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NORTH DAKOTA
Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

PRODUCED WATER MANAGEMENT THROUGH GEOLOGIC HOMOGENIZATION, CONDITIONING, AND REUSE (STAGE 1)

Presented to Oil & Gas Research Council
Bismarck, North Dakota
December 9, 2019

Jim Sorensen
Director of Subsurface R&D

ADVISORY PARTNERS ENGAGED THROUGH THE EERC LEAD BAKKEN PRODUCTION OPTIMIZATION PROGRAM

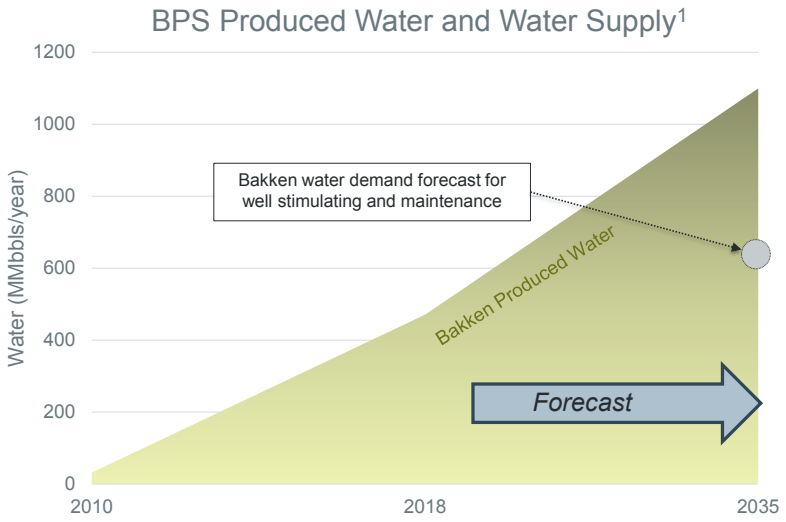
7 of top 10 Williston Basin Producers

AN EMERGING ISSUE

Produced water management (including flowback water) represents a significant economic and technical challenge for oil and gas production.

Produced water volumes associated with Bakken petroleum system (BPS) production in North Dakota have increased dramatically since 2010.[1]

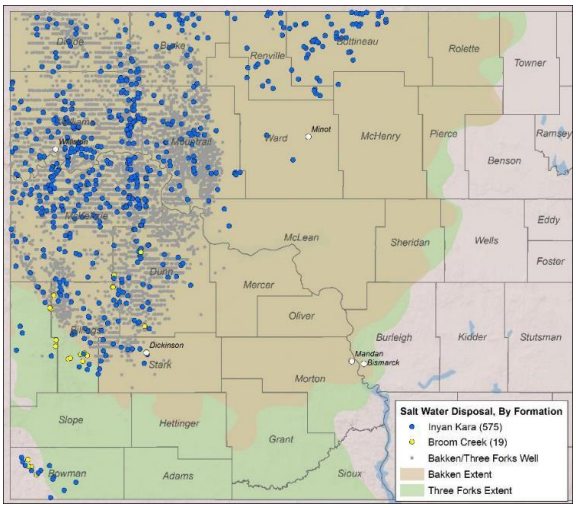
Freshwater demand is projected to surpass 700 million barrels by 2035.



[1] Kurz, B.A., Stepan, D.J., Glazewski, K.A., Stevens, B.G., Doll, T.E., Kovacevich, J.T., and Wocken, C.A., 2016, A review of Bakken water management practices and potential outlook: Final report for members of the Bakken Production Optimization Program, EERC Publication 2016-EERC-03-11, Grand Forks, North Dakota, Energy & Environmental Research Center, March.

THE CHALLENGE

- ND saltwater disposal (SWD) is already resulting in localized areas of high pressure in the Inyan Kara.
  - >95% of SWD occurs in Inyan Kara Formation.
  - Impacts economics and risk associated with oil and gas development.
    - Intermediate casing string increases drilling cost by $300–$700k per well due to Inyan Kara pressurization.
    - Sufficient capacity to continue to meet SWD demand?
- Produced water treatment and reuse is constrained by:
  - Variability and extremely high salinity
    - ~ 250,000–350,000 mg/L TDS fluids.
  - Large volume surface storage is challenged/constrained.
    - Regulatory and environmental considerations w/ attendant costs.



GHCR CONCEPT

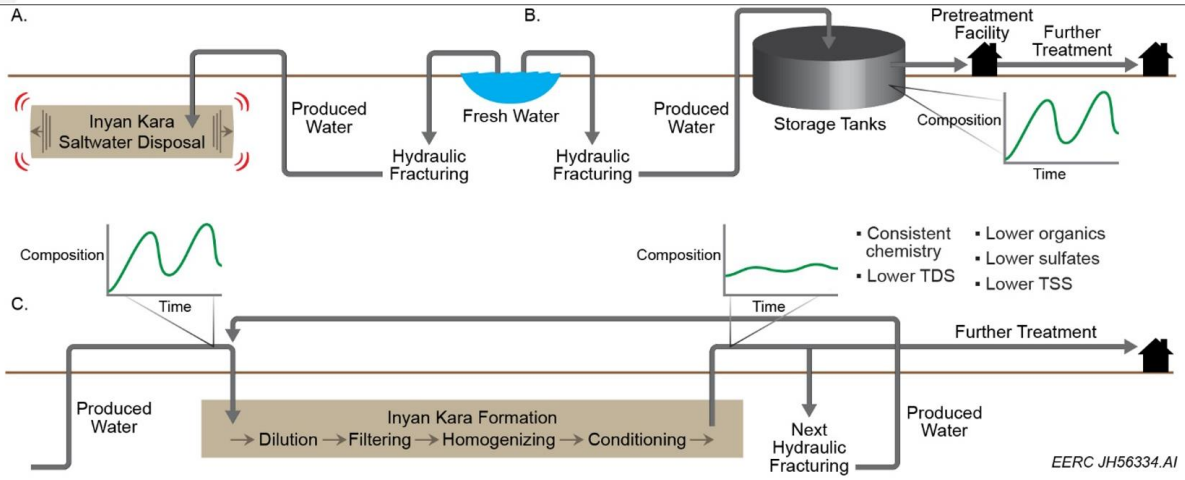


*Figure 1. A) Current approach to SWD; results in pressurization. B) Traditional approach to produced water treatment; requires large-volume storage on surface, challenged by variable water chemistry. C) G*eologic homogenization, conditioning, and reuse *(GHCR) concept; circumvents limitations of A and B.*

KEY ELEMENTS OF THE PROJECT

- EERC will evaluate the efficacy of the physical and geochemical filtering, conditioning, and homogenization processes provided by the Inyan Kara Formation through a series of laboratory, modeling, and simulation activities.
- The GHCR concept will be validated and the modeled performance calibrated by using an existing field laboratory at the Nuverra-operated Johnsons Corner SWD site, host to a DOE-funded brine extraction and storage test (BEST) site.
- An inventory of Bakken produced water and Inyan Kara water compositions present throughout the Williston Basin will inform laboratory studies that evaluate the efficacy of the Inyan Kara Formation for GHCR considering water chemistry variability. The results will provide further calibration of modeled performance to inform the techno-economics of the GHRC concept.

ACTIVITY 1 – PRODUCED WATER ASSESSMENT

- The EERC will update a 2016 Bakken Water Management Practice report[1].
  - Conduct an assessment characterizing the variability and distribution of Inyan Kara formation water and Bakken produced water quality in North Dakota.
  - The assessment will incorporate available water composition data provided by project partners, supplemented by the collection and analysis of water samples from partner locations.
- The EERC will engage with project partners to evaluate produced water management methods and costs;
  - Economic, regulatory, and technological considerations for water recycling and reuse applications.

ACTIVITY 2 – FIELD AND LABORATORY VALIDATION

The GHCR concept will be validated by using the Nuverra-operated, EERC-led Johnsons Corner SWD site, host to a DOE-funded Brine Extraction and Storage Test (BEST) site.

- Bakken produced water injected into the Inyan Kara through two SWD wells.
- Actively extracting water that has migrated through the Inyan Kara from a well approximately 1300 feet away as part of a field test of brine extraction as a strategy for pressure management for CO_2 storage.
- Characterization of produced water being injected into the SWD wells relative to the extracted water that has migrated through the Inyan Kara will be used to verify and validate GHCR.

GHCR performance will be benchmarked to several traditional treatment systems (e.g., thermal, chemical, membrane) that are being operated at the brine treatment test bed as part the DOE-funded BEST project.

Bakken and Inyan Kara water samples will be used in combination with Inyan Kara outcrop rock samples (collected near Spearfish, SD) to evaluate performance of GHCR relative to the variability in water chemistry, as well as variability in Inyan Kara rock mineralogy.

ACTIVITY 3 – GHCE TREATMENT SIMULATION

The EERC will use modeling and simulation to evaluate the efficacy, performance, and longevity of the GHCR concept using geologic and geochemical models calibrated with the results of Activities 1 and 2.

A range of implementation scenarios will be evaluated to assess commercial GHCR strategies.

The implementation scenarios will be evaluated based on several factors, including

- Spacing of injection/extraction wells.
- Injection/extraction rates compared to the effectiveness and performance of GHCR treatment.
- The impact of GHCR on the magnitude and extent of reduction in formation pressure.

Results will inform a techno-economic assessment.

ACTIVITY 4 – TECHNO-ECONOMIC ASSESSMENT

Building off the results from Activities 1–3, the EERC will assess the techno-economic viability of commercial GHCR applications for a range of implementation strategies.

Relevant technical, economic, regulatory, and financial considerations affecting commercial adoption of GHCR will be examined.

Technical, regulatory, and financial barriers that influence commercial adoption throughout North Dakota will be identified.

Relevant findings and results will be presented in the draft (D3) and final (D4) GHCR techno-economic reports.

POTENTIAL BENEFITS OF GHCR

- Reduce net SWD.
- Reduce magnitude and rate of pressurization in disposal zone:
  - Extended life of SWD wells.
  - Reduced oil and gas development costs associated with pressurization.
- Provide means of displacing freshwater demand, assuring water supply in event of future curtailments on water appropriations.
- Employs existing infrastructure.
- Enables large-volume storage and limitless supply of consistent-quality water for reuse.

GHCR deployed at scale could provide an **innovative solution** to the emerging challenge of Inyan Kara pressurization that will likely contribute to of $**1.5 to $10 billion*** in increased costs for Bakken development and SWD in the Williston Basin.

**If 20% of the projected remaining Bakken development is impacted by Inyan Kara pressurization.*

WHY THE PROJECT IS NEEDED

While the GHCR concept appears promising, commercial demonstration and adoption require diligent evaluation, technical validation, and the techno-economic feasibility information that the proposed Stage I effort will provide.

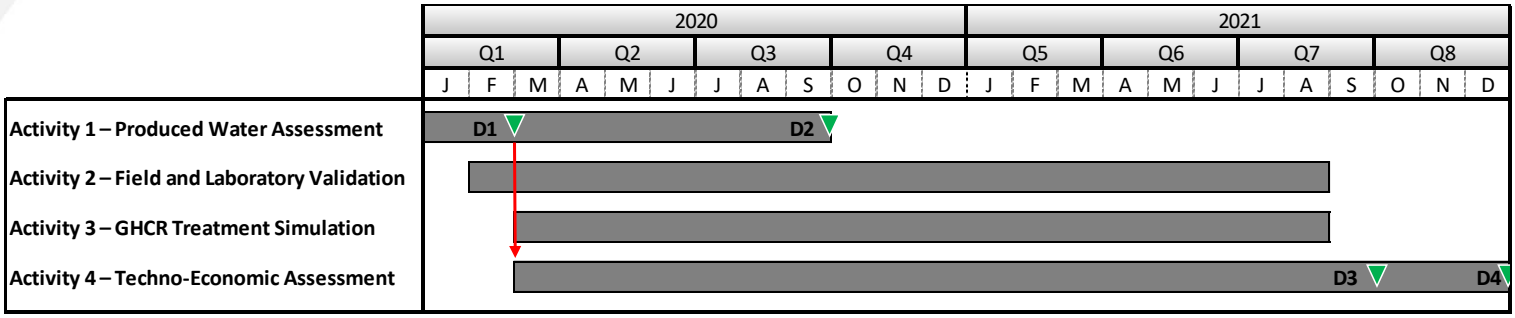
Lacking an imminent threat to produced water management practices in North Dakota, the proposed efforts are unlikely to be undertaken until such a threat (e.g., constraint on SWD injection, freshwater limitations, pervasive pressure impacts, and inflated drilling costs) are present.

The proposed effort provides foundational knowledge to enable prudent development and implementation of next-generation, sustainable produced water management practices that can be adapted for application in North Dakota.

PROVISIONAL SCHEDULE AND BUDGET

EERC intends to secure DOE cost share through its Cooperative Agreement. Once the EERC has commitment from NDIC, the EERC will submit a proposal to DOE for its concurrence.

Project Associated Expense	NDIC Share (Cash)	DOE Share (Cash)	Total Project
Total Project Costs	$ 300,000	$ 999,993	$ 1,299,993



Stage IA

D1 – Water Management Practice Update

D2 – Water Quality Assessment Report

Stage IB

D3 – GHCR Techno-Economic Draft Report

D4 – GHCR Techno-Economic Final Report

Activity Duration

Critical Path

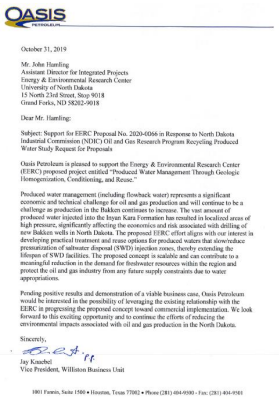
ANTICIPATED RESULTS

- A Stage IA produced water assessment final report.
- Stage IB final report of findings from laboratory and field validation, including a techno-economic assessment.
  - Technical
  - Economic
  - Regulatory
  - Financial
  - Scientific
- Technological considerations governing commercial viability of the GHCR concept.
- Will inform development of prudent rules for implementation (e.g. water appropriation, temporary storage, etc.)

Pending a favorable techno-economic disposition, the proposed Stage I effort will provide the requisite information and confidence for project partners to progress the GHCR concept to a Stage II pilot demonstration of beneficial end use of GHCR water.

Pending additional funding for Stage II made available through the NDIC OGRP, DOE and/or industry investment .

The Stage II pilot would use GHCR water supplied by the Inyan Kara extraction well for hydraulic fracturing to produce the field performance data for the end use of GHCR water to further inform commercial implementation.



OASIS PETROLEUM

October 31, 2019

Mr. John Hamling
Assistant Director for Integrated Projects
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Mr. Hamling:

Subject: Support for EERC Proposal No. 2020-0066 in Response to North Dakota Industrial Commission (NDIC) Oil and Gas Research Program Recycling Produced Water Study Request for Proposals

Oasis Petroleum is pleased to support the Energy & Environmental Research Center (EERC) proposed project entitled "Produced Water Management Through Geologic Homogenization, Conditioning, and Reuse."

Produced water management (including flowback water) represents a significant economic and technical challenge for oil and gas production and will continue to be a challenge as production in the Bakken continues to increase. The vast amount of produced water injected into the Inyan Kara Formation has resulted in localized areas of high pressure, significantly affecting the economics and risk associated with drilling of new Bakken wells in North Dakota. The proposed EERC effort aligns with our interest in developing practical treatment and reuse options for produced waters that slow/reduce pressurization of saltwater disposal (SWD) injection zones, thereby extending the lifespan of SWD facilities. The proposed concept is scalable and can contribute to a meaningful reduction in the demand for freshwater resources within the region and protect the oil and gas industry from any future supply constraints due to water appropriations.

Pending positive results and demonstration of a viable business case, Oasis Petroleum would be interested in the possibility of leveraging the existing relationship with the EERC in progressing the proposed concept toward commercial implementation. We look forward to this exciting opportunity and to continue the efforts of reducing the environmental impacts associated with oil and gas production in the North Dakota.

Sincerely,

Jay Knaebel
Vice President, Williston Business Unit

1001 Fannin, Suite 1500 • Houston, Texas 77002 • Phone (281) 404-9500 - Fax: (281) 404-9501

HESS

October 31, 2019

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Assistant Director for Integrated Projects
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
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Sincerely,

Brent Lohnes
Hess Corporation
General Manager – North Dakota

ConocoPhillips

equinor

HESS

LIBERTY RESOURCES

Marathon Oil

North Dakota oil & gas research program

OASIS PETROLEUM

PETRO-HUNT L.L.C.

WPXENERGY

XTO ENERGY

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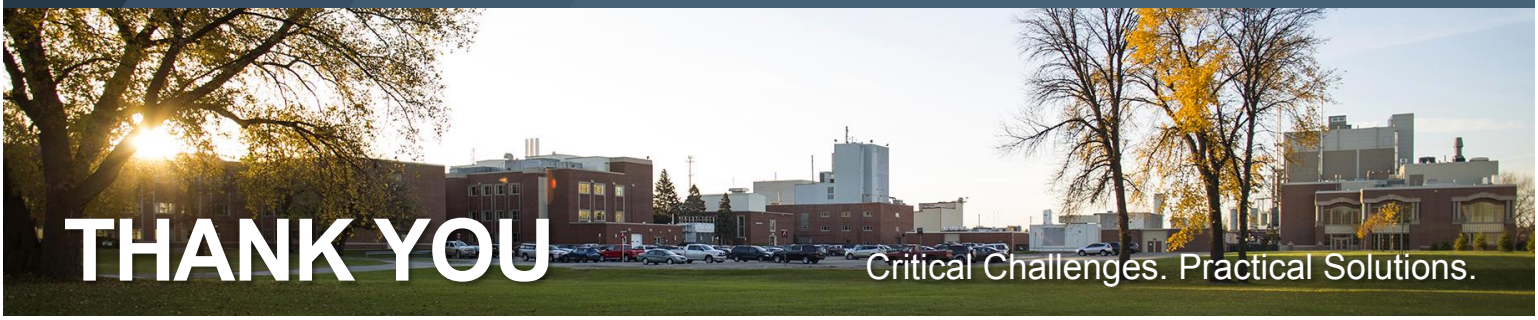


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