Wyoming Water Development Commission

Executive Summary

COAL BED METHANE - AQUIFER STORAGE AND RETRIEVAL PROJECT - LEVEL II

SOUTHERN FT. UNION WELL FIELD EXPLORATION PROGRAM AND DEVELOPMENT STUDY

December 2004

Westerstein & Associates
Consultants in Engineering and Hydrogeology
SECTION 1
Project Background

The City of Gillette originally obtained most of its water from the Wasatch Formation, which lies at the surface throughout most of the area surrounding the City. While the Wasatch Formation can be very prolific, the quality of water in the Gillette area is relatively poor with high concentrations of sulfates and sodium. In the early 1970's the City developed water from the Lance/Fox Hills Formation which lies about 3,500 feet deep in the Gillette area and has high concentrations of sodium and fluoride. In the mid 1970's, the City started developing the Fort Union Formation which had relatively good quality water and met most of the drinking water standards set forth by the U.S. Environmental Protection Agency.

In the late 1970's and early 1980's, the City developed the Madison Formation Well Field approximately 14 miles north of Moorcroft, Wyoming. The initial capacity of the well field was about 5,500 to 6,000 gallons per minute. With the drilling of 2 additional wells and the stimulation of one of the wells the well field capacity was increased to 8,500 to 8,800 gallons per minute.

Several studies have been conducted over the years on the adequacy of the City of Gillette's water supply. The first of these conducted in 1993 by HKM Associates was the Gillette Area Water Master Plan, which evaluated all of the water systems in the area and helped define the regional water supply concept for the area. This study concluded that the City needed to develop a new Madison well field to meet the future demand and provide redundancy in the event water was not available from the existing Madison Well Field. A second study conducted in 1994 by Wester-Wetstein & Associates, Inc. evaluated the performance of the wells and well pumps in the City's well field. This study recommended drilling two additional Madison wells and development of a new Fort Union Well Field to provide a back up to the Gillette Madison Well Field and provide additional soft water for blending with the hard Madison Formation water. This study also concluded that without the Madison Formation water, there was insufficient potable water available to the City to provide a base load winter-time demand.

In 1999, Wester-Wetstein & Associates, Inc., conducted a well field study for the City of Gillette and targeted an area about 10 miles south of the City. At the time the study was conducted, a substantial amount of coal bed methane was being developed in the area, and samples of the water were taken during the course of the study to examine the water quality. The water being produced with the coal bed methane had surprisingly high water quality. A project was then conceived to evaluate storing the coal bed methane water in the deeper portion of the Fort Union Formation and exploring the deeper portion of the Fort Union Formation for its potential to be developed as a new water source for the City of Gillette.
Unfortunately, by the time the project was funded and a consultant selected to perform the work, the production of water from the coal bed methane wells had fallen off substantially and it was not possible to conduct a storage test in the vicinity of the targeted well field. Other areas were evaluated, but an area that could meet the needs of the City and also be used to store produced coal bed methane water could not be identified. To meet the goal of evaluating the storage of coal bed methane water, the tests conducted for Pennaco Energy, the City of Gillette and some of the other coal bed methane producers were compiled and briefly evaluated and put forth in an interim report.

This report focuses primarily on the exploration of the Fort Union Formation for the development of a new well field for the City of Gillette.

SECTION 2
Aquifer Storage and Retrieval

When application was made to the Wyoming Water Development Commission for this project, the coal bed methane wells in the vicinity of the proposed Fort Union Well Field had been producing substantial quantities of water for several years. However, shortly after the application was made to the Commission, water production from individual coal bed methane wells dropped sharply. During the early stages of the project, the water production by coal bed methane wells was reviewed in detail in the vicinity of Gillette to try to find an area that could be used for exploration for a new well field for the City, and also be used to demonstrate aquifer storage and retrieval. An area could not be found so an interim report was prepared summarizing all of the injection that had been conducted to date in which Wester-Wetstein and Associates had been involved. This report summarized and put forth the data collected on several million dollars worth of drilling, testing and re-injection projects north, south and within the city limits of Gillette.

SECTIONS 3 AND 4
Population and Demand Projections

At approximately the same time this study was being conducted, the City of Gillette was updating the City's water master plan. During the course of updating the master plan, a new service area was defined along with population projections and demand projections. This service area includes many of the existing water districts near the City of Gillette including Sleepy Hollow, Antelope Valley, and Crestview subdivisions. The service area used for the population and planning projections is shown on Figure 1. For purposes of this study, the
population projects and demand project from the updated water master plan were used for this study.

The population in the service area is projected to be approximately 40,000 by the year 2034. This is based on U.S. Census estimates in the City of Gillette and population projections based on land use outside of the City of Gillette, but inside the Service Area Boundary. This correlates to a maximum day demand of about 23.87 million gallons per day (MGD) or 16,574 gallons per minute (gpm). Assuming every City of Gillette well and every well owned by Sleepy Hollow, Antelope Valley, and Crestview are operational at peak capacity, there is a shortage of 4.61 MGD or 3,230 gpm. With new Fort Union wells producing 300 gpm, a total of 11 new wells will be required. It is unrealistic to assume that all 25 of the City’s wells and all 12 of the remaining wells will have the capability to operate at peak capacity at any given time. There will also be some conservation measures taken within the next 30 years, which should reduce the per capita demand somewhat.

SECTION 5
Exploration Program

The exploration program consisted of initially drilling a fully penetrating Fort Union observation well. This well was drilled to a depth of 2,979 feet and cased with 7-inch O.D. casing to a depth of 2,879 feet. The casing was cemented in place and perforated opposite sands in the lower portion of the Fort Union Formation (2,811 to 2,841 below ground) with one shot per foot. This section was air developed and samples were taken for analyses. The water was found to be very high in total dissolved solid (978 mg/l) and exceeded the drinking water standard for fluoride with a concentration of 5.1 mg/l. (The maximum recommended by the U.S. Environmental protection agency is 2 mg/l and the maximum allowable is 4 mg/l.)

The lower zone was plugged off by filling the lower portion of the casing with sand. The casing opposite the upper sands was then perforated (1,534 to 2403 feet below ground). This section was air developed and samples were taken for analyses. The water from the upper sands was found to be very acceptable in water quality with total dissolved solids of 425 mg/l and a fluoride concentration of 1.8 mg/l.

A production-sized exploration well was then drilled, constructed, developed and tested approximately 350 away from the observation well. This well was cased to a depth of 1,310 feet below ground with 9½-inch O.D. casing and to a depth of 2,368 feet below ground with 5½-inch casing and 5-inch pipe size stainless steel well screen.
After development of the well, a step test was conducted at rates from 75 to 300 gpm. After allowing the well to recover, a constant rate test was conducted for a period of three days at a rate of 260 gpm. A problem was noted with the pump during the step test or the constant rate test would have been conducted at a slightly higher rate, however, it was decided to proceed with the constant rate test at the estimated maximum capacity of the pump that was installed. The transmissivity of the aquifer was quite a bit higher than that found on the recent Fort Union Wells completed for the City of Gillette. The transmissivity, as calculated from the data collected at the exploration well and monitor well, was 1,700 to 1,800 gallons per day per foot and the storage coefficient was $10^{-4}$. The higher transmissivity allows for higher production from individual wells with less drawdown.

Water samples were taken at the conclusion of the pump test and analyzed for the various components regulated by the U.S. Environmental Protection Agency. The water quality from the production-sized exploration well was found to be better than water analyzed from the upper part of the monitor well. The water from the production well had a concentration of total dissolved solids of 351 mg/l and a fluoride concentration of 1.56 mg/l.

**SECTION 6**

**Southern Fort Union Well Field**

The layout of the Southern Fort Union Well Field is shown on Figure 6-1 from the report. The well field is situated approximately 8 miles southwest of the City of Gillette along the Bell Road. The well field consists of 15 wells which are situated approximately 1 to 1¼ miles apart to try to minimize interference while keeping the wells close enough to minimize the collection pipelines and roads necessary to access the wells. Fortunately, because of the recent development of coal bed methane wells in the area, the cost to install power lines and roads to the wells is greatly reduced because much of this infrastructure was installed for the coal bed methane development. Most of the collection pipelines within the well field follow existing roads. The collection pipelines vary from 6 to 20 inches in diameter depending on the number wells connected to it. The working pressure on almost all of the collection pipelines is less than 100 psi.

It is anticipated that a well field booster station will be installed to boost the water from the well field to the City of Gillette. The well pumps could be sized to pump the water the additional head required to convey it to the City, but larger motors and pumps would be required. It is more economical to build and maintain a booster station than installing the higher head pumps that would be required at each well.
To convey the water to the City, a 20-inch diameter pipeline was preliminarily designed and is shown of Figure 6-2 from the report. The 20-inch pipeline is large enough to convey up to 5,600 gpm by gravity from the high point near the junction of Highway 50, but the velocities in the pipeline get quite high at this rate. The water is pumped from the well field booster station through the 20-inch pipeline to a planned Pump Station No. 4. At Pump Station No. 4, the water will be disinfected and blended with water from the Madison Well Field, the existing Fort Union Wells, and the Lance Fox Hills.

SECTION 7
Water Rights

The water rights were reviewed in the area and there hundreds, if not thousands, of wells situated within the four townships affected by the well field. Because the pump chambers are so deep in the planned wells, there are only about 7 known wells, within three miles of the well field, that are completed in the same producing horizons as the proposed well field wells. These wells are all currently being used for stock watering and if development of the well field severely impacts their water levels, some mitigation measures may be required.

SECTION 8
Water Treatment

Because the water is of such high quality, very little treatment is required. It is anticipated that the water will be disinfected with chlorine at the planned Pump Station No. 4. In the production sized exploration well, very little to no gas was observed during the course of constant rate pumping test. The existing Fort Union municipal wells produce significant amounts of gas and it necessary to degas the water at Pump Station No. 1 prior to disinfection and distribution within the system.

SECTION 9
Operational Plan

With the development of the Southern Fort Union Well Field, it will be possible to take some of the pressure off of the existing Fort Union Wells. Since only about a million gallons per day will be required from the Fort Union aquifer during the cold weather months to maintain a 50/50 blend with the Madison water, it will be possible to rotate the usage around over a much larger area thereby reducing the
residual drawdown at individual well sites. It will also allow for much more flexible and better management of the resource.

**SECTION 10**
Estimated Construction Costs

Table 10-8 shows the estimated cost for the entire project. A total of $100,000 has been allocated for permitting. This cost is primarily associated with conducting the cultural and environmental surveys necessary to obtain the permits. Filings were made with the Wyoming State Engineer’s Office for the wells in April 2004. A total of $100,000 has been allocated for legal fees and approximately $320,000 for access and rights of way.

<table>
<thead>
<tr>
<th>TABLE 10-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL PROJECT COST ESTIMATE</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wells</td>
<td>$3,259,950.00</td>
</tr>
<tr>
<td>2</td>
<td>Well Houses and Pumps</td>
<td>$2,032,500.00</td>
</tr>
<tr>
<td>3</td>
<td>Power</td>
<td>$192,700.00</td>
</tr>
<tr>
<td>4</td>
<td>Collection System</td>
<td>$2,705,873.00</td>
</tr>
<tr>
<td>5</td>
<td>Well Field Booster Station</td>
<td>$1,500,000.00</td>
</tr>
<tr>
<td>6</td>
<td>Transmission Pipeline</td>
<td>$3,562,815.00</td>
</tr>
<tr>
<td>7</td>
<td>Well Field Telemetry &amp; Controls</td>
<td>$225,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Roads</td>
<td>$459,600.00</td>
</tr>
<tr>
<td>9</td>
<td>Pump Station No. 4</td>
<td>$3,890,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Madison Pipeline Tie-In</td>
<td>$8,773,825.00</td>
</tr>
</tbody>
</table>

Total Construction Costs $26,602,263.00
Engineering $2,660,226.30
Subtotal $29,262,489.30
15 Percent Contingency $4,389,373.40

Construction Cost Total $33,651,862.70
Project Cost Total $36,831,806.50
It should be noted that the well field and transmission pipeline are contained in Items 1 through 8. Items 9 and 10 are associated with the planned Pump Station No. 4 and the improvements necessary to blend the water with the other municipal sources and get the water to the distribution system. The cost of Items 9 and 10 account for approximately 47 percent of the project. This component of the project will be thoroughly reviewed during the initial design phase.

**SECTION 11**

Well Field Development and Project Phasing

Because the project is quite large and further testing should be conducted to verify the number of wells and well spacing, the project has been divided into three phases. The first phase which has been proposed to start in 2005, will consist of conducting the cultural and environmental studies necessary for permitting and project funding. During this first phase two additional exploration wells will be drilled to verify that the well spacing and number of wells are adequate to meet the future needs of the City and service district area.

Also during this first phase, a ten percent pre-design effort will be conducted. Part of the primary focus of this pre-design effort will be how to treat and blend the water from the Southern Fort Union Well Field and blend it with the City's other sources of groundwater. As indicated previously, this is a very costly component of the project, and a more in depth design effort may help reduce the cost of this component. In addition, the costs estimates will be reviewed, modified and updated.

The environmental and cultural resource surveys associated with permitting the project and making it eligible for alternate sources of funding are time dependent. In other words, if construction has not started within a year of competing the surveys or obtaining the requisite approvals, the work may have to be repeated. To avoid this, an allowance has been made to commence drilling of two production wells in addition to the two exploration wells in the first phase of the project.

The second phase of the project, which is anticipated to start in 2006, consists of drilling the remaining wells and conducting the final design for the pipelines, booster stations, roads, well houses, pumps, etc. The third phase of the project consists of construction of the pipelines, well houses, booster stations, roads, etc. and is anticipated to start in 2007. Table 11-1 from the report shows the recommended phasing and funding of the project.
## TABLE 11-1

### PROJECT PHASING

<table>
<thead>
<tr>
<th>Year</th>
<th>Engineering (4 Wells and 10 Percent Pre-Design)</th>
<th>$</th>
<th>Permitting and Mitigation</th>
<th>$</th>
<th>Legal Fees</th>
<th>$</th>
<th>Acquisition of Access and Rights of Way</th>
<th>$</th>
<th>Construction (4 Wells)</th>
<th>$</th>
<th>15 Percent Contingency</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Engineering (4 Wells and 10 Percent Pre-Design)</td>
<td>$452,926.43</td>
<td>Permitting and Mitigation</td>
<td>$100,000.00</td>
<td>Legal Fees</td>
<td>$100,000.00</td>
<td>Acquisition of Access and Rights of Way</td>
<td>$319,717.50</td>
<td>Construction (4 Wells)</td>
<td>$869,320.00</td>
<td>15 Percent Contingency</td>
<td>$130,398.00</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>$1,972,361.93</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>Engineering (10 Wells and Final Design)</td>
<td>$2,557,201.17</td>
<td>Construction 10 Wells</td>
<td>$2,173,300.00</td>
<td>15 Percent Contingency</td>
<td>$325,995.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>$5,056,496.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>Engineering</td>
<td>$2,334,231.30</td>
<td>Construction</td>
<td>$23,342,313.00</td>
<td>15 Percent Contingency</td>
<td>$3,851,481.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>$29,528,025.95</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### SECTION 12

**Environmental Report**

Letters with appropriate maps were sent to several state and federal agencies summarizing the project and soliciting any concerns the different agencies might have. The most notable responses were from the State Historic Preservation Office, the U.S. Fish and Wildlife Service, Wyoming Department of Environmental Quality, and the U.S. Army Corps of Engineers. Due to the size of the impacted area, many of the contacted agencies requested that more detailed surveys be conducted to delineate potential conflicts. These surveys include an archeological survey of the project site, a wetland delineation survey, and surveys to establish if Ute Ladies'-tresses and/or their habitat exist within the proposed areas of disturbance. Additionally, it was recommended that nesting areas of migratory birds and raptors be documented, and if present, the construction season be adjusted to minimize impacts to the nesting birds.
SECTION 13
Conclusions and Recommendations

The water quality from the Tongue River and Lebo Shale members of the Fort Union formation is much better than that available from the lower Tullock member. The quality of water available from the Southern Fort Union Well Field is considerably better than the water available from the Fort Union Formation in town and individual well yields are anticipated to be significantly higher than the Fort Union wells in Town.

Cursory costs to construct a new Madison Formation Well Field were developed to compare to the costs of developing a new Southern Fort Union Well Field. The costs to develop a new Madison Formation Well Field were estimated to be about $17,000,000 more expensive than the cost to develop a new Southern Fort Union Well Field. Also, a new Madison Formation Well Field does not provide the redundancy and opportunity to improve the overall water quality that the Southern Fort Union Well Field does.

It was recommended that the project be phased with the first phase consisting of: drilling two additional exploration wells to confirm the well spacing, well yield, and sustainability of the aquifer; conducting the requisite environmental studies; obtaining the easements and permits necessary to construct the project; conducting a pre-design effort on the project to refine costs and determine the best way to tie into the City’s water system; and commencing drilling of two production wells. The second phase will consist of drilling the remaining wells and conducting the final design of the project. The third phase will be construction of the pipelines, booster stations, roads, telemetry, and controls.