FINAL REPORT
EXECUTIVE SUMMARY
FOR:

LANDER LEVEL II
WATER SUPPLY PROJECT
EXPLORATION WELL DEEPENING

Prepared for:
Wyoming Water Development Commission

Submitted by:
WESTON
GROUNDWATER ENGINEERING

OCTOBER 2007
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Weston Engineering, Inc

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LARAMIE, WYOMING 82072

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EXECUTIVE SUMMARY
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WELL DEEPENING PROJECT

INTRODUCTION

The City of Lander is located in west-central Wyoming in the foothills of the eastern slope of the Wind River Mountains at an elevation of approximately 5,350 feet above sea level. The City is situated in the valley of the Middle Popo Agie River in western Fremont County, of which it is the county seat.

Although Lander has historically obtained drinking water from the Middle Popo Agie River, an extended drought cycle has diminished flows in the river in recent years. In addition, the U.S. Environmental Protection Agency (EPA) determined that the City's infiltration gallery, which supplied up to 2 million gallons per day (MGD) to the City, was under the direct influence of surface water and must be abandoned or the water must be treated (Nelson, 1999). As a result, the City discontinued use of the infiltration gallery, effective June 15, 2004. Because the City of Lander is concerned about obtaining sufficient quantities of surface water to meet drinking water demands in the future, they have decided to investigate the potential of supplementing their surface water supply with groundwater sources. WESTON performed a well siting investigation over a 400 square mile study area to determine favorable locations for an exploration well. The results of the well siting study are presented in the Lander Level II Paleozoic Aquifer Well Siting Study Final Report (WESTON, 2002).

To explore the potential for developing groundwater from the Tensleep Sandstone, an exploration well was drilled and tested in the winter of 2003 and 2004. The location of the exploration well is depicted in Figure 1. Testing results indicated that yields were limited to less than 325 gallons per minute (gpm) when the well was pumped. Furthermore, it was determined that it is likely that pumping water from the Tensleep Sandstone would have the potential to cause impacts to other area water wells completed in the same formation. The results of the exploration well drilling program are provided in a report entitled Lander Level II Water Supply Project Final Report (WESTON, 2004).

Because the Lander Exploration Well, as completed in the Tensleep Sandstone, would not meet the needs of the City of Lander, the WWDC and the City of Lander decided to obtain additional funds to deepen the well to test the production potential of the Madison Limestone. This report describes the results of the deepening program.

SCOPE OF THE LEVEL II WELL DEEPENING STUDY

The Lander Level II Water Supply Study consists of four phases: Phase I – the Paleozoic Aquifer well siting study (WESTON, 2002); Phase II – exploration well construction (WESTON, 2004); Phase III – exploration well deepening, and Phase IV - conceptual design and cost estimates. Phases III and IV were completed in 2007 and are the subject of this report.

LANDER EXPLORATION WELL

The Lander Exploration Well was drilled to a total depth of 2,545 feet during the fall and winter of 2003. As depicted in the as-built diagram of the well shown on Figure 2, the top of the Tensleep Sandstone was penetrated at a depth of 1,920 feet and 9 5/8-inch O.D. casing was set and cemented to a depth of 1,922 feet. Groundwater flow from the well was contained by a 10-inch gate valve attached to the top of 9 5/8-inch casing. The base of the Tensleep Sandstone was encountered at a depth of 2,310 feet. After reaching this depth a short flow test was conducted to determine the production capacity of the well under flowing conditions before resuming drilling to the Madison Limestone. The well was tested for a period of 24 hours at a rate of 90 gpm. After
**LANDER LEVEL II WATER SUPPLY STUDY**
**AS-BUILT DIAGRAM**
**FIGURE 2**

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**DESIGN DETAILS**

- **10-INCH GATE VALVE**
- **PRESSURE GAUGE**

- **0 - 140 FEET: 13 3/8-INCH O.D. STEEL CASING CEMENTED IN PLACE**
- **CEMENT GROUT**
- **+1.0 - 1,922: FEET 9 5/8-INCH O.D. STEEL CASING**

- **140 - 2,434 FEET: 12 1/4-INCH DIAMETER BOREHOLE**
- **1,838 FEET: LINER-HANGER ASSEMBLY**
- **GUIDE SHOE**
- **2,434 - 2,662 FEET: 8 3/4-INCH BOREHOLE**
- **1,838 - 2,660 FEET: 7-INCH STEEL CASING (23 POUNDS PER FOOT) CEMENTED IN PLACE**
- **2,662 - 3,120 FEET: 6 1/4-INCH OPEN HOLE SECTION**

- **3,120 - 4,411 FEET: 6 1/4-INCH BOREHOLE PLUGGED WITH 200 SACKS TYPE III CEMENT GROUT**

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**NOT TO SCALE**

* WELL WAS OPEN FROM THE TOP OF THE MADISON LIMESTONE TO THE BASE OF THE FLATHEAD FORMATION

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EXECUTIVE SUMMARY

LANDER LEVEL II WATER SUPPLY PROJECT - WELL DEEPENING PROJECT

approximately 200 minutes of testing the drawdown leveled off and became constant at 207 feet. The well recovered to the pre-test shut-in pressure 23 minutes after closing the gate valve.

After allowing the well to recover, the drilling contractor continued drilling with the ultimate goal of testing the Madison Limestone. However, the borehole was terminated in the Amsden Formation at a depth of 2,545 feet on December 22, 2003 due to excessive sloughing of the Amsden Formation shales into the borehole. To prevent commingling of water from the Tensleep and Amsden formations, 20 x 40 graded frac sand and a cement cap were installed in the borehole from 2,430 to 2,545 feet.

Following well development by airlifting, the well was pump tested at a rate of 325 gallons per minute for a period of seven days in February, 2004. The drawdown at the end of the pump test was 1,015 feet, which corresponds to a pumping water level of 657 feet below ground level. The effective transmissivity of the aquifer in the vicinity of the well ranged from approximately 1,225 gpd/ft for the early-time data to 610 gpd/ft for the late-time data. A first-order analysis of the constant-rate pump test data indicates that the Lander Tensleep Well could sustain a constant production rate of 285 gpm for a period of one year. The predicted drawdown at the end of one year of continuous pumping is 750 feet below ground level.

The results of the exploration program indicated that incorporating the well into the Lander municipal water supply system would not be cost effective. Therefore, it was decided to deepen the well to test the productivity and water quality of the Madison Aquifer.

EXPLORATION WELL DEEPENING PROGRAM

Drilling and construction of the deepened well was performed from May 10 to July 12, 2007 by the drilling contractor, Weston Engineering, Inc. (WESTON), Upton, Wyoming, using a Failing Strat 100 HB drilling rig. WESTON first entered the well with an 8 3/4-inch diameter tri-cone drill bit and cleared cement and rock debris from 2,530 to 2,545 feet. An 8 3/4-inch diameter borehole was advanced to a depth of 2,660 feet. The top of the Madison Limestone was penetrated at 2,650 feet. Welded 7-inch outside diameter (O.D.) steel casing on a liner hanger was then placed in the borehole to a depth of 2,660 feet and cemented in place. A 6 1/4-inch diameter borehole was advanced to the top of the Big Horn Dolomite at a depth of 3,202 feet. Following well development and flow testing, the borehole was completed to a total depth of 4,411 feet into the base of the Flathead Formation on June 28, 2007.

As depicted in the as-built diagram shown in Figure 2, the well has an open-hole completion from 2,660 to 3,120 feet. To prevent commingling of water from the Bighorn Dolomite and lower Paleozoic formations with water produced from the Madison Limestone, a formation packer was placed at a depth of 3,120 feet and interval below the packer was subsequently cemented off from the formation above. Because the well flowed 30 gallons per minute (gpm) after emplacing the cement in the well, a new 10-inch gate valve was installed on top of the casing to control flow from the well. Additionally, a port on the side of the casing allows installation of a pressure gauge to monitor well pressure. On July 16, 2007, after the cement plug had cured, the shut-in pressure on the well, which is open solely to the Madison Limestone, was 250 pounds per square inch (psi).

A constant-rate flow test was performed on the Lander Exploration Well after drilling through the Madison Limestone. An 18.7-hour flow test at an average rate of 32 gpm was performed to determine well performance characteristics and aquifer parameters. The drawdown at the end of the flow test was approximately 422 feet and no hydrogeologic boundaries were observed during flow testing. The effective transmissivity of the aquifer determined from the flow test results ranges from 92 to 275 gpd/ft.
EXECUTIVE SUMMARY

LANDER LEVEL II WATER SUPPLY PROJECT - WELL DEEPENING PROJECT

A three-hour, constant-rate flow test at a rate of 100 gpm was performed on the well after drilling to the base of the Flathead Formation. The drawdown after only 55 minutes stabilized at approximately 314 feet and remained at that level for the duration of the test.

The quality of the water from the Lander Exploration Well during well development and aquifer testing was assessed through a series of field and laboratory analyses. The analyses indicate that the water developed by the well is good for all the intervals tested.

CONCLUSIONS AND RECOMMENDATIONS

The Lander Level II Water Supply Project was designed to locate and secure a viable, economical, groundwater-based drinking water source for the City of Lander. The project originally consisted of siting, drilling, constructing, and testing an exploration well drilled into the Tensleep Sandstone near the City of Lander. However, the production from the Tensleep Sandstone was limited and there was significant potential for interference with other appropriators. The project then evolved into deepening the existing exploration well to test the productivity of the Madison Limestone. The Madison Limestone yielded only 20 gpm, which was insufficient for meeting the needs of the City of Lander, and there was sufficient budget in the project to further deepen the well and test the productivity of the Flathead Aquifer. The well was tested at 100 gpm and the overall quality of the developed water from the Lower Paleozoic aquifers was good.

It is the expressed desire of the City of Lander to obtain a redundant water supply in the event that drought significantly reduces the flow of water in the Middle Popo Agie River. As stated in the Level II Well Siting Study (WESTON, 2002), the goal for the Lander Exploration Well was to aid in developing a well or wellfield capable of replacing the two million gallon per day infiltration gallery. Thus, in order to replace the capacity of the infiltration gallery, such a well or wellfield would have to yield approximately 1,400 gpm. It is clear from the well siting study and exploration well drilling program that without the presence of deformation associated with geologic structures or karst to provide secondary permeability in the aquifer material, a Paleozoic well is not likely to meet this demand. Furthermore, there are numerous wells in the Lander area that are completed in the Tensleep Sandstone and additional wells completed in this formation could cause interference with senior water rights. Furthermore, as rural developments continue to expand in the area surrounding Lander, the water supply demands of these developments will likely be met with additional wells drilled into the Paleozoic aquifers.

Based on the lack of favorable geologic structures to target in the vicinity of the City of Lander; the low yield of the Tensleep Sandstone and Madison Limestone at sites not located on a geologic structure; and the potential that a well completed in the Flathead Aquifer could yield 300 gpm without pumping, it is WESTON's recommendation that the City of Lander consider constructing a Flathead Aquifer well at a location near the water treatment plant (see Figure 1). A well at the water treatment plant offers the following advantages: lower construction costs than wells located to the east where the aquifer lies at greater depths, low costs of connection to the City's water system, and the ability to blend water from the well with finished surface water if the concentration of any constituent exceeds EPA standards for a public water supply well. Additional Flathead Aquifer wells could be incorporated into the water system at strategic locations based on proximity to infrastructure and interference concerns at later dates as more water is needed. A 300 gpm Flathead Aquifer well could offer the City the ability to meet the average daily demands of nearly 1,500 residents without the need for extensive treatment or pumping costs.

Table 1 summarizes the tasks and estimated costs for providing drilling and engineering services for constructing a Flathead Aquifer well located at the water treatment plant. The costs provided in Table 1 are based on the typical WWDC requirements for exploration well drilling projects.
EXECUTIVE SUMMARY
LANDER LEVEL II WATER SUPPLY PROJECT - WELL DEEPENING PROJECT

TABLE 1
COST ESTIMATE SUMMARY FOR ENGINEERING AND CONSTRUCTION SERVICES
FOR CONSTRUCTING PROPOSED LANDER FLATHEAD AQUIFER WELL

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Cost</th>
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</thead>
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<tr>
<td>Task 1</td>
<td>Scoping Meeting and Project Meetings (2)</td>
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<tr>
<td>Task 2</td>
<td>Permits, Access, Testing Program Development</td>
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<td>Task 3</td>
<td>Bid Preparation</td>
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<td>Task 4</td>
<td>Bidding Process</td>
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<td>Task 5</td>
<td>Consultant Services During Well Construction and Aquifer Testing</td>
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<td>Task 6</td>
<td>Water Quality, Reclamation</td>
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<td>Task 7</td>
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<td>Task 8</td>
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<td>Task 9</td>
<td>Project Reports</td>
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**PROJECT TOTAL COST (2007 Dollars)** $1,094,250