately 31 miles, and the length of the model in the Y direction is approximately 36 miles. The model grid covers an area of approximately 1,075 square miles. For the subsequent model analysis, both isotropic and anisotropic conditions with respect to horizontal hydraulic conductivity in the Madison Formation are considered.

5.2.2 Model Layering and Elevations

The model includes the Tensleep, Amsden, Darwin Sandstone and Madison Formations. Model layer 1 represents the Tensleep Formation, model layer 2 represents the Amsden Formation, model layer 3 represents the Darwin Sandstone and model layers 4 through 6 represent the Madison Formation. The Madison was subdivided into three layers based on regional hydrogeologic reports and log and core data. Westphal, et al. (2004) describe the Madison Formation in the WRB as consisting of four sequences, Sequence IV (topmost) through Sequence I (bottommost) (Figure 5-2). Sequence IV is characterized as a lower-permeability limestone (“tight”), while Sequences III, II, and I are generally considered more permeable. Based on the log data from the Marlin 29-21 WDW and core data from the Bighorn #2-3 well, the Madison Formation was subdivided as follows: a) model layer 4 (the topmost Madison model layer) represents Sequence IV and is considered a low-permeability unit, b) model layer 5 (the middle Madison model layer) represents Sequence III and is considered a higher-permeability unit, and c) model layer 6 (the bottommost Madison model layer) represents Sequence II and I combined and is considered a higher-permeability unit.

Elevations of the top and bottom of each model layer are based on interpreted surfaces of the structural contours and isopachs for the Tensleep, Amsden, and Madison Formations. Each model layer has variable elevation and thickness based on the structural contour and isopach maps developed as part of Tasks 1 and 2 and described and shown in Sections 3.2 and 4.0. The exception to this is the Darwin Sandstone. This layer has variable elevation and a constant thickness of 29 feet at every model grid cell. This is based on the interpretation of the re-processed Schlumberger RST log (Section 3.1.2) that shows a gross thickness of 29 feet for the Darwin Sandstone at the Marlin 29-21 WDW. A schematic of the model layering at the Marlin 29-21 WDW is shown in Figure 5-3.

5.2.3 Boundary Conditions

Boundary conditions used in the model are shown in Figure 5-4. Constant pressure boundary conditions were applied to the edge of the model along portions of each of the four sides of the model in all model layers. This was done to establish and maintain the regional groundwater flow system across the model domain during the time period being simulated. The pressures were based on the depth to the grid block center for each model layer, the density of the formation water (e.g., from the TDS data for each formation) and temperature. Faults that showed major structural relief (e.g., faults with a throw of hundreds of ft. or more across the fault, sufficient to break the hydraulic connection of the Madison across the fault) were considered sealed faults and were specified as inactive (e.g., no flow) in the model. Faults that showed minor or no structural relief were considered transmissive and were specified as active cells in the model.

5.2.4 Hydraulic Parameter Specification

Initial hydraulic parameters were specified in the model and are summarized in Table 5-1. Porosity values were based on values obtained as part of Tasks 1 and 2 and are expected to range from 4% to 12%. In addition, as discussed in Section 3.1.2, the interpretation of the re-processed Schlumberger RST log shows porosity values ranging from 4.3 to 10% for different porosity cutoffs (i.e., 3, 4, and 5% cutoff). The original value of 8% porosity was maintained and specified for the base-case simulations.

The densities of waters in the Tensleep and Madison Formations were based on water samples collected at the Marlin 29-21 WDW, and the density and viscosity of the proposed injectate fluid was based on information from Encana. The temperature of the Madison Formation at the Marlin 29-21 WDW was specified as 230°F based on information collected at the well during the SRT conducted in July 2014. Other temperatures throughout the basin were based on a temperature gradient of 0.012°F/ft, which was based on literature sources (Hinckley and Heasler, 1983). Viscosity values with respect to temperature were specified based on literature values (Engineering Toolbox, Waterloo University). The base-case value of dispersivity (longitudinal dispersivity, α_L = 150 ft and transverse dispersivity, α_T = 15 ft.) used in the model simulations was based on estimates described in literature (Xu and Eckstein, 1995; Neuman, 1990; Ayra, 1986).

Table 5-1 Model Parameters used in Marlin 29-21 WDW Performance Simulations

Parameter	Value
Compressibility (fluid)	3.15 x 10^{-6} psi^{-1}
Compressibility (rock)	4.35 x 10^{-6} psi^{-1}
Madison Formation fluid concentration	1,100 mg/L TDS
Injectate fluid concentration	8,000 mg/L TDS
Formation fluid viscosity	0.25 cp
Formation temperature (at Marlin 29-21 WDW)	230°F
Injectate fluid viscosity	1.0 centipoise (cp)
Porosity	0.08
Hydraulic conductivity (K) (three cases)	3.5, 8, and 17 millidarcy (md)
Horizontal to vertical anisotropy (K_h:K_v)	10:1 for Madison Formation, 1:1 for Amsden Formation
Horizontal K anisotropy (K_y:K_x)	1:1 (for base case simulations)
Longitudinal dispersivity (α_L)	150 ft
Transverse dispersivity (α_T)	15 ft

Hydraulic conductivity was specified based on estimates obtained from the interpretation of the SRTs conducted for both the Tensleep and Madison Formations at the Marlin 29-21 WDW as well as from literature sources (Westphal et al., 2004, Freeze and Cherry, 1979). The model layer representing the Amsden Formation was specified a value of 1 x 10^{-10} cm/sec for vertical hydraulic conductivity (K_v), which is representative of competent shale (Domenico and Schwartz, 1990). For the purposes of this analysis, model layers five and six (which represent the Madison Formation Sequence III and II/I) are assumed to have the same hydraulic conductivity specification. The topmost Madison Formation layer (model layer four), that represents a tight limestone, is assigned a hydraulic conductivity that is two orders of magnitude lower than the hydraulic conductivity of model layers five and six.

The Darwin Sandstone was assigned the same hydraulic parameters as the Amsden Formation. The assumption was made that the horizontal to vertical anisotropy (i.e., the ratio of horizontal to vertical permeabilities, k_h:k_v) for the Madison and Tensleep model layers was 10:1, while the anisotropy for the Darwin and Amsden model layers was 1:1. Flow is primarily in the horizontal direction in the injection zone and primarily vertical through the confining interval. In addition, the assumption was made the horizontal anisotropy (the ratio of permeability in the y-direction to permeability in the x-direction, k_y:k_x) was 1:1 for the Madison Formation for the base-case simulations. Additional anisotropy values for k_y:k_x were analyzed as part of the sensitivity analysis simulations.

For the predictive waste migration simulations, the assumption was made that no retardation or degradation of the injectate plume was occurring. This is a conservative assumption that results in the maximum migration of the simulated waste injectate plume.

5.3 Model Calibration

The numerical model was calibrated against the field data collected as part of the step-rate test (SRT) conducted on the Marlin 29-21 WDW in the Madison Formation (July 2014). The primary purpose of the test was to determine the formation breakdown pressure for the state regulatory agency (Encana personal communication, 2014). The SRT was conducted by injecting at a fixed rate for a period of time, after which the injection rate was increased. Table 5-2 summarizes the rates and time duration of each step in the test. Figure 5-5 shows the observed bottomhole pressures and temperatures during the SRT. Figure 5-6 is a linear plot of injection rate and observed bottomhole pressure and shows the break in the slope of the best-fit lines that indicates fracturing of the formation. This fracturing occurred at some point during the 3rd step of the test when the injection rate was increased to 4.1 bpm. The intersection of the two slope lines (pre- and post-fracture) provides an estimate of what the maximum bottomhole pressure can be before fracturing of the formation occurs. This value (approximately 9,850 psi) was used as a pressure constraint in the subsequent predictive simulations (described in Section 5.4).

Table 5-2 Summary of the SRT Conducted at the Marlin 29-21 WDW for the Madison Formation

Step Number	Clock Time (hrs)	Injection Rate (bpm)
1	25.2214	1.3
2	26*	2.3
3	27.8658	4.1
4	28.8694	8
5	29.8744	12
6	30.0494	0

Note: Data obtained from Encana spreadsheet, Marlin 29-21 WDW step rate 7-7-14 Downhole Pressures.xls
*The pressure curve and notation on the curve by Encana indicates that the second step occurred at elapsed time of 26 hours, rather than 26.5169 hours

The SRT was reproduced in the SWIFT model using actual rates that were used during the testing. Adjustments were made to the value of hydraulic conductivity for the Madison Formation as needed in order to match the model-calculated pressures to observed pressures. The result is shown in Figure 5-7. Some observations with respect to the SRT are noted here:

1. The test was not primarily designed to derive estimates of formation hydraulic properties (i.e., hydraulic conductivity), as such, the time that each step rate lasted (approximately 1 hour) was not long enough to establish steady-state or quasi steady-state conditions for each injection rate.
2. Bottomhole pressures showed fluctuations through time and were mainly still increasing at the end of each step. Ideally, the change in pressure would approach zero at the end of each step before an increase of rate occurs.
3. The first step showed a large drop in bottomhole pressure at a clock time of approximately 25.8 hours, indicating a potential rate control problem.
4. Near wellbore skin effects may also be manifested as part of this test, particularly during early injection times, which would affect estimated of formation permeability.

The model-calculated values did not match the observed pressures well, in part due to uncertainties in the test procedures and the reasons listed in 1 through 4 above. A reasonable match was obtained for the second step of the test (before fracturing occurred). The value of permeability that was used in the model for this match was 3.5 md. This value is in the range of conductivities found in literature that are representative of the Madison Formation in the WRB (Westphal et al., 2004). The 3.5 md value of permeability was used as the base-case value for permeability for the subsequent predictive simulations.

5.4 Predictive Simulations

The SWIFT model developed for the site was used to make long-term predictions of pressurization and waste injectate migration as a result of injection operations at the Marlin 29-21 WDW. The predictive simulations considered two time frames: 1) the operational period of 50 years in which it was assumed that the well was operating 24 hours a day, 365 days a year at a constant injection rate, and 2) the post-operational drift period of 10,000 years. These two periods were run as two separate simulations. First, the operational period was simulated using a reservoir pressure boundary at the Marlin 29-21 WDW. The second simulation used the pressure and concentration results from the first simulation, but with no boundary condition specified for the well.

Base-case simulations were performed based on the hydraulic parameters listed in Table 5-1. For each simulation, a reservoir pressure constraint of 9,850 psi was specified at the Marlin 29-21 WDW, which, as mentioned previously, is based on the results of the SRT conducted in the Madison Formation at the Marlin 29-21 WDW. Thus, the model-calculated pressure at the Marlin 29-21 WDW was not allowed to exceed the pressure constraint, with the result being that the injection rate was allowed to fluctuate (increase or decrease) through time in order to match the pressure constraint. At the end of the operational period, the total volume of fluid injected into the formation divided by 50 years results in an estimate of the average injection rate that can be achieved in bpd for the permeability specified for the Madison Formation. Table 5-3 lists the results of this analysis.

Table 5-3 Average Injection Rate Based on Reservoir Pressure Constraint and Various Values of Permeability for the Madison Formation

Hydraulic Conductivity Value (md)	Average Injection Rate (bpd) over 50 Year Operational Period
3.5	4,500
8	9,900
17	19,800

The results indicate that the average injection rate that can be expected to be maintained during the operational period of the Marlin 29-21 WDW ranges from approximately 4,500 to 9,900 bpd based on the expected range of permeabilities (3.5 to 8 md) for the Madison Formation in the vicinity of the well. A rate of 19,800 bpd can be achieved if the permeability of the Madison is higher (17 md). This value, while high, still falls within the range of reported hydraulic conductivities for the Madison Formation in the WRB (Westphal et al., 2004), but is more likely more representative of areas of the Madison Formation with higher porosity and/or at shallower depths and does not necessarily represent hydraulic conditions in and around the Marlin 29-21 WDW. For this analysis, however, the k = 17 md scenario was included as one of the base-case simulations for the sensitivity analysis and represents the most conservative ("worst case") estimate of waste migration (i.e., highest injection rate, high permeability, greatest extent of migration). Injectate migration up-dip (southeast) toward the Madison Formation outcrop and recharge area is of interest because the formation would be at shallower depths there than at the Marlin 29-21 WDW well. The Madison Formation would therefore be less costly to reach by a drilled well, and it could comprise a potential source of groundwater supply for non-industrial use if economically accessible by wells far enough up-dip from the Marlin 29-21 WDW well.

The relationship between the simulated injection rates and the permeabilities is not linear. This is a result of the different viscosities assigned to the injectate and formation fluids (1.0 and 0.25 cp, for the injectate and formation fluid, respectively). The larger volume of injectate that can be injected at the higher permeabilities causes a greater pressure gradient around the injection well and reduces the allowable injection rate a small amount.

Figure 5-8 shows graphically the injection rates through time for the three permeability values (3.5, 8, and 17 md) applied to the Madison Formation. Each curve shows that the injection rates are highest for approximately 1 year, but then begin to decrease as pressures begin to increase at greater distances from the injection well.

Figures 5-9, 5-10, and 5-11 show the pressure at the Marlin 29-21 WDW for the operational period followed by 50 years of post-operational falloff, for the simulations where the Madison Formation permeability is 3.5, 8, and 17 md, respectively. The three sets of results are very similar. As would be expected, the pressure response (i.e., falloff) is faster in the simulations with higher permeabilities.

As mentioned previously, the SWIFT model solves for unitless (or normalized) concentrations. That is, the concentration of the waste injectate is specified to be C = 1.0 and the concentration of the formation before injection begins is specified to be C = 0. Concentrations are calculated between 0 and 1. For this evaluation, the extent of the injectate plume is defined by the C = 1 x 10^{-3} normalized concentration contour, which is equal to a change in concentration of 6.9 mg/L (based on an injectate concentration of 8,000 mg/L and initial concentration of 1,100 mg/L, or a difference of 6,900 mg/L). This value is conservative, as this increase in concentration (6.9 mg/L) is a very low value given that the Madison Formation TDS concentration is approximately 1,100 mg/L. Normalized concentration contours are shown at two times: 1) 50 years (the end of the operational period), and 2) 10.000 years.

Figure 5-12 shows the model-calculated pressure buildup (change in pressure over static pressure) at the end of the operational period for the base-case simulation (K = 3.5 md). On this figure, the 2,000 and 3,000 psi contours are not visible, covered up by the small triangle representing the Marlin 29-21 WDW. The 1,000 and 500 psi contours are approximately circular, but the 100-psi contour is distorted, because of the non-uniform thickness of the Madison. Figures 5-13 and 5-14 show the model-calculated waste injectate normalized concentration contours for the base-case simulation (3.5 md) at the end of the operational period and after 10,000 years, respectively. For these concentration contour plots, the 1 x 10^{-1} and 1 x 10^{-2} concentration contours are also shown. For the operation period, the 10^{-3} normalized concentration contour is approximately 0.8 miles from the well. During the 10,000-year post-operational period, the contours shift to the northeast approximately 0.9 miles (for a total migration distance of approximately 1.7 miles and spread out slightly because of dispersion. The post-operational movement is down dip because of the natural flow of groundwater through the Madison Formation and the slightly higher density of the injectate. At the maximum injectate migration distance of approximately 0.8 mile structurally up-dip (southeast), the top of the Madison Formation is at an elevation of approximately -8,000 feet (8,000 feet below msl), or approximately 13,900 feet below the land surface.

Figures 5-15, 5-16, and 5-17 show the pressure and normalized concentration contours for the 8 md case. With the higher permeability, the rate of injection is higher, and the simulated pressure change extends over a larger area. The 100-psi pressure increase extends to the east to the faults that form the edge of the model. Because of the greater injection rate with a permeability of 8 md, the 10^{-3} normalized concentration contour line at the end of the operational period is located at a distance of approximately 1.2 miles in the northeast direction, 1.0 miles in the southwest direction, and 1.1 miles in the southeast direction. The injectate moves in the down-dip direction to the northeast during the injection period. At the end of the 10,000-year simulation, the injectate has migrated a distance of approximately 3.3 miles in the down-dip direction.

The 17-md case results are presented in Figures 5-18, 5-19, and 5-20. The pressure change contours cover a larger area in this case compared to the 8 md case. At the end of the operational period, the 10^{-3} normalized contour is located approximately 1.8 miles to the northeast, 1.4 miles to the southwest, and 1.5 miles to the southeast. After 10,000 years, the leading edge of the plume has migrated approximately 6.8 miles to the northeast. The center of the plume is estimated to be approximately 3 miles to the northeast.

In addition, vertical cross-section concentration contour plots are shown in Figures 5-21 through 5-23 for the 3.5, 8, and 17 md base cases, respectively, for 50 and 10,000 years. These cross sections extend from the Marlin 29-21 WDW to the north-northeast (down-dip). On these plots, only the 1×10^{-3} contour is shown, with the distance away from the Marlin 29-21 WDW shown on the X axis and the depth to the model layer center on the Y axis. The points are plotted in the middle of the layers. The results show that the injectate is primarily contained within the Madison Formation both during the operational and the post-operational drift period. While some waste injectate migrates into the overlying Darwin Sandstone, none of the waste plume migrates into the Tensleep Formation, even after 10,000 years.

For these three cases, the injectate primarily remains within the Madison, but there is some vertical migration into the Darwin Sandstone. The 3.5 md case is considered the most representative, based on the SRT results. The primary differences between the results for the three simulated permeabilities are due to the differences in the achievable injection rates, given a maximum downhole injection pressure of 9,850 psi. The greatest distance of injectate migration southeast (up-dip) from the Marlin 29-21 WDW in the three simulations was approximately 1.5 mile.

5.5 Sensitivity Analysis Simulations

In addition to the base-case simulations, a number of sensitivity analysis simulations were conducted to assess the effects of uncertainty in key hydraulic parameters that may affect injectate migration. For a sensitivity simulation, only one parameter is changed from the base case, allowing the effects of changes in a single parameter to be assessed. The base-case simulations described in Section 5.4 assumed gross thickness for the Madison Formation injection interval. Net thickness was simulated as a sensitivity run by scaling the base-case porosity value (i.e., 8%) by the ratio of net thickness divided by gross thickness at the Marlin 29-21 WDW for the Madison Sequence III and II/I layers (model layers 5 and 6) for the 3% porosity cutoff as described in Section 3.1.2. This resulted in a decrease of the porosity from 8% to 3.7% for the Madison Sequence III (model layer 5) and a decrease of the porosity from 8% to 3.6% for the Madison Sequence II/I (model layer 6). Predictive simulations were run using these net thickness porosities for all three permeabilities (i.e., 3.5, 8 and 17 md). The other sensitivity analyses that were conducted were based on the high value of permeability (17 md), as this case represents the “worst case” condition (i.e., greatest extent of waste migration). Table 5-4 summarizes the simulations that were performed.

Table 5-4 Summary of Sensitivity Analyses Simulated

Sensitivity Run #	Base Case Permeability Value (md)	Description of Sensitivity Analysis Simulated	Result of Sensitivity Analysis
1	3.5	Decreased porosity from 8 to 3.7% for Madison Sequence III (model layer 5) and from 8 to 3.6% for Madison Sequence II/I (model layer 6) to represent net thickness	Down-dip movement increased by approximately 1.3 miles after 10,000 years compared to base case
2	8	Decreased porosity from 8 to 3.7% for Madison Sequence III (model layer 5) and from 8 to 3.6% for Madison Sequence II/I (model layer 6) to represent net thickness	Down-dip movement increased by approximately 2.5 miles after 10,000 years compared to base case
3	17	Decreased porosity from 8 to 3.7% for Madison Sequence III (model layer 5) and from 8 to 3.6% for Madison Sequence II/I (model layer 6) to represent net thickness	Down-dip movement increased by approximately 5.5 miles after 10,000 years compared to base case
4	17	Increased porosity from 8 to 12%	Down-dip movement decreased by approximately 2 miles after 10,000 years compared to base case
5	17	Horizontal K anisotropy ($K_y = 2K_x$, K_y doubled from base case)	Down-dip movement approximately the same but rotated counter-clockwise compared to base case
6	17	Horizontal K anisotropy ($K_y = 10K_x$, K_y 10x from base case)	Down-dip movement increased by approximately 9.5 miles and rotated counter-clockwise compared to base case
7	17	Dispersivity increased from 150 to 300 ft (α_L = 300 ft and α_T = 30 ft.)	Minimal change in down-dip movement compared to base case
8	17	Constant pressure boundary condition applied in Tensleep Formation (model layer 1) along the northern Owl Creek fault zone	No change compared to base case
9	17	Vertical hydraulic conductivity (Kv) of the Darwin Sandstone and Amsden Formation increased from 1×10^{-10} to 1×10^{-9} cm/sec	Increase in vertical movement

Sensitivity Run #	Base Case Permeability Value (md)	Description of Sensitivity Analysis Simulated	Result of Sensitivity Analysis
10	17	Vertical hydraulic conductivity (Kv) of the Darwin Sandstone and Amsden Formation increased from 1 x 10^{-10} to 1 x 10^{-9} cm/sec for Sensitivity Run 3 (net thickness)	Increase in vertical movement

Figures 5-24, 5-25, and 5-26 show the pressure and normalized concentration contours for the 3.5 md case (Sensitivity Run 1 - net thickness). Figures 5-27, 5-28, and 5-29 show the pressure and normalized concentration contours for the 8 md case (Sensitivity Run 2 - net thickness). Figures 5-30, 5-31, and 5-32 show the pressure and normalized concentration contours for the 17 md case (Sensitivity Run 3 – net thickness). In addition, vertical cross-section concentration contour plots are shown in Figures 5-33 through 5-35 for the 3.5, 8, and 17 md net thickness cases, respectively, for 50 and 10,000 years. Figure 5-36 shows the normalized concentration contour for the 17 md case (Sensitivity Run 3) for both the base case and net thickness case at 50 years. The 10^{-3} normalized concentration contour is approximately 0.7 miles farther down-dip and 0.6 mile farther up-dip for the net thickness case compared to the base case. Figure 5-37 shows the normalized concentration contour for the 17 md case (Sensitivity Run 3) for both the base case and net thickness case at 10,000 years. The 10^{-3} normalized concentration contour is approximately 5.5 miles farther down-dip for the net thickness case compared to the base case.

Figures 5-38 through 5-51 show the model-calculated 10^{-3} normalized concentration contour at the end of the operational period and the 10,000 year post-operational period for Sensitivity Runs 4 through 10. Also shown, for comparison, is the 10^{-3} normalized concentration contour for the base-case simulation. In the worst-case simulation (Sensitivity Run 5, the 17 md case with Ky increased by a factor of ten), the 10^{-3} normalized concentration contour at the end of the operational period is approximately 1 mile farther down-dip and 0.6 mile farther up-dip compared to the base case. At the farthest up-dip extent of the injectate, the top of the Madison Formation is at an elevation of approximately -6,000 feet, or about 12,000 feet below the land surface. In addition, vertical cross-section concentration contour plots are shown in Figures 5-52 and 5-53 for Sensitivity Runs 9 and 10 (k_v for the Darwin Sandstone and Amsden Formation was increased by an order of magnitude for both the base case and net thickness case for 17 md). The results show the 10^{-3} normalized concentration contour migrating vertically into the Amsden Formation. None of the waste migrates into the Tensleep Formation, even after 10,000 years.

The results are briefly summarized:

1. Simulating net thickness by scaling porosity down for the Madison injection layers (scaling 8% porosity by the net/gross thickness ratio (based on 3% porosity cutoff) at the Marlin 29-21 WDW) increases the migration distance during both the operational and post-operational periods (i.e., 10, 000 years) for 3.5, 8 and 17 md cases (Figures 5-25 and 5-26, 5-28 and 5-29, and 5-31 and 5-32). In the worst-case scenario (i.e., 17 md), the 10^{-3} normalized concentration contour migrates approximately 5 miles farther down-dip compared to the base case (Figure 5-37). However, the plume is still fully contained laterally within the deepest portion of the Madison Formation. Increasing the porosity of the Madison reduces the migration distance during the operational (Figure 5-38) and post-operational period (Figure 5-39), because there is more pore space for accepting the injectate.

2. The consideration of the effects of the dominant fracture direction (striking to the northwest) causes the contour to become elliptical with the long access oriented approximately parallel to the dominant fracture strike (Figures 5-40 and 5-42). This simulation was performed by increasing the conductivity in the dominant fracture direction (northwestern direction). During the post-operational phase, the migration is rotated a small amount counter clockwise from the base case migration direction, and the distance of migration is approximately the same for the simulation where the conductivity in the dominant fracture direction was increased by 2 times (Figure 5-41), and much longer for the simulation where the conductivity in the dominant fracture direction was increased by 10 times compared to the base case results (Figure 5-43). For the simulation with the 10 times increase, the migration distances down-dip and up-dip at the end of the operational period increased 1 mile and 0.6 mile, respectively, compared to the base case (Figure 5-42). The plume remains fully contained laterally within the deepest portion of the Madison Formation in both cases.
3. Increasing the longitudinal dispersivity from 150 ft to 300 ft had a minor effect on the distance of migration during the operational phase (Figure 5-44). During the post-operational period (Figure 5-45), this increase in dispersivity had little effect on the down-dip edge, in contrast to the effect on the up-dip edge. This result is a well-known artifact caused by the advective-dispersion equation, in which migration is calculated as occurring opposite the direction of flow, and should be ignored.
4. In the simulation in which the pressure imposed on the north-western edge of the Tensleep was made lower than that of the Madison (to induce upward flow), the results for the operational (Figure 5-46) and post-operational phases (Figure 5-47) are indistinguishable from the base-case results.
5. Increasing the k_v of the Darwin Sandstone and Amsden Formation had little or indistinguishable effect on the location of the 10^{-3} normalized concentration contour laterally for both the operational and post-operational phases (Figures 5-48 and 5-49) for the base case. The cross-sectional view shows the 10^{-3} normalized concentration contour migrating vertically into the Amsden Formation for the base case (compare Figure 5-23 with Figure 5-52). For the net thickness simulation (Sensitivity Run 3), increasing the k_v of the Darwin Sandstone and Amsden Formation had indistinguishable effect on the location of the 10^{-3} normalized concentration contour laterally for the operational period (Figure 5-50) and a slight increase in down-dip migration laterally for the post-operational phase (Figure 5-51). The cross-sectional view shows the 10^{-3} normalized concentration contour migrating vertically into the Amsden Formation for the net thickness case (compare Figure 5-35 with Figure 5-53). None of the waste migrates into the Tensleep Formation, even after 10,000 years, for either the base case or net thickness case.

The sensitivity simulations show that the greatest effects are caused by changes in the permeability (because this parameter affects the injection rate, and thus the total injected volume) and the porosity (i.e., net thickness, because it affects the volume of rock required to store the injected volume). In all cases run, the 10^{-3} normalized concentration contour remains contained within the deepest portion of the Madison Formation laterally and extends vertically into the Amsden Formation approximately 100 ft only when the k_v of the Darwin Sandstone and Amsden Formation is increased by an order of magnitude. None of the waste migrates into the Tensleep Formation.

In summary, the 3.5 md case is probably the most representative for an injection well completed in the Madison Formation at the Marlin 29-21 WDW. In this simulation, the distance of greatest migration is predicted to be approximately 1.8 miles after 10,000 years. If injection of 10,000 bpd is needed, a second, nearby well may be required, and the 8 md case would be most representative. The maximum distance of migration is predicted to be approximately 3.3 miles after 10,000 years, in the down-dip direction.

6.0 ADDITIONAL INFORMATION

The chemical and isotopic compositions of water samples collected from the Marlin 29-21 WDW were discussed in a separate report prepared for Encana by Tetra Tech (2015a). Therefore, the objectives of this section are to: 1) discuss the chemical composition of Madison Formation water collected from the Marlin 29-21 WDW in the context of the plausible groundwater flow from recharge to the deeper WRB, and 2) use the recharge area groundwater chemical composition evaluated in Section 3, the conceptual model of flow from Section 4, and geochemical modeling to adjust measured ^{14}C results to more representative ages by accounting for chemical reactions along the flow path.

6.1 Chemical and Isotopic Analyses for the Madison Aquifer

6.1.1 Data from Oil and Gas Wells in the Southern Wind River Basin

Chemical analyses of produced water have been obtained for the southern WRB from the WOGCC as discussed in Section 3.4. Results are available for the area of interest, but only for wells in the Beaver Creek Oil Field, and the Madden Gas Field (Figure 3-1). The produced water analyses cannot be checked for quality with available information; nevertheless, the major ion composition from these two fields is useful in a general evaluation of the two principal potential flow pathways: from recharge area in the southwest WRB to the Marlin 29-21 WDW and on into the basin (Pathway 1, Figure 3-1), and from the south WRB through the Marlin 29-21 WDW to the deeper part of the basin (Pathway 3, Figure 3-1).

Flow from the Southwest. The Beaver Creek Oil Field is located approximately 35 miles southwest of the Marlin 29-21 well. This field location was evaluated as a potential intermediate point on a hypothetical flow path to the Marlin 29-21 WDW. The potential flow path could be from the recharge area near Lander, Wyoming, to the Beaver Creek Field, to the Marlin 29-21 WDW location, and then to the basin center (Pathway No. 1; Figure 3-1).

The groundwater composition of the recharge area is indicated by a few wells in the Madison Aquifer (Sections 3-4, 4.2), which would provide the initial chemical composition needed for the geochemical modeling. The second location is the Beaver Creek Field, from which there are 10 water analyses available from the WOGCC for producing wells. The published produced water compositions have Cl concentrations ranging from 161 to 402 mg/L, and reported TDS concentrations ranging from 1,593 to 2,424 mg/L. No information is provided regarding sample collection circumstances or the quality of the analyses. Nevertheless, in the absence of any other analyses, and assuming these analyses are representative of this portion of the basin, these results were used in the evaluation.

The third point along this hypothetical flow path would be the Marlin 29-21 WDW location which yielded a $Ca\text{-}SO_4$ type water with low chloride concentration (37 mg/L), significantly lower than the Beaver Creek Field, and a lower TDS (1,120 mg/L). The Marlin 29-21 WDW would be in a downgradient location from the Beaver Creek Field if the pathway were plausible, and the removal of such a large amount of chloride concentration to yield a water type observed in the Marlin 29-21 WDW is not reasonable. Although dissolved constituents that are reactive may be altered along the flow pathway, chemically conservative constituents such a chloride are not candidates for removal in this geological environment. Consequently, the chemical data do not support a flow path from the southwestern recharge area through the Beaver Creek Field to the Marlin 29-21 WDW, and thus this flow path is not a reasonable conceptual model based on evolution of the formation water chemical composition. This flow path was also discussed in more detail in Section

4, but based on potentiometric surface evaluations this flow path is similarly not considered as a plausible pathway (Section 4.4). A more reasonable flow path and the proposed path consistent with the conceptual model is for flow from recharge in the southwest portion of the basin to be diverted northerly into the basin, significantly west of the Marlin 29-21 WDW location (Figure 3-1; pathway 2).

<u>Flow from the Southeast.</u> The Madden Gas Field is located approximately 15 miles north of the Marlin 29-21 WDW on the Owl Creek Fault (Figure 3-1) and could be a location representing the deep basin end of a flow path originating south of the Marlin 29-21 WDW (Pathway 3; Figure 3-1).

Three analyses are available from the WOGCC for the Madison Formation in the Madden Field; however, no information is provided regarding sample collection circumstances or the quality of the analyses. The Madison Formation is exposed at the land surface in places north of the Owl Creek Fault but is located deep in the basin center on the south or downthrown side of the Owl Creek Fault. The three available analyses are for samples from the Madison Formation in the Bighorn 1-5 well and the Bighorn 2-3 well at depths of 23,000 ft. These samples have TDS concentrations that are surprisingly low for a typical oil field produced water, with values of 370, 410, and 1,010 mg/L; however, there are no supporting documents that can be used to determine the quality or reliability of these results. The dissolved sulfate is low (<25 mg/L) relative to Madison Formation water in other upgradient wells; this could be explained as a consequence of reduction of dissolved sulfate to sulfide. Chloride is the dominant anion, with concentrations of 170, 220, and 545 mg/L. A "distillation" process, essentially condensed water vapor from a deep and hot reservoir, has been suggested as a possible explanation for low TDS concentrations in Madden Field produced water samples. While the low TDS values from Madden Field samples are consistent with the Marlin 29-21 WDW TDS (1,120 mg/L), those results are provided here only for comparison.

The Madison Formation sample from the Marlin 29-21 WDW was collected using an *in-situ* sampling method designed to maintain the integrity of the sample to fulfill the analytical requirements and prevent any potential distillation from occurring (Tetra Tech, 2015a). Supported by other chemical methods (Tetra Tech, 2015a), the sample collected at the Marlin 29-21 WDW is therefore considered to be representative of the Madison Formation water at that location. Evaluation of the geochemical characteristics of groundwater from the Madison Formation at the Marlin 29-21 WDW (Tetra Tech, 2015a) was based solely on results of the Marlin 29-21 WDW.

As discussed earlier (Section 4.0), the most probable flow path in this segment of the basin would originate in the area southeast of the Marlin 29-21 WDW. The conceptual model is for recharge to occur in the Gas Hills area, passing through the region of the Marlin 29-21 WDW with a terminal downgradient location near the Owl Creek fault with the water sampled by these Bighorn wells potentially representing the composition at this deepest point. The change in chemical composition from the Marlin 29-21 WDW to the most concentrated analytical result from the Bighorn wells could be principally from the dissolution of halite and the loss of sulfate by reduction, along with some ion exchange. The other two much more dilute samples were collected later and are much too dilute to reasonably be representative of the Madison. The circumstances of sample collection are not provided, and well treatment water compositions are not known; the extremely low TDS below 500 mg/L may in fact not be representative of formation water and could be the consequence of introduction of fresh water during treatment or completion operations.

The sample collected earliest had a TDS of 1,010 mg/l; this early sample could be interpreted as being within reason for a Madison Formation water composition and could be considered as compatible with evolution from the Marlin 29-21 WDW to the Madden Field. Nevertheless, the change in formation water chemical composition from the Marlin 29-21 WDW to the basin center is not a consideration in the calculation of correction for the ^{14}C age at the Marlin 29-21 WDW. However, it does provide additional support to the assumption that the flow path from the suspected recharge area southeast of the Marlin 29-21 well, and west of the Rattlesnake Hills, through the Marlin 29-21 WDW location, to the Madden Field area, is plausible and the last segment of the potential flow path is somewhat supported by the available chemical analyses.

6.1.2 Data from Groundwater Wells

Assuming that the recharge area is southeast of the Marlin 29-21 WDW, then groundwater composition near that recharge area is required for the geochemical model. Groundwater wells in the Gas Hills and Rattlesnake Hills areas are sparsely distributed, and where present, they are not completed in the Madison Formation but rather in the shallow Wind River Formation which has adequate water for both domestic and stock watering requirements. Surface water on the topographic highs both on the east and west side of the Rattlesnake Hills can recharge the Madison Formation on the crest. Eastern slopes contribute to groundwater flowing east then north into the basin bypassing the Marlin 29-21 WDW, recharge on the western slopes of the Rattlesnake Hills can infiltrate directly into the Madison outcrop or infiltrate further west toward the Gas Hills into the Wind River Formation and older sediments (Figure 3-1; Section 4). Although the Madison Formation is not exposed on the slopes or valley floor in this region, it subcrops against these shallow aquifers; thus, in areas around the Gas Hills region the Madison would be recharged by leakage from the overlying shallow saturated sections (Section 4.2).

The Gas Hills region has been the site of extensive *in-situ* uranium mining and is part of the State of Wyoming Gas Hills Abandoned Mine Land remediation and monitoring project. Several wells have been designated as background wells and the most southerly background well outside the disturbed zone from mining activity is the LA-7 monitoring well (Figure 3-1; Umetco, 2001). The composition of LA-7 is well-established from numerous sampling episodes, and for the purposes of the geochemical modeling, the groundwater in this location is assumed to be representative of the water composition recharging the underlying Madison Formation (Table 4-1). This groundwater is still dilute enough to represent the recharge area with a TDS of 652 mg/L, Cl of 9 mg/L, and SO_4 of 305 mg/L. The elevated sulfate is derived from the Wind River Formation from dissolution of gypsum and potentially oxidation of pyrite. The LA-7 well is located sufficiently upgradient from the disturbed zone where mining activities have occurred that it should be minimally affected if at all by anthropogenic activities.

6.2 Chemical Modeling and Radiocarbon Data

The radiocarbon analyses obtained for the samples collected from the Marlin 29-21 WDW in May 2014 indicated an average uncorrected age of 37,990 years before present (ybp) from two samples (Tetra Tech, 2015a). The objective of this measurement was to determine the time that the DIC in the collected sample has been isolated from the reservoir of ^{14}C of the soil zone in the recharge area, and thus to obtain an approximate time of travel from recharge to the well location. The complicating factor in assessments such as these is that because the analysis for ^{14}C activity is measured per gram of inorganic carbon, it is not reasonable to assume that all of the DIC in the sample was derived from the soil zone in equilibrium with ^{14}C in the soil gas CO_2. DIC can also be derived from several other sources; carbon most often is added to the groundwater by dissolution of carbonate minerals, primarily calcite, but also from other phases (dolomite, siderite, oxidized organic material, etc.). Similarly, inorganic carbon concentration can be lowered by mineral precipitation, loss of carbon dioxide, or methane. The commonly accepted method for correction of measured ^{14}C values in such a manner that they are more representative of the soil-derived carbon is to use the stable carbon isotopic ratio ($\delta^{13}C$) in the carbon sources, assuming it will be different enough for each carbon contributor that it can be used to define the mixing of carbon sources. The correction approach excludes the carbon from other sources and quantifies the actual amount of carbon that originated in the soil, and thus the ^{14}C activity will apply to the carbon that was originally in equilibrium with the ^{14}C reservoir. This corrected value will represent the travel time.

The geochemistry of this process involves a number of dissolution, precipitation, ion exchange, and gas/water reactions, and to solve the equations simultaneously a computer simulation of the process is required. One generally accepted geochemical model for accomplishing this is NETPATH (Parkhurst and Charlton, 2008; Plummer et al., 1994) which was originally written by and is now continually maintained by the USGS. The acquisition and use of this model is unrestricted, it has been peer-reviewed, and the model has been well-accepted and used frequently as evidenced by references in the open literature.

6.2.1 Model Input Assumptions

The process of defining the mineral and gas constituents and the essential reactions which could affect the DIC and thus the evaluation of the true age of the groundwater is referred to generally as inverse geochemical modeling. In this process a final well and an initial well composition are determined for an identified flow path most directly connecting these two wells. It is assumed that the difference in chemical compositions from each well can be attributed to reactions with minerals, gases or mixing with other water sources at locations between the two wells.

In actual experience it has been demonstrated that the major ions in inverse modeling scenarios can be defined by a relatively small number of minerals and carbon dioxide gas or, where appropriate, hydrogen sulfide gas (H_2S) and methane (CH_4). Most aquifers in limestone lithology such as the Madison Formation contain only a few minerals soluble enough to impact the groundwater at ambient pH values and with abundance sufficient to provide the required dissolved ions. Minerals such as calcite, dolomite, siderite, strontianite, and pyrite are common, as are minor clay minerals, quartz, and oxyhydroxides of iron and manganese. The clay minerals provide a substrate for ion exchange, but the solubility of these minerals is relatively low in the aquifer itself, and dissolution of the clay minerals was not considered for this evaluation. Similarly, other silica phases are not important in this system for DIC considerations primarily because of slow dissolution in this pH environment.

Organic carbon distributed in the carbonate can be oxidized to carbon dioxide, which enters the water as carbonic acid and remains so or can react with minerals in the aquifer especially dolomite and calcite. Although the Madison Formation is not at the surface in the recharge area, the shallow soil zone and shallow groundwater are in sediments of the Wind River Formation that overlie the Madison. The modeling of recharge through these sediments into intervening sediments of Mesozoic and late Paleozoic age then into the limestone of the Madison Formation still only requires the inclusion of a minimal number of common minerals. The phases important to the geochemical modeling are predominantly minerals such as calcite, dolomite, anhydrite, and the presence of sulfide minerals such as pyrite. Furthermore, minerals that contribute only trace constituents to the water that do not alter the DIC are not relevant to the correction calculations examined here.

Numerous early studies concluded that a mineral suite such as that shown in Table 6-1 is sufficient for performing inverse modeling or the ^{14}C correction (Pearson and White, 1967; Plummer, 1977; Chapelle and Knobel, 1985; Plummer et al., 1990; Busby et al., 1991), and the use of geochemical models to solve the required equations is now a common practice. The basis for the confidence that the correct mineral and reaction equations have been employed is that the mass required to match the change in composition between the initial well and final well must be derived from the selected phases and gases; these components are expected to be present along the flow path, with correct and acceptable stoichiometry.

There are other constraints that further restrict the number and type of reactions that are possible. First is the thermodynamic requirement that mineral dissolution will not occur unless the solution is undersaturated with that particular phase, and likewise precipitation requires supersaturation, and this degree of saturation is evaluated in the geochemical model. Secondly, the stable isotope value ($\delta^{13}C$) of each carbon source can serve as an identification of the presence and potentially the percentage of that source in the dissolved carbon reservoir. For example, carbon that is derived from soil carbon dioxide has a different $\delta^{13}C$ than that of carbonate carbon derived from carbonate minerals. NETPATH is given the selected minerals and gases, the isotopic content, and the chemical and isotopic analyses for the bounding wells; from this the model examines all possible reaction combinations that satisfy the needed mass change between wells and reports each as a "model" that is a possible "reaction pathway."

There may be many possible models that are solutions, and the objective is to use the constraints or improve the mass balance calculation to narrow the number of models to the most plausible set. The use of constraints is done by examining the computed saturation state provided by NETPATH for each of the reactive minerals and by comparing the computed $\delta^{13}C$ value for the final well to the measured $\delta^{13}C$ for the well. If the mass transfer violates a saturation state requirement it must be eliminated; similarly, the $\delta^{13}C$ match between computed and measured values has been conventionally been attainable for a successful model to within one or two per mil for the final well DIC.

6.2.2 Geochemical Model Results

The reactants considered in the model are listed in Table 6-1; the phases considered here are assumed to have the commonly accepted stoichiometry, and minor impurities, solid solution and co-precipitation of other phases are not considered. For example, the calcite ideal composition is $CaCO_3$; although some small percentage of $MgCO_3$ or $FeCO_3$ may be present, the molar fraction of these phases in calcite would be too small to impact the calculations done for these purposes. The initial well is the well closest to the area of recharge and is defined as the recharge well. This well composition is defined by the LA-7 monitoring well described in Section 4.2 and Table 4.3. The final well is the Marlin 29-21 WDW (Table 4-3).

The mass balance method is the process selected for computing the adjusted value of ^{14}C at the Marlin 29-21 WDW (Parkhurst and Charlton, 2008), which is the most useful approach when only a limited number of wells are available with the required water compositions. In addition to the water composition of the initial and final well, the conditions of the typical soil environment are included to establish the beginning point for ^{14}C and $\delta^{13}C$ of the soil carbon dioxide, and the carbonate minerals. The reactants are pure water, soil $CO_{2(g)}$ with an initial ^{14}C of 100% modern carbon (pmc), a $\delta^{13}C$ of -25 ‰ derived from vegetative decay, and carbonate phases of calcite and dolomite with $\delta^{13}C$ of 0 ‰. Water composition in the Madison Formation evolves by reaction with the predominant minerals of calcite, dolomite, anhydrite, halite, and sylvite, which provide a source for Ca, K, Mg, Na, Cl, HCO_3, and SO_4, and ion exchange reactions with clay minerals are allowed. No measurements for the $\delta^{13}C$ of calcite and dolomite are available for this specific flow path, but regional studies provide a range of values for dolomite from $\delta^{13}C$ of +2 to +7.5 ‰ (Budai et al., 1987; Katz et al., 2006). Two values were selected for $\delta^{13}C$ values +4 ‰ and +7 ‰ for dolomite as reasonable ranges that bound the majority of expected values.

Additionally, the value for the $\delta^{34}S$ of anhydrite present in the Madison along this flow path is also not known, but values published by Claypool et al. (1980) for the early to late Mississippian Formations range from 25 ‰ to 15 ‰; whereas modeled values for the Madison by Plummer et al. (1990) for east central Wyoming are from 7.9 to 8.3 ‰, and core analyses from northeast Wyoming range from 10.2 to 13.3 ‰ (Plummer et al. 1990). The measured $\delta^{34}S$ in the Marlin 29-21 well is 9.0 ‰ which is in the range of published values; this suggests the sulfate in the 29-21 WDW was derived from dissolution of anhydrite.

The results in Table 6-1 provide the model output for the amount of mass transfer occurring from reactions which account for the changes observed from water recharging into a soil zone, passing through the LA-7 well (initial well), and ending at the Marlin 29-21 WDW (final well). Table 6-1 lists the mass of each phase that could dissolve (+) or precipitate (-) for two specific models that match the final composition. The thermodynamic constraints were checked and at LA-7 both dolomite and anhydrite are undersaturated and can dissolve, and at the Marlin 29-21 well the water is essentially at equilibrium with respect to calcite.

The net changes in water composition from LA-7 to the Marlin 29-21 WDW define the dissolution and precipitation reactions. The sulfate concentration increases between the wells due predominantly to the dissolution of anhydrite. Note that the bicarbonate and magnesium concentrations are higher in the recharge well and as a consequence these concentrations must diminish. Carbon is lost by a net calcite precipitation and also by a loss of CO_2. Early in the flow path dolomite and calcite dissolve because the water is undersaturated with respect to these minerals; carbon dioxide is an important sink for excess carbon since it is lost probably as the result of acid dissolution as pyrite is oxidized. Pyrite oxidation would also add sulfate, and the net effect is increased sulfate and loss of bicarbonate, CO_2, and magnesium. As anhydrite dissolves and Ca increases, the calcite becomes supersaturated and precipitates. It appears that the amount of dolomite that dissolves is small, and this yields a small amount of magnesium which is then eventually lost by ion exchange on the clay mineral surfaces.

Results indicate that the model predicted $\delta^{13}C$ values for the DIC ranging from -1.1 to -0.87 ‰ for the Marlin 29-21 WDW (Table 6-1), which are close enough to the measured value of $\delta^{13}C$ of 0.7 ‰ for DIC in the Marlin 29-21 WDW to be plausible solutions. The overall reaction is one of dedolomitization in which dolomite and anhydrite dissolve and calcite precipitates, accompanied with generation of CO_2 and ion exchange. The oxidation of organic material and the oxidation of pyrite were evaluated as a possibility for altering the composition of sulfate and bicarbonate, but by including organic material or pyrite as reactant phases no mathematical solutions were obtained that yielded results that were acceptable. The resultant models either required the precipitation of organic material, which is improbable, or yielded unacceptably large volumes of calcite mass. No other mineral reactions were needed to explain the evolution of the major ions in the aquifer, nor did any other minerals influence the age correction calculations.

The two models shown in Table 6-1 illustrate the dominant effect that the removal of CO_2 has on the change in composition. Calcium carbonate is dissolved in the soil zone to cause the $\delta^{13}C$ of the water to change significantly, but between the two wells excess CO_2 must be lost to account for the compositional change. Model 1 uses $\delta^{13}C$ of +4 ‰ for dolomite and +4 ‰ for calcite, and -10 ‰ for the CO_2; Model 2 uses $\delta^{13}C$ of +5 ‰ for dolomite and +2 ‰ for calcite, and -15 ‰ for the CO_2. These values represent reasonable conditions and are in the range of published values, and model runs outside these ranges yield poorer fits for predicted $\delta^{13}C$ for the Marlin 29-21 WDW or yield large and unacceptable quantities of either calcite precipitation or of CO_2 loss. The sensitivity to the mineral $\delta^{13}C$ is not significant because so much of the mass of carbon is lost not gained, and thus the effect on age correction is also small.

This geochemical modeling process has identified the plausible amount of carbon derived from the carbonate mineral reactions, the amount of anhydrite dissolved, the CO_2 lost, and the expected ion exchange along the flow path. This allows for a correction of the DIC due to mineral carbon added to the total amount of DIC such that the soil-derived carbon can be quantified. Thus, the percent modern carbon is minimally corrected from a measured average age of 37,990 ybp to a more probable range of adjusted ages from 36,878 to 37,658 ybp (Table 6-1). The geochemical modeling yielded many potential model solutions, but only two yielded a plausible prediction for the observed $\delta^{13}C$ in the Marlin 29-21 WDW and satisfied the thermodynamic and mass precipitation constraints. These become the best estimates of ^{14}C age for travel of the groundwater from recharge location to the Marlin 29-21 WDW (Table 6-1).

Table 6-1 Mass Transfer Models Computed by NETPATH

Phase/Isotope	Model 1	Model 2
anhydrite	3.27	3.27
calcite	-1.87	-1.63
Mg/Na IX	0.82	0.58
K/Na IX	0.48	
$CO_{2(g)}$	-4.3	-4.10
dolomite	0.59	0.36
halite	0.79	0.79
□^{13}C (0.7 ‰)	-0.87 ‰	-1.1 ‰
$^{14}C_{ADJ}$ (37,990 ybp)	36,878 ybp	37,658 ybp

Notes:

1. Mass transfer in units of mmoles
2. ‰ = per mil
3. ybp = years before present
4. Parenthetical values are analyses from the Marlin 29-21 WDW

7.0 SUMMARY AND CONCLUSIONS

- Tetra Tech obtained and reviewed published information including geologic and geophysical reports, seismic cross sections, hydrogeological maps, well logs, water quality reports, location and depth of geologic structures and features in the area.
- Tetra Tech completed an assessment of existing and relevant data to verify and validate its use in development of the site conceptual hydrogeologic model and the injection well performance simulations. These data include: downhole geophysical data evaluated for lithology and hydrogeologic properties; water chemistry for general water quality properties and for understanding groundwater flow within the basin; DST for formation pressure and hydraulic properties; core report for porosity and permeability; and original model input files from Encana for applicability to Tetra Tech's injection model.
- In general, the available data were very sparse within the central portion of the WRB which includes the location of the Marlin 29-21 WDW and our simulation model. A majority of the well data were located near the perimeter of the basin where the Madison Formation is closer to the surface than the deeper portions of the basin.
- Tetra Tech estimated potentiometric head elevations for the Madison and Tensleep aquifers from DST shut-in pressures, water-level elevations in water wells, spring elevations, and constraints of outcrop elevations. The potentiometric surface elevation contours indicate that groundwater flow in both aquifers is from recharge areas along the southern, western and northwestern parts of the WRB toward the central parts of the basin and toward producing oil and gas fields in the central and western parts of the basin. Recharge to the Madison aquifer in the Wind River Basin is estimated to be approximately 35,500 acre-ft. per year. Groundwater discharge is to oil and gas wells which produce water (an average of approximately 3,900 acre-ft. per year) in addition to oil and gas and to areally-distributed seepage upward or downward into adjacent aquitards and aquifers.
- Faults with vertical displacement of 1,000 ft. or more compartmentalize groundwater flow within the Madison aquifer and act as barriers to groundwater flow.
- Upward discharge of groundwater from the Madison aquifer via faults with enhanced vertical permeability is not likely, as investigations have shown that the open fractures of fault breccias in the Madison were subsequently filled by calcite. Additionally, there is no evidence of significant upward discharge of groundwater along the trace of the Owl Creek thrust fault that bounds the structurally deep northern side of the basin.
- Based on potentiometric, geochemical, and aquifer property data, the conceptual flow path deemed most probable for flow of groundwater to the vicinity of the Marlin 29-21 well is from the Madison outcrop area in the Rattlesnake Hills 14 miles southeast of the WDW site directly northwest toward the Marlin 29-21 WDW.
- Tetra Tech sampled formation water for chemical composition and for determining the radiocarbon age. In this report the ^{14}C measurements were adjusted by using a geochemical model NETPATH to account for chemical reactions that involve mass transfer of constituents that affect the interpretation of ^{14}C content for determining actual travel time. These corrections indicate the measured ^{14}C result of 37,990 ybp should be minimally adjusted to a more accurate value of from 36,878 to 37,658 ybp which would represent the travel time from recharge area on the southern edge of the WRB to the Marlin 29-21 WDW location. A more conservative value of 27,000 years was used in travel time assessments because of the uncertainty in groundwater compositions in the

recharge area and the undefined migration pathway from recharge at the land surface to the subcropping Madison aquifer.

- Tetra Tech constructed a regional groundwater flow and transport model using the SWIFT numerical modeling code to simulate pressurization and waste migration from proposed injection operations at the Marlin 29-21 WDW.
- The model includes the Madison Formation (the injection zone) and the overlying Amsden (confining unit) and Tensleep Formations.
- The model covers an area of approximately 1,075 square miles and encompasses recharge areas to the south and discharge areas to the north along the Owl Creek fault zone.
- Structural contour and isopach data were included for each formation/layer in the model (i.e., there are variable elevation and thickness at every grid block in the model).
- The modeling strategy employed in this analysis is based on US EPA Class I hazardous waste injection well standards, which are more stringent and conservative than the standards for a brine disposal well.
- A SRT was conducted at the Marlin 29-21 WDW in the Madison Formation in July 2014. The primary purpose of the SRT was to determine the breakdown pressure of the formation for regulatory agencies.
- To the extent possible, the SWIFT model matched a portion of the SRT before formation fracturing occurred. The permeability used in the model to match that portion of the SRT was 3.5 md, which is consistent with values reported in the literature for the Madison Formation in the WRB.
- Predictive simulations using base-case values for permeability for the Madison Formation (i.e., 3.5 and 8 md) and a reservoir pressure constraint of 9,850 psi (obtained from the SRT) indicate that the maximum average injection rate that can be sustained for the 50 year operational period ranges between approximately 4,500 to 9,900 bpd. These results are consistent with the data obtained from the SRT.
- An injection rate of approximately 19,800 bpd can be achieved if the permeability of the Madison Formation is 17 md. This value, while within the range of permeability values reported for the Madison Formation, is more likely associated with areas of the formation that have higher porosity and/or are at shallower depths.
- The 1 x 10^{-3} normalized concentration contour was used to define the edge of the waste injectate plume representing an increase of 6.9 mg/L, (based on an injectate concentration of 8,000 mg/L and formation water concentration of 1,100 mg/L).
- Simulations were performed on three conductivity values (3.5, 8, and 17 md) as well as a series of sensitivity analyses on key hydraulic parameters affecting waste migration (i.e., porosity, dispersivity, anisotropy, vertical conductivity of the Amsden Formation).
- Long-term simulations (10,000 years) indicate that the waste plume generated from the three base case conductivity values remains contained laterally within the deepest portions of the Madison Formation, even under the most conservative or "worst case" conditions. For the 3.5 md case, the waste plume migrated down-dip approximately 1.7 miles, for the 8 md case, the waste plume migrated down-dip approximately 3.3 miles, and for the 17 md case, the waste plume migrated down-dip approximately 6.8 miles.

- Long-term simulations (10,000 years) indicate that, under the worst-case conditions simulated, the waste plume will not migrate up-dip into areas where the top of the Madison Formation is less than about 12,000 feet below the land surface, nor will it move closer than about 12 miles from the nearest outcrop of the formation.
- Long-term simulations (10,000 years) also indicate that no waste injectate will migrate vertically into the Tensleep Formation under base case conditions or under any of the sensitivity analyses scenarios.

8.0 REFERENCES

Anna, L.O., 1986, Geologic Framework of the Ground-Water System in Jurassic and Cretaceous Rocks in the Northern Great Plains, in Parts of Montana, North Dakota, South Dakota, and Wyoming. U.S. Geological Survey Professional Paper 1402-B. 45 p.

Ayra, A., 1986. Dispersion and reservoir heterogeneity. Ph.D. Dissertation, University of Texas, Austin, TX.

Blackstone, D.L., Jr., 1993. Revised Precambrian basement map of Wyoming: outcrop and structural configuration. *in* Snoke, A.W., J.R. Steidtmann and S.M. Roberts, eds., Geology of Wyoming. Geological Survey of Wyoming Memoir No. 5.

Budai, J.M., K.C. Lohman, and J.L. Wilson, 1987. Dolomitization of the Madison Group, Wyoming and the Utah Overthrust Belt. American Association of Petroleum Geologists Bulletin, 71, pp. 909-924.

BLM, 2020, Final EIS for the Moneta Divide Natural Gas and Oil Development Project, Vol 2, Appendix O: https://eplanning.blm.gov/public_projects/nepa/64352/20013428/250018350/17 MD Final EIS AppendixO.pdf.

Busby, J.F., N. Plummer, R.W. Lee, and B.B. Hanshaw, 1991. Geochemical Evolution of Water in the Madison Aquifer in Parts of Montana, South Dakota, and Wyoming. U.S. Geological Survey Professional Paper 1273-F. 89 p.

Chapelle, F.H. and L.L. Knobel, 1985. Stable carbon isotopes of HCO_3^- in the Aquia aquifer, Maryland: evidence for an isotopically heavy source of CO2. Ground Water, 23, pp. 592-599.

Claypool, G.E., W.T. Holzer, I.R. Kaplan, H. Sakai, and I. Zak, 1980. The age curves of sulfur and oxygen isotopes in marine sulfate and their mutual interpretation. Chemical Geology, 27, 199-260.

Drean, T.A, 2012, Geologic Cross Sections, Wind River Basin, Wyoming, Wyoming State Geological Survey.

Domenico, P.A., and F.W. Schwartz, 1990. Physical and Chemical Hydrogeology, John Wiley and Sons, New York, 824 p.

EPA, 2013. Letter to Mr. Tom Kropatsch, regarding Docket No. 3-2013, Aguifer Exemption Review: Madison Formation, Encana Oil and Gas USA, Inc., Marlin 29-21, API No. 49-013-23374, Fremont County, Wyoming. 4 p.

Freeze, R.A., and J.A. Cherry, 1979. Groundwater, Prentice-Hall, Inc., Englewood Cliffs, NJ, ISBN 0-13-365312-9.

GeoTrans, 2000. Data Input Guide for SWIFT for Windows – The Sandia Waste-Isolation Flow and Transport Model for Fractured Media, Release 2.61

Golden Software, 2002. Surfer 8, Contouring and 3D Surface Mapping for Scientists and Engineers.

Hinckley, B.S., and H.P. Heasler, 1983. Report of Investigations-38, The Geological Survey of Wyoming, RI-38, Plates 1 through 4.

Katz, D.A., G.P. Eberli,, P.K. Swart, and L.B. Smith Jr., 2006. Tectonic-hydrothermal brecciation associated with calcite precipitation and permeability destruction in Mississippian carbonate reservoirs, Montana, and Wyoming. American Association of Petroleum Geologists Bulletin, 90, 1803-1841.

Keefer, W.R., 1970. Structural geology of the Wind River Basin, Wyoming. U.S. Geological Survey Professional Paper 495-D.

Mclaughlin, F., and Y. Ganshin, 2009, West-East Geologic Cross Section, Wyoming Greater Green River Basin. Wyoming State Geological Survey, 2009.

Myers, T., 2013, Comments on Encana Oil and Gas Inc.'s Application for the Madison Aquifer to be Exempt Wyoming Oil and Gas Conservation Commission Docket No. 3-2013, Technical Memorandum Prepared For: Natural Resources Defense Council, Powder River Basin Resource Council, June 12, 2013

Neuman, S.P., (1990). Universal scaling of hydraulic conductivities and dispersivities in geologic media. Water Resources Research, 26(8), 1749-1758.

Parkhurst, D.L., and S.R. Charlton, 2008. NETPAHXL – An EXCEL interface to the program NETPATH. U.S. Geological Survey Techniques and Methods 6-A26.1 p.

Pearson, F.J. and D.E. White, (1967). Carbon 14 ages and flow rates of water in Carrizo Sand, Atascosa County, Texas. Water Resources Research, 3, 251-261.

Peterson, J.A., 1978. Subsurface Geology and Porosity Distribution, Madison Limestone and Underlying Formations, Powder River Basin, Northeastern Wyoming and Southeastern Montana, and Adjacent Areas. U.S. Geological Survey Open-File Report 78-783, 12 p.

Peterson, J.A., 1984. Stratigraphy and sedimentary facies of the Madison Limestone and associated rocks in parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming. U.S. Geological Survey Professional Paper 1273-A.

Plummer, L.N., 1977. Defining reactions and mass transfer in a portion of the Floridan Aquifer. Water Resources Research, 13, 801-812.

Plummer, L.N., J.F. Busby, R.W. Lee, and B.B. Hanshaw, 1990. Geochemical modeling of the Madison Aquifer in parts of Montana, Wyoming, and South Dakota. Water Resources Research, 26, Issue 9, 1981-2014.

Plummer, L.N., E.C. Prestemon, and D.J. Parkhurst, 1994. An interactive code (NETPATH) for modeling NET geochemical reactions along a flow PATH Version 2.0. U.S. Geological Survey Water Resources Investigations Report 94-4169, 130 p.

Power Resources Inc., 1998. Gas Hills Project WDEQ-LQD Permit to Mine Application.

Quillinan, S., J. Rodgers, and D. Copeland, 2012. Geologic Cross Sections Wind/Bighorn River Basin, Wyoming. Wyoming State Geological Survey, Plate VI.

Rahkit, 2006. Hydrodynamics of the Wind River Basin, Wyoming, Rahkit Petroleum Consulting, LTD., 209 p.

Sando, W.J., 196). Madison Limestone (Mississippian), Wind River, Washakie, and Owl Creek Mountains. American Association of Petroleum Geologists Bulletin, 51, 529 – 557.

Sterrett, R.J., March 2012. Review of the United States Environmental Protection Agency DRAFT Report Entitled "Investigation of Ground Water Contamination near Pavillion, Wyoming", Prepared for: Encana Oil & Gas (USA) Inc., 50 p.

Taucher, P., T.T. Bartos, K.E. Clarey, S.A. Quillan, L.L. Hallberg, M.L. Clark, M. Thompson, N. Gribb, B. Worman, and T. Gracias, 2012. Wind/Bighorn River Basin Water Plan Update Groundwater Study Level I (2008-2011) Available Groundwater Determination Technical Memorandum. Laramie, Wyoming State Geological Survey.

Tetra Tech, 2013. Sampling and analysis plan. Prepared for Encana Oil & Gas (USA) Inc.

Tetra Tech, 2015a. Technical report on sampling and analysis of chemical and isotopic content of formation water in the Marlin 29-21 WDW, Fremont County, Wyoming. Prepared for Encana Oil & Gas (USA), Inc.

Tetra Tech, 2015b. Performance and Influence of the Marlin 29-21 Water Disposal Well on the Madison Formation in Fremont County, Wyoming. Prepared for Encana Oil & Gas (USA) Inc. January 27; revised September 22.

Thompson, R.C. and E.A. Erslev, 2009. Two-stage mechanical stratigraphy and extensional fracturing in the Wind River Basin, Wyoming. American Association of Petroleum Geologists Search and Discovery Article #10207.

Thompson, R.C., 2015. Post-Laramide, collapse-related fracturing and associated production; Wind River Basin, Wyoming. The Mountain Geologist, v. 52/4, p. 27-46. http://archives.datapages.com/data/mountain-geologist-rmag/data/052/052004/pdfs/27.pdf.

Thompson, R.C., 2010. Two-stage development of the Wind River Basin, Wyoming: Laramide shortening followed by post-Laramide regional extension, localized backsliding, and arch collapse. Master of Science thesis, Colorado State University.

U.S. Geological Survey, 2012. Summaries of Well Yield, Spring Discharge, and Hydraulic Properties, Wind River and Bighorn Basins, Absaroka Range and Yellowstone Volcanic Area, Wyoming. Plate IX, *in* Taucher, P., T.T. Bartos, K.E. Clarey, S.A. Quillan, L.L. Hallberg, M.L. Clark, M. Thompson, N. Gribb, B. Worman, and T. Gracias, 2012. Wind/Bighorn River Basin Water Plan Update Groundwater Study Level I (2008-2011) Available Groundwater Determination Technical Memorandum. Laramie, Wyoming State Geological Survey. http://waterplan.state.wy.us/plan/bighorn/2010/gw-finalrept/plate_IX.pdf.

Umetco Minerals Corporation, 2001. Final application for alternate concentration limits for Gas Hills, Wyoming. Volume 1.

Ward, D.S., M. Reeves, and L.E. Duda, 1984. Verification and Field Comparison of the Sandia Waste-Isolation Flow and Transport Model (SWIFT), NUREG/CR-3316, SAND83-1154, Sandia National Laboratories, Albuquerque, New Mexico.

Westphal, H, G.P. Eberli, L.B. Smith, G.M. Grammer, and J. Kislak, (2004). Reservoir characterization of the Mississippian Madison Formation, Wind River basin, Wyoming. American Association of Petroleum Geologists Bulletin, 88, no. 4, 405-432.

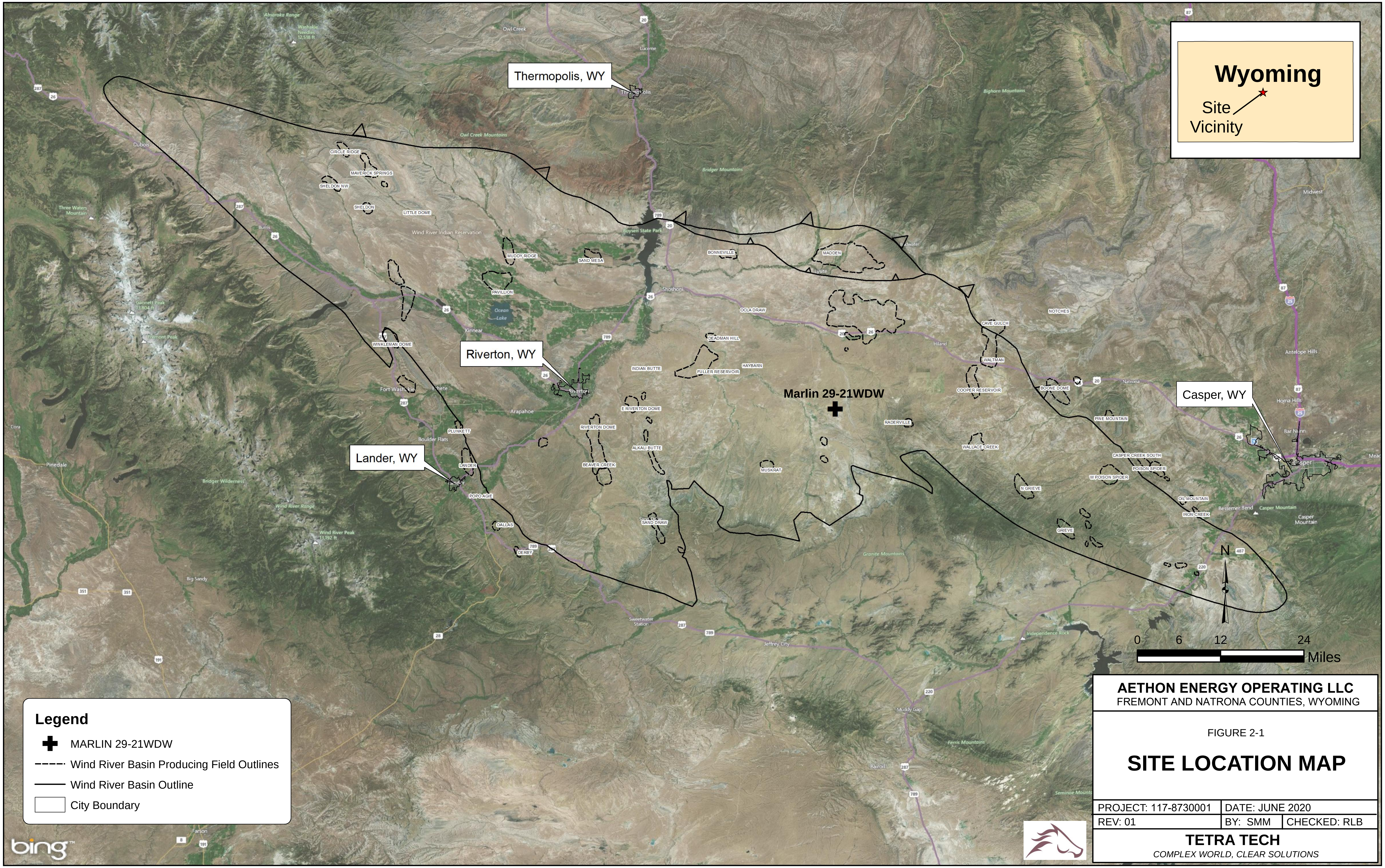
Whitcomb, H.A. and M.E. Lowry, 1968. Ground-water resources and geology of the Wind River Basin area, central Wyoming. U.S. Geological Survey Hydrologic Atlas HA-270.

Wyoming Water Development Office, 2010. Wyoming State Water Plan 2010 Wind/Bighorn River Basin GIS Products website. http://waterplan.state.wy.us/plan/bighorn/2010/gis/gis.html

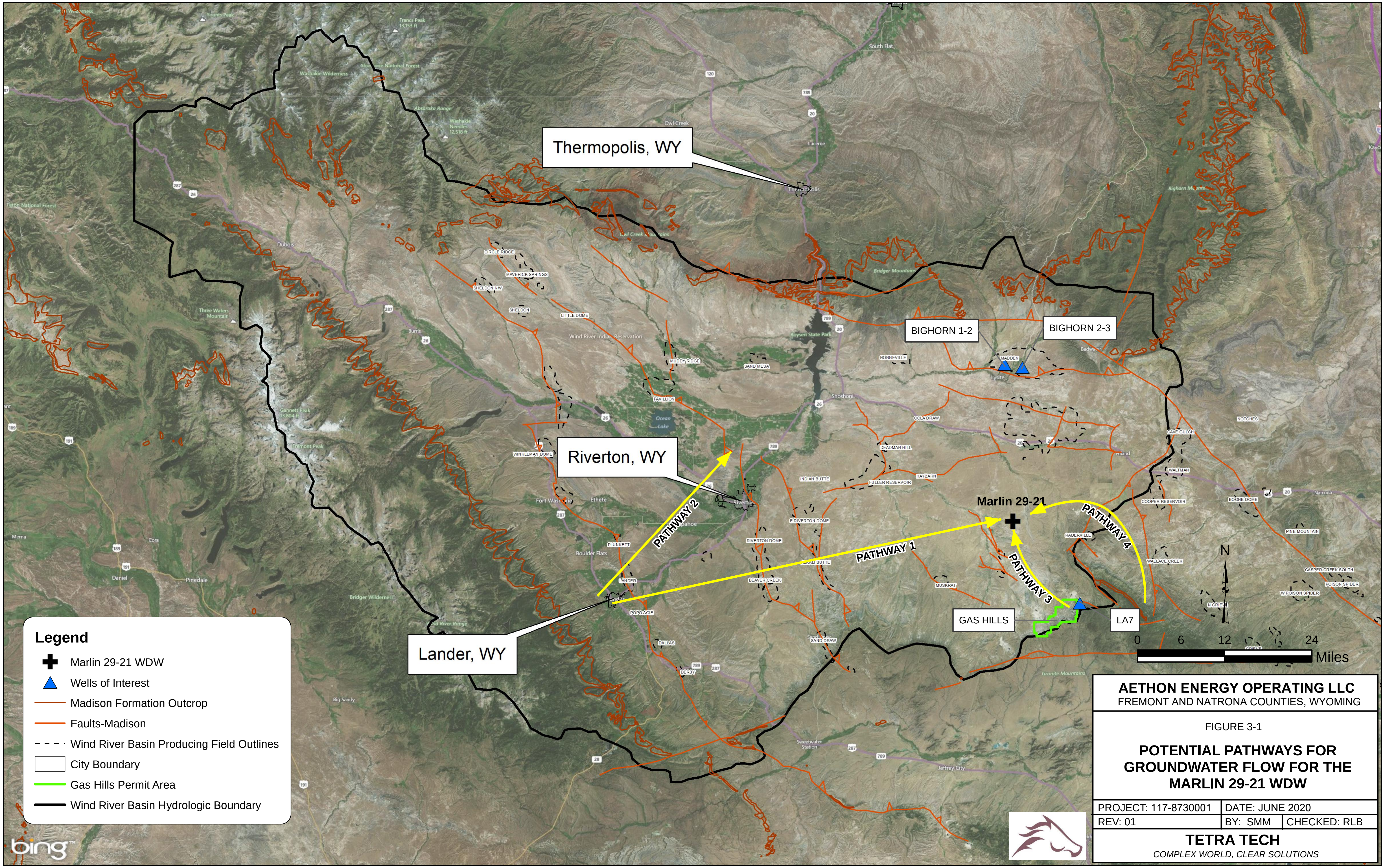
Xu, M., and Y. Eckstein, 1995. Use of weighted least-squares method in evaluation of the relationship between dispersivity and field scale. *Ground Water*, ***33***, 905-908, doi:10.1111/j.1745-6584,1995,tb00035.x.

Yin, P., 2005. Characterization of Tensleep Sandstone Reservoirs. Presented at Rocky Mountain Section AAPG Annual Meeting, Jackson, Wyoming, September 24-26, 2005. Search and Discovery Article #50024.

FIGURES



Wyoming
Site
Vicinity
Thermopolis, WY
Riverton, WY
Lander, WY
Casper, WY
Marlin 29-21WDW
N
0 6 12 24
Miles
Legend
MARLIN 29-21WDW
Wind River Basin Producing Field Outlines
Wind River Basin Outline
City Boundary
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING
FIGURE 2-1
SITE LOCATION MAP
PROJECT: 117-8730001
DATE: JUNE 2020
REV: 01
BY: SMM
CHECKED: RLB
TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS
bing


Thermopolis, WY
Riverton, WY
Lander, WY
BIGHORN 1-2
BIGHORN 2-3
Marlin 29-21
PATHWAY 1
PATHWAY 2
PATHWAY 3
PATHWAY 4
GAS HILLS
LA7
N
0 6 12 24 Miles
Legend
Marlin 29-21 WDW
Wells of Interest
Madison Formation Outcrop
Faults-Madison
Wind River Basin Producing Field Outlines
City Boundary
Gas Hills Permit Area
Wind River Basin Hydrologic Boundary
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING
FIGURE 3-1
POTENTIAL PATHWAYS FOR GROUNDWATER FLOW FOR THE MARLIN 29-21 WDW
PROJECT: 117-8730001
DATE: JUNE 2020
REV: 01
BY: SMM
CHECKED: RLB
TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS
bing

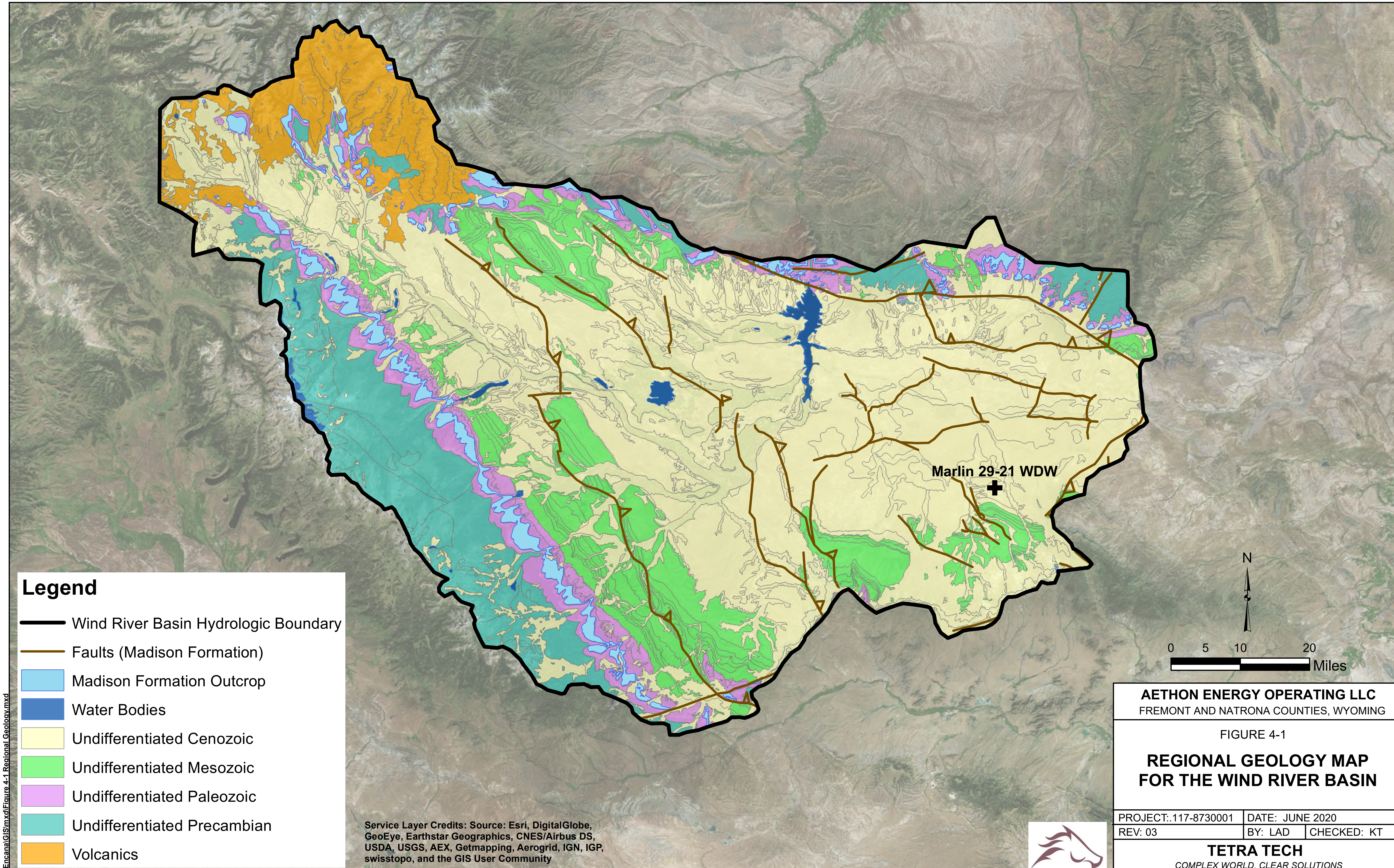
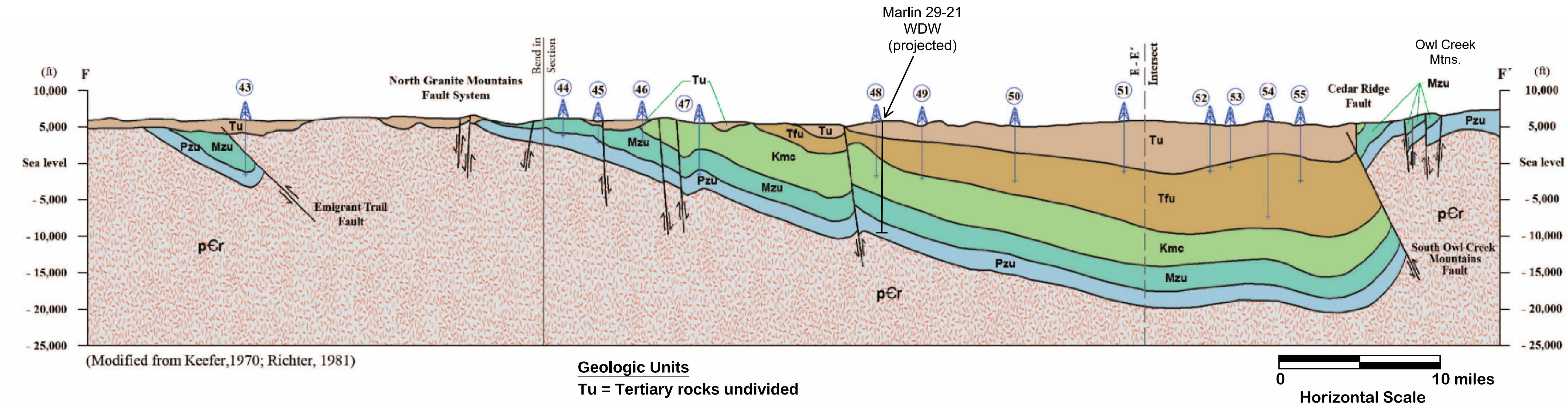


FIGURE 4-1

REGIONAL GEOLOGY MAP FOR THE WIND RIVER BASIN

T:\Encana\GIS\mxd\Figure 4-1 Regional Geology.mxd



Geologic Units

Tu = Tertiary rocks undivided

Tfu = Fort Union Formation

Kmc = Meeteetse and Mesaverde Formations and Cody Shale undivided

Mzu = Mesozoic rocks undivided

Pzu = Paleozoic rocks undivided

pCr = Precambrian igneous and metamorphic rocks

Vertical Exaggeration approx. 2X

AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

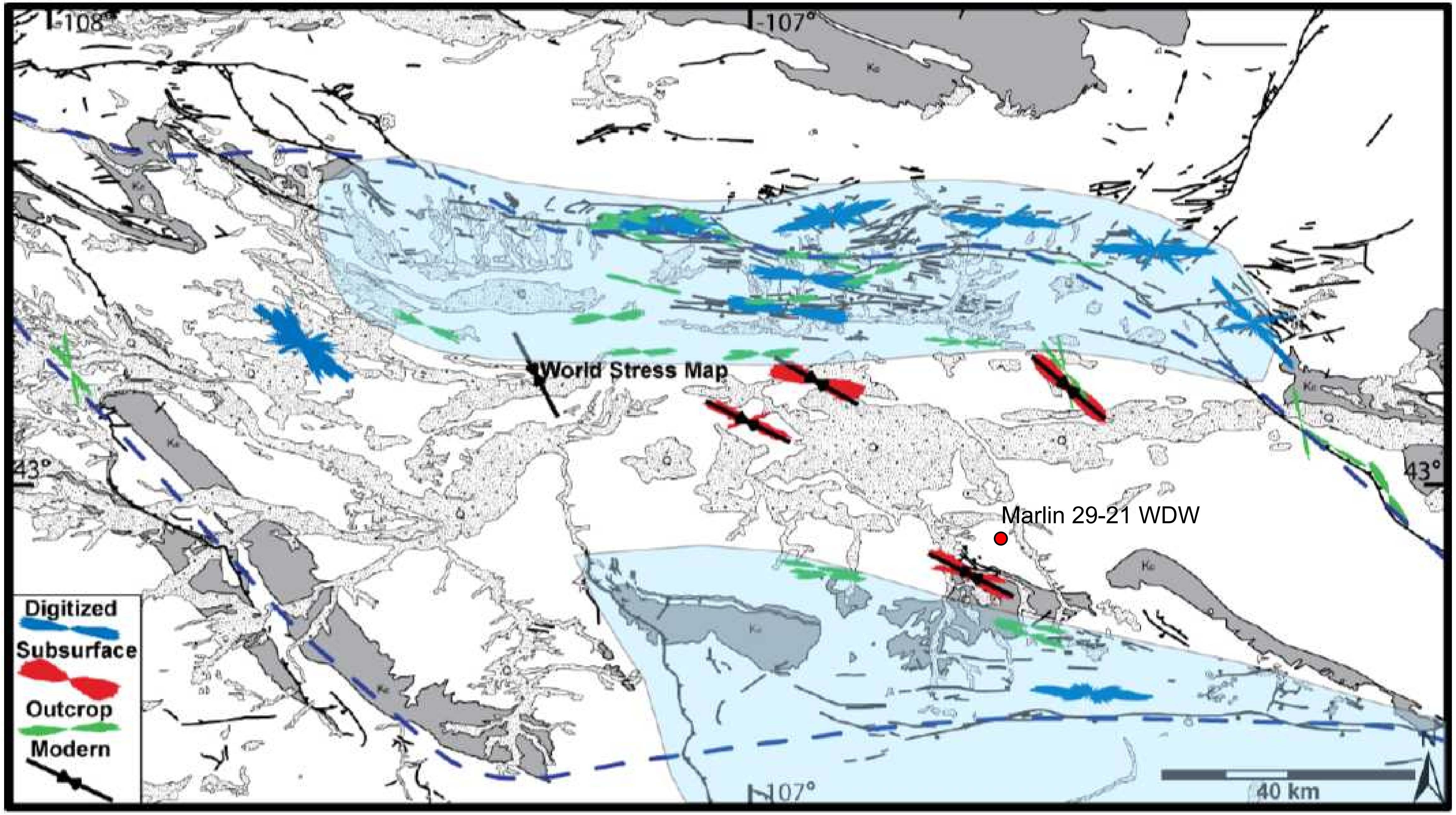
FIGURE 4-2

NORTH-SOUTH SCHEMATIC CROSS SECTION THROUGH EAST-CENTRAL WIND RIVER BASIN

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 01	BY: SMM	CHECKED: RLB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS

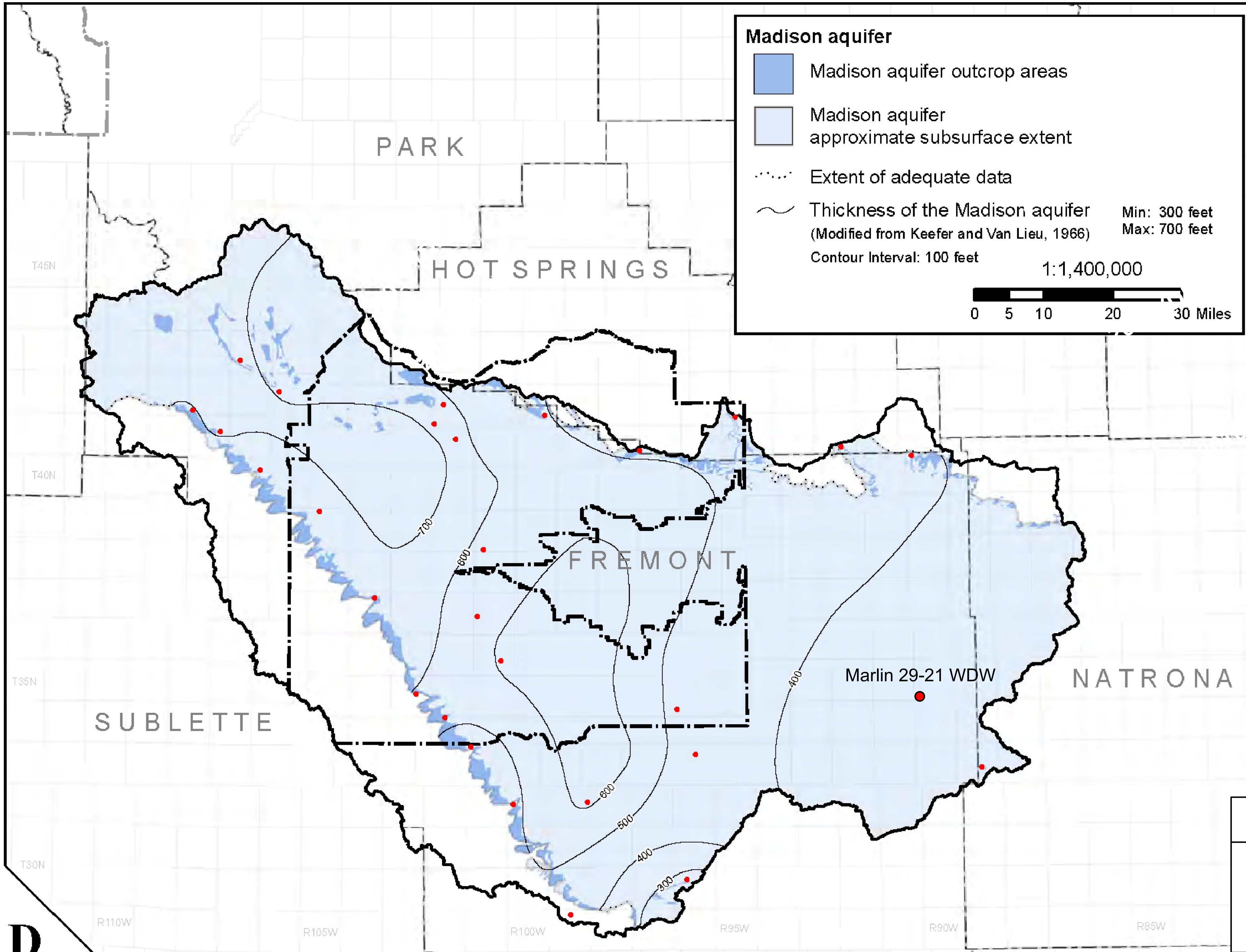
Source: Taucher et al. (2012), Plate VI



Fracture strike rose diagrams, 10° smoothed, digitized faults (blue), subsurface non-induced fractures (red), and outcrop systematic joints and normal faults (green) with modern maximum compressive stress trend (black arrows). Note how fracture strikes parallel the margins of the basin with a northwest-southeast trend and east-west trend (east-west domains highlighted in blue).

Source: Thompson (2010)

AETHON ENERGY OPERATING LLC FREMONT AND NATRONA COUNTIES, WYOMING	
FIGURE 4-3 **FAULT AND FRACTURE ORIENTATIONS IN THE WIND RIVER BASIN**	
PROJECT: 117-8730001	DATE: JUNE 2020
REV: 01	BY: SMM / CHECKED: RLB
TETRA TECH *COMPLEX WORLD, CLEAR SOLUTIONS*	



Source: Taucher et al. (2012)

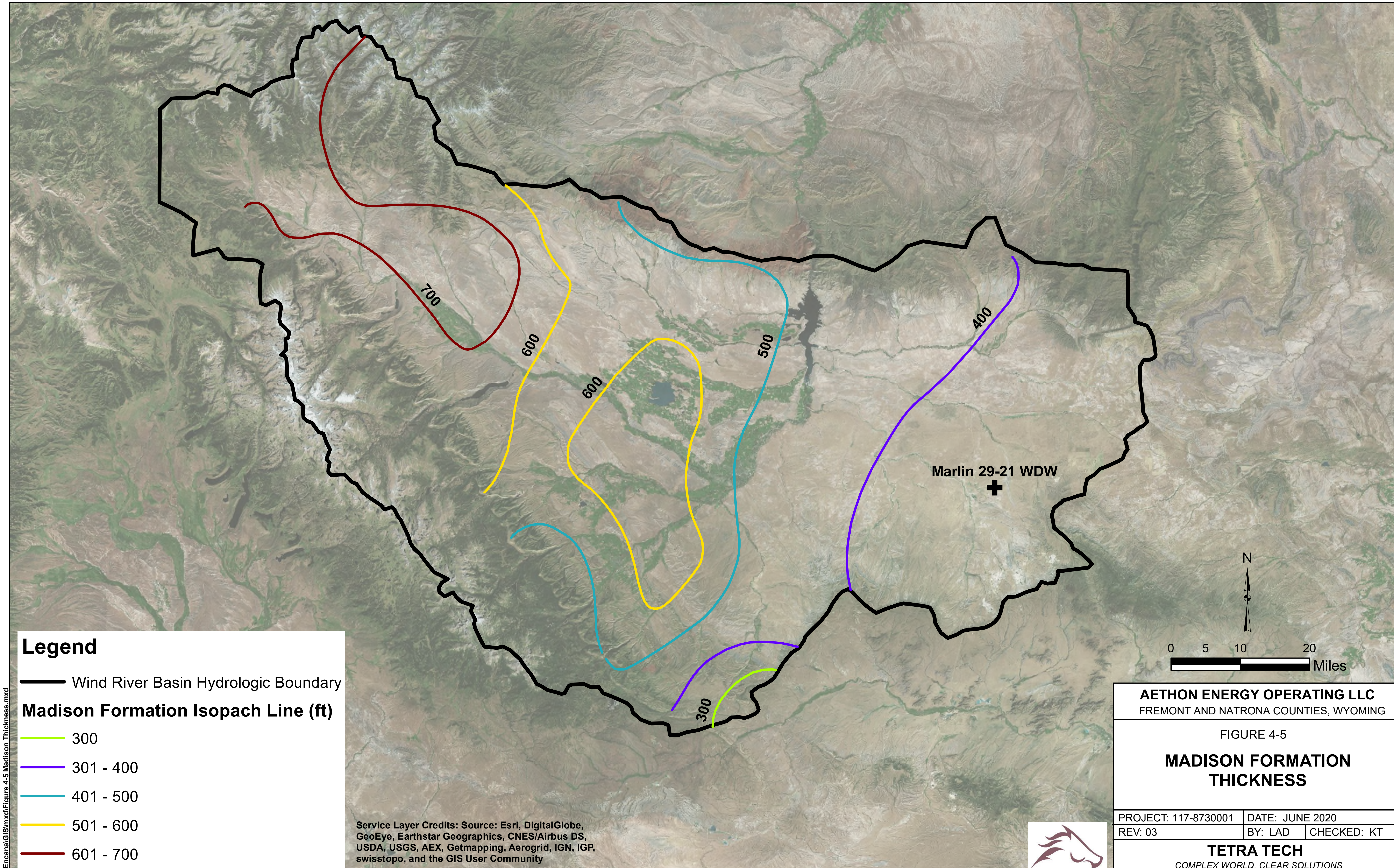
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 4-4

MADISON AQUIFER OUTCROP AREA, SUBSURFACE EXTENT, & THICKNESS IN WIND RIVER BASIN

PROJECT: 117-8730001	DATE: JUNE 2020
REV: 01	BY: SMM / CHECKED: RLB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



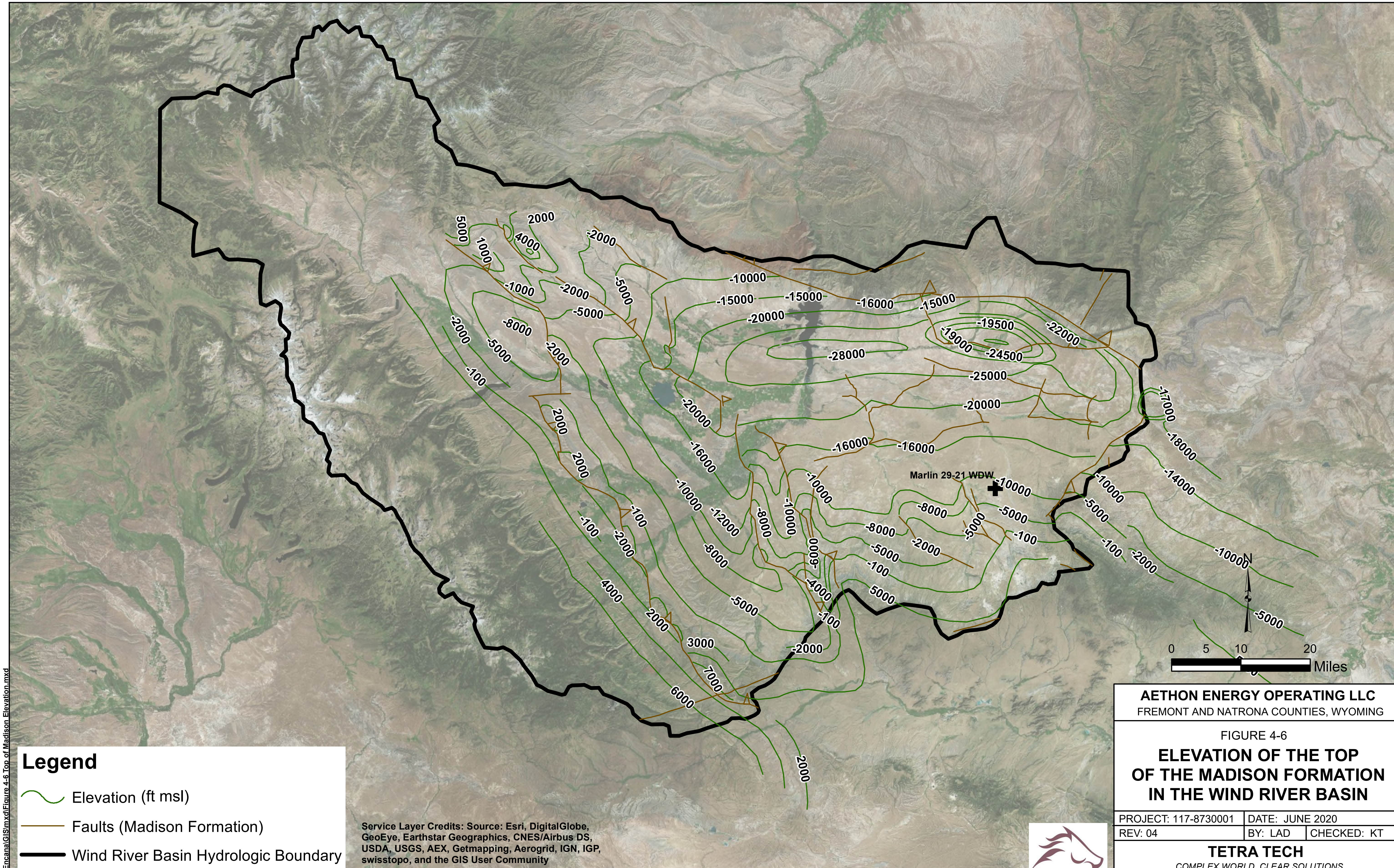
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 4-5

MADISON FORMATION THICKNESS

PROJECT: 117-8730001	DATE: JUNE 2020
REV: 03	BY: LAD / CHECKED: KT

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

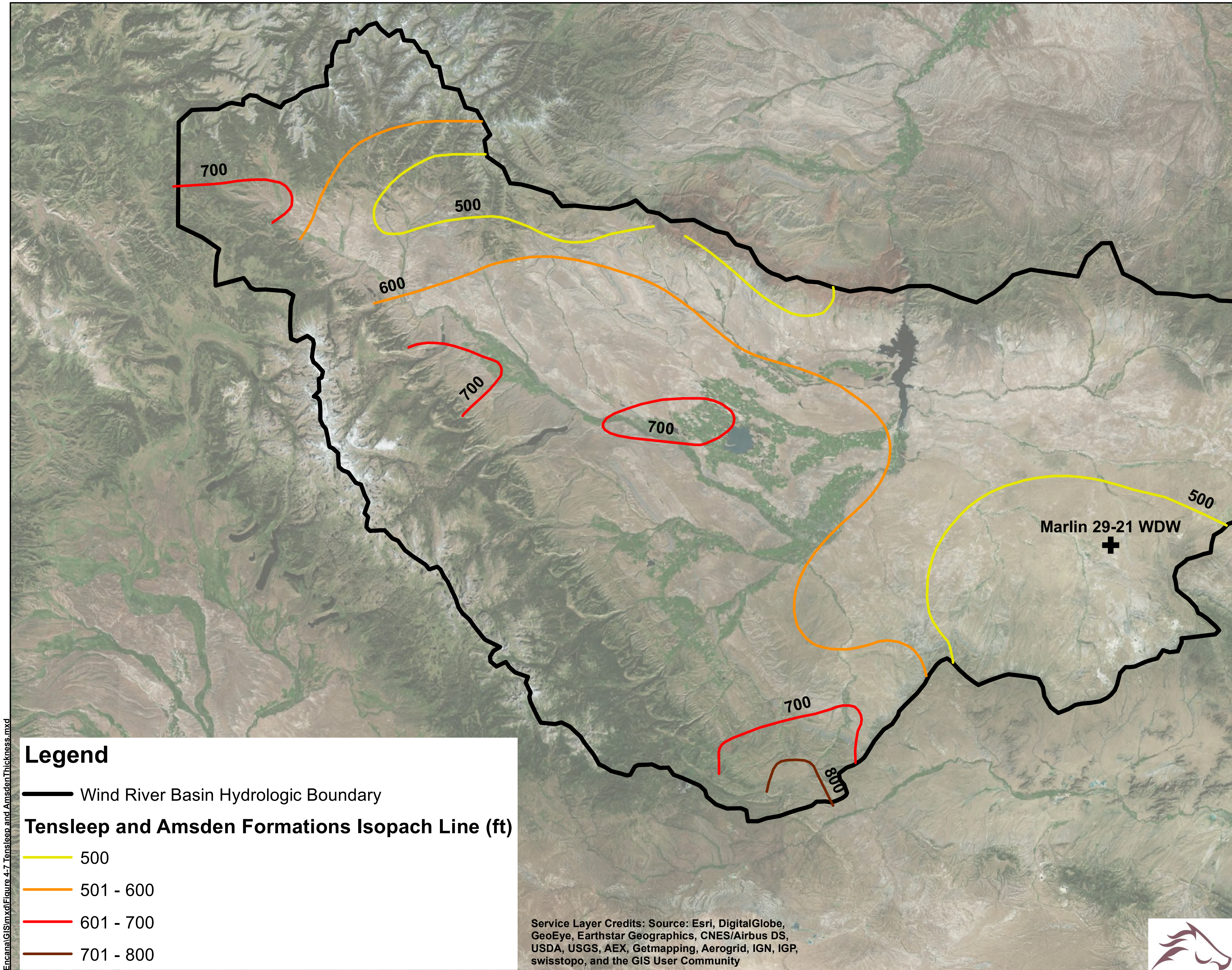
FIGURE 4-6

ELEVATION OF THE TOP OF THE MADISON FORMATION IN THE WIND RIVER BASIN

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 04	BY: LAD	CHECKED: KT

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS

T:\Encana\GIS\mxt\Figure 4-6 Top of Madison Elevation.mxd



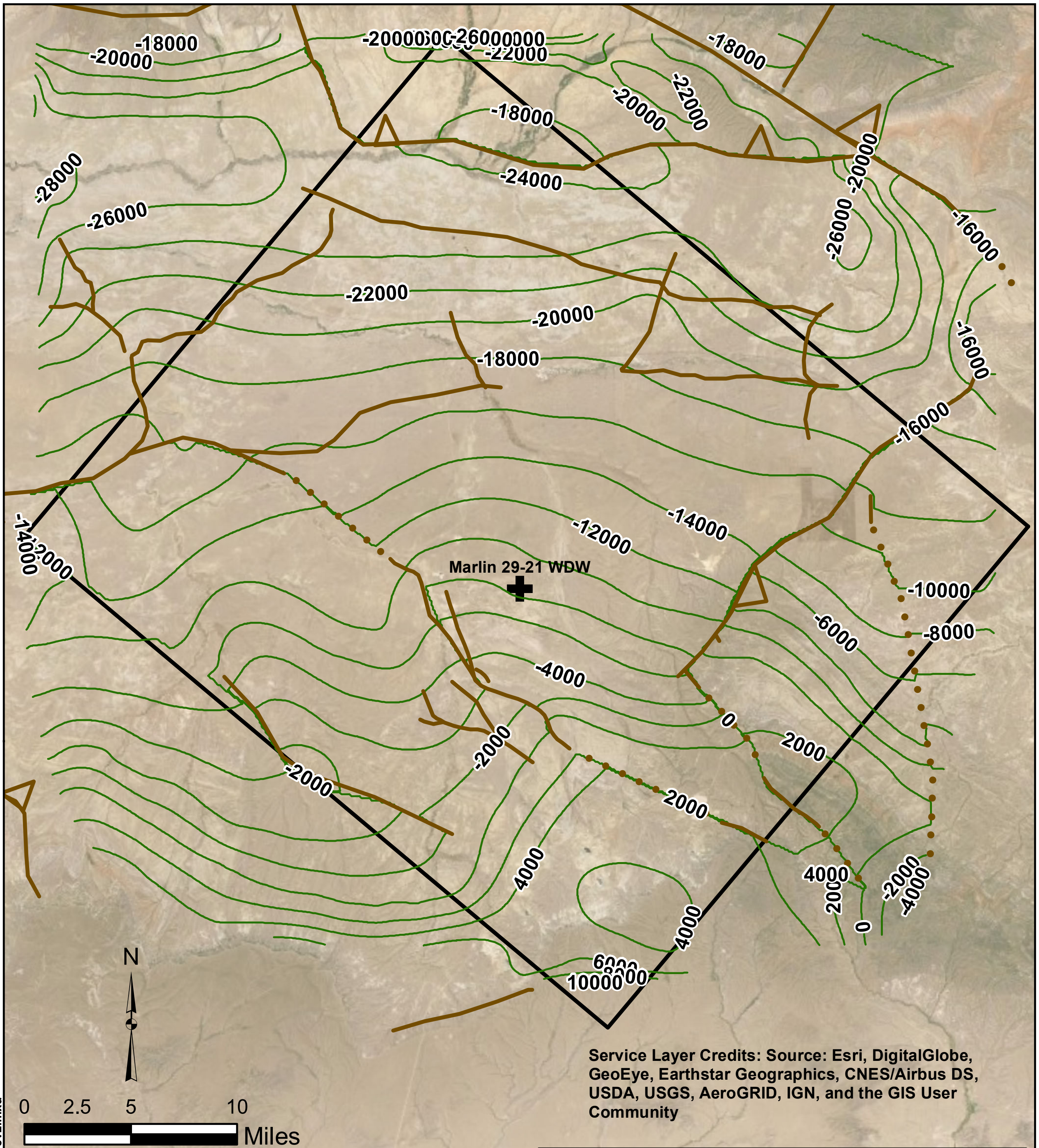
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 4-7
COMBINED TENSLEEP SANDSTONE AND AMSDEN THICKNESS

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: LAD	CHECKED: KT

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS

T:\Encana\GIS\mxd\Figure 4-7 Tensleep and AmsdenThickness.mxd



Legend

Elevation (ft msl)

Model Domain

Faults, Mapped

Faults, Inferred

Note:
Contour Interval = 2000 ft

AETHON ENERGY OPERATING LLC

WIND RIVER BASIN, WYOMING

FIGURE 4-8

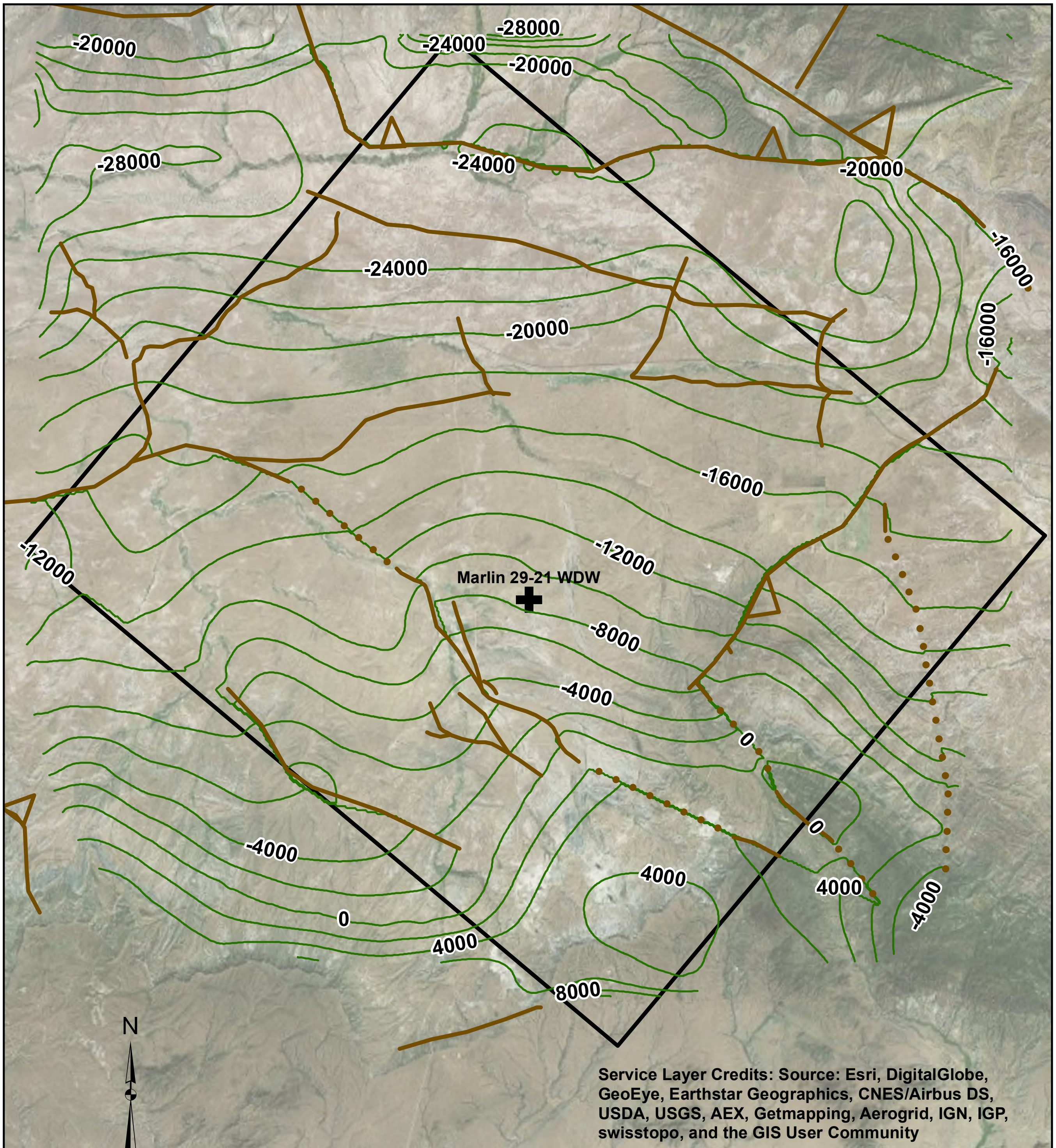
ELEVATION OF THE TOP OF THE TENSLEEP FORMATION

PROJECT: 117-8730001	DATE : JUNE 2020	
REV: 03	BY: LAD	CHECKED: KT

TETRA TECH

COMPLEX WORLD, CLEAR SOLUTIONS

T:\EncanaGIS\mxd\Figure 4-8 Top of Tensleep Elevationrev2.mxd



T:\Encana\GIS\mxd\Figure 4-9 Top of Amsden Elevation.mxd

Legend

- Elevation (ft msl)
- Model Domain
- Faults, Mapped
- Faults, Inferred

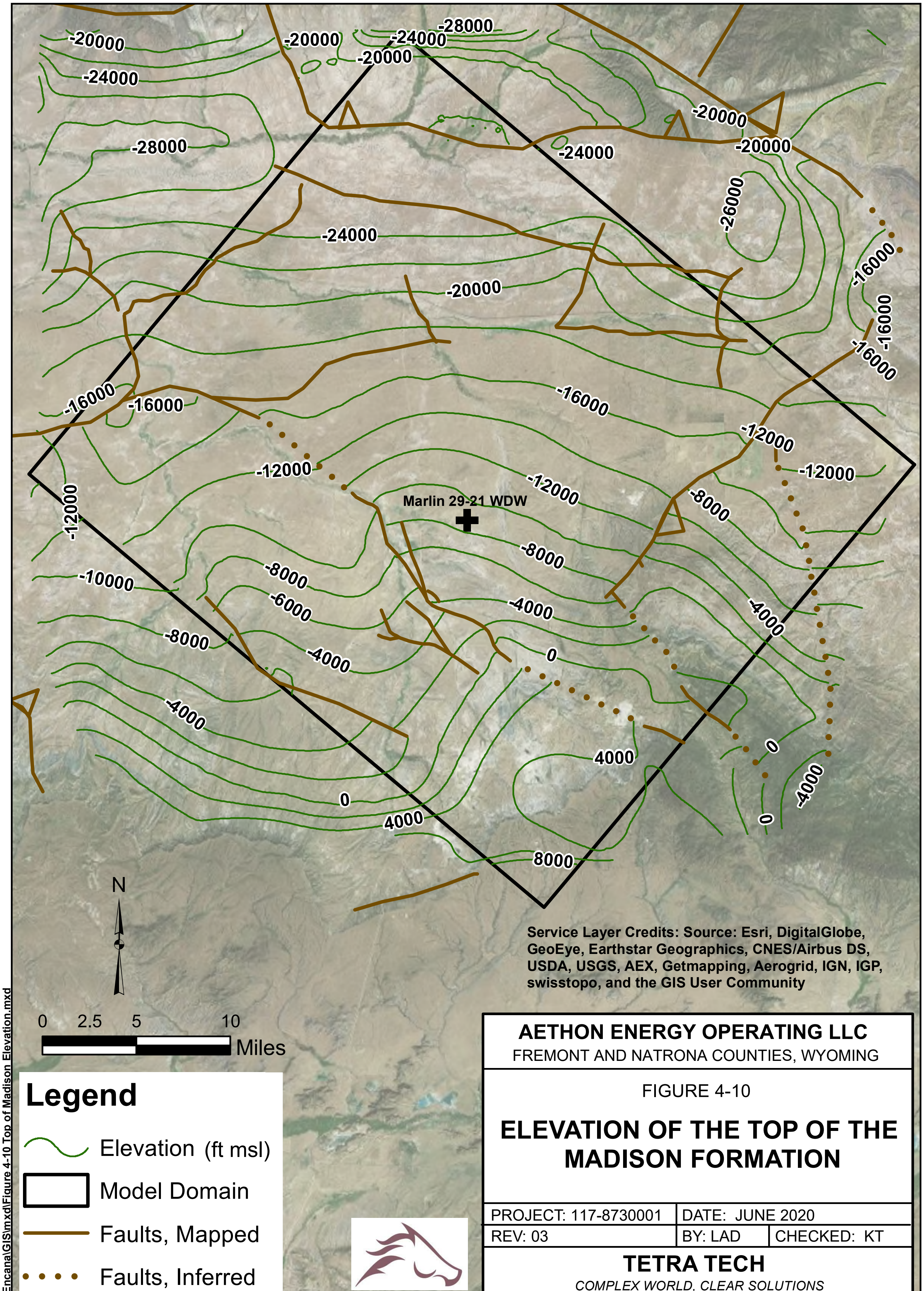
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 4-9

ELEVATION OF THE TOP OF THE AMSDEN FORMATION

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 03	BY: LAD	CHECKED: KT

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

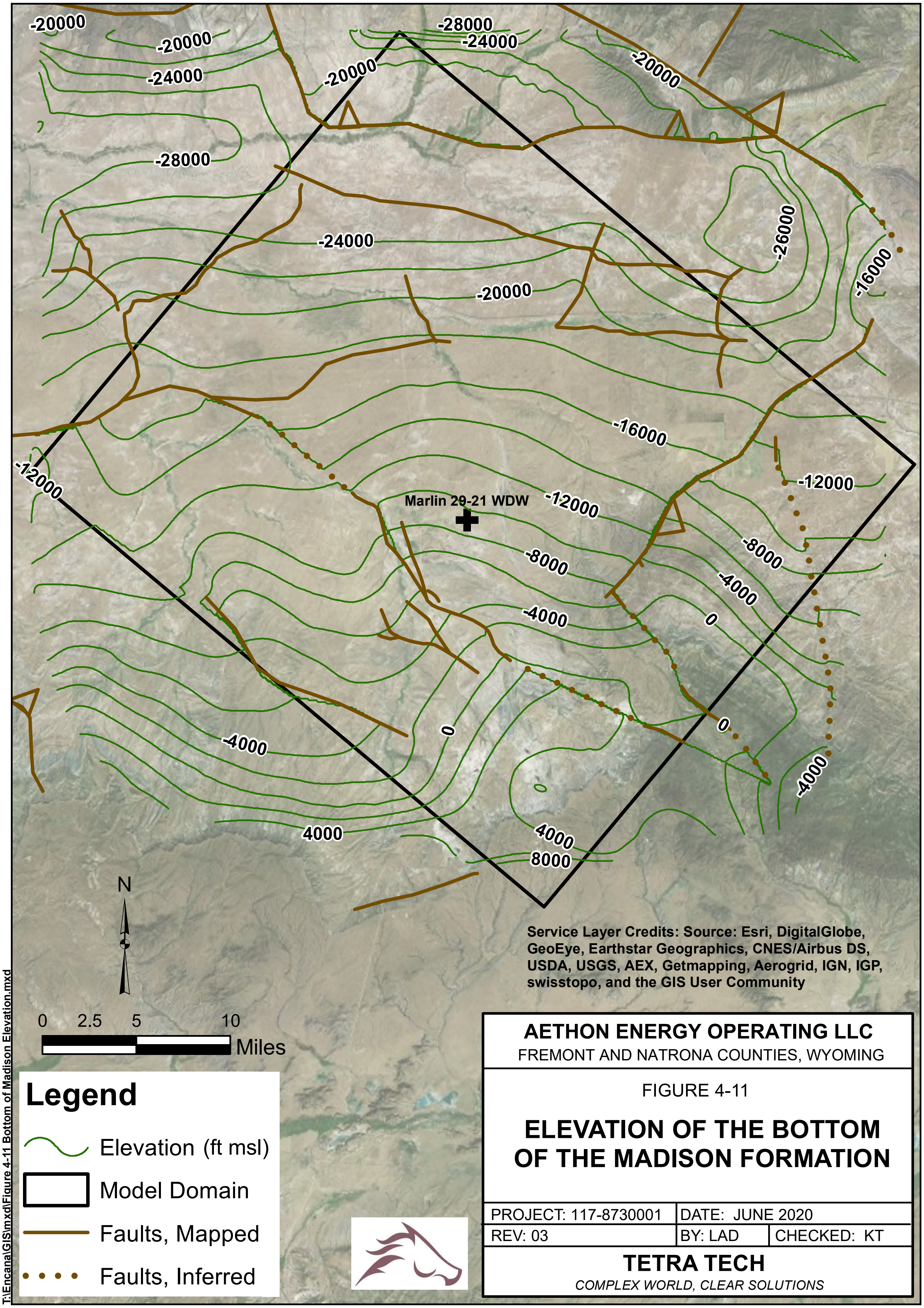
FIGURE 4-10

ELEVATION OF THE TOP OF THE MADISON FORMATION

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 03	BY: LAD	CHECKED: KT

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS

T:\Encana\GIS\mxd\Figure 4-10 Top of Madison Elevation.mxd



AETHON ENERGY OPERATING LLC

FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 4-11

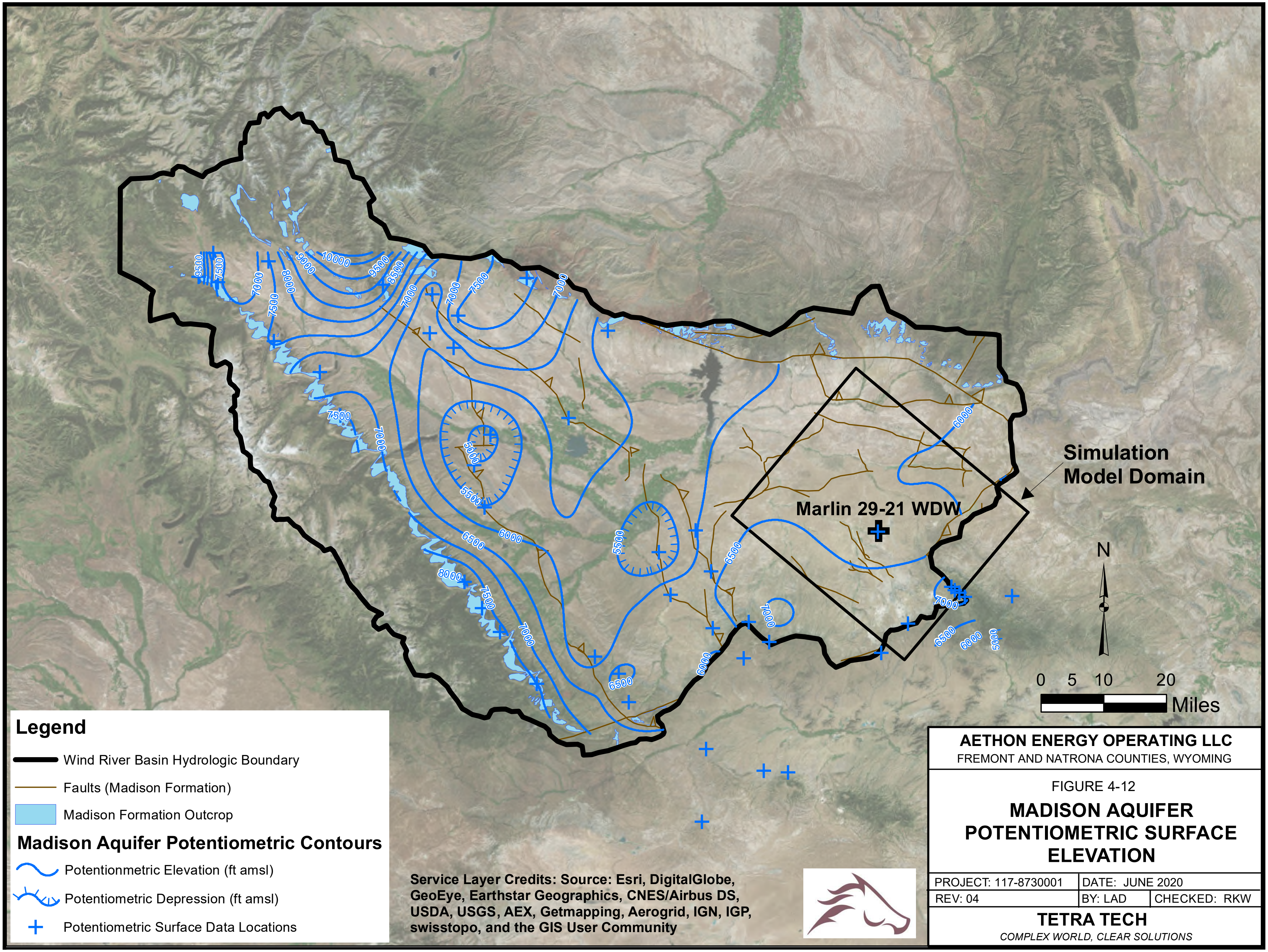
ELEVATION OF THE BOTTOM OF THE MADISON FORMATION

PROJECT: 117-8730001 | DATE: JUNE 2020

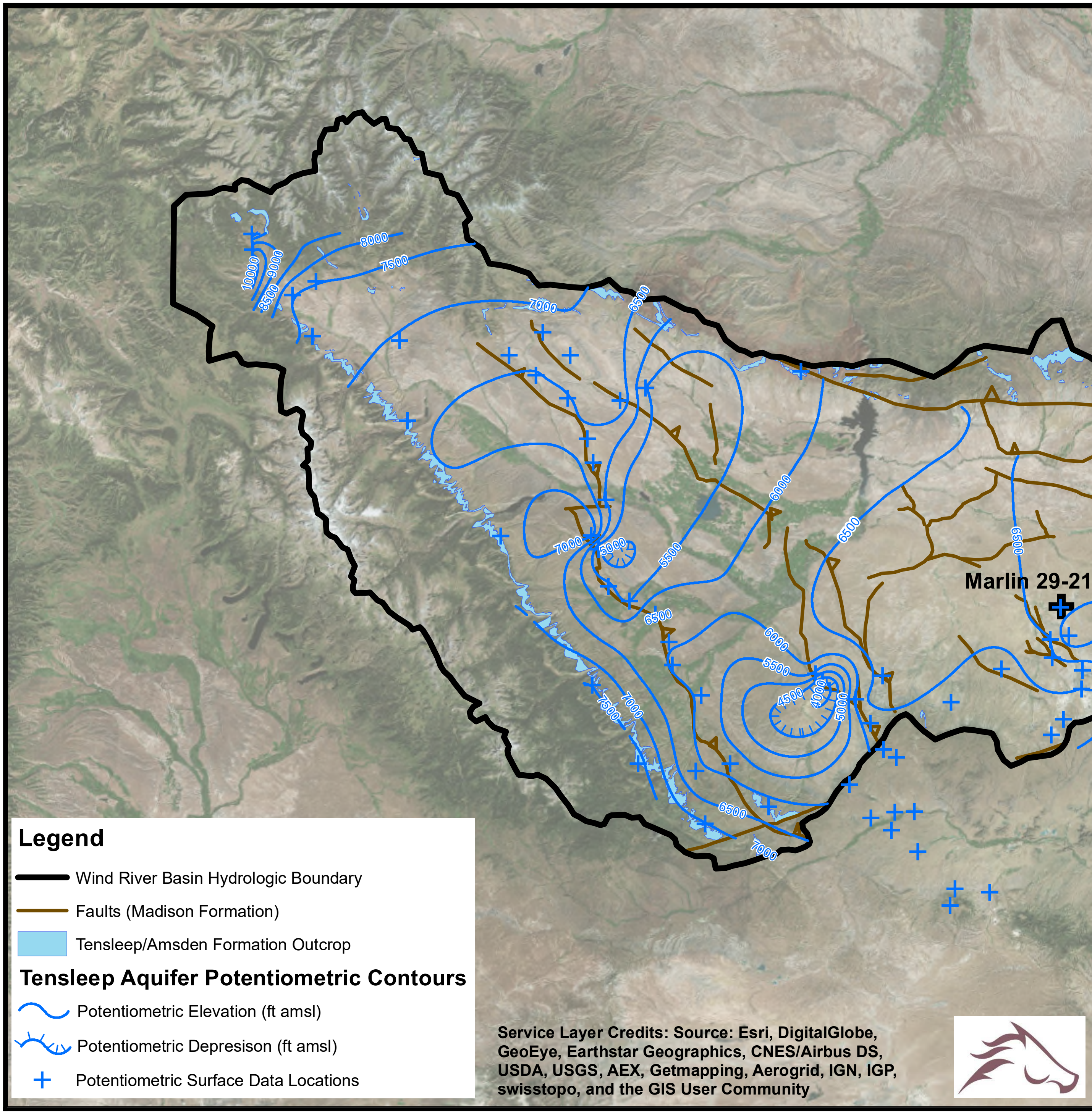
REV: 03 | BY: LAD | CHECKED: KT

TETRA TECH

COMPLEX WORLD, CLEAR SOLUTIONS



T:\Encana\GIS\mxd\Figure 4-12 Madison Aquifer Pot Surf Elevs.mxd



AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

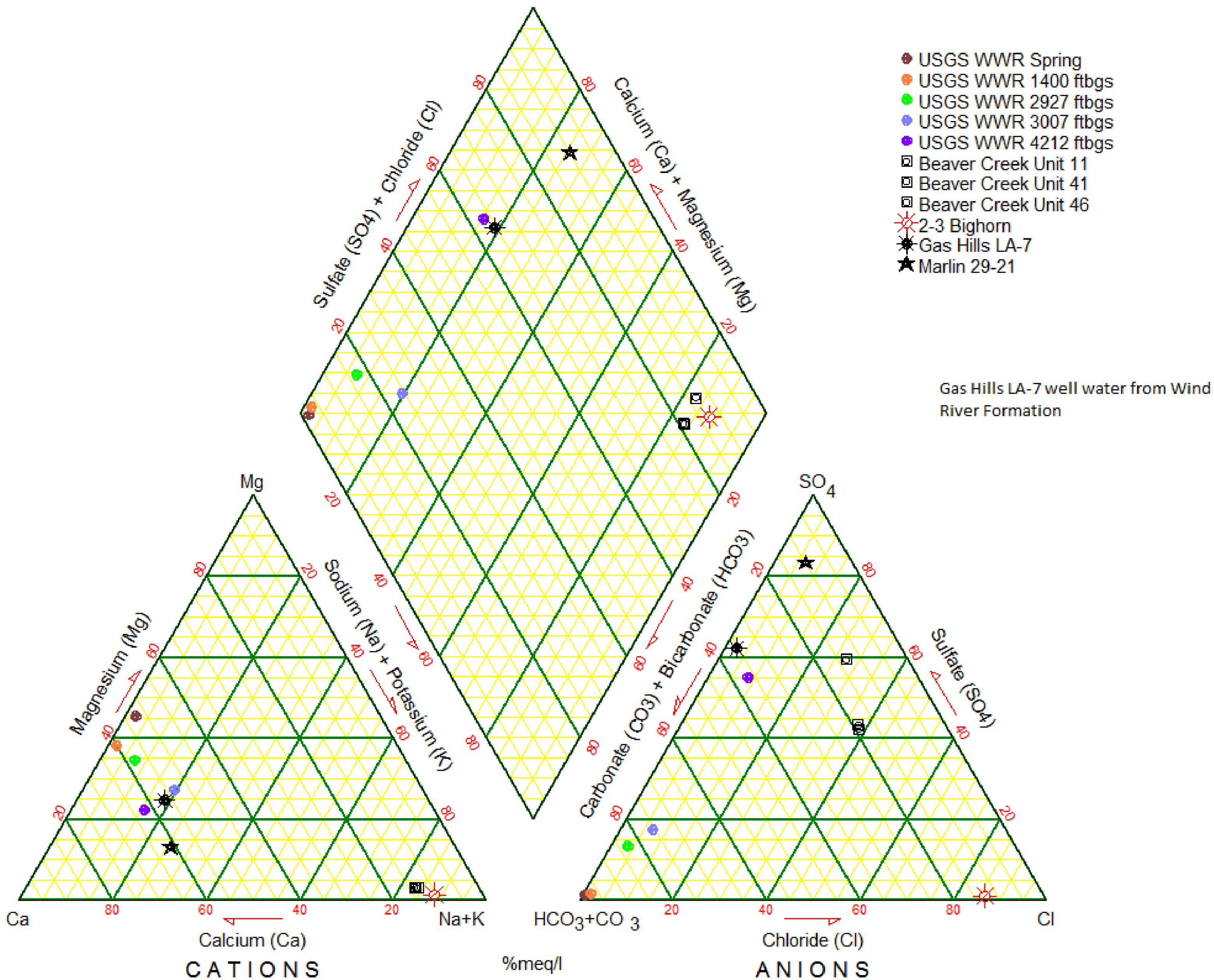
FIGURE 4-13

TENSLEEP AQUIFER POTENTIOMETRIC SURFACE ELEVATION

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 05	BY: LAD	CHECKED: RKW

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS

T:\Encana\GIS\mxd\Figure 4-13 Tensleep Aquifer Pot Surf Elevs.mxd



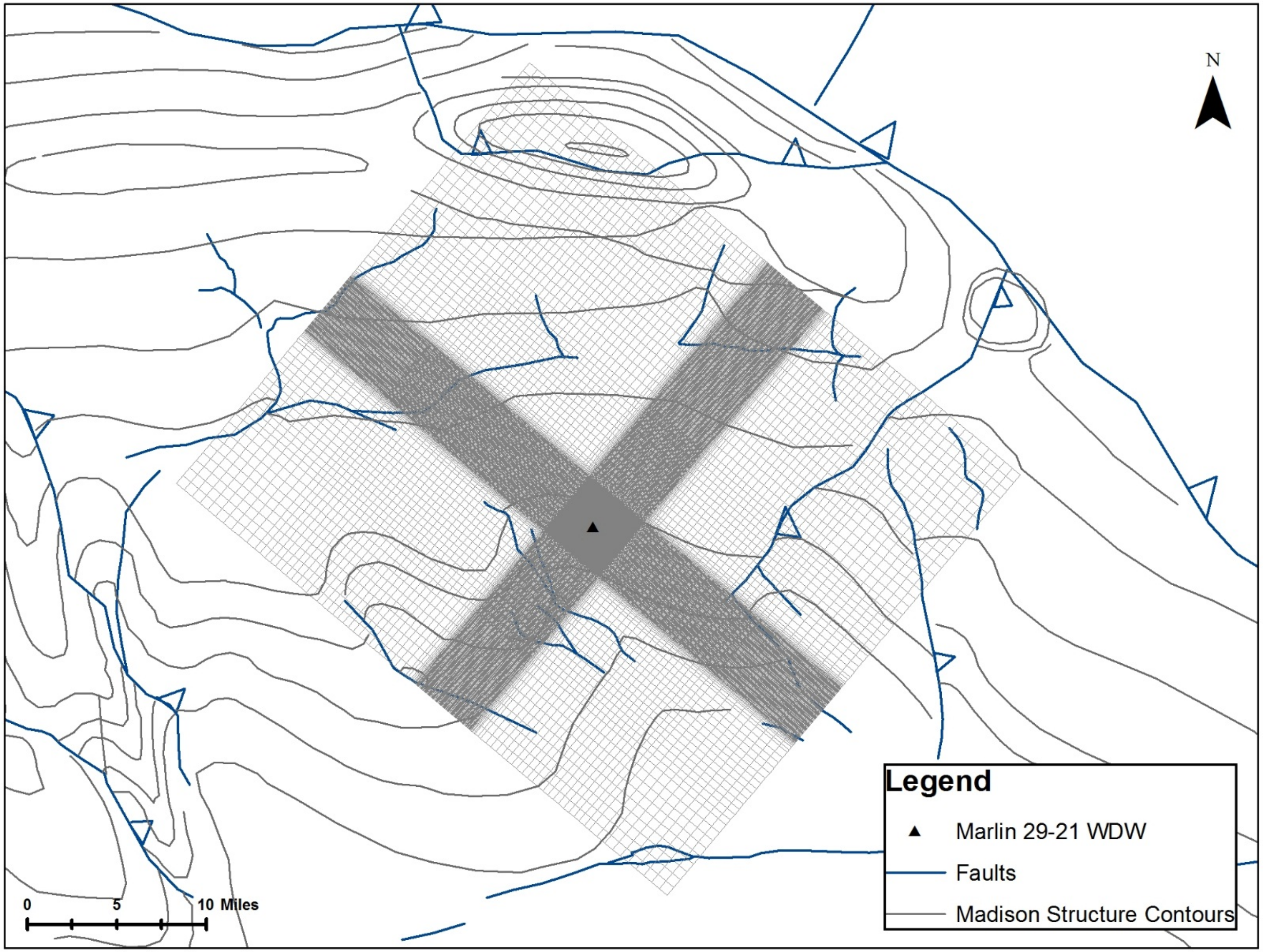
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 4-14

TRILINEAR DIAGRAM DEPICTING CHEMICAL COMPOSITION OF WATER FROM MADISON FORMATION

PROJECT: 117-8730001	DATE: JUNE 2020
REV: 01	BY: SMM / CHECKED: RLB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



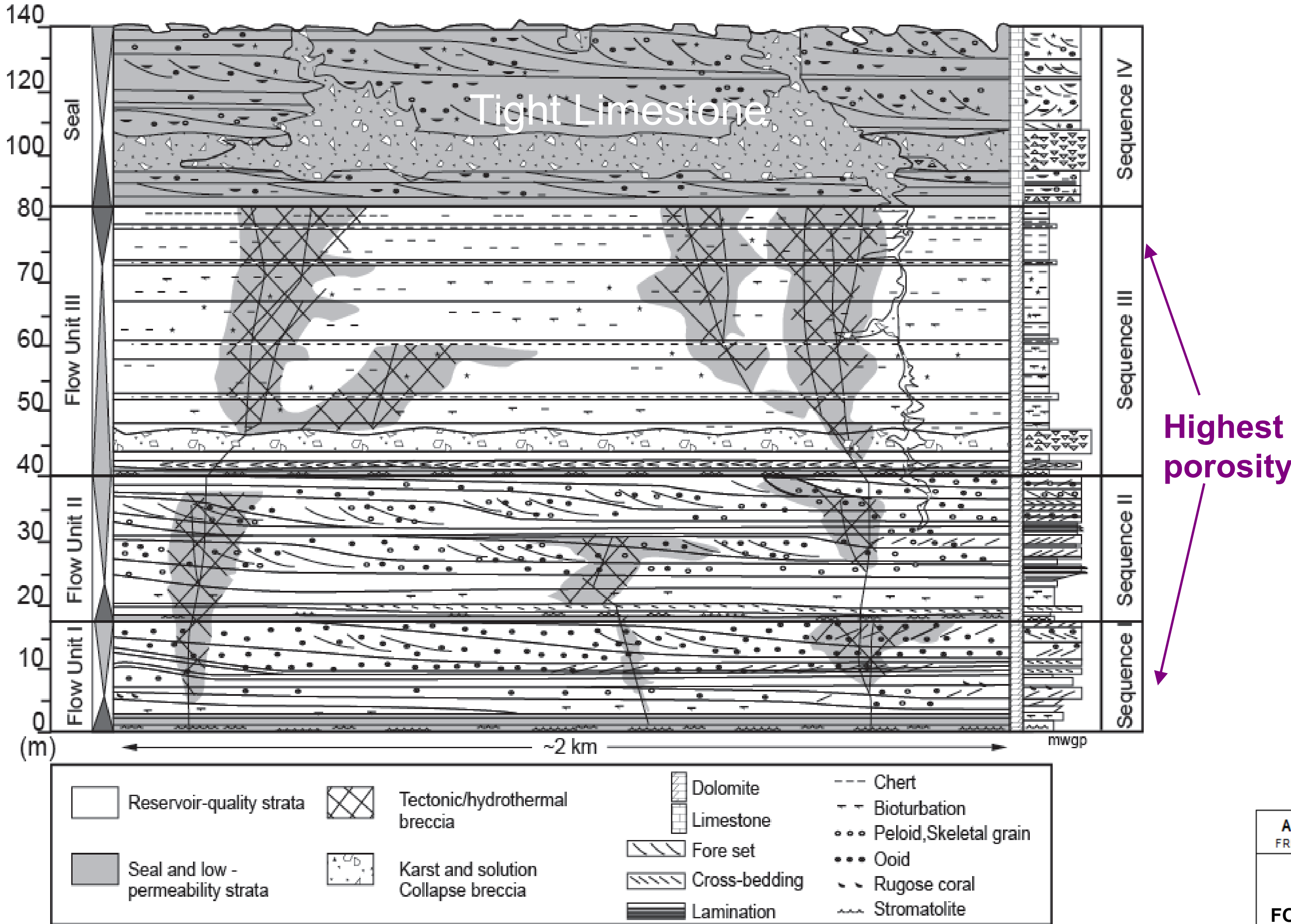
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-1

SWIFT FINITE-DIFFERENCE MODEL GRID

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



After: Westphal, et al. 2004

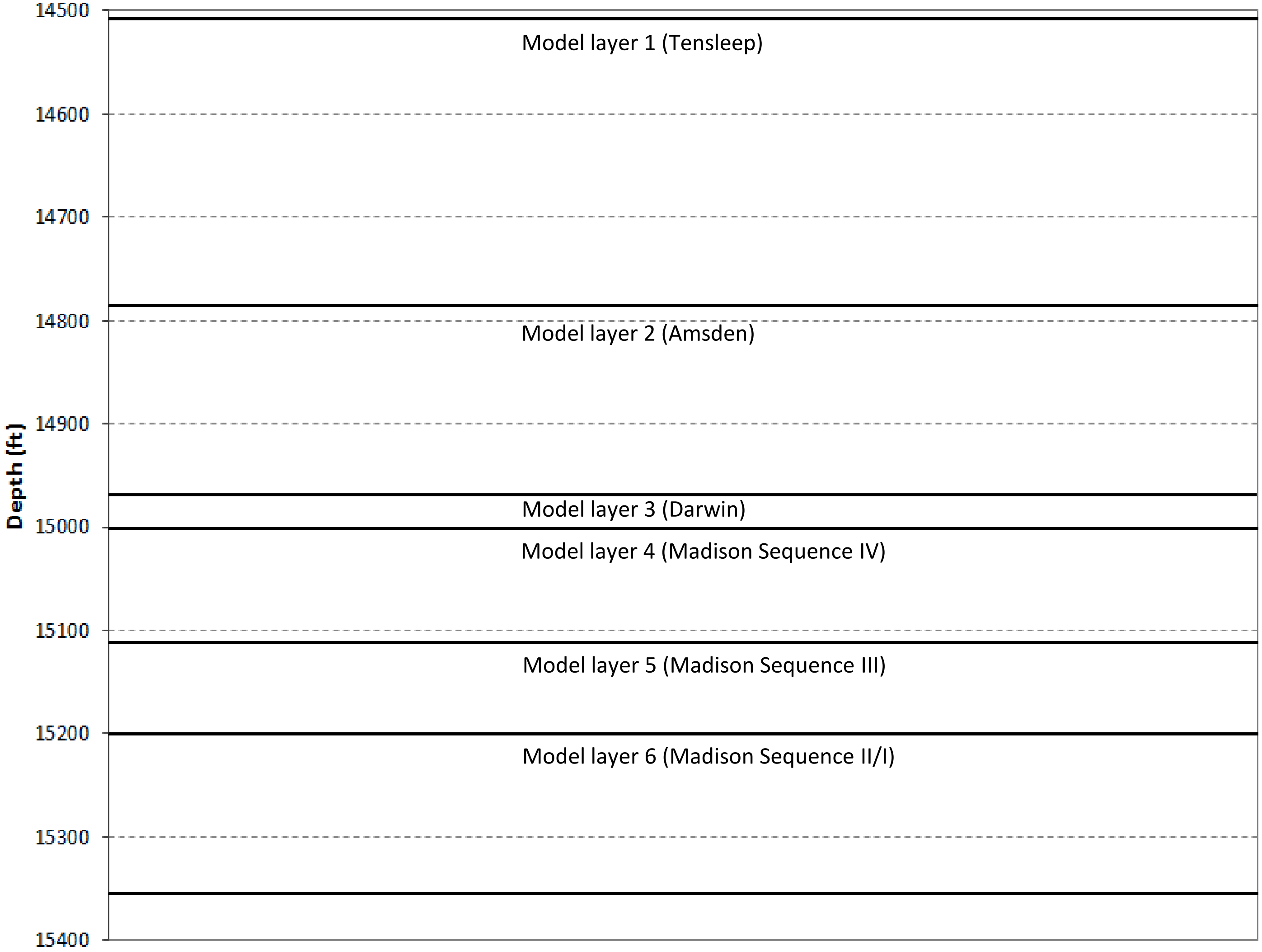
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-2

SCHEMATIC OF MADISON FORMATION STRATIGRAPHY IN THE WIND RIVER BASIN

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



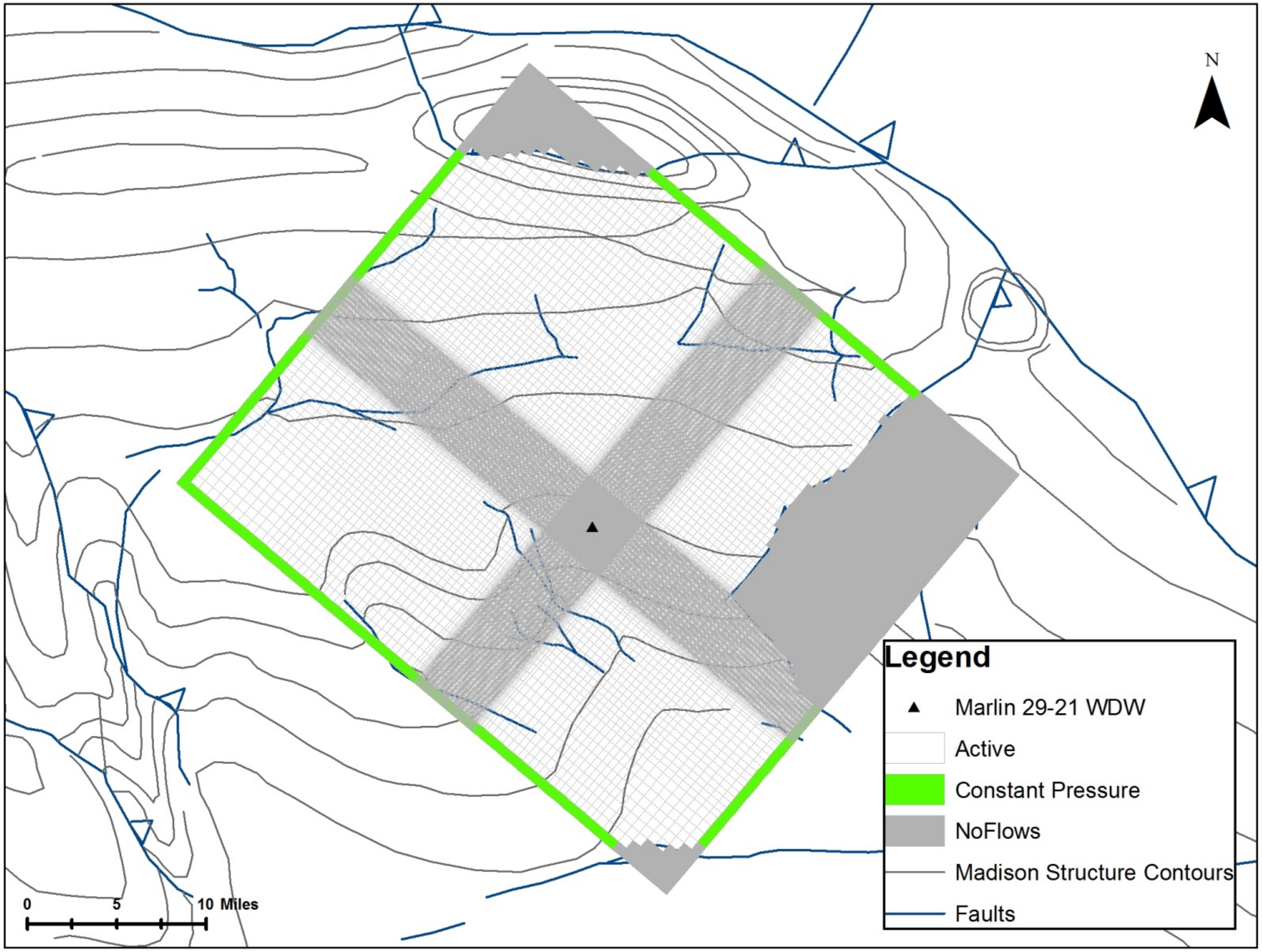
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-3

SCHEMATIC OF MODEL LAYERING AT THE GRID LOCATION OF THE MARLIN 29-21 WDW

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



AETHON ENERGY OPERATING LLC

FREMONT AND NATRONA COUNTIES, WYOMING

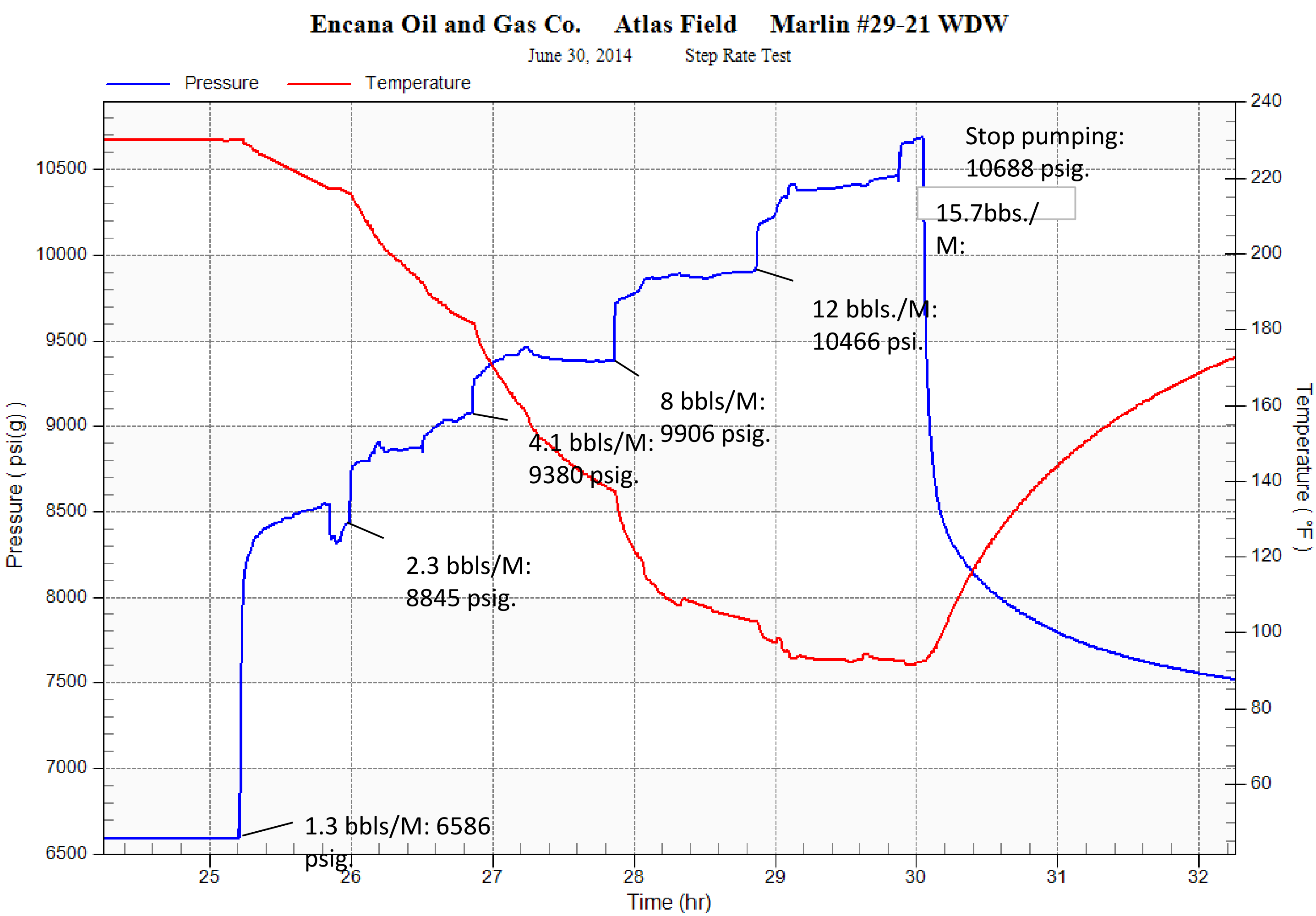
FIGURE 5-4

BOUNDARY CONDITIONS USED IN THE MODEL

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH

COMPLEX WORLD, CLEAR SOLUTIONS



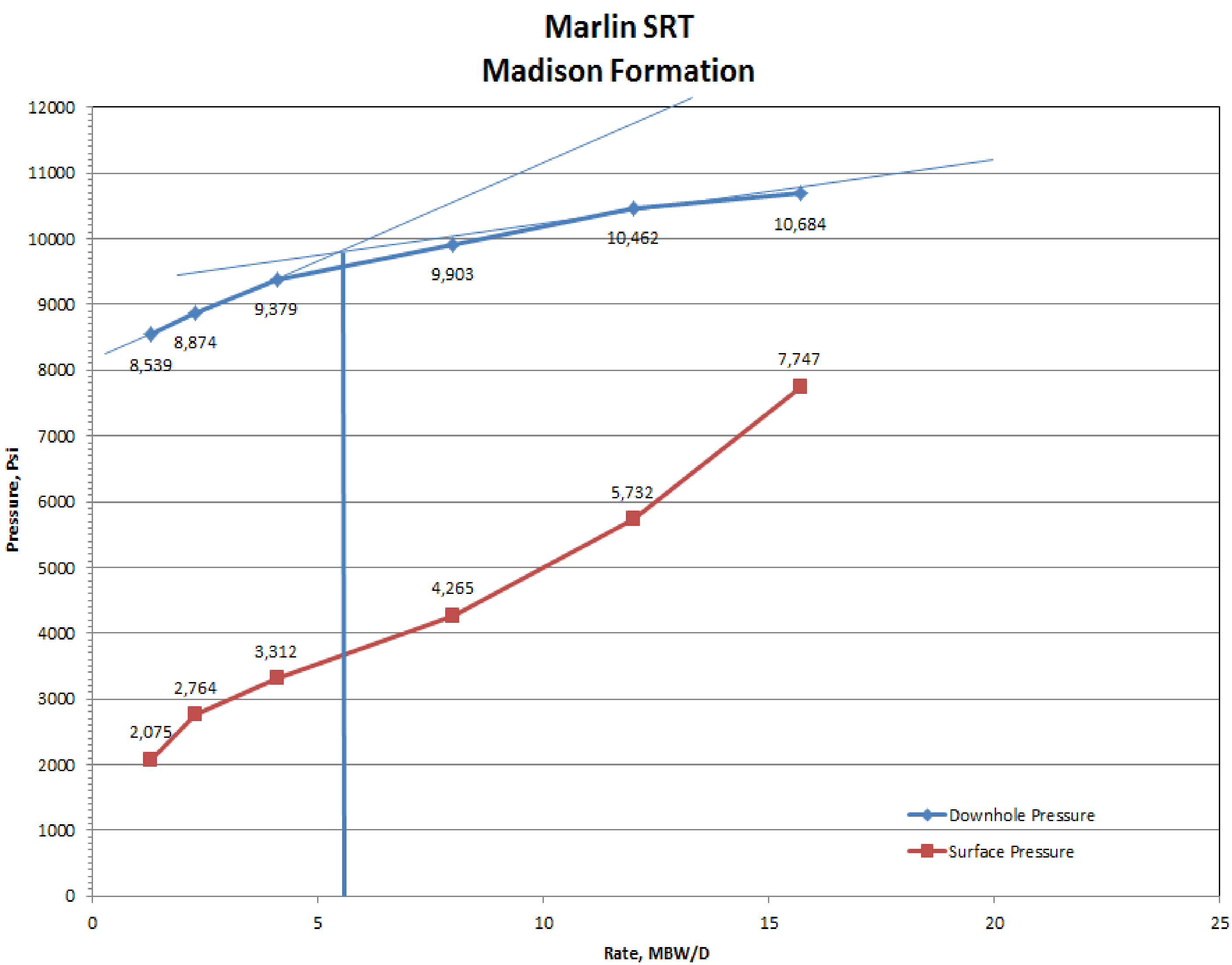
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-5

BOTTOMHOLE PRESSURE AND TEMPERATURE VS TIME FOR THE MADISON FORMATION STEP RATE TEST

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Reservoir pressure constraint of 9,850 psi based on change in slope between 3rd and 4th step of Madison Formation step rate test
2) Marlin Injection Pressure Analysis.xls

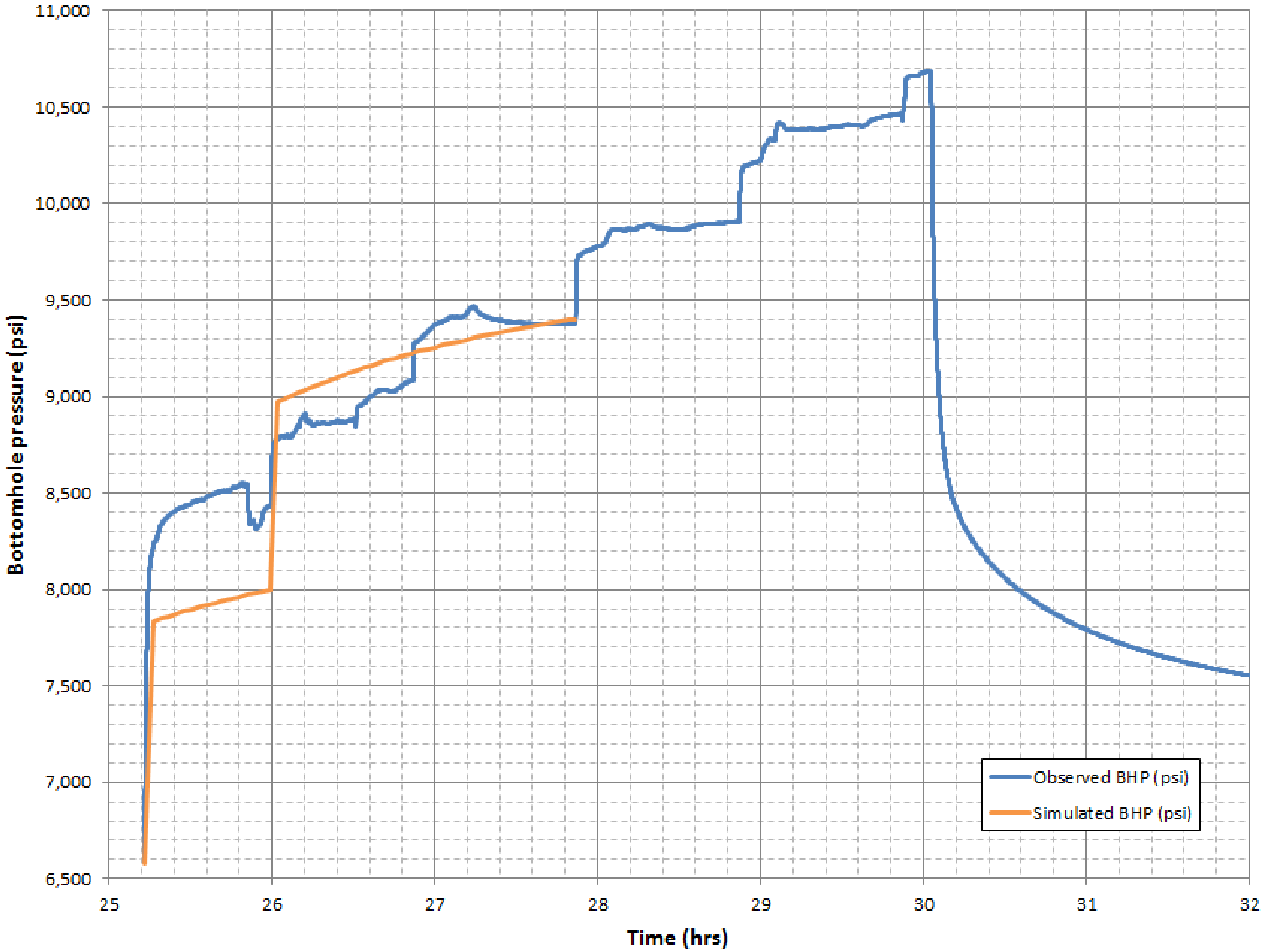
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-6

ANALYSIS OF MADISON FORMATION STEP RATE TEST TO DETERMINE RESERVOIR PRESSURE CONSTRAINT

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



<u>Notes</u>

1) Permeability value used for the Madison Formation in the model is 3.5 md
2) Second step of step rate test was used as the observed matching criteria

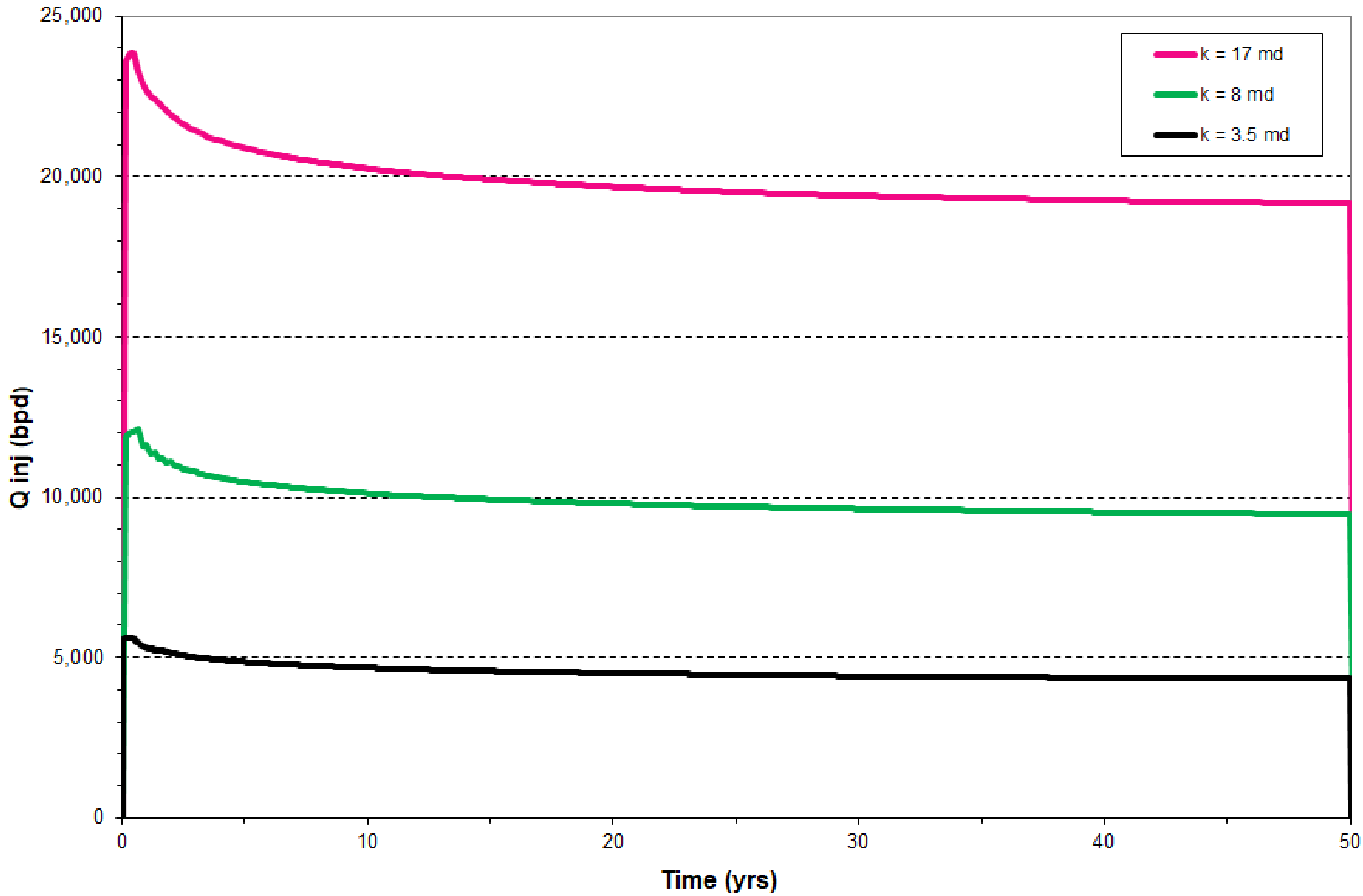
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-7

MODEL-CALCULATED PRESSURES COMPARED TO OBSERVED PRESSURES FOR MADISON STEP RATE TEST

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Injection rate based on reservoir pressure constraint of 9,850 psi
2) Operation injection period is 50 years

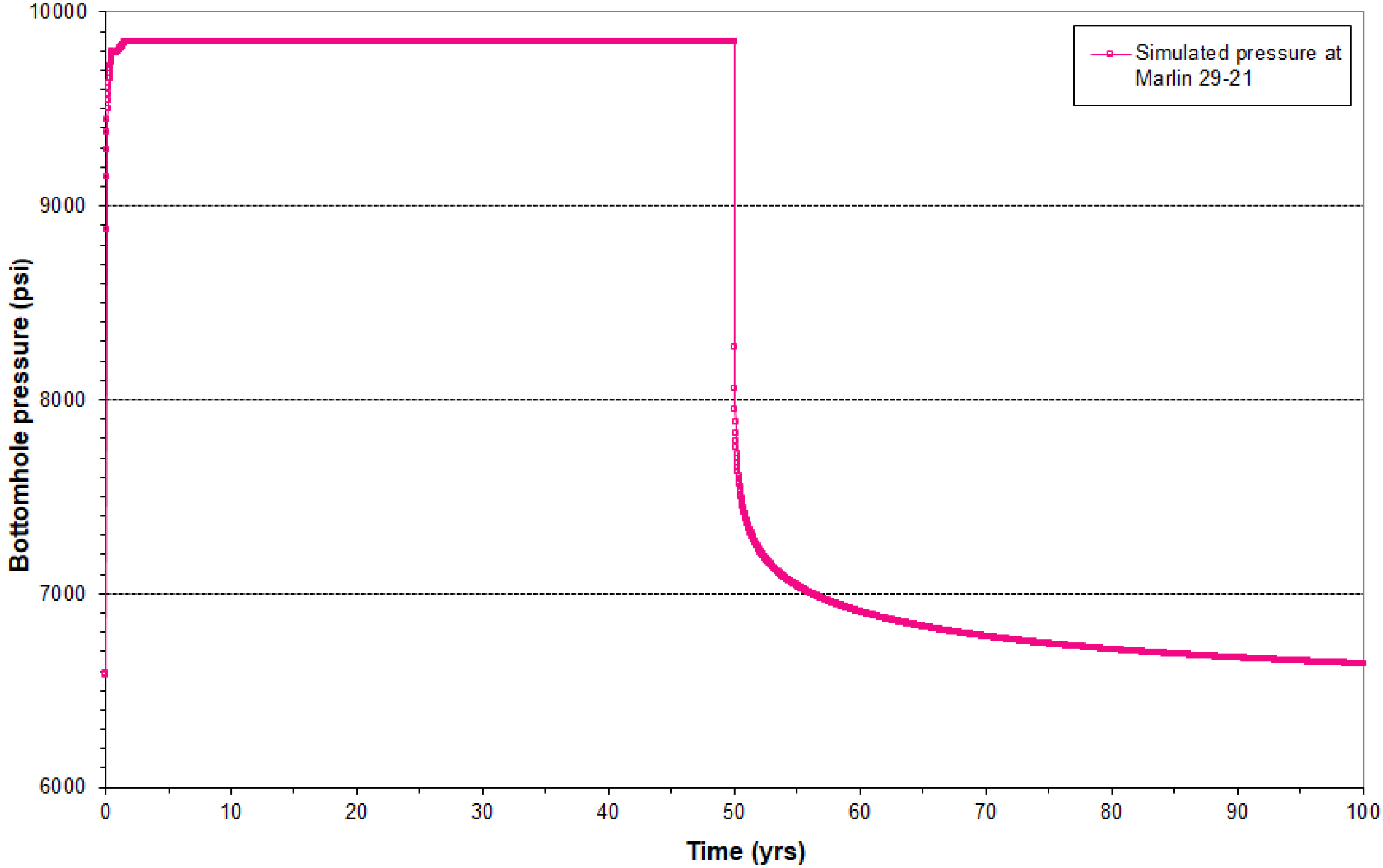
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-8

MODELED INJECTION RATES AT VARIOUS HYDRAULIC CONDUCTIVITIES FOR THE MADISON FORMATION

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Injection rate based on reservoir pressure constraint of 9,850 psi
2) Operation injection period is 50 years
3) Average injection rate is 4,500 bpd

AETHON ENERGY OPERATING LLC

FREMONT AND NATRONA COUNTIES, WYOMING

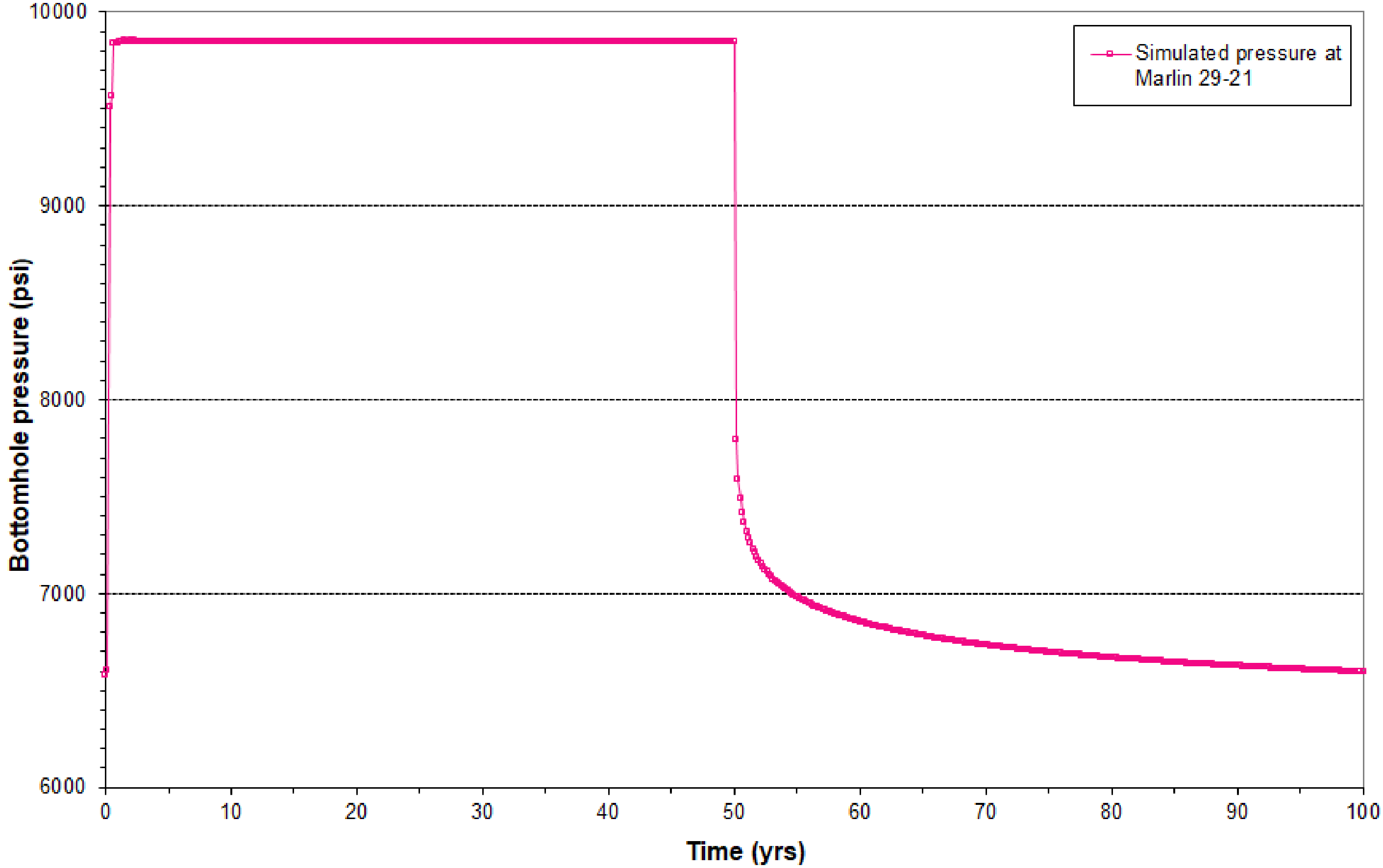
FIGURE 5-9

MODELED SIMULATED BOTTOMHOLE PRESSURE AT MARLIN 29-21 WDW FOR MADISON FORMATION K=3.5 md

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH

COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Injection rate based on reservoir pressure constraint of 9,850 psi
2) Operation injection period is 50 years
3) Average injection rate is 9,900 bpd

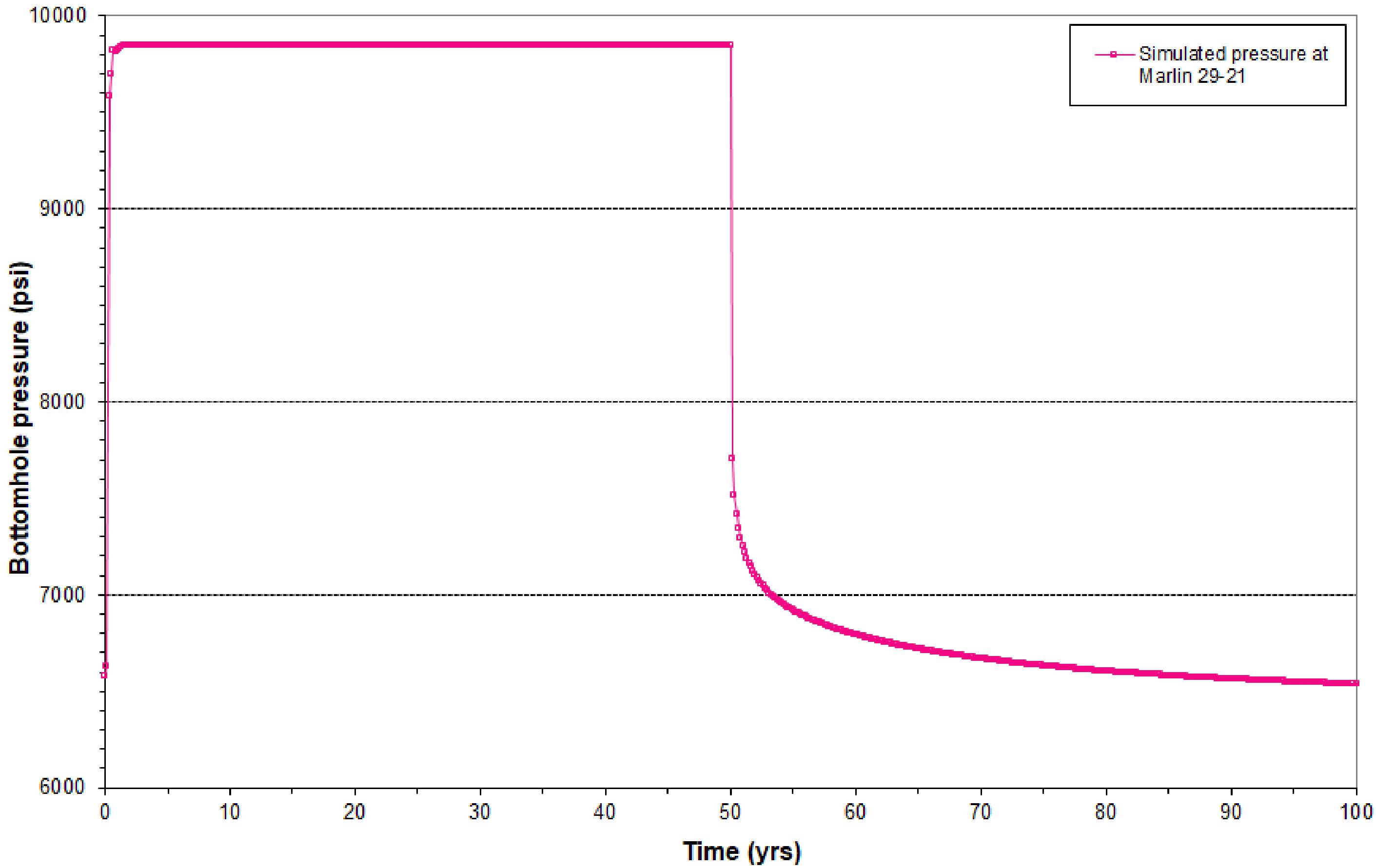
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-10

MODELED SIMULATED BOTTOMHOLE PRESSURE AT MARLIN 29-21 WDW FOR MADISON FORMATION K=8 md

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Injection rate based on reservoir pressure constraint of 9,850 psi
2) Operation injection period is 50 years
3) Average injection rate is 19,800 bpd

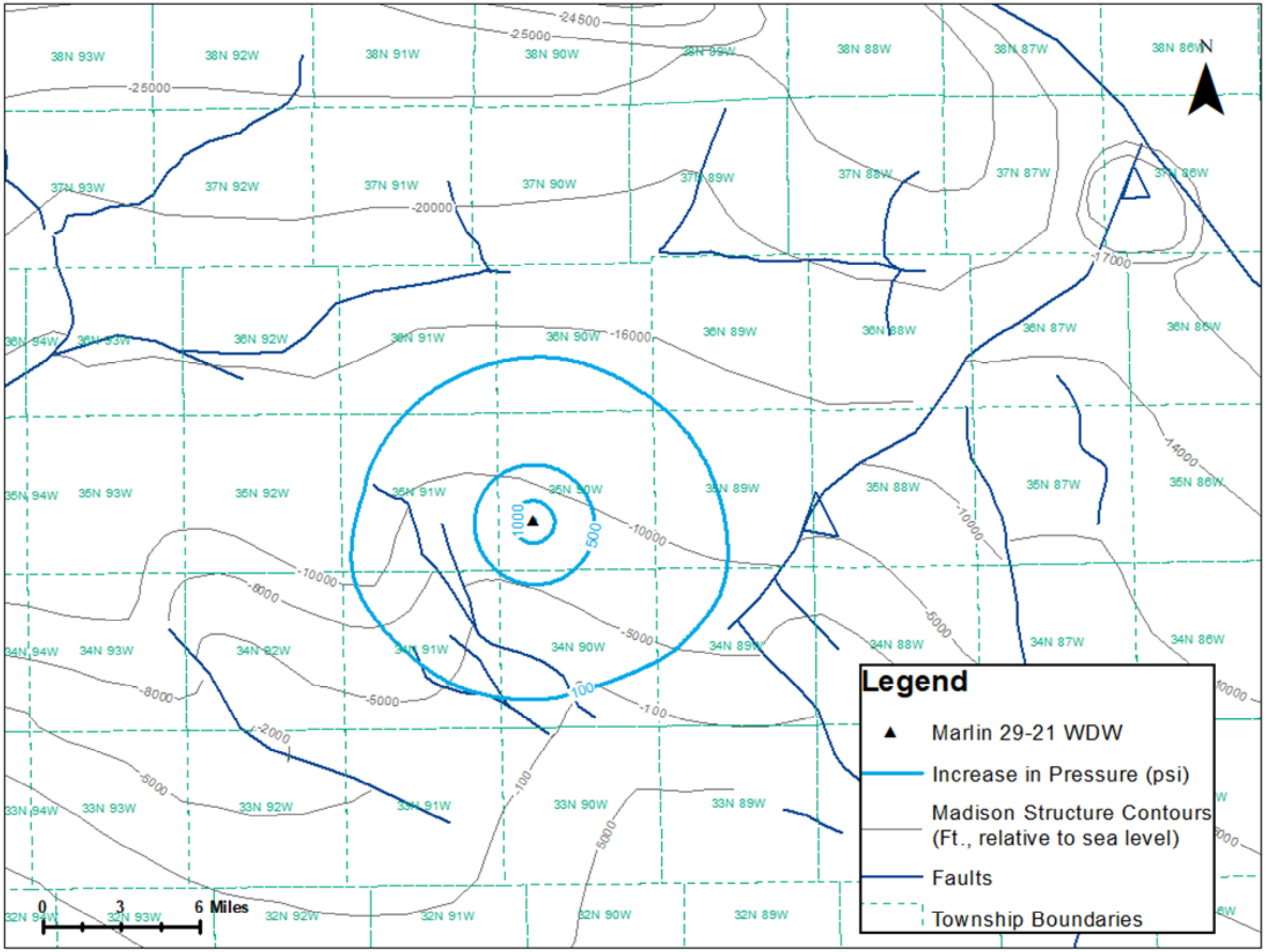
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-11

MODELED SIMULATED BOTTOMHOLE PRESSURE AT MARLIN 29-21 WDW FOR MADISON FORMATION K=17 md

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours represent the increase in pressure over static pressure at end of operational period (50 years)
2) Contours are at 100, 500, 1000, 2000, and 3000 psi
3) Average injection rate is 4,500 bpd

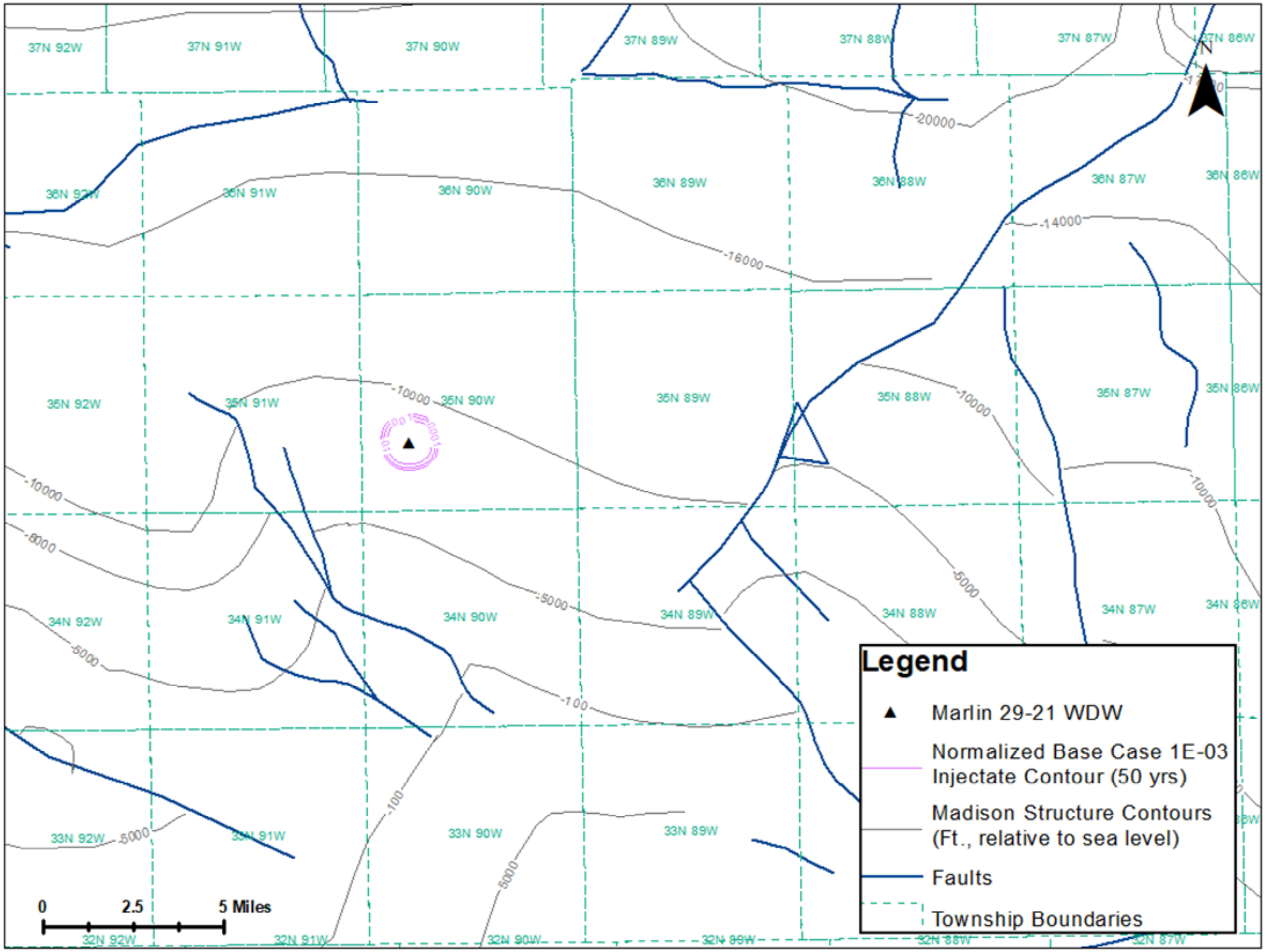
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-12

MODELED SIMULATED PRESSURE BUILDUP CONTOURS IN MADISON FORMATION AT t=50 years for K=3.5 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-01, 1e-02, and 1e-03
2) 1e-03 contour represents 6.9 mg/L TDS
3) Average injection rate is 4,500 bpd

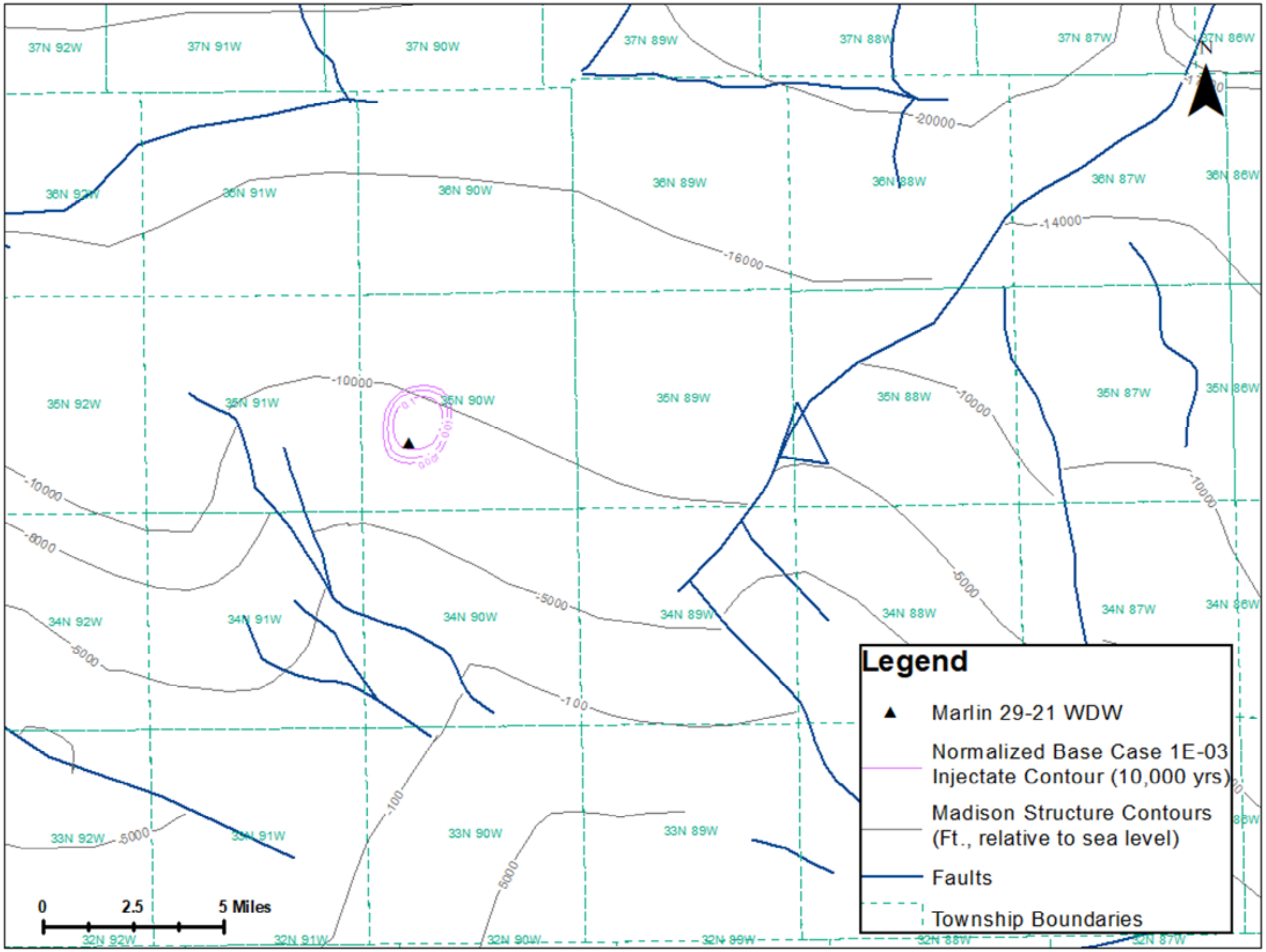
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-13

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=3.5 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-01, 1e-02, and 1e-03
2) 1e-03 contour represents 6.9 mg/L TDS
3) Average injection rate is 4,500 bpd

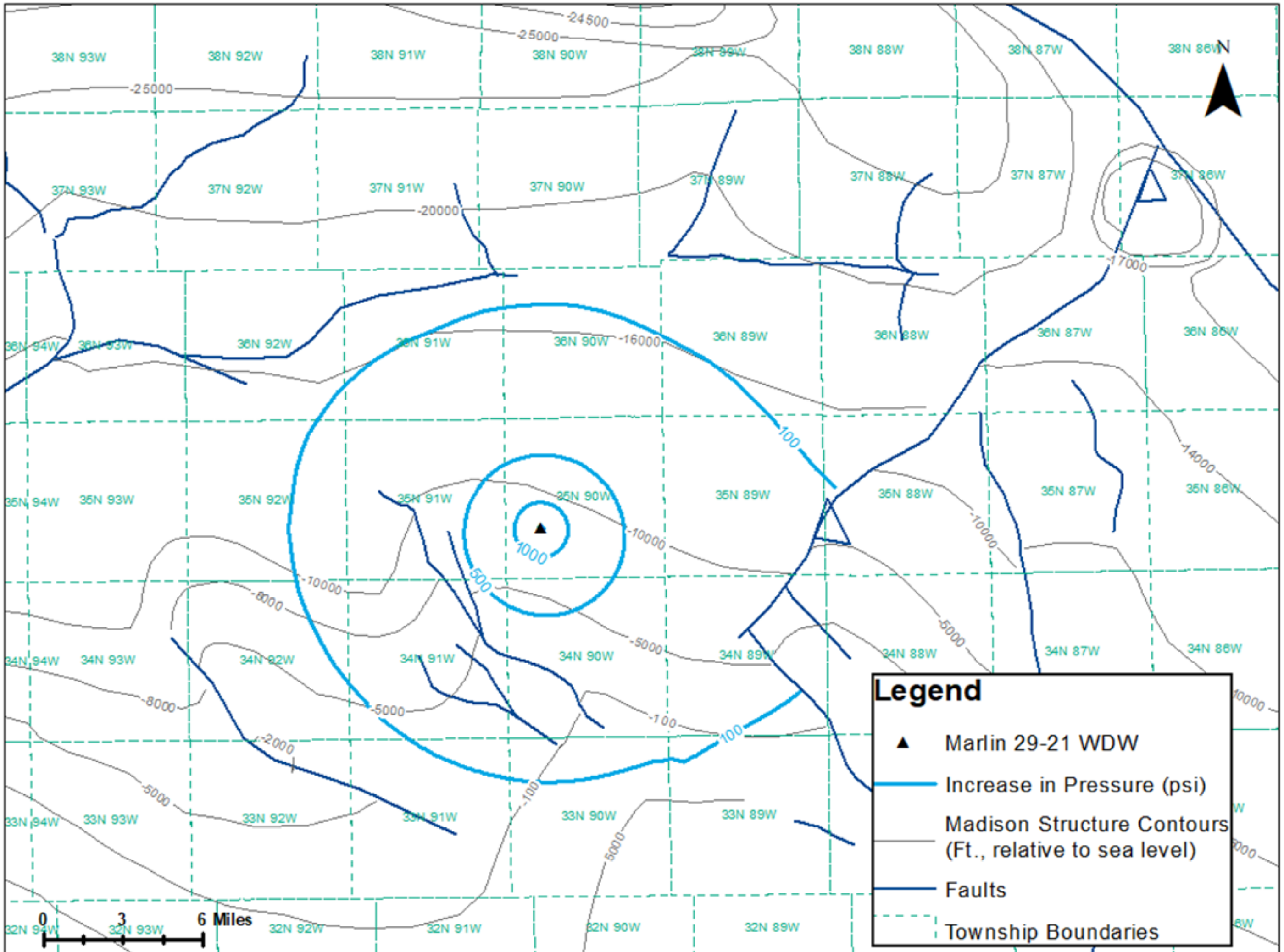
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-14

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=3.5 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours represent the increase in pressure over static pressure at end of operational period (50 years)
2) Contours are at 100, 500, 1000, 2000, and 3000 psi
3) Average injection rate is 9,900 bpd

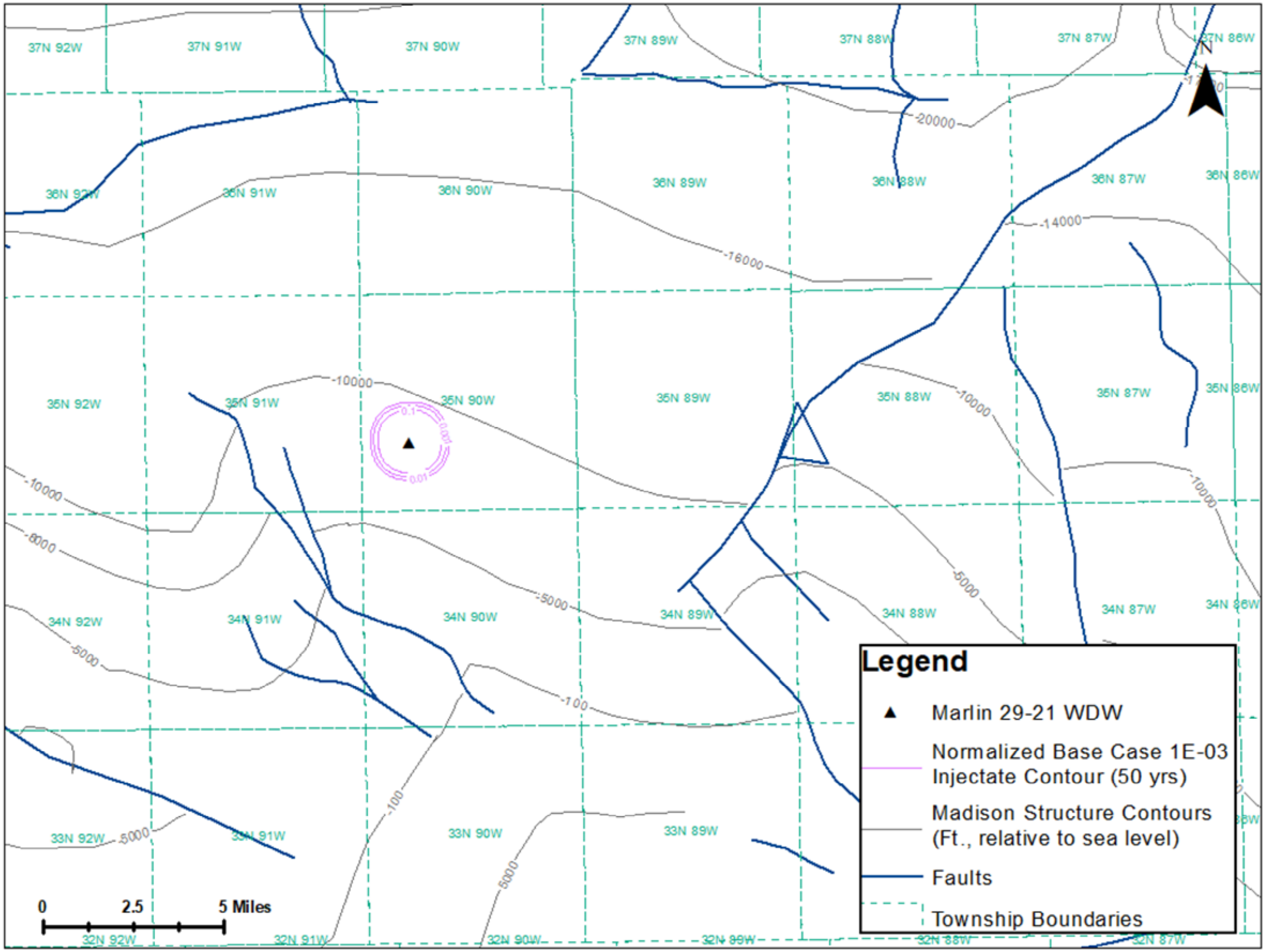
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-15

MODELED SIMULATED PRESSURE BUILDUP CONTOURS IN MADISON FORMATION AT t=50 years for K=8 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

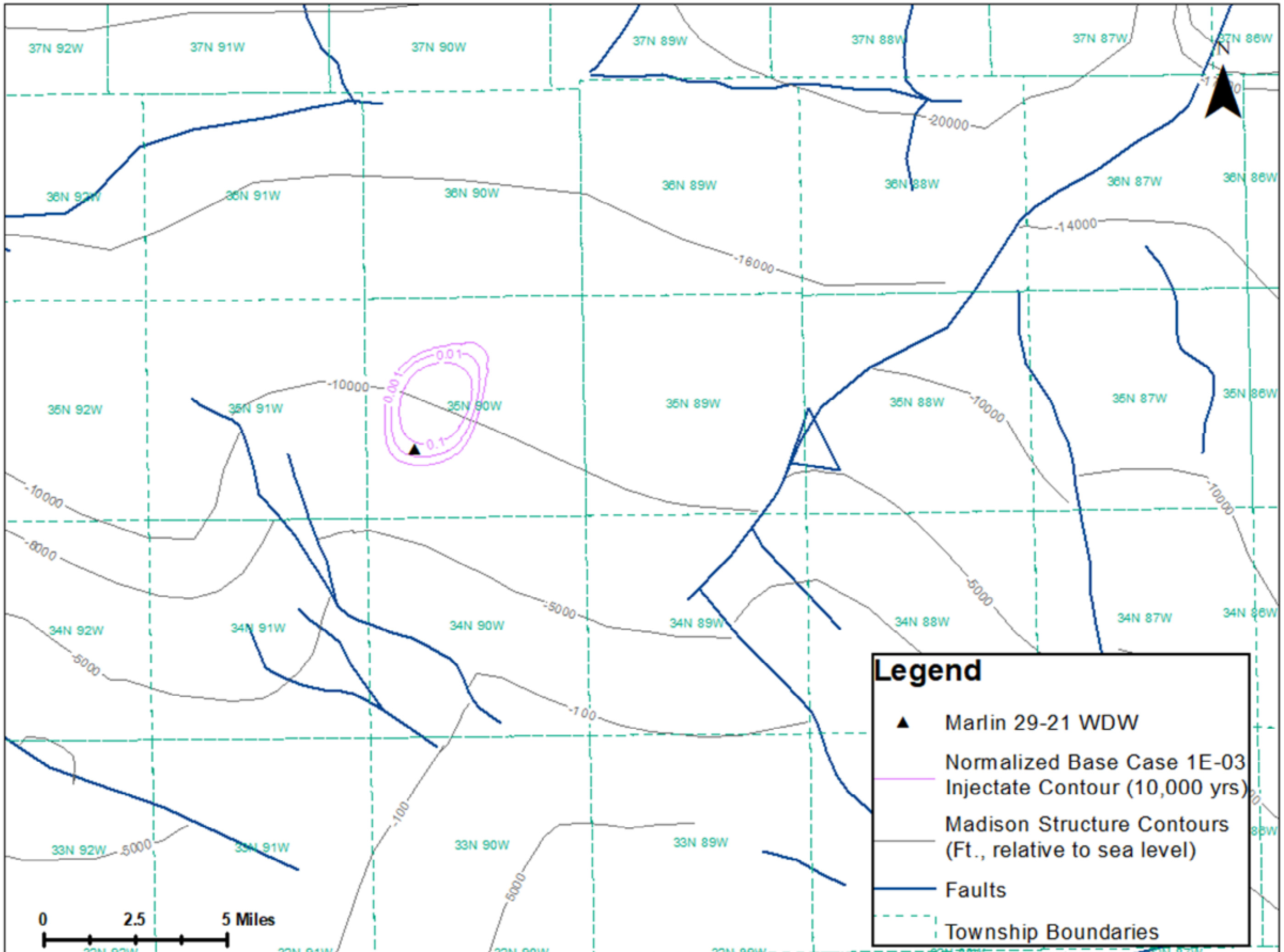
TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-01, 1e-02, and 1e-03
2) 1e-03 contour represents 6.9 mg/L TDS
3) Average injection rate is 9,900 bpd

AETHON ENERGY OPERATING LLC FREMONT AND NATRONA COUNTIES, WYOMING		
FIGURE 5-16 **MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=8 md CASE**		
PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB
TETRA TECH *COMPLEX WORLD, CLEAR SOLUTIONS*		



Notes

1) Contours are at 1e-01, 1e-02, and 1e-03
2) 1e-03 contour represents 6.9 mg/L TDS
3) Average injection rate is 9,900 bpd

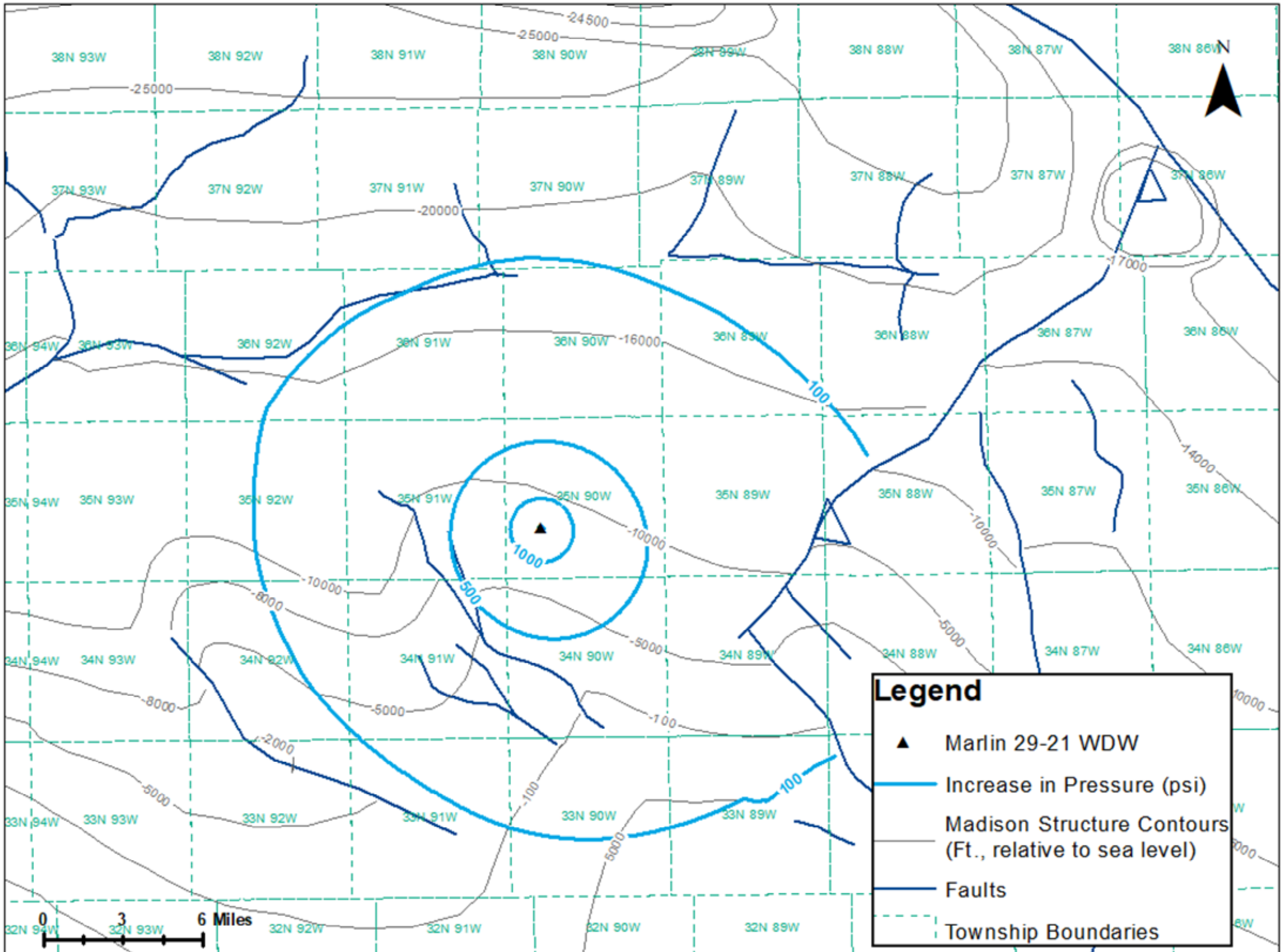
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-17

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=8 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours represent the increase in pressure over static pressure at end of operational period (50 years)
2) Contours are at 100, 500, 1000, 2000, and 3000 psi
3) Average injection rate is 19,800 bpd

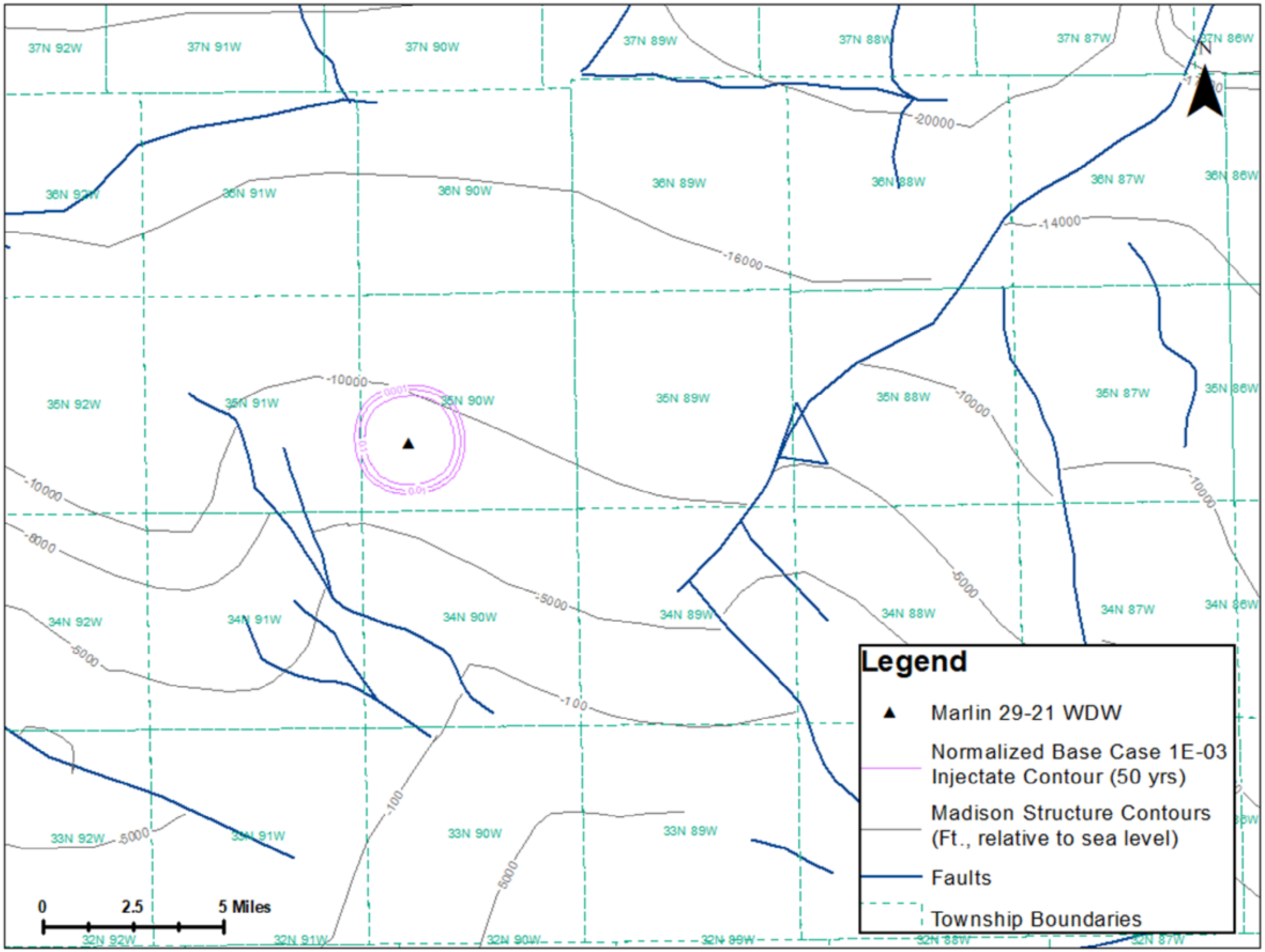
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-18

MODELED SIMULATED PRESSURE BUILDUP CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-01, 1e-02, and 1e-03
2) 1e-03 contour represents 6.9 mg/L TDS
3) Average injection rate is 19,800 bpd

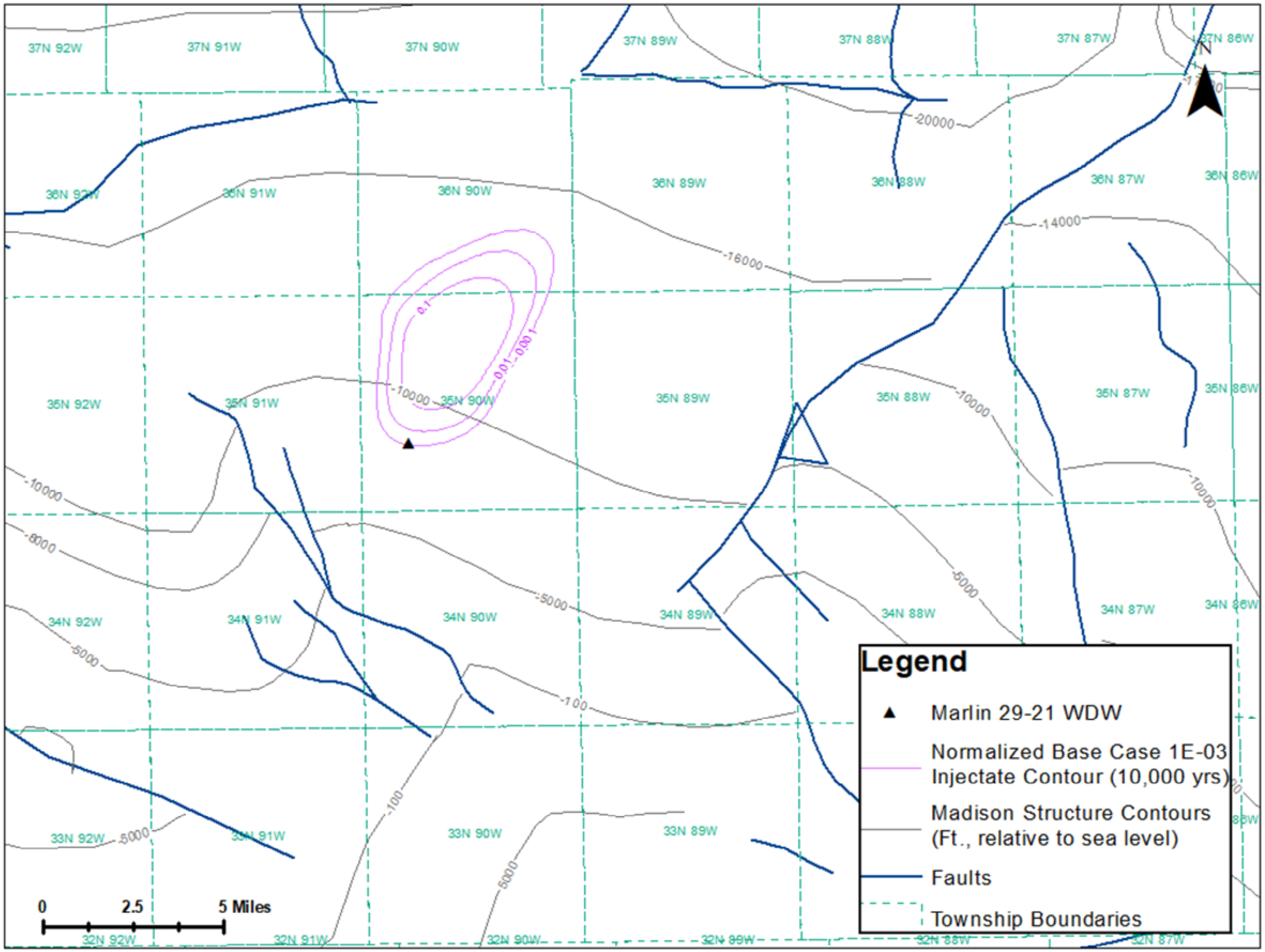
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-19

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-01, 1e-02, and 1e-03
2) 1e-03 contour represents 6.9 mg/L TDS
3) Average injection rate is 19,800 bpd

AETHON ENERGY OPERATING LLC

FREMONT AND NATRONA COUNTIES, WYOMING

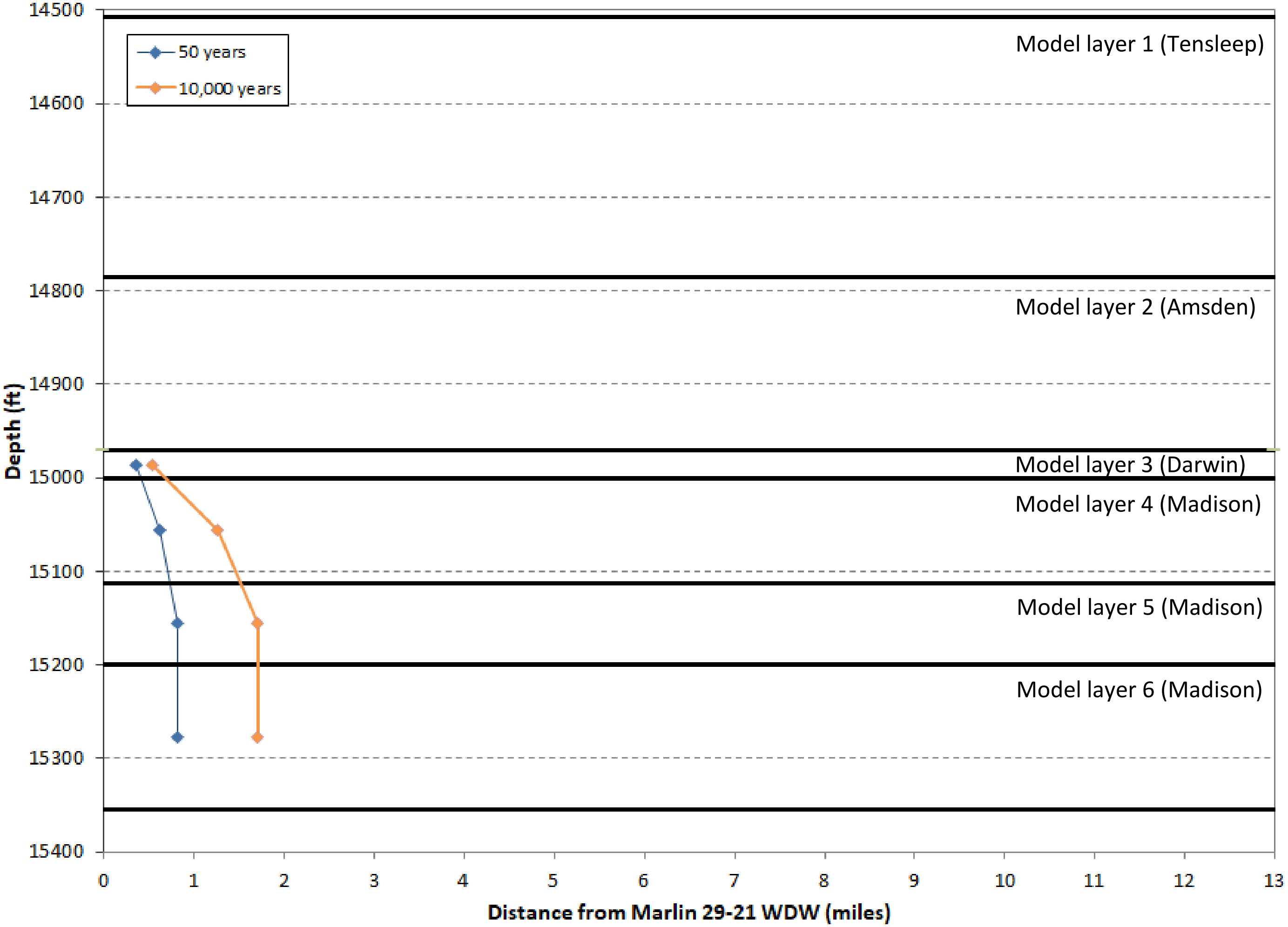
FIGURE 5-20

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH

COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) 1e-03 contour (6.9mg/L) shown
2) Simulated results for model layers 1 and 2 (Tensleep and Amsden) are less than 1e-03
3) Average injection rate is 4,500 bpd
4) Profile is oriented along the downdip direction

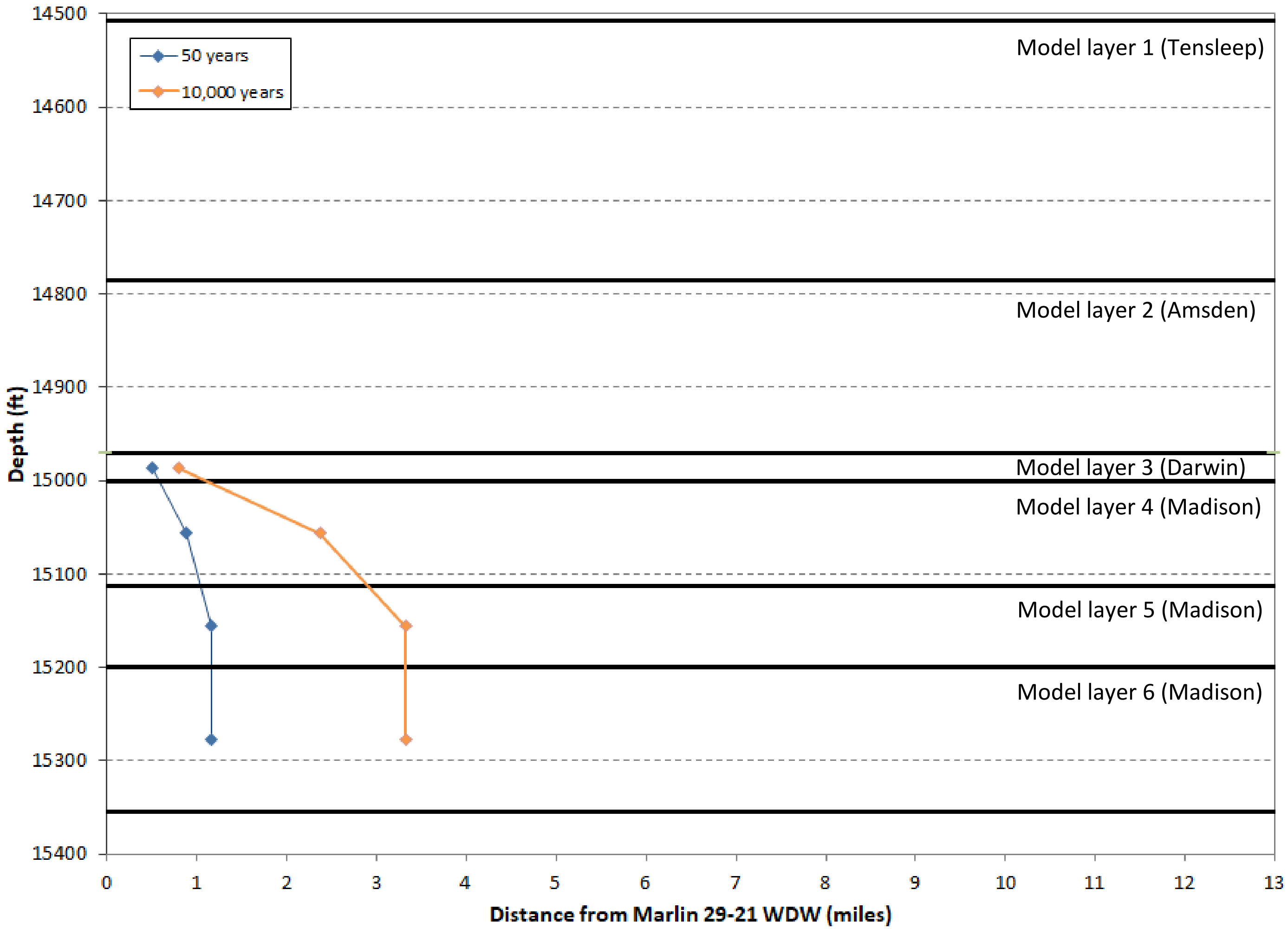
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-21

MODELED SIMULATED VERTICAL CONCENTRATION PROFILE FOR K=3.5 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) 1e-03 contour (6.9mg/L) shown
2) Simulated results for model layers 1 and 2 (Tensleep and Amsden) are less than 1e-03
3) Average injection rate is 9,900 bpd
4) Profile is oriented along the downdip direction

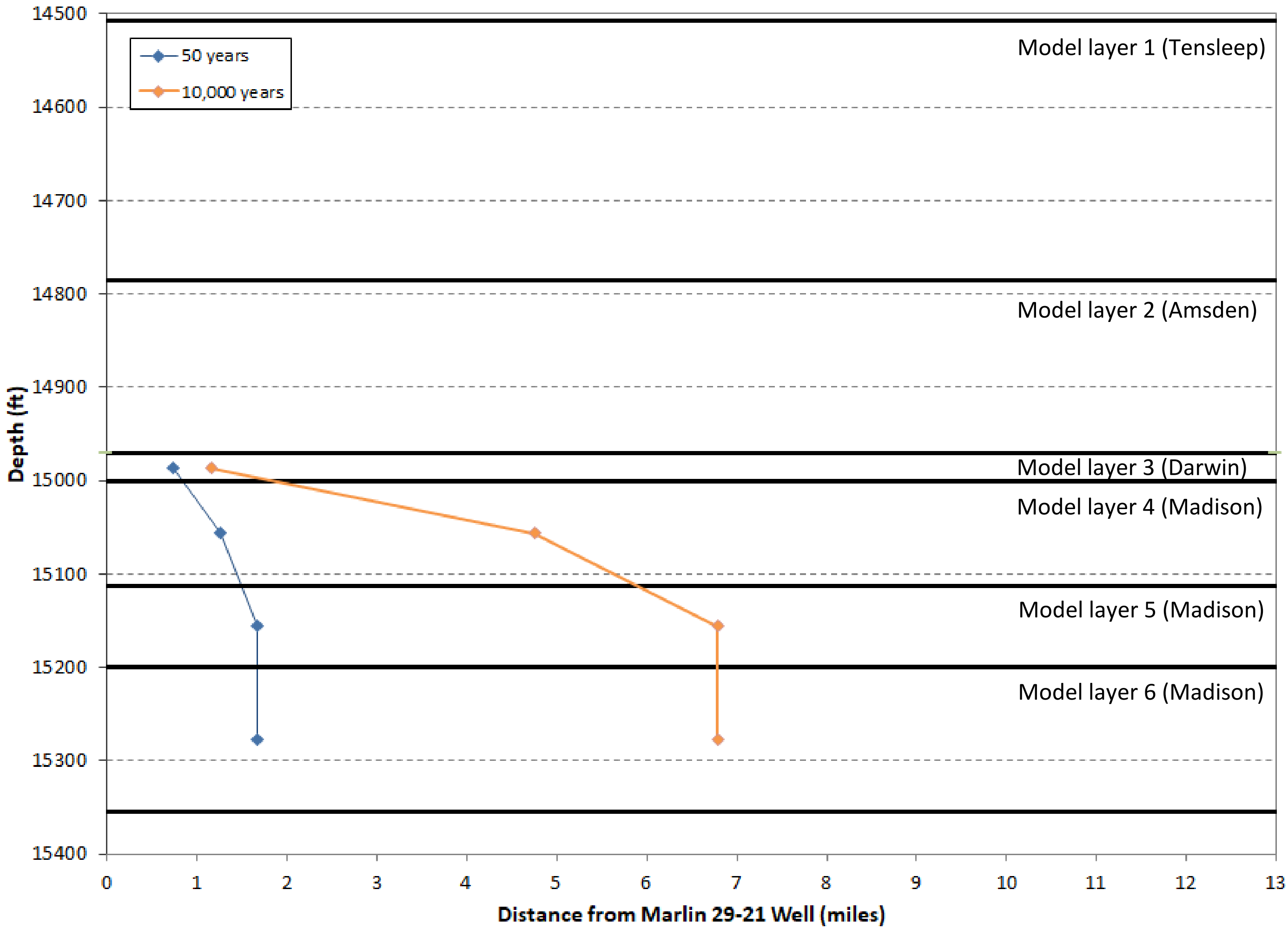
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-22

MODELED SIMULATED VERTICAL CONCENTRATION PROFILE FOR K=8 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) 1e-03 contour (6.9mg/L) shown
2) Simulated results for model layers 1 and 2 (Tensleep and Amsden) are less than 1e-03
3) Average injection rate is 19,800 bpd
4) Profile is oriented along the downdip direction

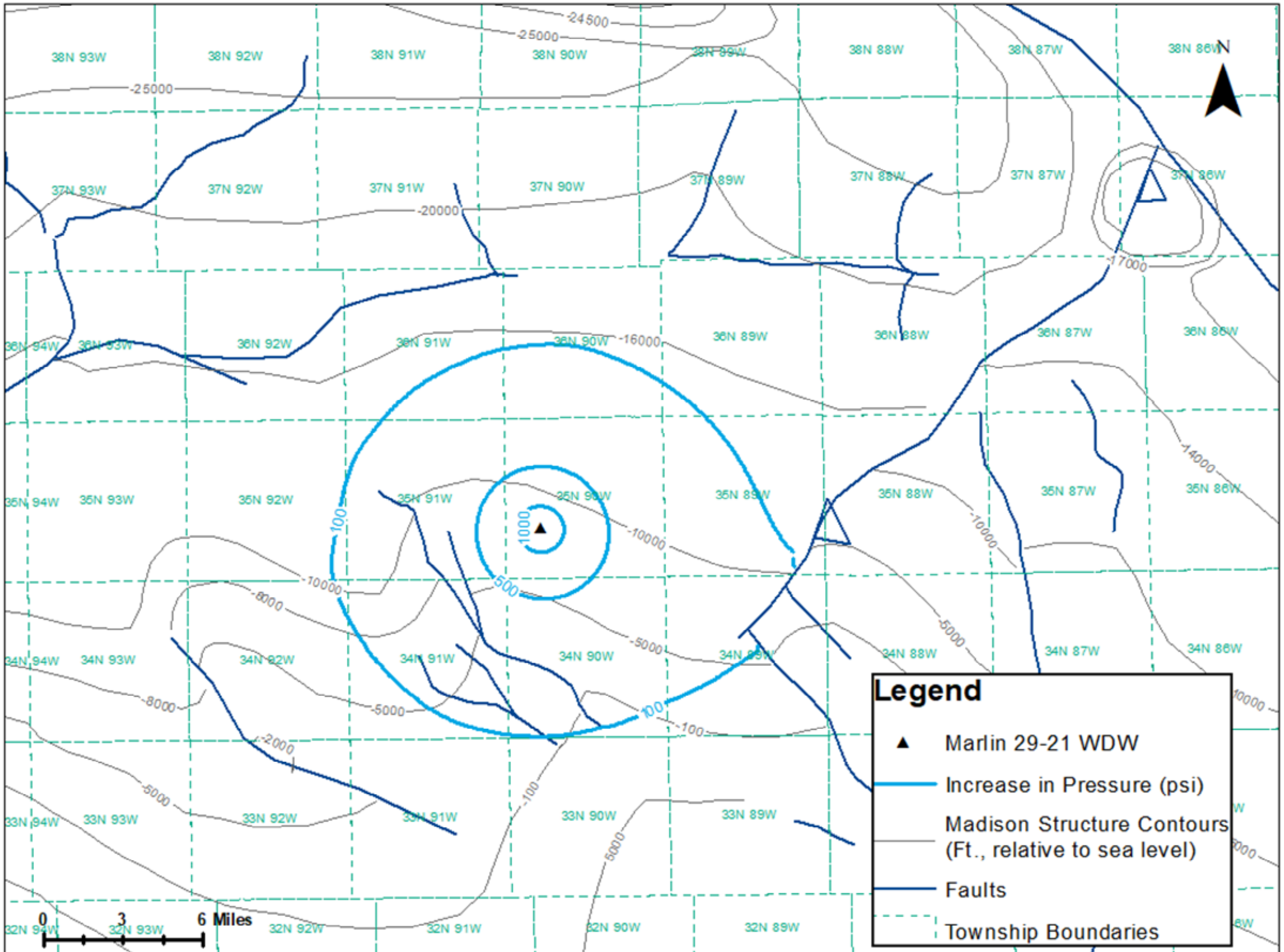
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-23

MODELED SIMULATED VERTICAL CONCENTRATION PROFILE FOR K=17 md CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours represent the increase in pressure over static pressure at end of operational period (50 years)
2) Scaled porosities to represent net thickness of Madison injection interval
3) Average injection rate is 4,500 bpd

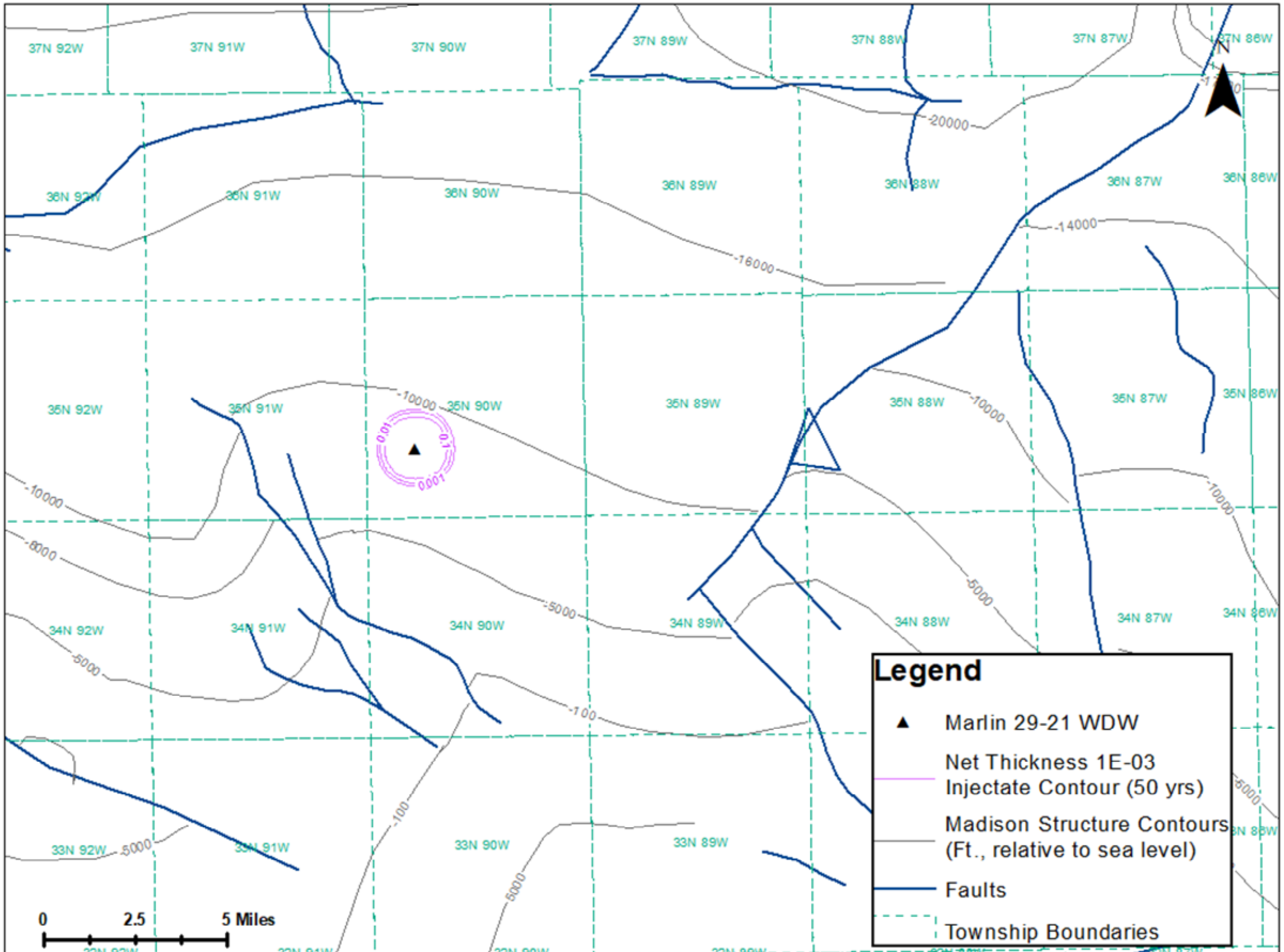
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-24

MODELED SIMULATED PRESSURE BUILDUP CONTOURS IN MADISON FORMATION AT t=50 years for K=3.5 md NET THICKNESS CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-01, 1e-02, and 1e-03
2) Scaled porosities to represent net thickness of Madison injection interval
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 4,500 bpd

AETHON ENERGY OPERATING LLC

FREMONT AND NATRONA COUNTIES, WYOMING

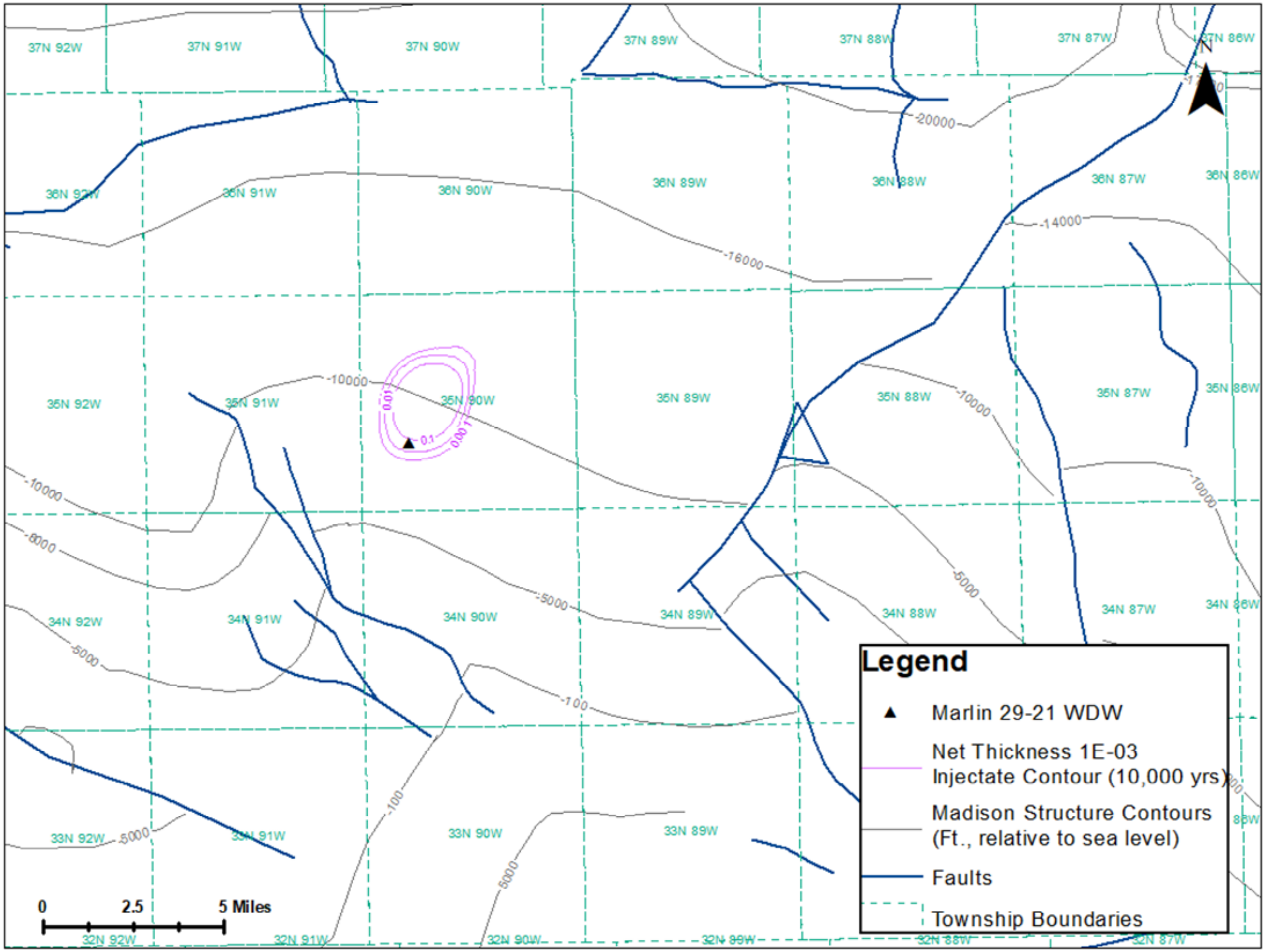
FIGURE 5-25

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=3.5 md NET THICKNESS CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH

COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-01, 1e-02, and 1e-03
2) Scaled porosities to represent net thickness of Madison injection interval
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 4,500 bpd

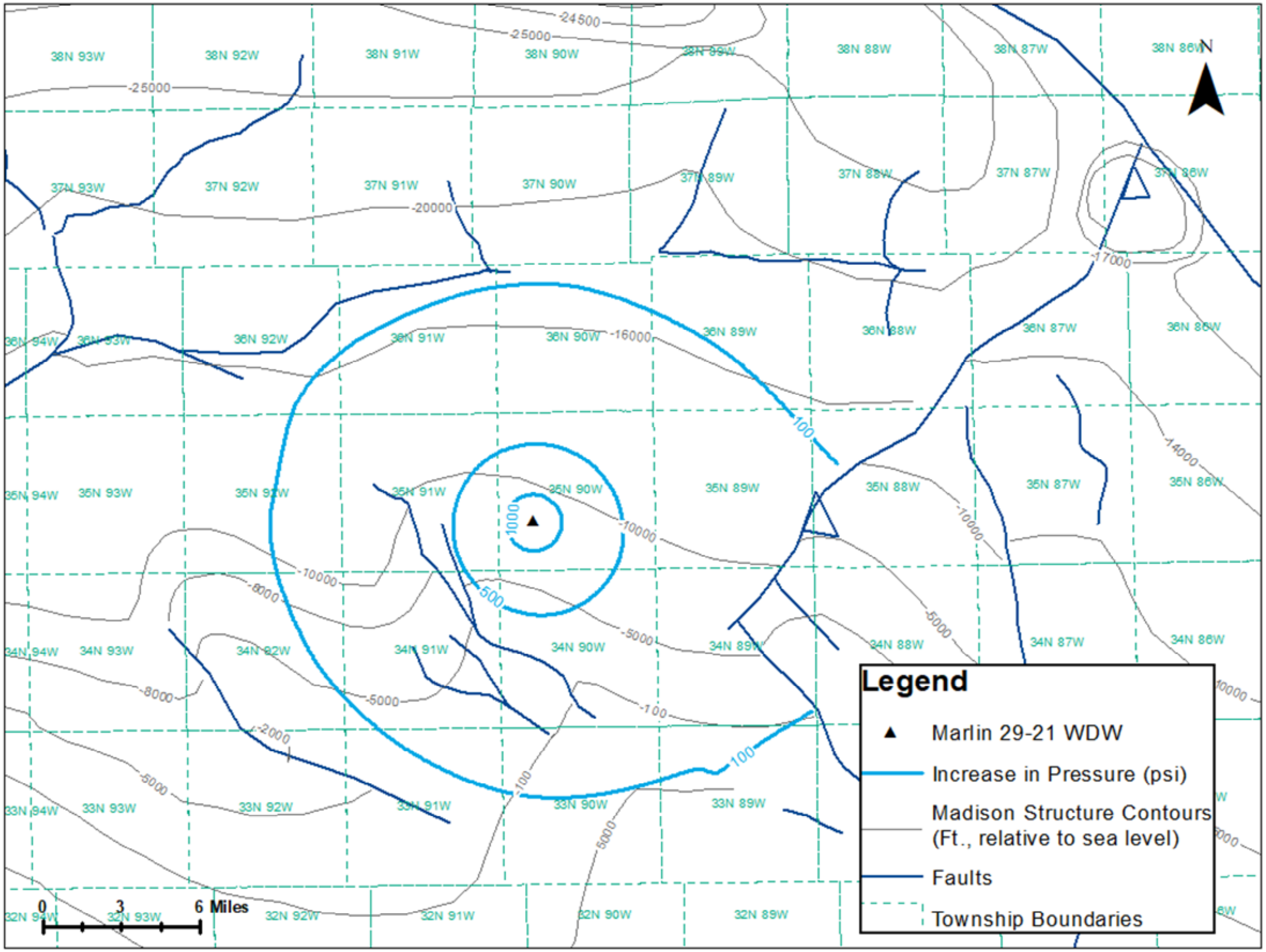
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-26

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=3.5 md NET THICKNESS CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours represent the increase in pressure over static pressure at end of operational period (50 years)
2) Scaled porosities to represent net thickness of Madison injection interval
3) Average injection rate is 9,900 bpd

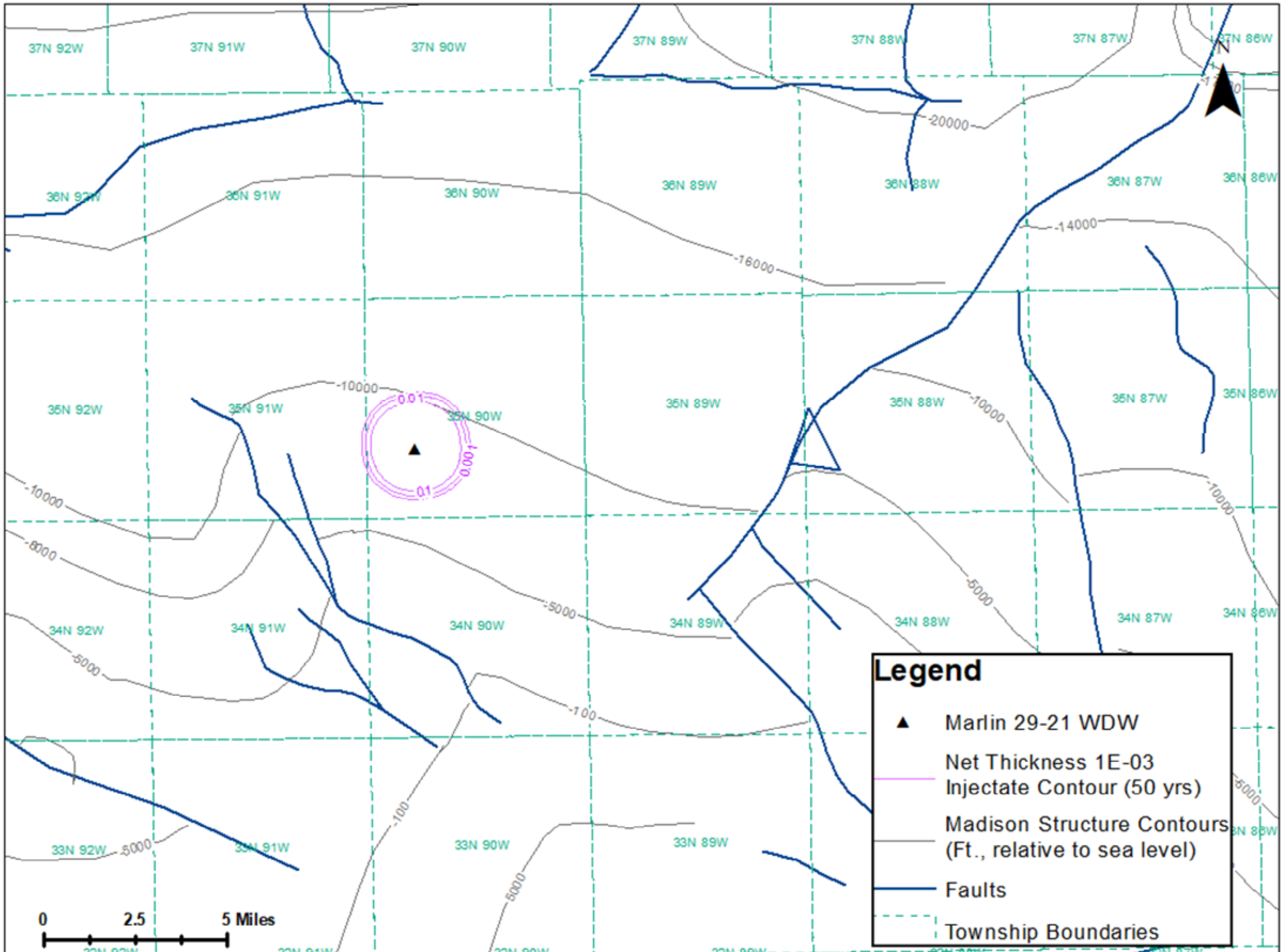
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-27

MODELED SIMULATED PRESSURE BUILDUP CONTOURS IN MADISON FORMATION AT t=50 years for K=8 md NET THICKNESS CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-01, 1e-02, and 1e-03
2) Scaled porosities to represent net thickness of Madison injection interval
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 9,900 bpd

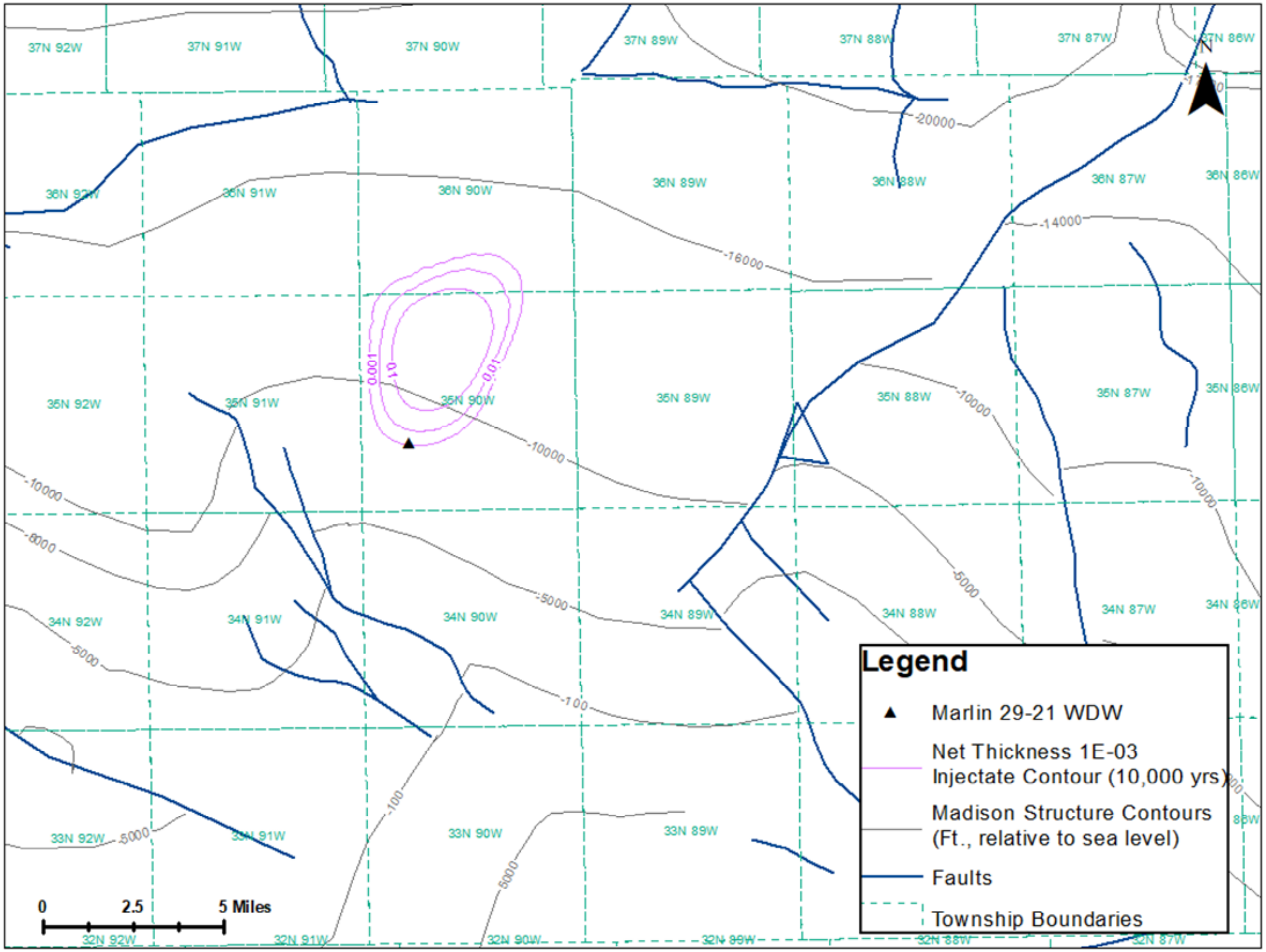
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-28

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=8 md NET THICKNESS CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-01, 1e-02, and 1e-03
2) Scaled porosities to represent net thickness of Madison injection interval
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 9,900 bpd

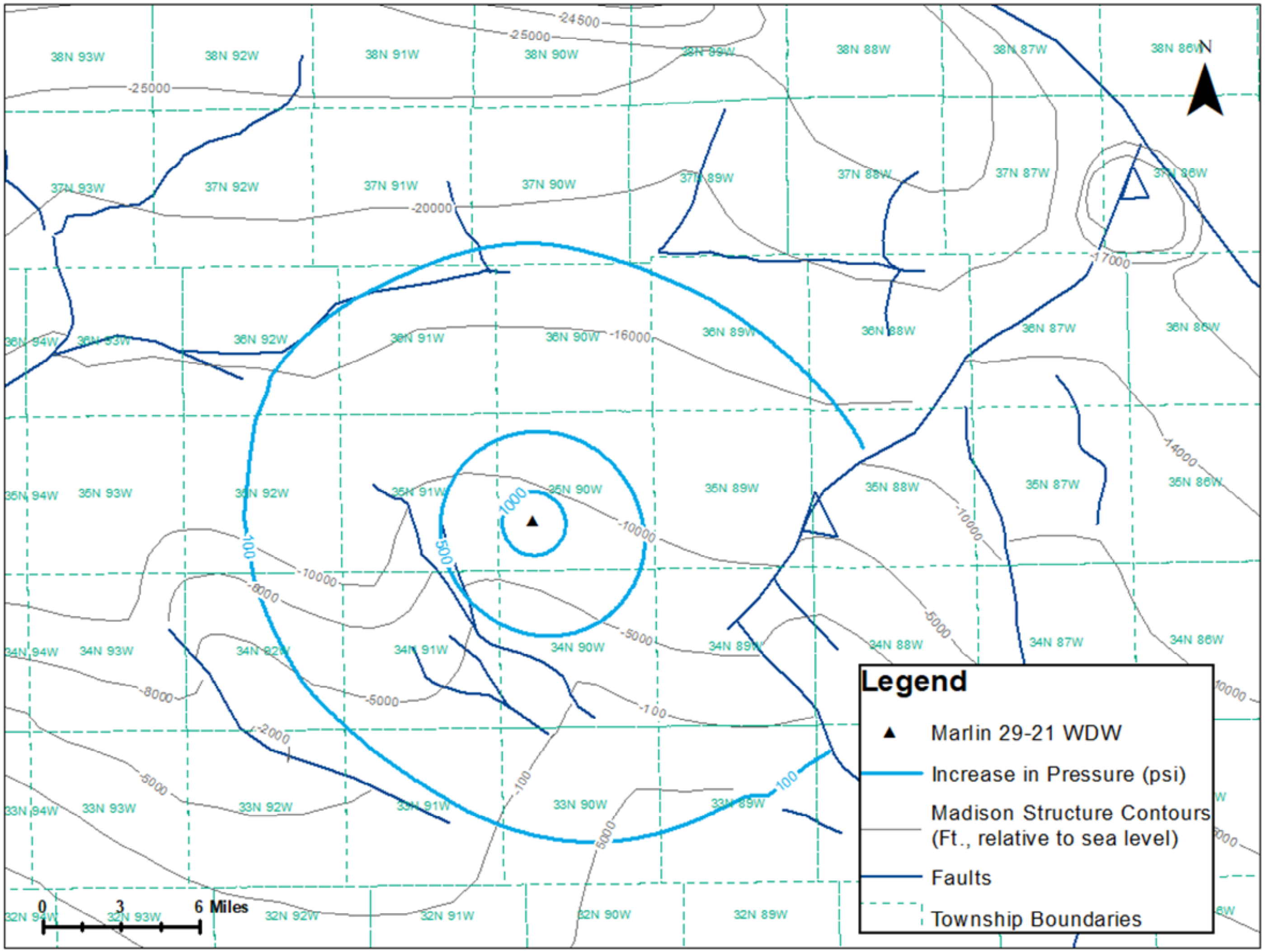
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-29

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=8 md NET THICKNESS CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours represent the increase in pressure over static pressure at end of operational period (50 years)
2) Scaled porosities to represent net thickness of Madison injection interval
3) Average injection rate is 19,800 bpd

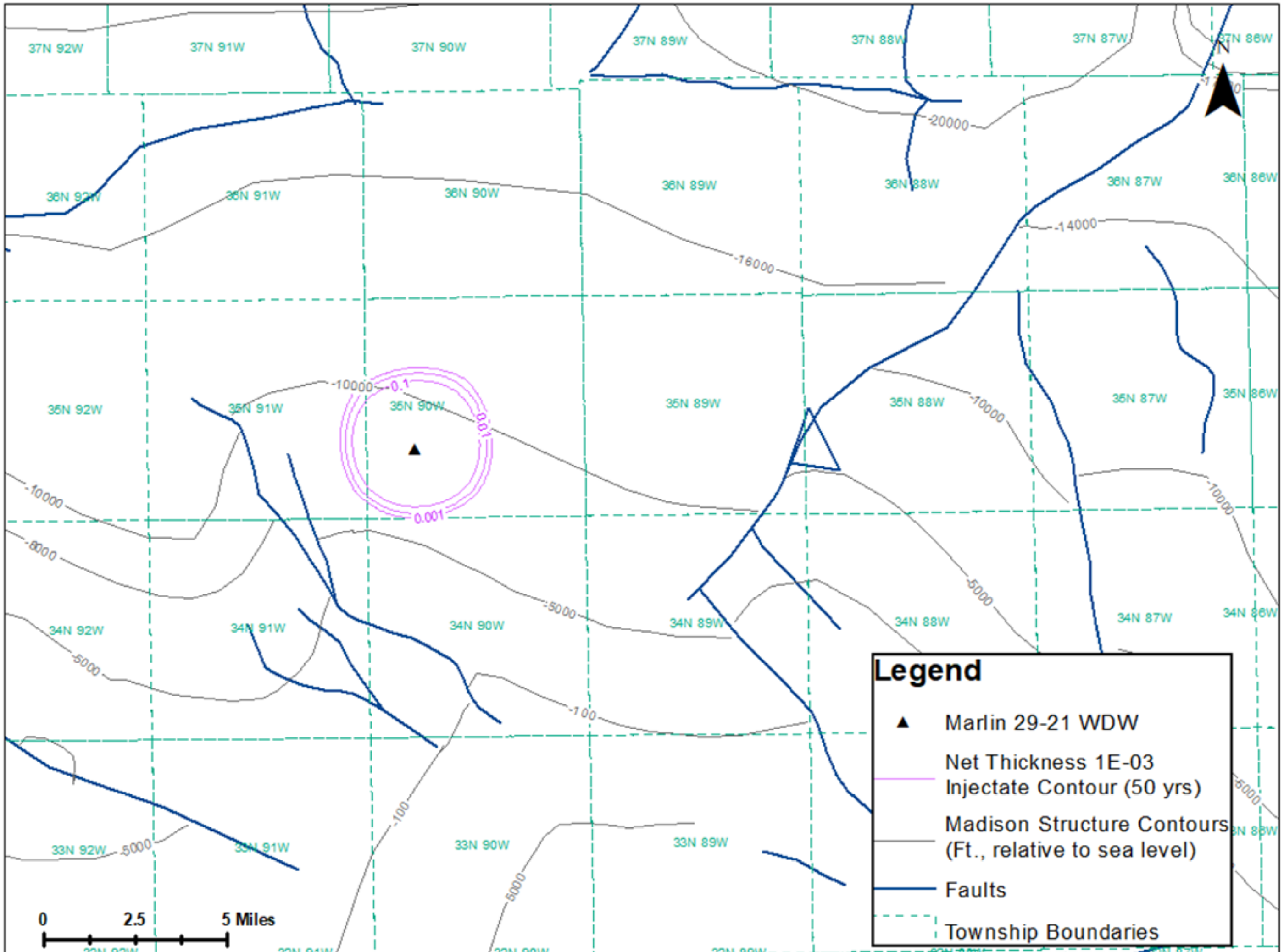
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-30

MODELED SIMULATED PRESSURE BUILDUP CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md NET THICKNESS CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-01, 1e-02, and 1e-03
2) Scaled porosities to represent net thickness of Madison injection interval
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

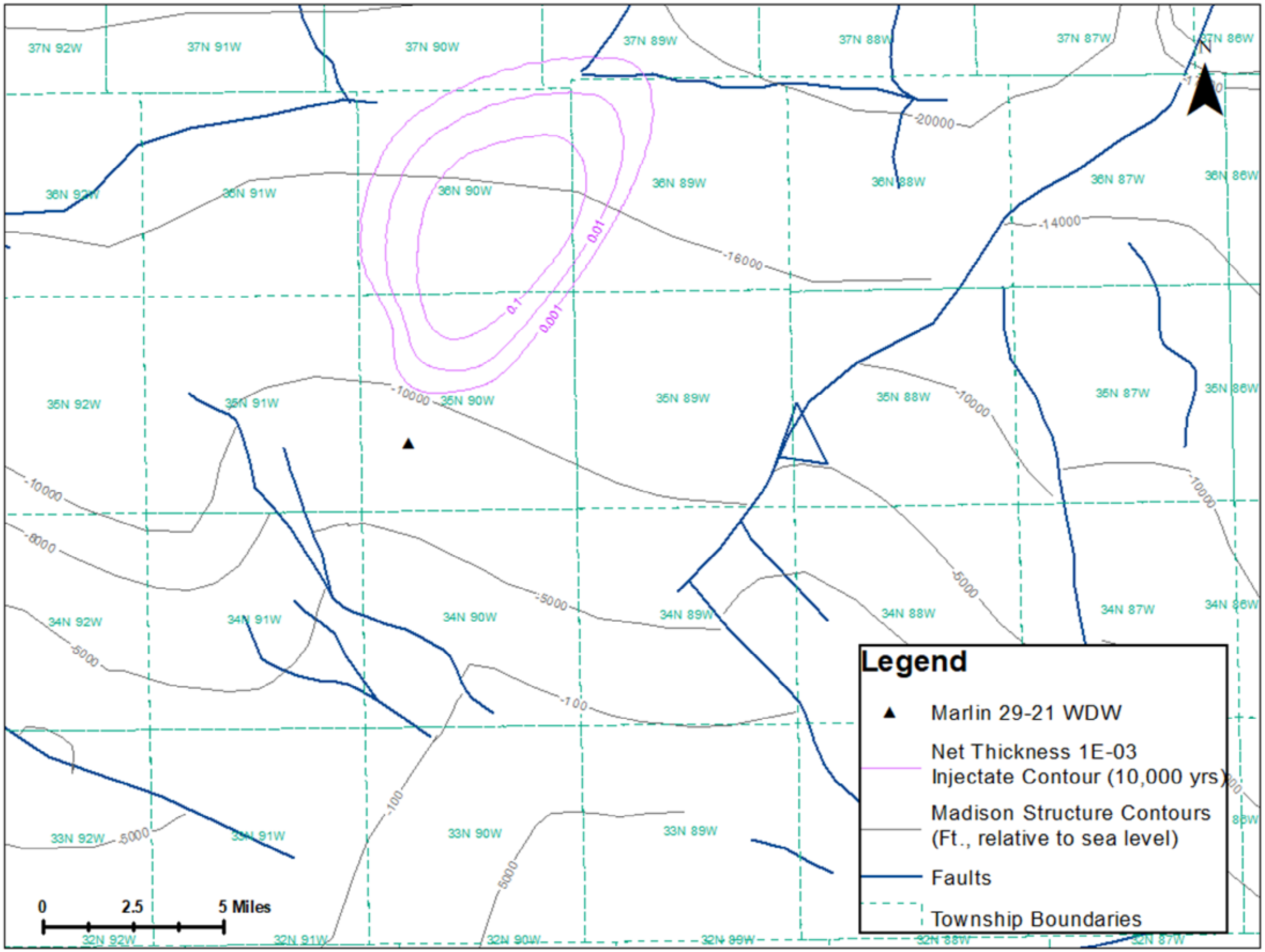
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-31

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md NET THICKNESS CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-01, 1e-02, and 1e-03
2) Scaled porosities to represent net thickness of Madison injection interval
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

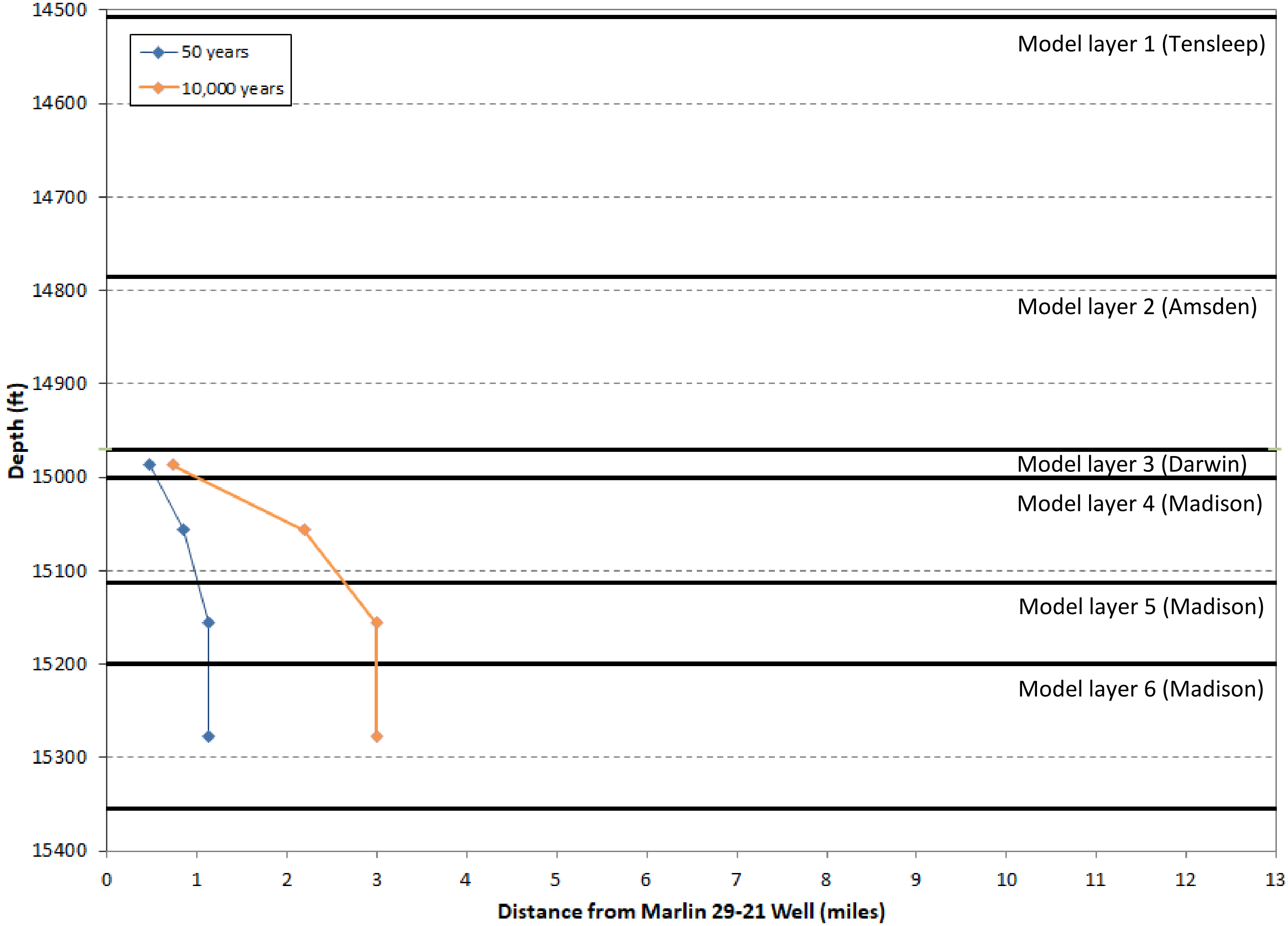
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-32

MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md NET THICKNESS CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) 1e-03 contour (6.9mg/L) shown
2) Simulated results for model layers 1 and 2 (Tensleep and Amsden) are less than 1e-03
3) Average injection rate is 4,500 bpd
4) Profile is oriented along the downdip direction

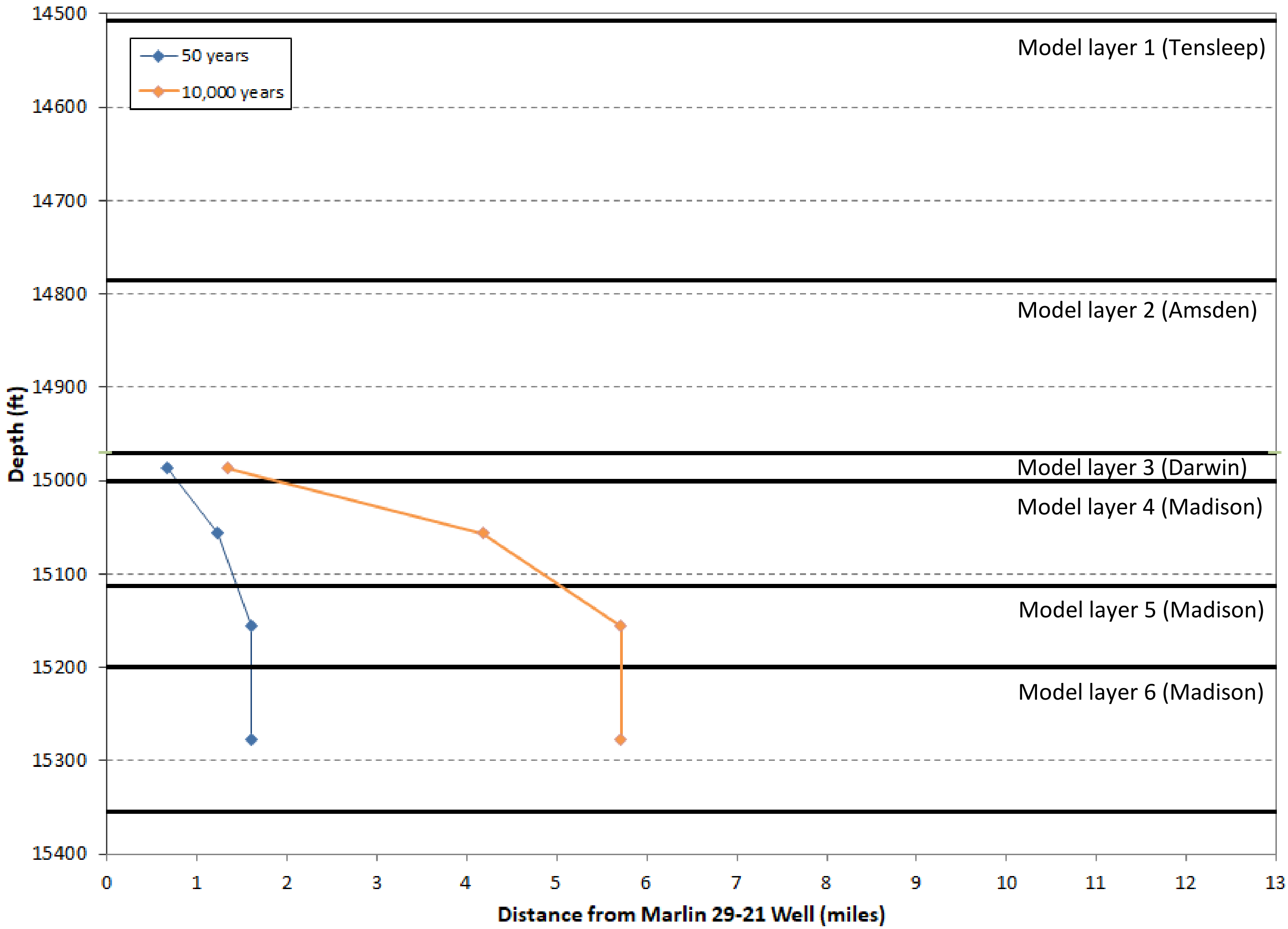
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-33

MODELED SIMULATED VERTICAL CONCENTRATION PROFILE FOR K=3.5 md NET THICKNESS

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) 1e-03 contour (6.9mg/L) shown
2) Simulated results for model layers 1 and 2 (Tensleep and Amsden) are less than 1e-03
3) Average injection rate is 9,900 bpd
4) Profile is oriented along the downdip direction

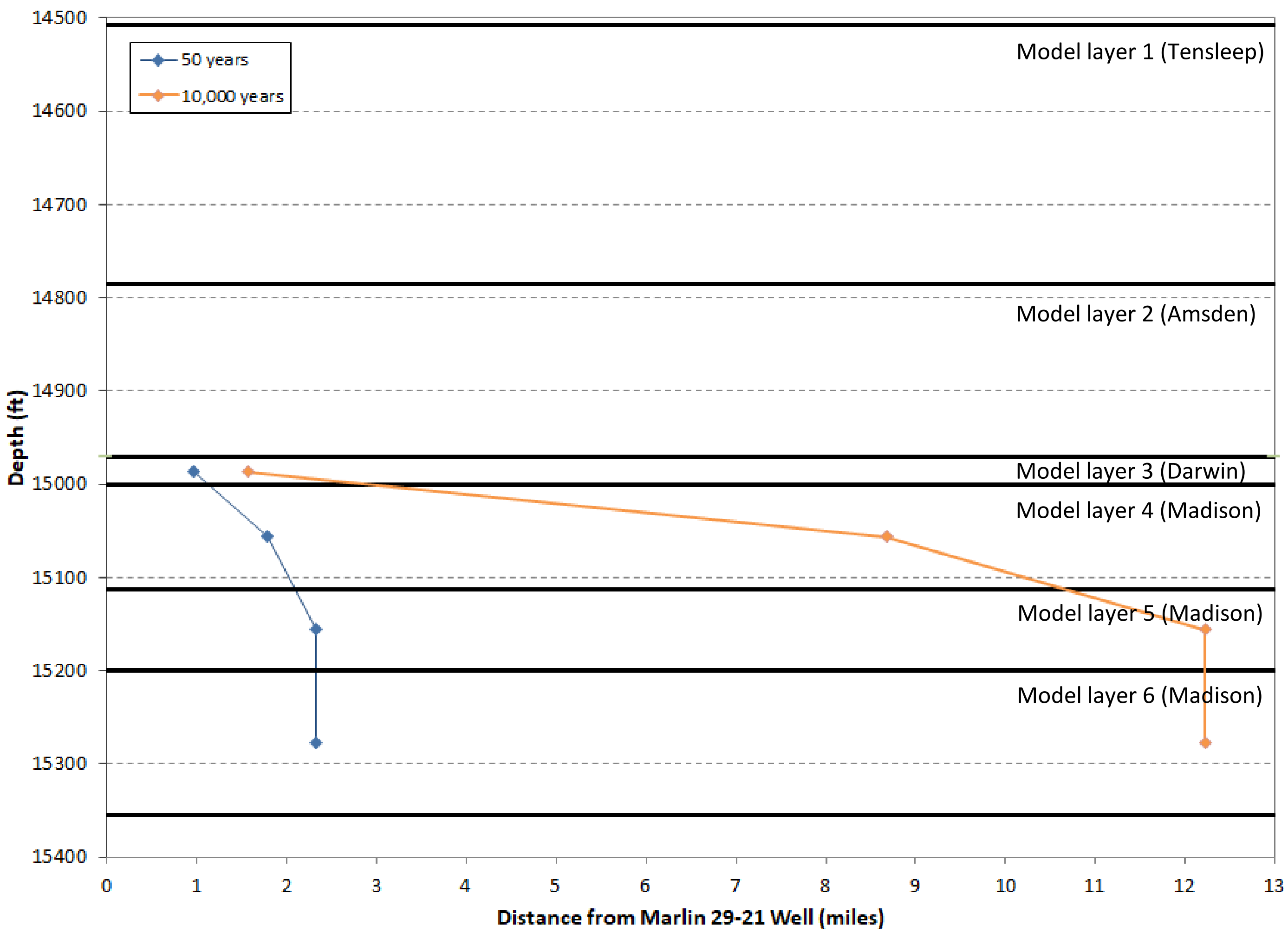
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-34

MODELED SIMULATED VERTICAL CONCENTRATION PROFILE FOR K=8 md NET THICKNESS

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) 1e-03 contour (6.9mg/L) shown
2) Simulated results for model layers 1 and 2 (Tensleep and Amsden) are less than 1e-03
3) Average injection rate is 19,800 bpd
4) Profile is oriented along the downdip direction

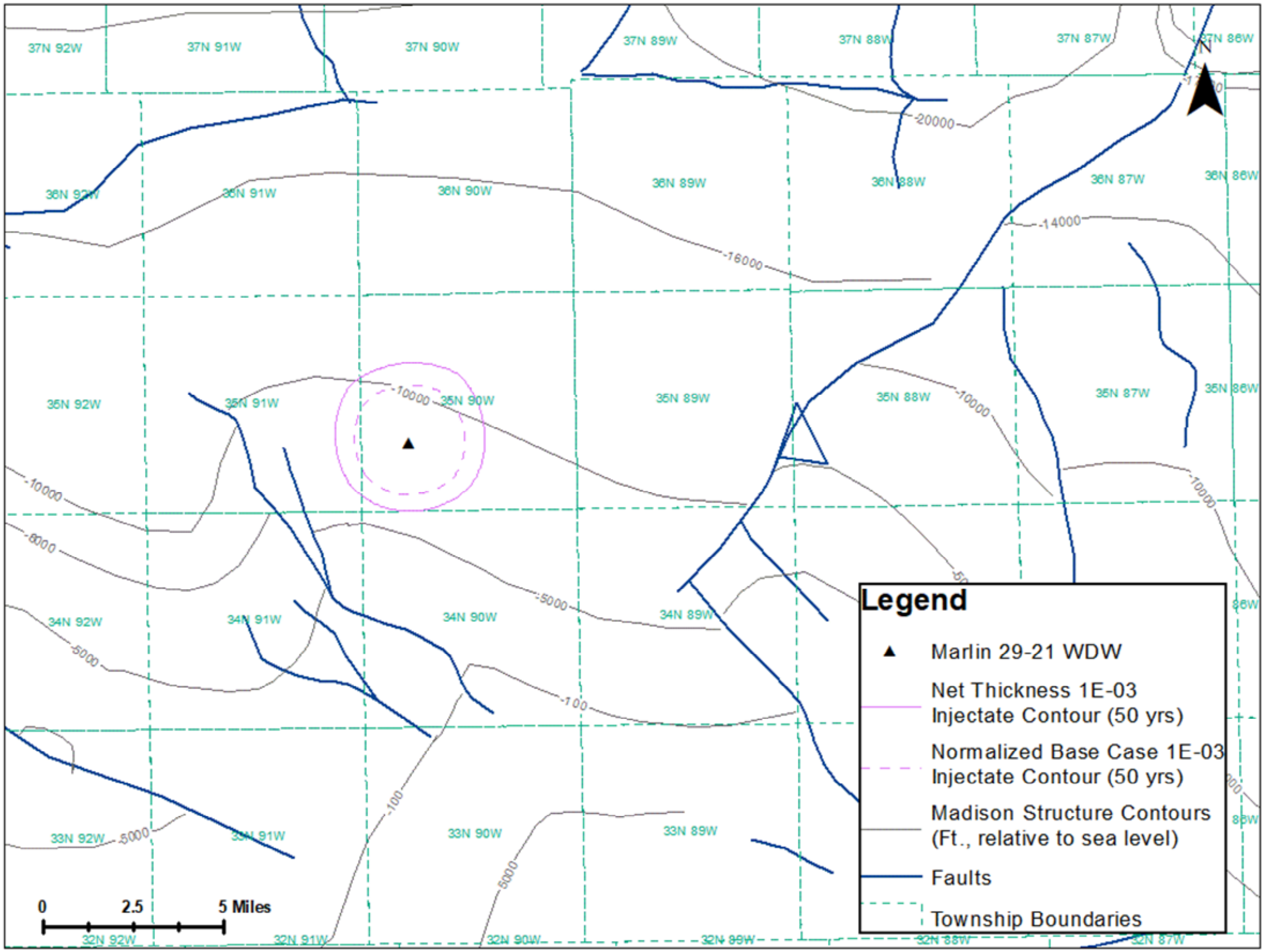
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-35

MODELED SIMULATED VERTICAL CONCENTRATION PROFILE FOR K=17 md NET THICKNESS

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-03
2) Scaled porosities to represent net thickness of Madison injection interval is solid line, base case is dashed line (gross thickness)
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

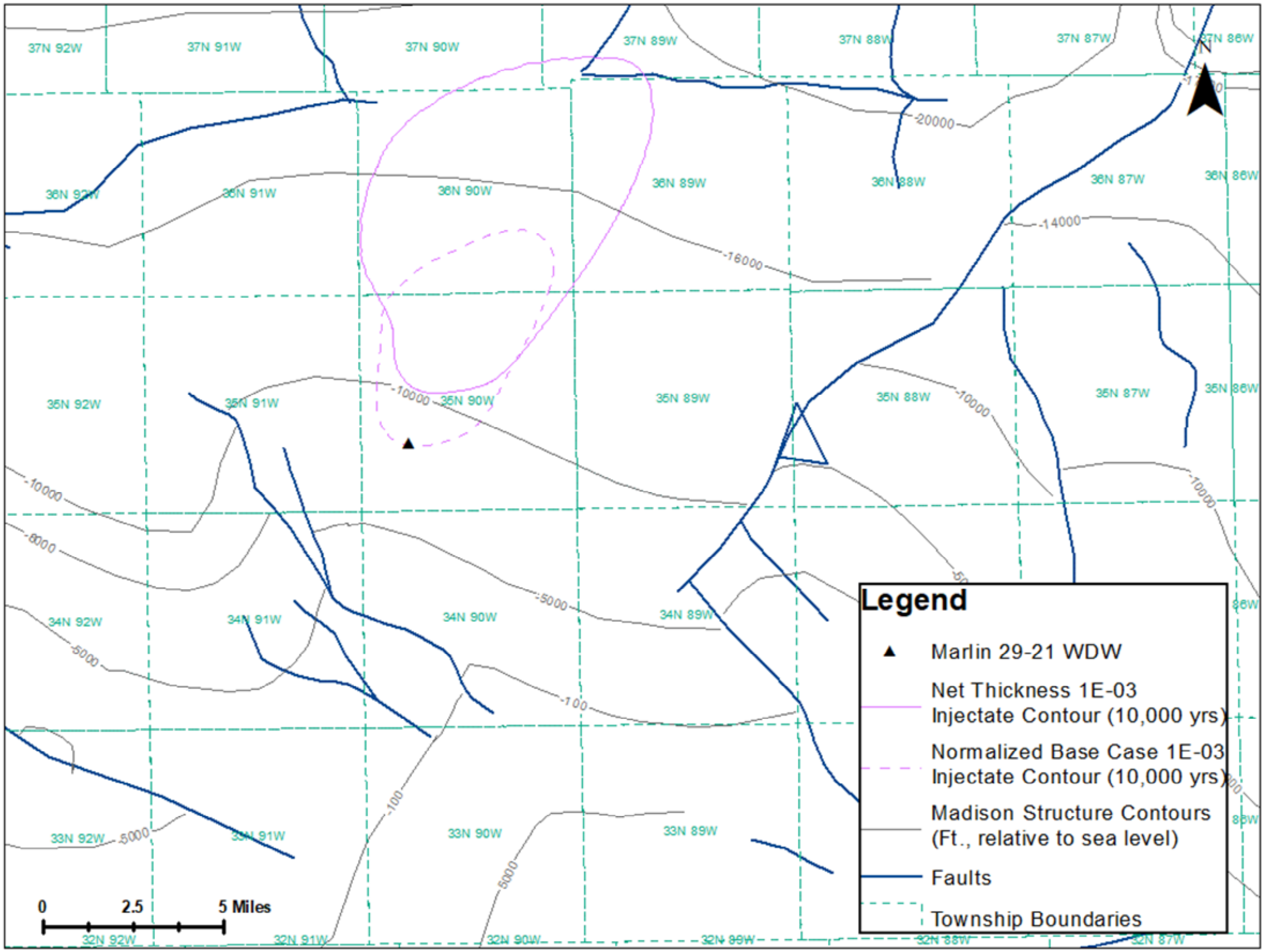
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-36

COMPARISON OF MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-03
2) Scaled porosities to represent net thickness of Madison injection interval is solid line, base case is dashed line (gross thickness)
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

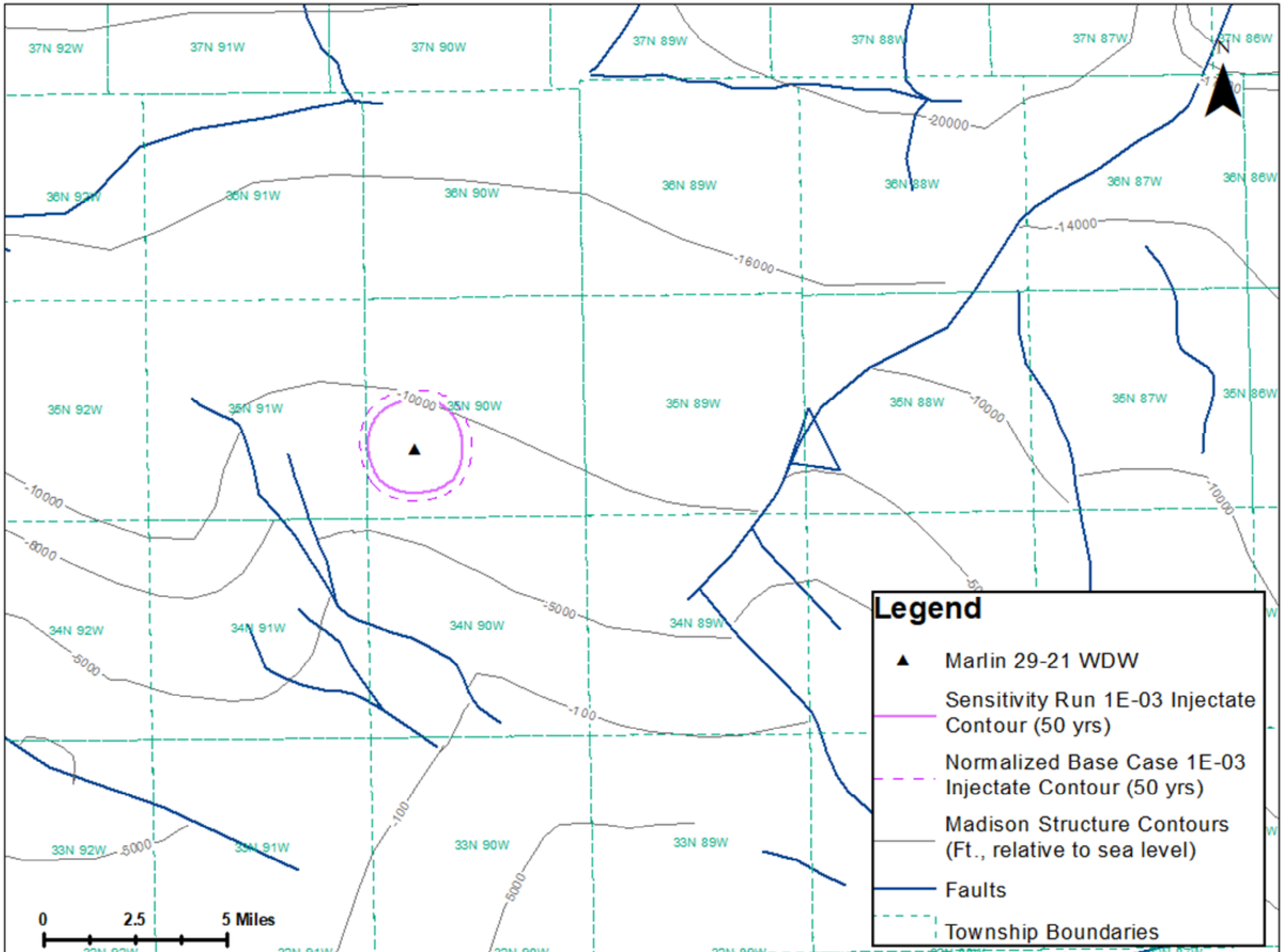
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-37

COMPARISON OF MODELED SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

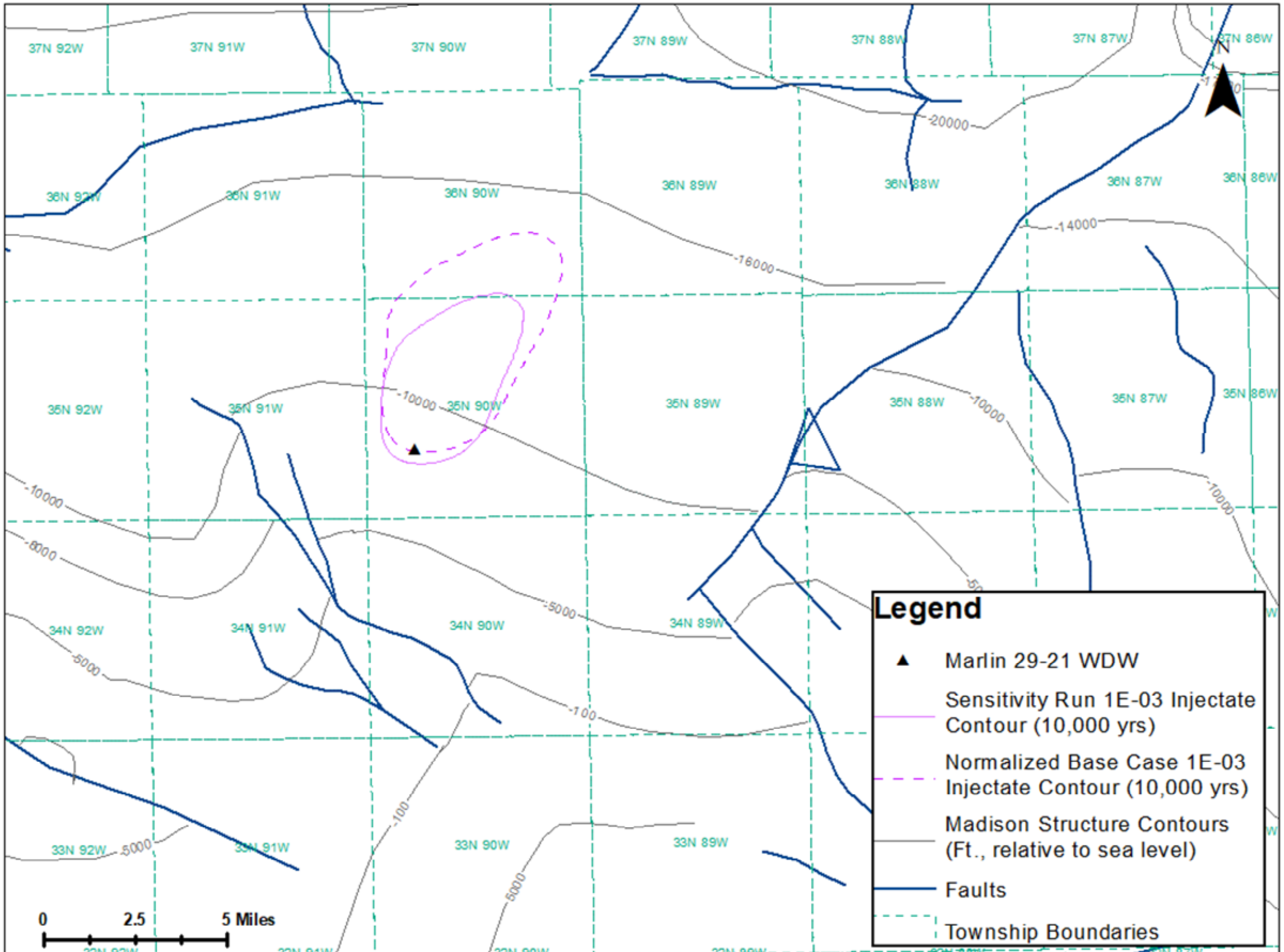
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-38

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md CASE, SENS. RUN: POROSITY = 12%

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

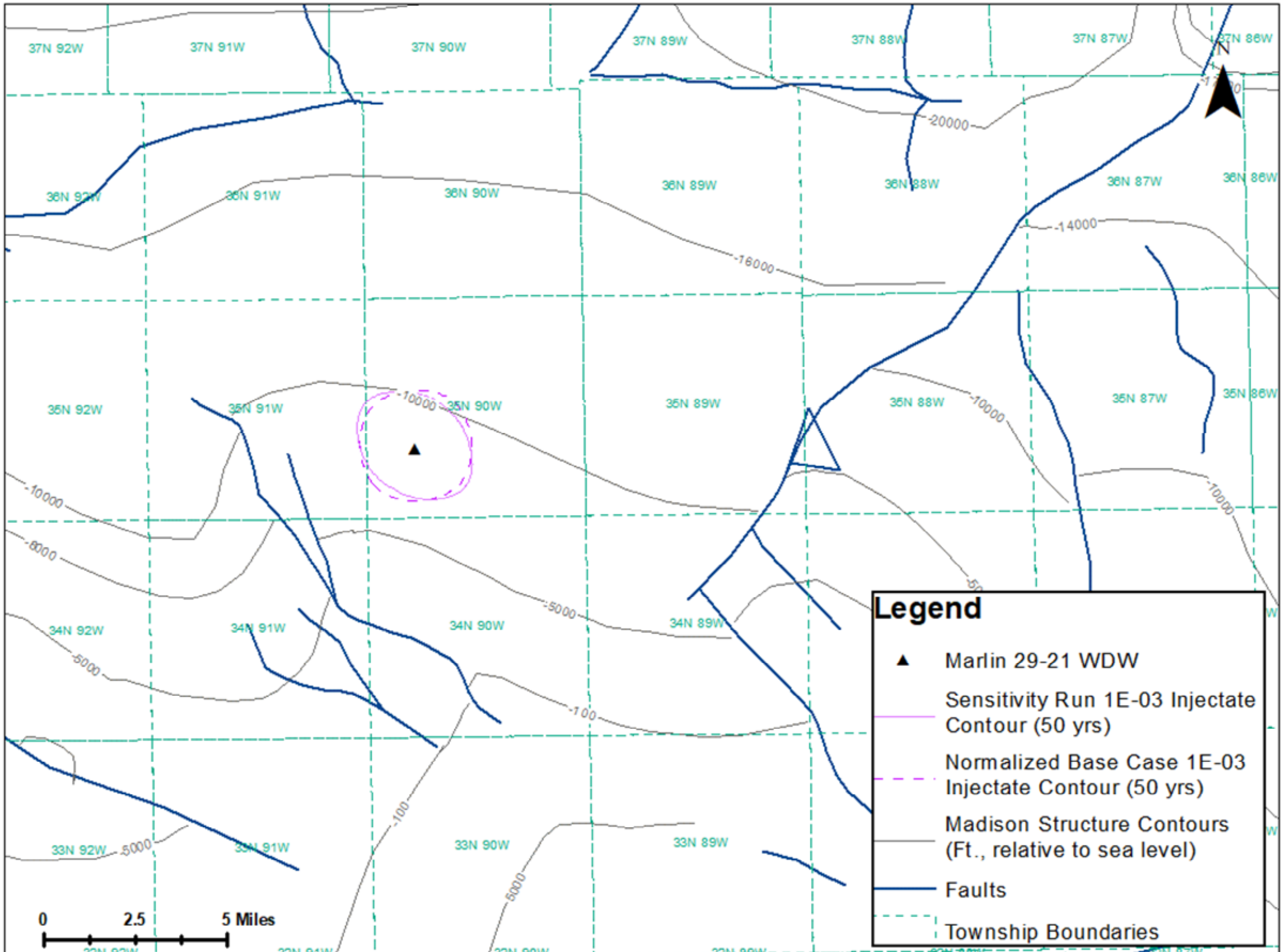
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-39

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md CASE, SENS. RUN: POROSITY = 12%

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

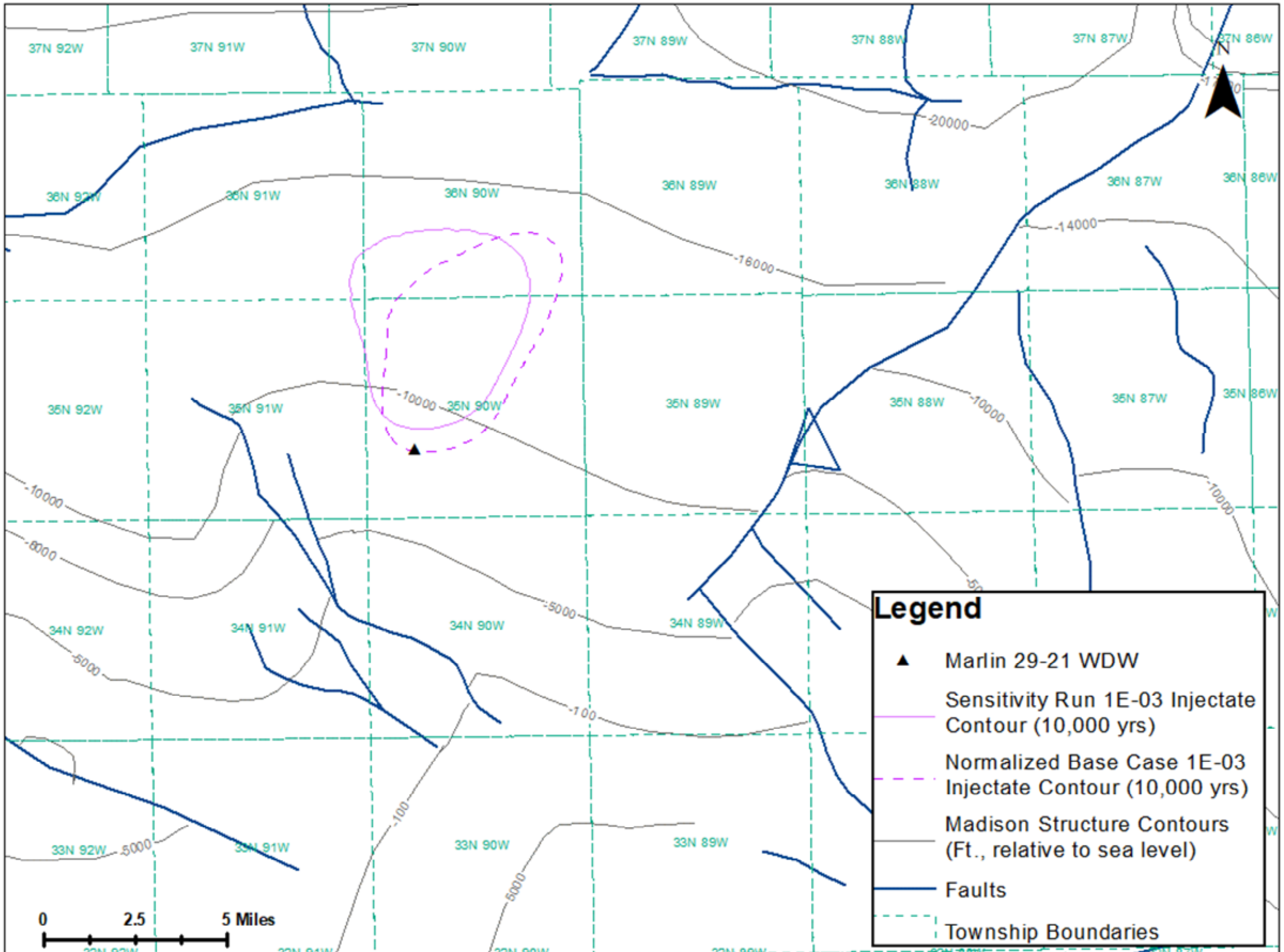
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-40

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md CASE, SENS. RUN: Ky=2Kx

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

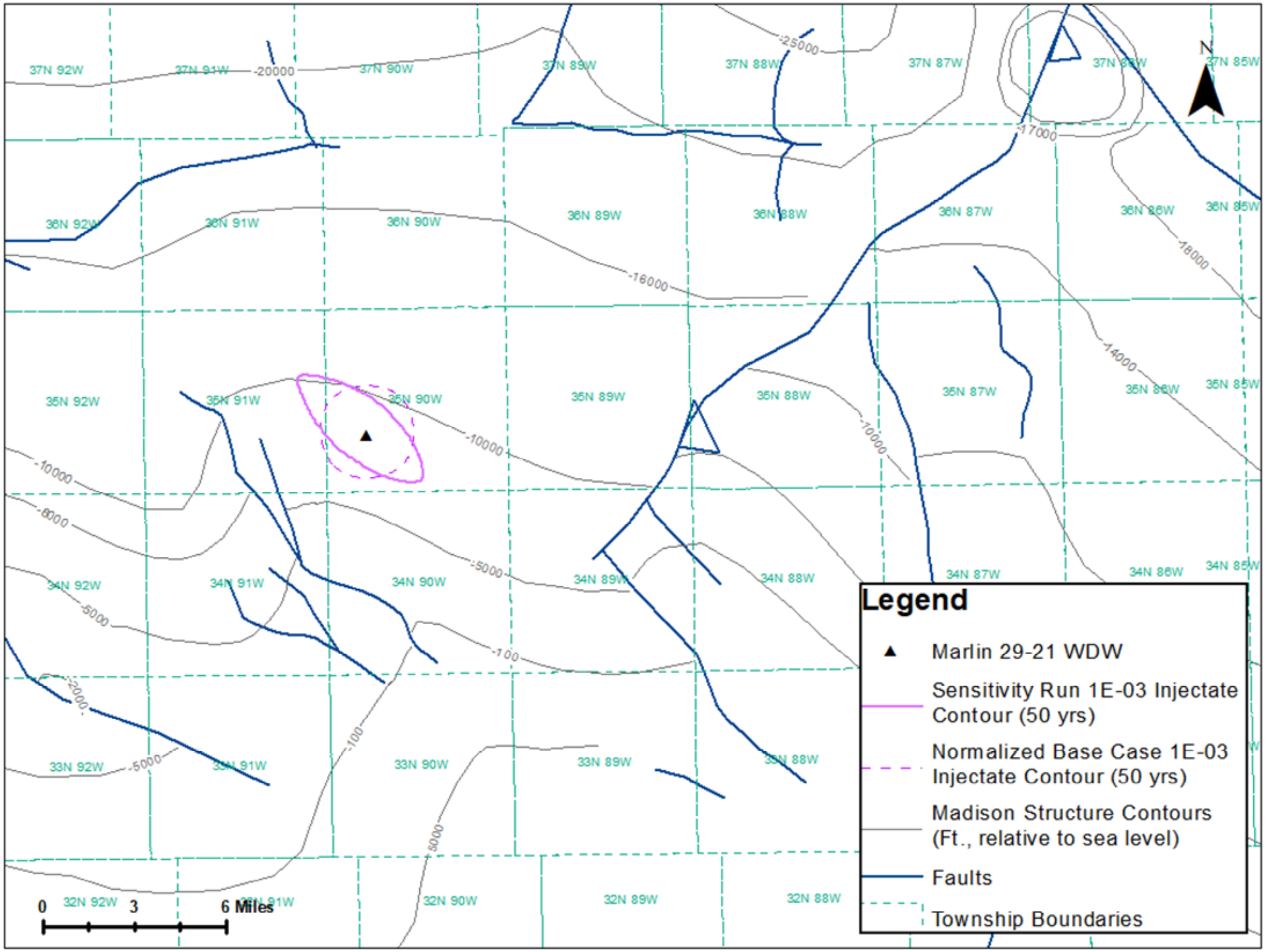
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-41

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md CASE, SENS. RUN: Ky=2Kx

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

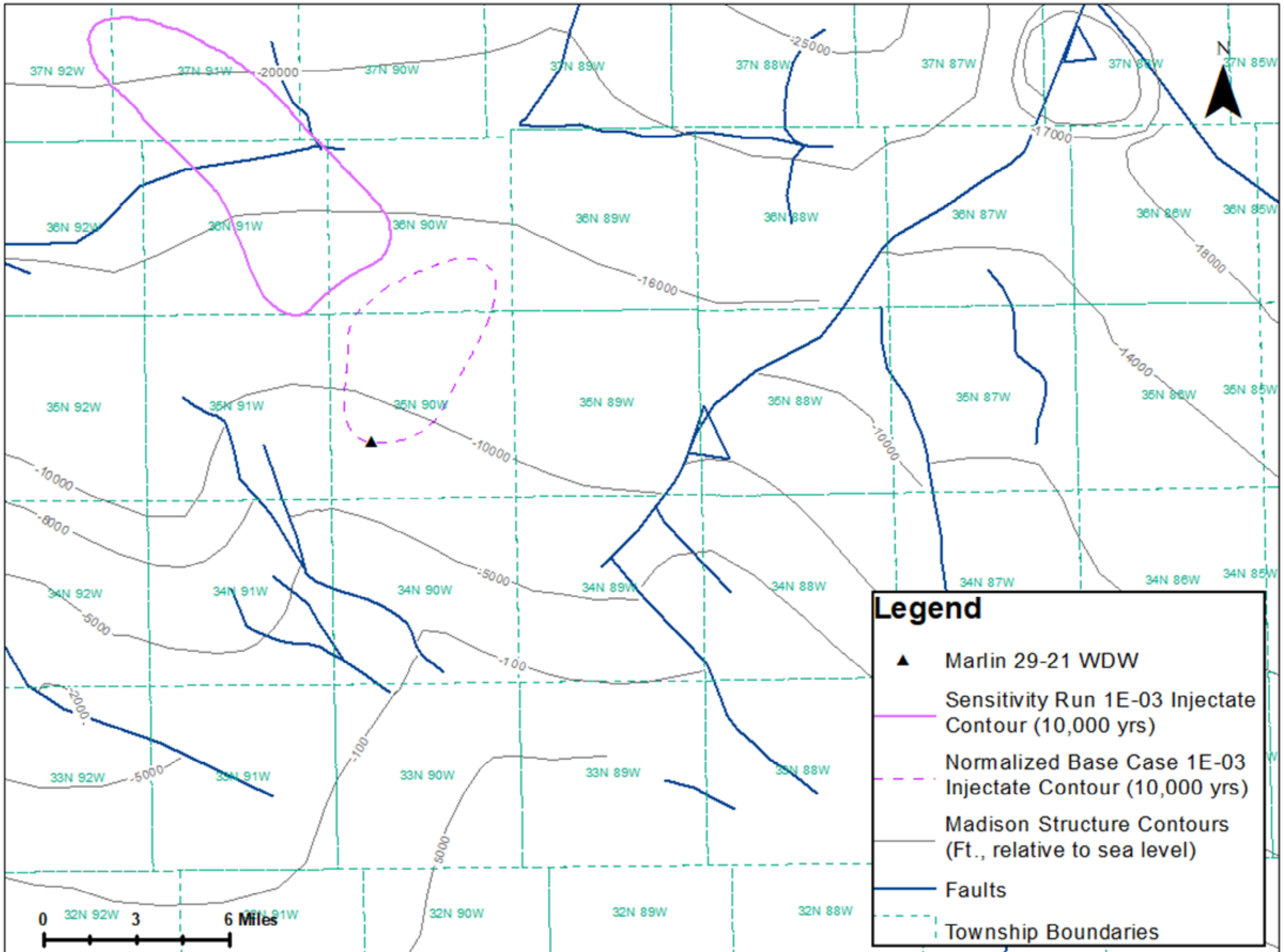
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-42

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md CASE, SENS. RUN: Ky=10Kx

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

AETHON ENERGY OPERATING LLC

FREMONT AND NATRONA COUNTIES, WYOMING

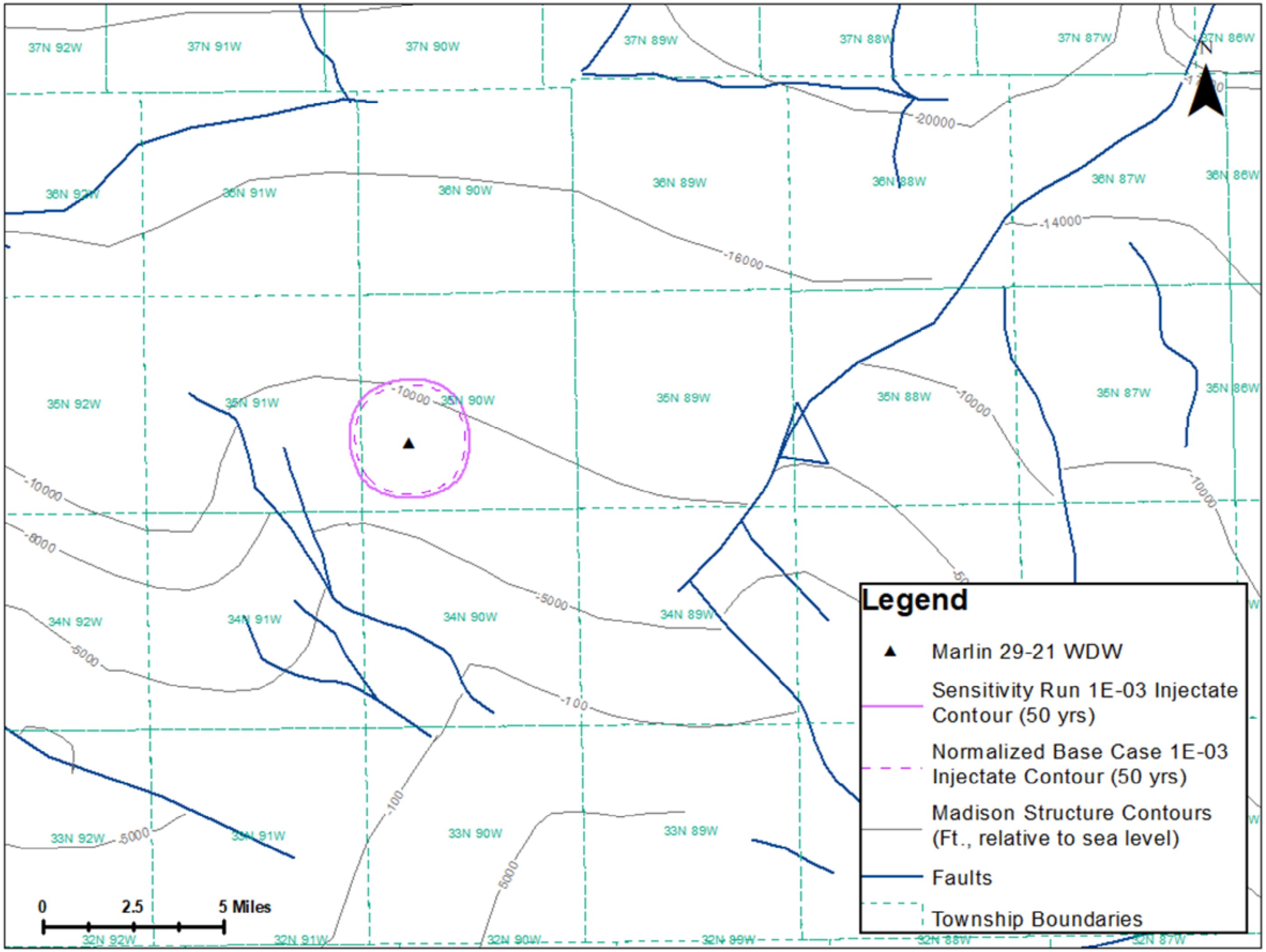
FIGURE 5-43

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md CASE, SENS. RUN: Ky=10Kx

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH

COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

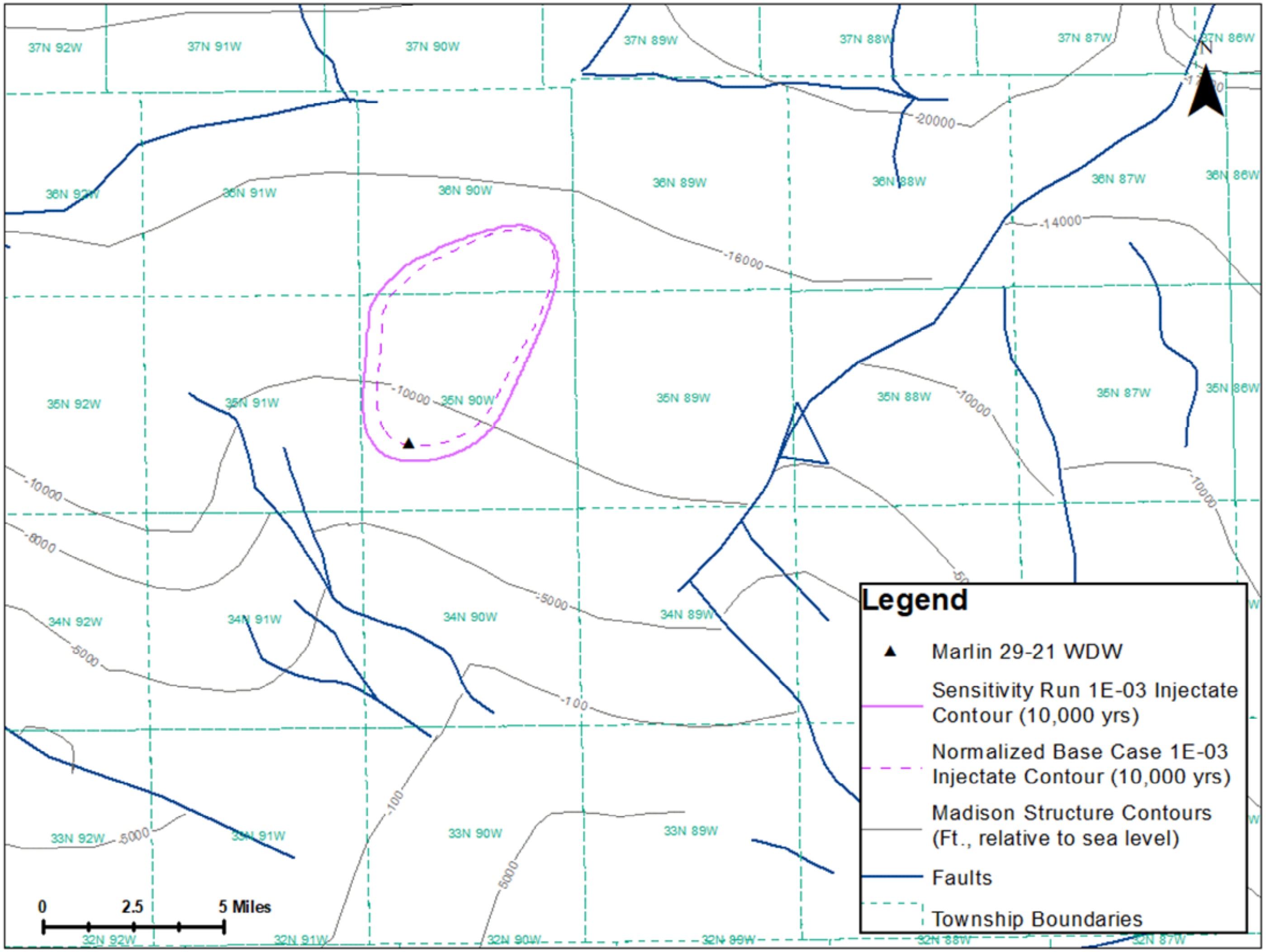
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-44

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md CASE, SENS. RUN: DISPERSIVITY=300 ft

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

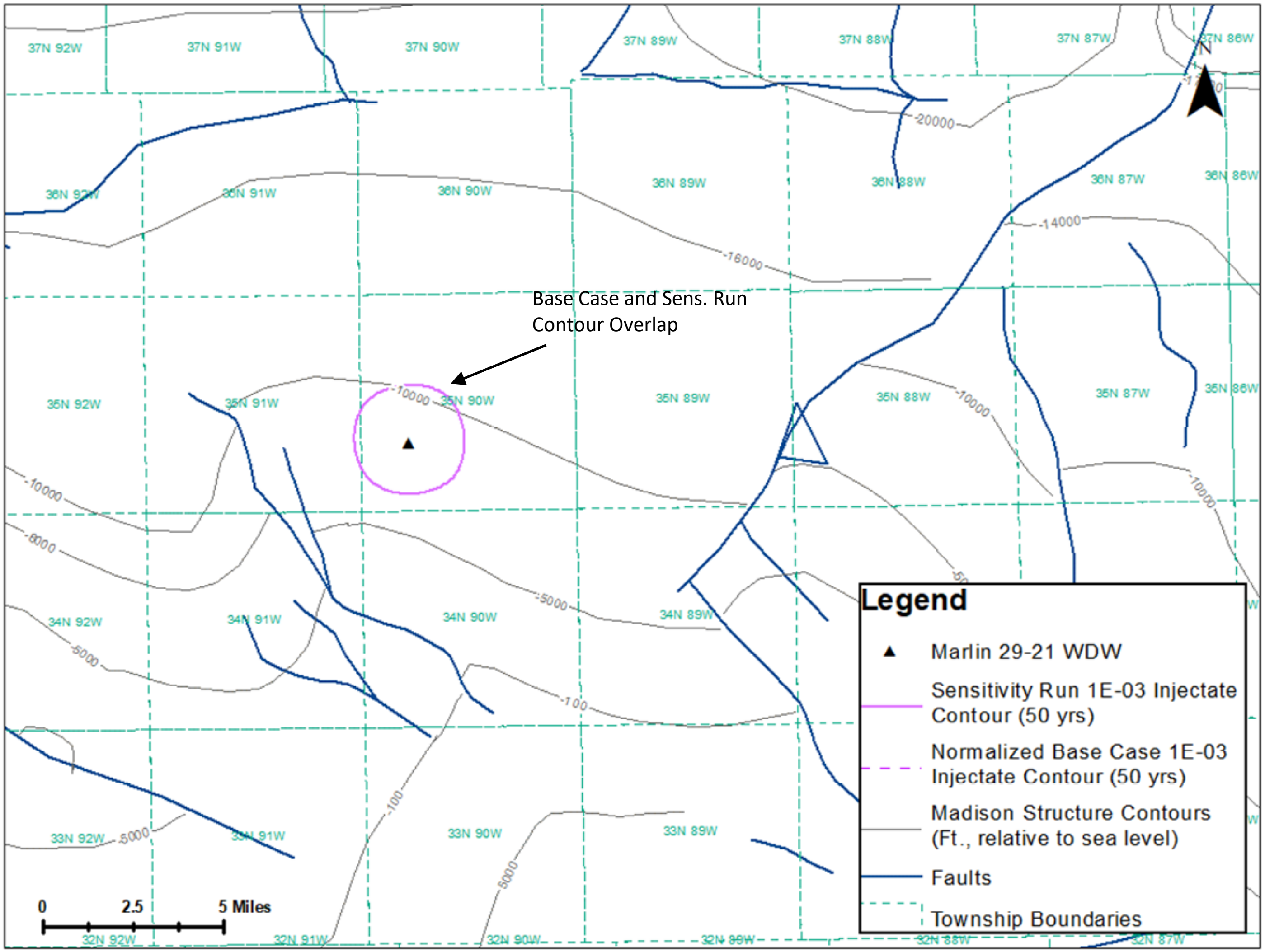
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-45

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md CASE, SENS. RUN: DISPERSIVITY=300 ft

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Constant pressure boundary condition applied along Owl Creek Fault in Tensleep model layer
2) Contours are at 1e-03
3) Sens. run contour is solid line, and base case is dashed
4) 1e-03 contour represents 6.9 mg/L TDS
5) Average injection rate is 19,800 bpd

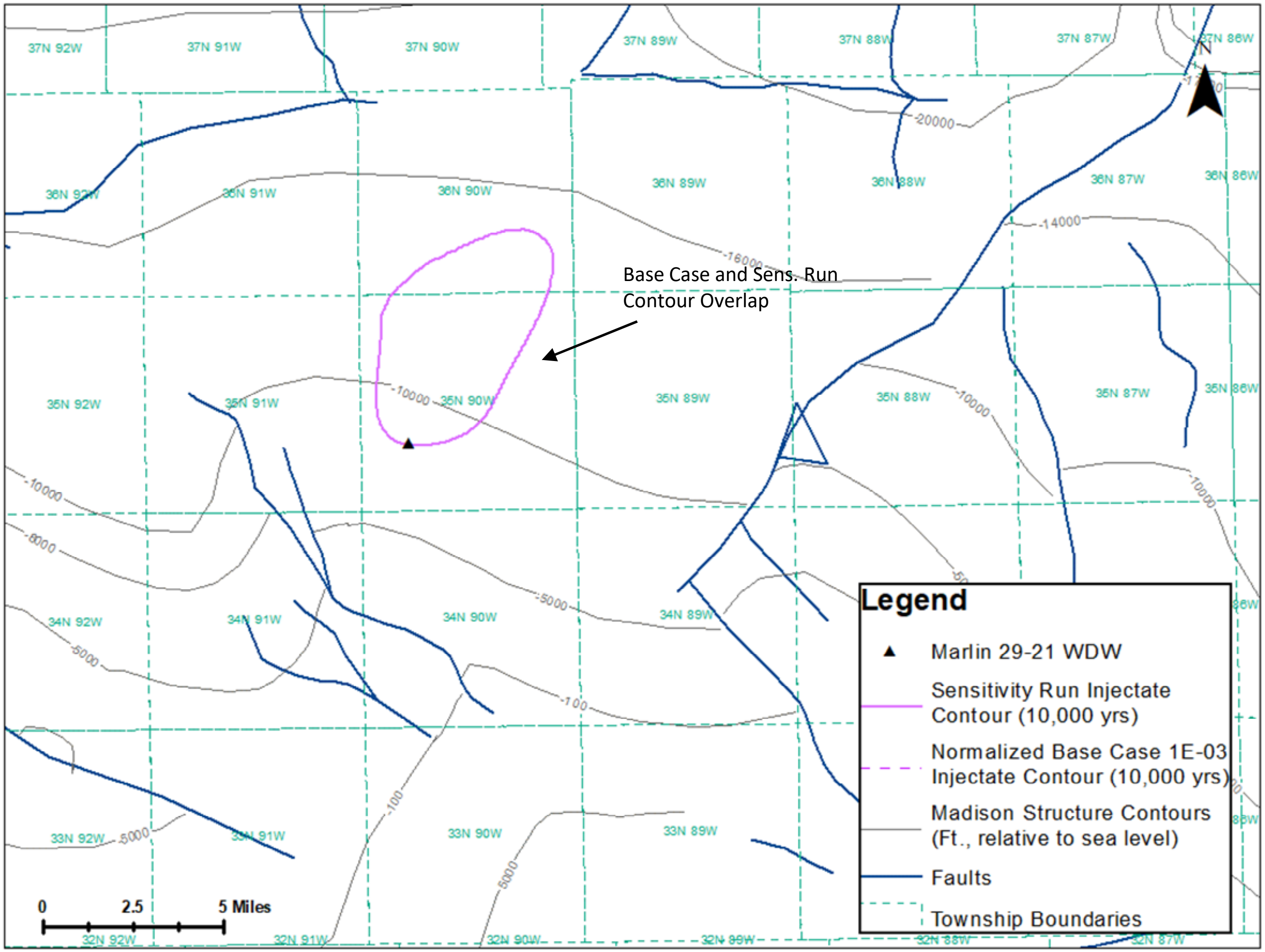
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-46

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md CASE, SENS. RUN: TENSLEEP BASE CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Constant pressure boundary condition applied along Owl Creek Fault in Tensleep model layer
2) Contours are at 1e-03
3) Sens. run contour is solid line, and base case is dashed
4) 1e-03 contour represents 6.9 mg/L TDS
5) Average injection rate is 19,800 bpd

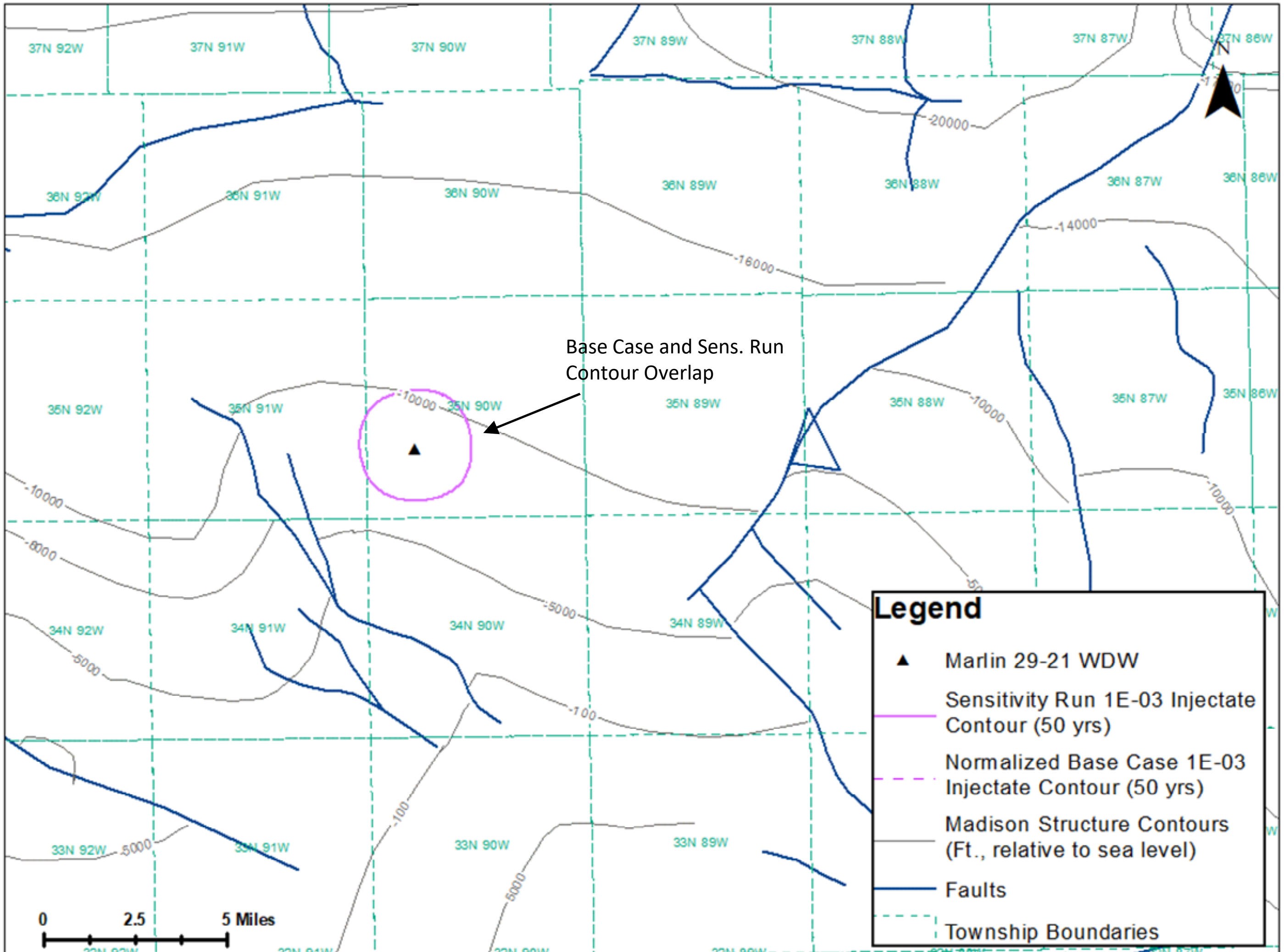
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-47

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md CASE, SENS. RUN: TENSLEEP BASE CASE

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

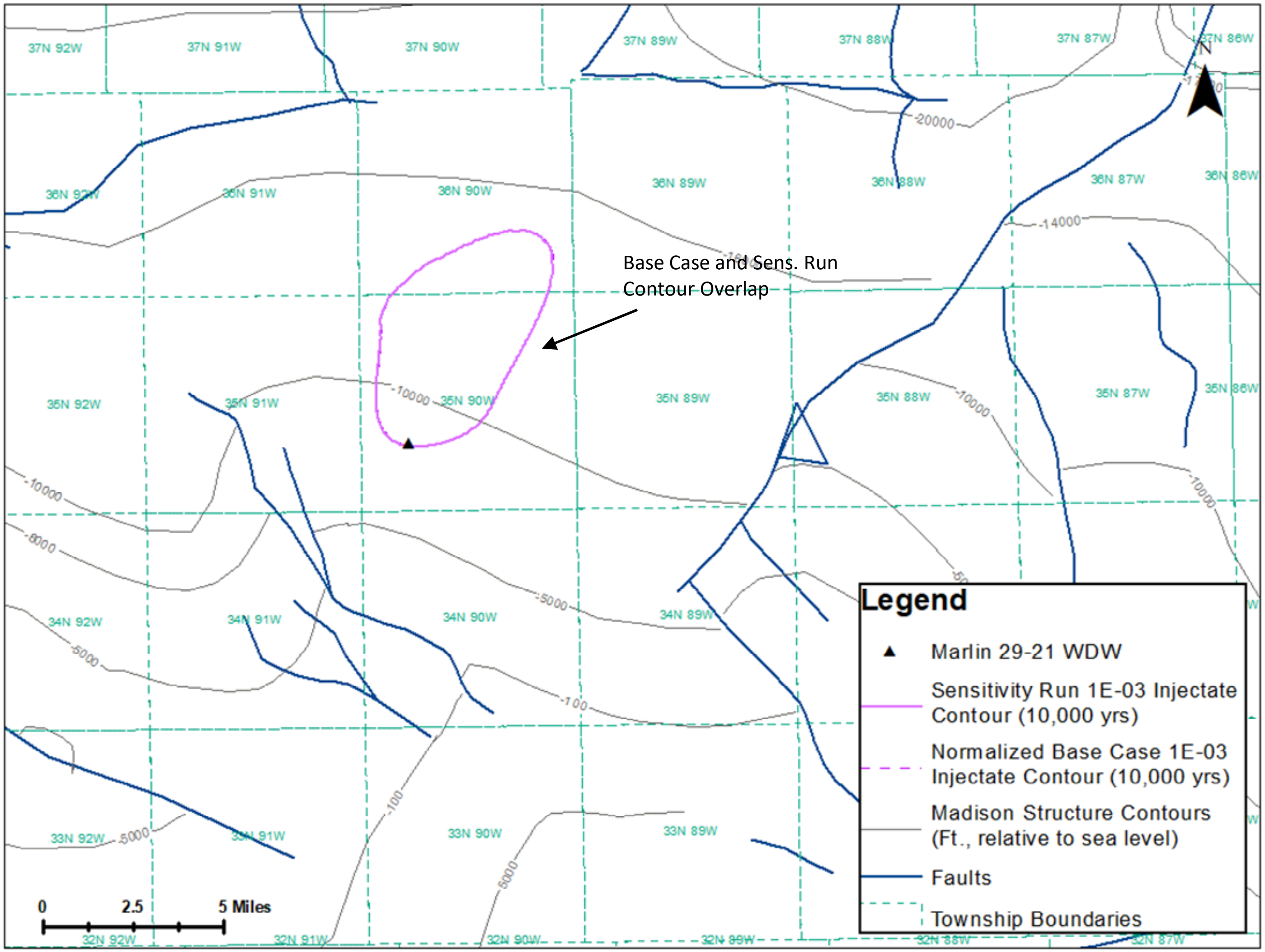
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-48

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md BASE CASE, SENS. RUN: AMSDEN Kv INCREASED

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

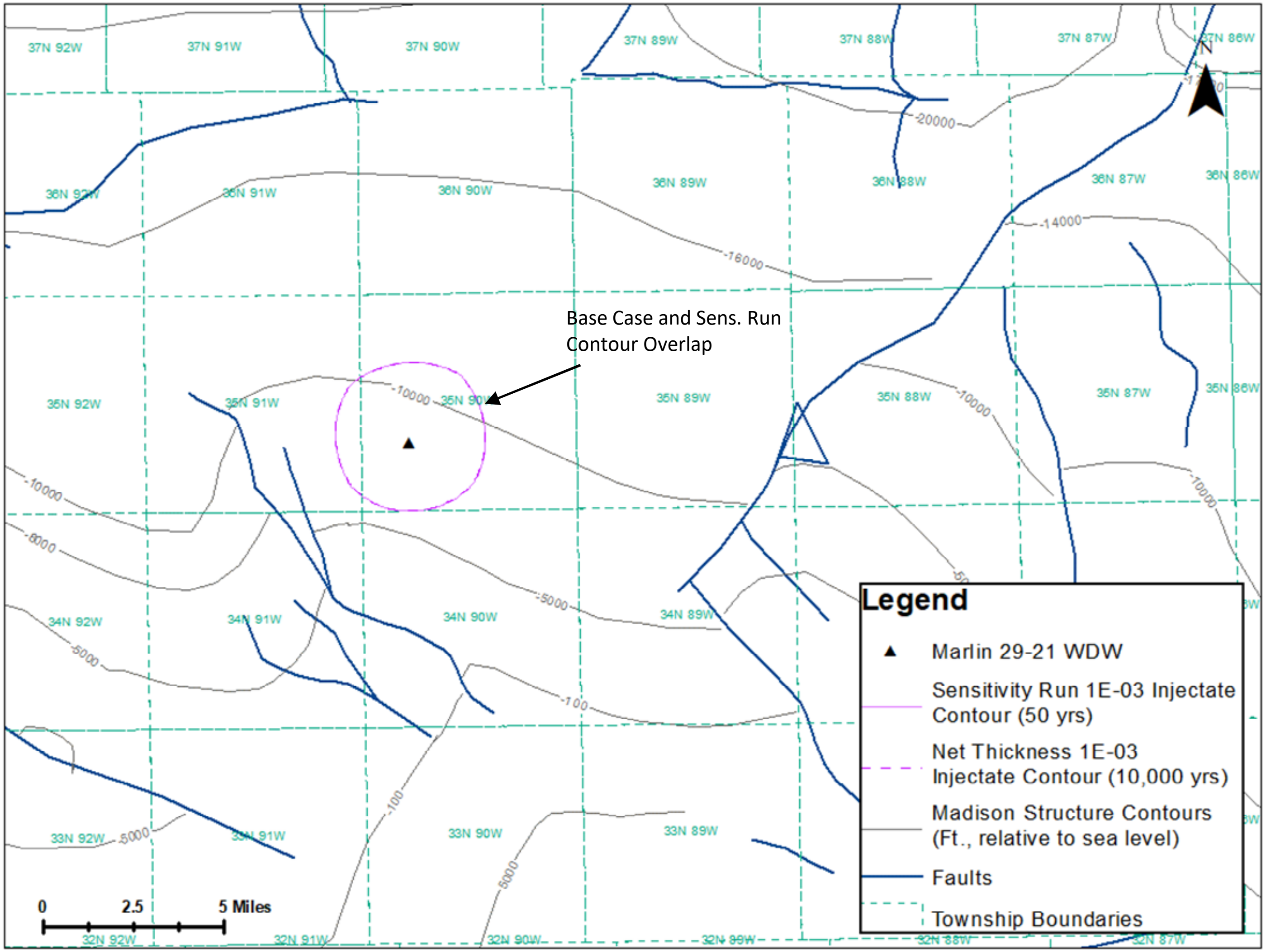
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-49

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md BASE CASE, SENS. RUN: AMSDEN Kv INCREASED

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes
1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

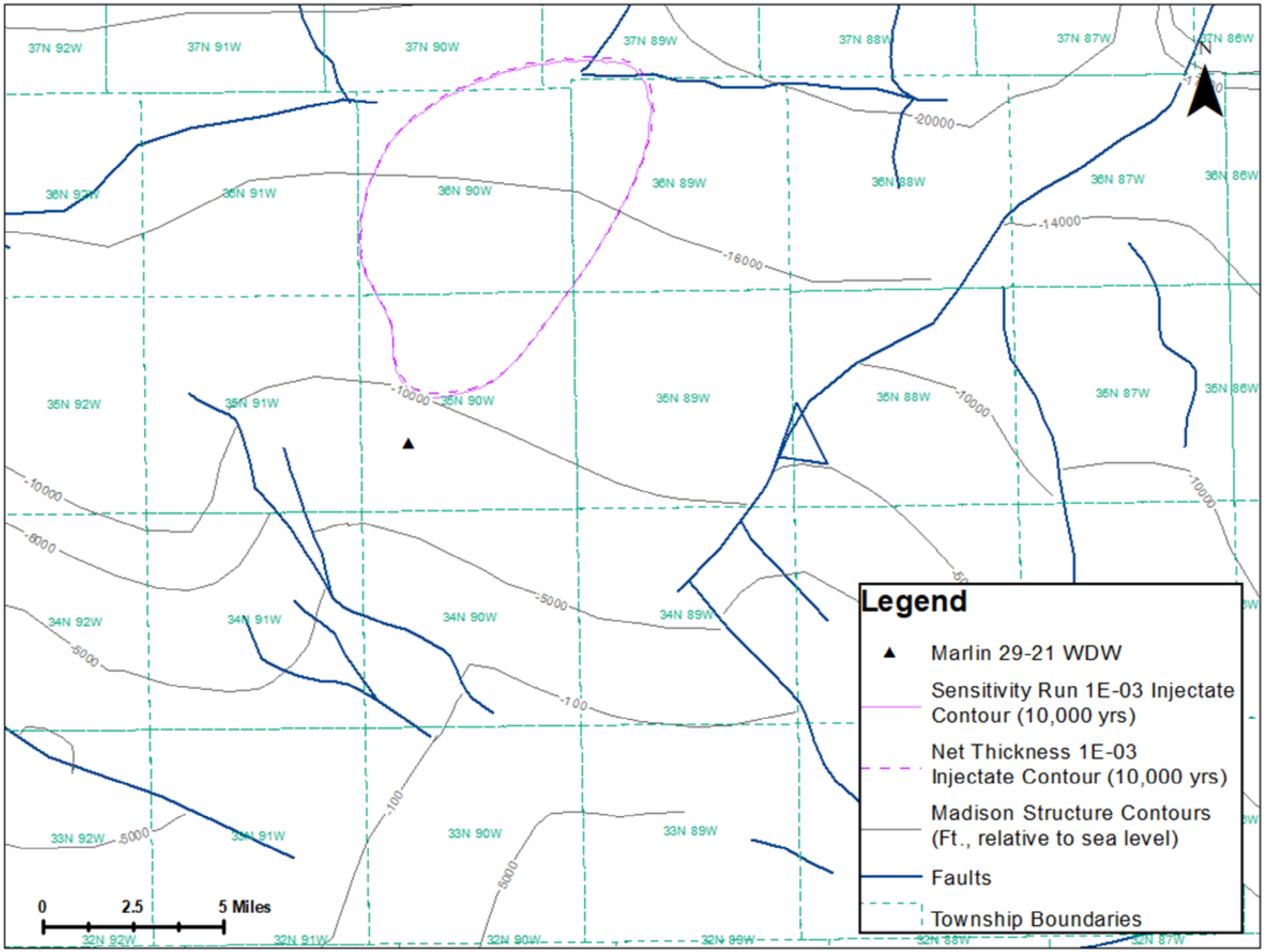
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-50

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=50 years for K=17 md NET THICKNESS, SENS. RUN: AMSDEN Kv INCREASED

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Contours are at 1e-03
2) Sens. run contour is solid line, and base case is dashed
3) 1e-03 contour represents 6.9 mg/L TDS
4) Average injection rate is 19,800 bpd

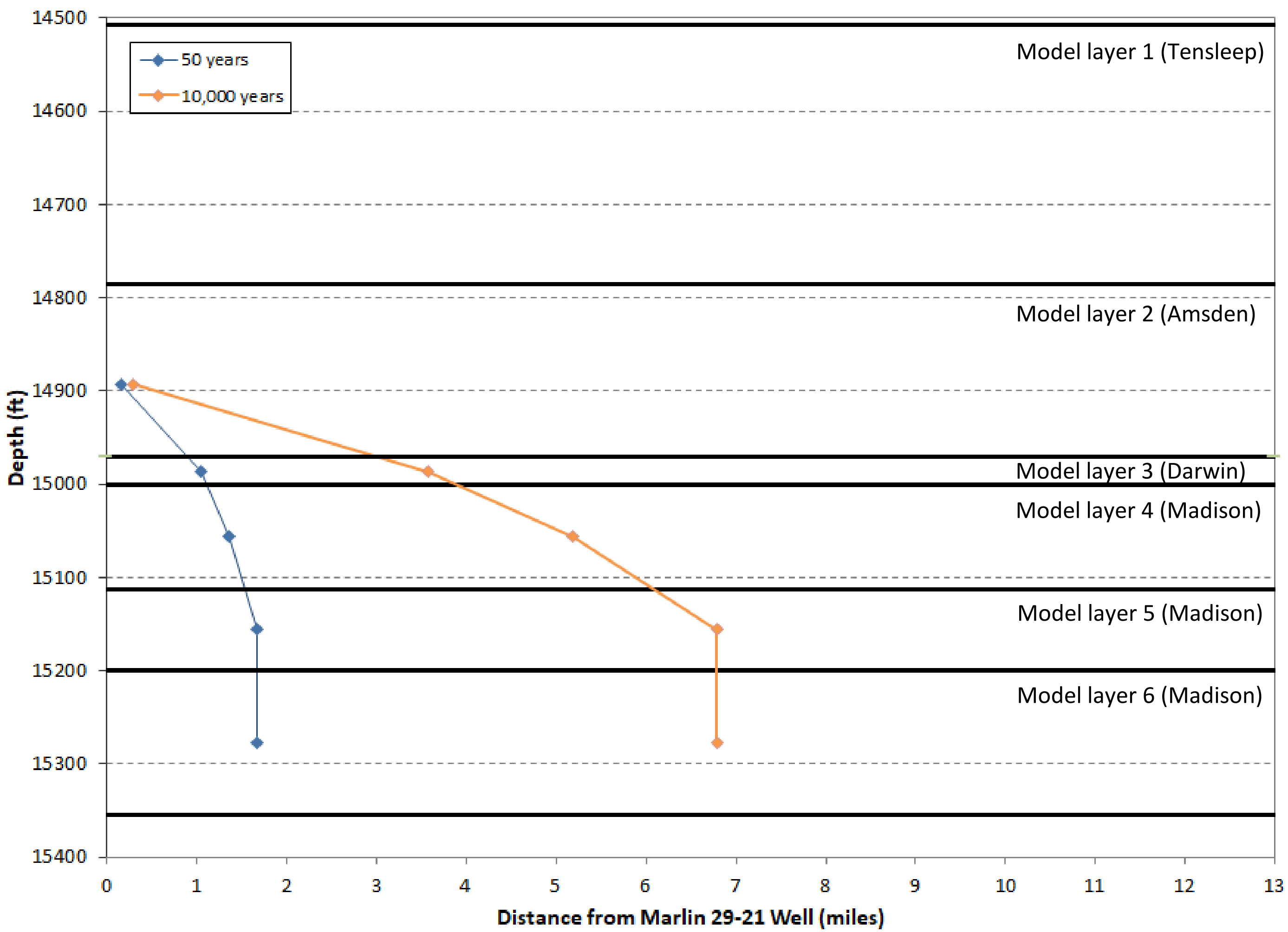
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-51

MODEL SIMULATED WASTE INJECTATE CONTOURS IN MADISON FORMATION AT t=10,000 years for K=17 md NET THICKNESS, SENS. RUN: AMSDEN Kv INCREASED

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Kv of Amsden model layer increased to 1E-09 cm/sec
2) Average injection rate is 19,800 bpd
3) Profile is oriented along the downdip direction

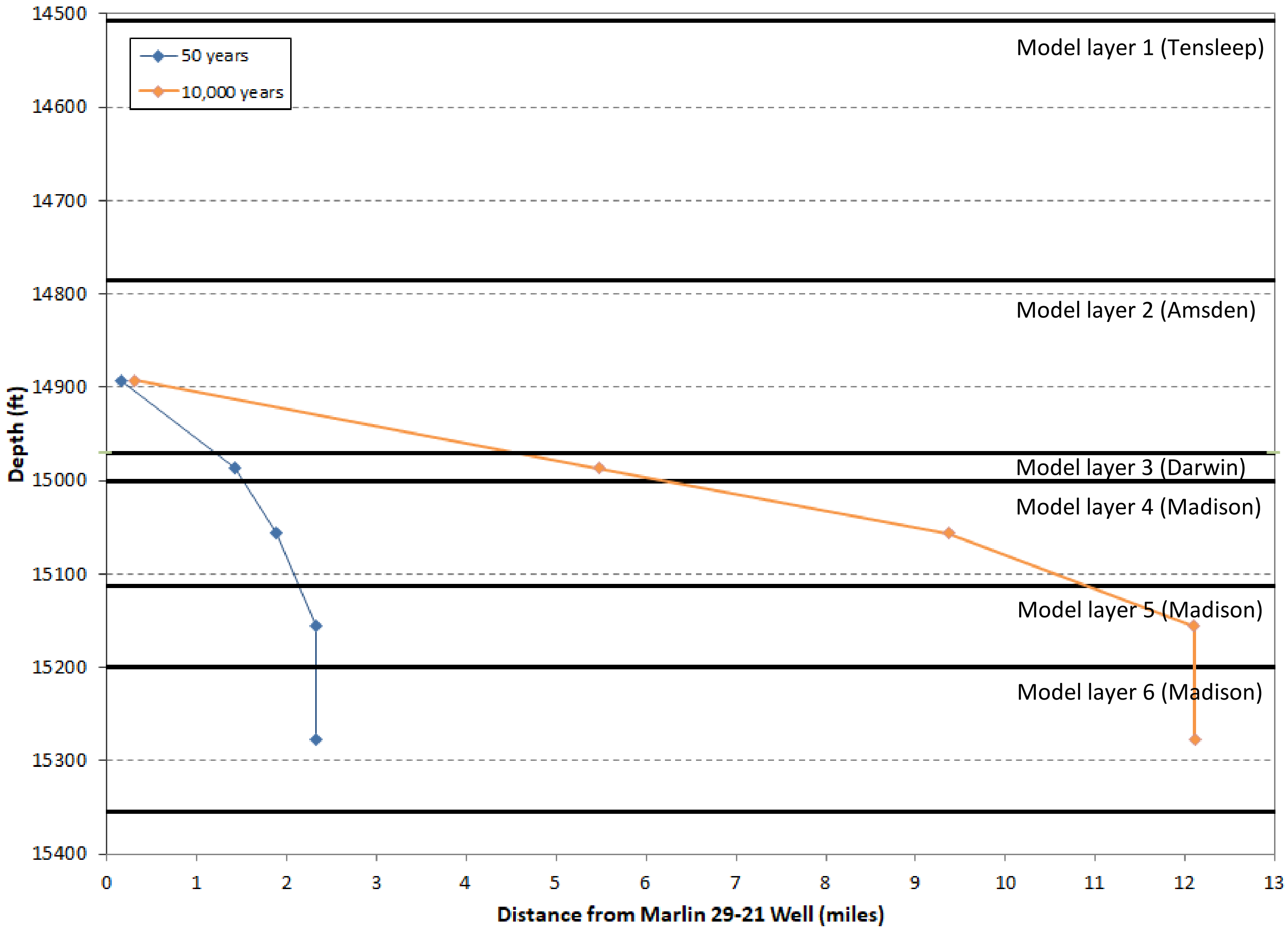
AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-52

MODELED SIMULATED VERTICAL CONCENTRATION PROFILE FOR K=17 md CASE, SENS. RUN: AMSDEN Kv INCREASED

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS



Notes

1) Kv of Amsden model layer increased to 1E-09 cm/sec
2) Average injection rate is 19,800 bpd
3) Profile is oriented along the downdip direction

AETHON ENERGY OPERATING LLC
FREMONT AND NATRONA COUNTIES, WYOMING

FIGURE 5-53

MODELED SIMULATED VERTICAL CONCENTRATION PROFILE FOR K=17 md NET THICKNESS, SENS. RUN: AMSDEN Kv INCREASED

PROJECT: 117-8730001	DATE: JUNE 2020	
REV: 02	BY: JB	CHECKED: JB

TETRA TECH
COMPLEX WORLD, CLEAR SOLUTIONS

APPENDIX

Output Files from Computer Simulations (CD)

BEFORE THE OIL AND GAS CONSERVATION COMMISSION

OF THE STATE OF WYOMING

IN THE MATTER OF THE APPLICATION OF AETHON ENERGY OPERATING LLC FOR AN ORDER FROM THE WYOMING OIL AND GAS CONSERVATION COMMISSION UNDER CHAPTER 4, SECTION 5 AND SECTION 12 OF THE RULES AND REGULATIONS OF THE UNDERGROUND INJECTION CONTROL PROGRAM AND AQUIFER EXEMPTION REGULATIONS TO APPROVE THE DISPOSAL OF WATER INTO THE AMSDEN AND MADISON FORMATIONS FROM THE MARLIN 29-21WDW WELL (API NO. 49-013-23374) AND TO TAKE WHATEVER OTHER ACTION WHICH IS DEEMED APPROPRIATE, *FREMONT COUNTY, WYOMING.*	)	DOCKET NO. 1711-2020

RECEIVED

NOV - 5 2020

WYOMING OIL & GAS CONSERVATION COMMISSION

AFFIDAVIT OF MAILING

STATE OF WYOMING)
)ss.
CITY AND COUNTY OF SHERIDAN)

I, S. Thomas Throne, of lawful age, and being first duly sworn upon her oath, hereby state and declare:

On October 6, 2020, I caused to be mailed by certified postage prepaid, return receipt requested, a copy of the above captioned Application to the following interest holders:

Thoren Enterprises, LP
825 Roundtop Drive
PO Box 431
Thermopolis, WY 82443

Return receipts are maintained at Throne Law Office, P.C.

S. Thomas Throne

Subscribed and sworn to before me on this 6th day of October 2020.

Notary Public

MORGAN K. STALICK - NOTARY PUBLIC
County of Sheridan
State of Wyoming
My Commission Expires July 27, 2024

July 28, 2022

Mr. Rick Arnold
EPA Region VIII
1595 Wynkoop Street
Denver, CO 80202-1129

Re: Docket # 1711-2020
Marlin 29-21 WDW
Public Comment Summary and Response

Dear Mr. Arnold:

The Wyoming Oil and Gas Conservation Commission (WOGCC) held a hearing in November 2020 to review an application from Aethon Energy Operating, LLC (Aethon) requesting an aquifer exemption and approval to utilize the Marlin 29-21 WDW to dispose of produced water into the Amsden and Madison Formations underlying certain lands in Fremont County, Wyoming. The WOGCC opened a public comment period prior to the hearing to accept email and written comments and utilized the hearing as a public meeting to accept verbal comments regarding the Aethon application.

This letter is meant to provide record of these comments to EPA and provide the WOGCC response to the comments. It is being submitted as part of the aquifer exemption package from WOGCC to EPA for request for EPA review of the WOGCC action granting approval of the Aethon application.

During the comment period, the WOGCC received what we consider to be eighteen (18) unique comments. These eighteen unique comments were submitted by 111 separate commenters. The comments and details regarding the party submitting the comment are provided on Exhibit A attached to this letter. The following information details the comments and provides the WOGCC response to the comments. The comment responses are typically formed by pulling information from Aethon's original application, from supplemental information that Aethon provided subsequent to their application, but prior to the hearing, or from general knowledge related to the UIC program or other publicly available sources.

On March 22, 2021, the WOGCC received another comment from Powder River Basin Resource Council (PRBRC). This comment letter was received after the public comment period closed so it is not accepted as an official public comment on the record, it is not addressed below, and is not recorded in Exhibit A. Although the letter was received after the close of public comments, it was reviewed by the WOGCC and no new information was presented that would cause

WOGCC to modify the decision in Docket 1711-2020.

The comments that were received during the public comment period are summarized below with the responses from the WOGCC following each comment:

1. Deny request. Cannot allow pollution to enter Madison Aquifer. Madison Aquifer is an important freshwater source for WY. Madison Aquifer in southern Bighorns is where many of the ranchers and rural residents get their water.

   WOGCC Response: The applicant provided significant and sufficient evidence to show that the Madison Aquifer within 3 miles of the Marlin 29-21 WDW well is not a location that would be targeted for siting of a municipal well.

2. Madison can produce significant quantity of fresh water for Wind River and Big Horn Basins. Aethon is a bad actor. Gillette WY uses Madison Aquifer water wells, WWDC believes Riverton, Pavillion, and Wind River Reservation could develop a similar source of water from Madison.

   WOGCC Response: The Madison Aquifer in Gillette is less than 5,000 feet below ground surface and is not comparable to the location of the Marlin 29-21 WDW well. WOGCC searched the 2019 Wyoming Water Development Commission (WWDC) legislative report and was not able to verify the uncited reference to WWDC information.

3. Deny the requrest.

   WOGCC Response: No information was provided therefore no response is necessary.

4. DEQ initially protested (in 2013) public water systems are increasingly interested in developing groundwater resources and Madison and Big Horn Aquifers have best potential for developing high yield wells.

   WOGCC Response: WOGCC approved the request for aquifer exemption based on depth and location of the aquifer, not potential yield.

5. Oil filled brines are rich in heavy metals. Injecting brines into the Madison means toxic metals will be injected into the aquifer. Once an aquifer is polluted it is nearly impossible to clean up.

   WOGCC Response: An aquifer exemption removes the aquifer from protection as a USDW. The aquifer within 3 miles of the Marlin 29-21 well is not intended to ever be remediated.

6. Wyoming is in a drought and could be forced to use the Madison. Do not endanger future of WY growth by sacrificing a potable water source which is scarce and precious. The injection water will not remain at a great depth but will filter throughout the aquifer. Deny request.

WOGCC Response: The applicant provided significant and sufficient evidence to show that the Madison Aquifer within 3 miles of the Marlin 29-21 WDW well is not a location that is targeted for siting of a municipal well. The Madison aquifer may well be utilized as municipal water source in Wyoming, but not within 3 miles of the Marlin 29-21 WDW well. The applicant also provided detailed modeling and geologic testimony demonstrating that the fluids will remain in zone.

7. Did we not learn from ozone layer and acid rain. Why would WY consider this. Deny this request and others that will endanger quality of groundwater.

   WOGCC Response: No information was provided therefore no response is necessary.

8. Deny request, this water is being/planned to be used *somewhere (Gillette, Buffalo,).

   WOGCC Response: WOGCC is unaware of any plans for municipal use of the Madison Aquifer within 3 miles of the Marlin 29-21 WDW.

9. May affect layers above via leaking pipes, in drought conditions water for drinking/irrigation may be needed if water levels drop, choose WY communities over outsider energy industry.

   WOGCC Response: UIC regulations enforced by WOGCC provide for protection of other USDWs located above the target injections zones.

10. Joe Biden's goal is to have zero CO_2 emissions by 2050, WY needs to participate. We drive a hybrid electric vehicle. Have 12 solar panels on home to charge batteries. Proud to be ahead of the curve. Aethon wants to increase rate of production, which will increase risk to Madison.

    WOGCC Response: No information was provided therefore no response is necessary.

11. WY is in a drought according to drought.gov, Madison is a clean source of drinking water, deny request.

    WOGCC Response: The applicant provided significant and sufficient evidence to show that the Madison Aquifer within 3 miles of the Marlin 29-21 WDW well is not a location that is targeted for siting of a municipal well.

12. Oil and gas has contaminated our water in this area and nearby. We will stand up against this.

    WOGCC Response: No information was provided therefore no response is necessary.

13. Do not pollute future water supply, water will be increasingly vital to WY viability.

WOGCC Response: The applicant provided significant and sufficient evidence to show that the Madison Aquifer within 3 miles of the Marlin 29-21 WDW well is not a location that is targeted for siting of a municipal well.

14. Deny the request, clean water is vital. Past requests to contaminate the Madison were denied and this one should be denied too.

    WOGCC Response: The applicant provided significant and sufficient evidence to show that the Madison Aquifer within 3 miles of the Marlin 29-21 WDW well is not a location that is targeted for siting of a municipal well.

15. When pollutants are discharged they remain in the underground water, soils, and surface water. Citizens will bear the brunt of development for years to come. Water that served important communities in Fremont County will become contaminated. No regulatory framework can mitigate the multiple risks of fracking.

    WOGCC Response: The applicant demonstrated that sufficient confinement exists to keep injected fluids in the exempted zones and prevent migration to other USDWs.

16. Madison aquifer is an important target for municipal water supply in the Wind River and Big Horn Basins. Argument that it is not economically or technologically practical is impersuasive because there are other water wells in the state that produce from similar depths. Disposing into groundwater that could supply or connect to fisheries is short or long term would not be prudent.

    WOGCC Response: A search of the Wyoming State Engineer's office records indicates that the deepest municipal well in Wyoming is the Maderson Wild Horse #1 well at a depth of approximately 5,400 feet. The Madison Aquifer at the Marlin 29-21 Well is located at a depth of approximately 15,000 feet.

17. The west is facing drought, climate change, and increased use. The aquifer plays a critical role in health and vitality of wildlife in the state and national park connected landscapes. The state should work to improve habitat and vitatlity of Wyoming's wildlife.

    WOGCC Response: WOGCC is not aware of any current use of the Madison Aquifer near the Marlin 29-21 WDW well.

18. The Madison Aquifer is one of the most important aquifers serving as both a current and future water source. Aethon fails to demonstrate that the groundwater in the Madison is both economically and technologically impractical for development in the future. The plume from the injected wastewater could exceed that area of containment. Failure to adequately characterize the hydrogeologic setting. Uncertainty in Aethon's groundwater modeling. Opening the door to additional Madison Aquifer exemptions.

    WOGCC Response: Commenters argue that the Marlin 29-21 WDW fits the siting criteria for a Madison public water supply (PWS) well. WOGCC disagrees. Siting of a PWS well in the Madison Formation in the Wind River Basin would target structures that have the potential for fracturing and are close to the recharge area because that lowers well cost and provides the best water quality. The Marlin 29-21 WDW well does not meet those criteria. The Madison wells referred to at the top of page 4 of Ms. Spencer's letter are the deepest PWS wells in the state at 5,400 feet and have a TDS concentration of about 200 mg/L. The water sample from the Madison/Amsden interval in the Marlin 29-21 WDW well had measured TDS concentrations from 910-1200 mg/L. The EPA secondary standard for TDS is 500 mg/L. Additional treatment would be necessary to provide water quality necessary for use as a public water supply.

Commenters also argue that there is doubt about the dependability of water supplies for the towns of Riverton and Shoshoni because they use the Wind River Aquifer and suggested they may need to use the Madison Formation. A review of Master Plans for Riverton available on the Wyoming Water Development Commission website revealed that utilizing groundwater from the Madison Formation in any location does not appear to have ever been considered.

Commenters also suggest that the applicant did not consider the effects of the karst features in the Madison formation. In the hearing transcript page 125 -126 Mr. Thompson testified that evidence at the Marlin 29-21 WDW and deeper in the basin show that the karst openings have been filled in and therefore the porosity and permeability are low.

Commenters suggested that data underpinning the modeling effort was not sufficient and there was great uncertainty in the modeling. WOGCC contends that the modeling was sufficient to make a reasonable determination of what the exemption area should be. In fact the up-gradient exempted area is greater than the modeling predicted. This is important because if the Madison ever were targeted it would be towards the outcrop not deeper into the basin. Even at the most up-gradient modeled extent of the injected fluids the Madison would be 12,000 feet below ground surface and 11 miles from outcrop (Page 126 of the hearing transcript).

The comments that were received during the hearing for Docket 1711-2020 are summarized below with the responses from the WOGCC following each comment:

1. Jill Morrison. The Madison at the location of the Marlin 29-21 WDW is economically feasible to use as a PWS. Gillette spent $200 million to develop and transmit Madison water and estimates to develop and transmit water from the Marlin well location is $169 million.

   WOGCC Response: Gillette's water situation is not comparable to the municipalities close to the Marlin 29-21 WDW well. Gillette does not have water of sufficient quality and quantity proximally located like the communities surrounding the Marlin 29-21 WDW well.

2. Sally Palmer. Comments about general contamination, testing, and aquifer recharge.

   WOGCC Response: WOGCC could not discern any comments about why the Marlin 29-21 WDW well should not be approved and therefore no response is necessary.

3. Shannon Anderson. The Madison is a good quality aquifer that is a potential source of drinking water into the future.

   WOGCC Response: The applicant provided significant and sufficient evidence to show that the Madison Aquifer within 3 miles of the Marlin 29-21 WDW well is not a location that would be targeted for siting of a municipal well.

4. Sue Spencer.

   WOGCC Response: See public comment response number 18.

5. Maria Katherman. Uneconomic water treatment options are not a reason to grant an aquifer exemption

   WOGCC Response: There is no requirement to consider alternatives to underground disposal of water. The cost of treating water to surface discharge standards is not a consideration in reviewing aquifer exemption applications.

Please contact me if you have any questions or need additional information.

Sincerely,

Joe Scott

Joe Scott
Natural Resources Supervisor

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to eloxcollute the Madison aquifer

1 message

Alan McConigly (crackermtn@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 6:17 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. The protection of our clean freshwater sources is of extreme priority. We can't allow any form of pollution to enter the Madison aquifer, because the Madison aquifer is an important freshwater source for Wyoming. I know, for a fact, that the Madison formation of the southern Bighorns is where the water for many ranchers and rural residents get their water. Please don't allow any pollution to endanger Wyoming's most valuable freshwater sources. Thank you, Alan

Sincerely,

Alan McConigly
1254 S. Jackson St.
Casper, WY 82601
crackermtn@gmail.com
(307) 277-3638

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket #1711-2020 - Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

1 message

nabowler@aol.com <nabowler@aol.com> Mon, Oct 12, 2020 at 1:43 PM
Reply-To: nabowler@aol.com
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>

Tom, it seems Aethon Energy will never learn and never give up. For years Aethon dueled with the Water Quailty Division of DEQ about disposing of volumes of polluted oil and gas wastewater into the Madison Aquifer. Now Aethon is back again wanting the WOGCC to approve an exemption for the Madison Aquifer to be exempted from the safe water standards. Currently, the Madison Aquifer has been found to have potable water and can produce significant quantites of fresh water for future generations in the Wind River and Big Horn River Basins.

Given Aethon's experience with the Moneta Divide Field starting in 2013, we know that Aethon is a bad actor. It's argument that at 15,000 feet depth make it too deep for future use doesn't "hold water". Gillette, Wyoming currently pumps groundwater from a Madison Aquifer well field at a cost of over $200 million. The Wyoming Water Develpment Commission believes that Riverton, Pavillion,and the Wind River Reservation could develop a similar source of water from the Madison Aquifer for near the same costs.

Bottom line, Aethon proposes to pollute an aquifer that currently has drinkable water. Aethon's application for an aquifer exemption (referenced in the subject line of this email) should be denied by the Commission.

Alex Bowler
Cheyenne Area Landowner's Coalition
nabowler@aol.com

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Alma Scherck (rscherck@msn.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 6:47 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

When does it become about the people, health and protecting our environment? You MUST DENY their request to pollute ANY of our water sources. Surely you understand the environmental impact of such a reckless action? As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections?

Sincerely,

Alma Scherck
300 Wright Way
Evanston, WY 82930
rscherck@msn.com
(307) 789-1234

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Amanda Gingrich (chef.amanda@hotmail.com) Sent You a Personal Message <automail@knowwho.com> Fri, Oct 30, 2020 at 8:29 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Amanda Gingrich
119 W 1st Ave
Cheyenne, WY 82001
chef.amanda@hotmail.com
(720) 539-0264

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Andrew Salter (asalter@tetonlaw.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 4:00 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Andrew Salter
PO Box 3414
Jackson, WY 83001
asalter@tetonlaw.com
(206) 612-4039

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Ann Jacobs (barnwood@wyoming.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 7:06 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Having spent 25 years working the Energy Industry I can truthfully say I have witnessed some pretty obscene damage to our environment. But to intentionally do harm to the water we all are dependent upon for life is a real low. This must stop!

Sincerely,

Ann Jacobs
2120 Binford St. #202
Laramie, WY 82072
barnwood@wyoming.com
(307) 460-3979

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Arne Johanson (arne_kj@yahoo.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 5:56 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

This is a no brainer that should have been turned down already.

Sincerely,

Arne Johanson
600 Meadowlark Rd
Jackson, WY 83001
arne_kj@yahoo.com
(858) 759-4769

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Bonnie Long (bonnielong77@aol.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 10:51 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Bonnie Long
1360 Payne Ave
Casper, WY 82609
bonnielong77@aol.com
(303) 847-8465

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020

1 message

Bonnie Miller <bmiller@serv.net> Tue, Oct 13, 2020 at 11:02 AM
To: tom.kropatsch@wyo.gov

Dear Mr. Kropatsch,

Future generations will praise or condemn your actions to protect clean water. Make the right choice.

In 2013 the Wyoming DEQ initially objected to the aquifer being polluted and cited from that study which said, “many municipalities and other public water supply systems are increasingly interested in developing groundwater resources.” It continued to say that the Madison and Big Horn Aquifers were cited as having “the best potential for developing high yield wells.”

Sincerely,

Bonnie Miller

900 University Street Apt 15BC

Seattle, WA 98101

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Bruno Novel (novelschloss@gmail.com) Sent You a Personal Message <automail@knowwho.com>
Wed, Oct 21, 2020 at 4:26 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Bruno Novel
307 Annie Morgan Ct
Cheyenne, WY 82007
novelschloss@gmail.com
(248) 250-4038

Tom Kropatsch <tom.kropatsch@wyo.gov>

Aethon Madison Aquifer Exemption for Marlin 29-21 Well.

1 message

Bryce R. Frost <RFrost@uwyo.edu> Fri, Oct 30, 2020 at 6:13 PM
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>

Dear Mr,. Kropatsch,
I want to raise my objections to thesuggestions that the Martin 29-21 well should be allowed to reinject waste fluids from the well into the Madison aquifer. This is based upon two simple facts:
1) Oil filed brines ar famous for being rich in heavy metals. In fact amy of the low-temperature ore deposits (for example the Pb-Zn MVT deposits) are proposed to have formed from oil field brines.injecting these brines into the Madison aquifer, which is an important aquifer in Wyoming, means that toxic metals will be injected into the aquifer.
2) once an aquifer is polluted it is nearly impossible to clean it up.
Although it is possible to allow the Martin 29-21 well to proceed but first the company must provide chemical analyses of the effluent to show that toxic metals are not present and if the company choses to inject the effluent into an aquifer that is closed and not used for human consumption. In its present form I think permission should not be accepted.

Sincerely
B. Ronald Frost
Professor emeritus of Geology
University of Wyoming
Laramie, Wy.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Cari Glantz (cglantz84@hotmail.com) Sent You a Personal Message <automail@knowwho.com> Mon, Oct 26, 2020 at 5:10 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission DENY Aethon Energy?s request to exempt the Madison aquifer from drinking water protections.
Allowing big energy corporations to intentionally pollute Wyoming?s clean water is unacceptable and not what the people of Wyoming want. Our sources of clean, fresh water are one of our most valuable resources, and must not be sacrificed.

Sincerely,

Cari Glantz
514 S 10th St Apt 3
Laramie, WY 82070
cglantz84@hotmail.com
(402) 867-4036

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Carl Stapler (wystaplers@hotmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 8:08 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Carl Stapler
104 Grand View Cir
Evanston, WY 82930
wystaplers@hotmail.com
(555) 555-5555

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Carol Schneebeck (carolschneebeck@gmail.com) Sent You a Personal Message <automail@knowwho.com>
Wed, Oct 21, 2020 at 5:25 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Carol Schneebeck
1505 W Percheron Dr
Jackson, WY 83001
carolschneebeck@gmail.com
(307) 733-1582

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Carole Davis (calliepatch@hotmail.com) Sent You a Personal Message <automail@knowwho.com>
To: tom.kropatsch@wyo.gov

Thu, Oct 22, 2020 at 10:31 PM

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Carole Davis
5719 Stonewood Dr
Cheyenne, WY 82001
calliepatch@hotmail.com
(307) 634-7896

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Carole Johnson (carolej@uwyo.edu) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 5:04 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Carole Johnson
530 Beaufort St Spc 7
Laramie, WY 82072
carolej@uwyo.edu
(307) 721-3962

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Caroline Kirsch (c_k_russell@hotmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 3:43 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Caroline Kirsch
2060 Waterford
Casper, WY 82609
c_k_russell@hotmail.com
(307) 321-5316

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket #1711-2020 Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

1 message

Marilyn Ham <in_wyoming@yahoo.com> Mon, Oct 12, 2020 at 9:45 PM
To: Tom Kropatsch <tom.kropatsch@wyo.gov>

We are long-time residents of Wyoming and wish to strongly voice our objection to the injection well use of the Madison Aquifer. Wyoming is currently in a drought situation and has been facing this many times in the past. With the uncertainty of weather conditions, it is very reckless and dangerous to a population that would be forced to depend on the Madison for water. You could easily be endangering the future of Wyoming growth by sacrificing a potable water source which is so scarce and precious here. The injection water which is planned at a great depth won't remain there but will filter throughout the aquifer over time. This is a fact. Please consider all the implications and refuse the permitting of this injection well.

Charles and Marilyn Ham, 2360 Road 217, Cheyenne, Wyoming 82009

Sent from Yahoo Mail for iPhone

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Chris Fortner (wyo1hygienist@yahoo.com) Sent You a Personal Message <automail@knowwho.com> Fri, Oct 23, 2020 at 5:49 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections My family drinks from the Madison formation in Gillette

Sincerely,

Chris Fortner
6 taxi dr
Sheridan, WY 82801
wyo1hygienist@yahoo.com
(307) 674-9580

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Christ Novotny (cbnovotny@ameritech.net) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 7:47 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Christ Novotny
961 Prairie River Dr
Casper, WY 82604
cbnovotny@ameritech.net
(307) 333-4334

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Aethon

1 message

Cissy Dillon <cmcvdil@gmail.com> Mon, Nov 2, 2020 at 10:22 AM
To: tom.kropatsch@wyo.gov

Please, please do not allow Aethon to pollute the Madison aquifer!!
Fresh water is a precious commodity- we can not afford to lose it.
Please do not allow this.
Cissy Dillon

Sent from my iPhone

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Curtis Johnson (thewidj@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 8:52 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Curtis Johnson
1830 Alabama St
Green River, WY 82935
thewidj@gmail.com
(307) 871-0337

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Aethon's request to exempt the Madison Aquifer from drinking water standards

1 message

Dan Brecht <dcbrecht1951@gmail.com> Mon, Oct 12, 2020 at 1:41 PM
To: tom.kropatsch@wyo.gov

Will we never learn? Why in God's name would we want to spoil our ground water ANYWHERE? This makes no sense to me. Did we not learn when we had to repair the damage to the ozone layer a quarter of a century ago? Did we not learn a lesson when acid rain from factories and coal power plants in the Midwest was acidifying lakes, rivers and streams throughout the northern U. S. and southeastern Canada? Why would the State of Wyoming want to even consider such a ridiculous idea?
I think it's time for the residents of Wyoming to draw a line in the sand and say "No" to this proposal and others that will only endanger the quality of our groundwater.
This ploy by Aethon is just another way for corporations to take advantage of the people of this state.
Thank you.

Dan Brecht
875 Gilchrist St, Wheatland, WY 82201
307.322.6232

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

David Sheppard (shepparddave428@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 5:23 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

David Sheppard
22 Sportsman's Loop PO box 285
Pinedale, WY 82941
shepparddave428@gmail.com
(307) 231-5086

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Dean Knauer (deank@vcn.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 9:11 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. I can't f**king believe that Aethon would propose this. I believe Buffalo plans to use water from this aquifer. Deny this proposal once and for all.

Sincerely,

Dean Knauer
38 Langdon Rd
Buffalo, WY 82834
deank@vcn.com
(307) 684-5621

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Deborah Richards (dkrichards15@hotmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 5:41 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. Aquifers must be protected.

Sincerely,

Deborah Richards
3932 Antelope Meadows Dr
Burns, WY 82053
dkrichards15@hotmail.com
(307) 547-2255

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Deborah Stowe (stowebear@aol.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 7:27 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Deborah Stowe
6413 Merritt Rd
Cheyenne, WY 82009
stowebear@aol.com
(307) 274-0162

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well, Docket#1711-2020

1 message

Violabloom Violabloom <icedviolabloom@gmail.com> Thu, Oct 29, 2020 at 2:22 PM
To: tom.kropatsch@wyo.gov

Dear Mr. Kropatsch,

This email is undoubtedly unneeded as I expect anyone with your intelligence, integrity and commitment to the welfare of both community and environment, realized immediately the absurdity of Aethon's request for an exemption from the protections guaranteed under the Safe Drinking Water Act. One would expect from you nothing less than adamant vocal objections along with a firm NO vote.

That said, I cannot resist sharing some of my reasoning regarding this issue, in the chance that you have time in your busy schedule to read further;

1) It seems criminal fraud for Aethon to suggest that pumping hazardous waste deep in the aquifer will not affect the layers of water above. Pumping through injection wells would undoubtedly be at high pressure through pipes extending down through upper layers; it would be impossible to 'reclaim" higher levels of the aquifer if those pipes were to leak or break, as they often do on land.

2) Also, in drought conditions, aquifers are gradually drained from the top down; the technology Aethon proposes for pumping hazardous waste to a 15,000-ft depth may be the very technology needed to withdraw pure drinking/irrigating water from the same depth should water levels drop at a faster rate than they are doing now, and communities, farms and ranches face shortages.

Given the drastic climate changes already in progress, we certainly cannot gamble on 'business as usual' in the future; we must choose to protect Wyoming's communities and citizen-based economy by not risking critical resources for the benefit of truly "outsider" energy industries that are interested not in Wyoming's welfare but in immediate---but no doubt short-lived---profits for their investors.

Although our family currently only pays taxes on our summer home in Crook County, our family roots (Ice & McClung) go back many generations in the Black Hills of Wyoming and South Dakota. The welfare of Wyoming would be of deep concern to us, even if we were not planning to relocate full-time to the family 'cabin," whose water source is said to be dependent on the Madison Aquifer.

Best wishes and thank you for your service!

Diana Ice Filner
361 Sand Creek Road
Beulah, WY 82712

Mailing:
717 Glen Road
Danville, CA 94526
icedviolabloom@gmail.com

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Diane Verna (info@skithetetons.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 10:42 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Diane Verna
1110 Alta North Rd
Alta, WY 83414
info@skithetetons.com
(307) 353-2900

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Duane Keown (dkeown@uwyo.edu) Sent You a Personal Message <automail@knowwho.com> Fri, Oct 23, 2020 at 11:06 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections
Joe Biden will be the next U.S, president. His goal is for the U.S. to have zero CO2 emissions by 2050. This will take Wyoming's participation.

Since 2012 my wife and I have driven a hybrid electric car that gets more than 100 miles per gallon around Laramie and averages 70 mpg on trips away from electric plugins. The 12 solar panels on our home charge the batteries and supply our home electricity. We pay $34 per month, the minimum for continued connection to the grid. We are proud to be way ahead of the curve. Aethon Energy wants to increase the rate of taking oil and gas from the field with new wells, the reason for wanting to increase the risk to the Madison Aquifer. Make the field last longer as the transition to non polluting forms of energy continues. Wyoming needs to join the future.
Duane and Joy Keown, Laramie, WY 82070

Sincerely,

Duane Keown
2117 Spring Creek Dr
Laramie, WY 82070
dkeown@uwyo.edu
(307) 721-4922

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020

1 message

E Heyward <ejheyward@hotmail.com> Tue, Oct 13, 2020 at 10:23 AM
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>

Re: Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

Good morning Mr. Kropatsch,
I would like to comment on Aethon's request to exempt and pollute the Madison aquifer.

In the recent past the Wyoming DEQ has objected to the aquifer being polluted and cited from a study which said, "many municipalities and other public water supply systems are increasingly interested in developing groundwater resources." The Madison and Big Horn Aquifers were cited as having "the best potential for developing high yield wells." The DEQ letter said, "Clearly, future potential use of the Madison Aquifer in the area of development is within the realm of possibility."

I urge the Commission to deny Aethon Energy's request to exempt the Madison aquifer from drinking water standards.

Thank you,
E. Heyward

Sheridan, WY

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020, the Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

1 message

Edward Koncel <elkoncel@wyoming.com>
To: tom.kropatsch@wyo.gov
Mon, Nov 2, 2020 at 4:25 PM

Dear Mr. Kropatsch—

I am writing to you today to **strongly object** to Aethon's request to exempt and pollute the Madison aquifer. According to the drought.gov website:

> As of August 25, 2020, every state from the Great Plains to the West Coast has some drought. In this area, OR, CA, NV, UT, **WY**, CO, AZ, NM, OK, and TX all have parts in Extreme (D3) or Exceptional Drought (D4). Outside of the West, much of the Northeast is in drought. Drought has also developed recently in western PA.
>
> https://www.drought.gov/drought/news/2020-drought-update-look-drought-across-united-states-15-maps#:~:text=As%20of%20August%2025%2C%202020,developed%20recently%20in%20western%20PA.
>
> https://www.ncdc.noaa.gov/sotc/drought/202007

The Madison aquifer is a clean, viable source of future drinking water. Unpolluted, this could become an extremely valuable source of drinking water. Once polluted, it can never be returned to its pristine condition.

Please consider this information and **deny** Aethon Energy's request to exempt the Madison aquifer from drinking water standards.

Respectfully,

Ed Koncel

Laramie, Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Elizabeth Robison (dibba32@vcn.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 8:47 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Elizabeth Robison
18 Cedar Ln
Sheridan, WY 82801
dibba32@vcn.com
(307) 752-1241

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Evelyn Griffin (egriffin@wyoming.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 2:50 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. Allowing big energy corporations to intentionally pollute Wyoming's clean water is unacceptable and not what the people of Wyoming want!

Sincerely,

Evelyn Griffin
330 E Pavillion Rd
Pavillion, WY 82523
egriffin@wyoming.com
(307) 856-5737

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Aethon Madison Aquifer Exemption

1 message

Gary and Sue Peters <gspeters@vcn.com> Tue, Oct 13, 2020 at 9:20 PM
To: tom.kropatsch@wyo.gov

We are Campbell County residents who strongly urge you to DENY the Aethon Madison Aquifer Exemption. We need the aquifer to remain a clean, viable water source for the future. Gary & Sue Peters

6406 Tassel Ave
Gillette 82718

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Gina Waldon (nichols.selchie.gina@gmail.com) Sent You a Personal Message <automail@knowwho.com> Tue, Oct 27, 2020 at 9:20 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. Dumping waste into water is not appropriate at any time, anywhere; and, demonstrates corporate greed.

Sincerely,

Gina Waldon
717 Trabing rd
Buffalo, WY 82834
nichols.selchie.gina@gmail.com
(307) 689-3586

Tom Kropatsch <tom.kropatsch@wyo.gov>

Vote NO ... on Madisom Aquifer Exemption

1 message

Gloria McCloskey <1.ruralspirit@gmail.com> Tue, Nov 3, 2020 at 5:23 AM
To: tom.kropatsch@wyo.gov

Please Vote No on the request on the marlin 29-21 Injection Well
Gloria

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Ian Metz (iantmetz@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 9:27 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections to ensure clean water for generations to come.

Sincerely,

Ian Metz
4700, Van Buren Avenue
Cheyenne, WY 82009
iantmetz@gmail.com
(307) 365-0073

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

jackie taylor (jackietaylor11@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 6:16 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. I want clean water for Wyoming future residents

Sincerely,

jackie taylor
1088 Brundage Rd
cheyenne, WY 82009
jackietaylor11@gmail.com
(307) 635-0749

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Jean Priest (jpriest517@aol.com) Sent You a Personal Message <automail@knowwho.com>
To: tom.kropatsch@wyo.gov

Wed, Oct 21, 2020 at 7:54 PM

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Jean Priest
1406 Prairie Ave Apt 221
Cheyenne, WY 82009
jpriest517@aol.com
(307) 514-3836

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Jessica Barnhouse (jessicabarnhouse@yahoo.com) Sent You a Personal Message <automail@knowwho.com> Fri, Oct 23, 2020 at 6:29 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Jessica Barnhouse
PO Box 1222
Wilson, WY 83014
jessicabarnhouse@yahoo.com
(502) 494-2759

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Jessica Jern (jessica.jern@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 6:18 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Jessica Jern
3660 Cheney Ln
Wilson, WY 83014
jessica.jern@gmail.com
(307) 690-6110

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket #1711-2020

1 message

jotaylr@tribcsp.com <jotaylr@tribcsp.com> Mon, Nov 2, 2020 at 5:19 PM
To: tom.kropatsch@wyo.gov

Refer to Docket #1711-2020 (Aethon Madison Aquifer Exemption request for Martin 29-21 Injection well

I strongly oppose this request. The Madison Aquifer is a clean viable source of future drinking water.

Joanna Taylor
601 HemlockSt.
Buffalo, Wyoming 82834
307 684 7765

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Joanna Taylor (jotaylr@tribcsp.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 3:44 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Joanna Taylor
601 Hemlock St
Buffalo, WY 82834
jotaylr@tribcsp.com
(307) 684-7765

Tom Kropatsch <tom.kropatsch@wyo.gov>

An Outrage!

1 message

joel saur <joelsaur@gmail.com> Mon, Oct 12, 2020 at 2:10 PM
To: tom.kropatsch@wyo.gov

Hi Tom,
Bummer that these guys are still trying to contaminate our water sources. Let me know how we can help. We are here in Sheridan and the oil and gas has contaminated our groundwater in this area and others nearby.
We will stand up against this.
Thanks for all you are doing
Joel Saur
Helixweaver

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

John Larsen (jmichael1229@gmail.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 2:06 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

John Larsen
6922 Columbia River Rd
Casper, WY 82604
jmichael1229@gmail.com
(720) 219-8359

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Madison aquifer Docket # 1711-2020

1 message

Karl Schneider <schneiderkl12@gmail.com> Mon, Oct 12, 2020 at 3:09 PM
To: Tom Kropatsch <tom.kropatsch@wyo.gov>

Hello,
I am:
KarlSchneider
4900 Christensen Rd.
Cheyenne, WY 82009
307-631-1926

I understand Aethon Energy wants to inject polluted wastewater into the Madison Aquifer. Fresh water availability is and in the future will increasingly be vital to Wyoming's viability. No person in their right mind would consider polluting a future water supply. I strongly object to the Aethon Madison aquifer exemption. Please don't let them drill their waste injection well(s) and pollute the Madison Aquifer.

Thank you,
Karl Schneider

Tom Kropatsch <tom.kropatsch@wyo.gov>

Madison aquafer

1 message

Kathleen Connell <brucie38@me.com> Mon, Oct 12, 2020 at 2:13 PM
To: tom.kropatsch@wyo.gov

As the world heats and there is increasing need for water, especially clean water, there is np need to allow industries the ability to pollute the clean water we have. Stream pollution is bad, aquifer pollution is dreadful.

Aethon Energy must not be allowed to commit this pollution of a valuable water source.

Kathleen Connell
Buffalo

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Kathryn Brogan (phosphate108@yahoo.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 7:46 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Kathryn Brogan
PO Box 2823
Jackson, WY 83001
phosphate108@yahoo.com
(704) 887-3500

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Aethon Madison Aquifer

1 message

Kathy Moriarty <kathyintorridtown@yahoo.com> Mon, Oct 12, 2020 at 5:53 PM
To: tom.kropatsch@wyo.gov

I am writing to express my STRONG objection to the Aethon Madison Aquifer Exemption. The aquifer is a clean source of future drinking water.

Please deny Aethon Energy's request to exempt the Madison Aquifer From drinking water standards.

Sincerely,

Kathleen Moriarty

Sent from my iPad

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Kevin Mahaffey (mahaffeyko@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 8:18 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Kevin Mahaffey
314 S Grant St
Casper, WY 82601
mahaffeyko@gmail.com
(307) 333-3818

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Kim Wilbert (dkimwilbert@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 7:48 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections
Please - this proposal to inject terribly polluted water into a relatively pristine aquifer is a slap in the face of future generations!! Think about it - the planet has a finite amount of water AND YOU DON'T JUST RUIN SOME OF IT FOR EVER BECAUSE YOU HAVE SUCH A LIMITED IMAGINATION YOU CAN'T UNDERSTAND THE FUTURE POSSIBILITIES FOR THAT WATER.
If Wyoming is to have any future whatsoever, we all must do all we can to protect the resources we have left, and trust me, water is a biggie. Please do not abuse any of our water for a one time resource play. The water is our future, not the oil or gas.

Sincerely,

Kim Wilbert
1400 W Park Ave
Riverton, WY 82501
dkimwilbert@gmail.com
(307) 851-6591

Tom Kropatsch <tom.kropatsch@wyo.gov>

No Aquafers Used For Anything Other Than Their Initial Purpose

1 message

Kristin Schneider <Opaltourmaline@hotmail.com> Mon, Oct 12, 2020 at 2:58 PM
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>

Dear Tom Kropatsh:

I will never approve any aquafer people use for their drinking water to be used as a dumping ground by Aethon Energy, ever.

Sincerely,

Kristin Schneider
4900 Christensen Rd.
Cheyenne, WY 82009
(307)635-6460

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Kyle Welsh (mictaykamac@gmail.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 2:46 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. Please do not allow Big Oil to impact our greatest resource by discharging their polluted wastewater into our waterways and aquifers.

Sincerely,

Kyle Welsh
6632 Monarch Dr
Cheyenne, WY 82009
mictaykamac@gmail.com
(307) 631-8641

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Aethon discharge permit

1 message

Linda Raynolds <lsr00@tritel.net> Mon, Oct 12, 2020 at 11:15 PM
To: tom.kropatsch@wyo.gov
Cc: Linda Raynolds <lsr00@tritel.net>

to the WOGCC:

It's come to my attention that Aethon Energy is renewing their request to be allowed to pollute the Madison Aquifer (Docket #1711-2020) with a produced water injection well from their Moneta Divide field. Please retain protection under the Clean Water Act for this aquifer, which has the potential to be developed as a clean source of drinking water for future human use.

The Wyoming DEQ has objected in the past to jeopardizing the future use of the Madison Aquifer as a source of municipal or public drinking water. Those studies that indicated that oilfield waste injection wells could threaten the integrity of this clean water source should be reexamined in light of this new request for an exemption.

Thank you for the opportunity to voice my concerns.

Linda Raynolds, Cody, Wyoming

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020 or Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

1 message

Linda and Ronn Smith <tiltonsmith1949@gmail.com>
To: tom.kropatsch@wyo.gov

Mon, Oct 12, 2020 at 1:04 PM

Dear Mr. Kropatsch:

We are writing to urge denial of Aethon's request to exempt the Madison Aquifer from drinking water standards. Our understanding is that even though the aquifer is deep at the proposed point of waste injection, the current water quality is good and could in the future be pumped to the surface for municipal and/or industrial water supplies. Deep wells are becoming more common as demand for fresh water increases and options for shallow wells or surface water utilization diminish.

It is also likely that oilfield waste pumped into the Madison would migrate upgradient, potentially affecting fresh water sources closer to the surface. There is no justifiable reason to jeopardize a quality, long-term resource merely because oil prices are low and oilfield operators are looking to cut costs. Like responsible operators, they should send their waste to a licensed treatment facility with the resulting brine going to injection wells that are confined to deep, brackish or saltwater aquifers.

Thank you for your consideration.

Sincerely,

Ronn and Linda Smith
1098 Morning Glory Ln
Powell, WY 82435

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Lisa Balmain (lb_poenation@live.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 4:50 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Lisa Balmain
PO Box 100
Laramie, WY 82073
lb_poenation@live.com
(530) 613-3992

Tom Kropatsch <tom.kropatsch@wyo.gov>

Madison Aquifer

1 message

llgrutz@ida.net <llgrutz@ida.net> Mon, Nov 2, 2020 at 12:48 PM
To: tom.kropatsch@wyo.gov

Please object the Aethon Madison Aquifer Exemption. The water quality in the Madison Aquifer in this area is good, and capable of producing significant quantities of freshwater for future generations in the Wind and Big Horn River Basins. This exemption was defeated in 2013 due to citizen opposition and concerns raised about polluting this future source of water, and I am sure things have not changed in the people's opinions. The original DEQ letter in 2013 said, "Clearly, future potential use of the Madison Aquifer in the area of development is within the realm of possibility." This statement was only reversed due to pressure from industry.

PLEASE deny Aethon Energy's request to exempt the Madison aquifer from drinking water standards.
Sincerely Yours,

Lisa Grutzmacher
1505 N Heights Dr.,
Sheridan, WY 82801

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Lisa Smith (llauritzen@bresnan.net) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 3:34 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Lisa Smith
735 Rodeo Dr
Jackson, WY 83001
llauritzen@bresnan.net
(307) 413-3590

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Lloyd Mahaffey (mahaffey38@msn.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 8:27 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. The health of our children is my number one priority. We must protect our future. I have drilled oil and gas wells all over the world, over the last 50 years, and seen the positive and negative impact of drilling.
The choice is yours!!!

Sincerely,

Lloyd Mahaffey
5030 East 15th Street
Casper, WY 82609
mahaffey38@msn.com
(970) 485-5366

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Lucinda Abbe (lucindaabbe@charter.net) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 6:07 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

I am a Wyoming resident, for the last 25 years, and one of the things I appreciate about Wyoming is our good, clean, fresh air and water. I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. I believe we need to think to the future and protect our resources, for the benefit of the next generations as well as for ourselves.

Sincerely,

Lucinda Abbe
1540 W Percheron Dr.
Lucinda, WY 83001
lucindaabbe@charter.net
(307) 690-5727

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Lynn Heeren (heeren@fiberpipe.net) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 3:58 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. We?ve run out of space on our planet to continue polluting and destroying. It?s time to be responsible.

Sincerely,

Lynn Heeren
29 Club House Dr
Sheridan, WY 82801
heeren@fiberpipe.net
(307) 673-5271

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020, Madison exemption, don't approve!

1 message

Lynn Middelstadt <lmiddelstadt@wyoming.com> Fri, Oct 16, 2020 at 11:40 AM
Reply-To: lmiddelstadt@wyoming.com
To: tom.kropatsch@wyo.gov

Hello Mr. Kropatsch,

I am emailing to request that the Wyoming Oil and Gas Commission NOT APPROVE any application by Aethon Energy to dispose of oilfield wastewater or produced water from gas or oil wells into the Madison Formation. This refers to the Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well.

I hereby notify you that as a citizen of the State of Wyoming, who is extremely interested in maintaining the integrity of our State's potable water producing formations, that allowing any company to dispose of contaminated water into a viable potable water formation like the Madison is being extremely irresponsible and short sighted.

I am in favor of the responsible development of our oil and gas resources, but not at the expense of contaminating our good quality drinking water. I come from a background of 15 years of dealing with water contamination in our area by oil and gas development. And the water that is being supplied to us to help mitigate the impact is from the Madison Formation! I believe that injecting wastewater into this formation even at a very deep depth could cause unknown consequences and irreparable harm to the water, so why risk it? I say NO, and hope that our elected and appointed governmental officials will have the good common sense to also say NO.

Potable Clean drinking water is a valuable resource to be protected!! We have to figure out how to develop our oil & gas resources without polluting our good supplies of water.

Thank you for your consideration.

Lynn Middelstadt
336 E Pavillion Rd
Pavillion Wy 82523
Site of DEQ pit cleanup, Tribal Pavillion 14-11

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket #1711-2020

1 message

M. Dudley Case <md_case@icloud.com> Mon, Nov 2, 2020 at 3:27 PM
To: tom.kropatsch@wyo.gov

Dear Sir:

I am opposed to Author Energy's request to expempt the Madison Aquifer from drinking water standards.

Hydro-geologists hired by Powder River Basin Resource Council say waste water put into the aquifer at a depth of 15,000 feet will not stay at that depth and could pollute the aquifer at shallower depths. They also note the Madison Aquifer is a good future source of water for the area, and Gillette, Wyoming pumps groundwater from the Madison Aquifer well field over 25 miles away at a cost of over $200 million dollars.

In 2013 the Wyoming DEQ initially objected to the aquifer being used for waste water and in part said "many municipalities and other public water supply systems are increasingly interested in developing groundwater resources." The Madison and Big Horn Aquifers were cited as having "the best potential for developing high yield wells." The DEQ letter said, "Clearly, future potential use of the Madison Aquifer in the area of development is within the realm of possibility."

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Macey Mott (maceymott@hotmail.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 12:18 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Macey Mott
PO Box 6447
Jackson, WY 83002
maceymott@hotmail.com
(307) 733-6454

Tom Kropatsch <tom.kropatsch@wyo.gov>

NO to Docket # 1711-2020

1 message

red jacket <redjacket12@hotmail.com> Thu, Oct 15, 2020 at 11:51 AM
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>

Dear Mr. Kropatsch
Deputy Supervisor, WOGCC

re: Docket # 1711-2020
Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well.

Dear Sir;

I am once again writing to speak up against allowing pollution of the Madison aquifer near the Moneta Divide Field. This is a bad idea and was already denied to Encana a few years ago. Now here it is again, which is ridiculous. This is a precious, clean aquifer that could be needed for human water supply and is one of the sources of one of the world's finest fisheries, the Middle Fork of the Powder River. PLEASE DO NOT ALLOW EXEMPTING ANY PORTION OF THIS AQUIFER from protections provided in the Safe Drinking Water Act.

How many times must the WOGCC hear from Wyomingites that we do not want the Madison to be used as a dumping ground for oil and gas waste, frack wastewater or produced water? Hear us this time & be done with it!

The Moneta divide is at the top of major water basins in Wyoming and the water from the Madison is the best source of good drinking water to be saved for the future, not wasted on some money-saving solution for a company that will be gone or bankrupt or sold 10 years from now. It would be a short-sighted decision to sacrifice the potential future use of great water just to save a damn company some money. If they can't figure a better way to dispose of their mess, then don't allow them to make it from the start.

We may likely face a future where clean, potable water is in short supply. Please don't be part of the problem that we leave for our grandchildren. DENY AETHON ENERGY'S REQUEST TO EXEMPT THE MADISON AQUIFER FROM DRINKING WATER STANDARDS! It is obvious & please don't try to slip this pass us again.

Thanks for your attention,

Maria Katherman 797 Inez Rd. Douglas WY 82633

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Mark Heineken (m.heineken@bresnan.net) Sent You a Personal Message <automail@knowwho.com> Sat, Oct 24, 2020 at 7:13 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Mark Heineken
4310 Balsam Ln
Jackson, WY 83001
m.heineken@bresnan.net
(307) 413-0784

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Mark Sehnert (sehnert@wyoming.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 3:40 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Mark Sehnert
3815 Burton Ln
Riverton, WY 82501
sehnert@wyoming.com
(307) 850-4825

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Martha Colby (thingthree@hotmail.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 1:16 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. There is nothing more important for our health than clean water. It is a much more precious resource than gas or oil.

Sincerely,

Martha Colby
POB 2346
YNP, WY 82190
thingthree@hotmail.com
(307) 527-0825

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Matthew Smedley (mcsmeds@msn.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 9:41 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. Clean water is a vital resource that we cannot afford to pollute for any reason. Past requests to deliberately contaminate the Madison aquifer have been denied for good reason and nothing has changed but the company requesting permission to pollute. I sincerely hope that this unacceptable act of polluting is denied by you.

Thanks, Matt Smedley

Sincerely,

Matthew Smedley
128 Jim Creek Rd
Banner, WY 82832
mcsmeds@msn.com
(303) 772-4110

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Melanie Palluck (melanpal@bresnan.net) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 4:29 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Melanie Palluck
901 Warren Ave Unit 1
Cheyenne, WY 82007
melanpal@bresnan.net
(307) 638-1248

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

NO to dump pollution into Madison aquifer

1 message

Melvin ZumBrunnen <mzumbrun@wyomail.com> Mon, Oct 12, 2020 at 9:25 PM
To: tom.kropatsch@wyo.gov

no to dump pollution into Madison Aquifer!

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020

1 message

MICHAEL PALMER <mpalmernet@msn.com> Fri, Oct 30, 2020 at 12:27 PM
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>

In reference to Docket # 1711-2020 or Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

I am sending this email to oppose the injection of wastewater underground into the Madison Aquifer. Water that can potentially be used by towns and by agriculture is becoming more and more scarce. This is particularly true in our region in the West that is in drought now and is scientifically anticipated to be in shorter and shorter supply of water in the years ahead, due to how climate change is changing the weather in the western states.

Since the Madison Aquifer has the potential to be an effective clean water source for the region's towns, it seems foolish to risk polluting the aquifer. Once wastewater is injected into the Madison Aquifer it is a one-way street without the option to turn back and potentially use the aquifer for clean water uses. In the future, clean water will be a more in-demand resource than fossil fuels — much more in demand due to climate change. It seems very short-sighted not to preserve this potential resource for an uncertain future.

Sincerely,
Michael Palmer
715 S 11th Street
Laramie, WY 82070
307-742-0471

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Nancy Mccoy (mccoyfamily@nemont.net) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 10:07 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

My name is Nancy McCoy from Clark, Wyoming and as a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Nancy Mccoy
705 Road 1AB
Clark, WY 82435
mccoyfamily@nemont.net
(307) 645-3331

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Nicholas Apicelli (asmewelder28@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 7:18 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Nicholas Apicelli
1233 Saker Ct
Casper, WY 82601
asmewelder28@gmail.com
(307) 258-5721

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please say no Aethon Energy?s request.

1 message

Paul Taylor (pauldidj@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 4:23 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

Polluting a high quality drinking water aquifer is fundamental foolishness that will have long term contamination consequences. Safeguarding clean water is essential to the future health and prosperity of our land and communities. As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections.
Sincerely
Paul Taylor

Sincerely,

Paul Taylor
PO Box 1427
Laramie, WY 82073
pauldidj@gmail.com
(307) 721-8853

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020, Aethon Madison Aquifer Exemption Request for Merlin 29-21 Injection Well

1 message

Peter Schulman <peter@schulmanco.com> Sat, Oct 17, 2020 at 11:01 AM
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>

Dear Mr. Kropatsch,

I am a Wyoming resident. I live in Crook County.

The above matter has recently come to my attention. This email is to express my objection to Aethon Energy's request for exemption. This is not the first time Aethon has made this request. I hope it will be the last time it's necessary for WOGCC to reject Aethon's request.

Sincerely,

Peter

Peter Schulman

Cell: 303-810-9898

Email: Peter@SchulmanCo.com

www.SchulmanCo.com

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020

pkrogle@aol.com <pkrogle@aol.com> Sat, Oct 17, 2020 at 11:59 AM
Reply-To: pkrogle@aol.com
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>

Dear Mr. Kropatsch;

I object to Aethon Energy's request to exempt the Madison aquifer from drinking water standards for Marlin 29-21 Injection well.

I base my objection on information presented in a 1981 Water Resource Series report and on information in a 2007 Wyoming Water Development Commission report. In the 1981 report, the Madison formation was included as part of the Tensleep aquifer system and had potential for domestic and municipal use. In the 2007 report, both the Tensleep aquifer and Madison aquifer were tested as possible drinking water supplies. Both reports are available online at the University of Wyoming, Water Resources Data System Library.

Injected fluids under pressure may move within the Madison aquifer polluting the aquifer and may move to other portions of the Tensleep aquifer system polluting those aquifers as well.

Thank you,
Philip Ogle

Tom Kropatsch <tom.kropatsch@wyo.gov>

Madison Aquifer

1 message

Rich & Judy Finch <rjfinch@scottsbluff.net> Mon, Nov 2, 2020 at 12:46 PM
To: tom.kropatsch@wyo.gov

Dear Mr. Kropatsch,

Please don’t bow to industry, don’t let them polute Wyoming.

Please do the right thing, and keep our clean water.

Thank you

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Richard Miller (rickgmiller3@gmail.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 8:21 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Richard Miller
PO Box 131
Wilson, WY 83014
rickgmiller3@gmail.com
(540) 270-3937

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Robert Betts (bettsrobertf@yahoo.com) Sent You a Personal Message <automail@knowwho.com>
To: tom.kropatsch@wyo.gov

Wed, Oct 21, 2020 at 4:15 PM

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. It?s been too long Wyoming gives in to pollution from energy producers. If Wyoming took time to make the lower wind river a blue ribbon fishery than there wouldn?t be any concern about extra needed revenue because the town of Riverton would be a fishing town with a strong tourist economy. Save our rivers!

Sincerely,

Robert Betts
PO box 1464
Dubois, WY 82513
bettsrobertf@yahoo.com
(818) 800-8879

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Robert Cardillo (hando1964@msn.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 8:34 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Robert Cardillo
841 E Carlson St
Cheyenne, WY 82009
hando1964@msn.com
(307) 256-3467

Moneta Divide--the Economics of Expansion and the Real Cost to Communities
by Rev. Dr. Sally Palmer of the Wyoming Interfaith Network

The life-changing issue about disposal of fracked or produced water is clear—when pollutants are either discharged into the subsurface of the earth or when they are collected on the surface, the toxins remain—in the underground water, in the soils, in the surface water, and in the very web-of-life that communities depend on.

Scientific tests make this clear: "Toxins, like Chloride, Benzene, Sodium, Lead, Mercury, and other heavy metals do not disappear—they are absorbed into the very life of the soil and water that contain them, and on to humans, birds, and mammals that depend on clean water simply to stay alive." (Physicians for Social Responsibility-report 2018)

Moreover, the economics of expanding fracking in Wyoming show that it is the *oil giants which receive the benefits and the local communities which pay the cost*—in health services, in mitigation, in long-term restoration of the land and the web-of-life it sustains. **In short, when dealing with toxic wastes, it is the citizens who live on the land and who drink the water, who will bear the brunt of "development" for years to come.**

In Wyoming's case, specifically, the Moneta Divide Project will pour more pollutants into a tributary of Boysen Reservoir and be absorbed by the soils. **Or, as is the question now, the high-volume fracking operations will inject up to 8 million gallons of water per day into the Madison Aquifer. What was once clean water serving important communities in Fremont County will become contaminated. As The Physicians for Social Responsibility report concludes: "No known regulatory framework can adequately mitigate the multiple risks of fracking…the significant adverse public health and public environmental impacts from allowing high-volume hydraulic fracturing to proceed under any scenario cannot be adequately avoided…"**

Now, in Wyoming, we have the industry-imposed choice to LOSE AGAIN—to grant easy permits to out-of-state companies so they can reap the profits from our low standards and our low taxes.

It is the oil and gas companies which make the profits, while Wyomingites pay for mitigation—remediation—public health and public welfare. ***The real costs for fracking and either dumping or injecting produced water into deep wells rests on the shoulders of the people of Wyoming***, not the profit-making corporations who would use our clean water to frack, then drown the clean water in wastes that will prove toxic to Wyomingites for years to come.

In its headlines about the Moneta Divide project, the Casper Star Tribune wrote:

This time, "W***e need to get it right***." But, under the flurry of loose permissions, which undermine the Clean Water Act, and under the federal force of "energy dominance," we have not tried to "get it right." In Wyoming, there is no authority above the producer, in this case, Athenon, that is allowed to check the ways it tests produced water. They claim "We have cleaned the produced water," yet tests on current levels show TEN TIMES the amount of Chloride in the fracked water. **Equally important, injected water only drives toxins into the aquifer…in this case a "Class 1 Aquifer,"—or the cleanest!** But, there are long-term effects of toxic substances which effect the health of our communities. In short, with permitting granted to expand water discharge by 400%, there is no authority above Athenon Energy to test, to monitor, or to mitigate. And, this second request is made by an oil company which has already "violated its existing permits." Casper Star Tribune, February 25,2020.

"Produced water 'cleans itself' is a myth, when dealing with heavy metals. Dilution is not a solution. It is the communities' health that is it risk, not just now but in years to come. **"We need to get it right this time" and we have not done so. Especially in a time of drought, we need to cherish the water which sustains life in Wyoming for us all.**

Sincerely, Rev. Dr. Sally Palmer of the Wyoming Interfaith Network

Tom Kropatsch <tom.kropatsch@wyo.gov>

For Wyoming Oil and Gas Conservation Commission and State Engineers Office--Ground Water Division--Re: docket #1711-2020 Athenon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

1 message

Sal <revsal@compuserve.com> Thu, Oct 29, 2020 at 1:40 PM
Reply-To: Sal <revsal@compuserve.com>
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>, "warrencmurphy@gmail.com" <warrencmurphy@gmail.com>, "lisalindemann@wyo.gov" <lisalindemann@wyo.gov>

Thank you for realizing that toxins are real....and last in the ground, soil, water, for generations to come.

Moneta Divide--the Economics of Expansion and the Real Cost to Communities 10-29-2020.doc
56K

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Sandra Materi (materi44@bresnan.net) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 8:20 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Sandra Materi
1600 W Odell Ave
Casper, WY 82604
materi44@bresnan.net
(307) 235-3375

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Sandy Shuptrine (sandyshuptrine@wyom.net) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 3:50 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. Relocating the site to be polluted is a disastrous method of dealing with waste and very short sited. The only beneficiaries are those connected to the company's immediate bottom line. Long term effects are risking one of the basics of life...clean drinking water and river systems. Wyoming's hope for future economic sustainability are its increasingly rare natural assets in a crowded world. I have never heard a desire to become a wasteland or source for one.

Sincerely,

Sandy Shuptrine
1955 E Porcupine Rd.
Jackson, WY 83001
sandyshuptrine@wyom.net
(307) 733-6371

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Sarah Anderson (sarah.mcintyre36@gmail.com) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 12:53 AM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Sarah Anderson
212 Birch St Apt 402
Evanston, WY 82930
sarah.mcintyre36@gmail.com
(307) 677-0416

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy's application to dump wastewater into the Madison Aquifer

1 message

Mentock <mentock@wyoming.com> Tue, Oct 13, 2020 at 2:07 PM
To: tom.kropatsch@wyo.gov

Dear Supervisor Kropatsch and Wyoming Oil and Gas Commission members,

I am writing to urge you to deny Aethon Energy's request to exempt a portion of the Madison Aquifer from the Safe Drinking Water Act. Tens of thousands of Wyomingites currently rely on the Madison for their drinking and irrigation water, and many more will need to rely upon it in the future. To allow the Madison to be jeopardized in this way is, in my view, untenable.

The single most precious resource in our state is water. It is our future. We must look to that future when making decisions today. I want my grandchildren to be able to access clean water. I want to rest in the knowledge that the quality of life offered in Wyoming will allow them to stay here, to thrive here.

Sincerely,

Sarah Mentock
Sheridan, Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Scott McGee (scottmcgee@wyom.net) Sent You a Personal Message <automail@knowwho.com> Fri, Oct 23, 2020 at 2:35 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Scott McGee
405 Aspen Dr #4, POB 468
Jackson, WY 83001
scottmcgee@wyom.net
(307) 413-6552

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Scott Mcgee (scottmcgee@wyom.net) Sent You a Personal Message <automail@knowwho.com> Thu, Oct 22, 2020 at 2:57 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Scott Mcgee
405 Aspen Dr
Jackson, WY 83001
scottmcgee@wyom.net
(307) 413-6552

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Sean Mcandrews (sdmcandrews@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 6:48 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Sean Mcandrews
1262 W 7th St
Powell, WY 82435
sdmcandrews@gmail.com
(406) 366-5569

Tom Kropatsch <tom.kropatsch@wyo.gov>

No pollutants in the Madison

1 message

stef@wyoming.com <stef@wyoming.com> Mon, Oct 12, 2020 at 9:08 PM
To: tom.kropatsch@wyo.gov

Please say no to injecting pollutants into the Madison Aquifer. We no our demand for usable fresh water is only growing as the resource is shrinking. We cannot be sacrificing such a reserve for a dumping site. Alternatives must be demanded.
Thank you

Stefani Smith

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Steven Petersen (swpete@centurylink.net) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 9:52 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. The energy extraction industries have created this problem, and now they want the public at large to clean up and pay for their their messes, while they walk away with their profits, and snidely tell us that they did this for us. Whew, such BS.

Sincerely,

Steven Petersen
PO Box 1535
Pinedale, WY 82941
swpete@centurylink.net
(800) 555-1234

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Suzanne Lewis (shlewis@bresnan.net) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 4:51 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections.
This is not the first time a fossil fuel corporation has wanted to dump contaminated water into the Madison aquifer. When former Moneta Divide owner Encana made similar requests in 2011 and 2013, the WOGCC rejected their proposals after concluding that the Madison was a valuable source of fresh water and should not be intentionally polluted. Aethon Energy, which acquired the Moneta Divide fields in 2015, now wants to pump 1.26 million gallons a day of polluted water into the aquifer, contaminating it and putting future clean drinking water supplies at risk.
Without clean, protected aquifers, Wyoming could not support its current population. Let?s keep the Madison clean for our future generations.

Sincerely,

Suzanne Lewis
1155 Inca Dr
Laramie, WY 82072
shlewis@bresnan.net
(307) 721-4891

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Sylvia Bagdonas (silverforestfox@gmail.com) Sent You a Personal Message <automail@knowwho.com> Sat, Oct 24, 2020 at 2:27 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections. It is unbelievable that such a request would be made when our drinking water supplies are dwindling. Clean water is a rare gift to Wyoming. It is more valuable than a temporary oil or gas well. We have to think long term to our future generation's benefit.

I urge you to make sure that Wyoming's oil and gas resources are developed in such a way that our clean drinking water sources are not damaged. Thank you.

Sincerely,

Sylvia Bagdonas
28 East St
Laramie, WY 82072
silverforestfox@gmail.com
(307) 742-8434

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Terry Mcclellan (terrybmcclellan@hotmail.com) Sent You a Personal Message <automail@knowwho.com> Fri, Oct 23, 2020 at 7:22 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Terry Mcclellan
1005 W Longhorn Dr
Jackson, WY 83001
terrybmcclellan@hotmail.com
(307) 734-1270

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Tom Parkins (taparkins@yahoo.com) Sent You a Personal Message <automail@knowwho.com> Fri, Oct 23, 2020 at 3:42 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Tom Parkins
1815 S 5th Ave
Cheyenne, WY 82007
taparkins@yahoo.com
(503) 644-9781

This message was sent by KnowWho, as a service provider, on behalf of an individual associated with Sierra Club. If you need more information, please contact Lillian Miller at Sierra Club at core.help@sierraclub.org or (415) 977-5500.

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

Vernon Palmour (palmourv@aol.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 6:34 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

Vernon Palmour
803 Meadow Lane Ave Apt 1
Cody, WY 82414
palmourv@aol.com
(307) 587-3993

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020-Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

1 message

Wayne Lax <waynebassthunder5@hotmail.com> Wed, Oct 14, 2020 at 11:24 AM
To: "tom.kropatsch@wyo.gov" <tom.kropatsch@wyo.gov>

Greeting Tom,
I'm writing you today to ask you to please oppose Aethon's Aquifer exemption request. As I'm sure you know, the Madison Aquifer is a vital source of potable water for this state. Pumping industry water containing benzene is an extremely dangerous idea. I'll just leave it at that. We need to protect every source of good water in this state. Especially with the nature of droughts around Wyoming, water is life to all of us. Please do not jeopardize this vital water source.

Sincerely,
Wayne Lax
Vice-President - Cheyenne Landowners Coalition
Board- Powder River Basin Resource Council

Tom Kropatsch <tom.kropatsch@wyo.gov>

Madison aquifer

1 message

Wayne Roadifer <roadie1947@gmail.com> Mon, Nov 2, 2020 at 1:47 PM
To: Tom Kropatsch <tom.kropatsch@wyo.gov>

Please stop this atrocity!

Tom Kropatsch <tom.kropatsch@wyo.gov>

Madison Acquifer proposal

1 message

Wendy Condrat <wcondrat@gmail.com> Mon, Nov 2, 2020 at 10:36 AM
To: tom.kropatsch@wyo.gov

Dear Sir:
I am writing to oppose the proposal to allow fracked wastewater to be dumped into the Madison Aquifer. There is too much at risk for pollution of safe drinking water to allow Aethon a permit. Please register my opposition to this proposal.
Thank you.
Wendy Condrat
307-655-3834

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please deny Aethon Energy?s request to pollute the Madison aquifer

1 message

William Crawford (wpcrawford313@gmail.com) Sent You a Personal Message <automail@knowwho.com> Wed, Oct 21, 2020 at 6:15 PM
To: tom.kropatsch@wyo.gov

Dear Deputy Supervisor WOGCC,

As a Wyoming resident, I?m writing to ask that the Wyoming Oil and Gas Conservation Commission deny Aethon Energy?s request to exempt the Madison aquifer from drinking water protections

Sincerely,

William Crawford
PO Box 142
Evanston, WY 82931
wpcrawford313@gmail.com
(307) 789-9438

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket # 1711-2020 or Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well.

1 message

Dainis Hazners <dainis@trcable.tv>
To: tom.kropatsch@wyo.gov
Wed, Nov 4, 2020 at 4:58 PM

Dear Sir,

Please deny Aethon Energy's request to exempt the Madison aquifer from drinking water standards.

Sincerely,
Dainis Hazners

Sue Ann Spencer, P.G.
9 State Highway 10
Jelm WY 82063
307-742-2643

October 29, 2020

Powder River Basin Resource Council
934 North Main Street
Sheridan, WY. 82801

ATTN: Jill Morrison, Executive Director

RE: Technical review of the August 13, 2020 *Amended Application for Aquifer Exemption (AE) and Underground Disposal of Water in Accordance with Wyoming Oil and Gas Conservation Commission (WOGCC) Rules and Regulations Chapter 4, Sections 5 and 12* which was submitted to the WOGCC by Aethon Energy.

Dear Jill:

This technical review of the above-referenced amended application was made in consultation with Mike Wireman, Granite Ridge Groundwater, of Boulder, Colorado. The following comments summarize our review.

Importance of Madison Aquifer

The Paleozoic Aquifer System, which includes the Madison Aquifer, is the most reliable and prolific aquifer system in the state of Wyoming. As the primary funding agency for developing source supplies for communities throughout the state, the Wyoming Water Development Commission (WWDC) has increasingly prioritized funding of well siting studies that target the Paleozoic Aquifer System and the Madison Aquifer in areas where suitable hydrogeologic targets are available because the aquifer has the potential to provide higher potential yields, excellent water quality, and reliability as a groundwater source that is less influenced by drought than shallower target aquifers.

The Paleozoic Aquifer System currently supplies reliable, good quality groundwater to the cities of Gillette, Newcastle, Laramie, Pine Haven, Vista West, Beulah, Moorcroft, Dayton, Lander, Laramie, Douglas, Glenrock, as well as most of the towns in the southeastern Bighorn Basin. The Bighorn Regional water system is comprised of a 70-mile pipeline that extends from Greybull to Kirby and provides water to 15 public water systems. This system is supplied by eight water supply wells, all of which are completed in the Madison Aquifer. In addition to serving as a sole source of groundwater for many Wyoming municipalities, the Madison Aquifer also supplies large quantities of groundwater to many ranching operations in the Bighorn Basin, Powder River Basin, and the Black Hills of eastern Wyoming.

Throughout Wyoming and particularly in the Bighorn and Wind River basins, the Madison Aquifer is considered the primary target for municipal water supply wells funded by the WWDC. Based on data provided in the Wind/Bighorn River Basin Water Plan Update Groundwater Study Level 1 study 2008 to 2011 (Wind River/Bighorn Basin Groundwater Study), at least 12 additional WWDC-funded studies in the area targeted the Madison Aquifer. These well siting studies generally involve conducting a complex evaluation of specific geologic structures within each basin.

Hydraulic conductivity and well yields are higher in areas where the Madison Formation has been extensively faulted and folded, in areas with well-developed karst porosity (generally more common in upper member) and in areas where there is a source of recharge and pathways for recharge. Focused recharge can occur along basin boundary outcrops and sub-crops which dip steeply basinward. In these types of recharge areas, recharge is not evenly distributed. Snowmelt and rain will preferentially recharge to limestones and sandstones compared to shales and siltstones. The quality of water in the Madison Aquifer also varies but is commonly very good due to low dissolution of cations/anions and fairly well mixed water due to active flow systems. Total dissolved solids (TDS) concentrations below 1,500 mg/l and low dissolved metals and radionuclides are common in the Madison Aquifer.

Economically and Technologically Impractical Criteria

Aethon's request for an aquifer exemption is based on the criteria outlined in 40 CFR 146.4 (b) (2). To exempt a portion of an aquifer it must be demonstrated that *"it cannot now and will not in the future serve as a source of drinking water because it is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical"*. Water quality and yield data obtained to date from the Marlin 29-21 WDW indicate that the water quality in the Madison Aquifer at this location is very good (TDS < 1,100 mg/l, very low dissolved metals and radionuclides) and, based on step tests performed by Aethon's contractor, the aquifer is capable of yielding hundreds of gallons per minute. If the initial yields are sustainable, wise water resource management policy would preserve this aquifer as a future water supply for beneficial uses. Technology advances in drilling, high-efficiency pumps, energy-recovery devices and cheaper, more effective treatment membranes and water delivery systems have improved the performance and cost of developing and delivering deep groundwater resources.

In the application document, Aethon maintains that because "the Amsden and Madison Formations are very deep, and the well is located large distances from populations centers" the Madison Aquifer is economically and technologically impractical for use as a fresh and potable water supply at the Marlin 29-21 WDW site. The permit application relies on the analysis presented in Appendix B of the application document, as summarized in Exhibit E-9, to demonstrate the economic impracticality of developing a Madison Aquifer water supply at this location. The analysis presented in Appendix B is oversimplistic and doesn't reflect the reality of the myriad of issues related to securing source water supplies faced by many Wyoming towns in 2020.

In the analysis summarized in Exhibit E-9, the applicant reviewed four community water supplies located nearest the Marlin 29-21 WDW in order to assess the economic feasibility of using the Madison Aquifer as a source supply. Based on Aethon's over-optimistic analysis for the communities of Riverton, Shoshoni, Thermopolis, and Casper, all of these entities appear to enjoy huge excesses in current source capacity and are "able to have their capacity increased at minimal cost" by making enlargements to their SEO groundwater and/or surface water permits. The reality faced by these communities is much different.

Three of the communities used in Aethon's analysis, Riverton, Casper and Thermopolis, are wholly or partially dependent on the use of a water treatment plant to treat surface water obtained from shallow alluvial wells as a source supply. In fact, the Wind River/Bighorn Basin Groundwater Study noted that because of treatment requirements for surface waters under the Safe Drinking Water Act (SDWA) and recent drought conditions, many municipalities and other public water supply systems are increasingly interested in developing groundwater resources. Under new SDWA regulations, the treatment process is far too expensive for small communities. Furthermore, some towns do not have sufficient water rights to meet their needs for a surface water source supply.

The towns of Riverton and Shoshoni rely on water supply wells completed in the Wind River Aquifer, which is comprised of a series of discontinuous sandstone lenses that provide marginal water quality and quantities in some areas. Because the Wind River Aquifer is relatively shallow with limited recharge potential, this source is also susceptible to drought and the potential for contamination. One nearby community that is not cited in the Exhibit E-9 analysis is the community of Pavillion, which is located approximately 35 miles northeast of the Marlin 29-21 WDW. The Wind River Aquifer is the sole source of potable water for the Town of Pavillion as well as for many private landowners in the greater community located in the Pavillion gas field area. Many of the residents in the Pavillion gas field have been without a source of potable water for the past 15 years due to contamination of the shallow Wind River Aquifer resulting from improperly completed gas wells in the area.

According to the Wind River/Bighorn Basin Groundwater Study, “the Paleozoic aquifers, primarily the Madison–Bighorn aquifer in the Bighorn Basin (the Madison Aquifer in the Wind River Basin), probably have the best potential for developing high-yield wells, depending on site-specific hydrogeologic conditions. Yields up to 14,000 gpm under flowing artesian conditions have been measured from the Madison–Bighorn along the west side of the Bighorn Basin. Because Paleozoic aquifers are confined in most places, lowered hydraulic head associated with large withdrawals, great drilling depth, and poor water quality may constrain development in some areas. Large variations in structure- and solution-controlled permeability will necessitate site-specific investigations to evaluate new development prospects. “

Because of the large variations in structure and solution-controlled permeability, a detailed well siting study is a necessity when identifying a suitable Madison Aquifer well site. A typical Madison Aquifer well siting study involves gathering specific data to enable evaluation of each site against several criteria including hydrogeologic setting, potential water quality, and proximity to existing infrastructure.

The geologic and hydrologic setting is the single-most important criteria for a Madison Aquifer well siting study. The geologic setting is defined by the geologic formations present, the lithology of the rocks, and the depth at which the formations occur. The hydrogeologic setting is defined by the presence and movement of ground water within the geologic formations. Saturated, permeable formations (aquifers) must be identified that are likely to yield sufficient quantities of water for the intended uses. If a suitable structure can be located for a potential well, the Madison Aquifer is the most attractive target because of the potential for prolific yields of good water quality that is reliable and not susceptible to drought conditions.

For large capacity municipal well siting studies in Wyoming basins, well sites frequently must target geologic structures that enhance primary permeability. This is especially important for aquifers that have very low primary permeabilities such as the Madison Aquifer. Structures that have the highest potential for development of secondary permeability are anticlines, monoclines, and in some instances, faults and fractures. In order to even be considered as a potential well site, a suitable hydrogeologic structure must be identified.

Groundwater circulation in the Paleozoic aquifers in the southern Bighorn Basin and a large portion of the Wind River Basin is controlled by geologic structures that formed during the Laramide Orogeny. Groundwater recharge originates along the Paleozoic outcrops that comprise the margins of the basins where seasonal accumulations of snow and runoff in the mountain highlands provide recharge to the Paleozoic Aquifer system. Based on potentiometric maps developed by Spencer (1986) and Jarvis (1986), once the groundwater in the Paleozoic Aquifer moves basinward from the basin margin, groundwater flow paths in the southern Bighorn Basin either (1) parallel the trends of the structures oriented obliquely to the basin margin (obliquely faulted homoclines), or (2) are diverted by faults that are oriented parallel to the basin margin.

Obliquely faulted homoclines are characterized by faults and fault-cored folds that are overprinted obliquely onto the basin margin and typically plunge basinward. Extensional fracturing along the crests of the anticlinal and monoclinal folds not only increases lateral flow of water along the crest of the structure, they also cause vertical communication between the Paleozoic aquifers. Based on this criterion, the site of the Marlin 29-21 WDW, as depicted in Aethon Exhibits G-2 and G-3, would be considered a suitable target structure for a Madison Aquifer water supply well. The WWDC has awarded millions of dollars to fund well siting studies to target exactly these types of structures throughout Wyoming in search of suitable sites for deep Madison Aquifer wells to supply municipalities throughout the state.

Although the depth of the Madison Aquifer in the Marlin 29-21 WDW has been cited by the applicant as uneconomical and unfeasible for development of a water supply, such depths for a water supply well are not uncommon in Wyoming. A 2015 search of the SEO database indicates that there were 4 permitted water wells in the State of Wyoming with a depth greater than 15,000 feet, 27 permitted wells that range in depth from 10,000 to 15,000 feet and 240 water supply wells that range between 5,000 and 10,000 feet deep. The eight Madison Aquifer wells that supply the Bighorn regional water system range in depth from 2,061 to 5,430 feet. As discussed above, the availability of a suitable structure for a well site is by far the most important criteria for siting a successful well. The depth of well is a secondary criterion that is only considered in ranking a particular site once a suitable target is identified.

Technology advances in drilling, high-efficiency pumps, energy-recovery devices and cheaper, more effective treatment membranes and water delivery systems have improved the performance and cost of developing and delivering deep groundwater resources.

With climate changes and droughts currently experienced in the western US, it is reasonable to assume that there will be a strong future demand for this water by towns, cities and agriculture in the region. The applicant restricted the future use analysis only to nearby towns in Wyoming. There is no referenced, cited data or information regarding future water needs for agriculture, mining or large regional water systems. Using the aquifer for disposal of up to 547,500,000 barrels of waste fluid is not wise water resource management policy.

With concerns about drinking water supplies growing in many parts of the country and desalination technologies becoming more accessible, the number of communities using brackish ground water is increasing. For example, Texas' first brackish groundwater desalination facility went on-line in 1981, with 50,000 gpd capacity. Texas currently has 44 municipal brackish water desalination facilities with a design capacity of approximately 120 million gallons per day treating source waters with TDS up to 4365 mg/l and several more facilities are planned or under construction.

The applicant needs to provide a better analysis of the potential for future use. The application does not evaluate future use by larger regional water supply systems nor whether the Madison Aquifer is economically and technologically impractical for uses other than drinking water, including agriculture, livestock watering and industrial uses.

<u>Contaminant Plume Migration</u>

A critically important issue is the potential for future migration of the injected waste fluids. Aethon estimates injection volumes of 1,000 to 30,000 bbl/d for a period of 50 years. This is a total of 18,250,000 bbl to 547,500,000 bbl (22.9 billion gallons) with average daily injection of 4,500 to 9,900 bbl for 50 years (82,125,000 bbl to 180,625,000 bb) with a TDS of 8,000 mg/l. Over a 50-year life of operation, this is an enormous volume of highly contaminated produced water and a variety of waste fluids related to drilling, production and treatment. The modeling done by Tetra Tech predicts migration of 0.8 to 1.8 miles after 50 years of operation and 1.7 to 6.8 miles after 10,000 years. These estimated migration distances are derived from additional (post 2015) "groundwater flow and transport modeling" conducted to support the August 2020 application. However, the hydrologic data used for the modeling is extremely sparse and no new field data was collected at or near the Marlin 29-21 WDW. As a result**,** the migration distance values have great uncertainty and could vary significantly.

The injected waste-fluid will move from the well due to injection pressure or natural flow gradients in the aquifer. Flow of groundwater and the waste-fluid plume will be controlled in some part by preferential flow paths as a result of karst developed in the Madison Formation and fractures and faults associated with the uplift of the Owl Creek Mountains. Injection pressure could cause waste fluid to move vertically upward or up-dip through fractures or other preferential flow-paths in confining layer or along the contact of the Madison Formation and intrusive rock comprising the uplift.

Aethon is requesting an aquifer exemption for the area of the aquifer within a 3-mile radius of the Marlin 29-21 WDW even though the recent modeling suggests the radius of migration could be up to 6.8 miles. The UIC regulations do not require downgradient monitoring wells that could be used to monitor the migration of the plume. Injection of such large volumes of wastewater into a high-quality aquifer would preclude the use of a precious resource. If a contaminant plume migrates beyond the 3-mile aquifer exemption area into a USDW (Madison Aquifer), there could be a violation of the SDWA.

Inadequate Characterization of Hydrogeologic Setting

The supporting data and information for the amended application do not provide an adequate characterization of the hydrogeologic setting and the groundwater flow system that delivers low TDS recharge water to that portion of the Madison Aquifer that is intercepted by the Marlin 29-21 WDW. This is important both for a full evaluation of the Madison Aquifer and for evaluating the fate and transport of the contaminant plume(s). The information presented is regional and is at an inappropriate scale for assessing the sustainable yield of the Madison Aquifer and for evaluating the fate and transport of the contaminant plume that will result from injection of billions of gallons of produced water and other waste fluids.

It is apparent from the data reported by Aethon that there is an active flow system in the Madison Aquifer in the vicinity of the Marlin 29-21 WDW. It is likely that there is a quasi-local flow system that is recharged nearby - perhaps associated with the synclinal structure immediately south of the Marlin 29-21 WDW. The application should provide a discussion of the potential for focused recharge along permeable structures which flows downgradient by piston flow. This is a common recharge mechanism in mountain hydrogeologic settings. It is important that this more local flow system be characterized adequately in order to evaluate the fate and transport of the wastewater plume.

The applicant did not consider the control that karst features in the Madison Formation may have on groundwater flow and contaminant transport. The top of the Madison Formation is bounded by a regional karstified unconformity representing 20 million years of exposure and erosion. This karstified surface may result in significant porosity and permeability in parts of the upper Madison Aquifer and should not be considered (or modeled) as a low porosity and permeability layer. The karst and local faulting /fracturing would result in significant anisotropy with respect to groundwater flow. In an April 25, 2013 email from Tom Drean (Wyoming State Geologist) to WOGCC, he informs WOGCC that the Madison Aquifer porosity at Marlin 29-21 is “karstic in nature”

The applicant concludes that groundwater in the Madison Aquifer contains benzene. However there is no data to indicate that the Madison Aquifer is a hydrocarbon reservoir in the vicinity of the Marlin 29-21 WDW. Benzene concentrations in the samples collected from the Marlin 29-21WDW on July 3, July 5 and July 9, 2012 were 110, 22 and 18 ug/l respectively. If the benzene is naturally occuring it is unlikely that the concentrations would vary this much. It is more likey that the presence of benzene is a result of contaminants introduced during drilling and well construction than naturally occurring in the formation water.

Stable isotope data for the Madison Aquifer groundwater at the Marlin 29-21 WDW are reported in the 2015 Tetra Tech report - *Sampling and Analysis for Chemical and Isotopic Content of Madison Formation in Fremont Cy, WY*. The report includes the results of ^{13}C, ^{14}C, $\delta^{18}O$, ^{36}Cl and tritium sampling for purposes of age dating the groundwater in the Madison.

- There was only one tritium sample analyzed, no duplicate sample, which was specified in the SAP was collected. The Tetra Tech report does not include the tritium value for the one sample collected.
- The ^{14}C data indicate an uncorrected "age" of 36,910 to 38,990 years. The report states that a “small correction to a younger age may be made…“. Based on the amount of “dead” carbon in the water, the correction would be large. Based on likely values for the corrected ^{14}C data and the $\delta^{18}O$ data, the groundwater sampled via the Marlin 29-21 is likely post-Pleistocene (less than 10,000 years old and more than 75 years old).
- The Tetra Tech report presents only one value for $\delta^{18}O$ and ^{36}Cl. Data for these isotopes is much more useful if there is data over an annual hydrograph.

- It should be noted that just because groundwater is "old" does not mean that the sustainable well yield will be low or that the water quality will be bad.

Groundwater flow velocities and “age” were estimated by Plummer et al (1990) for the Madison Aquifer east of the Wind River Basin. Flow velocities ranged from 7 to 87 ft/yr and the “age” was estimated at 23,000 years.

Numerical Groundwater Flow Modeling

Most of the hydrologic and well data included in the August 2020 amended application is the same information presented in the November, 2015 application. It appears that Aethon only updated the groundwater model as follows: (a) added the Darwin Sandstone member of the overlying Amsden Formation as a receiving zone; (b) reprocessed Reservoir Sigma Logs to obtain new porosity estimates for the Madison Aquifer; and (c) obtained 2D seismic lines and “utilized” the data to refine local structure. In the amended application, Aethon presents results from the numerical modeling to characterize groundwater flow in the Madison Aquifer and to predict waste fluid migration distances as follows:

- All of the modeling results and predictions included in the report have very significant uncertainty. While the models that were used are modern and sophisticated, the sparse amount of available empirical data significantly limits the ability to model. The reports do not provide any discussion of the magnitude of these uncertainties. This is especially important for estimating the extent of waste fluid migration.
- Except for the horizontal to vertical permeability (10:1), the model assumes homogenous and isotropic conditions in the Madison Aquifer. This is highly unlikely due to the karst in the upper part of the aquifer and local structures.
- The modeled area for this analysis was about 1,075 mi^2. The area is too large to adequately simulate conditions in the immediate area of the Marlin 29-21 WDW.
- The amount of empirical data for the elevation of the Madison Aquifer potentiometric surface is extremely limited in the vicinity of the Marlin 29-21 WDW. Only one potentiometric surface contour is shown for the modeled area (1,075 mi^2) in Figure 4-12 in the Tetra Tech report entitled: *Performance and Influence of Marlin 29-21 WDW on Madison Formation, Fremont Cy, WY, Tetra Tech, January 27, 2015.* This means that there is significant uncertainty with respect to the direction and rate of groundwater flow in the Madison Aquifer in the vicinity of the Marlin 29-21 WDW.
- The Marlin 29-21WDW does not fully penetrate the Madison Aquifer. The perforated interval is only 78% of formation thickness. The hydraulic properties estimated by the model assume full penetration of the aquifer.
- The model uses a longitudinal dispersivity value of 150 ft and a transverse dispersivity value of 15 ft. There is no discussion or citation as to the source of these values.
- The modeling that was conducted to evaluate the zone of impact assumed no-flow boundaries at the top and bottom of the Madison Aquifer and assumed that no faults extended from the Madison Formation upward or downward to /through confining formations. This does not represent hydrogeologic reality.
- The model classifies faults as transmissive versus impremeable based on offset. Whether a fault zone functions as a barrier to flow across the fault or along the strike of the fault zone is dependent on permeability in the fault zone and the permeability of the rocks that are juxtaposed adjacent to the fault.
- The uncertainty regarding the zone of emplacement and subsequent impact and contaminant migration within the Madison Aquifer constrains the ability to determine the appropriate size for an exempted area. There is significant concern that the plume will migrate beyond the boundary of the exempted area.

Moneta Divide Development

The decision regarding an aquifer exemption for the Madison Aquifer for the Marlin 29-21 WDW should not be made in isolation. Aethon proposes to develop the Moneta Divide gas field which will include up to 4,100 wells and require a cumulative disposal of trillions of gallons of waste fluid. Given the fact that the total proposed injection to the Marlin 29-21 WDW is a small fraction of the total potential disposal needs for the Moneta Divide field - will more Madison disposal wells, with associated aquifer exemptions, be necessary?

Thank you for the opportunity to review and respond to this permit application amendment. I look forward to discussing it with you further. Please don't hesitate to let me know if you have any questions.

Sincerely,

Sue Ann Spencer
Wyoming P.G. #238

References Cited

Jarvis, W.T., 1986, Regional Hydrogeology of the Paleozoic Aquifer System, Southeastern Bighorn Basin, Wyoming with an Impact Analysis on Hot Springs State Park. Unpublished Masters Thesis, University of Wyoming.

Plummer LN, Busby JF, Lee RW, Hanshaw BB (1990) Geochemical Modeling of the Madison Aquifer in Parts of Montana, Wyoming, and South Dakota. Water Resources Research 26(9):1981-2014.

Spencer, 1986, Groundwater Movement in the Paleozoic Rocks and Impact of Petroleum Production on Water Levels in the Southwestern Big Horn Basin, Wyoming. Unpublished Masters Thesis, University of Wyoming.

Wyoming State Geological Survey, Wind/Bighorn River Basin Water Plan Update Groundwater Study Level 1, 2008 to 2011

POWDER RIVER BASIN
Resource Council

Wyoming Outdoor Council

November 6, 2020

Wyoming Oil and Gas Commission sent via email to: tom.kropatsch@wyo.gov
P.O. Box 2640
Casper, WY 82602

RE: Docket 1711-2020 Aethon Madison Aquifer Exemption Marlin 29-21 Disposal Well (previously associated with Docket 3-2013)

Dear Commissioners:

Thank you for the opportunity to review and comment on the proposed Madison aquifer exemption concerning the Marlin 29-21 waste disposal well proposed for the Madison aquifer.

Our members and affiliate organizations in the Wind River and Bighorn Basin have a direct interest in the impacts of the proposed Marlin 29-21 disposal well into the Madison aquifer. The Madison aquifer has been identified by the state of Wyoming (WWDC and WSGS) as being critically important for current and future water supply to communities in the Wind River and Big Horn Basin. The proposal before you in this hearing is essentially the same proposal that was rejected by the WOGCC on November 10, 2015 and February 9, 2016. Those transcripts are attached for your review.

In addition, we have consulted with geologists who have reviewed the current Aethon proposal and we have attached the full report. In summary, and according to these expert comments, the proposal still fails to overcome the following criteria or requirements for an aquifer exemption:

1. **The Madison aquifer is one the most important aquifers serving as both a current and future water source.**

The Paleozoic Aquifer System currently supplies reliable, good quality groundwater to the cities of Gillette, Newcastle, Laramie, Pine Haven, Vista West, Beulah, Moorcroft, Dayton, Lander, Laramie, Douglas, Glenrock, as well as most of the towns in the southeastern Bighorn Basin. The Bighorn Regional water system is comprised of a 70-mile pipeline that extends from Greybull to Kirby and provides water to 15 public water systems. This system is supplied by eight water supply wells, all of which are completed in the Madison Aquifer. In addition to serving as a sole source of groundwater for many Wyoming municipalities, the Madison Aquifer also supplies large quantities of groundwater to many ranching operations in the Bighorn Basin, Powder River Basin, and the Black Hills of eastern Wyoming.

Throughout Wyoming and particularly in the Bighorn and Wind River basins, the Madison Aquifer is considered the primary target for municipal water supply wells funded by the WWDC. Based on data provided in the Wind/Bighorn River Basin Water Plan Update Groundwater Study Level 1 study 2008 to 2011 (Wind River/Bighorn Basin Groundwater Study), at least 12 additional WWDC-funded studies in the area targeted the Madison Aquifer. These well siting studies generally involve conducting a complex evaluation of specific geologic structures within each basin.

2. **Aethon fails to demonstrate that the groundwater in the Madison is economically and technologically impractical for development in the future.**

According to the Wind River/Bighorn Basin Groundwater Study, "the Paleozoic aquifers, primarily the Madison–Bighorn aquifer in the Bighorn Basin (the Madison Aquifer in the Wind River Basin), probably have the best potential for developing high-yield wells, depending on site-specific hydrogeologic conditions. Yields up to 14,000 gpm under flowing artesian conditions have been measured from the Madison–Bighorn along the west side of the Bighorn Basin. Because Paleozoic aquifers are confined in most places, lowered hydraulic head associated with large withdrawals, great drilling depth, and poor water quality may constrain development in some areas. Large variations in structure- and solution-controlled permeability will necessitate site-specific investigations to evaluate new development prospects. "
Although the depth of the Madison Aquifer in the Marlin 29-21 WDW has been cited by the applicant as uneconomical and unfeasible for development of a water supply, such depths for a water supply well are not uncommon in Wyoming. A 2015 search of the SEO database indicates that there were 4 permitted water wells in the State of Wyoming with a depth greater than 15,000 feet, 27 permitted wells that range in depth from 10,000 to 15,000 feet and 240 water supply wells that range between 5,000 and 10,000 feet deep. The eight Madison Aquifer wells that supply the Bighorn regional water system range in depth from 2,061 to 5,430 feet. As discussed above, the availability of a suitable structure for a well site is by far the most important criteria for siting a successful well. The depth of well is a secondary criterion that is only considered in ranking a particular site once a suitable target is identified.
Technology advances in drilling, high-efficiency pumps, energy-recovery devices and cheaper, more effective treatment membranes and water delivery systems have improved the performance and cost of developing and delivering deep groundwater resources.

3. **The plume from the injected wastewater could exceed that area of containment.**

A critically important issue is the potential for future migration of the injected waste fluids. Aethon estimates injection volumes of 1,000 to 30,000 bbl/d for a period of 50 years. This is a total of 18,250,000 bbl to 547,500,000 bbl (22.9 billion gallons) with average daily injection of 4,500 to 9,900 bbl for 50 years (82,125,000 bbl to 180,625,000 bb) with a TDS of 8,000 mg/l. Over a 50-year life of operation, this is an enormous volume of highly contaminated produced water and a variety of waste fluids related to drilling, production and treatment. The modeling done by Tetra Tech predicts migration of 0.8 to 1.8 miles after 50 years of operation and 1.7 to 6.8 miles after 10,000 years. These estimated migration distances are derived from additional (post 2015) "groundwater flow and transport modeling" conducted to support the August 2020 application. However, the hydrologic data used for the modeling is extremely sparse and no new field data was collected at or near the Marlin 29-21 WDW. As a result, the migration distance values have great uncertainty and could vary significantly.

4. Failure to adequately characterize the hydrogeologic setting

It is apparent from the data reported by Aethon that there is an active flow system in the Madison Aquifer in the vicinity of the Marlin 29-21 WDW. It is likely that there is a quasi-local flow system that is recharged nearby - perhaps associated with the synclinal structure immediately south of the Marlin 29-21 WDW. The application should provide a discussion of the potential for focused recharge along permeable structures which flows downgradient by piston flow. This is a common recharge mechanism in mountain hydrogeologic settings. It is important that this more local flow system be characterized adequately in order to evaluate the fate and transport of the wastewater plume.

The applicant did not consider the control that karst features in the Madison Formation may have on groundwater flow and contaminant transport. The top of the Madison Formation is bounded by a regional karstified unconformity representing 20 million years of exposure and erosion. This karstified surface may result in significant porosity and permeability in parts of the upper Madison Aquifer and should not be considered (or modeled) as a low porosity and permeability layer. The karst and local faulting /fracturing would result in significant anisotropy with respect to groundwater flow. In an April 25, 2013 email from Tom Drean (Wyoming State Geologist) to WOGCC, he informs WOGCC that the Madison Aquifer porosity at Marlin 29-21 is "karstic in nature"

5. Uncertainty in Aethon's Groundwater Modeling

All of the modeling results and predictions included in the report have very significant uncertainty. While the models that were used are modern and sophisticated, the sparse amount of available empirical data significantly limits the ability to model. The reports do not provide any discussion of the magnitude of these uncertainties. This is especially important for estimating the extent of waste fluid migration. Except for the horizontal to vertical permeability (10:1), the model assumes homogenous and isotropic conditions in the Madison Aquifer. This is highly unlikely due to the karst in the upper part of the aquifer and local structures.

6. Opening the Door to additional Madison Aquifer Exemptions

The decision regarding an aquifer exemption for the Madison Aquifer for the Marlin 29-21 WDW should not be made in isolation. Aethon proposes to develop the Moneta Divide gas field which will include up to 4,100 wells and require a cumulative disposal of trillions of gallons of waste fluid. Given the fact that the total proposed injection to the Marlin 29-21 WDW is a small fraction of the total potential disposal needs for the Moneta Divide field - will more Madison disposal wells, with associated aquifer exemptions, be necessary?

In conclusion, we want to emphasize that we believe the Moneta Divide field should be developed in a responsible fashion which includes a water management plan that entails the treatment and reuse of produced water rather than a plan that proposes to dump millions or billions of barrels of produced water into freshwater streams or freshwater aquifers.

Thank you again for your attention and consideration of our comments. We ask that you follow the previous WOGCC decision and deny Aethon's request to exempt this viable freshwater aquifer in the Madison Formation because it still fails to meet the regulatory and legal criteria for an aquifer exemption. We also respectfully request a written response to our comments that address the issues raised herein.

Sincerely,

Jill K. Morrison

Jill Morrison
Executive Director
Powder River Basin Resource Council
934 N Main St.
Sheridan, WY 82801
(307) 672-5809

John W Rader

John Rader
Wyoming Outdoor Council
262 Lincoln St.
Lander, WY 82520
(307) 332-7031

Attachments:

1. Sue Spencer, PG-238 Technical Review of Aethon Aquifer Exemption

2. WOGCC Hearing transcripts for November 10, 2015 and February 9, 2016

cc: Doug Minter EPA, Region 8

Sue Ann Spencer, P.G.
9 State Highway 10
Jelm WY 82063
307-742-2643

October 29, 2020

Powder River Basin Resource Council
934 North Main Street
Sheridan, WY. 82801

ATTN: Jill Morrison, Executive Director

RE: Technical review of the August 13, 2020 *Amended Application for Aquifer Exemption (AE) and Underground Disposal of Water in Accordance with Wyoming Oil and Gas Conservation Commission (WOGCC) Rules and Regulations Chapter 4, Sections 5 and 12* which was submitted to the WOGCC by Aethon Energy.

Dear Jill:

This technical review of the above-referenced amended application was made in consultation with Mike Wireman, Granite Ridge Groundwater, of Boulder, Colorado. The following comments summarize our review.

Importance of Madison Aquifer

The Paleozoic Aquifer System, which includes the Madison Aquifer, is the most reliable and prolific aquifer system in the state of Wyoming. As the primary funding agency for developing source supplies for communities throughout the state, the Wyoming Water Development Commission (WWDC) has increasingly prioritized funding of well siting studies that target the Paleozoic Aquifer System and the Madison Aquifer in areas where suitable hydrogeologic targets are available because the aquifer has the potential to provide higher potential yields, excellent water quality, and reliability as a groundwater source that is less influenced by drought than shallower target aquifers.

The Paleozoic Aquifer System currently supplies reliable, good quality groundwater to the cities of Gillette, Newcastle, Laramie, Pine Haven, Vista West, Beulah, Moorcroft, Dayton, Lander, Laramie, Douglas, Glenrock, as well as most of the towns in the southeastern Bighorn Basin. The Bighorn Regional water system is comprised of a 70-mile pipeline that extends from Greybull to Kirby and provides water to 15 public water systems. This system is supplied by eight water supply wells, all of which are completed in the Madison Aquifer. In addition to serving as a sole source of groundwater for many Wyoming municipalities, the Madison Aquifer also supplies large quantities of groundwater to many ranching operations in the Bighorn Basin, Powder River Basin, and the Black Hills of eastern Wyoming.

Throughout Wyoming and particularly in the Bighorn and Wind River basins, the Madison Aquifer is considered the primary target for municipal water supply wells funded by the WWDC. Based on data provided in the Wind/Bighorn River Basin Water Plan Update Groundwater Study Level 1 study 2008 to 2011 (Wind River/Bighorn Basin Groundwater Study), at least 12 additional WWDC-funded studies in the area targeted the Madison Aquifer. These well siting studies generally involve conducting a complex evaluation of specific geologic structures within each basin.

Hydraulic conductivity and well yields are higher in areas where the Madison Formation has been extensively faulted and folded, in areas with well-developed karst porosity (generally more common in upper member) and in areas where there is a source of recharge and pathways for recharge. Focused recharge can occur along basin boundary outcrops and sub-crops which dip steeply basinward. In these types of recharge areas, recharge is not evenly distributed. Snowmelt and rain will preferentially recharge to limestones and sandstones compared to shales and siltstones. The quality of water in the Madison Aquifer also varies but is commonly very good due to low dissolution of cations/anions and fairly well mixed water due to active flow systems. Total dissolved solids (TDS) concentrations below 1,500 mg/l and low dissolved metals and radionuclides are common in the Madison Aquifer.

Economically and Technologically Impractical Criteria

Aethon's request for an aquifer exemption is based on the criteria outlined in 40 CFR 146.4 (b) (2). To exempt a portion of an aquifer it must be demonstrated that *"it cannot now and will not in the future serve as a source of drinking water because it is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical"*. Water quality and yield data obtained to date from the Marlin 29-21 WDW indicate that the water quality in the Madison Aquifer at this location is very good (TDS < 1,100 mg/l, very low dissolved metals and radionuclides) and, based on step tests performed by Aethon's contractor, the aquifer is capable of yielding hundreds of gallons per minute. If the initial yields are sustainable, wise water resource management policy would preserve this aquifer as a future water supply for beneficial uses. Technology advances in drilling, high-efficiency pumps, energy-recovery devices and cheaper, more effective treatment membranes and water delivery systems have improved the performance and cost of developing and delivering deep groundwater resources.

In the application document, Aethon maintains that because "the Amsden and Madison Formations are very deep, and the well is located large distances from populations centers" the Madison Aquifer is economically and technologically impractical for use as a fresh and potable water supply at the Marlin 29-21 WDW site. The permit application relies on the analysis presented in Appendix B of the application document, as summarized in Exhibit E-9, to demonstrate the economic impracticality of developing a Madison Aquifer water supply at this location. The analysis presented in Appendix B is oversimplistic and doesn't reflect the reality of the myriad of issues related to securing source water supplies faced by many Wyoming towns in 2020.

In the analysis summarized in Exhibit E-9, the applicant reviewed four community water supplies located nearest the Marlin 29-21 WDW in order to assess the economic feasibility of using the Madison Aquifer as a source supply. Based on Aethon's over-optimistic analysis for the communities of Riverton, Shoshoni, Thermopolis, and Casper, all of these entities appear to enjoy huge excesses in current source capacity and are "able to have their capacity increased at minimal cost" by making enlargements to their SEO groundwater and/or surface water permits. The reality faced by these communities is much different.

Three of the communities used in Aethon's analysis, Riverton, Casper and Thermopolis, are wholly or partially dependent on the use of a water treatment plant to treat surface water obtained from shallow alluvial wells as a source supply. In fact, the Wind River/Bighorn Basin Groundwater Study noted that because of treatment requirements for surface waters under the Safe Drinking Water Act (SDWA) and recent drought conditions, many municipalities and other public water supply systems are increasingly interested in developing groundwater resources. Under new SDWA regulations, the treatment process is far too expensive for small communities. Furthermore, some towns do not have sufficient water rights to meet their needs for a surface water source supply.

The towns of Riverton and Shoshoni rely on water supply wells completed in the Wind River Aquifer, which is comprised of a series of discontinuous sandstone lenses that provide marginal water quality and quantities in some areas. Because the Wind River Aquifer is relatively shallow with limited recharge potential, this source is also susceptible to drought and the potential for contamination. One nearby community that is not cited in the Exhibit E-9 analysis is the community of Pavillion, which is located approximately 35 miles northeast of the Marlin 29-21 WDW. The Wind River Aquifer is the sole source of potable water for the Town of Pavillion as well as for many private landowners in the greater community located in the Pavillion gas field area. Many of the residents in the Pavillion gas field have been without a source of potable water for the past 15 years due to contamination of the shallow Wind River Aquifer resulting from improperly completed gas wells in the area.

According to the Wind River/Bighorn Basin Groundwater Study, "the Paleozoic aquifers, primarily the Madison–Bighorn aquifer in the Bighorn Basin (the Madison Aquifer in the Wind River Basin), probably have the best potential for developing high-yield wells, depending on site-specific hydrogeologic conditions. Yields up to 14,000 gpm under flowing artesian conditions have been measured from the Madison–Bighorn along the west side of the Bighorn Basin. Because Paleozoic aquifers are confined in most places, lowered hydraulic head associated with large withdrawals, great drilling depth, and poor water quality may constrain development in some areas. Large variations in structure- and solution-controlled permeability will necessitate site-specific investigations to evaluate new development prospects. "

Because of the large variations in structure and solution-controlled permeability, a detailed well siting study is a necessity when identifying a suitable Madison Aquifer well site. A typical Madison Aquifer well siting study involves gathering specific data to enable evaluation of each site against several criteria including hydrogeologic setting, potential water quality, and proximity to existing infrastructure.

The geologic and hydrologic setting is the single-most important criteria for a Madison Aquifer well siting study. The geologic setting is defined by the geologic formations present, the lithology of the rocks, and the depth at which the formations occur. The hydrogeologic setting is defined by the presence and movement of ground water within the geologic formations. Saturated, permeable formations (aquifers) must be identified that are likely to yield sufficient quantities of water for the intended uses. If a suitable structure can be located for a potential well, the Madison Aquifer is the most attractive target because of the potential for prolific yields of good water quality that is reliable and not susceptible to drought conditions.

For large capacity municipal well siting studies in Wyoming basins, well sites frequently must target geologic structures that enhance primary permeability. This is especially important for aquifers that have very low primary permeabilities such as the Madison Aquifer. Structures that have the highest potential for development of secondary permeability are anticlines, monoclines, and in some instances, faults and fractures. In order to even be considered as a potential well site, a suitable hydrogeologic structure must be identified.

Groundwater circulation in the Paleozoic aquifers in the southern Bighorn Basin and a large portion of the Wind River Basin is controlled by geologic structures that formed during the Laramide Orogeny. Groundwater recharge originates along the Paleozoic outcrops that comprise the margins of the basins where seasonal accumulations of snow and runoff in the mountain highlands provide recharge to the Paleozoic Aquifer system. Based on potentiometric maps developed by Spencer (1986) and Jarvis (1986), once the groundwater in the Paleozoic Aquifer moves basinward from the basin margin, groundwater flow paths in the southern Bighorn Basin either (1) parallel the trends of the structures oriented obliquely to the basin margin (obliquely faulted homoclines), or (2) are diverted by faults that are oriented parallel to the basin margin.

Obliquely faulted homoclines are characterized by faults and fault-cored folds that are overprinted obliquely onto the basin margin and typically plunge basinward. Extensional fracturing along the crests of the anticlinal and monoclinal folds not only increases lateral flow of water along the crest of the structure, they also cause vertical communication between the Paleozoic aquifers. Based on this criterion, the site of the Marlin 29-21 WDW, as depicted in Aethon Exhibits G-2 and G-3, would be considered a suitable target structure for a Madison Aquifer water supply well. The WWDC has awarded millions of dollars to fund well siting studies to target exactly these types of structures throughout Wyoming in search of suitable sites for deep Madison Aquifer wells to supply municipalities throughout the state.

Although the depth of the Madison Aquifer in the Marlin 29-21 WDW has been cited by the applicant as uneconomical and unfeasible for development of a water supply, such depths for a water supply well are not uncommon in Wyoming. A 2015 search of the SEO database indicates that there were 4 permitted water wells in the State of Wyoming with a depth greater than 15,000 feet, 27 permitted wells that range in depth from 10,000 to 15,000 feet and 240 water supply wells that range between 5,000 and 10,000 feet deep. The eight Madison Aquifer wells that supply the Bighorn regional water system range in depth from 2,061 to 5,430 feet. As discussed above, the availability of a suitable structure for a well site is by far the most important criteria for siting a successful well. The depth of well is a secondary criterion that is only considered in ranking a particular site once a suitable target is identified.

Technology advances in drilling, high-efficiency pumps, energy-recovery devices and cheaper, more effective treatment membranes and water delivery systems have improved the performance and cost of developing and delivering deep groundwater resources.

With climate changes and droughts currently experienced in the western US, it is reasonable to assume that there will be a strong future demand for this water by towns, cities and agriculture in the region. The applicant restricted the future use analysis only to nearby towns in Wyoming. There is no referenced, cited data or information regarding future water needs for agriculture, mining or large regional water systems. Using the aquifer for disposal of up to 547,500,000 barrels of waste fluid is not wise water resource management policy.

With concerns about drinking water supplies growing in many parts of the country and desalination technologies becoming more accessible, the number of communities using brackish ground water is increasing. For example, Texas' first brackish groundwater desalination facility went on-line in 1981, with 50,000 gpd capacity. Texas currently has 44 municipal brackish water desalination facilities with a design capacity of approximately 120 million gallons per day treating source waters with TDS up to 4365 mg/l and several more facilities are planned or under construction.

The applicant needs to provide a better analysis of the potential for future use. The application does not evaluate future use by larger regional water supply systems nor whether the Madison Aquifer is economically and technologically impractical for uses other than drinking water, including agriculture, livestock watering and industrial uses.

Contaminant Plume Migration

A critically important issue is the potential for future migration of the injected waste fluids. Aethon estimates injection volumes of 1,000 to 30,000 bbl/d for a period of 50 years. This is a total of 18,250,000 bbl to 547,500,000 bbl (22.9 billion gallons) with average daily injection of 4,500 to 9,900 bbl for 50 years (82,125,000 bbl to 180,625,000 bb) with a TDS of 8,000 mg/l. Over a 50-year life of operation, this is an enormous volume of highly contaminated produced water and a variety of waste fluids related to drilling, production and treatment. The modeling done by Tetra Tech predicts migration of 0.8 to 1.8 miles after 50 years of operation and 1.7 to 6.8 miles after 10,000 years. These estimated migration distances are derived from additional (post 2015) "groundwater flow and transport modeling" conducted to support the August 2020 application. However, the hydrologic data used for the modeling is extremely sparse and no new field data was collected at or near the Marlin 29-21 WDW. As a result, the migration distance values have great uncertainty and could vary significantly.

The injected waste-fluid will move from the well due to injection pressure or natural flow gradients in the aquifer. Flow of groundwater and the waste-fluid plume will be controlled in some part by preferential flow paths as a result of karst developed in the Madison Formation and fractures and faults associated with the uplift of the Owl Creek Mountains. Injection pressure could cause waste fluid to move vertically upward or up-dip through fractures or other preferential flow-paths in confining layer or along the contact of the Madison Formation and intrusive rock comprising the uplift.

Aethon is requesting an aquifer exemption for the area of the aquifer within a 3-mile radius of the Marlin 29-21 WDW even though the recent modeling suggests the radius of migration could be up to 6.8 miles. The UIC regulations do not require downgradient monitoring wells that could be used to monitor the migration of the plume. Injection of such large volumes of wastewater into a high-quality aquifer would preclude the use of a precious resource. If a contaminant plume migrates beyond the 3-mile aquifer exemption area into a USDW (Madison Aquifer), there could be a violation of the SDWA.

Inadequate Characterization of Hydrogeologic Setting

The supporting data and information for the amended application do not provide an adequate characterization of the hydrogeologic setting and the groundwater flow system that delivers low TDS recharge water to that portion of the Madison Aquifer that is intercepted by the Marlin 29-21 WDW. This is important both for a full evaluation of the Madison Aquifer and for evaluating the fate and transport of the contaminant plume(s). The information presented is regional and is at an inappropriate scale for assessing the sustainable yield of the Madison Aquifer and for evaluating the fate and transport of the contaminant plume that will result from injection of billions of gallons of produced water and other waste fluids.

It is apparent from the data reported by Aethon that there is an active flow system in the Madison Aquifer in the vicinity of the Marlin 29-21 WDW. It is likely that there is a quasi-local flow system that is recharged nearby - perhaps associated with the synclinal structure immediately south of the Marlin 29-21 WDW. The application should provide a discussion of the potential for focused recharge along permeable structures which flows downgradient by piston flow. This is a common recharge mechanism in mountain hydrogeologic settings. It is important that this more local flow system be characterized adequately in order to evaluate the fate and transport of the wastewater plume.

The applicant did not consider the control that karst features in the Madison Formation may have on groundwater flow and contaminant transport. The top of the Madison Formation is bounded by a regional karstified unconformity representing 20 million years of exposure and erosion. This karstified surface may result in significant porosity and permeability in parts of the upper Madison Aquifer and should not be considered (or modeled) as a low porosity and permeability layer. The karst and local faulting /fracturing would result in significant anisotropy with respect to groundwater flow. In an April 25, 2013 email from Tom Drean (Wyoming State Geologist) to WOGCC, he informs WOGCC that the Madison Aquifer porosity at Marlin 29-21 is "karstic in nature"

The applicant concludes that groundwater in the Madison Aquifer contains benzene. However there is no data to indicate that the Madison Aquifer is a hydrocarbon reservoir in the vicinity of the Marlin 29-21 WDW. Benzene concentrations in the samples collected from the Marlin 29-21WDW on July 3, July 5 and July 9, 2012 were 110, 22 and 18 ug/l respectively. If the benzene is naturally occuring it is unlikely that the concentrations would vary this much. It is more likey that the presence of benzene is a result of contaminants introduced during drilling and well construction than naturally occurring in the formation water.

Stable isotope data for the Madison Aquifer groundwater at the Marlin 29-21 WDW are reported in the 2015 Tetra Tech report - *Sampling and Analysis for Chemical and Isotopic Content of Madison Formation in Fremont Cy, WY.* The report includes the results of ^{13}C, ^{14}C, $\delta^{18}O$, ^{36}Cl and tritium sampling for purposes of age dating the groundwater in the Madison.

- There was only one tritium sample analyzed, no duplicate sample, which was specified in the SAP was collected. The Tetra Tech report does not include the tritium value for the one sample collected.
- The ^{14}C data indicate an uncorrected "age" of 36,910 to 38,990 years. The report states that a "small correction to a younger age may be made…". Based on the amount of "dead" carbon in the water, the correction would be large. Based on likely values for the corrected ^{14}C data and the $\delta^{18}O$ data, the groundwater sampled via the Marlin 29-21 is likely post-Pleistocene (less than 10,000 years old and more than 75 years old).
- The Tetra Tech report presents only one value for $\delta^{18}O$ and ^{36}Cl. Data for these isotopes is much more useful if there is data over an annual hydrograph.

- It should be noted that just because groundwater is "old" does not mean that the sustainable well yield will be low or that the water quality will be bad.

Groundwater flow velocities and "age" were estimated by Plummer et al (1990) for the Madison Aquifer east of the Wind River Basin. Flow velocities ranged from 7 to 87 ft/yr and the "age" was estimated at 23,000 years.

Numerical Groundwater Flow Modeling

Most of the hydrologic and well data included in the August 2020 amended application is the same information presented in the November, 2015 application. It appears that Aethon only updated the groundwater model as follows: (a) added the Darwin Sandstone member of the overlying Amsden Formation as a receiving zone; (b) reprocessed Reservoir Sigma Logs to obtain new porosity estimates for the Madison Aquifer; and (c) obtained 2D seismic lines and "utilized" the data to refine local structure. In the amended application, Aethon presents results from the numerical modeling to characterize groundwater flow in the Madison Aquifer and to predict waste fluid migration distances as follows:

- All of the modeling results and predictions included in the report have very significant uncertainty. While the models that were used are modern and sophisticated, the sparse amount of available empirical data significantly limits the ability to model. The reports do not provide any discussion of the magnitude of these uncertainties. This is especially important for estimating the extent of waste fluid migration.
- Except for the horizontal to vertical permeability (10:1), the model assumes homogenous and isotropic conditions in the Madison Aquifer. This is highly unlikely due to the karst in the upper part of the aquifer and local structures.
- The modeled area for this analysis was about 1,075 mi^2. The area is too large to adequately simulate conditions in the immediate area of the Marlin 29-21 WDW.
- The amount of empirical data for the elevation of the Madison Aquifer potentiometric surface is extremely limited in the vicinity of the Marlin 29-21 WDW. Only one potentiometric surface contour is shown for the modeled area (1,075 mi^2) in Figure 4-12 in the Tetra Tech report entitled: *Performance and Influence of Marlin 29-21 WDW on Madison Formation, Fremont Cy, WY, Tetra Tech, January 27, 2015.* This means that there is significant uncertainty with respect to the direction and rate of groundwater flow in the Madison Aquifer in the vicinity of the Marlin 29-21 WDW.
- The Marlin 29-21WDW does not fully penetrate the Madison Aquifer. The perforated interval is only 78% of formation thickness. The hydraulic properties estimated by the model assume full penetration of the aquifer.
- The model uses a longitudinal dispersivity value of 150 ft and a transverse dispersivity value of 15 ft. There is no discussion or citation as to the source of these values.
- The modeling that was conducted to evaluate the zone of impact assumed no-flow boundaries at the top and bottom of the Madison Aquifer and assumed that no faults extended from the Madison Formation upward or downward to /through confining formations. This does not represent hydrogeologic reality.
- The model classifies faults as transmissive versus impremeable based on offset. Whether a fault zone functions as a barrier to flow across the fault or along the strike of the fault zone is dependent on permeability in the fault zone and the permeability of the rocks that are juxtaposed adjacent to the fault.
- The uncertainty regarding the zone of emplacement and subsequent impact and contaminant migration within the Madison Aquifer constrains the ability to determine the appropriate size for an exempted area. There is significant concern that the plume will migrate beyond the boundary of the exempted area.

Moneta Divide Development

The decision regarding an aquifer exemption for the Madison Aquifer for the Marlin 29-21 WDW should not be made in isolation. Aethon proposes to develop the Moneta Divide gas field which will include up to 4,100 wells and require a cumulative disposal of trillions of gallons of waste fluid. Given the fact that the total proposed injection to the Marlin 29-21 WDW is a small fraction of the total potential disposal needs for the Moneta Divide field - will more Madison disposal wells, with associated aquifer exemptions, be necessary?

Thank you for the opportunity to review and respond to this permit application amendment. I look forward to discussing it with you further. Please don't hesitate to let me know if you have any questions.

Sincerely,

Sue Ann Spencer
Wyoming P.G. #238

PROFESSIONAL GEOLOGIST
SUE ANN SPENCER
PG-238
WYOMING

References Cited

Jarvis, W.T., 1986, Regional Hydrogeology of the Paleozoic Aquifer System, Southeastern Bighorn Basin, Wyoming with an Impact Analysis on Hot Springs State Park. Unpublished Masters Thesis, University of Wyoming.

Plummer LN, Busby JF, Lee RW, Hanshaw BB (1990) Geochemical Modeling of the Madison Aquifer in Parts of Montana, Wyoming, and South Dakota. Water Resources Research 26(9):1981-2014.

Spencer, 1986, Groundwater Movement in the Paleozoic Rocks and Impact of Petroleum Production on Water Levels in the Southwestern Big Horn Basin, Wyoming. Unpublished Masters Thesis, University of Wyoming.

Wyoming State Geological Survey, Wind/Bighorn River Basin Water Plan Update Groundwater Study Level 1, 2008 to 2011

Tom Kropatsch <tom.kropatsch@wyo.gov>

Dockett 1711-2020 comments

Jill Morrison <jmorrison@powderriverbasin.org> Fri, Nov 6, 2020 at 7:56 AM
To: Tom Kropatsch <tom.kropatsch@wyo.gov>
Cc: John Rader <john@wyomingoutdoorcouncil.org>, "Minter, Douglas" <Minter.Douglas@epa.gov>

Dear Tom,

Thank you for consideration. Attached for the Commission hearing regarding Aethon Docket #1711-2020 Madison aquifer exemption please find a copy of comments from Powder River Basin Resource Council and Wyoming Outdoor Council. Attached to our comments is the analysis and review by our consultants and previous WOGCC transcripts regarding this proposal and hearing in 2015 and 2016.

Jill Morrison

Executive Director

Powder River Basin Resource Council

934 North Main

Sheridan,Wyoming 82801

(307) 672-5809 – office

(307) 751-5574 – cell

www.powderriverbasin.org

4 attachments

- **transcript Nov 10 2015 Madison aquifer exemption hearing-compressed.pdf**
  8704K
- **WOGCC feb 9 2016 transcript on madison aquifer exemption reconsideration.pdf**
  2000K
- **PRBRC and WOC comments with expert report on Aethon Madison Aquifer Exemption 1711-2020 FINAL.pdf**
  5260K
- **2020 Spencer and Wireman expert review of Madison exemption Aethon 1711-2020 Final.pdf**
  143K

Tom Kropatsch <tom.kropatsch@wyo.gov>

Docket #1711-2020

1 message

Robert Condrat <tardnoc.r@gmail.com> Fri, Nov 6, 2020 at 2:36 PM
To: Tom Kropatsch <tom.kropatsch@wyo.gov>

Please do NOT give exemption for Aethon to inject contaminated water (with oil and gas wastewater) into the Madison Aquifer. This aquifer will eventual be important water source for people of the Wind River and Bighorn Basins.
Thanks Robert Condrat

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Madison Aquifer, Exeption Request Comments Bensel

1 message

billb@fiberpipe.net <billb@fiberpipe.net> Fri, Nov 6, 2020 at 11:33 AM
To: tom.kropatsch@wyo.gov

TO: Tom Kropatsch, Deputy Supervisor WYOGCC

FROM: Bill Bensel

RE: Aethon Madison Aquifer Exemption

DATE: Nov. 6, 2020

Dear Mr. Kropatsch,

The Madison is one of Wyoming's most important groundwater aquifers. It is utilized by a large part of our states population as a high-quality source of drinking water. Further, as the state continues to grow, this groundwater source will become even more critically valuable. The uncertainties of surface water availability and quality make continued protection of this source all the more essential.

As a former member of the Wyoming Water Development Commission, it is indeed true that the Madison has been determined to be a viable source to supply the needs of communities in the Southern Big Horn and Wind River Basins. Where there is demand, groundwater will be tapped, depth notwithstanding.

The Madison in the Moneta area is still part of the wider, highly porous and mobile aquifer. This serves a wide area of the state from north to south. An impact to one area will be seen in another. If we hope to grow and prosper into the future, negative impacts to our finite potable drinking water sources, the Madison in particular, must absolutely be avoided.

Our oil and gas resources are also important to our state. However, by-product waters and related drilling wastes must use the available alternative disposal and storage methods if we are to keep the Madison intact as a high-quality water source for today and into the future. To do otherwise would be counter to the best interests of the people and of the state of Wyoming.

I would most respectfully urge you and our WYOGCC to reject this request for exemption.

Thank you for your service and attention to this important matter.

William E. Bensel

Ranchester, WY

3077523489

Madison Exemption Request Comments WYOGCC 1142020.docx
16K

WYOMING TROUT UNLIMITED

PO Box 22182 • Cheyenne, WY 82003

Conserving, protecting and restoring Wyoming's coldwater fisheries and their watersheds

November 6, 2020

Wyoming Oil and Gas Conservation Commission
Attn: Tom Kropatsch, Deputy Oil and Gas Supervisor
P.O. Box 2640
Casper, WY 82602

Submitted via e-mail to: tom.kropatsch@wyo.gov

Dear Wyoming Oil and Gas Conservation Commissioners,

Thank you for considering the following comments from Wyoming Trout Unlimited regarding Docket Matter 1711-2020, the injection permit and aquifer exemption that could allow Texas-based Aethon Energy Operating LLC (Aethon) to inject wastewater into the Madison Formation in Wyoming.

The Wyoming Council of Trout Unlimited (TU) is a group of committed volunteers who live throughout the state and work hard to enhance and protect coldwater fisheries in Wyoming. We represent 12 local chapters, two of which are located in the Wind River and Bighorn Basins (the Popo Agie Anglers Chapter in Lander and the East Yellowstone Chapter in Cody). We also represent more than 1,600 members who are anglers and conservation-minded people that choose to call Wyoming home. Wyoming TU members and volunteers directly contribute to and benefit from healthy fisheries, and consistently advocate for the protection of freshwater sources so that Wyoming residents and anglers can enjoy our state's great water and recreation resources for generations to come. Wyoming Trout Unlimited is affiliated with our national organization, Trout Unlimited, whose mission is to protect, restore, reconnect, and sustain our nation's trout and salmon fisheries and their watersheds.

Neither TU nor Wyoming TU is opposed to energy development. Many of our members work in, or have worked in the energy industry and we recognize the industry's important role in Wyoming's economy. It is Wyoming TU's policy to encourage responsible, strategic energy development that meets the needs of people and communities but avoids unnecessary risks and impacts to coldwater fisheries and water resources. Clean, cold freshwater sources are critical to sportsmen, sportswomen, and all Wyoming residents. As such, we respectfully ask the Commission to deny Aethon's request for underground disposal of potentially billions of gallons of wastewater into the Madison Formation under Chapter 4, Section 5 and its application for aquifer exemption under Chapter 4, Section 12.

The Madison Aquifer's Current and Future Value

In addition to being an important target for municipal water supply currently, the Madison aquifer's value as a potable water source that can address the needs of municipalities, fish, wildlife, and agriculture in the Wind River and Big Horn Basins will increase in the future. In Wyoming- and throughout the West- we are experiencing increasingly intense and frequent drought, longer fire seasons, warming surface water temperatures, algal blooms every summer, population growth, increased tourism for outdoor recreation, and tensions over water rights and compact compliance. As both anglers and Wyoming residents, we worry about the availability of clean, cold, reliable water sources in the future. Aethon's argument that recovery of fresh and potable water from the Madison Formation in this area is not economically or technologically impractical is not persuasive, considering that there are other water wells in the state of Wyoming drilled to similar depths, and that need drives innovation. Protecting the integrity of our freshwater resources to ensure that Wyoming has options for meeting future demand for clean, cold freshwater (for humans and fish and wildlife) is a priority for TU.

Wastewater Threats to Fish

Disposing toxic and contaminated compounds into groundwater that could supply or connect to fisheries in the short-term and/or long-term would not be prudent from our perspective. Whether due to fluid migration (especially hard to predict in karstic environments) or pumping, this water could end up as surface water. Studies in Wyoming have identified and discussed the adverse effects of produced water and wastewater (even treated wastewater) on aquatic life and wetland and riparian habitat, and yet we continue to observe failures in compliance with the current regulations and limits, thus we are concerned. Aethon's application notes that they do not have water analyses for all source wells from which their wastewater would be produced. Appendix D shows that all source wells analyzed expectedly have high levels of dissolved solids relative to what is suitable for fish, but there are many other chemicals and compounds that would be present in wastewater and reason for concern. It seems there remains an unsettling level of uncertainty in Aethon's analysis.

We would prefer that Aethon's wastewater be treated and reused, then disposed of in a manner that does not risk contaminating a freshwater aquifer, especially one that is used for drinking water and that could be more widely used in the future for municipal and agricultural purposes before flowing to fish-bearing streams or lakes.

Thank you very much for considering our concerns and comments pertaining to Docket Matter 1711-2020. We appreciate your consideration of the risks and impacts associated with energy production in Wyoming. The job of balancing the protection and production of our state's natural resources can surely be a challenging one, but we are hopeful that innovative water treatment options will continue to be developed and that sophisticated water management plans will be implemented across Wyoming to simultaneously facilitate responsible energy development and environmental stewardship.

Sincerely,

Kathy Buchner

Cole Sherard
Chair

Kathy Buchner
Vice Chair/Conservation Committee

Tom Kropatsch <tom.kropatsch@wyo.gov>

Aethon Madison Aquifer Docket 1711-2020

JoAnne Puckett <pucketts82834@gmail.com> Sun, Nov 8, 2020 at 1:02 PM
To: tom.kropatsch@wyo.gov

RE: Docket 1711-2020

We are writing in opposition to the Aethon Madison Aquifer Exemption Waste Disposal Proposal. As Wyoming citizens, we do not understand why allowing even the slightest potential to compromise any significant water source like the Madison aquifer, or any water source in our fine state for that matter, would be considered by our government.

Thank you for the opportunity to comment.

V/R,
JoAnne Puckett
James HB Puckett
Buffalo, WY

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

DOCKET # 1711-2020, Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

1 message

Margaret Smith-Braniff <crazywoman@wbaccess.net> Mon, Nov 9, 2020 at 10:45 AM
To: tom.kropatsch@wyo.gov
Cc: crazywoman@wbaccess.net

Margaret Smith

P.O. Box 1003

Buffalo, Wyoming 82834

November 9, 2020

Wyoming Oil and Gas Commission

Director Supervisor, Tom Kropatsch

Dear Mr. Kropatsch,

This letter is in regard to the decision your committee will be making about the Madison Aquifer and the request being made by the Aethon Energy and Encana to discharge into the aquifer. (Docket#1711-2020/ Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well.) I am asking that your committee to decide *against allowing this discharge*.

The reasons are primarily because water is of even greater importance than oil and gas. I recognize the continued need to develop oil and gas for our nation, but the scarcity of potable water in the West increases in these seasons of extreme drought. The recharge of our water resources has diminished and we need to recognize that with the increased number of human beings moving to this region, the demand for water is also going to increase. The likelihood of accessing those deep water sources means they need protection for future use.

I had a wise woman advise me once: “No one cares about *facts,* Margaret. People make decisions on their *feelings* about an issue—and then find the facts that support their opinion.” I have found this is a truism for much policy making and economic decision making—whether on a personal level or governmental. So I will leave the fact-finding and distribution of white papers to the experts.

I can only go on my personal experience on our ranch. We have had many water wells drilled here—some good ones and some dry holes. The driller who has done most of our wells in the past 20 years has smiled a wry smile and made no promises when asked how much water we can expect. He knows better than to be definitive about quantity, quality or depths. We have been within 100 yards of a well that produces 25 g/m and one that produces 10. I realize the depth of the Madison is significantly different from the “shallow” wells of 350-500 feet, but importance of the driller’s caution can be applied to the deeper, larger, and more significant Madison aquifer: there might be much known generally, but the potential impacts of injecting pollutants of any kind into this aquifer can only be guessed at. The potential harms continue to be too great to make this a viable decision.

PLEASE VOTE NO to the request to discharge into the Madison Aquifer by Aethon Energy—or any other company wishing to discharge into this precious resource.

Thank you for including my remarks in your hearing.

Margaret Smith, property owner and ranch manager for Trail Land, LLC

307-684-7849

---

the Madison aquifer--hearing 11-10-20.docx
14K

Wyoming

Tom Kropatsch <tom.kropatsch@wyo.gov>

Aethon Madison Aquifer Exemption Request for 29-21 Injection Well

1 message

Sharon Mader <smader@npca.org>
To: "Tom.kropatsch@wyo.gov" <Tom.kropatsch@wyo.gov>
Cc: Sharon Mader <smader@npca.org>

Tue, Nov 10, 2020 at 8:21 AM

NATIONAL PARKS CONSERVATION ASSOCIATION

November 9, 2020

Wyoming Oil and Gas Conservation Commission

Attn: Mr. Tom Kropatsch

P.O. Box 2640

Casper, WY 82602

RE**: Aethon Energy Operating LLC injection permit and aquifer exemption**

Submitted via email to tom.kropatsch@wyo.gov

Dear Mr. Kropatsch,

Please accept comments on behalf of the National Parks Conservation Association (NPCA) regarding Aethon Energy Operating LLC injection and aquifer exemption application.

The mission of the NPCA is to "protect and enhance America's National Park System for present and future generations." Founded in 1919, NPCA is the leading citizen voice for the national parks. We are a national nonprofit with headquarters in Washington, DC, and 27 regional and field offices across the country including our Grand Teton Field Office located in Jackson, Wyoming. NPCA represents thousands of Wyoming residents who, along with our 1.3 million members and supporters nationwide, understand the need to conserve and protect our National Park System throughout the country.

A top priority for NPCA is protecting the resources within parks, including the larger watersheds in which they are embedded. Poorly planned oil and gas development including the discharge or injection of oil and gas byproducts and pollutants without full understanding of the potential negative impacts can result in significant impacts to national park resources. NPCA is working to ensure that oil and gas development on Wyoming's other public lands, including BLM lands connected to national park units is planned with consideration and care for the many non-drilling uses of the land as well as the potential impacts on park resources, visitor experience and human health.

NPCA has participated in previous state permit processes associated with Aethon's proposal to discharge oil and gas waste into Boysen Reservoir. After review of the permit application NPCA concluded that the renewal of the permit to discharge approximate 2 million gallons of oil and gas wastewater per day into Boysen Reservoir requires additional regulatory oversight and accountability. We opposed the renewal of the existing permit that agrees to the discharge of a potential oil and gas pollutant into a national park unit connected reservoir until our concerns were addressed.

The latest iteration of this proposal could adversely impact water resources in the state and subsequently negatively impact flora and fauna connected to Wyoming's national park ecosystem. As a result, we respectfully ask the Commission to deny Aethon's request for underground disposal of wastewater into the Madison Formation and its application for aquifer exemption.

Water is the west's most valuable commodity. A commodity, that because of drought, climate change and increased use is now much shorter supply, placing increased stress on western states. In addition to being one of the primary sources of drinking water for the state of Wyoming, the aquifer plays a critical role in the health and vitality of wildlife in the Wind River and Big Horn Basins. Protecting the integrity of Wyoming's water resources, is a priority for NPCA, as the integrity of these resources directly impacts the future of wildlife in the state, and equally national park connected landscapes. Currently, populations of wildlife are in crisis because of oil and gas development, as poorly planned oil and gas development has decimated the mule deer population in recent years.

It is NPCA's position that the state of Wyoming work to improve habitat and vitality of Wyoming's wildlife and connected ecosystems, rather than create additional risks by disposing of toxic wastewater into one of the west's most valuable resources. Risks include groundwater contamination, habitat contamination and ultimately the loss of potentially billions of gallons of water that could be treated and reused by industry versus create immense risk to the state's people, wildlife, economy, and collective ecosystems.

As a solution to the wastewater disposal issue, we urge Aethon and state of Wyoming to pursue 21st century solutions that will ensure protection of human health and our national parks as well as allowing for oil and gas development to occur where appropriate without immense risk to Wyoming's watershed. Use of state-of-the-art water treatment facilities, technology and regulatory oversight will aide in ensuring the protection of national parks and communities in Wyoming's complex watersheds.

The Wyoming Oil and Gas Conservation Commission should deny Aethon's request for underground disposal of wastewater into the Madison Formation and its application for aquifer exemption.

Thank you for your consideration of our comments.

Respectfully,

Sharon Mader

Sharon Mader

Grand Teton Program Manager

National Parks Conservation Association

NPCA Aethon Injection Permit Letter.11.9.20.docx
62K

Tom Kropatsch <tom.kropatsch@wyo.gov>

Moneta water disposal

1 message

Phylisr2004 <phylisr2004@yahoo.com> Tue, Nov 10, 2020 at 7:24 AM
To: tom.kropatsch@wyo.gov

I am writing to you to oppose the proposal to inject Moneta produced water into the Madison formation. I find it hard to believe you might approve contamination of our future domestic water supply. Are we that callous to jeopardize our children's and grandchildren's health for a few dollars? This goes to the heart of our moral strength in our society. We as parents and grandparents are relying on you to do your job and protect all of our future generations need for clean water. It just seems crazy to purposefully pollute our water supply!

The argument by the company that benzene is occurring naturally does not hold up to scrutiny of the facts. Historic accidental benzene injection and differences in concentration levels in the aquifer make this "naturally" occurring benzene story a fiction and specious argument.

The company should spend the money to properly treat the eater before discharging. It's the only moral and responsible action for this company to take. Polluting the water supply for the entire surrounding community is unfairly throwing the companies cost of doing business into the company. They should be responsible for their actions from beginning to end. If they want to reap the profits, they should pay the costs.

Please do your job and protect the public depending on you. Thank you.

Phyllis Roseberry

Tom Kropatsch <tom.kropatsch@wyo.gov>

Please reject Docket Matter 1711-2020

1 message

Shane Sims <shagresims@gmail.com> Mon, Nov 9, 2020 at 6:12 PM
To: tom.kropatsch@wyo.gov

Dear Mr. Kropatsch,

As a young (28) person raised in Wyoming I've struggled with seeing a place for me here in the long-term. I will soon finish a graduate degree at UW and need to decide where I would like to take the next step in building my life. WOGCC approval of the contamination of a potentially viable resource seems like a decision which sacrifices the long-term interests of our State for a relatively small and dubious short-term gain. I understand that Madison Formation water is deep, however I value forward-thinking decisions about precious resources such as water when I consider where to build a life.

Thank you,

Shane Sims
333 Roger Canyon Road
Laramie, WY 82072

Tom Kropatch, Deputy Supervisor
WOGCC
P.O. Box 2640
Casper, WY 82602

RE: Docket #1711-2020
Aethon Madison Aquifer Exemption Request for Marlin 29-21 Injection Well

Mr. Kropatch,

I oppose Aethon's Energy Repeat effort to pollute the Madison Aquifer. They want to exempt the Madison Aquifer from drinking water standards so they can dump their polluted gas and oil wastewater in that aquifer. It was once defeated; why not now? The aquifer is a clean, viable source of future drinking water. I believe we must conserve all fresh water, not pollute it!

Sincerely,

Evelyn Griffin

Evelyn Griffin
P.O. Box 21
Pavillion, WY 82523