POWDER RIVER BASIN
Resource Council

Wyoming Outdoor Council

Transmitted via the DEQ's Public Comment Portal

February 19, 2020

Ronald Steg
Wyoming Department of Environmental Quality
519 Meadowview Drive
Lander, WY 82520

Re: Comments on Public Review Draft of *Wyoming's 2020 Integrated 305(b) and 303(d) Report*

Dear Mr. Steg,

These comments are submitted on behalf of the Powder River Basin Resource Council and Wyoming Outdoor Council in response to the Department of Environmental Quality's January 6, 2020 public notice inviting comments on the public review draft of *Wyoming's 2020 Integrated 305(b) and 303(d) Report* (hereinafter "2020 Integrated Report").

I. DESCRIPTION OF PARTIES

Powder River Basin Resource Council (PRBRC) was founded in 1973 by rural landowners and concerned citizens working to protect their land, water, and air. For 47 years our citizen-based organization has been dedicated to civil society and to the stewardship of Wyoming's human and natural resources. We are committed to community organizing, leadership development, and the empowerment of citizens.

Established in 1967, the Wyoming Outdoor Council (WOC) is the state's oldest and largest independent conservation organization. Our mission is to protect Wyoming's environment and quality of life for future generations.

II. DISCUSSION

Wyoming's 303(d) list is comprised of waters that do not meet water quality standards and require the development of Total Maximum Daily Load (TMDL) studies. While we commend DEQ for assessing attainment of water quality standards in approximately 7 percent of Wyoming's stream miles, we believe the agency missed the opportunity to include both

Badwater Creek and Alkali Creek on the 303(d) list provided in Appendix D of the 2020 Integrated Report.

Based on the documents, photos and videos released by the DEQ Water Quality Division and that we have reviewed it is obvious that Badwater Creek and Alkali Creek do not meet their designated uses. (Badwater Creek is a Class 2AB stream protected for the following uses: drinking water, fisheries, aquatic life other than fish, recreation, wildlife, agriculture, industry and scenic value. Alkali Creek is a Class 3 stream protected for aquatic life other than fish, recreation, wildlife, agriculture, industry and scenic value.)

In order for streams or lakes to be assessed, DEQ's Water Quality Assessment Program must receive water quality-related data by April 15 of odd-numbered years (e.g., 2019) for possible inclusion in the subsequent year's Integrated Report (e.g., the 2020 Integrated Report). While we are aware of the April 15th deadline, in the case of Badwater Creek and Alkali Creek, we believe the deadline is irrelevant because *DEQ itself* is the source or repository of substantial data and information showing these streams do not meet water quality standards resulting from excessive chloride, TDS, oil and grease, pH, dissolved iron, dissolved zinc and other pollutants from the Moneta Divide oil and gas field. The DEQ records also document the presence of a black sediment, surface foams, mineral deposits and oil and grease in Alkali and Badwater Creeks. In addition, DEQ has documented TDS concentrations in Alkali Creek that exceed the limit of 5,000 mg/L for wildlife and livestock water quality standards.

A. Aethon Violations of WYPDES Permit WY0002062

Aethon Energy Operating currently discharges produced water to Alkali Creek under WYPDES permit WY0002062. Discharge Monitoring Reports and a DEQ Letter of Violation demonstrate that Aethon Energy is not in compliance with the WYPDES permit or Wyoming's water quality regulations. Details follow.

1. Discharge Monitoring Reports

Discharge Monitoring Report (DMR) data sets from the DEQ and the Environmental Protection Agency's Enforcement and Compliance History Online (ECHO) database reveal fifteen violations of effluent limits during monitoring periods ending May 31, 2015 to December 31, 2019. Aethon violated the permit effluent limits for dissolved iron, dissolved zinc, oil and grease, pH and total dissolved solids. See Exhibit 1 table.

2. DEQ Letter of Violation to Aethon Energy

On December 17, 2019, the DEQ issued a Letter of Violation (LOV) to Aethon for the presence of black sediment deposits, water surface foams, mineral deposits, and free oil accumulations in Alkali and Badwater Creeks. See Exhibit 2, LOV. Aethon is aware of these violations as indicated by its January 16, 2020 response. See Exhibit 3, LOV response.

B. Chloride Values Above 230 mg/L Exceed the Instream Limit of 230 mg/L in Badwater Creek

As noted earlier, Badwater Creek is a Class 2AB stream. Chapter 1 Appendix B of the Wyoming Water Quality Rules and Regulations establish a chloride standard of 230 mg/L for Class 2AB streams. In 2019 DEQ collected water samples from Badwater Creek on 11 occasions ("sampling events") from April through December. This sampling was conducted in accordance with DEQ's *Sampling and Analysis Plan for Badwater Creek 2019-2020* (SAP), one of several DEQ's monitoring initiatives noted on page 11 of the Integrated Report.

To date, lab results for just two sampling events (April and June) of 11 sampling events have been released to the Wyoming Outdoor Council and Powder River Basin Resource Council. Importantly, however, in both April and June, chloride levels exceeded the 230 mg/L standard for Badwater Creek. See Exhibit 4.

C. High Chloride Concentrations Badwater Creek and Alkali Creek Do Not Support *Aquatic Life Other Than Fish* Use

We incorporate by reference the full comments of aquatic scientists Drs. Harold Bergman and Joseph Meyer on DEQ's proposed discharge permit WY0002062-RENEWAL-12-17-19 (Draft 2) for Aethon. See attached memorandum dated Feb. 18, 2020, Exhibit 5.

As mentioned earlier, *Aquatic Life Other Than Fish* is one of the designated uses of both Badwater Creek and Alkali Creek. In their section on Chloride (excerpted, below, from full comments), Drs. Bergman and Meyer conclude that "chloride concentrations exceeding 230 mg Cl/L would not be safe for many invertebrates." That is, Badwater Creek and Alkali Creek do not support the *Aquatic Life Other Than Fish* designated use and therefore these waters should be included on the 303(d) list. Below is an excerpt of from Drs. Bergman and Meyer comments:

> Chloride:
>
> In the Compliance Schedule section of the draft permit, WDEQ concludes that there is a reasonable potential for this facility to exceed the in-stream chloride standard of 230 mg Cl/L for Badwater Creek (Class 2AB), because Badwater Creek is intermittent, resulting in no dilution flow during parts of the year. Thus, in the draft permit WDEQ appropriately sets the discharge limit for all of Aethon's outfalls the same as the in-stream standard of 230 mg Cl/L in Badwater Creek.
>
> We note that this 230 mg Cl/L effluent limit technically applies to all of the unnamed tributaries to Alkali Creek and to Alkali Creek as well as Badwater Creek, particularly because outfalls 001 to 015 all discharge to unnamed tributaries of Alkali Creek and outfall 016 discharges to Alkali Creek (Table 1 and Attachment 1 in Aethon's original application for this permit renewal dated August 8, 2016).
>
> Even though WDEQ's justification for the 230 mg Cl/L effluent limit is based on a reasonable potential analysis of in-stream requirements in Badwater Creek, WDEQ should explicitly also apply that same logic and same reasonable potential analysis for in-

stream requirements and effluent limits for Alkali Creek and its tributaries (Class 3B – aquatic life other than fish). Because Alkali Creek and its tributaries are also intermittent, no dilution flow can be expected for much of the year; and because a Class 3B water must protect aquatic life other than fish, the same 230 mg Cl/L instream requirement should also apply. Given a recent analyzed Chloride concentration of 1,540 mg/L in Alkali Creek on August 20, 2019 (Table 2 in ERM's Blackwater – Alkali Creek: Sediment and Surface Water Sampling Results report), the aquatic community in Alkali Creek is not meeting the designated use and needs more regulatory protection than the draft renewal permit will provide.

The current USEPA freshwater aquatic life chronic criterion for chloride of 230 mg Cl/L was derived numerically (i.e., based on lab toxicity tests, not based on field observations) and first appeared in the USEPA water quality criteria document for chloride in 1988 (EPA 440/5-88-001) (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table). The chloride criterion is "driven" by invertebrates (see Table 3 in that document). Of the 12 genera of aquatic organisms used in the 1988 derivation, the 6 most-sensitive genera were invertebrates [including cladocerans (two *Daphnia* species), a snail, an isopod, midges, and a caddisfly -- meaning a wide variety of types of aquatic invertebrates]; and 5 of the 6 least-sensitive genera were fish [i.e., only 1 of the 6 least-sensitive genera was an invertebrate (a mosquito)]. Thus, based on that toxicity dataset, it would be appropriate to conclude that chloride concentrations exceeding 230 mg Cl/L would not be safe for many invertebrates. [Note: The USEPA water quality criteria are intended to protect 95% of species. Thus, "on average", one might expect approximately 5% of the species to be adversely affected even at only 230 mg Cl/L.]

Thus, in our professional opinion, the existing USEPA criteria document provides sufficient evidence to support an argument that 230 mg Cl/L should be a maximum instream chloride concentration for protection of aquatic invertebrates in Alkali Creek, and a reasonable potential analysis would support an effluent limit of 230 mg Cl/L for all permitted effluent outfalls into Alkali Creek or its tributaries.

D. Concentration of Total Dissolved Solids in produced water is unsafe for wildlife and livestock and is impacting designated uses

Information contained in Aethon's permit application show that TDS levels in the effluent are much higher than 5,000 mg/L, yet the DEQ has presented no scientific evidence of any kind confirming that the higher TDS levels contained in the produced water are safe for wildlife and livestock use.

As explained by EPA, the effluent concentration limit of 5,000 mg/L for TDS was based on "research and data concerning the effects of produced water on livestock and wildlife to determine what level of effluent could be considered "of good enough quality." See EPA's Response to General Comments on Permits WY-0020338, WY0024953, WY0024945,

WY0025232, WY0025606, March 9, 2015, available at: https://www.epa.gov/sites/production/files/2017-01/documents/wy-0020338-eagle-oil-and-gas-sheldon-dome-field-response-to-general-comments.pdf.

In addition to EPA's explanation, a review of the pertinent literature - funded by the DEQ - indicates that TDS concentrations in excess of 5,000 mg/L may be harmful to livestock and wildlife. The review further cautions that concentrations well below 5,000 mg/L are a cause for concern:

> Total dissolved solids in drinking water serve as a very poor predictor of animal health. … We do not recommend relying upon TDS to evaluate water quality for livestock and wildlife; however, if no other information is available, TDS concentrations less than 500 mg/L should ensure safety from almost all inorganic constituents. Above 500 mg/L, the individual constituents contributing to TDS should be identified, quantified, and evaluated.

See Water Quality for Wyoming Livestock & Wildlife, A Review of the Literature Pertaining to Health Effects of Inorganic Contaminants, at 50 (hereinafter " 2007 water quality report"). Available at: http://www.wyomingextension.org/agpubs/pubs/B1183.pdf

The lack of a TDS effluent concentration limit in the revised draft permit, coupled with produced water containing TDS concentrations much higher than the maximum limits specified in Appendix H, raise substantial doubts about whether the produced water is of good enough quality for livestock and wildlife use.

Impacts to agricultural and wildlife uses.

Analysis of 2019 water quality data collected by DEQ from Alkali Creek show that TDS concentrations *in the creek* exceed the maximum limit specified for *produced water* in Appendix H. *See* Exhibit 6, DEQ data. As stated earlier, Alkali Creek is a Class 3B stream with the following designated uses: aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value. *See* DEQ Ch. 1, Section 4(c). Chapter 1 explains that agriculture use includes livestock watering. Ch. 1, Sec. 3(a). Similarly, wildlife use "includes protection of water quality to a level which is safe for contact and consumption by avian and terrestrial wildlife species." Ch. 1, Sec. 3(h).

TDS concentrations in the stream exceed the levels that have been determined safe for wildlife and livestock watering and therefore are likely to impact designated uses in Alkali Creek. In order to determine whether higher, potentially unlimited, concentrations of TDS present in the produced water entering Alkali Creek will violate Wyoming water quality standards in Chapter 1, the DEQ must conduct a reasonable potential evaluation to determine whether the water uses described in Chapter 1, Section 3 pertaining to Alkali Creek, including in particular, agricultural and wildlife uses, will be protected. *See* Chapter 2, Section 5(c)(iii)(C). A 303(d) listing would provide added impetus to conduct this important evaluation.

III. CONCLUSION

Oil and gas wastewater discharges from the Moneta Divide field have severely impacted both Alkali and Badwater Creeks. Alkali Creek is impaired by a variety of oil field pollutants including high levels of chloride that have harmed aquatic life and high TDS concentrations that exceed limits that are safe for wildlife and livestock. It is clear that high chloride concentrations and other pollutants present in the oil and gas effluent and in Alkali Creek are preventing the attainment of designated uses. The quality of water in Badwater Creek, which receives the polluted wastewater from Alkali Creek is also negatively impacting the existing uses of Badwater Creek which are also not being maintained and protected. The pollutants are flowing into Badwater Creek and entering Boysen Reservoir causing further degradation to Boysen Reservoir. Because the water quality standards are not being achieved and pollutants are causing the nonattainment of designated uses, we respectfully request that DEQ list Badwater and Alkali creeks on the 303(d) list in the 2020 Integrated Report.

Thank you for your consideration and attention to our comments.

Sincerely,

Jill K. Morrison

Jill Morrison
Executive Director
Powder River Basin Resource Council
934 N Main St.
Sheridan, WY 82801
(307) 672-5809
jmorrison@powderriverbasin.org

Dan Heilig

Dan Heilig
Senior Conservation Advocate
Wyoming Outdoor Council
262 Lincoln St.
Lander, WY 82520
(307) 332-7031 x13
dan@wyomingoutdoorcouncil.org

Exhibit 1

Aethon Permit WY0002062: Violations of permit limits for monthly monitoring periods ending 5/31/15 to 12/31/19

Pollutant	Outfall No.	Effluent Limit	Value Reported in DMR	Percent Exceedence	Monitoring Period End Date
Dissolved Iron µg/L	001	1000	1300	30%	2/28/18
Dissolved Zinc, µg/L	006	118.1	170	44%	8/31/15
Dissolved Zinc, µg/L	009	118.1	260	120%	12/31/16
Oil and Grease, mg/L	009	10	38.9	289%	12/31/16
Oil and Grease, mg/L	009	10	19.5	95%	6/30/17
Oil and Grease, mg/L	009	10	11	10%	10/31/17
Oil and Grease, mg/L	003	10	21	110%	12/31/17
Oil and Grease, mg/L	009	10	22	120%	2/28/18
Oil and Grease, mg/L	003	10	10.8	8%	2/28/18
Oil and Grease, mg/L	009	10	15	50%	4/30/18
pH	001	6.5 - 9.0	10.8	n/a	6/30/16
pH	001	6.5 - 9.0	3.8	n/a	12/31/16
pH	001	6.5 - 9.0	9.6	n/a	6/30/18
pH	001	6.5 - 9.0	9.91	n/a	12/31/18
Total Dissolved Solids, tons/month	sum of all outfalls	908	1347	48%	3/31/18

Sources of data:

EPA Enforcement and Compliance History Online

https://echo.epa.gov/tools/data-downloads/icis-npdes-dmr-and-limit-data-set
https://echo.epa.gov/detailed-facility-report?fid=110055199663

DEQ Paper DMR Download Utility
https://paperdmr.wyo.gov/

https://paperdmr.wyo.gov/ReportDisplay.aspx?Ty=LR&IV=yes&RT=PDF&PN=WY0002062&EE=08/31/2015,12/31/2017&LR=05/01/2015,12/15/2027

Exhibit 2

Department of Environmental Quality

To protect, conserve and enhance the quality of Wyoming's environment for the benefit of current and future generations.

Mark Gordon, Governor

Todd Parfitt, Director

December 17, 2019

Ms. Andrea Taylor
Aethon Energy Operating LLC
450 S. Federal
Riverton, WY 82501

RE: Letter of Violation: WYPDES Permit WY0002062

Dear Ms. Taylor:

Since April 2019, the Wyoming Department of Environmental Quality (DEQ) has been collecting water quality data on Alkali, Badwater, Bridger, and Dry Creeks on an approximately monthly basis to determine whether the designated uses and water quality criteria applicable to Badwater Creek are appropriate and attainable. At DEQ's request, Aethon has also collected and submitted water quality data as part of this effort. Throughout the 2019 sampling season, WDEQ personnel documented the presence of black sediment on the bottom of the stream channel of Alkali Creek near its confluence with Badwater Creek, as well as Badwater Creek downstream of Alkali Creek. Staff also noted the presence of foam on the water surface at these locations. On August 27, 2019 and September 24, 2019, samples of foam as well as black sediment were collected by the DEQ to determine their chemical makeup and potential origin. Staff also collected samples from the three primary Aethon outfalls (001, 006, and 009) on August 27. At that time, foam was observed in the channels below each outfall and free oil accumulations were observed in wire weirs below outfall 006.

The DEQ has evaluated the currently available data and our analyses have identified the following violations:

Black sediment deposits are present in channels below outfalls 001, 006, and 009; Alkali Creek below the Moneta Divide oil and gas field, and; Badwater Creek for approximately seven miles downstream of its confluence with Alkali Creek. These deposits were identified as iron sulfide by applying hydrogen peroxide and watching the color disappear as FeS is converted to aqueous FeSO4 and by applying hydrochloric acid and noting the release of H2S gas. The deposits were not observed elsewhere in the Badwater Creek watershed and appear to be created when sulfide reacts with iron. In addition, precipitate mineral deposits covering the substrate materials were identified below the outfalls and in Alkai and Badwater Creeks.

Part I A.1 of Permit WY0002062 states that "There shall be no deposition of substances in quantities that could result in significant aesthetic degradation, or degradation of habitat for aquatic life, plant life or wildlife; or which could adversely affect public water supplies or those intended for agricultural or industrial use."

Foam was observed on the water surface below outfalls 001, 006 and 009; in Alkali Creek above its confluence with Badwater Creek, and; in Badwater Creek downstream of Alkali Creek. The foam was confirmed to be an anionic surfactant using a methylene blue activated substances (MBAS) colorimetric test. Water surface foams were not observed elsewhere in the Badwater Creek watershed. Free oil accumulations were observed in wire

weirs below outfall 006. In addition, petroleum hydrocarbons were identified in Alkali Creek sediments below outfall 6 and at the Downstream Monitoring Point (DMP).

Part I A.1 of Permit WY0002062 also states that "There shall be no discharge of floating solids or visible foam in other than trace amounts, nor shall the discharge cause formation of a visible sheen or visible hydrocarbon deposits on the bottom or shoreline of the receiving water."

The DEQ's review of currently available data indicates the following water quality criteria may have also been impacted by the permitted discharge: chloride concentrations, temperature changes, dissolved oxygen concentrations, and turbidity in Badwater Creek below its confluence with Alkali Creek. The DEQ will continue to evaluate these parameters as part of its ongoing investigation into designated uses and water quality criteria applicable to Badwater Creek. The department noted the presence of benzene, ethylbenzene, toluene and xylene in outfall samples collected by Aethon, however, samples collected at the DMP indicate the concentrations were within allowable limits.

The Water Quality Division is attempting to resolve these violations through conference and conciliation. Aethon should provide a written response within 30 days of the date of this letter presenting its plans and schedule to implement corrective measures to resolve these violations.

The intent of this letter is to provide an opportunity for your company to show good faith efforts toward resolving the problem and to prevent the need for more formal enforcement action by this office. I am requesting that Aethon provide a written response within 30 days of the date of this letter presenting its plans and schedule to implement corrective measures to resolve these violations. Failure to provide a written response may result in elevated enforcement actions and may include penalties.

Should you have any questions concerning this letter, please contact Kevin Wells at 307-777-8669 or Kevin.Wells@wyo.gov.

Thank you for your time and attention to this matter.

Sincerely,

Kevin Frederick
Administrator
Water Quality Division

KF/SG

cc: Todd Parfitt, Director
Kevin Wells, WYPDES Inspections and Compliance Supervisor
David Waterstreet, Watershed Section Manager
Jason Thomas, WYPDES Section Manager (Acting)

Exhibit 3

AETHON

January 16, 2020

Kevin Frederick, Administrator
Water Quality Division, WDEQ
200 West 17th Street
Cheyenne, WY 82002

Re: WYPDES Permit No. WY0002062, Response to Letter of Violation

Dear Administrator Frederick:

Aethon is providing written response regarding your correspondence dated 12/17/2019 outlining specific violations in accordance with WYPDES permit authorization WY0002062. Aethon appreciates the opportunity to provide its plan and schedule to resolve these violations.

Presence of Petroleum Hydrocarbons below Outfall 006 and at the DMP

Aethon has immediately implemented increased visual monitoring of the active discharge pits to assess the presence of oil accumulation. Pit skimming operations are now being conducted if the presence of oil on the pit surface approaches 25%. During monthly compliance sampling, a visual assessment will occur to verify there is not accumulation of oil below the outfall. During quarterly channel stability monitoring, a visual assessment will occur to verify there is not accumulation in Alkali Creek.

Presence of black sediment deposits below the discharge

Aethon has identified three potential solutions to address the black sediment deposits downstream of its outfalls. The first option is chemical oxidation where batch treatments of sodium hypochlorite (bleach) would be injected upstream in the pit system and eliminate the sulfide. The primary disadvantage of this approach is the resulting increase in TDS load that will occur as the TDS of the surface discharge will increase. The other options include increased aeration and/or introduction of dissolved oxygen to facilitate a SuperOxygenation process upstream of the pit system. The disadvantage of these approaches are that they have not been pilot tested.

AETHONENERGY.COM
12377 Merit Drive › Suite 1200 › Dallas, Texas 75251
Tel 214-750-3820 › Fax 214-750-1526

Regardless of which solution is selected, Aethon is also evaluating consolidation of the surface discharge to one active outfall location (016). The advantages Aethon anticipates by centralizing the water management system include increased retention time as all water would flow through mechanical separation systems at the Hendry Water facility, decreased water temperature prior to surface discharge, and increased efficiency for implementation of a sulfide treatment solution.

The following schedule is proposed to select and implement a sulfide reduction technology:

Q2 2020 – begin water consolidation testing (to a single outfall)
Q3 2020 – submit permit for pilot project (if consolidation testing unsuccessful)
Q4 2020 – conduct pilot testing (if consolidation testing unsuccessful)
Q1 2021 – evaluate data from pilot testing efforts and select final sulfide reduction solution
Q4 2021 – implement final sulfide reduction solution

Presence of foam below the discharge

Aethon has consulted with our chemical supplier regarding the presence of foam downstream of its outfalls and an evaluation was conducted (see enclosure). A total of 5 chemicals that Aethon uses were confirmed to contain trace amounts of surfactants (3 corrosion inhibitors, 1 scale inhibitor and 1 water clarifier). Testing conducted by our supplier indicate foam issues only arising at >5,000 ppm treatment, whereas Aethon's maximum treatment level on any given injection point is 30 ppm. The water clarifier (RBW213), however, did exhibit presence of surface bubbles at levels as low as 50 ppm. Aethon's treatment rate for this chemical is 6 ppm. Aethon will continue to investigate this particular chemical to determine if a suitable replacement exists. It is possible that use of this chemical could be reduced or eliminated altogether based on results from the water consolidation testing that will occur in Q2 2020.

Aethon understands that Energy Labs performed Methylene Blue Active Substances (MBAS) colormetric test (A5540C) to identify presence of anionic surfactants. Enclosed is a Hach TNT874 method for Anionic Surfactants. This method indicates interference may be possible with chloride levels exceeding 500 ppm. Considering detections were representative of chloride levels approximately 2,000 ppm, interference may be possible if a 4-5x dilution was not made. Aethon has reached out to Energy Labs to understand the method used in Lab Analysis C19081203 dated 9/10/2019. Considering a qualifier is not listed on the analytical report, it does not appear that a dilution occurred. Nonetheless, Aethon continues to monitor for the presence of foam. On 1/11/2020, Aethon operators walked the four active outfall drainages to Alkali Creek and no presence of foam was observed. Due to winter freeze conditions along Alkali Creek, no observation was possible along Alkali itself.

Aethon appreciates the opportunity to provide its assessment and proposed resolution to these concerns. Please contact me if you have questions regarding Aethon's written response.

Sincerely,

Andrea Taylor

Andrea Taylor
Regulatory & HSE Manager
307-200-4391
ataylor@aethonenergy.com

pdf: Tom Nelson, VP Operations Support

Enclosures: Field Project Foaming Evaluation, Baker Hughes
TNT 874 Anionic Surfactants, Hach Company, dated 5/2018, Edition 2
Analytical Summary Report, C19081203, Energy Laboratories dated 9/10/2019

Exhibit 4

Chloride results for Instream Water Samples Collected Pursuant to SAP
Results over 230 mg/L indicates exceedance of Chapter 1, Appendix B chloride standard

Creek	Instream Site ID	Chloride Results (mg/L)	
		04/23/19	06/17/19
Badwater Creek	1	183	83
Badwater Creek	2	219	78
Badwater Creek	3	210	96
Dry Creek	4	6	4
Badwater Creek	5	234	103
Badwater Creek	6	249	108
Badwater Creek	7	5	4
Badwater Creek	8	929	419
Badwater Creek	9	1066	203
Alkali Creek	10	1318	410
Badwater Creek	11	38	20
Badwater Creek	12	15	7
Badwater Creek	13	2	1

Sources of data: DEQ Laboratory Analytical Report
2019-04-24-001_V3_Final.pdf and 2019-06-18-001_Final.pdf)

Exhibit 5

Memorandum

February 18, 2020

To: Dan Heilig, Wyoming Outdoor Council, Lander, WY; and
Jill Morrison, Powder River Basin Resource Council, Sheridan, WY

From: Harold Bergman, PhD, Professor Emeritus, University of Wyoming, Laramie, WY; and
Joseph Meyer, PhD, Chief Scientist, Applied Limnology Professionals LLC, Golden, CO

Regarding: Analysis of, and comments on, proposed WDEQ Wastewater Discharge Permit for Aethon Energy Operating, LLC – WY0002062-RENEWAL-12-17-19 (Draft 2)

We have reviewed a series of documents including WDEQ-WQD's proposed WYPDES discharge permit WY0002062-RENEWAL-12-17-19 (Draft 2) for Aethon Energy Operating, LLC, Moneta Divide Gas Field; Aethon's original application for this permit renewal dated August 8, 2016; portions of Environmental Resources Management's (ERM's) Water Quality Compliance Analysis report to Aethon Energy dated April 23, 2018; ERM's Blackwater – Alkali Creek: Sediment and Surface Water Sampling Results report to Aethon Energy dated October 23, 2019; WDEQ's Response to Public Comments from the original draft permit; ERM Whole Effluent Toxicity Test Result reports dated 12 July 2017 and 13 March 2019; WDEQ's Letter of Violation for WYPDES permit WY0002060 dated December 17, 2019; and Aethon's Response to Letter of Violation dated January 16, 2020. We also have reviewed and used information from a several peer-reviewed publications on the chemistry of produced waters from oil and gas operations and the toxicity of these waters to aquatic biota, and we have cited these references, as appropriate, in the text below.

We commend the WDEQ-WQD for this improved draft WYPDES renewal permit, which is a substantial improvement compared to DEQ's earlier draft renewal permit, in that the current draft includes better analysis of the conditions related to Aethon's discharge and its effects on downstream water quality, and it imposes more stringent requirements of the discharger, particularly a reduction in allowed discharge from 8.274 MGD to 2 MGD and the eventual effluent limit of 230 mg Chloride/L. However, we have several concerns about other parts of the draft renewal permit.

In the text that follows, we present our analyses, conclusions and positions related to water chemistry and aquatic toxicity of Aethon's produced water and WDEQ's proposed issuance of a discharge permit renewal for Aethon's discharge.

Compliance schedule for Chloride final effluent limits (Pages 2 and 3):

The compliance schedule of 4 years until July 1, 2024 to meet the 230 mg Cl/L effluent limit is much too long and should be shortened, especially since WDEQ has provided no justification for a 4-year compliance schedule or provided interim effluent limits at, say, annual

intervals up to the 4-year deadline to meet the 230 mg Cl/L limit. A shorter compliance schedule or, at least, annually staged improvements in effluent limits for Chloride would be reasonable, given that the technology for water treatment to reduce Chloride is straightforward, and given that Aethon already has a reverse osmosis plant in place (Neptune Plant). This plant is apparently inoperable at this time but could be repaired/improved in time to meet a shorter compliance schedule.

We acknowledge, however, that the draft permit specifies that the 230 mg Cl/L effluent limit is being required for all Aethon outfalls (001-016), and this is what will be required to begin the recovery of what can clearly be characterized as severely impaired conditions in both Alkali and Badwater creeks. With this Chloride limit placed on all 16 discharge outfalls, it is likely that Aethon will need to consolidate its outfalls to one reverse osmosis treatment plant to reduce the current untreated discharge of around 2,200 mg Cl/L. Aethon's current Neptune Plant is located at outfall 001, yet Aethon is actively considering consolidating all its surface discharges to outfall 016 (Aethon's January 16, 2020, Response to WDEQ Letter of Violation), to improve their ability to treat wastewater for reduction of sulfide and temperature.

Thus, given the requirement to meet the 230 mg Cl/L discharge limit for all outfalls (including unnamed tributaries to Alkali Creek and Alkali Creek), Aethon may need to consolidate its discharges to outfall 001 where the current Neptune Plant is located, or build a new reverse osmosis plant at a consolidation location at outfall 016. Under these circumstances, Aethon and WDEQ will likely need to negotiate an appropriate time frame for consolidating all the current outfalls (presumably using pipelines to avoid in-stream violations in Alkali Creek and Alkali Creek tributaries) and treatment upgrades at this new outfall location to achieve compliance with the 230 mg Cl/L discharge limit as well as the need to comply with limits for sulfide and temperature. Under no circumstances, though, should the discharge be allowed to exceed the 230 mg Cl/L at any discharge location, including on Alkali Creek or tributaries to Alkali Creek.

Instream Monitoring (Pages 3 and 4):

In WDEQ's new draft 2 Aethon discharge permit, the only monitoring station WDEQ will require on Badwater Creek is BWC1 "below its confluence with Alkali Creek." The BWC1 station will likely totally miss the elevated pH that we predicted in our earlier comments (dated June 27, 2019 on the first proposed renewal permit) will occur as the over-saturated CO_2 gas in the effluent degasses from Alkali and Badwater Creeks enroute to Badwater Bay in Boysen Reservoir. We strongly recommend that, in addition to BWC1, at least one other monitoring station on Badwater Creek should be required immediately upstream of Badwater Bay (where the highest pH values in Badwater Creek might be expected).

We extensively explained and reviewed this likely problem of over-saturated CO_2 partial pressure in Aethon's produced water causing elevated instream pH values above 9 in our earlier comments (dated June 27, 2019) to WDEQ's draft 1 proposed permit. In summary, we estimated that the partial pressure of CO_2 (pCO_2) in Aethon's discharge could be approximately 372-fold over-saturated in CO_2 at Aethon's discharge. This means that the over-saturated CO_2 will de-gas from the discharge water as it flows downstream in Alkali and Badwater Creeks until the CO_2

reaches equilibrium with the atmosphere. As the CO_2 degasses, the H^+ concentration will decrease and, thus, the pH of the water will increase. In our earlier analysis of this issue, we used the WHAM geochemical-speciation software (Lofts, 2012) and calculated that the in-stream water might reach a pH as high as 9.6 after the discharged produced water's over-saturated pCO_2 level fully equilibrated with the atmosphere, thus exceeding WDEQ's instream standard of pH 6.5 to 9. The realized pH will also depend on the extent to which concomitant precipitation of calcite ($CaCO_3$) remains oversaturated in the creek water.

Based on this analysis, as noted above, we strongly recommend an additional Badwater Creek monitoring station immediately upstream of its discharge into Badwater Bay. In addition, we also strongly recommend that Aethon be required to report temperature and alkalinity (from which, along with pH, pCO_2 can be calculated) of the discharge and at all monitoring sites so that this potential instream pH violation can be evaluated.

Water Quality Based Effluent Limits (Pages 4-7):

Chloride:

In the Compliance Schedule section of the draft permit, WDEQ concludes that there is a reasonable potential for this facility to exceed the in-stream chloride standard of 230 mg Cl/L for Badwater Creek (Class 2AB), because Badwater Creek is intermittent, resulting in no dilution flow during parts of the year. Thus, in the draft permit WDEQ appropriately sets the discharge limit for all of Aethon's outfalls the same as the in-stream standard of 230 mg Cl/L in Badwater Creek.

We note that this 230 mg Cl/L effluent limit technically applies to all of the unnamed tributaries to Alkali Creek and to Alkali Creek as well as Badwater Creek, particularly because outfalls 001 to 015 all discharge to unnamed tributaries of Alkali Creek and outfall 016 discharges to Alkali Creek (Table 1 and Attachment 1 in Aethon's original application for this permit renewal dated August 8, 2016).

Even though WDEQ's justification for the 230 mg Cl/L effluent limit is based on a reasonable potential analysis of in-stream requirements in Badwater Creek, WDEQ should explicitly also apply that same logic and same reasonable potential analysis for in-stream requirements and effluent limits for Alkali Creek and its tributaries (Class 3B – aquatic life other than fish). Because Alkali Creek and its tributaries are also intermittent, no dilution flow can be expected for much of the year; and because a Class 3B water should protect aquatic life other than fish, the same 230 mg Cl/L instream requirement should also apply. Given a recent analyzed Chloride concentration of 1,540 mg/L in Alkali Creek on August 20, 2019 (Table 2 in ERM's Blackwater – Alkali Creek: Sediment and Surface Water Sampling Results report), the aquatic community in Alkali Creek needs more regulatory protection than the draft renewal permit will provide.

The current USEPA freshwater aquatic life chronic criterion for chloride of 230 mg Cl/L was derived numerically (i.e., based on lab toxicity tests, not based on field observations) and first appeared in the USEPA water quality criteria document for chloride in 1988 (EPA 440/5-

88-001) (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table). The chloride criterion is "driven" by invertebrates (see Table 3 in that document). Of the 12 genera of aquatic organisms used in the 1988 derivation, the 6 most-sensitive genera were invertebrates [including cladocerans (two *Daphnia* species), a snail, an isopod, midges, and a caddisfly -- meaning a wide variety of types of aquatic invertebrates]; and 5 of the 6 least-sensitive genera were fish [i.e., only 1 of the 6 least-sensitive genera was an invertebrate (a mosquito)]. Thus, based on that toxicity dataset, it would be appropriate to conclude that chloride concentrations exceeding 230 mg Cl/L would not be safe for many invertebrates. [Note: The USEPA water quality criteria are intended to protect 95% of species. Thus, "on average", one might expect approximately 5% of the species to be adversely affected even at only 230 mg Cl/L.]

Thus, in our professional opinion, the existing USEPA criteria document provides sufficient evidence to support an argument that 230 mg Cl/L should be a maximum instream chloride concentration for protection of aquatic invertebrates in Alkali Creek, and a reasonable potential analysis would support an effluent limit of 230 mg Cl/L for all permitted effluent outfalls into Alkali Creek or its tributaries.

Total Dissolved Solids (TDS):

Though water quality for protection of aquatic life in Alkali and Badwater Creeks would be improved by reducing Chloride concentrations in the Aethon effluent to 230 mg/L, there is still a major problem with WDEQ's allowed in-stream Total Dissolved Solids (TDS) concentrations. High concentrations of TDS, exceeding 5,000 mg/L, in the effluent have clearly harmed aquatic life in Alkali Creek. The proposed waiver of the Appendix H effluent concentration limit for TDS will continue to cause harm to aquatic life in Alkali Creek and downstream in Badwater Creek, threatening aquatic life use designation for these surface waters. Table 2 in Aethon's original application for permit renewal at Frenchie Draw (dated August 8, 2016) shows a TDS concentration of 5,940 mg/L in the effluent at outfall 6. A more recent analysis of inorganic constituents from an in-stream water sample from Alkali Creek taken immediately upstream of the confluence with Badwater Creek on August 20, 2019, added up to a TDS concentration of 6,303 mg/L (Table 2 in ERM's Sediment and Surface Water Sampling Results report to Aethon Energy).

To estimate the effect of this high a measure of TDS on aquatic biota, we ran the Mount et al. (1997) major-ion-toxicity model with the water chemistry data in Table 2 of the 2019 ERM report. The model-predicted survivals of *Ceriodaphnia dubia* (48 hours), *Daphnia magna* (48 hours), and fathead minnows (96 hours) are less than or equal to 0.2%. An approximately 5-fold dilution of that high TDS water with distilled water (or with really pure reverse-osmosis water) would be needed for the model-predicted survivals to exceed 90%. And that's only for acute toxicity, which is all the model is designed to predict. By simple logic, even more dilution would be needed to avoid chronic toxicity. These model-predicted acute toxicity results demonstrate that Alkali Creek is impaired downstream of the Aethon effluent discharges.

In our professional opinion, even the WDEQ's traditionally allowed TDS limit of 5,000 mg/L is way too high for protection of aquatic life. WDEQ should complete a reasonable potential analysis to re-evaluate the 5,000 mg/L TDS limit.

Total Sulfide:

In our professional opinion, the WDEQ effluent limit of 20 micrograms/L (µg/L) for Total Sulfide in this proposed discharge permit will not be stringent enough to meet the 2 µg/L instream standard for Hydrogen Sulfide. WDEQ is requiring a Total Sulfides analysis rather than a direct Hydrogen Sulfide measurement, which would be acceptable if the permit limit for Total Sulfide were set low enough to not allow high concentrations of Hydrogen Sulfide at all times. However, they used an indirect approach for estimating Hydrogen Sulfide concentrations that would allow the Hydrogen Sulfide concentration to exceed the 2 µg/L standard 50% of the time. Specifically, WDEQ looked at the historical pH data for the effluent (data not provided) and stated that the median pH was 7.9. At that pH, only approximately 10% of the total sulfide ($H_2S + HS^- + S^{2-}$) is H_2S. Thus, WDEQ reasoned that if "the instream standard for Hydrogen Sulfide is 2 µg/L, a Total Sulfide level of 20 µg/L or less at the outfalls would be required to achieve an output level 2 µg/L or less for Hydrogen Sulfide." But hidden in that reasoning is the fact that 50% of the historical pH values were, by definition of the word "median", less than pH 7.9 -- meaning that the H_2S concentration exceeded 10% of the total sulfide concentration more than 50% of the time. Therefore, WDEQ should have chosen a lower pH percentile than the median (which is the 50th percentile), perhaps something like the 10th percentile (meaning one would not expect to err more than 10% of the time). We don't know what the 10th percentile of those historical pH values is, because WDEQ did not provide the pH data. However, just to give an idea of how important this could be, H_2S is approximately 50% of the total sulfide concentration at pH 7.0 (see the speciation diagram at the top of page 6 in the proposed permit). Thus, at a pH of 7.0, the total sulfides concentration should not exceed 4 µg/L (instead of the 20 µg/L at pH 7.9) in order to not exceed an H_2S concentration of 2 µg/L. Therefore, it is important to know the entire distribution of historical pH values, not only the median pH.

Actually, the simplest and best thing for WDEQ to do would be to specify that the water quality based effluent limit is 2 µg H_2S/L and require that the permit holder calculate and report the H_2S concentration based on the measured and reported pH and the measured and reported total sulfide concentration in each effluent, using the well-known pK_a (acid dissociation constant) of H_2S (Broderius and Smith 1976) -- thus avoiding any intermediate assumptions and thereby directly knowing the concentration of actual interest rather than a measurement of Total Sulfide.

Reasonable Potential (Page 7):

WDEQ should provide the historical data, that they presumably have, for concluding that there is no reasonable potential for exceedances of the standards (or limits) for F, Mn, U, and *E. coli*.

Screening for Well Additives and Hydraulic Fracturing Fluids (Pages 9-10):

We agree that these kinds of well additives and fracturing chemicals should be monitored in the Aethon discharge to demonstrate that Aethon is not violating its permit by comingling these chemicals with production water and including them in their discharge. But we recommend that, in addition to listing of the suspect chemicals and their CAS#, WDEQ also should require reporting of analytical methods used and the detection limit for each analysis. In our professional experience, under these circumstances, a "non-detectable" analyte determination may not be trustworthy or may not be at a low enough detection limit to be toxicologically interpretable. By requiring the permittee to report the analytical method and detection limit, this potential problem can be avoided.

Whole Effluent Testing (Pages 10-11):

The newly revised draft permit only requires annual acute lethality Whole Effluent Toxicity (WET) tests with *Daphnia magna* and Fathead Minnows (*Pimephales promelas*). It is problematic that, in this new Aethon draft renewal discharge permit (12/17/2019), WDEQ eliminated chronic WET testing that had been included in the earlier draft permit dated 5/4/2017. Alkali Creek is Class 3B, and "Uses protected for Class 3B streams such as this include aquatic life, ..." (page 8). We do not understand how WDEQ can support an argument that passing only acute lethality toxicity tests with *Daphnia magna* and Fathead Minnows (*Pimephales promelas*) will ensure protection of aquatic life, especially sensitive invertebrates.

As we stated in our earlier comments (dated June 27, 2019) related to the earlier draft permit, to test whether Aethon's produced water discharges might adversely affect fish and/or other aquatic organisms in Alkali Creek, Badwater Creek and Badwater Bay, stricter toxicity testing requirements will be needed in a final discharge permit. Whole Effluent Toxicity (WET) tests should be required quarterly (rather than annually), include each outfall, include acute 48-hour lethality tests with *Daphnia magna* and acute 96-hour lethality tests with Fathead Minnows, and include chronic toxicity tests for 7-day larval Fathead Minnow growth and 7-day *Ceriodaphnia magna* reproduction. In addition, to facilitate interpretation of all WET test results, WDEQ should require Aethon to analyze and report concentrations of a full suite of inorganic constituents (including Ca, Mg, Na, K, Cl, and SO_4), alkalinity, pH, BETX constituents, and Total Organic Carbon in the water sample collected for each WET test.

In fact, from several sets of information available to us now from reports on in-stream sample chemistry and toxicity, we already know that the Aethon discharge will be toxic most or all the time. For instance, WET test results on in-stream samples from monitoring site DMP1 in Alkali Creek above its confluence with Badwater Creek from June 2017 and February 2019 were recently released by WDEQ (ERM Whole Effluent Toxicity Test Result reports dated 12 July 2017 and 13 March 2019). The two WET test files present two different views of Alkali Creek. In June 2017, the acute toxicity for *Daphnia magna* and Fathead Minnows at all sites in Alkali and Badwater Creeks was almost nil, even at the Alkali Creek DMP1 site many miles downstream from Aethon's discharge and above Alkali Creek's confluence with Badwater Creek. However, in February 2019, the acute toxicity for *Daphnia magna* and Fathead Minnows

at the same DMP1 site was substantial, resulting in test failure. And, as might be expected, the chronic toxicity for Fathead Minnows in the February, 2019 sample from DMP1 was even greater than the acute toxicity, with significant lethality and growth reduction. We can only speculate about the difference in the June 2017 and February 2019 WET test results, but it may be that there was significant dilution flow in Alkali Creek in June 2017, when no toxicity was observed, and little or no dilution flow in Alkali Creek in February 2019, when significant toxicity was observed. Or perhaps treatment-plant operating conditions differed considerably between the two time periods. Since stream discharge in Alkali Creek and descriptions of operating conditions were not included in these reports, we can only speculate about the observed difference in toxicity.

Given what we know about Aethon's discharge, at least until Aethon completes its effluent treatment upgrades under the WDEQ's proposed Compliance Schedule, we can be sure that Aethon's effluent will consistently fail any WET tests. We base this conclusion on mortality predictions for *Ceriodaphnia dubia*, *Daphnia magna*, and Fathead Minnows using Mount et al. (1997) models for major-ion toxicity, with major-ion concentrations that were reported in Table 2 in the first version of the draft renewal permit and in Table 2 in ERM's Blackwater – Alkali Creek: Sediment and Surface Water Sampling Results report. Additionally, the untreated effluent is highly contaminated with roughly 2,200 mg Cl/L plus very high concentrations of organic carbon (68 mg/L on August 20, 2019, as reported in Table 2 in ERM's Blackwater – Alkali Creek: Sediment and Surface Water Sampling Results report), Hydrogen Sulfide and other contaminants; and the Neptune reverse osmosis plant at outfall 001 is inoperable at this time. With regulatory oversight from WDEQ, Aethon should use regular WET tests along with Toxicity Identification procedures to identify other specific contaminants in addition to Chloride, Hydrogen Sulfide and temperature that will need to be controlled during the period of time allowed under WDEQ's proposed Compliance Schedule.

References Cited

Broderius, S.J. and **L.L. Smith, Jr.** 1976. Effect of hydrogen sulfide on fish and invertebrates. Part II – Hydrogen sulfide determination and relationship between pH and sulfide toxicity. EPA-600/3-76-062b. U.S. Environmental Protection Agency, Duluth, Minnesota, USA.

Lofts, S. 2012. User's Guide to WHAM7: Windermere Humic Aqueous Model, Version 7. Centre for Ecology and Hydrology, Natural Environment Research Council, UK.

Mount, D.R., D.D. Gulley, J.R. Hockett, T.D. Garrison and **J.M. Evans.** 1997. Statistical models to predict the toxicity of major ions to *Ceriodaphnia dubia, Daphnia magna* and *Pimephales promelas* (fathead minnows). *Environ. Toxicol. Chem.* **16**:2009–2019.

Curriculum Vitae for Bergman and Meyer

Harold L. Bergman
Emeritus Professor of Zoology and Physiology
University of Wyoming
bergman@uwyo.edu • (307) 460-0015

EDUCATION
Eastern Michigan University Biology B.A., 1968
Eastern Michigan University Biology M.S., 1971
Michigan State University Fisheries Biology Ph.D., 1973

PROFESSIONAL POSITIONS
2011-2013 Department Head, Department of Zoology and Physiology, University of Wyoming
1995-2016 J.E. Warren Distinguished Professor of Energy and Environment, University of Wyoming
1998-2008 Director, William D. Ruckelshaus Institute and Helga Otto Haub School of Environment and Natural Resources, University of Wyoming
1988 Visiting Scientist, U.S. Environmental Protection Agency, Duluth, Minnesota
1986-1987 Acting Director, Wyoming Water Research Center, University of Wyoming
1984-2016 Professor, Department of Zoology and Physiology, University of Wyoming (Retired 2016)
1984-1999 Director, Red Buttes Environmental Biology Laboratory, University of Wyoming
1975-1984 Asst. & Assoc. Professor, Dept. of Zoology and Physiology, University of Wyoming

PROFESSIONAL AWARDS AND DISTINCTIONS (Selected)
Founder's Award, Society of Environmental Toxicology and Chemistry, 2018
Distinguished Faculty Graduate Mentor Award, University of Wyoming, 2014
Extraordinary Merit in Advising, Arts & Sciences College, University of Wyoming, 2014
Elected Fellow, American Association for the Advancement of Science, 1995
George Duke Humphrey Distinguished Faculty Award, University of Wyoming, 1995
Conservation Educator of the Year, Wyoming Wildlife Federation, 1986
President of the Society of Environmental Toxicology and Chemistry, 1984-85
President of the Water Quality Section, American Fisheries Society, 1982-83
Editorial Board, Environmental Toxicology and Chemistry, 1981-84
EPA Doctoral Traineeship, Michigan State University, 1971-73

STATE, NATIONAL AND INTERNATIONAL ADVISORY & REVIEW PANELS (Selected)
Wyoming Environmental Quality Council, 1983-95; Chairman, 1985-87
National Research Council - National Academy of Sciences Committees/Board
- Ecological Risk Assessment, 1986-87
- Animals as Monitors of Environmental Hazards, 1987-91
- NRC Board of Agriculture and Natural Resources, 2009-2016

Environmental Protection Agency, ORD, Peer Review Panels/Review Committees
- Exploratory Grants Program, Environmental Biology Panel, 1986-96
- National Acid Precipitation Assessment Program, Aquatic Effects Program, Panel Chair, 1987
- Graduate Fellowship Review Panel, 1995-98, 2009-12
- Environmental Protection Agency, Science Advisory Panel for Pesticides (FIFRA), 1984-87
- Science and Technology Achievement Awards, 1986-87
- Water Quality Standards Research Review, 1986
- Ecological Risk Assessment Research Review, 1986
- Environmental Protection Agency, Board of Scientific Councilors, 1996-97

The Royal Society (London), Surface Water Acidification Program Review Panel, 1990
Private Sector Board and Advisory Positions
- PacifiCorp, Inc., Environmental Forum, Portland, OR, 2000-04
- Wyoming Outdoor Council Board, Lander, WY, 2009-2015; 2017-present

SELECTED RELEVANT PUBLICATIONS (Selected from over 100 publications)

Johnson, E.O., B.D. Cherrington and H.L. Bergman. 201_. Assessment of endocrine disrupting compounds in Wyoming surface waters. Environ. Toxicol. Chem. (In Preparation).

Firkus, T., F.J. Rahel, H.L. Bergman and B.D. Cherrington. 2017. Warmed winter water temperatures alter reproduction in two fish species from the South Platte River, Colorado. Environmental Management 61(4) https://doi.org/10.1007/s00267-017-0954-9.

Pham, D.T., H.M. Nguyen, T.Boivin, A. Zajacova, S.V. Huzurbazar and H.L. Bergman. 2015. Predictors for dioxin accumulation in residents living in Da Nang and Bien Hoa, Vietnam, many years after Agent Orange use. Chemosphere 118:277-283.

Godwin, B.L., S.E. Albeke, H.L. Bergman, A. Walters and M. Ben-David. 2015. Density of river otters (*Lontra canadensis*) in relation to energy development in the Green River Basin, Wyoming. Science of the Total Environment 532: 780-790.

Wood, C.M., H.L. Bergman, A. Bianchini, P. Laurent, J. Maina, O.E. Johannsson, L. Bianchini, C. Chevalier, G.D. Kavembe, M.B. Papah and R.O. Ojoo. 2012. Transepithelial potential in the Magadi tilapia, a fish in extreme alkalinity. J. Comp. Phyiol. B 182: 247-258.

Bergman, H.L. (ed.). 2009. Research and Development Concerning Coalbed Natural Gas. Final Report to the NETL, U.S. Department of Energy, Ruckelshaus Institute of Environment and Natural Resources, University of Wyoming, Laramie, Wyoming. 177pp.

Bergman, H.L., A.M. Boelter, and K.S. Parady (eds.). 2008. Research needs and management strategies for pallid sturgeon recovery. Final Report to the U.S. Army Corp of Engineers, Ruckelshaus Institute of Environment and Natural Resources, University of Wyoming, Laramie, Wyoming. 36pp. + App.

Bergman, H.L. (ed.). 2005. Water Production from Coalbed Methane Development: A Summary of Quantity, Quality and Management Options. Ruckelshaus Institute of Environment and Natural Resources, University of Wyoming, Laramie, Wyoming. 64 pp. + App.

Lease, H.M., J.A. Hansen, H.L. Bergman and J.S. Meyer. 2003. Structural changes in gills of Lost River suckers exposed to elevated pH and ammonia concentrations. Comp. Biochem. Phys. Part C, 134: 491-500.

Bergman, A.N., P. Laurent, G. Otiang'a-Owiti, H.L. Bergman, P.J. Walsh, P.W. Wilson, and C.M. Wood. 2003. Physiological adaptations of the gut in the Lake Magadi tilapia, *Alcolapia grahami*, in an alkaline- and saline-adapted teleost fish. Comp. Biochem. Phys. Part A, 136. 701-715.

DiToro, D.M., H.E. Allen, H.L. Bergman, J.S. Meyer, P.R. Paquin and R.C. Santore. 2001. Biotic ligand model of the acute toxicity of metals. 1. Technical basis. Environ. Toxicol. Chem. 20:2383-2396.

Hansen, J.A., D.F. Woodward, E.E. Little, A.J. DeLonay and H.L. Bergman. 1999. Behavioral avoidance: Possible mechanism for explaining abundance and distribution of trout species in a metals-impacted river. Environ. Toxicol. Chem. 18: 126-130.

MacRae, R.K., D.E. Smith, N. Swoboda-Colberg, J.S. Meyer and H.L. Bergman. 1999. Copper binding affinity of rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*) gills: Implications for assessing bioavailable metal. Environ. Toxicol. Chem. 18:1180-1189.

Bergman, H.L. and E.J. Dorward-King. (eds.). 1997. Reassessment of Metals Criteria for Aquatic Life Protection: Priorities for Research and Implementation. SETAC Press, Pensacola, FL. 114 pp.

Boelter, A.M., F.N. Lamming, A.M. Farag, and H.L. Bergman. 1992. Environmental effects of saline oil-field discharges on surface waters. Environ. Toxicol. Chem. 11:1187-1195.

Gulley, D.D., D.R. Mount, J.R. Hockett and H.L. Bergman. 1992. A statistical model to predict toxicity of saline produced waters to freshwater organisms. pp 89-96 In: J.P. Ray and F.R. Engelhardt (eds.). Produced Water: Technological/Environmental Issues and Solutions. Plenum Press, New York.

Bergman, H.L., R.A. Kimerle and A.W. Maki (eds.). 1986. Environmental Hazard Assessment of Effluents. Pergamon Press, Elmsford, N.Y. 366 pp.

Joseph S. Meyer
Chief Scientist, Applied Limnology Professionals LLC
jsmeyer@ALPsColorado.com • (303) 524-4373

EDUCATION
Lehigh University, Chemical Engineering B.S., 1973
University of Wyoming, Zoology and Physiology Ph.D., 1986
PROFESSIONAL POSITIONS

2016-Present	Chief Scientist, Applied Limnology Professionals LLC, Golden, CO
2012-Present	Affiliated Faculty Member, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, CO
2007-2016	Technical Expert and Principal Scientist, Arcadis, Lakewood, Colorado
2005-2007	Professor, Department of Zoology and Physiology, University of Wyoming
1999-2005	Associate Professor, Department of Zoology and Physiology, University of Wyoming
1999 2004	Director, Red Buttes Environmental Biology Laboratory, University of Wyoming
1994-1999	Assistant Professor, Department of Zoology and Physiology, University of Wyoming
1991-1993	Coordinator, Wastewater Utilization Graduate Program, Humboldt State University, Arcata, CA
1990-1993	Lecturer, Department of Fisheries, Humboldt State University, Arcata, CA
1989-1990	Postdoctoral Researcher, University of Wyoming-National Park Service Research Center, University of Wyoming
1988-1989	Postdoctoral Researcher, Lake Research Laboratory, Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG/ETH), Kastanienbaum, Switzerland
1987-1988	NATO Postdoctoral Research Fellow, Lake Research Laboratory, Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG/ETH), Kastanienbaum, Switzerland
1987	Research Scientist, Department of Zoology and Physiology, University of Wyoming
1986	Graduate Research and Teaching Assistant, Department of Zoology and Physiology, University of Wyoming
1980-1983	Associate Scientist, Western Aquatics, Inc., Laramie, WY [part-time]
1976-1985	Research Scientist, Department of Zoology and Physiology, University of Wyoming
1972	Student Participant, NASA Summer Institute for Biomedical Engineering, Howard University and Goddard Space Flight Center, Greenbelt, MD

PROFESSIONAL AWARDS AND DISTINCTIONS (Selected)
Fellow of Society of Environmental Toxicology and Chemistry, 2018-Present
President of Rocky Mountain Chapter of Society of Environmental Toxicology and Chemistry, 2004-2005
Member of Editorial Board, *Environmental Toxicology and Chemistry*, 1997-2000
Member of Board of Directors of Rocky Mountain Association of Environmental Professionals, 1983-1984

STATE, NATIONAL AND INTERNATIONAL ADVISORY & REVIEW PANELS (Selected)
U.S. Environmental Protection Agency: Member, Aquatic Life Criteria Consultative Panel of the Science Advisory Board of the U.S. Environmental Protection Agency. 2005.
U.S. Environmental Protection Agency: Member, Health and Ecological Effects Subcommittee of the Advisory Council on Clean Air Compliance Analysis of the Science Advisory Board (SAB) of the U.S. Environmental Protection Agency. 1998-2002.
Environment Canada: Member, Environmental Resource Group for the Assessment of Chloramine under the Canadian Environmental Protection Act. 1996-1999.
U.S. Environmental Protection Agency: Member, Advisory Council on Clean Air Compliance Analysis Physical Effects Review Subcommittee of the Science Advisory Board of the U.S. Environmental Protection Agency. 1994-1997.
U.S. Department of Energy: Review of documents addressing damages and benefits of various fuel cycles. 1992-1993.

SELECTED RELEVANT PUBLICATIONS (Selected from 100 publications)

Meyer, J.S. and D.K. DeForest. 2018. Protectiveness of copper water quality criteria against impairment of behavior and chemo/mechanosensory responses: An update. *Environmental Toxicology and Chemistry* 37:1260-1279.

Traudt, E.M., J.F. Ranville and J.S. Meyer. 2017. Acute toxicity of ternary Cd-Cu-Ni and Cd-Ni-Zn mixtures to *Daphnia magna*: Dominant metal pairs change along a concentration gradient. *Environmental Science and Technology* 51:4471-4481.

Müller, B., J.S. Meyer and R. Gächter. 2016. Alkalinity regulation in calcium carbonate-buffered lakes. *Limnology and Oceanography* 61:341-352.

Traudt, E.M., J.F. Ranville, S.A. Smith and J.S. Meyer. 2016. A test of the additivity of acute toxicity of binary-metal mixtures of Ni with Cd, Cu, and Zn to *Daphnia magna*, using the inflection point of the concentration-response curves. *Environmental Toxicology and Chemistry* 35:1843-1851.

Farley, K.J. and J.S. Meyer. 2015. Metal mixtures modeling evaluation: 3. Lessons learned and steps forward. *Environmental Toxicology and Chemistry* 34:821-832.

Farley, K.J., J.S. Meyer, L.S. Balistrieri, Y. Iwasaki, M. Kamo, S. Lofts, C.A. Mebane, W. Naito, A.C. Ryan, R.C. Santore and E. Tipping. 2015. Metal mixtures modeling evaluation: 2. Comparison of four modeling approaches. *Environmental Toxicology and Chemistry* 34:741-753.

Meyer, J.S., K.J. Farley and E.R. Garman. 2015. Metal mixtures modeling evaluation: 1. Technical background. *Environmental Toxicology and Chemistry* 34:726-740.

Meyer, J.S., J.F. Ranville, M. Pontasch, J.W. Gorsuch and W.J. Adams. 2015. Acute toxicity of binary and ternary mixtures of Cd, Cu, and Zn to *Daphnia magna*. *Environmental Toxicology and Chemistry* 34:799-808.

Fulton, B.A. and J.S. Meyer. 2014. Development of a regression model to predict copper toxicity to *Daphnia magna* and site-specific copper criteria across multiple surface-water drainages in an arid landscape. *Environmental Toxicology and Chemistry* 33:1865-1873.

Meyer, J.S. and GG. Pyle. 2013. Effects of anthropogenic chemicals on chemosensation and behavior in fish: Organismal, ecological, and regulatory implications. *Fisheries* 38:283-284.

Meyer, J.S., S.J. Clearwater, T.A. Doser, M.J. Rogaczewski and J.A. Hansen. 2007. *Effects of Water Chemistry on the Bioavailability and Toxicity of Waterborne Cadmium, Copper, Nickel, Lead, and Zinc to Freshwater Organisms*. SETAC Press, Pensacola, Florida, USA.

Meyer, J.S., W.J. Adams, K.V. Brix, S.N. Luoma, D.R. Mount, W.A. Stubblefield and C.M. Wood (eds.). 2005. *Toxicity of Dietborne Metals to Aquatic Organisms*. SETAC Press, Pensacola, Florida, USA.

Meyer, J.S. and J.A. Hansen. 2002. Subchronic toxicity of low dissolved oxygen concentrations, elevated pH, and elevated ammonia concentrations to Lost River suckers. *Transactions of the American Fisheries Society* 131:656-666.

Dare, M.R., W.A. Hubert and J.S. Meyer. 2001. Influence of stream flow on hydrogen sulfide concentrations and distributions of two trout species in a Rocky Mountains tailwater. *North American Journal of Fisheries Management* 21:971-975.

Di Toro, D.M., H.E. Allen, H.L. Bergman, J.S. Meyer, P.R. Paquin and R.C. Santore. 2001. Biotic ligand model of the acute toxicity of metals. 1. Technical basis. *Environmental Toxicology and Chemistry* 20:2383-2396.

Goldstein, J.N., W.A. Hubert, D.F. Woodward, A.M. Farag and J.S. Meyer. 2001. Naturalized salmonid populations occur in the presence of elevated trace element concentrations and temperatures in the Firehole River, Yellowstone National Park, Wyoming. *Environmental Toxicology and Chemistry* 20:2342-2352.

Santore, R.C., D.M. Di Toro, P.R. Paquin, H.E. Allen and J.S. Meyer. 2001. Biotic ligand model of the acute toxicity of metals. 2. Application to acute copper toxicity in freshwater fish and *Daphnia*. *Environmental Toxicology and Chemistry* 20:2397-2402.

Meyer, J.S., D.A. Sanchez, J.A. Brookman, D.B. McWhorter and H.L. Bergman. 1985. Chemistry and aquatic toxicity of raw oil shale leachates from Piceance Basin, Colorado. *Environmental Toxicology and Chemistry* 4:559-572.

Exhibit 6

LABORATORY ANALYSIS REPORT

Prepared by Wyoming DEQ

Client:	WATERSHED_SWM	Report Date:	12/30/2019
Project:	WATERSHED PROTECTION PRO	Collection Date:	04/23/2019 16:39
Lab ID:	AE00500	Date Received:	4/24/19
Field ID:	MJT-19-113-11	Matrix:	WATER
Field Location:	ALKALI CREEK - SITE 10		

Analysis	Result	Units	Qual	RL	Method	Analysis Date	By
Hardness, Calculation (as CaCO3)	273	mg/L		10	SM2340B-2011	06/25/2019 16:40	MLATADY
Total Dissolved Solids	5568	mg/L		10	SM2540 C	04/25/2019 11:37	MLATADY
Chlorides	1318	mg/L		20	EPA300.0 R2.1	05/01/2019 18:40	JOHANNAHMAY
Sulfates	1140	mg/L		50	EPA300.0 R2.1	05/01/2019 18:40	JOHANNAHMAY
Calcium Dissolved	45	mg/L		10	EPA 200.7	06/18/2019 17:59	MLATADY
Magnesium Dissolved	39	mg/L		10	EPA 200.7	06/18/2019 17:59	MLATADY
Potassium Dissolved	28	mg/L		10	EPA 200.7	06/18/2019 17:59	MLATADY
Sodium Dissolved	2170	mg/L		10	EPA 200.7	06/18/2019 17:59	MLATADY
Aluminum Dissolved	<50	ug/L		50	EPA 200.8	06/07/2019 17:55	MLATADY
Antimony Total	<11	ug/L		11	EPA 200.8	07/03/2019 17:26	MLATADY
Arsenic Dissolved	11	ug/L		1	EPA 200.8	06/07/2019 17:55	MLATADY
Arsenic Total	13	ug/L		11	EPA 200.8	07/03/2019 17:26	MLATADY
Barium Total	<110	ug/L		110	EPA 200.8	07/03/2019 17:26	MLATADY
Beryllium Total	<11	ug/L		11	EPA 200.8	07/03/2019 17:26	MLATADY
Cadmium Dissolved	<0.1	ug/L		0.1	EPA 200.8	06/07/2019 17:55	MLATADY
Cadmium Total	<1	ug/L		1	EPA 200.8	07/03/2019 17:26	MLATADY
Chromium Total	<55	ug/L		55	EPA 200.8	07/03/2019 17:26	MLATADY
Copper Dissolved	<5	ug/L		5	EPA 200.8	06/07/2019 17:55	MLATADY
Copper Total	<55	ug/L		55	EPA 200.8	07/03/2019 17:26	MLATADY
Iron Dissolved	<50	ug/L		50	EPA 200.7/200.8	06/07/2019 17:55	MLATADY
Iron Total	7339	ug/L		550	EPA 200.7/200.8	07/03/2019 17:26	MLATADY
Lead Dissolved	<1	ug/L		1	EPA 200.8	06/07/2019 17:55	MLATADY
Lead Total	<11	ug/L		11	EPA 200.8	07/03/2019 17:26	MLATADY
Manganese Dissolved	17	ug/L		1	EPA 200.8	06/07/2019 17:55	MLATADY
Nickel Dissolved	<10	ug/L		10	EPA 200.8	06/07/2019 17:55	MLATADY
Nickel Total	<110	ug/L		110	EPA 200.8	07/03/2019 17:26	MLATADY
Selenium Dissolved	1	ug/L		1	EPA 200.8	06/07/2019 17:55	MLATADY
Selenium Total	<11	ug/L		11	EPA 200.8	07/03/2019 17:26	MLATADY
Silver Dissolved	<0.5	ug/L		0.5	EPA 200.8	06/07/2019 17:55	MLATADY
Silver Total	<5.5	ug/L		5.5	EPA 200.8	07/03/2019 17:26	MLATADY
Thallium Total	<11	ug/L		11	EPA 200.8	07/03/2019 17:26	MLATADY
Uranium Total	12	ug/L		5.5	EPA 200.8	07/03/2019 17:26	MLATADY
Zinc Dissolved	<10	ug/L		10	EPA 200.8	06/07/2019 17:55	MLATADY
Zinc Total	<110	ug/L		110	EPA 200.8	07/03/2019 17:26	MLATADY
Ammonia (as Nitrogen)	0.83	mg/L		0.05	SM4500-NH3 G2011	05/06/2019 11:33	JOHANNAHMAY
Nitrate-Nitrite (as Nitrogen)	NR	mg/L		0.05	SM4500-NO3 F2011	05/06/2019 11:33	JOHANNAHMAY
Nitrogen, Wet Digestion	1.8	mg/L		0.1	SM4500-N B-2011	05/06/2019 11:09	JOHANNAHMAY
Phosphorus, Total	0.32	mg/L		0.01	SM4500-P.I 2011	05/10/2019 12:06	JOHANNAHMAY
Dissolved Organic Carbon Combustion	17.454	mg/L		2.00	SM5310 B-2011	05/13/2019 18:50	SVIEN
Alkalinity	1318	mg/L		10	SM 2320-B-2011	05/01/2019 13:00	MLATADY
Fluoride	1.6	mg/L		0.1	SM4500-F-C	05/06/2019 09:45	MLATADY
Total Sulfide (S2-)	NR	mg/L		0.05	SM4500-S2-D	04/29/2019 13:15	MLATADY

Sample Comment: Chlorides: most dilute sample had a concentration greater than the highest calibration point but was within 105%. 05/02/2019 JM.