

**Office of Water Programs
The University of Wyoming**

**Annual Technical Report
2019**

Products

1. Drogos, D.L., Nye, C., Quillinan, S., Urynowicz, M.A., Wawrousek, K., “Microbial communities in oil and gas produced water from unconventional wells in the Powder River, Wind River, and Green River Basins, Wyoming,” manuscript in preparation. (Project 2019WY96B)
2. Drogos, D.L., Nye, C., Quillinan, S., Urynowicz, M.A., Wawrousek, K., “Differing Microbial Communities from Similar Deep Subsurface Environments in Two Unconventional Oil Wells in the Wyoming Powder River Basin,” manuscript in preparation. (Project 2019WY96B)
3. Fan, Maohong and Andrew T. Jacobson: “Multifunctional Titanium Oxyhydroxide – A New Inexpensive, Effective and Environmentally Friendly Candidate for Resolving a Challenging Water Quality Issue: High Alkalinity” has been patented—provisional. (Project 2019WY97B)
4. Huang, Zaixing, Xin He, Charles Nye, David Bagley, Michael Urynowicz, M. Fan. “Anaerobic treatment and energy recovery of produced water from petroleum production using activated sludge from a brewery wastewater treatment facility”*Journal of Hazardous Materials*, vol 407 5 April 2021. <https://doi.org/10.1016/j.jhazmat.2020.124348>. (Project 2019WY96B)
5. Jacobson, A., et al. (2019) Evaluation of natural goethite on the removal of arsenate and selenite from water, *Journal of Environmental Sciences*, Vol. 76, No. 2, PP 131-141. (Project 2019WY97B)
6. Mazzetti, T, 2019: “Climatology of Favorable Conditions for Ground Based Cloud Seeding In the Wind River Range”. MS Thesis, Publication 22621623. Available through ProQuest (<https://search-proquest-com>). (Project 2018WY95B)
7. Mazzetti, T. , B. Geerts, L. Xue, S. Tessoroff, and R. Rasmussen, 2021: Changes in glaciogenic seeding opportunities over mountains in the Interior Western US in a warming climate. *J. Appl. Meteor. Climat.* Submitted, in review, major changes required. (Project 2018WY95B)
8. Nye, C. “New Data from an Old Well: Changes in the Chemistry of Runoff Geothermal Well Water,” April 2020, World Geothermal Congress 2020. <https://pangea.stanford.edu/ERE/db/WGC/papers/WGC/2020/14005.pdf>. (Project 2019WY96B)
9. Rath, P. and K.M. Befus (2019), Impacts of Reservoir Stage Fluctuations on Groundwater Dynamics, Presentation at the American Geophysical Union Fall Meeting, Dec 2019. <https://ui.adsabs.harvard.edu/abs/2019AGUFM.H41K1854R/abstract>. (Project 2018WY94B)
10. Rath, P. and K.M. Befus (2018), Estimating Changes In Bank Storage and Groundwater Movement Due to Reservoir Level Variations, Presentation at the Wyoming Water Association, Oct 26th, 2018. (Project 2018WY94B)
11. Shahabadi, Mahdi, Jonathan Brant, Slippery Nanofibrous Membrane to Mitigate Scaling and Enhance Flux in Membrane Distillation (MD) for Treatment of Produced Water. Under Preparation. (Project 2019WY96B)
12. Shahabadi, Mahdi, Jonathan Brant, Membrane Distillation as a Viable Option for Desalination of Highly Saline Oil/Gas Produced Waters. Under Preparation. (Project 2019WY96B)
13. Wawrousek, K, C. Nye, D. Astling, D. Drogos, S. Quillinan, “Comparative Analysis of Microbial DNA Isolated from Unconventional Wells of the Powder River and Greater Green River Basins.” submitted. (Project 2019WY96B)

Information Transfer Program

Project 2015WY90B, PI: Kerr

Office of Water Program interacts with various State and Federal groups. After March of 2020 activities were performed on Zoom. These included: 9 Wyoming Water Forums, 6 Wyoming Water Association Board meetings, co-sponsor of the annual Wyoming Water Association Conference, 1 Wyoming Water Association Tour, 3 Water Legislative committees, 7 Wyoming Water Development Commission/Select Water Committee meetings, 1 Wyoming Water Development Commission/Select Water Committee tour, 3 meetings as Advisor to the Wyoming Weather Modification Program, 2 National meetings, and 2 Water Program Planning Advisory Committee sessions. The WRP supports other technology and information transfer activities throughout the year. In order to facilitate dissemination of results of WRP funded research projects, and other closely related water research projects, information transfer includes support of peer publications and conference and meeting presentations for PIs and students of ongoing and completed WRP funded research projects and other closely related projects. Project activities included: one public GitHub data repository, and one public GitHub modeling repository of Project 2018WY94B, four public media interviews, six oral presentations, and one poster presentation by participants of Project 2018WY95B, four stakeholder reports, three poster presentations, and two oral presentations by participants of Project 2019WY96B, and two presentations by participants of Project 2019WY97B. The OWP maintains a website posting the most recent request for proposals and project reports.

Project 2018WY94B, PI: Befus

We have created a GitHub repository for all of the work produced as part of this research project (https://github.com/kbefus/wy_gwres). The repository is publicly available and will be updated as we continue to process the field data. It already contains the bulk of the Python code and the raw field datasets. A separate repository will be made for the generic modeling study to support the journal article, and a link to that new repository will be added to the main project repository. Two journal articles are currently in preparation with submissions planned in early and late 2021.

Project 2018WY95B, PI: Geerts

The following presentations have been given at conferences, seminars, and working group meetings:

- Mazzetti, Geerts and Xue, 2019: Climatology of Favorable Conditions for Ground Based Cloud Seeding In the Wind River Range. Oral presentation at the Weather Modification Association (WMA) annual meeting, April '19, Phoenix AZ (presented by Mazzetti)
- Dept of Atmospheric Science seminar, April '19 (Mazzetti)
- How frequently is the Wind River Range a suitable target for ground-based and airborne seeding? Presentation at the Wyoming Weather Modification Technical Advisory Team (TAT) meeting of summer '19, Saratoga (Geerts)
- Xue, Mazzetti, and Geerts 2019: "Glaciogenic cloud seeding potential of cold-season orographic clouds in a warming climate over the mountains in western Wyoming". Oral presentation at the American Geophysical Union (AGU) Fall meeting: <https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/508901> (presented by Xue)
- Mazzetti, Geerts, and Xue, 2020: "Potential of Glaciogenic Seeding of Cold-Season Orographic Clouds in a Warming Climate". Poster presentation at the American Meteorological Society (AMS) Annual Meeting: <https://ams.confex.com/ams/2020Annual/meetingapp.cgi/Paper/364049> (presented by Mazzetti)
- Mazzetti, Geerts, and Xue, 2020: "Potential of Glaciogenic Seeding of Cold-Season Orographic Clouds in a Warming Climate". To be presented at the Weather Modification Association (WMA) annual meeting in 2021 (online or in Corpus Christi TX).
- Mazzetti, et al. 2020: "Potential of Glaciogenic Seeding of Cold-Season Orographic Clouds in a Warming Climate". Virtual oral presentation at the American Meteorological Society (AMS) 19th

Mountain Meteorology Conference, July 13-17. Available at <https://ams.confex.com/ams/19Mountain/meetingapp.cgi/Paper/376318>

The TAT meetings are attended by representatives from state and federal agencies, and are open to the public. The WMA meetings are attended by weather modification operators and cloud seeding researchers. The AMS and AGU audiences are very diverse.

Public outreach presentations, contributions to popular science magazines, interviews with the media:

- Mazzetti (October 2019): “Potential of Glaciogenic Seeding of Cold-Season Orographic Clouds in a Warming Climate”.
- Public education/outreach, informal “Science on Tap” presentation (October 2019).
- Geerts and others (18 Jan 2020): interview with the Durango Herald, Colorado
- Geerts, Xue (3 Feb 2021): interview for Le Temps (www.letemps.ch), which is one of Switzerland's leading daily newspapers, on cloud seeding efficacy.
- Geerts (28 Feb 2021): interview for Science et Vie (<https://www.science-et-vie.com/>), a French magazine

Project 2019WY96B, PI: Nye

- A report on their samples and a thank you letter were sent to all four sample set providers.
- Mahdi Shahabadi, PhD candidate in civil & architectural engineering, published and presented a poster at the Wyoming Water Association Annual Meeting and Educational Seminar (October 26, 2018) titled “Nano-Filtration for Treatment of Produced Water and Rare Earth Element Pre-Concentration”. Mahdi Shahabadi was advised by Dr. Jonathan Brant and during the 2018-2019 school year, was funded through this project.
- Nye, Charles and Mahdi Shahabadi (2019) Water Chemistries Associated with Light and Heavy Oils in the Powder River Basin and Laramie Basin, Wyoming. GSA Abstracts with Programs. 51(5). <http://dx.doi.org/10.1130/abs/2019AM-339606>
- Aspen Golding, an undergraduate in chemical engineering, published and presented a poster at University of Wyoming’s Undergraduate Research Day (April 27, 2019) titled “Microbial Communities Composition in Water Samples from a Geothermal Well”. Aspen Golding is advised by Dr. Karen Wawrousek, and co-advised by Charles Nye.
- Nunzio Carducci, an undergraduate in chemical engineering, published and presented a poster at a meeting of the Rocky Mountain Branch of the American Society of Microbiology (May 4, 2019) titled “Microbial Community Composition in Water Samples from a Geothermal Well”. Nunzio Carducci is advised by Dr. Karen Wawrousek, and co-advised by Charles Nye.
- Donna Drogos, a PhD candidate in civil & architectural engineering, presented “Biogeochemistry of Produced Water from Unconventional Wells in the Powder River Basin, Wyoming,” at the Rocky Mountain Geobiology Symposium, Golden, CO, (April 7, 2018). Donna Drogos is advised by Dr. Michael Urynowicz and received samples and data as part of this project.
- Donna Drogos also presented “Microbial Community Analysis of Produced Water from Hydraulically Fractured Wells in Wyoming” at the Laramie Engineers Club, Laramie, WY, (May 17, 2019). Donna Drogos is advised by Dr. Michael Urynowicz and received samples and data as part of this project.

Project 2019WY97B, PI: Fan

The team has been using publication as the major way for the information transfer activities and knowledge dissemination. Two papers have been published. Also, we planned to attend a water conference. Due to the uncertain characteristics of the time, the plan was canceled.

Student Support

Undergraduate – 7

Graduate – 7

PhD – 1

Notable Achievements and Awards

Project 2018WY94B, PI: Befus

P. Rath passed his PhD qualifying exam in Spring 2019 and preliminary exam in Spring 2021.

Project 2018WY95B, PI: Geerts

Thomas Mazzetti was a recipient of the 2018 North American Weather Modification Council student award, which supported his presentation at the 2019 WMA meeting.

Thomas Mazzetti passed the preliminary examination in January 2021, admitting him to PhD candidacy.

Project 2019WY96B, PI: Nye

The Poster presented by Nunzio Carducci was awarded second place at the Rocky Mountain Branch of the American Society of Microbiology meeting.

Zaixing's work showed that combination of very low oxygen content produced water and an inoculant derived from beer-brewing sludge resulted in a 89% reduction in total organic carbon, and also production of methane equal to 65.9% of the theoretical yield. This performance was achieved without any added nutrients, pH adjustment, nor energy input other than holding the mixture at 30 degrees C in the dark.

Project 2019WY97B, PI: Fan

Project award from US DIA: The results obtained from the project are helpful to the project awarded to the collation team consisting of the members from New Mexico Institute of Mining and Technology and University of Wyoming. The project is focused on removal of contaminants (including organic and inorganic materials) in the waters including produced waters. The total support for the project from the U.S. Department of the Interior is \$350k.

Dr. Jacobson supported by the project has grown into a great water research expert. He can not only independently do water research projects but also successfully write research papers. He has mastered various water research skills including water research instruments. More importantly, he has learned various water and waste water treatment technologies, and will be very valuable to society and development of Wyoming's economy.

Lia Anjani Tan, an undergraduate at UW, trained with the project, is teaching high-school students in Cheyenne of Wyoming. The knowledge she gained from the project are very helpful to the expansion of the STEM knowledge of the K-12 students in the school.

Developing A Framework For Estimating Groundwater Connections To Wyoming Reservoirs

Project Type: Annual Base Grant

Project ID: 2019WY283B

Project Impact:

Our study provides both general and specific insights into how groundwater interacts with and responds to changing water levels in reservoirs. With the generic modeling study, we identify combinations of hydrologic and topographic conditions that are likely to create the supporting environment for groundwater seepage, and we show how varying the water level of a reservoir can affect these relationships. Importantly, these sites with groundwater seepage are also where fringe wetlands are most likely to be located, and the models can help to set the water level range over which these wetlands would be kept wet by active groundwater seepage. Maintaining and managing the water levels in reservoirs with seepage wetlands for the conditions identified in our generic modeling study could set the limits for resilient wetlands and be used as both a management and design tool. This generic modeling is a diagnostic tool that can be used to identify which systems may be most at risk in times of drought, though the method is not sufficiently complex to provide all of the information. We also conducted the fieldwork and more detailed modeling for WYHRR2. As we continue to finalize our datasets and analyses for WYHRR2, we will create a case study for how to monitor and manage combined reservoir water levels to maximize groundwater storage. In drought, we will quantify how this additional groundwater storage is discharged back to the reservoir, leading to some amount of time where the groundwater discharge will offset the effects of the drought.

Numerical Simulations Of The Impact Of Cloud Seeding In The Wind River Range On Precipitation, Snowpack, And Streamflow

Project Type: Annual Base Grant

Project ID: 2019WY284B

Project Impact:

We are using the WRF model with weather modification module (Xue et al. 2013), as well as WRF Hydro, to simulate the impact of 10 years of operational ground-based cloud seeding over the Wind River Range (WRR) on snowfall, the snowpack, and seasonal runoff. Our key preliminary finding is that the seeding impact is positive, and that 90% of the snowfall enhancement resulted from just over 10% of the cases, i.e. the AgI-induced yield is much higher in some winter storms than in others. The “good” cases were marked by a high supercooled liquid water (SLW) content in the clouds, which must be measured more extensively (Mazzetti et al. 2022., in preparation). Mazzetti (2019) used our 30-year regional climate simulation (Wang et al. 2018) to characterize the natural snowfall over the WRR, and to identify conditions that are suitable for cloud seeding. We find that about 50% of the natural precipitation can be seeded over the WRR. Of that, 80% is seedable from the ground; the other 20% requires a seeding aircraft, since the AgI nuclei from the ground generators remain at low levels, unable to be lofted over the mountain because the low-level flow is blocked. Mazzetti et al. (2021) broadened this study by quantifying the feasibility of glaciogenic seeding to enhance precipitation for all mountain ranges in the interior western US. This study also predicts a significant reduction in seedability in the interior Pacific Northwest, but little reduction over the mountains in Colorado and Wyoming by ~2050.

Statement of COVID-19 impact on research:
The COVID-19 pandemic resulted in a ~9 month delay in the submission of the paper Mazzetti et al. (2021), on account of a number of issues, including access to large data files from home, disruptions in the computer based daily work flow, adaptation to a drastically different lifestyle, altogether resulting in reduced productivity. Also, planned visits to NCAR facilities for training and collaboration with coauthors/collaborators were canceled, and conducted remotely, which was less valuable and less efficient a learning experience. Finally, we intended to present at conferences that ended up being canceled or were held online, namely the 2020 WMA meeting (postponed), 2020 ICCP meeting in Pune, India (postponed), and 2020 AMS Mountain Met Conference (online presentation).

Treatment Of Produced Water And Rare Earth Element Resource Cost-offsets, Wyoming

Project Type: Annual Base Grant

Project ID: 2019WY285B

Project Impact:

This work produced four sample sets using the same methods and procedures. By sharing these methods and procedures with the “PRB” work which inspired this study, we generated a very large body of data which can be readily compared internally.

These data have already produced presentation and publication opportunities for the students involved, and are expected to be used by future students to continue generation of new findings. For example: the NF experiments have shown that NF membranes in flow-by orientation are resistant to fouling by oil droplets and salts in produced waters. This and the evidenced reduction in salt content suggests that NF could be used in serial configuration to produce a water of arbitrarily high quality, if adequate pressure can be supplied.

The team’s past history of working together reduced the challenges of SARS- CoV-2. This was possible in large part to the familiarity the team members had from past projects together, and joint understanding of other team member’s workflow. Future work using this team could continue to benefit from that familiarity.

This work provides many opportunities for future work. The data are suitable for many visualization and statistical testing methods. The data could be resampled in the future to learn which change over time has occurred over the years between the inspirational “PRB” study, this study, and the resampling study. Future partnership with a University of Wyoming expert in extractive chemistry could attempt to electrowin or extract REEs from the NF-concentrate solution.

Recycling Co-produced Waters (CWS) In The Energy Industry For Economic Development

Project Type: Annual Base Grant

Project ID: 2019WY286B

Project Impact:

The proposed project has been focused on investigation of the research has been focused on removal of organic and inorganic materials in waters discharged by energy industry. The produced waters contain extremely high chemical oxygen demand (COD) and total organic carbon (TOC). Conventional technologies used for removal of the contaminants are not only expensive but also generate secondary pollutions. Transformative technologies are needed in this R&D area. This project is designed to overcome the challenges.

Economic and environmental impacts:

Energy is the backbone of economic development. Before affordable renewable energies become widely available, fossil fuel-based energies will still dominate our lives due to their advantages, although their disadvantages are obvious also and among them is the generation of large amount of water with high concentrations of pollutants. The success in the treatment of the produced waters will not only be beneficial to environmental quality but also economy because the water treatment technology can help employment.