Executive Summary

Water is closely intertwined with oil and gas production, including **sourced water** (water supplied to support operations) and **produced water** (formation water brought to the surface during well completion and oil and gas production). Determining how to find sourced water and manage produced water efficiently and cost effectively is an important component of producing oil and gas. Produced water can be managed within an individual lease area or over a larger field that incorporates many wells and leases and extends over more than one county, river basin, or state.

In a 2015 Ground Water Protection Council (GWPC) report, which analyzed 2012 data, about 45 percent of produced water was used within conventional oil and gas enhanced recovery operations, leaving about 55 percent to be disposed of in permitted underground injection control (UIC) wells with a small percentage managed in other ways including evaporation and discharge.

Produced water varies widely in quality. Most produced water is highly saline and may contain a mix of mineral salts; organic compounds; hydrocarbons, organic acids, waxes, and oils; inorganic metals and other inorganic constituents; naturally-occurring radioactive material; chemical additives; and other constituents and byproducts.

GWPC recognizes that, as fresh water resources become more constrained, the ability to use produced water to offset freshwater demands both inside and outside of oil and gas operations will offer opportunities and challenges. This report is part of an effort by the GWPC to work with a variety of stakeholders to identify those opportunities and challenges and provide suggestions that policy makers, researchers, regulators, and others can use to address them. To that end, the report focuses on three key areas:

- Regulatory and legal frameworks for produced water reuse
- Current and future potential for produced water reuse in unconventional oil and gas production
- Opportunities and research needs for future reuse of produced water for purposes outside of the oil and gas industry

About This Report

This report addresses the drivers and potential benefits for increasing produced water reuse both in unconventional oil and gas operations and outside the industry, as well as complex economic, scientific, regulatory, and policy considerations, specifically with respect to risk management. It also identifies research that will be needed to enable informed decision-making on produced water reuse, as well as regulatory and policy initiatives that would facilitate reuse.

An overriding theme of this report is that opportunities for increased produced water reuse will vary greatly depending on:

- **Local conditions**, including the quality and quantity of produced water available, the profile of regional water supply and demand, geological and demographic characteristics, the cost and availability of permitted UIC disposal, and the existence or lack of infrastructure for transporting, storing, and treating produced water; and
- **The envisioned end-use scenario** and specific cost, environmental, operational, policy, regulatory, and public perception considerations, especially the level of treatment required to make the produced water suitable for the intended end use, or "fit for purpose."

Reflecting the paramount importance of local considerations and a "fit-for-purpose" approach, this report includes:

- **Profiles of the top seven basins/regions based on oil and gas production and current unconventional drilling activity:** the Permian,

Appalachian, Bakken, Niobrara/ Denver-Julesburg (DJ), Oklahoma, Haynesville, and Eagle Ford basins/regions.

- **Data on water management from 18 producing companies**, with operations summarized for these seven major unconventional regions.
- **A summary — developed with the Louisiana State University School of Law —evaluating how selected states regulate produced water**, focusing on differing regulatory frameworks for produced water management, agencies responsible for regulating these processes, and produced water ownership and liability.
- **A four-phase conceptual research framework designed to assist decision-makers in assessing and reducing risks associated with a given reuse scenario where produced water is considered for uses outside of oil and gas operations**, incorporating the traditional concepts of risk-based decision-making — research, risk assessment, and risk management — as applied to produced water treatment and reuse.
- **An overview of various treatment technologies** that exist or are being actively researched today within academic, governmental, and industrial arenas.
- **A literature review** identifying hundreds of published, peer-reviewed studies and referencing other reports, which may be relevant to assessing produced water reuse or identifying knowledge gaps and current limitations.

Opportunities and Challenges

Increasing produced water reuse holds promise for making available a substantial volume of water that could potentially offset, or supplement, fresh water demands in some areas. Reuse also can be beneficial to oil and gas producers as an alternative to disposal in UIC wells, which can be costly, locally unavailable, or subject to volume restrictions. States and regulators may want to investigate reuse for reasons ranging from drought and groundwater depletion to disposal-related induced seismicity.

For the end user, in addition to considerations related to the quality of treated produced water, the economic attractiveness of reuse depends on whether the supply of produced water is predictable, whether it can be delivered reliably to the point of use, and how the cost compares to other available sources of water after factoring in the costs of its treatment and transportation as well as the disposal of treatment residuals. If local water supplies of fresh water are adequate or abundant, there is less incentive to consider beneficial reuse of treated produced water, especially given its potential associated risks.

Reuse in Unconventional Oil and Gas Operations

The multi-stage hydraulic fracturing of a single horizontal well can use an average of about 12 million gallons of water. Growth in the volumes of sourced and produced water required in hydraulic fracturing operations has raised sustainability concerns in unconventional regions, prompting greater emphasis on long-term water planning. In regions where either source water or disposal capacities are limited, produced water reuse may become economically viable and operationally practical. The area where reuse is highest, Pennsylvania and West Virginia (Appalachia), and the area where reuse is growing fastest, West Texas and New Mexico (Permian), are regions where disposal options have been or may become limited and disposal costs have been high or are increasing. In addition, several of the top basins are in arid regions with limited availability of sourced water.

Water treatment requirements for reusing produced water in hydraulic fracturing are far less demanding than for uses outside the industry. Advances in hydraulic fracturing chemistry allow operators to use produced water with minimal treatment, addressing only a few specific constituents to create “clean brine.” The approach is significantly less costly than more advanced treatment regimes such as those necessary to remove salts. However, in limited cases, advanced treatment is still done to provide an option that could meet discharge water quality requirements or reduce the potential risk from a spill.

The high costs of transporting and storing produced water, particularly in areas lacking an established water pipeline infrastructure, remain a barrier to reuse in most regions. Achieving significant levels of produced water use in unconventional producing regions will require capital investment in storage, transportation, and treatment capacity; a predictable supply

of produced water; ongoing demand for source water for nearby production operations; and a supportive regulatory framework. Managing environmental risk related to transporting and storing produced water for reuse requires minimizing and remediating spills and leaks, managing residuals, controlling air emissions, and taking actions to protect wildlife. These considerations must be paramount in production operations, as well as in the design and construction of storage impoundments or tanks and permanent or temporary pipelines.

The recent emergence of water midstream solutions (coordinating water sourcing for completion operations with produced water reuse across multiple producing companies) holds promise for smoothing out the peaks and valleys of individual company water demands, reducing transportation and disposal, and reducing demands on infrastructure through shared use. The scale of water midstream could allow reuse to grow steadily, especially in the most active areas in the Permian, Appalachia, and Oklahoma.

Reuse Outside the Oil and Gas Industry

Potential options for treatment and reuse of produced water outside the oil and gas industry include land application (e.g., irrigation, roadspreading), introduction to water bodies (e.g., discharges to surface water, injection or infiltration to ground water) and industrial uses (e.g., industrial feed streams, product or mineral mining). While some options, such as surface water discharge, are in limited use today, most remain theoretical.

Currently, the feasibility of reuse is significantly greater in unconventional oil and gas operations than in applications outside the oil and gas industry, where the costs of transporting and storing produced water and, particularly, of treating it to a "fit for purpose" level can be limiting. Potential risks to health and the environment must be well understood and appropriately managed in order to prevent unintended consequences of reuse. Produced water is complex, and in most cases further research and analysis is needed to better understand and define the "fit for purpose" quality goals for treatment and permitting programs. Environmental considerations beyond direct health or ecosystem impacts include emissions from treatment, managing waste materials from treatment, cumulative ecosystem impacts, or other localized issues.

Overview of Research Needs

Most research needs identified for this report pertain to produced water treatment and reuse outside the oil and gas industry. Managing potential risks with such applications requires improved understanding of the composition of a specific produced water source and identification of the health and environmental risks of reuse or release. This information is then used to determine the standards of quality that must be met to make the produced water fit for purpose. Finally, a user must evaluate the costs, benefits, and risks entailed in achieving those standards.

Produced water is a subject on which research is rapidly advancing, including the development of knowledge and tools for produced water characterization, treatment, risk assessment, and feasibility for reuse. Yet many knowledge gaps remain to be tackled. Strategic advancements in data and analysis will be needed to inform risk-based decisions and support the development of reuse programs that are protective of human health and the environment.

A central challenge will be researching and designing effective and economical treatment trains for specific reuse scenarios, which can entail analyzing the complex character of a specific produced water; managing variability; significantly reducing high total dissolved solid levels, organic constituents, metals, and naturally occurring radioactive material; and handling residuals. The most purposeful and actionable research and development strategy will be to identify and focus on specific reuse options where circumstances align to make reuse a potential need or opportunity in the near-future, in specific regions, taking into account the volume and quality of produced water potentially available and the needs of nearby water users.

For reuse within the oil and gas industry, research needs are more modest, addressing such areas as optimized leak detection systems, water treatment technologies to cost effectively address specific water quality challenges related to scale buildup or a specific analyte or other component, improvements in enhanced evaporation or desalination, development of automated treatment systems that can be operated remotely with little or no human intervention, and methods for separation of saleable products during treatment.

Overview of Regulatory and Legal Challenges and Opportunities

Nearly every aspect of produced water — including management practices, construction standards, and operational requirements — is regulated by federal, state, or local agencies. Disposal of produced water through surface discharges or injection in underground wells is subject to two key federal permitting programs — the National Pollutant Discharge Elimination System (NPDES) program and the Underground Injection Control (UIC) program — both of which are administered primarily at the state level.

Presently, regulatory frameworks for overseeing beneficial use of produced water, particularly reuse outside the oil and gas industry, are not well developed. As interest in beneficial reuse of produced water grows, agencies could be expected to develop new regulatory programs to authorize and manage those activities. Legal and regulatory considerations include determining state water rights as well as applicable regulations such as those relating to water quality standards and permitting. The determination of a specific beneficial use would depend on federal and state jurisdiction and the circumstances of each case.

Similarly, midstream water operations and other forms of water sharing are often outside traditional state oil and gas regulatory frameworks and require state authorization and oversight for activities that are not associated with other permitted oil and gas operations. Expanding midstream and other water-sharing opportunities may require state-level regulatory or legislative solutions to several issues, including management of risk associated with commercial management of large volumes of produced water from multiple sources at one facility, ownership of produced water, transfer of ownership, surface storage, and determination of liability if there is a spill or other environmental damage.

There are also other concerns regarding ownership and legal liability. In many cases, the lease holder, typically an oil and gas company, is the owner of the produced water and has the legal liability to properly treat, transport, and dispose of it. Reuse within the oil and gas industry is typically not subject to additional regulations other than tracking the flow and disposition of the produced water. However, if treated produced water is being reused outside the oil and gas industry, there must be a clear understanding of the current and future liability and transfer point of the liability and ownership.

Conclusions

Operators and regulators alike are rethinking the economics and long-term sustainability of traditional produced water management practices. Many operators are reusing more produced water than ever. As water becomes scarcer, the increasing benefits of reusing produced water in some regions may outweigh the costs of managing, treating, storing, and transporting it if health and environmental risks can be understood and appropriately managed. While most near-term alternatives focus on reuse of produced water to reduce fresh water consumption in unconventional oil and gas operations, interest is growing in the potential for reuse outside the oil and gas industry.

Produced water is not uniform, and neither are the circumstances of its potential treatment and reuse. Research, treatment decisions, risk management strategies, and in some cases even approval processes should be tailored to address the reuse of a particular produced water for a particular type of reuse. Identifying specific reuse options that address current or emerging needs or drivers in specific regions is an important next-step opportunity in order to prioritize investment in purposeful and actionable research and development with a defined set of facts and circumstances. Additional regulations to protect public health and the environment may apply or be developed in response to increased beneficial reuse outside the oil and gas industry.