Oil & Natural Gas Technology

DOE Award No.: DE-FE0024297

Quarterly Research Performance

Progress Report (Period Ending 9/30/2019)

Marcellus Shale Energy and Environment Laboratory (MSEEL)

Project Period (October 1, 2014 – September 30, 2019)

Submitted by:
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Signature

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Executive Summary
Quarterly Progress Report

July 1 – September 30, 2019

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development. An auxiliary goal is to improve the technological knowledge personnel base for continued unconventional resource development.

Plans developed for MSEEL Phase 3 were executed at the Boggess Pad just west of Morgantown, WV. The Boggess pad consisting of six wells were drilled and fracture stimulated. Production is scheduled to start in mid-November.

This quarter work focused on the stimulation and completion of MSEEL Phase 3 wells at the Boggess Pad. As of this report, stimulation/completion is complete. Two wells were geometrically completed, two wells were engineered by a private consultant and two wells were engineered using software developed by the MSEEL team. Research on machine learning for improved production efficiency with LANL was initiated and we have provided data and consultation. Project overviews were presented in several papers at URTeC in July 2019.

We continue to process the 108 terabytes of data from the downhole microseismic sensors and the fiber-optic data to better understand geomechanical properties and slow slip events during hydraulic fracture stimulation. Several manuscripts were published, and a number of talks presented at URTeC and the Geological Society of America.

Project Performance

This report summarizes the activities of Cooperative Agreement DE-FE0024297 (Marcellus Shale Energy and Environment Laboratory – MSEEL) with the West Virginia University Research Corporation (WVURC) during the fourth quarter of FY2019 (July 1 through September 30, 2019).

This report outlines the approach taken, including specific actions by subtopic. If there was no identified activity during the reporting period, the appropriate section is included but without additional information.

One aspect of the MSEEL Project is the involvement and training of students. A total of 38 students at West Virginia University have been directly involved in the project. Additional students were directly supported at Ohio State, and MSEEL data has provided research projects for students at numerous universities including the University of Pittsburgh and University of New Hampshire. Below is a list of graduate and undergraduate students directly involved and supported in numerous departments at West Virginia University (Table 1.1).

Table 1.1: Students directly supported by the MSEEL project at West Virginia University.*

Student	Department	Classification
Hulcher, Carter Lawrence	Civil Engineering	Graduate
Barre, Jennifer Louise	Environmental Health	Undergraduate
Dzomba, Alexandria Rae	Environmental Health	Undergraduate
Nye, Maya Jessica Cassel	Environmental Health	Undergraduate
Cyphers, Levi Jacob	Environmental Technology	Graduate
Agrawal, Vikas	Geology and Geography	Graduate
Akondi Nkerh, Rawlings	Geology and Geography	Graduate
Baird, John Edward	Geology and Geography	Graduate
Bhattacharya, Shuvajit	Geology and Geography	Graduate
Evans, Kaitlin Gayle	Geology and Geography	Graduate
Hupp, Brittany Nicole	Geology and Geography	Graduate
Martin, Keithan Garrett	Geology and Geography	Graduate
Odegaarden, Natalie A	Geology and Geography	Graduate
Paronish, Thomas Jay	Geology and Geography	Graduate
Schubert, Erica Noelle	Geology and Geography	Graduate
Song, Liaosha	Geology and Geography	Graduate
Toth, Randy Todd	Geology and Geography	Graduate
Zhong, Zhi	Geology and Geography	Graduate
Zhu, Yixuan	Geology and Geography	Graduate
Brewer, Jessica Lyne	Geology and Geography	Undergraduate
Elliott, Justin Ray	Geology and Geography	Undergraduate
Hinegardner, Lucas	Geology and Geography	Undergraduate
Mackey, Paige Elizabeth	Geology and Geography	Undergraduate
Wilson, Cody Tyler	Geology and Geography	Undergraduate
Cappellini, Brian Philip	Mechanical Engineering	Graduate
Dranuta Ferrer, Diego German	Mechanical Engineering	Graduate
Heltzel, Robert Scott	Mechanical Engineering	Graduate
Oliver, Dakota Wesley	Mechanical Engineering	Graduate
Qi, Wei	Mechanical Engineering	Graduate
Barrow, Rebekah M	Mechanical Engineering	Undergraduate
Boggs, Mikinzy Cabot	Mechanical Engineering	Undergraduate
Hilgar, Lisa Michele	Mechanical Engineering	Undergraduate
Ravi, Sri Satya	Mechanical Engineering	Undergraduate
Miller, Rene Nicole	Applied Microbiology	Graduate
Kessel, April Dawn	Applied Microbiology	Undergraduate
Elsaig, Mohamed M	Petroleum Natural Gas Eng.	Graduate
Filchock, Joseph Jonathan	Petroleum Natural Gas Eng.	Graduate
Hosseini Boosari, Seyed Sina	Petroleum Natural Gas Eng.	Graduate

**note – students from Ohio State University will be included at the next quarterly report*

Phase 3 Plans

A phase 3 of MSEEL is moving forward with completion/stimulation through the next two quarters and production is scheduled to begin in mid-November. Six 10,000+ foot horizontal Marcellus Shale wells off a single pad (Boggess) are near the initial MIP pad (Figure 1.1). The pad will have at one permanent fiber optic (FO) cable installed that will provide digital acoustic sensing (DAS) during stimulation and distributed temperature sensing (DTS) during stimulation and long-term production monitoring along the lateral (Boggess 5H). We acquired DAS data for the entire 5H well, but the FO failed around stage 30 and we will not have long-term DTS data below that stage to the toe. We will have data from the upper stages through the heel. Deployable FO systems was proposed (Boggess 1H and 17H), but due to the fiber failure in the 5H the fiber was not placed in the 17H. However, we acquired significant DAS and DTS and microseismic data from the 5H and 1H that provided significant insight of stimulation effectiveness in near real-time and the 100's of terabytes of data to evaluate and model the reservoir across each individual stage, and at individual clusters within stages for the 5H which will be used for all Boggess wells. We have developed techniques to use the permanent DAS and DTS monitoring in the 5H along with the logging while drilling (LWD) image and geomechanical logs to design an improved methodology to complete wells. This methodology used computed Sh_{min} and avoidance of fracture locations to complete the 1H and 3H wells. The new methodology appears to improve completion efficiency. When the wells come on production, we will have a basis to evaluate production efficiency by comparing to the geometrically completed wells (9H and 17H with identical 200 feet stages with identical number of clusters in each stage). We will also compare to the design provided which only used the geomechanical logs and ignored the imaged fractures (5H and 13H). We plan to monitor the 5H DAS for several days during initial flow-back and the long-term DTS during production.

The cored and logged vertical pilot well continues to be evaluated to develop a high-resolution geomechanical model (stratigraphy) to type each 6 inches of the Marcellus. Logging while drilling (LWD) logs in each of the six laterals provided similar geomechanical logs and image logs to geomechanically type each foot of the laterals as the horizontal laterals move stratigraphically up and down through the Marcellus. This approach permitted direct coupling and evaluation of cost-effective LWD technologies to the relatively high-cost permanent FO data and the basis for engineering stages in all wells. It was applied to two of the Boggess wells.

We will use the LWD and permanent FO in the one well (extremely large big data) and the LWD and microseismic only (relatively "thin" data) in two other wells to engineer stage and cluster spacing. Coupled with production data from all the wells including the control wells, this will provide the basis to evaluate the reservoir through modeling and direct monitoring to develop a first ever, publicly available, multi-well unconventional fractured reservoir simulation.

The Boggess wells will be compare across each of the six wells, and with the two wells at the MIP pad (MSEEL 1) and use these data to form the basis for robust big data modeling. One aspect will be to compare zipper fracturing to sequential fracture treatment and the use of recycled water in the Boggess wells to the 100% fresh water in the MIP wells. The MIP wells generated almost 10 terabytes of data and created approaches and capabilities to handle and process big data sets (i.e., volume, variety, velocity and veracity) from a single well to address the spacing between laterals and stage length, the importance of modeling at multiple scales from nanopores in kerogen to healed fractures spaced along the lateral, and the approaches to engineering stage and cluster design and stimulation processes. The multiple wells at Boggess

Pad using the new generation high resolution fiber and LWD tools provided 108 terabytes of data in a series of similar wells under controlled conditions to test and enhance the understanding of shale reservoirs. We are moving this data from Houston to the servers at West Virginia University. MSEEL will test new technologies and approaches to provide robust models that can be modified in near real-time using "thick" relatively high-cost data sets limited to science wells, or when calibrated more cost-effective "thin" data sets that could be used in broader field development and basin evaluation.

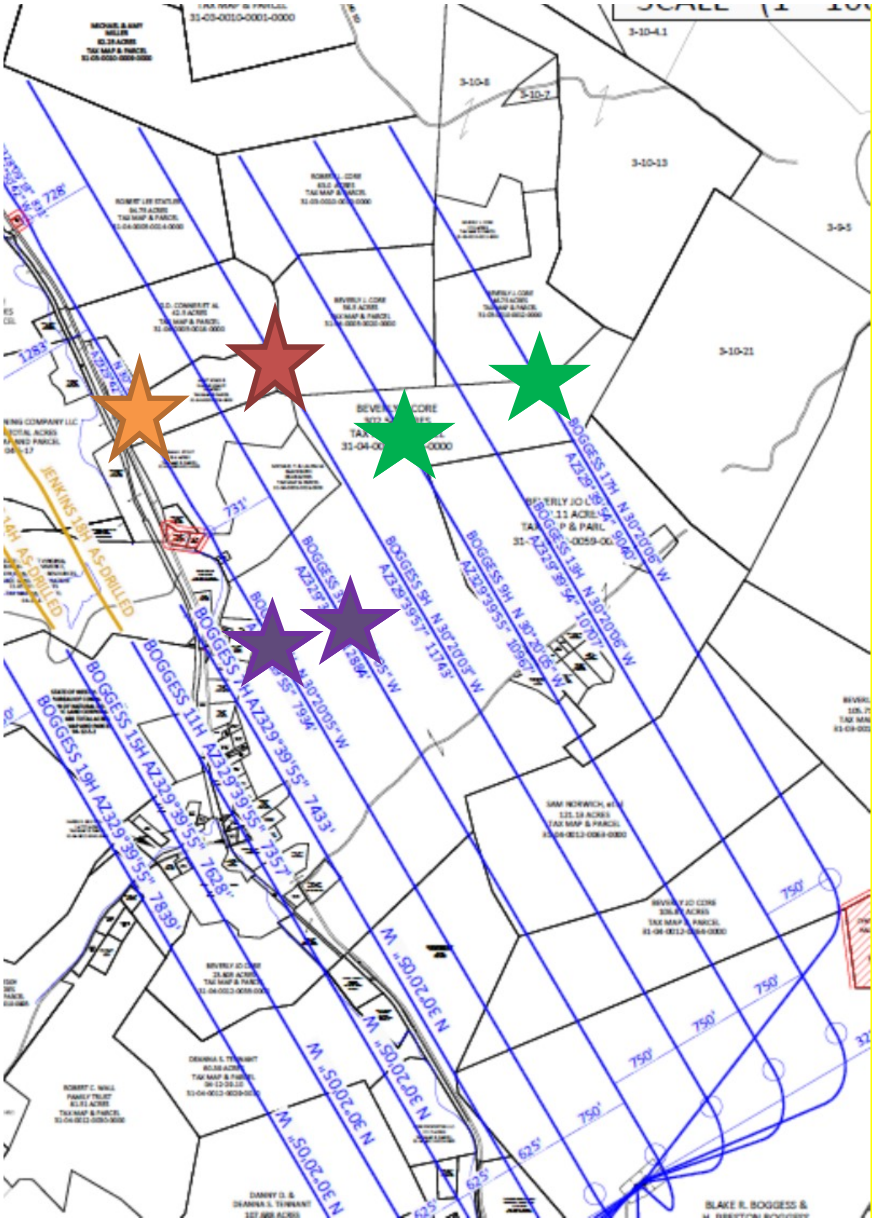


Figure 1.1: Boggess Pad with new generation permanent fiber in the central well (Boggess 5H, red star)) and deployable fiber in adjoining wells skipping one (orange star). Two wells were geometrically completed with identical 200 feet stages with identical number of clusters in each stage (green stars) and two wells were engineered using software and methodology developed by the MSEEL project (purple stars). A vertical pilot was drilled, cored, and logged (Boggess 17).

Project Management Update

Approach

The project management team continues to work to generate timely and accurate reporting, and to maintain project operations, including contracting, reporting, meeting organization, and general oversight.

Results and Discussion

The project team is tracking eight (8) milestones in this budget period.

	Task	Milestone	Status	Due Date
1.	3.2.1	Methane Audit 10 Completed	Complete	5/31/2019
2.	3.2.1	Sample collection and analysis of horizontal drill cuttings and drilling mud	Complete 139.2' of core and core plugs were collected from the vertical 17H pilot well. Drilling fluids collected.	6/30/2019
3.	3.2.1	Sample collection and analysis of makeup water and frac fluids	Samples will be collected from Boggess Wells	Ongoing/Complete
4.	3.2.1	Eddy Covariance Methane Detection Deployed at Wellsite (MIP)	New methane detection approach will be field tested at the MIP site on producing wells.	9/30/2019
5.	3.1.3	Boggess wells turned in.	Scheduled Nov-18	Oct-19
6.	3.1.2	Characterization of organic matter - Total Organic Carbon and Pyrolosis Experiments Complete	Characterization of samples from Boggess wells.	12/31/2019
7.	3.1.2	Isotopic characterization of produced water and gases - sampling and analysis complete	Characterization of produced water and samples from Boggess Wells	12/31/2019
8.	3.1.3	Provide final DAS/DTS data from completion activities to researchers (Boggess)	Final DAS/DTS data from well completion will be available to researchers.	12/31/2019
9	3.2.1	Sample collection and analysis of flowback/produced water	Characterization of produced water and samples from Boggess Wells	12/31/2019
10	3.2.1	Energy Audit System Deployed with Patterson Rig (Boggess)	CAFEE team members will deply energy audit equipment with the Patterson drilling rig. Activity is focused on cold weather months. Location is likely not Boggess	12/31/2019

			specifically, but will follow field activities.	
11	3.4.1	Statistical Analysis of production stages complete	Initial data analysis for Machine Learning Tasks.	12/31/2019

Topic 1 – Geologic Engineering

Approach

In addition to advances in improving our understanding of chemical evolution of produced water, methane emissions, microbiology and rock-fluid geochemistry, we are working to better understand the microseismic monitoring by downhole geophones, surface seismic, fiber-optic distributed acoustic sensing (DAS), and distributed temperature sensing (DTS) observations made during the hydraulic fracture stimulation. We have used the LWD image logs in the Boggess laterals and compared their location to the DAS data from the 5H and the microseismic data, which has both NE-SW trends as expected and E-W trends similar to the MIP wells, which may be controlled by preexisting but mineralized natural fractures.

We have made a thick and thin-sections of the mineralized natural fractures in the organic-rich Middle Devonian Marcellus shale cores (Odegaarden and Carr 2019) (Figure 1.2). In the MIP-3H well, image logs have recorded over 1600 calcite-filled fractures and a similar number in the Boggess laterals. Based on vein orientation, the paleo-stress was approximately east-west and appears to affect completion and production efficiency. The Marcellus Shale core from the vertical pilot at the MIP-3H well contains a diverse orientation of fractures. Four natural fracture families were identified: horizontals and horizontal swarms (0^o-16^o dip), obliques (16^o-60^o dip), and verticals (60^o-90^o dip). A fracture family is identified and is described as veinlets because the veinlets are smaller in width, crosscut veins, are interconnected, and have varying dip of 0^o-90^o.

A paper looking at the porosity and storage capacity of Middle Devonian Marcellus Shale using MSEEL and other wells in the Appalachian basin looked at the effect of thermal maturity, total organic carbon, and clay content (Song et al. 2019). This paper was recognized by Advances in Engineering as a key scientific article contributing to research excellence (https://advanceseng.com/porosity-storage-capacity-middle-devonian-shale/)

Figure 1.2: Examples of the numerous calcite and bitumen filled fractures observed in the core from the MIP 3H pilot well. These fractures appear to influence hydraulic fracture stimulation efficiency.

Results and Discussion

Presented an overview of the MSEEL project at the URTeC Annual Meeting, Denver, CO (22-24 July). We presented the results of the preliminary DAS analysis and our completion design methodology at DOE-NETL conference Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting August 26-30, 2019 in Pittsburgh, PA. Presented results of core analysis concentrating on cemented fractures at the Geological Society of America meeting 22-25 September, Phoenix, AZ.

Products

Carr, Timothy R., Payam Kavousi Ghahfarokhi, BJ Carney, Jay Hewitt, and Robert Vagnetti, 2019, Marcellus Shale Energy and Environmental Laboratory (MSEEL) Results and Plans: Improved Subsurface Reservoir Characterization and Engineered Completions, URTeC 415, Paper prepared for presentation at the Unconventional Resources Technology Conference (URTeC) held in Denver, Colorado, USA, 22-24 July 2019, 10 pages, DOI 10.15530/urtec-2019-415.

Evans, Kaitlin, Randy Toth, Tobi Ore, Jarrett Smith, Natalia Bannikova Timothy Carr, and Payam Kavousi Ghahfarokhi, 2019, Fracture analysis before and after Hydraulic Fracturing in the Marcellus Shale using the Mohr-Coulomb failure criteria, URTeC 650,
Paper prepared for presentation at the Unconventional Resources Technology Conference (URTeC) held in Denver, Colorado, USA, 22-24 July 2019, 11 pages, DOI 10.15530/urtec-2019-650.

Odegaarden, Natalie and Timothy Carr, Vein Evolution due to Thermal Maturation of Kerogen in the Marcellus Shale, Appalachian Basin, Paper presented at the Annual Meeting of the Geological Society of America 22-25 September, Phoenix, AZ.

Song, Liaosha, Keithan Martin, Timothy R. Carr, Payam Kavousi Ghahfarokhi, 2019, Porosity and storage capacity of Middle Devonian shale: A function of thermal maturity, total organic carbon, and clay content, Fuel 241, p. 1036-1044, https://doi.org/10.1016/j.fuel.2018.12.106 .

Plan for Next Quarter

Working to set up production monitoring at the Boggess pad as production begins in mid-November.

Topic 2 – Geophysical & Geomechanical

Approach

Geophysical and Geomechanical

We continue to work with LANL to examine the influence of discrete fracture networks on the growth of hydraulic fractures through numerical modeling. All numerical modeling results incorporated the microseismic data and lateral logs. The current modeling study will be used to evaluate the influence of geomechanical properties including preexisting cemented natural fractures on fracture geometries in comparison to microseismic estimates. A statistical methodology is being explored to better reconcile numerical model calculated fracture heights and lengths, and microseismic height and length estimates.

Results & Discussion

Have transfer all MSEEL data from MIP pad to LANL and continue biweekly conference calls.

Plan for Next Quarter

Work to evaluate methodologies for looking at the effect of sequential fracture stimulation (MIP) compared to zipper multi-well fracturing (Boggess) on completion and on production.

Topic 3 – Deep Subsurface Rock, Fluids, & Gas

Approach

The approach is to work across a broad spectrum of detailed geochemical and biogeochemical investigations that could have significant impact on completion and production.

Results & Discussion

Sharma Group MSEEL Report

1. Experiments to understand kerogen-frac fluid and interaction. ^{13}C NMR analysis of kerogen extracted from the MSEEL shale samples (MIP-3H) before and after the high P-T experiment were completed. The NMR data was analyzed using a NMR data processing software *Topspin* to characterize the aliphatic and aromatic structural parameters of kerogen. Our results indicate that both aliphatic and aromatic kerogen structural parameters of MIP-3H shale remained similar before and after the shale-fracturing fluid interaction (Fig.3.1). This observation provides evidence that kerogen at higher maturity window (VRo=2.9) does not degrade and release organic contaminants at reservoir temperature and pressure conditions on interaction with hydraulic fracturing fluid (HFF).

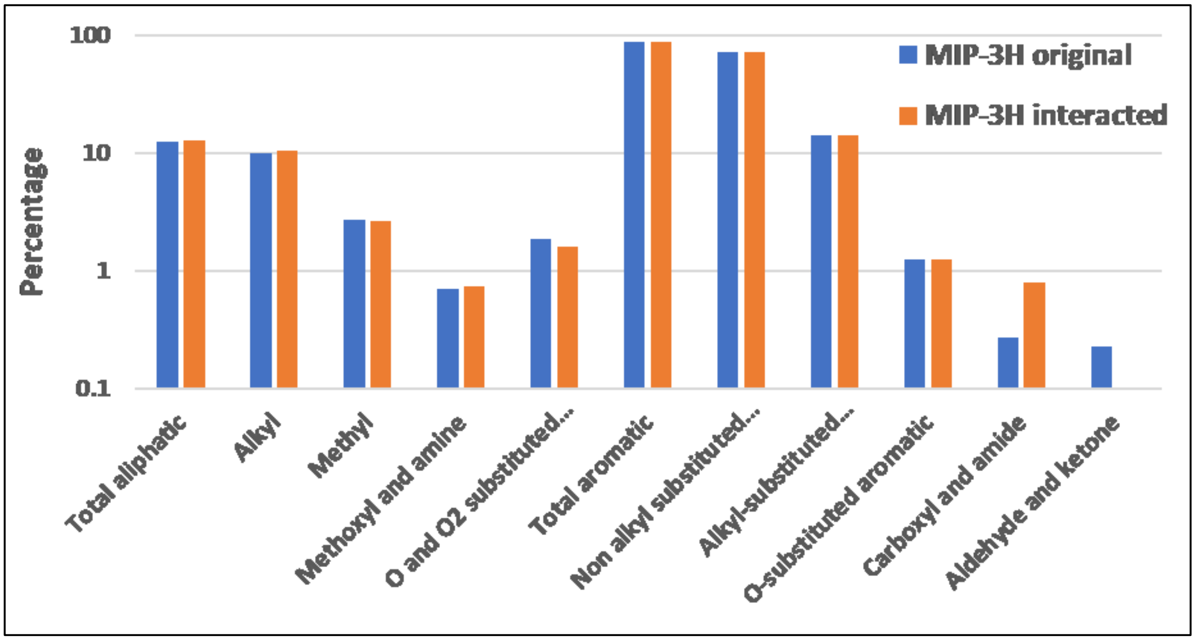


Figure. 3.1: Aliphatic and aromatic kerogen structural parameters before and after the shale-fracturing fluid interaction

Deliverables: 1) Completed ^{13}C NMR analysis and data analysis of MIP-3H kerogen samples. 2) Analyze NMR data from lower maturity kerogen samples by the end of fall 2019. 3) Present key finding in a conference in early-mid 2020.

2. Understanding the type, amount and origin of the gas. The data analysis and interpretation of the open and closed system pyrolysis results were completed. The key findings of these experiments were presented by Vikas Agrawal at Eastern Section AAPG in October, 2019. The major finding of these experiments was the discovery of "late gas" in Marcellus Shale at dry gas window which is not accounted in traditional open system pyrolysis experiments. The "late gas" is estimated to be ~43mg/g TOC. This evidence indicates that the Gas in Place (GIP) estimates of Marcellus Shale are significantly underestimated as they are based on traditional pyrolysis experiments.

Deliverable: 1) Presented results at ES-AAPG 2019, Columbus, OH. 2) Submit a manuscript by the end of Fall, 2019.

PUBLICATIONS & PRESENTATIONS

1. Sharma, S. Agrawal, V., Akondi R. 2019. Role of Biogeochemistry in efficient shale oil and gas production. Fuel. https://doi.org/10.1016/j.fuel.2019.116207
2. Phan T., Hakala A., Sharma S. 2019. Application of geochemical signals in unconventional oil and gas reservoir produced waters towards characterizing in situ geochemical fluid-shale reactions. International Journal of Coal Geology (in review)
3. Akondi, R., Sharma S., Texler, R., Pfifnner S. (2019). Effects of Sampling and Long-Term Storage on Microbial Lipid Biomarker Distribution in Deep Subsurface Marcellus Shale Cores. Geomicrobiology (in review)
4. Agrawal, V. and Sharma, S. 2019. Are we modelling properties of unconventional shales correctly? Fuel (in review)

5. Agrawal, V., S. Sharma, N. Mahlstedt 2019, Determining the type, amount and kinetics of hydrocarbons generated in a Marcellus shale maturity series. Eastern Section AAPG 48th Annual Meeting in Columbus, OH.
6. Carney BJ, Carr TR, Hewitt J, Vagnetti R, Sharma S, Hakala A. 2019. Progress and Findings from “MSEEL 1” and the Transition to “MSEEL 2”: Creating Value from a Cooperative Project. Annual Eastern Section AAPG Meeting, Columbus, Ohio.
7. Phan TT, Hakala JA, Lopano C L, & Sharma S. 2019. Rare earth elements and radiogenic strontium isotopes in carbonate minerals reveal diagenetic influence in shales and limestones in the Appalachian Basin. GAC-MAC-IAH conference, Quebec City, Quebec, Canada.
8. Ferguson, B., Sharma, S., Agrawal, V., Hakala, A., 2019. Investigating controls on mineral precipitation in hydraulically fractured wells. Geological Society of America Annual Meeting, Phoenix, (GSA), Annual meeting, Phoenix, Arizona.
9. Akondi R, Sharma S. 2019. Microbial Signatures of Deep Subsurface Shale Biosphere. Geological Society of America (GSA), Annual meeting, Phoenix, Arizona.
10. Evans, Morgan, Andrew J. Sumner, Rebecca A. Daly, Jenna L. Luek, Desiree L. Plata, Kelly C. Wrighton, and Paula J. Mouser, 2019, Hydraulically Fractured Natural-Gas Well Microbial Communities Contain Genomic Halogenation and Dehalogenation Potential, Environmental Science and Technology Letters, online preprint, 7p., DOI: 10.1021/acs.estlett.9b00473.

Plan for Next Quarter

Prepare to sample Boggess wells for produced fluid and gas.

Topic 4 – Produced Water and Solid Waste Monitoring –

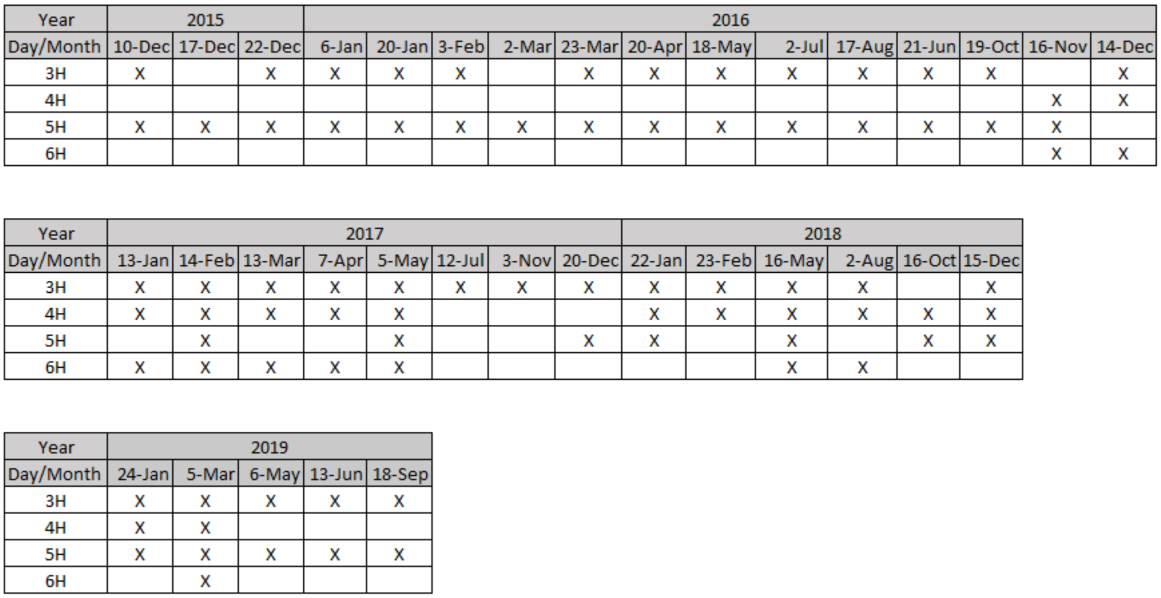
Approach

MIP Site

Over three years into the post completion part of the program, the produced water and solid waste component of MSEEL has continued to systematically monitor changes in produced water quality and quantity. During year one of the study, hydraulic fracturing fluid, flowback, produced water, drilling muds and drill cuttings were characterized according to their inorganic, organic and radio chemistries. In addition, surface water in the nearby Monongahela River was monitored upstream and downstream of the MSEEL drill pad. Toxicity testing per EPA method 1311 (TCLP) was conducted on drill cuttings in both the vertical and horizontal (Marcellus) sections to evaluate their toxicity potential. Sampling frequency has been slowly scaled back following well development.

Table 4.1 4.1 shows an “X” for sample collection dates. Wells 4H and 6H were brought back online in late 2016. Other blank sample dates in Table 4.1 indicate that samples were not collected, due to lack of availability of produced water from the well(s).

Table 4.1. MIP sampling events are indicated with an "X".



Year	2015			2016												
Day/Month	10-Dec	17-Dec	22-Dec	6-Jan	20-Jan	3-Feb	2-Mar	23-Mar	20-Apr	18-May	2-Jul	17-Aug	21-Jun	19-Oct	16-Nov	14-Dec
3H	X		X	X	X	X		X	X	X	X	X	X	X		X
4H															X	X
5H	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
6H															X	X

Year	2017								2018					
Day/Month	13-Jan	14-Feb	13-Mar	7-Apr	5-May	12-Jul	3-Nov	20-Dec	22-Jan	23-Feb	16-May	2-Aug	16-Oct	15-Dec
3H	X	X	X	X	X	X	X	X	X	X	X	X		X
4H	X	X	X	X	X				X	X	X	X	X	X
5H		X			X			X	X		X		X	X
6H	X	X	X	X	X						X	X		

Year	2019				
Day/Month	24-Jan	5-Mar	6-May	13-Jun	18-Sep
3H	X	X	X	X	X
4H	X	X			
5H	X	X	X	X	X
6H		X			

Boggess Site

Two control wells; 9H and 17H were selected for solids and aqueous studies at the newly developed Boggess well site.

Tophole was completed in Feb 2019 for 9H and Jan 2019 for 17H. Samples of vertical drilling were not obtained due to completion prior to the start of the Boggess project.

Horizontals were initiated on 19 June 2019 for 17H and 20 May 2019 for 9H (Table 4.2). A drilling mud sample along with depth samples at 8,500ft; 10,000ft; 11,000ft; 13,000ft; and 15,000ft were collected and analyzed for parameters shown in

Table 4.3.

Table 4.2. Sample depth and dates for collection of horizontal drilling mud and cutting samples.

Depth	Mud 9H	8500 9H	10000 9H	11000 9H	13000 9H	15000 9H
Date	5/27/2019	5/27/2019	5/28/2019	5/29/2019	5/29/2019	5/30/2019

Table 4.3. Solids analysis list.

Analysis	Method	Units	Parameter
Diesel Range Organics by GC-FID	SW8015M	mg/Kg-dry	DRO (C10-C28)
			ORO (C28-C40)
		% Rec	Surr: 4-terphenyl-d14
Gasoline Range Organics by GC-FID	SW8015D	ug/Kg	GRO C6-C10)
		% Rec	Surr: Toluene-d8
Volatile Organic Compounds	SW8260B	ug/Kg-dry	Ethylbenzene
			m,p- Xylene
			o- Xylene
			Styrene
			Toluene
			Xylenes total
		% Rec	Surr: 1,2- Dichloroethane-d4
			Surr: 4-Bromofluorobenzene
			Surr: Dibromofluoromethane
			Surr: Tolouene-d8
Radionuclides	EPA 901.1	pCi/g	Potassium-40
			Radium-226
			Radium-228
	9310		Gross Alpha
			Gross Beta
Inorganics	SW9056A	mg/Kg-dry	Br
			Cl
			SO4
	SW9034		sulfide
	E353.2		nitrate
	E354.1		nitrite
	A2510M	µS/cm	EC
	SW9045D	units	pH
	A4500-CO2 D	mg/Kg-dry	alk bicarb
			alk carb
			alk t
	E365.1 R2.0		TP
	SW6020A		Ag
			Al
			As
			Ba
			Ca
			Cr
			Fe
			K
			Li
			Mg
			Mn
			Na
			Ni
			Pb
			Se
			Sr
			Zn
Moisture	E160.3M	%	Moisture
Chemical Oxygen Demand	E4104 R2.0	mg/Kg-dry	COD
Organic Carbon - Walkley-Black	TITRAMETRIC	% by wt-dry	OC-WB
Oil & Grease	SW9071B - OG	mg/Kg-dry	O&G

Results & Discussion

MIP Site

Major ions – trends in produced water chemistry

While makeup water was characterized by low TDS (total dissolved solids) and a dominance of calcium and sulfate ions, produced water from initial flowback is a sodium/calcium chloride water (

Figure 4.1). While produced water TDS (total dissolved solids) increased by an order of magnitude from initial flowback to the present, the ionic composition of produced water changed very little through 1281 days post completion. Produced water TDS was affected by shut-in/turn-in cycles at individual wells. For example, upon turn-in TDS was invariably very low but reached pre-shut-in concentrations within a month.

MIP 3H was shut-in sometime after day 966 and turned back in just prior to sampling on day 1101. While concentrations are magnitudes lower, the proportion of ionic compounds is consistent with previous samples (

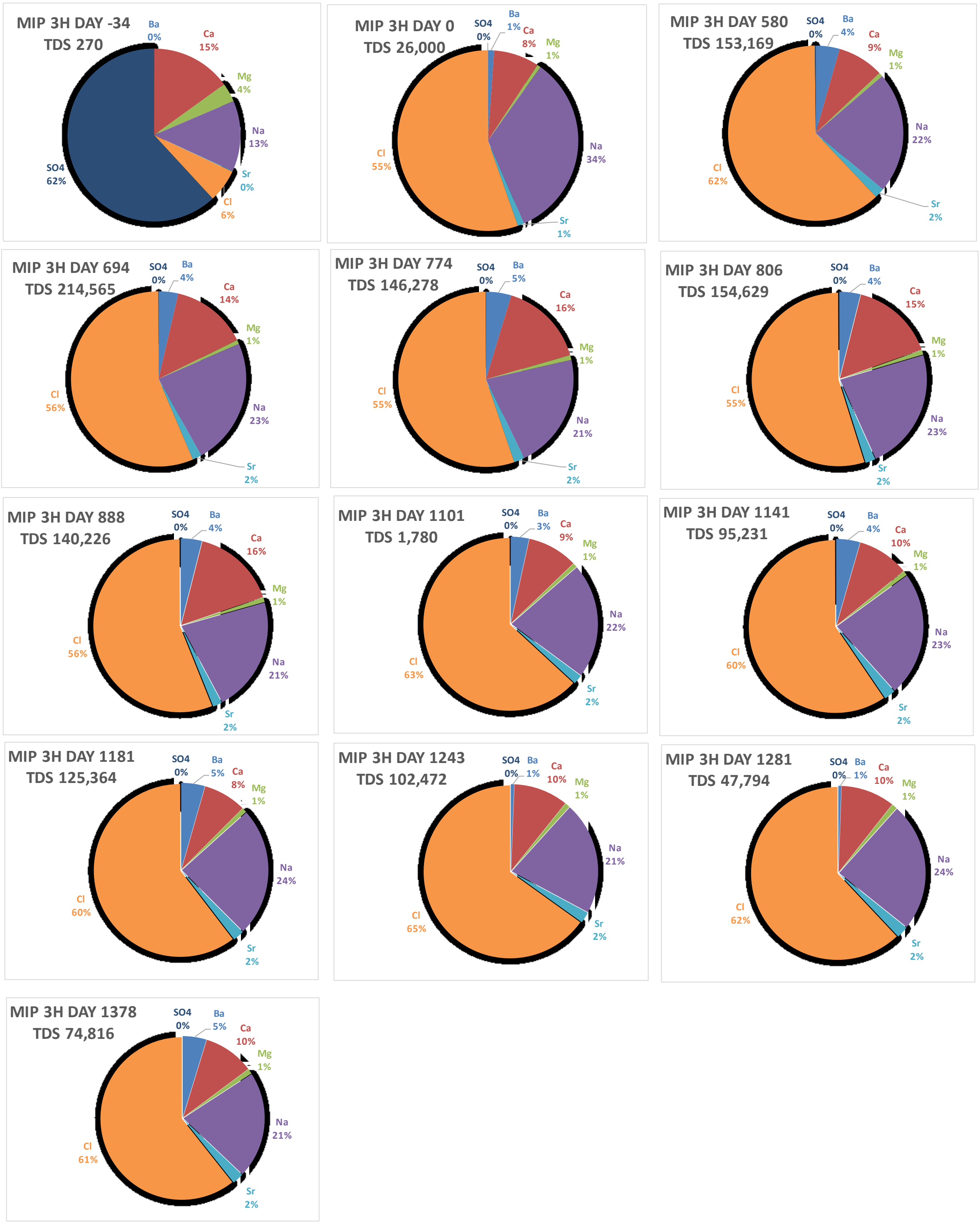


Figure 4.1).

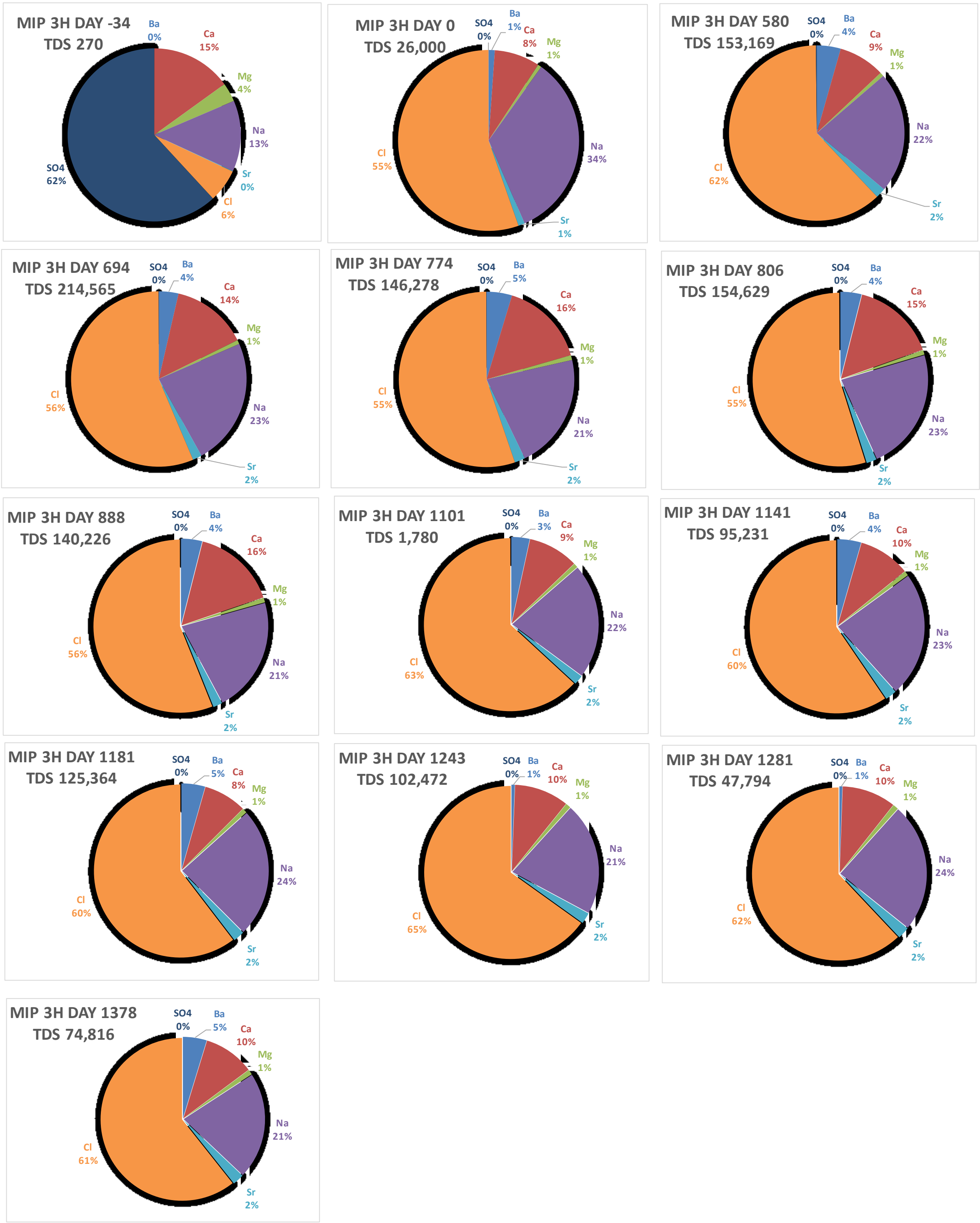


Figure 4.1. Changes in major ion concentrations in produced water from well MIP 3H. Top left Day -34 represents makeup water from the Monongahela River, top center is produced water on the first day (Day 0) and the remainder of pie charts show flowback and produced water on sampling dates through the 1378th day post completion.

In wells 3H and 5H, TDS increased rapidly over the initial 90 days post completion while TDS stabilized between 100,000 and 200,000 mg/L through day 1181(3H) (Figure 4.2). Note that 3H and 5H were both shut-in near day 966 and brought back online prior to sampling on day 1101. 3H and 5H are showing an upward trend following day through day 1243 (e.g. May 2019). Results from day 1281 (e.g. June 2019), TDS declined in both wells. It's uncertain if the wells were shut down between day 1243 and day 1281, which might explain the decline in TDS.

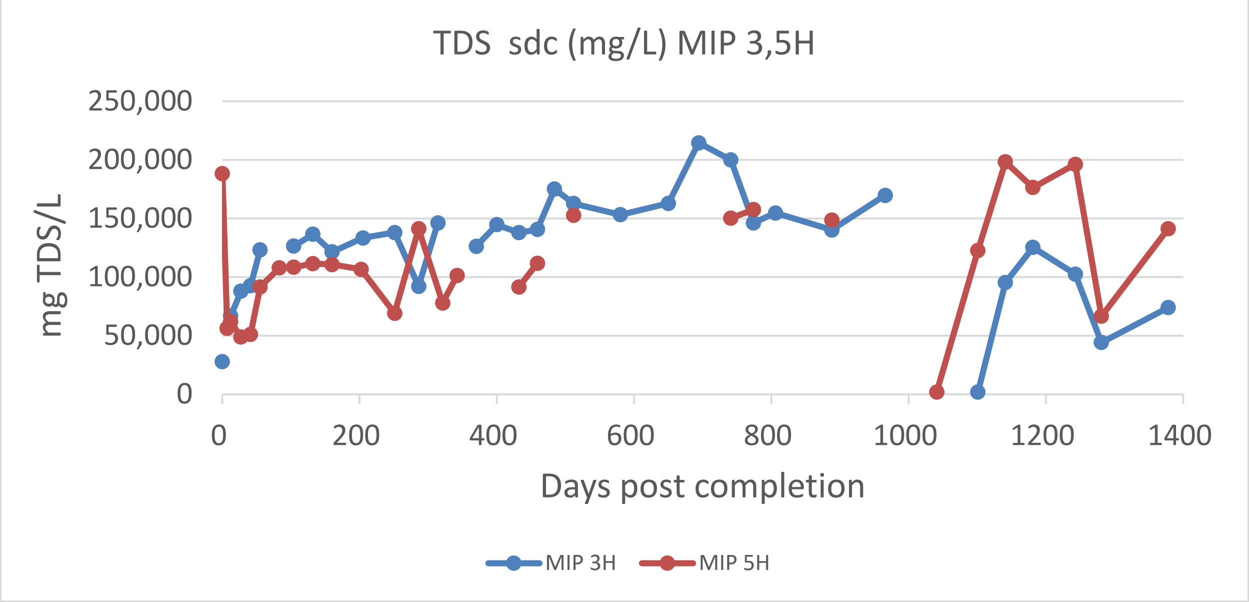


Figure 4.2. Changes in produced water TDS sdc (sum of dissolved constituents) through the first 1181 days post completion (3,5H).

The older 4H and 6H were not sampled during this reporting period.

Water soluble organics

The water-soluble aromatic compounds in produced water: benzene, toluene, ethylbenzene and xylene were never high. With two exceptions at post completion day 321 and 694, benzene has remained below 30 µg/L (Figure 4.34). This seems to be a characteristic of dry gas geologic units. After five years, benzene has mostly declined below the drinking water standard of 5 µg/L. An exception to this was a measurement of 11 µg/L noted on day 1378 at 5H.

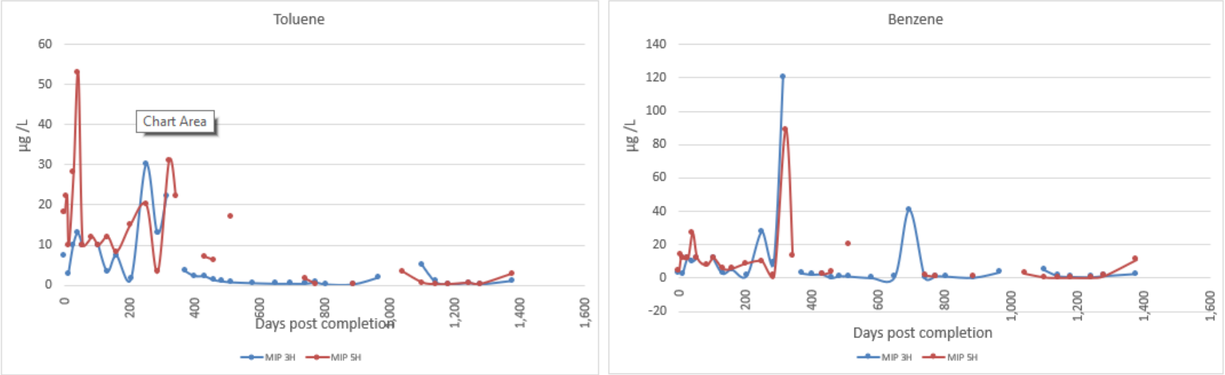


Figure 4.3. Changes in benzene and toluene concentrations. The figure shows data from well both 3H and 5H.

Radium isotopes

The radiochemical concentrations were determined by Pace Analytical in Greensburg PA, a state certified analytical lab. Radium concentrations generally increased through 800 days post completion at wells MIP 3H and 5H. Maximum levels of the radium isotopes reached about 21,800 pCi/L at the unchoked 3H well and around 17,800 5H. After returning online prior to day 966, both wells are on a general upward trend through the most recent sampling event, except for 3H on day 1101. (Figure 4.4).

<u>Radioactivity in produced water</u>

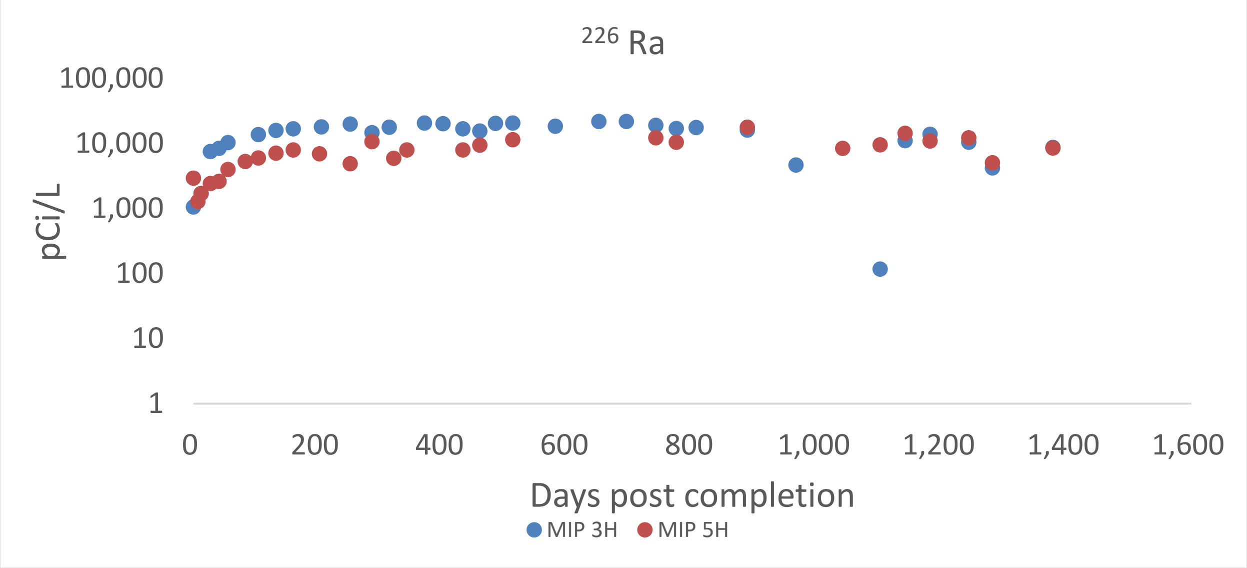


Figure 4.4. The radium isotopes are plotted against days post well completion. Well 5H was choked more periodically the 5H. 3H produced less water and lower concentrations of radium.

Radium concentrations at wells 4H and 6H were below 9,000 pCi/L during all sampling periods. Both wells were choked at day 1963. Well 4H was reopened at day 2225, radium was 58 pCi/L on the first sampling after the reopening and 3719 pCi/L at day 2257, a month later (

Figure 4.5) peaked at 5,127 pCi/L then returned to 3,892 pCi/L. The same trend is noted at day 2492 when 4H returned online with 57 pCi/L then peaked at day 2632 with 8,197 pCi/L. Additional data is needed to capture long-term trends. 4H and 6H were not sampled during this reporting period.

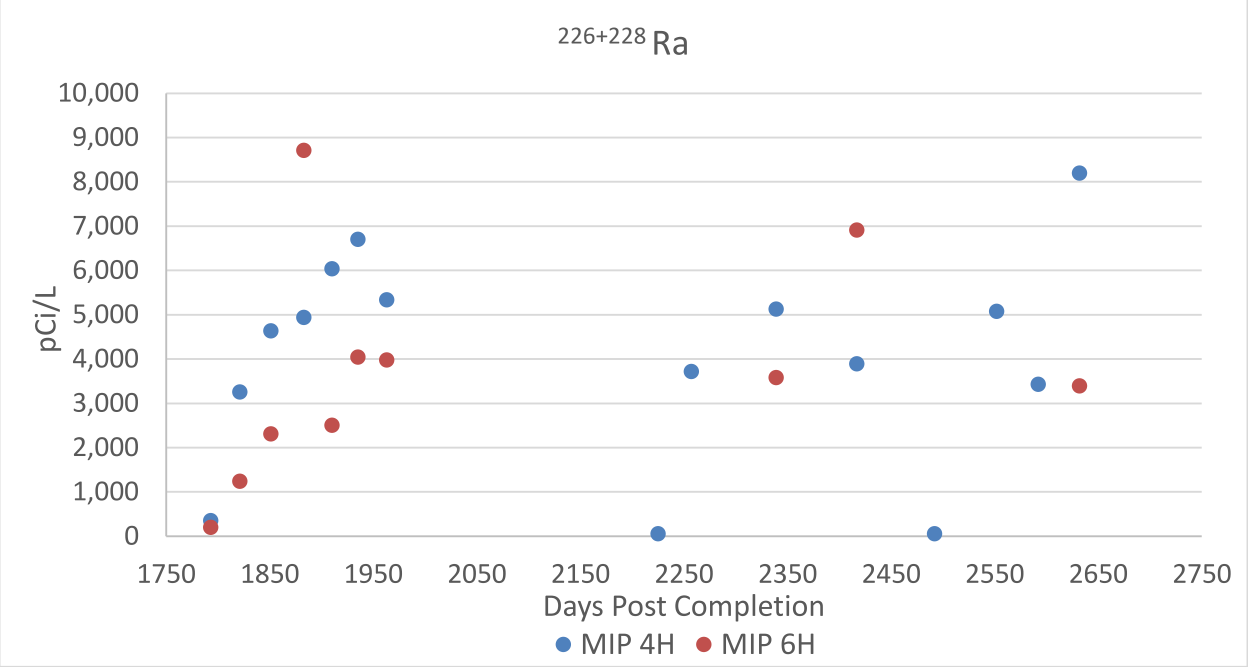


Figure 4.5. The radium isotopes are plotted against days post well completion. Well 4H and 6H were choked at day 1963. At day 2225, 4H was reopened showing a value of 58 pCi/L and reopened again at day 2492 showing a value of 57 pCi/L.

Figure 4.6 and 4.7 show the relationship between gross alpha and ^{226}Ra at 3H and 5H. Analysis for alpha was not conducted after day 1181.

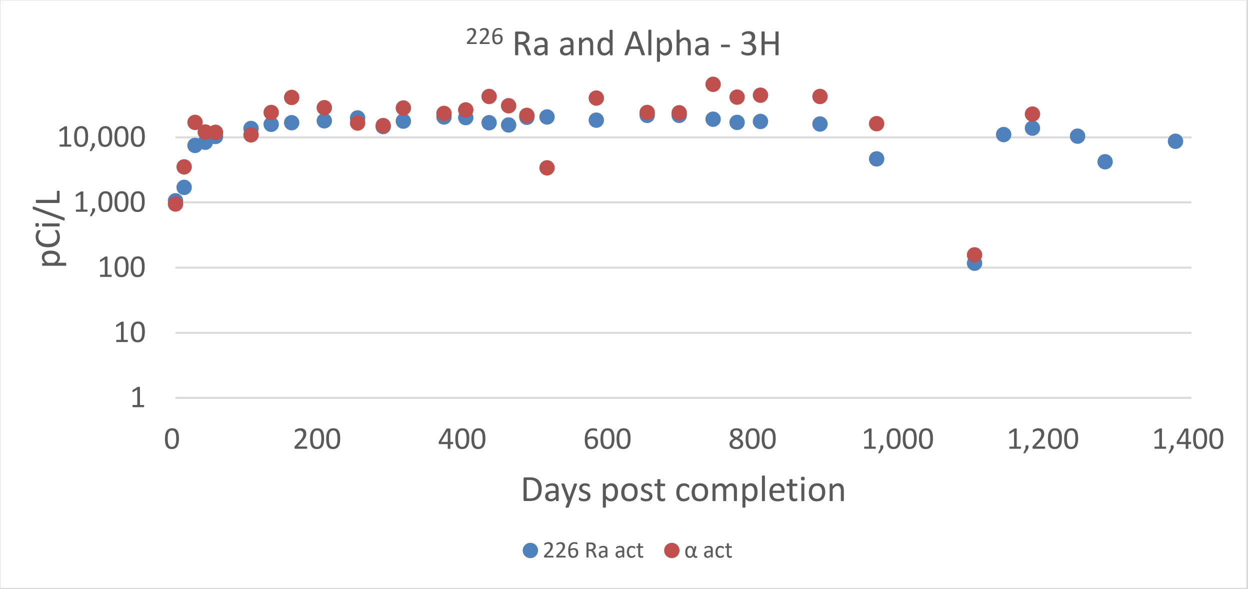


Figure 4.6. The relationship between gross alpha and ^{226}Ra as a function of time post completion at 3H. Note: analysis for alpha was not conducted after day 1181.

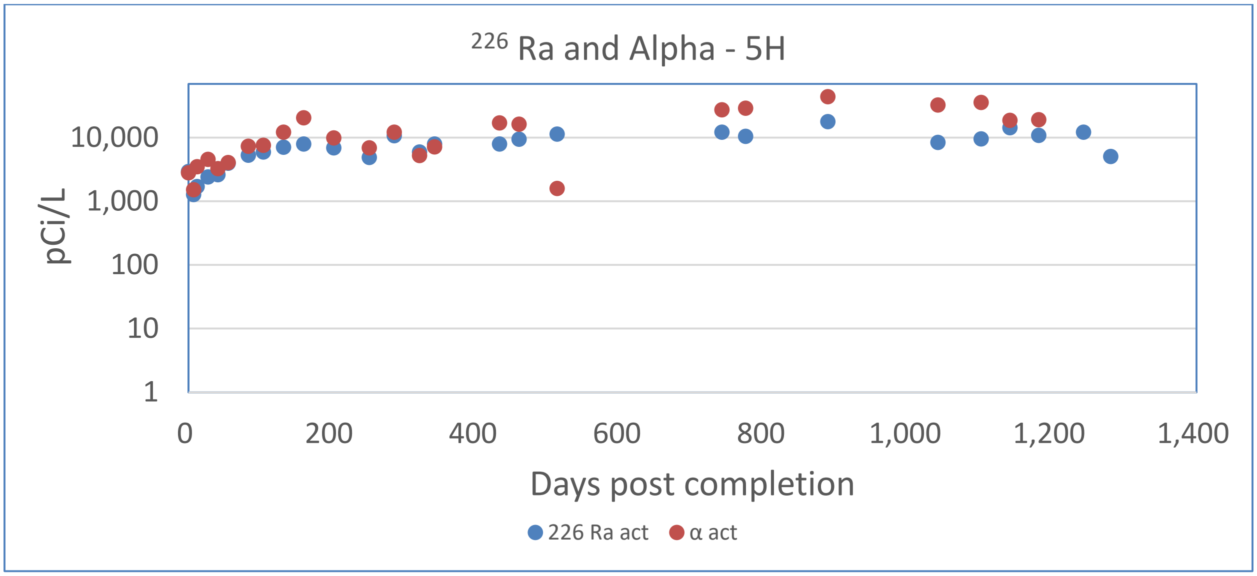


Figure 4.7. The relationship between gross alpha and ^{226}Ra as a function of time post completion at 5H.

The highest values reported in the older wells at 4H and 6H were 17,550 pCi/L gross alpha and 8,197 pCi/L ^{226}Ra. The relationship between gross alpha and ^{226}Ra for wells 4H and 6H are shown in Figure 4.8 and 4.9. 4H and 6H were not sampled during this reporting period.

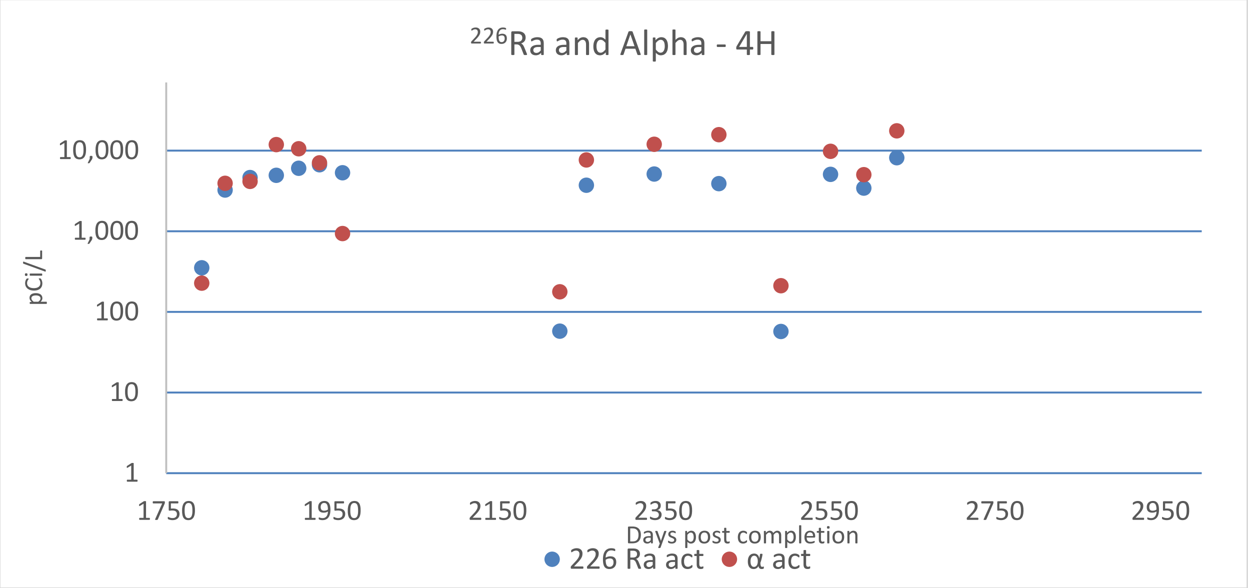


Figure 4.8. The relationship between gross alpha and ^{226}Ra as a function of time post completion at 4H.

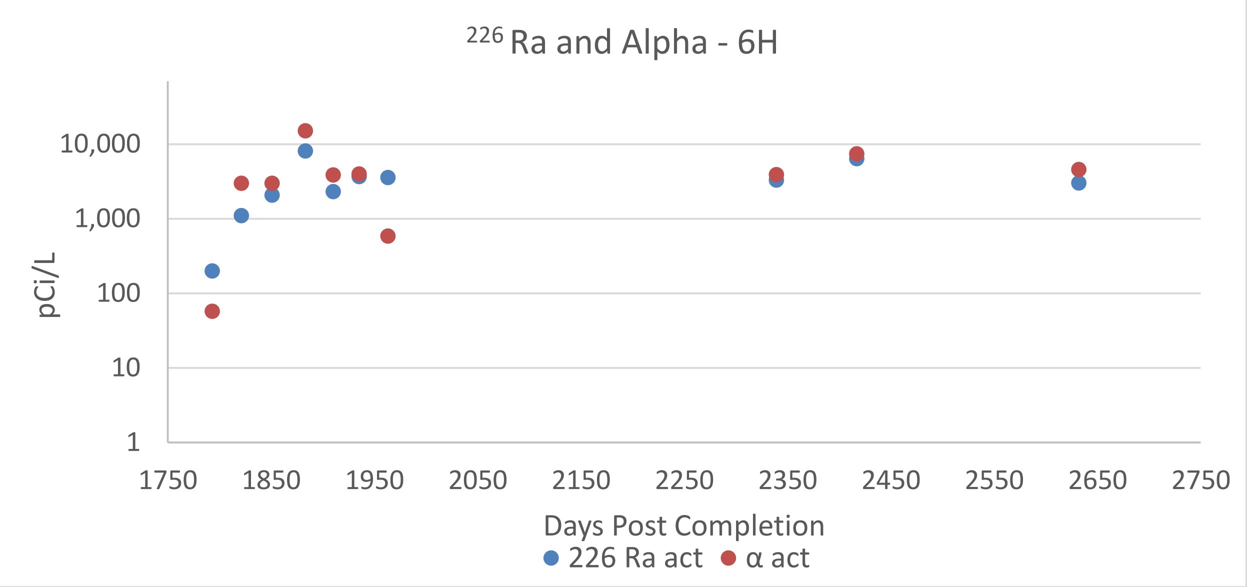


Figure 4.9. The relationship between gross alpha and ^{226}Ra as a function of time post completion at 6H.

Boggess Well

Solids

Analytical results have been received for drilling muds and cuttings collected at 9H at depth intervals of 8,500ft; 10,000ft; 11,000ft; 13,000ft; and 15,000ft. Anions (e.g. Br, Cl, and SO4) and Cations (e.g. Ba, Ca, Mg, Mn, Na, and Sr) are shown in Figure 4.10. Drill cuttings from 9H are predominately Calcium.

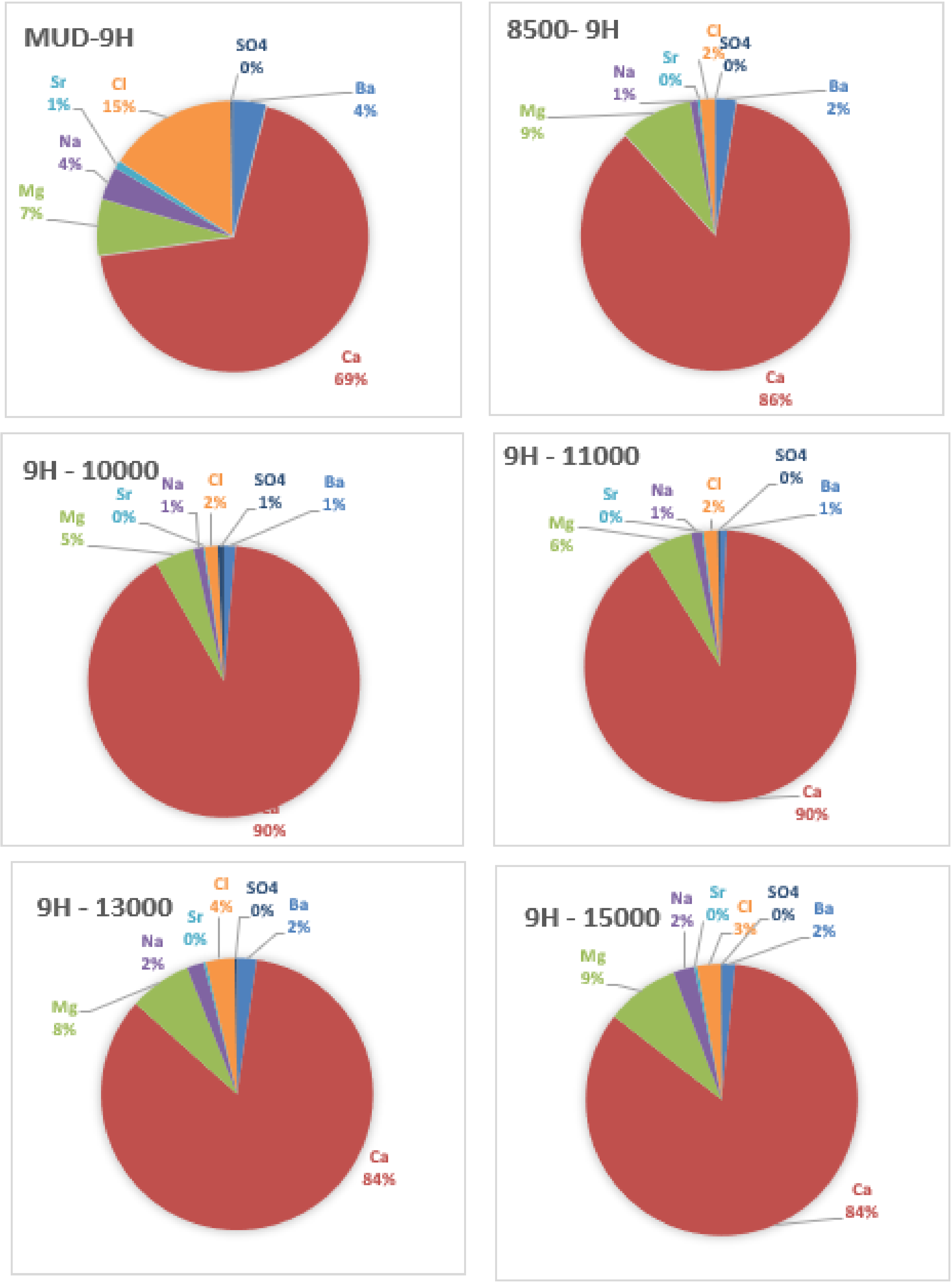


Figure 4.10. Anions/cations of drilling mud and cutting from 9H.

Error! Reference source not found. depicts anions/cations of drilling mud and cuttings from 17H. Magnesium was more prevalent in the 8500 and 10000 depts for 17H in comparison to the same depths for 9H.

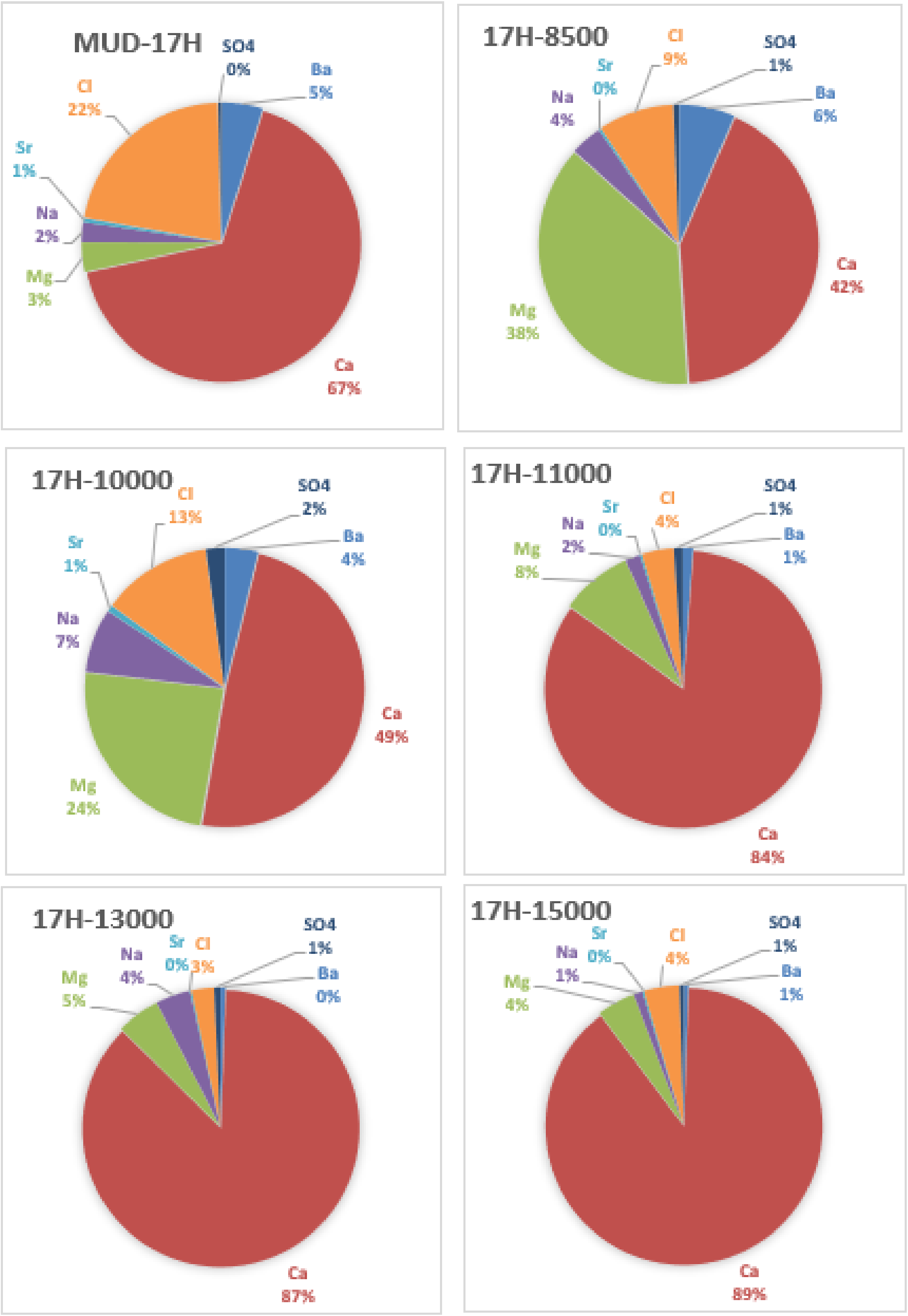


Figure 4.11. Anions/cations of drilling mud and cuttings from 17H.

Figure 4.12 and 4.13 depict combined radium 226 and 228 of solids in drilling mud and cuttings from 9H and 17H.

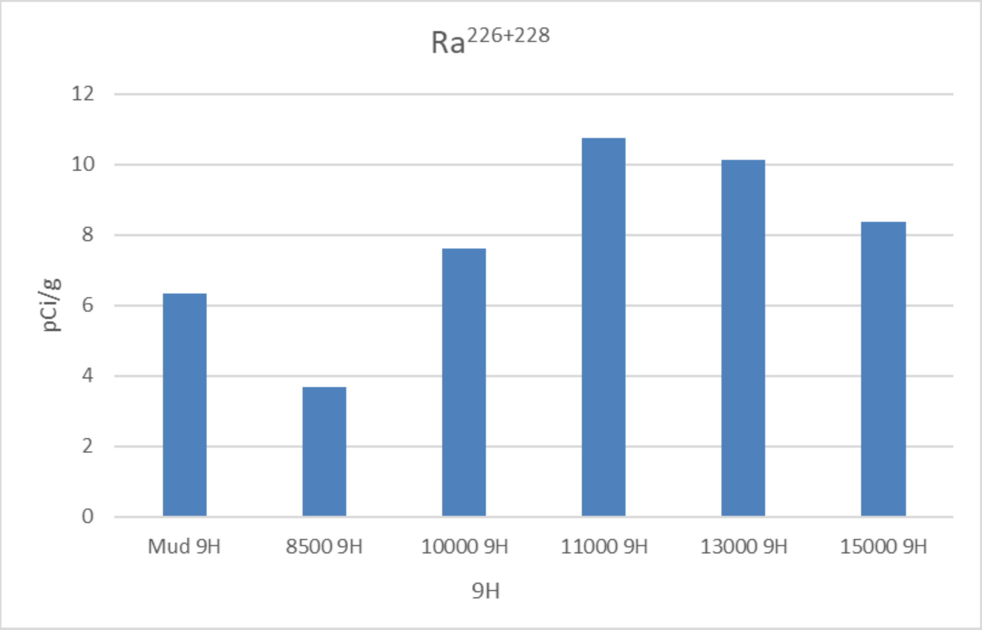


Figure 4.12. 9H Combined radium 226 and 228 for drilling mud and cuttings.

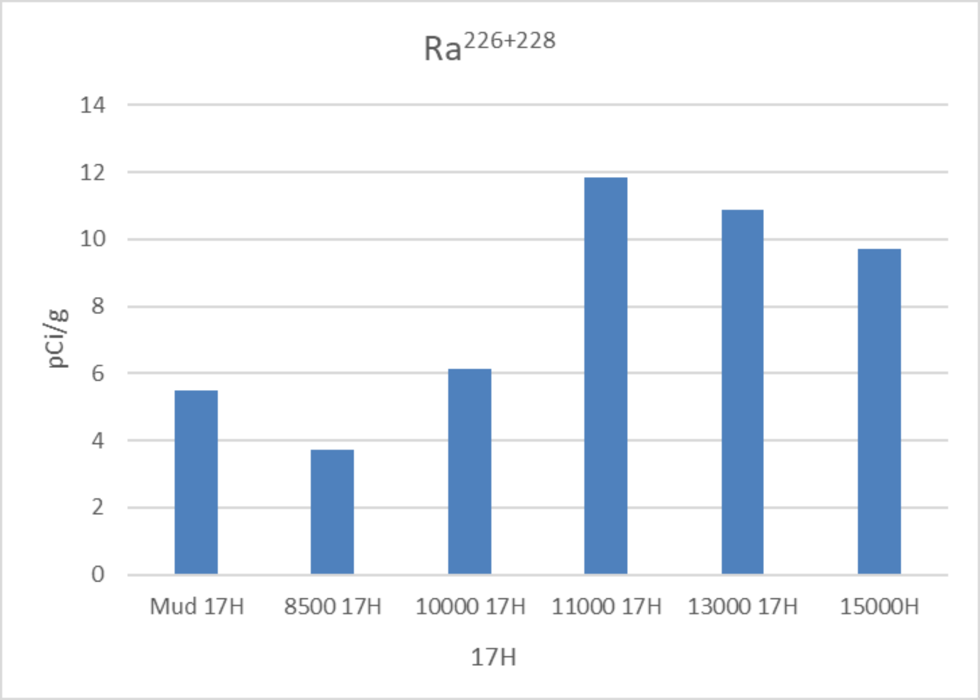


Figure 4.13. 17H Combined radium 226 and 228 for drilling mud and cuttings.

For comparison purposes, solids radium analysis from MIP 5H and 3H are shown in Figure 4.15. In all wells analyzed, 3H and 5H from MIP along with 9H and 17H at Boggess, combined radium 226 and 228 remained below 12 pCi/g.

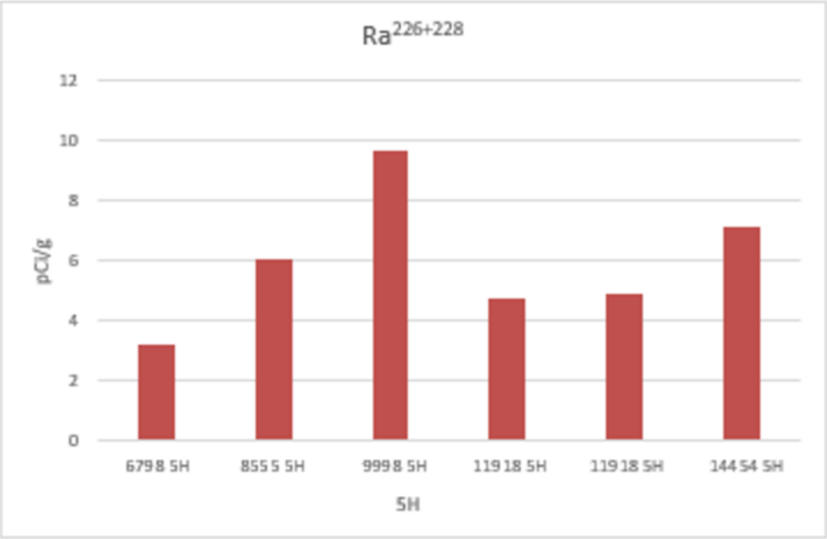


Figure 4.14. Combined Ra 226 + 228 for 5H MIP sites.

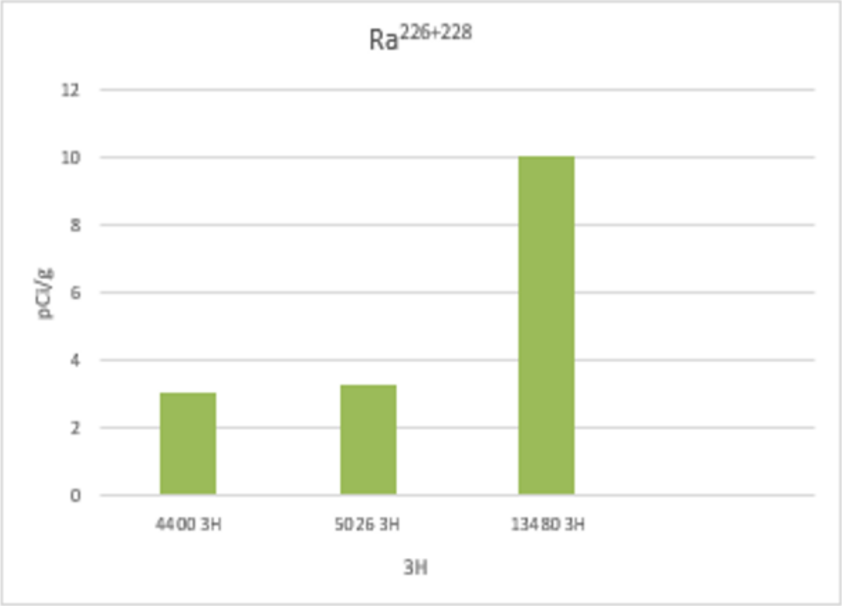


Figure 4.15. Combined Ra 226 + 228 for 3H MIP sites.

Products

None for this quarter.

Plan for Next Quarter

We will continue monthly sampling at MIP and analyze flowback/produced water (FPW) from MIP 3H, 4H, 5H and 6H if they are online.

We will continue sampling at Boggess Pad control wells 9H and 17H. Plans include collection of flowback/produced water. Following the same protocols used at MIP wells, we will characterize their inorganic, organic and radio chemistries.

Topic 5 – Environmental Monitoring: Air & Vehicular

Approach

Unfortunately, there was a delay in completing the 12th audit during September of 2019 and the subsequent installation of the complete OTM/Eddy Covariance tower at the MIP site. We hope that these will occur in October/November at the latest. The new fast methane/ethane analyzer was purchased as part of Dr. Johnson's NSF project and start-up package. Figure 5.1 shows the new analyzer which will enable direct quantification of leaks and losses to include both methane and ethane mass emissions. Our primary focus was on continued development and preparation for the new energy audit systems. Dr. Johnson and Mr. Heltzel and Dranuta met this quarter with Mr. Travis Shirly and Mr. Stanley Dean of Patterson UTI at the Mt. Morris rig service yard to review the needs for the energy audit. This included and in-depth discussion on the use of diesel or natural gas fired boilers – the primary focus of our measurement campaign. Patterson-UTI has examined the efficiency of the boilers to be approximately 80%. Based on site layout and equipment, we will instrument the boilers with a dual KRAL fuel meter system that was previously deployed when we assessed the drilling engines. We also obtained data on day tank volume, setpoint pressure, and setpoint temperatures. We will measure the day tank temperature and exhaust stack temperature along with the fuel flow rate. We also reached out to the special projects' manager based on our initial meeting and are awaiting approval from headquarters to instrument the rig. the CAFEE team completed their 10th and 11th audit of the first MSEEL site.

In addition to our preparatory work, we also continued baseline methane releases at the WVU Reedsville Farm location since MIP deployment was delayed. We have processed the data using conventional OTM 33A methods and the standard Eddy-Covariance method. An overview of the results is presented in the following section. Note that controlled leak rates and distances were selected based on MIP methane audits and data available in literature.

$[CH_4]$ = 2.3185 PPM
$[C_2H_6]$ = 0.0500 PPM
$[H_2O]$ = 12757.12 PPM
$[CH_4]_{dry}$ = 2.3500 PPM
$[C_2H_6]_{dry}$ = 0.0381 PPM

Figure 5.1: Baseline Telemetry System to be Modified for Energy Audits.

Results & Discussion

To simulate leaks like those seen at natural gas well pads an experiment was conducted at an offsite location. The Reedsville Farm is a West Virginia University-operated cattle farm around 15 miles southeast of the Marcellus Shale Energy and Environment Laboratory (MSEEL). It was used as a test location due to the availability of large open fields. At this site both background data and simulated leaks were measured using the Eddy Covariance Trailer Tower (ECTT) setup. These measurements were taken over the course of several months starting in May 2019 and concluding in September 2019. Data were collected on 99 separate days during that span of time. Of the 99 days in which data were collected, 49 included some time with a simulated leak. The remaining days were considered background. Leaks were simulated at various distances from the ECTT. At each distance, several different methane leak rates were simulated. The time of each simulated leak varied based on gas availability, weather, equipment failures and other conditions that affected researchers' ability to obtain quality datasets.

Based on the research of others and the rates recorded at MSEEL. A test matrix was constructed that was believed to be representative. Table 5.1 shows the test matrix of leaks and distances as well as the amount of time each leak was simulated. These times include the total time that the leak was present, not the total amount of quality data obtained during that time. Part of the goal of the research was to determine the amount of valuable data lost and how this could be minimized during an MSEEL on-site campaign.

Table 5.1: The total time (hours) of each simulated leak in the test matrix.

Test Matrix		**Distances (m)**		
		50	**75**	**100**
Leak Rates (kg/hr)	**0.13**	163.25	120	117.5
	0.43	123.25	45.5	43
	0.86	23	18.5	7.5

The tower and leak locations were initially chosen based on the average wind direction observed during background data collection. The goal was to maximize the amount of time that the wind direction corresponded to the bearing between the leak and the tower to obtain as much useful data as possible. However, during the campaign the tower and leak locations had to be moved several times due to other activities occurring at the farm. Each time the tower was moved, a series of background measurements were taken to ensure that the leak data could be compared to backgrounds of the same location. The sensitivity of EC measurements to site setup are well documented**.** The technique is conventionally used for homogeneous vertical fluxes which typically is sensitive to local terrain, vegetation, human and animal activity, and other conditions. The use of this method for quantification of point-sources is somewhat novel and therefore it was unclear how site selection and positioning would affect results.

Figure 5.2: Leak and tower locations during data collection at the WVU Reedsville Farm.

Table 5.2: Details of different leak and tower locations.

Leak			Tower				Distance (m)	Bearing (°EoN)
Location #	Altitude (m)	Height (m)	Location #	Altitude (m)	Height (m)	Anemometer Offset (°EoN)		
1	522.1	2.286	2	521.5	4.0	152	42.4	82.2
2	522.1	2.286	3	524.0	4.0	0	71.8	44.8
3	523.6	2.286	3	524.0	4.0	0	57.0	74.1
4	523.6	2.286	4	528.5	4.0	15	118.7	47.6

The bulk of the initial analysis was performed based on these 2923 periods of data. In the 2923 periods, 830 were “leaks” and 2093 were “background”. Those periods that were “background” were used as a base for comparison of the “leaks”. Data was separated based on the leak rate, distance from the data acquisition tower, and day/night. A complete breakdown of data used for analysis is shown in Table 5.3. The data that was analyzed included results and outputs from both EddyPro® processing and OTM33A processing. The focus of the analysis was contained to those variables involving methane and micrometeorological variables such as wind speed and direction. Some basic micrometeorological and weather variables are shown in Table 5.4. These are simply the averages of the day and night mean values from the respective periods. The max wind speed is the average of the max wind speed from each period, either day or night. TKE and u* represent the turbulent kinetic energy and friction velocity, respectively.

Table 5.3: Breakdown of data periods recorded during farm campaign.

Analysis	Initial Periods	Final Periods	Percentage
EddyPro Processed	-	3258	
Valid "ch4_flux"	4351	3258	75%
OTM33A Processed	-	3033	
Valid "ch4 rate"	4351	3033	70%
EddyPro and OTM	4351	2923	67%
Background	**2923**	**2093**	**72%**
Time: Day	2093	1281	61%
Time: Night	2093	812	39%
Leak	**2923**	**830**	**28%**
Time: Day	830	500	60%
Rate: 3 slpm	500	315	38%
Distance: 50 meters	315	142	17%
Distance: 75 meters	315	99	12%
Distance: 100 meters	315	74	9%
Rate: 10 slpm	500	120	14%
Distance: 50 meters	120	27	3%
Distance: 75 meters	120	47	6%
Distance: 100 meters	120	46	6%
Rate: 20 slpm	500	65	8%
Distance: 50 meters	65	33	4%
Distance: 75 meters	65	18	2%
Distance: 100 meters	65	14	2%
Time: Night	830	330	40%
Rate: 3 slpm	330	205	25%
Distance: 50 meters	205	68	8%
Distance: 75 meters	205	51	6%
Distance: 100 meters	205	86	10%
Rate: 10 slpm	330	94	11%
Distance: 50 meters	94	24	3%
Distance: 75 meters	94	37	4%
Distance: 100 meters	94	33	4%
Rate: 20 slpm	330	31	4%
Distance: 50 meters	31	12	1%
Distance: 75 meters	31	19	2%
Distance: 100 meters	31	0	0%

Table 5.4: Micrometeorological averages during data collection.

Variable	Units	Day	Night
Air Temperature	**K**	296.14	291.29
Air Pressure	**kPa**	95.79	95.75
Solar Loading	**W/m^2**	480.46	23.23
Wind Speed	**m/s**	2.17	0.91
Max Wind Speed	**m/s**	5.50	2.44
u*	**m/s**	0.31	0.14
TKE	**m^2/s^2**	0.92	0.23
CH4 Concentration	**ppm**	2.15	2.41

Figure 5.3 shows the elevated methane concentrations on an average ppm basis. A linear trend is seen as the rate of the leak is increase. The averages shown include leaks performed at all distance (50, 75 and 100 meters).

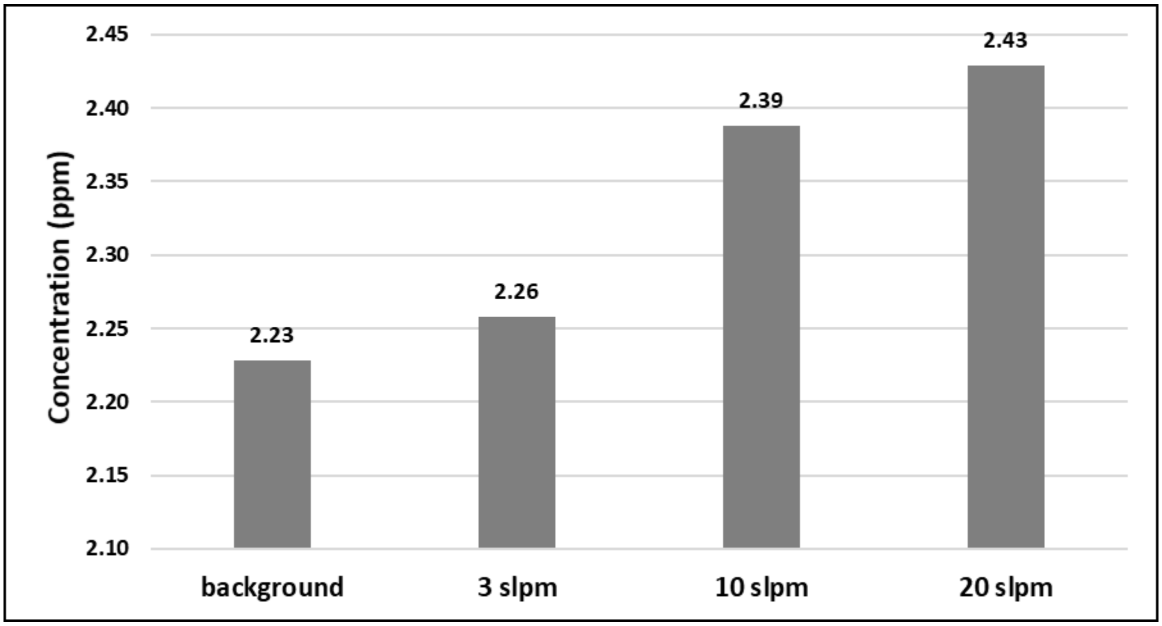


Figure 5.3: Average methane concentrations measured during different leak rates.

Figure 5.4 shows two variables that are direct outputs of EddyPro®: methane flux (ch4_flux) and uncorrected methane flux (un_ch4_flux). The other four variables: absolute methane flux (abs_ch4_flux), absolute uncorrected methane flux (abs_un_ch4_flux), positive methane flux (pos_flux) and negative methane flux (neg_flux) are derived from those two direct variables. The positive and negative methane flux values are the average of the positive and negative values of ch4_flux, respectively. These values were chosen as a starting point to see if trends could be derived from the simple averaging of direct outputs.

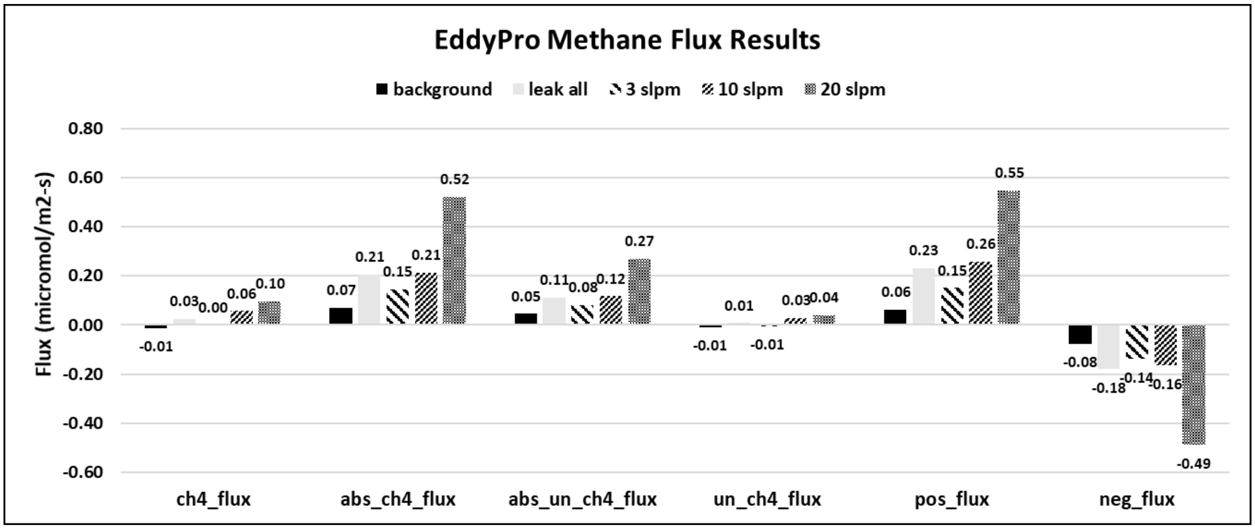


Figure 5.4: EddyPro® direct and modified flux results averaged over all leak times.

Figure 5.5 shows the difference between the OTM33A estimated leak rates and the actual leak rate averaged over all the distances tested. The solid and dotted error bars represent the variance and the 95% confidence interval of the period, respectively. While there is a clear positive trend between estimated and actual leak rate the confidence intervals are large. A goal of future work will be to reduce such confidence intervals, giving more reliable, consistent results. There are several ways this could be done. Prior knowledge of site such as possible locations of leaks and historical weather conditions like wind direction and speed could help to improve the OTM33A results. These things are used in a general OTM33A approach in which leak locations are assumed and the vehicle is positioned downwind of such a location. A non-mobile long-term tower could use an optimal placement, however, if such placement is intrusive, more stringent filtering could be applied to data. Analysis of usable data could be enhanced with further filtering and machine learning techniques such as classification and fuzzy logic. Figure 5.6 shows a further breakdown with respect to leak distance. The error bars here represent variance, confidence intervals are not displayed. These initial results show distance can have a significant impact on the estimated results of OTM33A. Variances are in general grow as distance increases. This is to be expected and is a product of wind variations and more dispersion at these distances downwind. The differences between the estimated values and the actual leak rates for all scenarios tested are shown in Table 5.5.

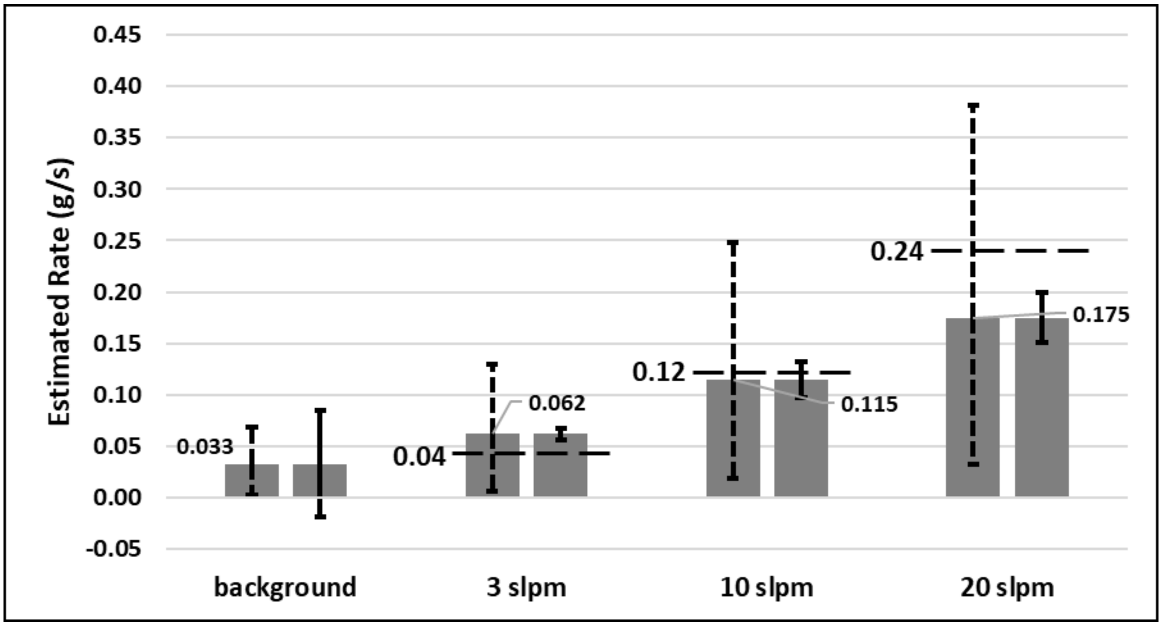


Figure 5.5: Average OTM33A results of all periods categorized by actual leak rate.

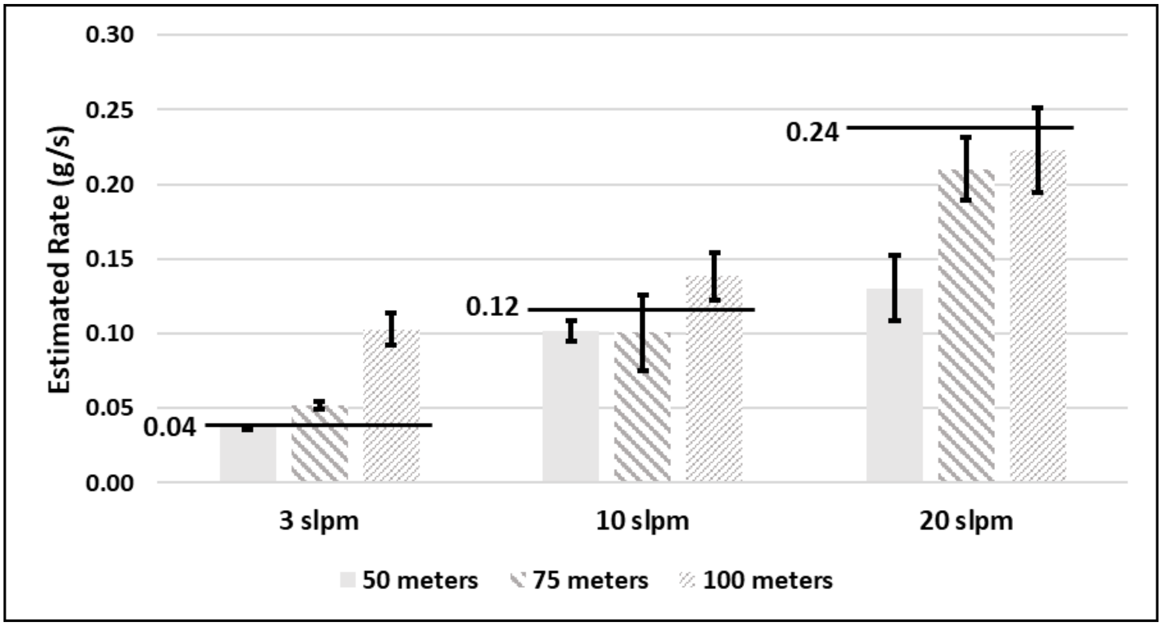


Figure 5.6: Average OTM33A results of periods with an active leak categorized by leak rate and distance.

Table 5.5: Differences between OTM33A-estimated and actual leak rate.

Leak Rate (slpm)	Distance (m)	Estimated (g/s)	Low 95% Confidence	High 95% Confidence	% Difference	Over/Under/Within Interval
3	All	**0.062**	0.055	0.068	54%	Over
	50	**0.037**	0.032	0.042	7%	Within
	75	**0.052**	0.043	0.060	29%	Over
	100	**0.103**	0.087	0.119	158%	Over
10	All	**0.115**	0.097	0.133	4%	Within
	50	**0.102**	0.079	0.125	15%	Within
	75	**0.100**	0.066	0.135	16%	Within
	100	**0.138**	0.110	0.167	15%	Within
20	All	**0.175**	0.143	0.206	27%	Under
	50	**0.130**	0.085	0.175	46%	Under
	75	**0.210**	0.161	0.260	12%	Within
	100	**0.223**	0.122	0.324	7%	Within

It was found that both the OTM33A unfiltered results and EddyPro® outputs had positive correlations with actual leak rates. This was expected, however, EddyPro® results tell the user nothing about a leak rate without further analysis or knowledge of “footprint” which can be defined by several advanced processing methods. OTM33A in its best practice relies on knowledge of leak location and ideal weather conditions to effectively determine a mass rate of emissions. If such information is not available, however, eddy covariance footprint analysis and flux measurements could assist with enhanced accurate quantification. A combination of the two methods along with machine learning techniques could paint a picture of site leaks and losses. Long term monitoring could help explain temporal and spatial variability, increase data sets and help contribute to national inventories through refined emissions and activity factors.

Products

Nothing to report.

Plan for Next Quarter

- Complete 12th MSEEL 1.0 Audit – Previously Scheduled for September 2019, Awaiting NNE Approval for Site Access.
- Install OTM/Eddy-Covariance at MSEEL 1.0 – Previously Scheduled to Coincide with September 2019 Audit, Awaiting NNE Approval for Site Access.
- Integrate DAQ Systems on Rig at Regional Surface Yard Prior to Deployment
- Deploy Energy Auditing DAQ At Regional Well Site.

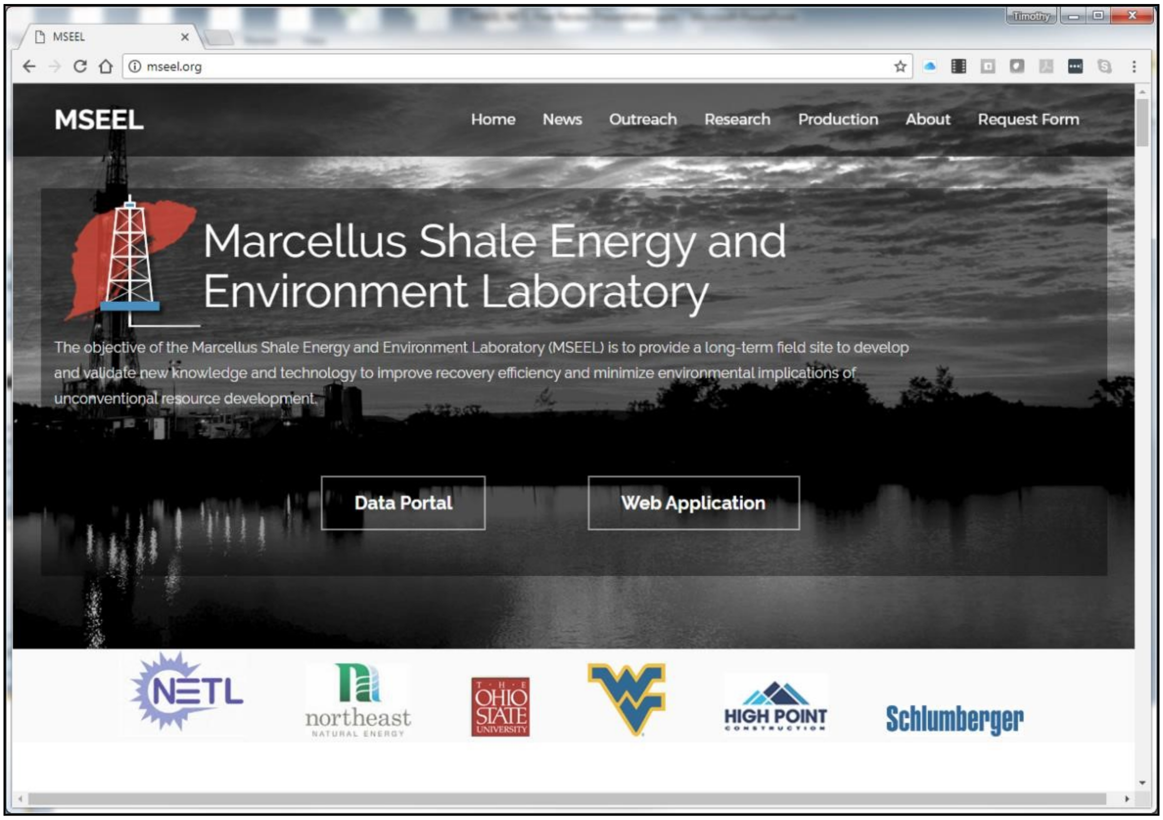
Topic 6 – Water Treatment

<u>This task is complete and will not be updated in future reports.</u>

Topic 7 – Database Development

Approach

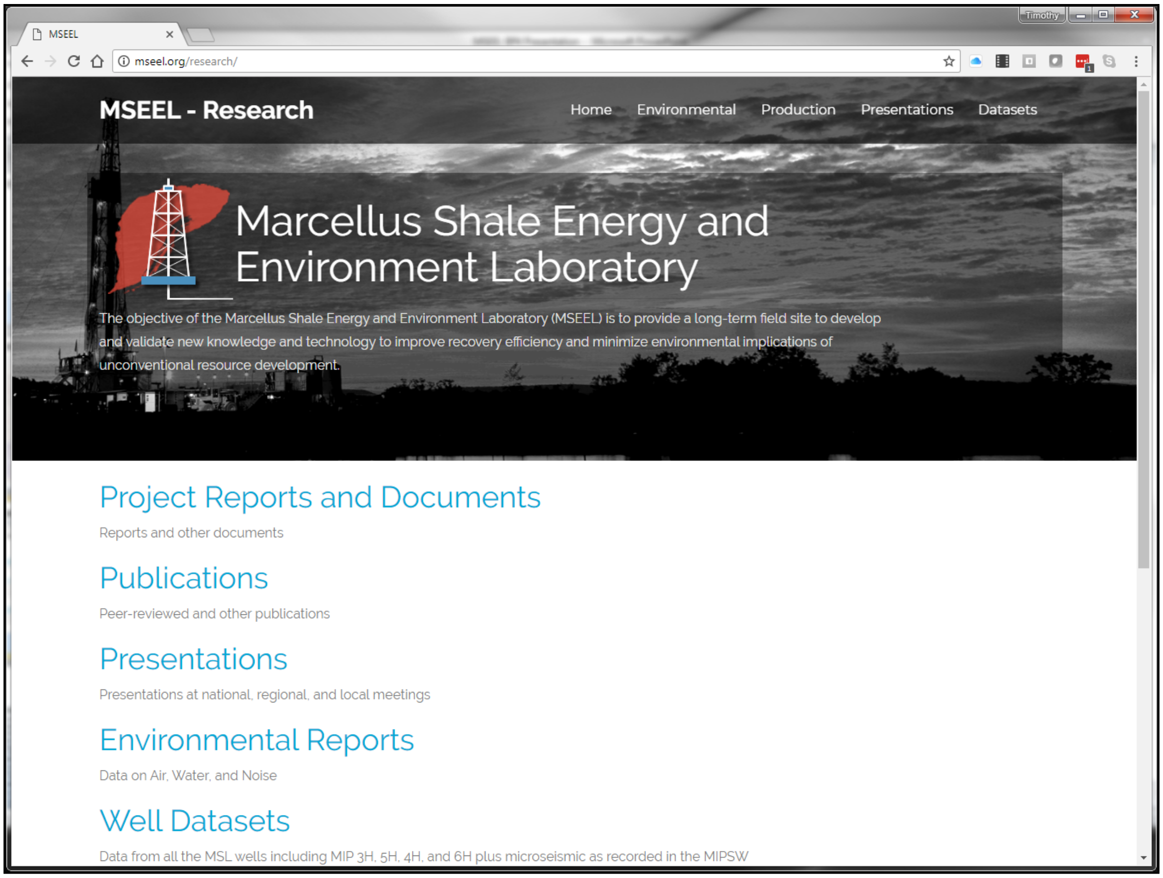
All MSEEL data is online and available to researchers (Figure 7.1 and 7.2). The website continues to be updated with the latest production beyond the end of the quarter (Figure 7.3). Work continues and we are adding data from MSEEL 3 Boggess Pad.



Marcellus Shale Energy and Environment Laboratory

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development.

Figure 7.1: MSEEL website at http://mseel.org/.



Marcellus Shale Energy and Environment Laboratory

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development.

Project Reports and Documents

Reports and other documents

Publications

Peer-reviewed and other publications

Presentations

Presentations at national, regional, and local meetings

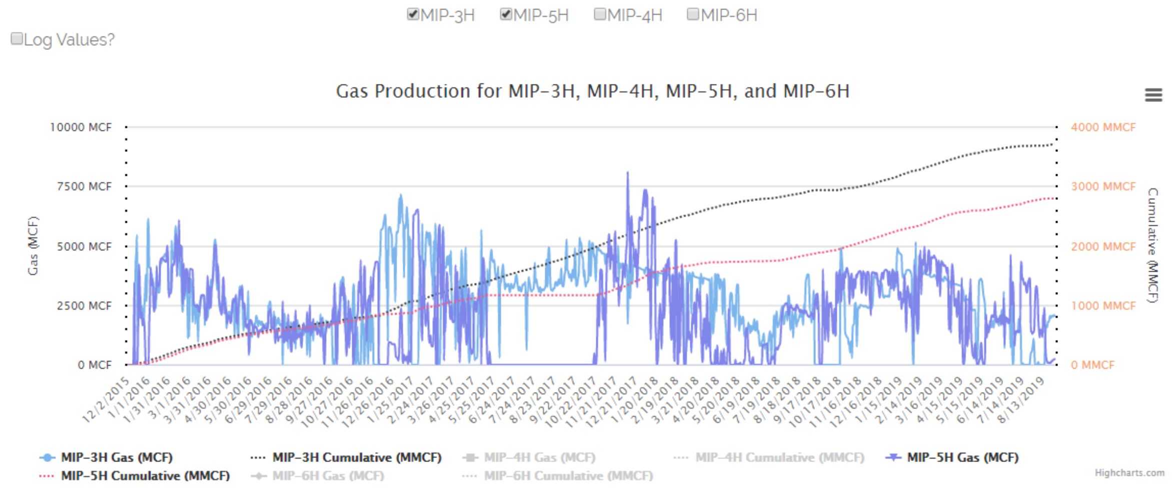
Environmental Reports

Data on Air, Water, and Noise

Well Datasets

Data from all the MSL wells including MIP 3H, 5H, 4H, and 6H plus microseismic as recorded in the MIPSW

Figure 7.2: All data generated by the MSEEL project is available for download at http://mseel.org/.



Water Production

Download Water Production Data (all wells)

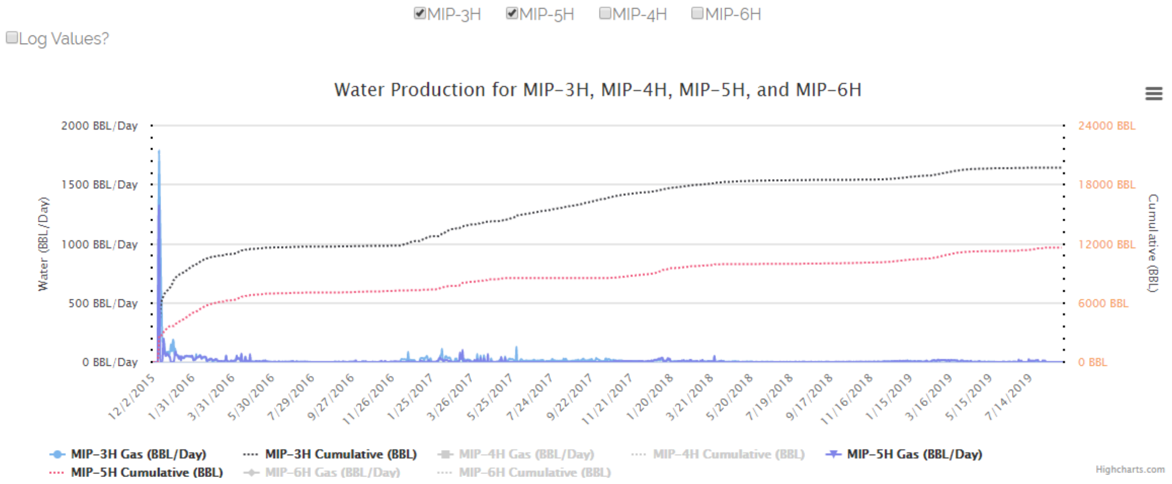


Figure 7.3: Gas and water production have been updated through the end of the quarter and are available at http://mseel.org/.

Results & Discussion

Data and publications are now available at http://mseel.org/.

Products

Web site enhanced and updated.

Plan for Next Quarter

Working to add data from the new Boggess Pad and prepare for production data.

Topic 8 – Economic and Societal

This task is complete and will not be updated in future reports.

Cost Status

Year 1

Start: 10/01/2014 End: 09/30/2019

Baseline Reporting Quarter

	Q1 (12/31/14)	Q2 (3/31/15)	Q3 (6/30/15)	Q4 (9/30/15)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share	$549,000		$3,549,000	
Non-Federal Share	$0.00		$0.00	
Total Planned (Federal and Non-Federal)	$549,000		$3,549,000	
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$0.00	$14,760.39	$237,451.36	$300,925.66
Non-Federal Share	$0.00	$0.00	$0.00	$0.00
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$0.00	$14,760.39	$237,451.36	$300,925.66
Cumulative Incurred Costs	$0.00	$14,760.39	$252,211.75	$553,137.41
Uncosted				
Federal Share	$549,000	$534,239.61	$3,296,788.25	$2,995,862.59
Non-Federal Share	$0.00	$0.00	$2,814,930.00	$2,814,930.00
Total Uncosted - Quarterly (Federal and Non-Federal)	$549,000	$534,239.61	$6,111,718.25	$5,810,792.59

Start: 10/01/2014 End:
09/30/2019

Baseline Reporting Quarter

	Q5 (12/31/15)	Q6 (3/31/16)	Q7 (6/30/16)	Q8 (9/30/16)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share	$6,247,367		$7,297,926	
Non-Federal Share	2,814,930		$4,342,480	
Total Planned (Federal and Non-Federal)	$9,062,297	$9,062,297.00	$11,640,406	
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$577,065.91	$4,480,939.42	$845,967.23	$556,511.68
Non-Federal Share	$0.00	$2,189,863.30	$2,154,120.23	$0.00
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$577,065.91	$6,670,802.72	$3,000,087.46	$556,551.68
Cumulative Incurred Costs	$1,130,203.32	$7,801,006.04	$10,637,732.23	$11,194,243.91
Uncosted				
Federal Share	$5,117,163.68	$636,224.26	$1,004,177.30	$447,665.62
Non-Federal Share	$2,814,930.00	$625,066.70	($1,503.53)	($1,503.53)
Total Uncosted - Quarterly (Federal and Non-Federal)	$2,418,796.68	$1,261,290.96	$1,002,673.77	$446,162.09

Start: 10/01/2014 End: 09/30/2019

Baseline Reporting Quarter	Q9 (12/31/16)	Q10 (3/31/17)	Q11 (6/30/17)	Q12 (9/30/17)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share				$9,128,731
Non-Federal Share				$4,520,922
Total Planned (Federal and Non-Federal)				$13,649,653
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$113,223.71	$196,266.36	$120,801.19	$1,147,988.73
Non-Federal Share	$0.00	$0.00	$0.00	$0.00
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$113,223.71	$196,266.36	$120,801.19	$1,147,988.73
Cumulative Incurred Costs	$11,307,467.62	$11,503,733.98	$11,624535.17	$12,772,523.90
Uncosted				
Federal Share	$334,441.91	$138,175.55	$17,374.36	$700,190.63
Non-Federal Share	($1,503.53)	($1,503.53)	($1,503.53)	$176,938.47
Total Uncosted - Quarterly (Federal and Non-Federal)	$332,938.38	$136,672.02	$15,870.83	$877,129.10

Start: 10/01/2014 End: 09/30/2019

Baseline Reporting Quarter	Q13 (12/31/17)	Q14 (3/31/18)	Q15 (6/30/18)	Q16 (9/30/18)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share				$11,794,054
Non-Federal Share				$5,222,242
Total Planned (Federal and Non-Federal)				$17,016,296.00
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$112,075.89	$349,908.08	$182,207.84	$120,550.20
Non-Federal Share	$0.00	$31,500.23	$10,262.40	$4,338.00
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$112,075.89	$381,408.31	$192,470.24	$124,888.20
Cumulative Incurred Costs	$12,884,599.79	$13,266008.10	$13,458,478.34	$13,583,366.54
Uncosted				
Federal Share	$588,114.74	$238,206.66	$55,998.82	$2,600,771.62
Non-Federal Share	$176,938.47	$145,438.24	$135,175.84	$832,157.84
Total Uncosted - Quarterly (Federal and Non-Federal)	$765,053.21	$383,644.90	$191,174.66	$3,432,929.46

Start: 10/01/2014 End: 09/30/2019

Baseline Reporting Quarter	Q17 (12/31/18)	Q18 (3/31/19)	Q19 (6/30/19)	Q20 (9/30/19)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share			$15,686,642.00	
Non-Federal Share			$9,180,952.00	
Total Planned (Federal and Non-Federal)			$24,867594.00	
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$80,800.03	$133,776.98	$714,427.48	$1,136,823.21
Non-Federal Share	$4,805.05	$130,449.21	$4,099,491.20	$334,919.08
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$85,605.08	$264,226.19	$4,813,918.68	$1,471,742.29
Cumulative Incurred Costs	$13,668,971.62	$13,933,197.81	$18,747,116.49	$20,218,858.78
Uncosted				
Federal Share	$2,519,971.59	$2,386,194.61	$5,564,355.13	$4,427,531.92
Non-Federal Share	$827,352.79	$696,903.58	$412,612.38	$221,203.30
Total Uncosted - Quarterly (Federal and Non-Federal)	$3,347,324.38	$3,083,098.19	$5,976,967.51	$4,648,735.22

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