Beneficial Use of Produced Water: A Case Study of Projects in Colorado and Wyoming

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Review

This paper discusses our combined experience in the beneficial use of produced water. Produced water is becoming an issue in the extraction and production (E&P) industry and is a significant constraint on energy production. We have designed and operated the first treatment plant for an oil field to sell produced water as a by-product of the oil field E&P operation. We are also working on several coal bed methane projects in the development of treating and discharging produced water as a valuable by-product of the operation. Stewart Environmental Consultants, Inc. and Kennedy/Jenks Consultants have formed a new company, Produced Water Development, LLC, which will design/build/own/operate these treatment facilities and sell the produced water to water agencies. This paper will discuss the process on how produced water can become a valuable by-product. This involves understanding the various water laws of each state, the treatment process of the produced water for both oil and CBM waters and the associated environmental constraints on this process. We will update previous presentations on the progress made in other projects and how this is becoming a significant contribution to the energy industry.

Key words: produced water, energy, environment, coal bed methane, oil

The Energy Industry and Produced Water

The energy industry has an issue with produced water and its associated costs. Produced water is water that is generally mineralized and contains particulate and dissolved organics and is brought to the surface with oil and gas operations. The produced water that is generated is a constraint on the industry for the amount of domestic production. The amount of energy that can be produced is directly related to how much produced water can be disposed of into injection wells or discharged to the surface water. It is currently the industry standard to reinject produced water, which places a constraint on the amount of production of domestic energy from oil and CBM projects.

We also face a significant water shortage in the western United States. This water shortage is causing considerable issues associated with water transfers from agricultural to urban users as well as constraints on growth of urban areas in the west.

We believe that produced water can be part of the portfolio of water rights that can assist with less dependence of agriculture to urban transfers, as well as becoming a new water resource for the western United States. This will also allow for the increase in domestic energy development by removal of the constraint on energy production.

Stewart Environmental and Kennedy/Jenks have been working on both oil production water, as well as CBM water, for treatment and proposed beneficial use of this water as a new water resource. Others have discussed this idea of beneficial s, but until the Wellington facility was built in Colorado, had never been actually completed (1).

In 2005, 2.5 billion barrels of oil and 196 trillion cubic feet of natural gas were produced in the United States (API). These activities resulted in nearly 25 billion barrels of produced water (2). This equates to 3.2 million acre feet of water annually. If this was usable water, this would support over 10 million people annually based on 0.3 ac-ft per home per year.
Population growth, drought in the western United States and climate change have substantially increased the demand for water in the arid west. This lack of water is creating a water crisis in the west. The areas of high demand were highlighted in the U.S. Bureau of Reclamation Study – Water 2025 (3). In reviewing this report, we combined data from the U.S. Geological Survey on the location of produced water and the projected water short areas of the western United States. Figure 1 contains this information.

As shown in this figure, the produced water generation is either directly in the area of a water short location, such as the front range of Colorado, or can be delivered through a stream system such as the lower Colorado River area of Las Vegas, the Central Arizona Project and the Metropolitan Water District Colorado River Aqueduct.

**Water – Energy Nexus**

There is a water energy nexus that needs to resolved in order to help in the development of domestic energy and also the development of water resources in the western United States.

Currently, it is estimated that between 20 to 30 percent of our electric and natural gas energy in the west is for the movement of water (4). This is a significant number that needs to be improved.

For produced water, it is estimated that 30 percent of the energy that was brought to the surface in the form of oil or natural gas is being expended in the reinjection of this produced water back into the subsurface.

Energy producers will save a considerable amount of costs associated with reinjection through a Class II injection well with this proposed program of beneficial use of the produced water. When comparing the energy needed for reinjection of 30 percent to the cost of treatment of 5 percent to 8 percent, there is a significant savings in the energy needed for disposal.

The amount of produced water generated in the United States is estimated at 20 billion barrels per year (5). The interaction and estimate are shown in Figure 2.

There are several issues associated with this figure. First, in our internal studies, we found that the amount
of produced water is normally under reported. Second, we found that there are significant water resources that are not withdrawn due to cost of disposal, but could add to this value significantly. This is one potential opportunity that should be investigated further.

We found estimates of the amount of produced water in basins of interest for CBM projects to be:

<table>
<thead>
<tr>
<th>Basin</th>
<th>Estimated Produced Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder River Basin</td>
<td>2.75 to 4 bbls per MCF</td>
</tr>
<tr>
<td>Raton Basin (Southern Colorado)</td>
<td>1.3 to 2 bbls per MCF</td>
</tr>
<tr>
<td>Atlantic Rim/Green River Basin</td>
<td>2 to 4 bbls per MCF</td>
</tr>
</tbody>
</table>

We believe that these values are underestimated. In our research, we have found these values to be 2 to 4 times larger than the estimates provided by USGS.

**Beneficial Use of Produced Water Raton Basin**

The Raton Basin (Figure 4) has a considerable amount of produced water that can be delivered to the Arkansas River near Pueblo, Colorado. Through exchanges and utilization of the various ditch systems in the area, we can deliver this water to Pueblo, Colorado Springs and southern Denver/Aurora areas. Our first project that we hope to complete will deliver 10,000 af per year to this area and will likely utilize aquifer storage recharge systems that will allow this water to be delivered on demand.

**Beneficial Use of Produced Water Colorado River Basin**

Figure 3 provides a profile of the Colorado River basin, which shows both the upper and lower basin under the seven state compact (6). As shown, this figure shows that the projects in the upper basin will deliver water to the natural stream system. The system is then capable of delivering water to the lower basin through the Colorado River system.

In order for this to occur, there needs to be engineering studies by the Colorado River Seven States Commission regarding the use and application of this water. However, based on the existing water shortages that are projected for this area, it appears that the timing is correct for this to proceed in a study and analysis phase.

It is estimated that the amount of produced water that could be generated during production of CBM well fields could range from 500,000 to 1,000,000 af per year. At the present time, the need for this water is being discussed by the Upper Colorado River Commission.
Benefits of Produced Water to the Overall Water Resource

What are the benefits to the river system? We have outlined a few of these benefits:

1. Water into the system can be used beneficially to downstream users, such as municipalities that are short of water.

2. This water can be stored in numerous vessels that already exist. Some of these vessels are large dams; other vessels might include underground aquifers that could deliver the water on demand.

3. This beneficial use of produced water will assist in the need for additional instream flows.

4. Produced water is delivered regardless of the current drought situation that exists on the surface. Climate changes that are predicted for this area will only increase the need for this new water resource.

5. If the produced water is reinjected to the subsurface, there is not an opportunity for recovery and this asset is lost forever.

Who Owns this Produced Water

Historically, produced water has been reinjected through a Class II injection well, placed in an evaporation pit or disposed of through a direct discharge. All of these techniques have some adverse environmental impacts.

Produced Water Development, LLC was formed to turn this wastewater into an asset. This marketable product is achieved...
through a treatment system that achieves discharge standards through a National Pollutant Discharge Elimination System permit system. We then go through the regulatory and legal hurdles to be able to take this treated water and sell it as an augmentation water.

Colorado has the most complicated and controlled system of water rights in the west. It is the only state that has its own water court system. In Colorado, the groundwater is classified as either tributary to a stream or non-tributary. Most produced water, due to the geologic formation, is likely non-tributary. This will allow for the complete consumption or utilization to exhaustion of this water.

Recently, Colorado passed HB 1303, which is a result of a produced water case in southwest Colorado (Vance vs. Simpson/Wolfe). In this particular case, the produced water had a tributary component. Due to this factor, the State Engineer was required to classify the withdrawal of this produced water as a beneficial use. This required the energy company to obtain a permit from the State Engineer’s office.

The Wellington case (Wellington Water Works vs. Dumont) is a case where the water right was obtained and is consistent with the Colorado Supreme Court decision in the Vance case. Specifically, if the energy company wants to utilize the produced water beneficially, they need to do the following:

1. Obtain a beneficial use permit from the State Engineer.
2. Contact the Colorado Department of Public Health and Environment for a preliminary effluent limit determination for discharge to a surface water.
3. Obtain a discharge permit from the Colorado Oil and Gas Conservation Commission.
4. Apply to Water Court to obtain a vested right in the produced water for beneficial use.

We followed this path in the Wellington case and were able to obtain the water court ruling in March 2008. As stated above, other states are not as burdensome with their requirements and likely will follow the prior appropriation doctrine, which would allow the first in use to have the first in right.

**Update on the Wellington Colorado Production Water Plant**

The first produced water project to beneficially use this water is near Wellington, Colorado. This project is treating oil production water as a new water resource. This new water resource will be used to augment shallow water aquifers to prevent injury to senior water users. The oil company is embarking on this project to increase oil production. A separate company will then purchase and utilize this water as an augmentation water source. This water is under a preliminary contract to allow the Town of Wellington and northern Colorado water users to increase their drinking water supplies significantly. In this example, the Town of Wellington can increase their water supply by 300 percent due to this new water source.

The overall process of this project was to accomplish the following:

1. Obtain concurrence with the State Engineer that this water was non-tributary. This was accomplished in 2004.
2. A discharge permit was required from the COGCC with a technical review by the CDPHE. This permit was obtained in December 2005.
3. A water court ruling is required to allow this water to be used in perpetuity. This was granted in March 2008.

As shown by the above timeline, this project has taken a significant amount of time. One of the issues in this project is being the first entity to accomplish these tasks. Now that a precedent has been set, we believe that this will proceed in a timelier manner in the future.

The economic reasons for this plant are as follows:

1. The cost of the production water treatment plant is approximately $2,000 to $3,000 per ac-ft of capacity. The operational cost for this plant is approximately $350 per ac-ft.
2. The cost of the reverse osmosis plant for the drinking water portion of the plant is $2,000 to $3,000 per ac-ft.
3. For the two plants, the cost for capacity is $4,000 to $6,000 per ac-ft.
4. The market for this water is $20,000 per ac-ft for the non-tributary water, and the market for the finished water is an additional $15,000 per ac-ft.
5. Therefore, for an investment of $4,000 to $6,000 per ac-ft, the return is close to $35,000 per ac-ft.

In addition, the energy company is able to expand their production by over 50 percent based on the capacity of the treatment facility.
We believe that the economic value will only increase in the future. This is due to the lack of water in the western United States.

CBM Projects – Western and Southern Colorado

A second example is the CBM production waters that are being developed in the west. These waters need to be removed in order to develop the resource of CBM. This is a difficult water to dispose of due to the organics and mineral content of the water. Technologies have been developed to treat this water, but the beneficial use of this water has not been researched or developed. Potential uses of this water are for municipal augmentation of a new water resource, industrial and agricultural interests as well as environmental enhancement through the creation of wetlands and in-stream flows.

We are currently working on a project in the southern portion of Colorado as well as two projects in western Colorado and southern Wyoming. This southern Colorado project currently has a significant amount of water being discharged to the Arkansas River basin. The Arkansas River is experiencing a significant shortage of water within the basin. There are several municipalities that depend on water in the Arkansas basin, including Pueblo, Colorado Springs and a new user of this water, Aurora, Colorado. In addition, Colorado lost a water rights compact case to Kansas, which is requiring a limitation of water in the basin. The western Colorado projects are similar in size and have the same constraints on the Colorado River basin.

The typical CBM project produces approximately 10,000 ac-ft per year. The cost of a treatment facility will be approximately $3 to $5 million. This will include a membrane treatment facility as well as brine management and treatment.

We are currently going through the determination of the tributary/non-tributary status of the groundwater. Based on our most current analysis, we believe that the water will be totally non-tributary. This water will have a projected value between $500 to $2,000 per ac-ft per year on an annual basis. This would result in a water lease revenue of $5 million to $20 million per year. The life of this project is estimated to be approximately 20 years. The return on the water leases ranges between $100 million to $400 million.

The cost of treatment of this water for CBM production water has been estimated between $0.25 to $1.00 per barrel. The cost of deep well injection has been as high as $2.00 per barrel. This translates into a cost of $2,000 to $8,000 per ac-ft for treatment and $16,000 per ac-ft for disposal. The market price for this water is close to $20,000 per ac-ft for a long-term lease. If the energy companies are currently paying $2.00 per bbl for disposal, then treatment would lower their overall costs. In addition, the first activity at a CBM facility is the dewatering phase. If the water could be sold at this point, then the cost of development is greatly reduced.

Produced Water Development, LLC

We have identified the need to be able to connect energy companies with water users. In our work with energy companies, they typically do not have the water resource expertise to beneficially use this water. Therefore, Stewart Environmental and Kennedy/Jenks has formed a new company that will engineer, procure financing and construct and operated these facilities as a service to the industry. We will also maximize the value of this asset for the energy companies, taking a waste and turning into an income-generating asset that can be as valuable as the energy being produced.

A Need for Produced Water Research

We believe that there is a real need for production water research. Presently, there is a lack of information on the amount of effort required to treat this produced water. We have been working on this effort in California and Colorado for more than five years. Most of this time was spent obtaining regulatory approvals and working on the legal aspects of our project.

The Colorado School of Mines and Research Partnership to Secure Energy for America are working together to help resolve some of these issues. We are encouraging the support of these activities to assist in taking this wastewater to a valuable resource.

Conclusions

Production water can be a new water resource for the western United States. This has been proven true for several areas in Colorado, Wyoming and California. There are several reasons that this should move forward:

1. Economically, this approach will be beneficial to the energy companies as well as the water providers.
2. The technology for treatment of these waters has been proven. There are issues with several aspects, but overall the technology exists for this type of production water treatment.
3. Communication of this issue is the largest hurdle to providing this new water resource. We need the energy companies and the water providers to communicate needs and requirements in order to make this new water resource a reality.

References Cited