3.5 Surface Waters, Wetlands and Aquatic Ecology

3.5.1 Surface Waters

The Permit Area is located in the Basin, a topographically closed system that drains internally due to a divergence in the Continental Divide. **Figure 1.2-1** shows the location of the Permit Area within the Basin. Runoff from precipitation or snowmelt within the Basin infiltrates into the soils, is evaporated or transpired, or drains to low areas within the Basin, forming seasonal playa lakes. Due to the fact that all of the channels are ephemeral and that the Permit Area lies within a closed, isolated basin, no surface water features on the property connect to a tributary of a navigable water body. As such, no surface waters within the Permit Area are considered waters of the US under the jurisdictional authority of the US Army Corps of Engineers (USACE). However, surface waters within the Permit Area are considered 'waters of the state' (WS 35-11-103(c)(vi)), and are afforded protection under State and BLM regulations (RMP Page 3-127)(BLM, 2008c)

Section 3.10 describes the meteorological and climatic conditions of the Basin and the Permit Area in detail. Due to the arid climate and high infiltration capacity of the soils, all of the streams in the Permit Area are ephemeral; there are no perennial or intermittent drainages in the Permit Area, according to the conventional definition by Meinzer (1923) and as applied by BLM (1998):

> **Perennial** - A stream that flows continuously. Perennial streams are generally associated with a water table in the localities through which they flow.
> **Intermittent** - Intermittent streams receive their base flow from groundwater and flow is augmented by seasonal events such as precipitation or snowmelt runoff.
> **Ephemeral** – Ephemeral streams are seasonal and have no contribution from groundwater; they only flow in direct response to seasonal events such as precipitation or snowmelt runoff.

Based on the loam and sandy-loam soils found at the site, the steady-state saturated infiltration rate under laboratory conditions is estimated at 0.2 to 0.8 inches per hour (Hillel, 1980). However, the practical infiltration rate is likely much higher because saturated conditions are rare, and more macropores are present under field conditions and at large scales. Infiltration-excess (Hortonian) overland flow has not been observed at the site, except on the compacted soils found in existing two-track roads. When present, runoff is conveyed by numerous ephemeral channels that are vegetated by sagebrush and do not support aquatic life. Alluvial deposits, if any, along drainages are not extensive, and the shallow groundwater table is typically 150 to 200 feet below ground surface (**Section 3.6.2.1**).

3.5.1.1 Surface Water Features

Figure 3.5-1 shows the surface water features in the main Permit Area; and **Figure 3.5-2** shows the features along the East and West Roads to the Permit Area. The main Permit Area consists of three principle watersheds that, together, drain greater than 99 percent of the main Permit Area. Only one drainage in the main Permit Area is named on the USGS 1:24,000 scale topography maps: Battle Spring Draw. For the purposes of the WDEQ-LQD Permit to Mine (LCI, 2011b), the principle drainages were named Western Draw, West Battle Spring Draw, and East Battle Spring Draw by LCI.

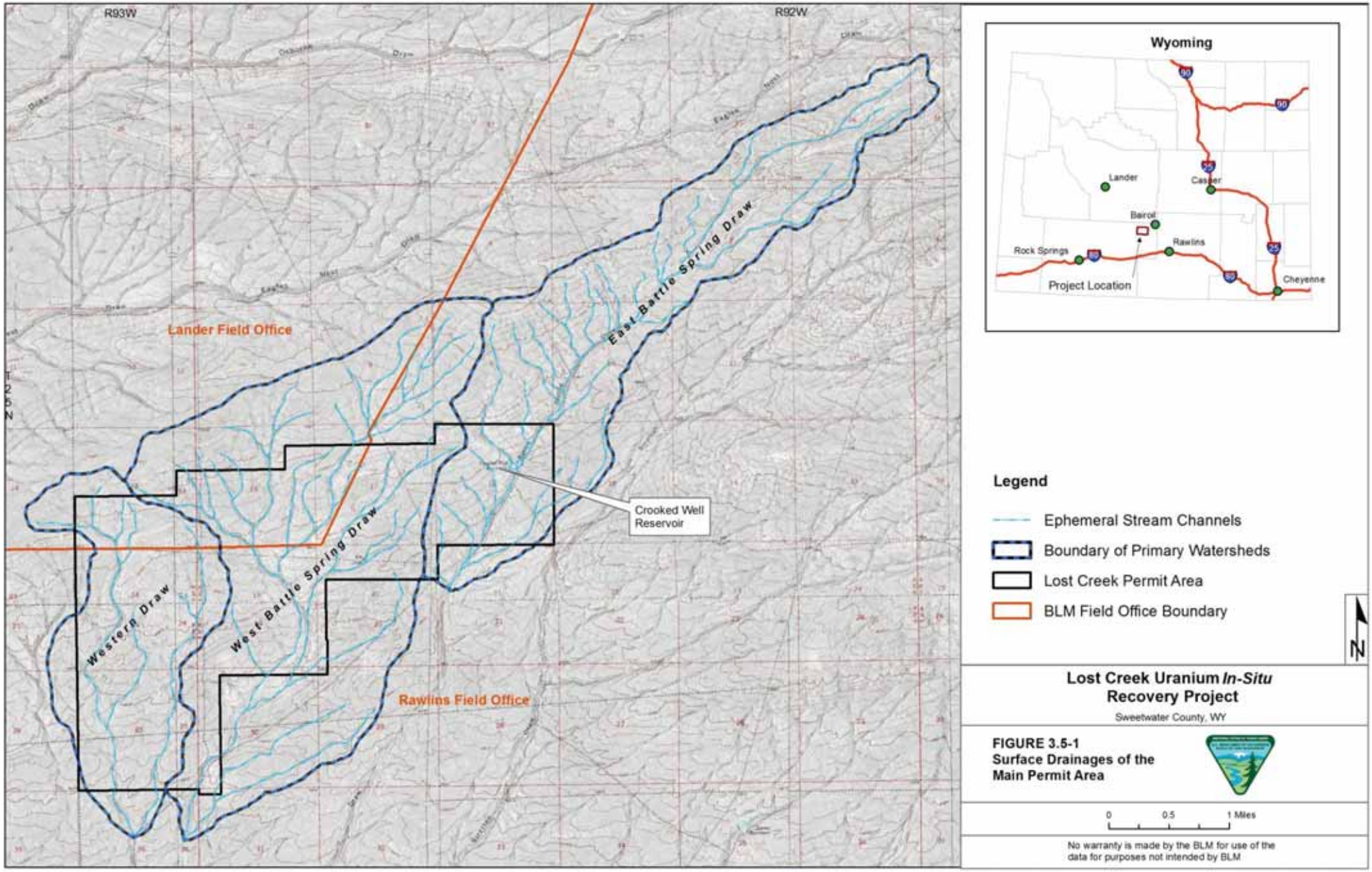
The Western Draw watershed covers 2.9 square miles, of which 2.4 square miles are within the Permit Area; the West Battle Spring Draw watershed covers 7.0 square miles, of which 3.1 square miles are within the Permit Area; the East Battle Spring Draw watershed covers 5.1 square miles, of which 1.0 square mile is within the Permit Area. The entire main Permit Area drains into the Battle Spring Flat, approximately nine miles southwest of the Permit Area.

The East Road to the Permit Area is in the Stratton Draw and East Fork Stratton Draw watersheds, both of which are shown on USGS 1:24,000 scale topography maps. The Stratton Draw Watershed is 13.8 square miles, of which 0.02 square miles are in the Permit Area. The East Fork Stratton Draw is 5.6 square miles, of which 0.03 square miles are in the Permit area. No substantial drainages cross the East Access Road in the East Fork Stratton Draw watershed.

The West Road is within the Eagles Nest Draw and Far Western Draw watersheds, both of which are shown on USGS 1:24,000 scale topography maps. The Eagles Nest Draw watershed is 16,021 acres, of which 16.6 acres are within the Permit area, and the Far Western Draw is 2,618 acres, of which 68.5 acres are within the Permit Area. The road traverses the ridgeline that divides these watersheds, and does not cross any significant drainages.

Figure 3.5-3 shows a longitudinal profile of the main channel in each of the primary watersheds within the main Permit Area, and the endpoints are shown in **Figure 3.5-2**. Within the Permit Area, the average slope of the main channel in the Western Draw, West Battle Spring Draw, and East Battle Spring Draw watersheds is 1.4, 1.2, and 1.1 percent, respectively. The sinuosity (channel length divided by valley length) of the main channels are 1.24, 1.10, and 1.03, respectively, and the drainage density is 3.0, 4.2, and 5.0 miles per square mile, respectively.

The ephemeral channels are typically trapezoidal and U-shaped in cross-section; they are approximately ten to 15 feet wide, and incised three to six feet near the downstream Permit Area boundary. Channel side slopes generally range from 1:1 to 2.5:1; however, vertical and slumping banks occur in areas of active erosion. The bed material in the larger drainages is sandy in texture and non-cohesive.



Lost Creek Uranium *In-Situ* Recovery Project

Sweetwater County, WY

FIGURE 3.5-1
Surface Drainages of the Main Permit Area

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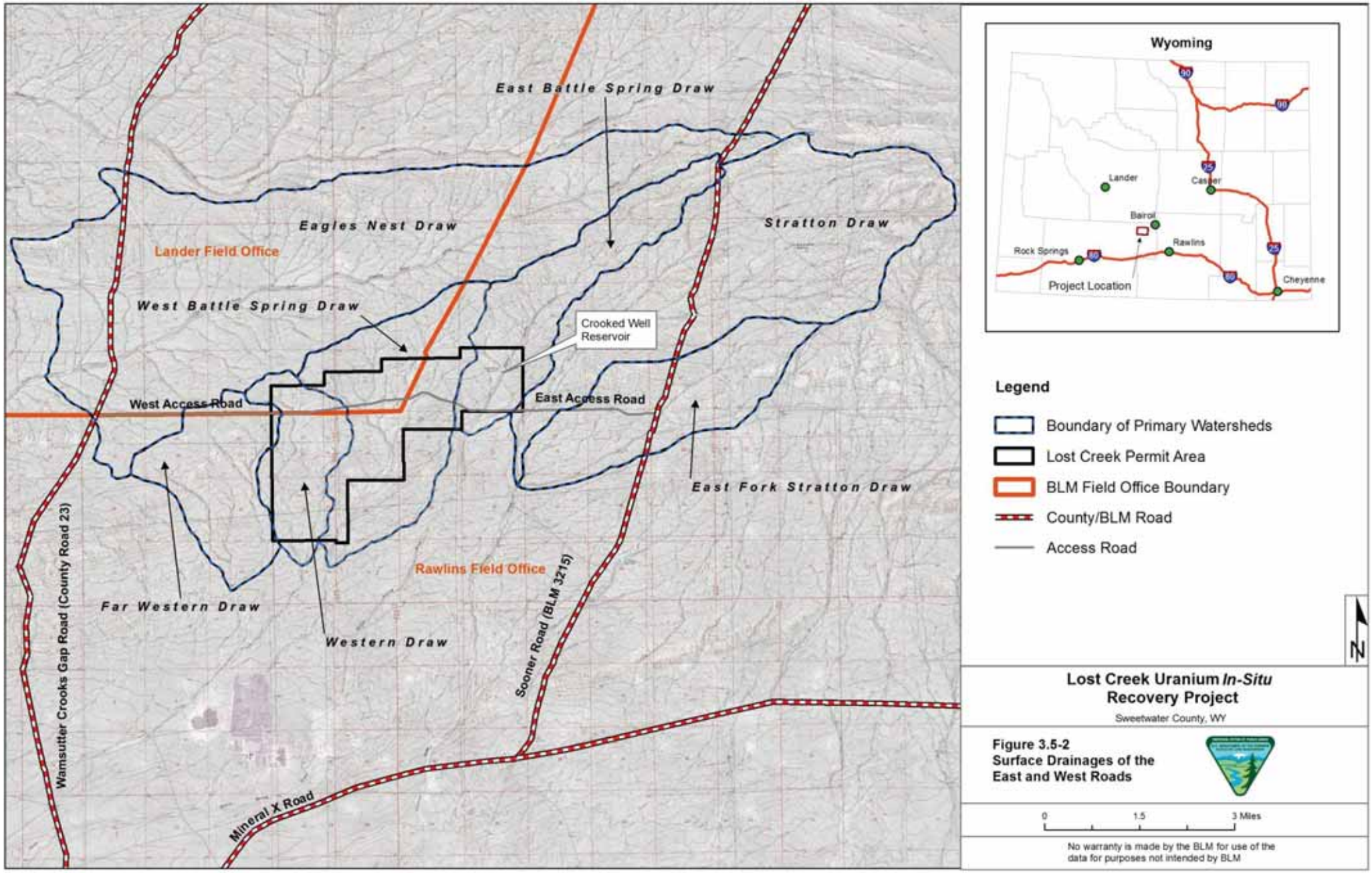

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Figure 3.5-2
Surface Drainages of the East and West Roads

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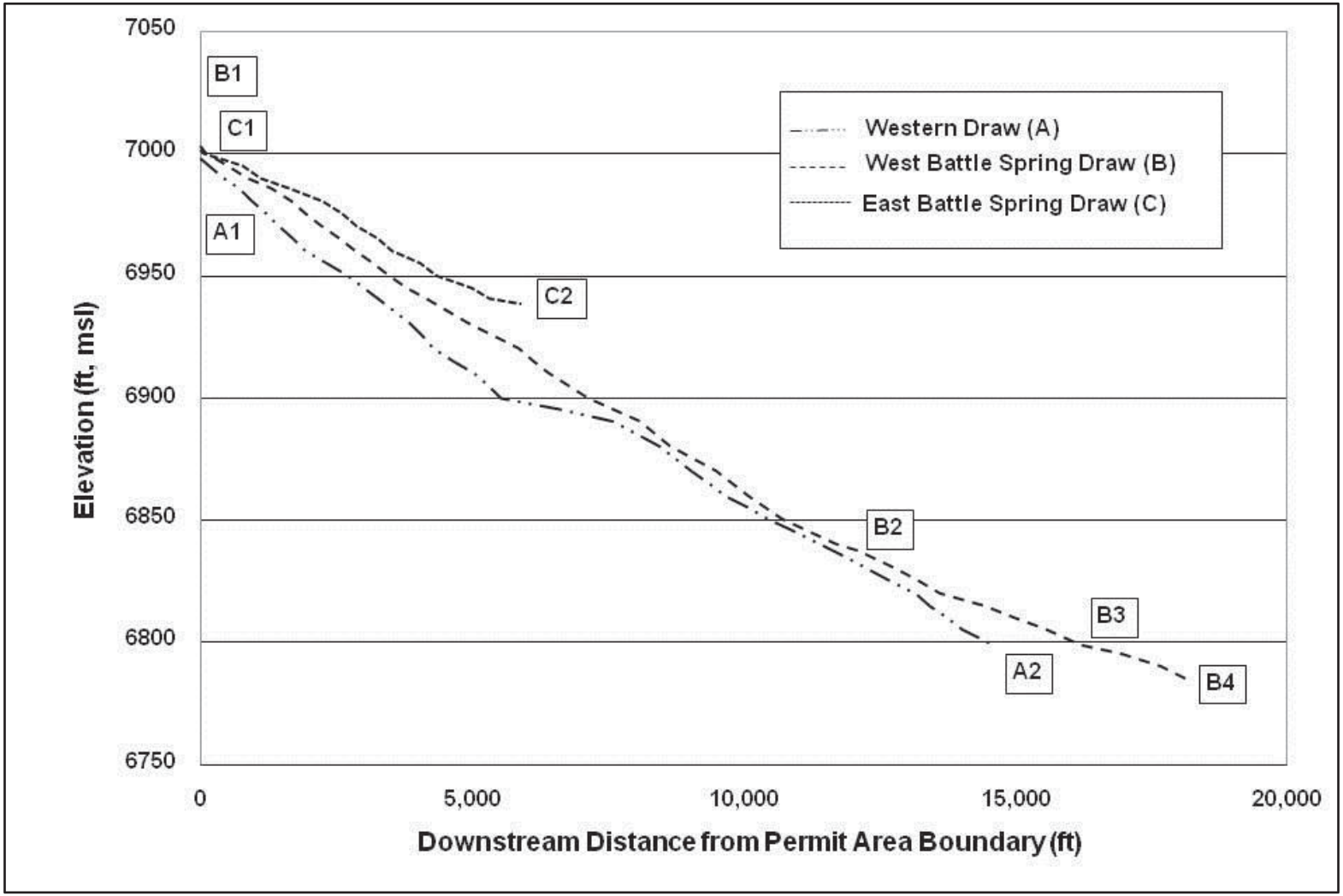
Figure 3.5-3 Longitudinal Profiles of the Main Permit Area's Principle Drainages



One small (less than one-quarter acre) seasonal stock pond, Crooked Well Reservoir, is located in the northeast portion of the Permit Area (**Figure 3.5-1**). The reservoir detains seasonal flow behind a dirt berm across East Battle Springs Draw (**Figure 3.5-4**) and is used by cattle, wild horses, and wildlife as a water source. Crooked Well Reservoir fills in March or April, when there is sufficient snowmelt runoff in East Battle Springs Draw, and is dry for most of the year.

Figure 3.5-4 Crooked Well Reservoir

Looking southwest.
April 2006.

Looking north.
April 2007.

Looking west.
April 2009.

3.5.1.2 Streamflow

The long-term mean annual precipitation is approximately ten inches per year in the Project region. April, May, and June are the wettest months, as discussed in **Section 3.10.1.2**. Annual runoff is very low due to the dry climate and high infiltration capacity of the soils. Runoff generally occurs as a result of spring snowmelt (**Figure 3.5-5**) or, less frequently, in response to large summer thunderstorms. The quantity of spring runoff is variable, depending on the amount of winter snowfall accumulation. Peak flows are driven by high intensity rain events, but surface flow from rainfall is generally short-lived.

Figure 3.5-5 Typical Snowmelt Runoff

Approximately 15 miles northeast of the Permit Area in April 2007

Field personnel (with formal training in hydrology), working on-site from 2006 through 2009, visually and conservatively estimated the flow of an on-site streamflow event at 0.5 cubic feet per second (cfs). This streamflow event was in response to snowmelt in the springtime. Due to the lack of disturbance of bed sediment and litter in the ephemeral channels, the low slope of the area, and the paucity of overland flow in response to observed rainfall events, it is believed that no flows greater than 1.0 cfs occurred during that period. Low flows, while

present, were dispersed across the channels and too shallow to measure using standard velocity-area methods (**Figure 3.5-5**).

Peak flows were estimated using a statistical regression model developed for Wyoming by Miller (2003). Peak flows for the smallest of the three watersheds in the main Permit Area, Western Draw, were estimated as 17 cfs for the two-year event and 227 cfs for the 100-year event; peak flows in the largest watershed in the main Permit Area, West Battle Springs Draw, were estimated as 29 cfs for the two-year event and 344 cfs for the 100-year event. Stratton Draw is the only significant channel that would generate substantial peak flows in the East and West Road portions of the Permit Area. The calculated two-year and 100-year peak discharges for this watershed are 43 and 477 cfs, respectively. Actual peak runoff rates may be lower because of the high infiltration capacity of the soils. The deeply incised channels are expected to convey and contain peak flows within their banks.

3.5.1.3 Surface Water Quality

Under the WDEQ-WQD Classification, Battle Spring Draw is listed as a Class 3B water body. Beneficial uses for Class 3B waters can include recreation, wildlife, "other aquatic life", agriculture, industry, and scenic value, but do not include drinking water, game fish, non-game fish, and fish consumption. Water quality data of samples collected in 1975 and 1976 from Battle Spring Draw for the Sweetwater Uranium Mill and Mine near the Permit Area are presented in **Table 3.5-1** (Sheperd Miller, 1994). The pH was highly alkaline at 9.5 standard units (SU). Uranium concentrations ranged from 0.006 to 0.95 mg/L.

Storm Water Samplers, fitted with Nalgene bottles, were installed to collect one-liter grab samples of first flush streamflow during runoff events (**Figure 3.5-6**). The sampling locations were selected based on their topographic potential to concentrate the ephemeral surface flows. In April 2006, samplers were installed at 12 locations in the main Permit Area (LC1 through LC12 on **Figure 3.5-7**). In April 2007, an additional sampler (LC13) was added to represent an area in the southeastern corner that was added to the Permit Area in the summer of 2006. Three of these locations were selected to capture runoff as it enters the main Permit Area from the upstream side (LC6, LC11 and LC12), and the others capture runoff within the main Permit Area (LC1, LC2, LC3, LC5 and LC10) or at the downstream boundary (LC4, LC7, LC8, LC9 and LC13). In September 2009, two samplers (LC14 and LC15) were added along Stratton Draw, upstream and downstream of the East Access Road (**Figure 3.5-7**).

Table 3.5-1 Historic Surface Water Data – Battle Spring Draw

Sample Date	1975					1976
	July	April	June	August	October	July
Sodium (mg/L)	116	--	--	--	--	--
Potassium (mg/L)	8	--	--	--	--	--
Calcium (mg/L)	23	--	--	--	--	--
Magnesium (mg/L)	5	--	--	--	--	--
Sulfate (mg/L)	130	--	--	--	--	--
Chloride (mg/L)	18	--	--	--	--	--
Carbonate (mg/L)	0	--	--	--	--	--
Bicarbonate (mg/L)	220	--	--	--	--	--
TDS (mg/L)	276	--	--	--	--	--
pH (SU)	9.5	--	--	--	--	--
Gross Alpha (pCi/L)	--	--	--	156 ± 34	--	--
Gross Beta (pCi/L)	--	--	--	90.3 ± 8.8	--	--
Thorium-230 (pCi/L)	--	--	--	3.34 ± 0.43	--	--
Radium-226 (pCi/L)	--	--	--	33.5 ± 1.1	--	--
Strontium-90 (pCi/L)	--	--	--	1.5 ± 0.6	--	--
Uranium (mg/L)	0.006	0.153	0.153	0.289	0.95	0.5

pCi/L = picoCuries per liter
-- = No data

Figure 3.5-6 Storm Water Sampler

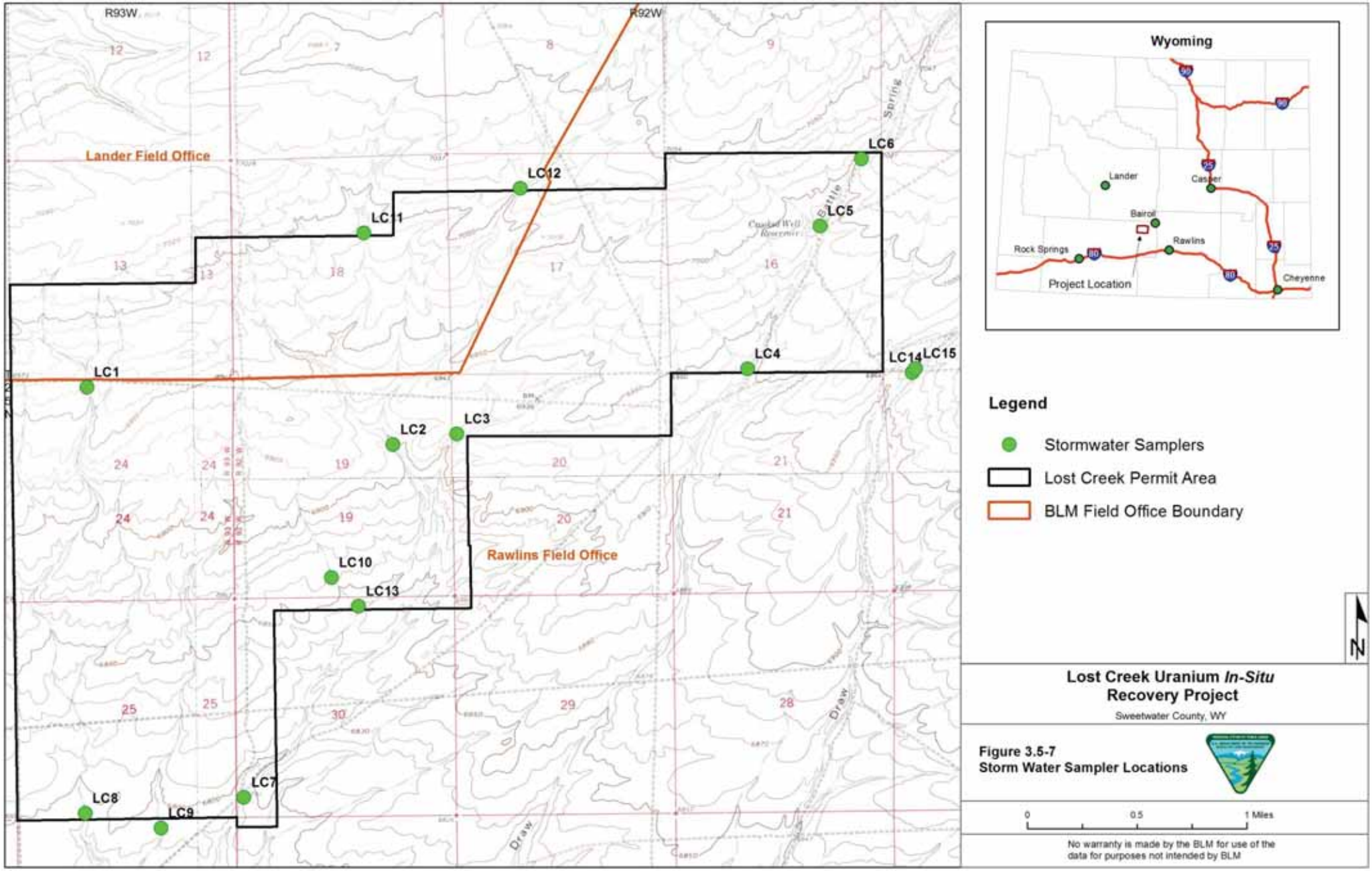


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Figure 3.5-7
Storm Water Sampler Locations

No warranty is made by the BLM for use of the data for purposes not intended by BLM

Seven of the samplers in the main Permit Area collected full, one-liter samples from snowmelt runoff in March and April 2007. These samples were retrieved on April 17, 2007. No water (or insufficient water for analysis) was collected in the other samplers. The water quality data for the seven surface water samples are summarized in **Table 3.5-2**. Ionic strength was low in all samples, which is probably due to the majority of the sample being snowmelt. For all samples, the dissolved and total concentrations of trace metals were near or below the detection limit. Radiometric parameters, including uranium, lead-210, polonium-210, and thorium-230, were generally below detection with the exception of dissolved uranium, which was detected at very low concentrations (0.0003 to 0.0004 mg/L) in two samples, suspended uranium (0.0003 to 0.0009 mg/L) in two samples, and total uranium (0.0003 to 0.0009 mg/L) in four samples. Total radium-226 was detected at a low concentration (0.5 pCi/L) in one sample. This was the LC2 location in one of the larger channels in the center of the Permit Area. Gross alpha was also detected in small amounts (1.1 to 3.6 pCi/L) in six samples. The highest concentration was 3.6 pCi/L and was again from the LC2 location. The pH of the samples was slightly acidic to neutral, ranging from 6.39 to 7.12 SU. Conductivity was low with no more than 100 micromhos per centimeter (µmhos/cm) for all samples.

In general, the quality of water was very good for all samples. The radiometric parameters detected in the LC2 sample correlate well with the radiological scans of the Permit Area. This central area has the highest radioactive activity, as indicated by the results from the radiological surveys. Still, the levels are well below all Wyoming agricultural and drinking water standards. Differences between the 2007 and historical data could be attributed to either a difference in streamflow during the sampling period or differences in the sampling locations.

3.5.1.4 Surface Water Uses

Surface-water permits with legal descriptions inside and within three miles of the main Permit Area were queried using the WSEO Water Rights Database (WSEO, 2010). **Table 3.5-3** lists the twelve surface water permits within three miles of the Permit Area. None of these locations are within one mile of the Permit Area, and all are related to mining operations to the southwest of the Permit Area.

There are four BLM wells within one mile of the main Permit Area. These wells have stock ponds associated with them. Stock ponds are typically used for overflow water whenever wells are pumped to provide water to wildlife, livestock, or wild horses. The water-use permits for these ponds are associated with the wells that supply the ponds, i.e., they are not associated with any surface-water-use permits. These wells are described in more detail in **Section 3.6.3.1**.

As noted in the previous section, the Crooked Well Reservoir (**Figure 3.5-1**) is in the Permit Area. However, it is a small off-channel detention pond, less than one-quarter acre in size, and there is no water-use permit associated with it.

Table 3.5-2 Surface Water Quality Data (Page 1 of 5)

Parameter	Units	Detection Limit	Sampling Location						
			LC1	LC2	LC4	LC5	LC10	LC11	LC12
Major Ions-Dissolved									
Calcium	mg/L	1.0	2.8	5.6	3.3	5.5	3.3	5.2	7.4
Magnesium	mg/L	1.0	0.9	1.5	0.9	1.6	0.6	1.3	1
Sodium	mg/L	1.0	1.1	1.1	0.8	1.2	1.4	1	1
Potassium	mg/L	1.0	4.1	6.2	5	7.8	8.4	9.4	3.4
Carbonate	mg/L	1.0	<1	<1	<1	<1	<1	<1	<1
Bicarbonate	mg/L	1.0	12	27	17	30	29	15	24
Sulfate	mg/L	1.0	3	3	3	5	13	6	6
Chloride	mg/L	1.0	2	1	1	2	1	2	<1
Ammonia as N	mg/L	0.05	0.46	0.6	0.55	1.11	8.7	0.86	0.41
Nitrite as N	mg/L	0.10	<0.1	<0.1	<0.1	<0.1	0.3	0.2	<0.1
Nitrite + Nitrate as N	mg/L	0.10	0.3	0.3	0.3	<0.1	0.7	0.6	0.9
Fluoride	mg/L	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silica	mg/L	1.0	6.9	9.9	7.1	14.5	0.9	1.1	3.9
Trace Metals-Dissolved									
Aluminum	mg/L	0.10	0.3	0.7	0.6	0.6	<0.1	0.2	0.7
Arsenic	mg/L	0.001	0.002	0.003	0.002	0.006	0.002	0.002	0.001
Barium	mg/L	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table 3.5-2 Surface Water Quality Data (Page 2 of 5)

Parameter	Units	Detection Limit	Sampling Location						
			LC1	LC2	LC4	LC5	LC10	LC11	LC12
Boron	mg/L	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	mg/L	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	mg/L	0.05	0.66	0.76	0.66	1.26	0.04	0.17	0.35
Lead	mg/L	0.001	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Manganese	mg/L	0.01	0.03	0.01	0.07	0.4	0.07	0.13	0.04
Mercury	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.004	<0.001
Silver	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/L	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	mg/L	0.01	0.07	0.04	0.05	0.03	0.22	0.13	0.08
Trace Metals-Total									
Aluminum	mg/L	0.10	0.5	1.4	1.6	2.7	0.1	0.3	0.8
Arsenic	mg/L	0.001	0.001	0.002	<0.001	0.004	<0.001	<0.001	<0.001
Barium	mg/L	0.10	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1

Table 3.5-2 Surface Water Quality Data (Page 3 of 5)

Parameter	Units	Detection Limit	Sampling Location						
			LC1	LC2	LC4	LC5	LC10	LC11	LC12
Boron	mg/L	0.10	0.6	1	0.8	0.4	0.7	0.8	1.2
Cadmium	mg/L	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Copper	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	mg/L	0.05	0.24	0.54	0.29	1.83	0.06	0.21	0.17
Lead	mg/L	0.001	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Manganese	mg/L	0.01	0.04	0.13	0.08	1.45	0.06	0.13	0.03
Mercury	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel	mg/L	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	mg/L	0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Silver	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/L	0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	mg/L	0.01	0.06	0.03	0.05	0.08	0.22	0.13	0.09
Radiometric-Dissolved									
Uranium	mg/L	0.0003	<0.0003	0.0004	<0.0003	0.0003	<0.0003	<0.0004	<0.0003
Lead 210	pCi/L	2.2	<2.4	<2.2	<2.2	<2.5	<2.2	<2.3	<2.2
Polonium 210	pCi/L	2.2	<2.4	<2.2	<2.2	<2.5	<2.2	<2.3	<2.2

Table 3.5-2 Surface Water Quality Data (Page 4 of 5)

Parameter	Units	Detection Limit	Sampling Location						
			LC1	LC2	LC4	LC5	LC10	LC11	LC12
Thorium 230	pCi/L	0.4	<0.5	<0.4	<0.4	<0.5	<0.4	<0.5	<0.4
Radiometric-Suspended									
Uranium	mg/L	0.0003	<0.0003	0.0005	<0.0003	0.0006	<0.0003	<0.0003	<0.0003
Lead 210	pCi/L	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Polonium 210	pCi/L	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium 230	pCi/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Radium 226	pCi/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Radiometric-Total									
Uranium	mg/L	0.0003	0.0003	0.0008	0.0003	0.0009	<0.0003	<0.0003	<0.0003
Radium 226	pCi/L	0.2	<0.2	0.5	<0.2	<0.2	<0.2	<0.2	<0.2
Radium 228	pCi/L	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Gross Alpha minus Rn & U	pCi/L	1	1.3	3.6	1.4	2.6	1.2	<1.0	1.1
Gross Beta	pCi/L	2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Non-Metals									
pH	SU	0.01	7.1	6.86	6.66	6.83	7.12	6.41	6.39
Conductivity	µmhos/cm	1.0	36.4	57.3	40.5	64.5	100	66.4	62.6
Total Suspended Solids @ 105°C	mg/L	1.0	36	422	24	5280	4	14	9
Alkalinity as $CaCO_3$	mg/L	1.0	10	22	14	25	24	12	20

Table 3.5-2 Surface Water Quality Data (Page 5 of 5)

Parameter	Units	Detection Limit	Sampling Location						
			LC1	LC2	LC4	LC5	LC10	LC11	LC12
Quality Assurance Data		Target Range							
Anion	meq/L		0.355	0.571	0.377	0.655	0.823	0.486	0.609
Cation	meq/L		0.462	0.766	0.537	0.881	1.12	0.748	0.698
WDEQ A/C Balance	percent	-5 to +5	13	14.6	17.4	14.7	15.2	21.3	6.82
Calculate TDS	mg/L		29	43	30	52	46	37	40

Table 3.5-3 Surface Water Rights within Three Miles of the Main Permit Area

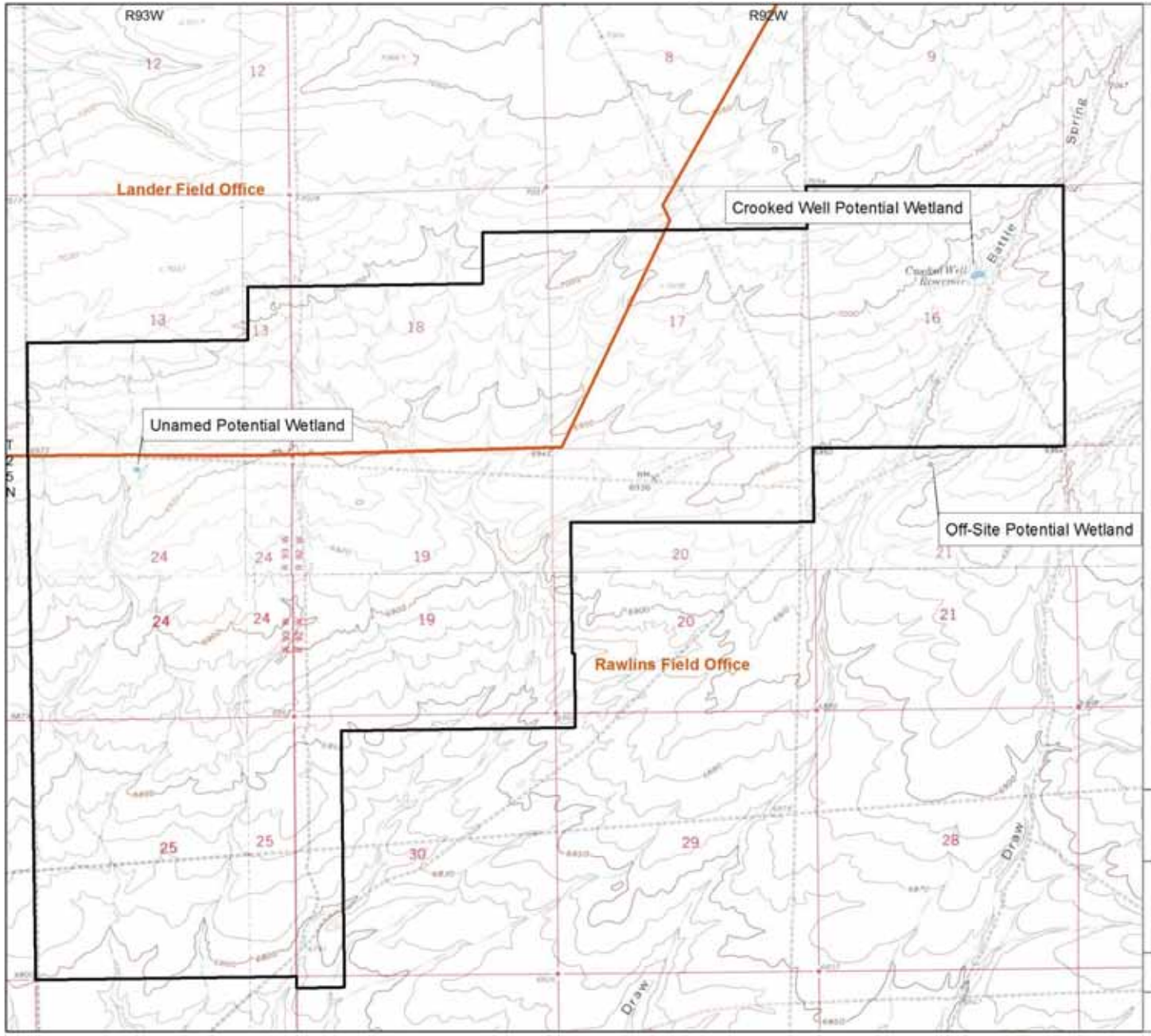
Map ID	Permit Number	Applicant	Township, Range, Section, ¼¼	Uses	Priority	Status	Permit Facility Name	Source	Amount (ac-ft)
1	P7871R	Green Mountain Mining Venture	24N, 93W, 3, SESW	Wildlife, Stock	7/28/1977	Unadjudicated	Blue No. 5 Reservoir	Minerals Draw	4106.4
2	P7871R	Green Mountain Mining Venture	24N, 93W, 3, SWSW	Wildlife, Stock	7/28/1977	Unadjudicated	Blue No. 5 Reservoir	Minerals Draw	4106.4
3	P7871R	Green Mountain Mining Venture	24N, 93W, 9, NENE	Wildlife, Stock	7/28/1977	Unadjudicated	Blue No. 5 Reservoir	Minerals Draw	4106.4
4	P10088R	Kennecott Uranium Co.	24N, 93W, 9, NESE	Industrial, Temporary Use	7/27/1994	Unadjudicated	Sweetwater Pit Reservoir	Road Draw	3809.32
5	P10088R	Kennecott Uranium Co.	24N, 93W, 9, SESE	Industrial, Temporary Use	7/27/1994	Unadjudicated	Sweetwater Pit Reservoir	Road Draw	3809.32
6	P7871R	Green Mountain Mining Venture	24N, 93W, 10, NENW	Wildlife, Stock	7/28/1977	Unadjudicated	Blue No. 5 Reservoir	Minerals Draw	4106.4
7	P7871R	Green Mountain Mining Venture	24N, 93W, 10, NWNW	Wildlife, Stock	7/28/1977	Unadjudicated	Blue No. 5 Reservoir	Minerals Draw	4106.4
8	P10088R	Kennecott Uranium Co.	24N, 93W, 10, NWSW	Industrial, Temporary Use	7/27/1994	Unadjudicated	Sweetwater Pit Reservoir	Road Draw	3809.32
9	P7871R	Green Mountain Mining Venture	24N, 93W, 10, SWNW	Wildlife, Stock	7/28/1977	Unadjudicated	Blue No. 5 Reservoir	Minerals Draw	4106.4
10	P10088R	Kennecott Uranium Co.	24N, 93W, 10, SWSW	Industrial, Temporary Use	7/27/1994	Unadjudicated	Sweetwater Pit Reservoir	Road Draw	3809.32
11	P10671R	Kennecott Uranium Co.	24N, 93W, 11, SESW	Industrial, Temporary Use	1/21/1998	Unadjudicated	Blue No. 10 Reservoir	Battle Spring Draw	2040.42
12	P10671R	Kennecott Uranium Co.	24N, 93W, 11, SWSW	Industrial, Temporary Use	1/21/1998	Unadjudicated	Blue No. 9 Reservoir	Battle Spring Draw	2040.42

3.5.2 Wetlands

Evaluation of potential wetland areas was initially conducted by reviewing aerial photographs of the Permit Area for topographic low areas and drainages. Other than the Crooked Well Reservoir, no potential wetland areas were identified from the aerial photographs. Three potential wetlands were identified using the Geographic Information System (GIS) layers from the National Wetlands Inventory (NWI) database (National Wetlands Inventory, 2006), and their locations are shown in **Figure 3.5-8**. The National Hydrography Dataset (NHD) was also referenced (National Hydrography Dataset, 2011), this dataset only showed the Crooked Well Reservoir (**Figure 3.5-8)** as a potential wetland.

The potential wetland areas were visited in the field during the 2006 growing season and again in the spring of 2009. The sites were evaluated using the criteria listed in the USACE wetland delineation manual (Department of the Army, 1987). Two of the three locations were not wetlands, as none of the criteria related to hydrology, soils, or vegetation were met. A more detailed evaluation of the vegetation at one potential location, the Crooked Well Reservoir, was conducted because of the potential for inundation of the area during some seasons. The indicator status for wetland species has been developed by the USFWS, and a specific publication for Region 9 (which includes western Wyoming) is available (Reed, 1988).

Based on more detailed field observations during April 2006 (vegetation survey, surface water sampling, and other site activities), the Crooked Well Reservoir was determined not to be a wetland under the 1987 USACE criteria (hydrology, soils, and vegetation). **Figure 3.5-4** shows the reservoir conditions in April of 2006, 2007, and 2009. Hydrology is the criteria most likely to be met in a given year; however, the variability and timing of precipitation do not result in inundation for at least five days during the growing season each year. There may be sufficient snowmelt for water to accumulate for five days in some years, but because of the variability in temperatures, snowmelt often occurs (and the reservoir dries) before the growing season starts in June (National Climatic Data Center, 2008). There may also be water present after an intense summer thunderstorm, but only at rare intervals from year to year.



Legend

- Potential Wetlands
- Lost Creek Permit Area
- BLM Field Office Boundary

N

Lost Creek Uranium *In-Situ* Recovery Project

Sweetwater County, WY

Figure 3.5-8
Potential Wetlands Delineated by NWI

0 0.5 1 Miles

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The bottom of the reservoir is composed of sand, silt, and clay, with no surficial evidence of extensive organic material or anaerobic conditions. The bottom of the reservoir is essentially bare, probably due in part to wind scour. Although there is no specific vegetation density requirement for wetlands, the density is a factor that should be taken into account (Department of the Army, 1987). Scattered small sagebrush and grasses are present along the edges of the bare area; these grade quickly to the more dense sagebrush community, however hydrophytic plants were not observed.

Of the other two potential wetlands identified in the NWI, one is off channel in the northern portion of Township 25 North (T25N), Range 93 West (R93W), Section 24 (**Figure 3.5-9**). The other location is near a channel and just south of the Permit Area. It was apparently associated with the BLM Battle Spring Draw Well No. 4451 in the northern portion of T25N, R92W, Section 21. When the site was first visited in April 2006, and again in November 2007, the well was not in use. However, the well is back in service and was visited in April 2009 and October 2011 (**Figure 3.5-10**).

3.5.3 USACE Jurisdiction

In May 2010, LCI submitted a request to USACE for a jurisdictional determination of waters within the Permit Area, based on the information in Appendix D11 of the WDEQ-LQD Permit to Mine (LCI, 2011b), which is essentially the same information in this EIS. The USACE's jurisdictional determination is in a letter dated August 10, 2010 (Attachment D11-1 of the WDEQ-LQD Permit to Mine [LCI, 2011b]). The information provided was determined to provide an accurate depiction of potential wetlands and other waters within the Permit Area. In addition, "all waters within the permit area do not contain any areas that meet the definition of waters of the United States". The water bodies are considered isolated since: they have no surface connection to a traditional navigable water; they occur within a closed hydrologic basin; they do not provide habitat suitable for migratory birds; and they do not support any form of interstate commerce.

3.5.4 Aquatic Ecology

Research and field investigations confirmed that aquatic life was determined not to exist within the boundaries of the Permit Area. Surface water may be present occasionally, but it does not sustain aquatic life.

Figure 3.5-9 NWI Potential Wetland in T25N, R93W, Section 24

Looking East, April 2009.

Looking West, April 2009.

Figure 3.5-□□ NWI Potential Wetland at □□□ □attle S□ring □ra□ Well No. 445□

Battle Spring Draw Well No. 4551. November 2007.

Battle Spring Draw Well No. 4551. April 2009.

Pipeline from Battle Spring Draw Well No. 4551 to dirt 'tank'. April 2009.

Battle Spring Draw Well No. 4551. October 2011.

Pipeline outlet from Battle Spring Draw Well No. 4551 to dirt 'tank'. April 2009.

Dirt 'tank' at pipeline outlet from Battle Spring Draw Well No. 4551. April 2009.

3.6 Groundwater

This section summarizes the regional and local groundwater hydrology, including hydrostratigraphy, groundwater flow patterns, hydraulic gradient, and aquifer parameters. Data for this section of the report were obtained from the NRC Technical Report (LCI, 2010) and the WDEQ-LQD Permit to Mine (LCI, 2011b).

3.6.1 Regional Groundwater Hydrology

The Permit Area is located in the northeastern portion of the Great Divide Basin, a closed basin with all surface water flows toward the interior of the basin. Existing data suggest that groundwater flow within the Basin is also predominately toward the interior of the basin (Collentine et al., 1981; Welder and McGreevy, 1966; and Mason and Miller, 2005). The Green Mountains located to the northeast, the Rawlins Uplift, Rock Springs Uplift, and Creston Junction, located east, southwest, and southeast, respectively, from the Permit Area, were identified as major recharge areas for aquifers within the basin (Fisk, 1967). The main discharge area for the Battle Spring/Wasatch aquifer system is to a series of lakes, springs, and playa lake beds near the center of the Basin.

Hydrologic units of interest within the northeast portion of the Basin are shown on the stratigraphic column in **Figure 3.6-1** and further described below, from deepest to shallowest:

- Lewis Shale (aquitard between Tertiary and Mesaverde aquifer systems);
- Fox Hills Formation (Cretaceous);
- Lance Formation (Tertiary aquifer system);
- Fort Union Formation (Tertiary aquifer system);
- Battle Spring Formation-Wasatch Formation (Tertiary aquifer system);
- Undifferentiated Tertiary Formations (Upper Tertiary aquifer system, including Bridger, Uinta, Bishop Conglomerate, Browns Park, and South Pass); and
- Undifferentiated Quaternary Deposits (Tertiary aquifer system).

The Tertiary aquifer system has been identified as “the most important and most extensively distributed and accessible groundwater source in the study area” (Collentine et al., 1981). The term Tertiary aquifer system is used herein as the shallow Undifferentiated Quaternary Deposits through the Lance Formation. Although the Lance Formation is Cretaceous in age, Collentine et al. included it with the Tertiary aquifer system in the 1981 report, “Occurrence and Characteristics of Ground Water in the Great Divide and Washakie Basins, Wyoming”, and that convention was adopted by LCI for the Project.

ERA	SYSTEM, SERIES AND OTHER SUBDIVISIONS			STRATIGRAPHIC UNIT	HYDROGEOLOGIC UNIT
Cenozoic	Quaternary			Unnamed Alluvium	Alluvial Aquifers
	Tertiary	Miocene	Upper	Browns Park, North Park, and South Pass Formations	UpperTertiary Aquifers (Not present near Lost Creek)
		Oligocene		Bishop Conglomerate	
		Eocene	Lower	Bridger Formation	Tertiary Aquifers
				Green River Formation	
		Paleocene		Wasatch Formation-Battle Spring Formation	
				Fort Union Formation	
				Lance Formation	
Mesozoic	Cretaceous			Fox Hills Sandstone	
			Upper	Lewis Shale	Confining Unit
				Mesaverde Formation	Measaverde Aquifer
				Steele Shale	Confining Unit
				Cody Shale	
				Niobrara Formation	
				Frontier Formation	Frontier Aquifer
			Lower	Mowry Shale	Confining Unit
				Muddy Sandstone	
				Thermopolis Shale	
				Cloverly Formation	Cloverly (Dakota) Aquifer
	Jurassic			Morrison Formation	Confining Unit
				Sundance Formation	Sundance/Nugget Aquifer
	Triassic			Nugget Sandstone	
				Chugwater Formation	Confining Unit
				Dinwoody Formation	
Paleozoic	Permian			Phosphoria Formation	Paleozoic Aquifers
	Pennsylvanian			Tensleep Sandstone	
				Amsden Formation	
	Mississippian			Madison Formation	
	Cambrian			Flathead Sandstone	

Lost Creek Uranium *In-Situ* Recovery Project

Sweetwater County, WY

Figure 3.6-1
Regional Hydrostratigraphic Units of Interest

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The Battle Spring Formation of the Tertiary aquifer system crops out over most of the northeast portion of the Basin; and the Quaternary deposits and Upper Tertiary aquifer systems are absent or minimal in extent. In the northeast portion of the Basin, the shallower aquifer systems (Quaternary and Upper Tertiary) are typically found along the margins of the Basin where the Battle Springs Formation is absent, and in localized areas can be a source of groundwater.

Aquifers in formations deeper than the Lewis Shale are generally too deep to economically develop for water supply or have elevated total dissolved solid (TDS) concentrations that render them unusable for human consumption. However in the northeast portion of the Basin, near structural highs such as the Rawlins Uplift, these aquifer systems can be sources of groundwater in the vicinity of outcrops.

3.6.1.1 Lewis Shale

The Lewis Shale a regionally extensive aquitard in the Basin underlies the Fox Hills Formation (Collentine et al., 1981). This unit is described by Welder and McGreevey (1966) as light to dark gray, carbonaceous shale with beds of siltstone and very fine-grained sandstone. The Lewis Shale is up to 2,700 feet thick, generally increasing in thickness toward the east side of the Basin. In the Permit Area, the Lewis Shale is 1,200 feet thick. Small quantities of water may be available from the thin sandstone beds within this unit near the margins of the Basin. The Lewis Shale acts as the confining unit between the Tertiary and Mesaverde aquifer systems (Collentine et al., 1981).

3.6.1.2 Fox Hills Formation

The Fox Hills Formation overlies the Lewis Shale and consists of very fine-grained sandstone, siltstone and coal beds. It is not considered to be an important aquifer in the Permit Area.

3.6.1.3 Lance Formation

Overlying the Fox Hills Formation is the Lance Formation, consisting predominately of very fine-to fine-grained lenticular, clayey, calcareous sandstone. Shale, coal and lignite beds are present within the formation, which reaches a maximum thickness of approximately 4,500 feet (Welder and McGreevy, 1966). In the Permit Area, the Lance Formation is approximately 3,000 feet thick.

Collentine et al. (1981) include the Lance Formation (Aquifer) as the lower-most aquifer within the Tertiary aquifer system. However, the Lance Aquifer is included as part of the Mesaverde aquifer system by Freethey and Cordy (1991). Several stock wells, located along the eastern outcrop area of the Basin, are completed in the Lance Aquifer. The stock wells have estimated yields of five to

30 gpm. Hydraulic conductivity for the Mesaverde aquifer system reported by Freethey and Cordy (1991) (which, by the authors' designation, includes the Fox Hills Sandstone, Lewis Shale, and Mesaverde Group, in addition to the Lance Aquifer) is reported to range from 0.0003 to 2.2 feet per day (ft/d).

3.6.1.4 Fort Union Formation

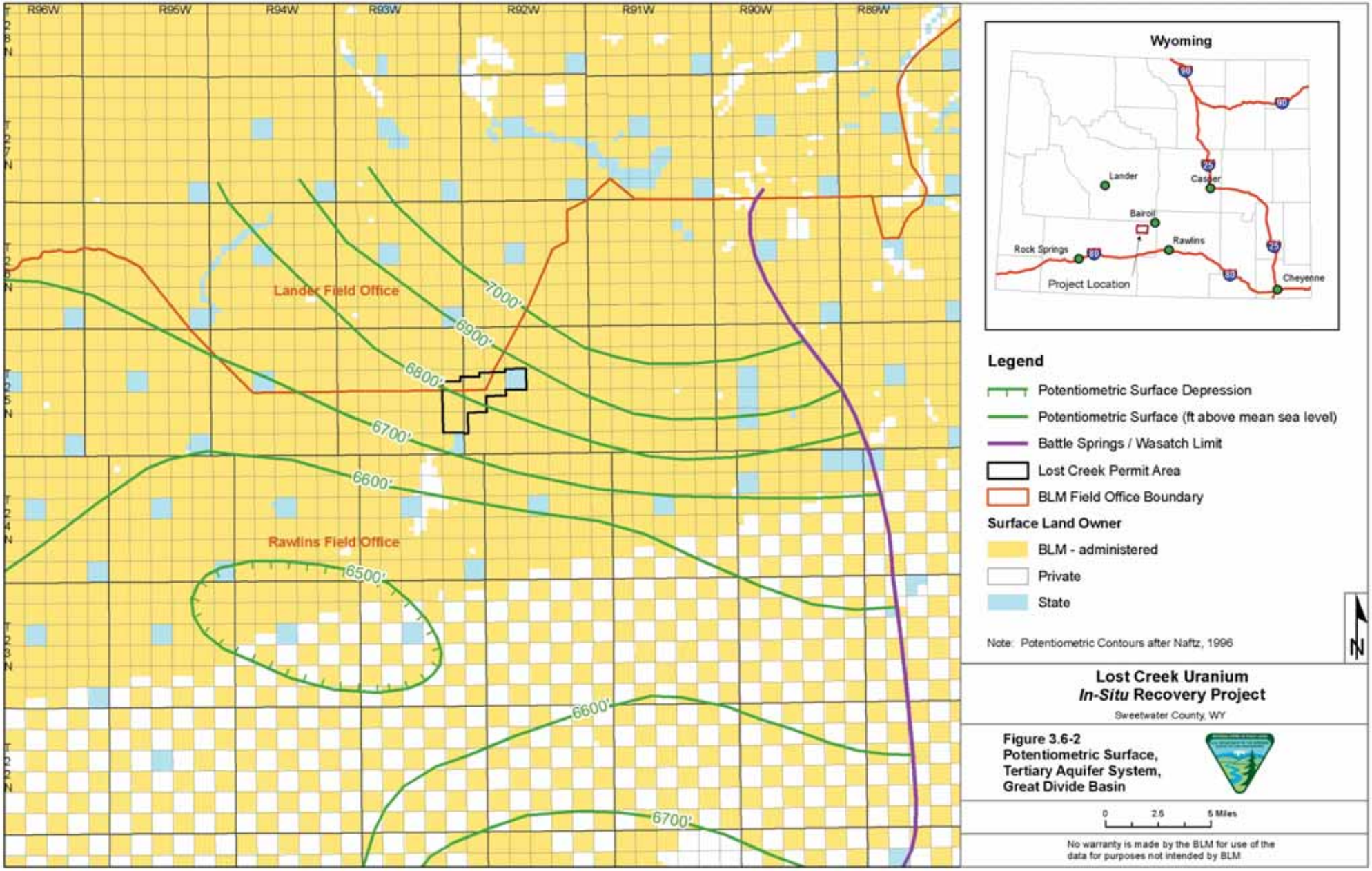
The Paleocene-age Fort Union Formation is between the Lance Formation and the overlying Wasatch and Battle Spring Formations, reaching a maximum thickness of approximately 6,000 feet within the Great Divide/Washakie Basin area. In the Permit Area, it is approximately 4,650 feet thick. The Fort Union Formation is present at or near land surface in a band around the Rock Springs Uplift and in the northeastern corner of the Basin (Mason and Miller, 2005). The Fort Union Formation is described as fine- to coarse-grained sandstone with coal and carbonaceous shale. Siltstone and claystone are present in the upper part of the formation (Welder and McGreevy, 1966).

A potentiometric surface map, prepared by Natfz (1996) that groups the Fort Union aquifer with the Battle Spring/Wasatch aquifers, shows inferred movement of groundwater toward the Basin's center (**Figure 3.6-2**).

The Fort Union aquifer is largely undeveloped and unknown as a source of groundwater supply except in areas where it occurs at shallow depths along the margins of the Basin. Well yields from the Fort Union aquifer within the Great Divide and Washakie Basins range from 3 to 300 gpm. Estimates of transmissivity for the Fort Union aquifer are highly variable, ranging from less than 3 square feet per day (ft^2/d) to325 ft^2/d (Ahern et al., 1981) and (Collentine et al., 1981).

3.6.1.5 Battle Spring Formation-Wasatch Formation

The most important water-bearing aquifers within the Basin are in the Wasatch Formation and the Battle Spring Formation. The Wasatch and Green River Formations grade into the Battle Spring Formation in the northeastern portion of the Basin. The Battle Spring Formation is absent along the eastern margin of the Basin, near the county line between Sweetwater and Carbon Counties. The termination of the Battle Spring Formation to the east and north is abrupt, controlled largely by structural features, including the Rawlins Uplift to the east and the Green Mountains to the north. A dry oil test in Section 14, Township 24 North, Range 90 West, located within a few miles of the eastern limit of the Battle Spring Formation, had a reported thickness of over 6,000 feet of fine- to coarse-grained sandstone that was interpreted by the American Stratigraphic Company as the Battle Spring Formation. Within the Permit Area, the Battle Spring Formation is over 6,200 feet thick. **Figure 3.3-1** shows the regional geology of the area.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Lander Field Office
Rawlins Field Office
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6800'
6700'
6600'
6500'
6600'
6700'
Wyoming
Lander
Casper
Bairoil
Rock Springs
Rawlins
Cheyenne
Project Location
Legend
Potentiometric Surface Depression
Potentiometric Surface (ft above mean sea level)
Battle Springs / Wasatch Limit
Lost Creek Permit Area
BLM Field Office Boundary
Surface Land Owner
BLM - administered
Private
State
Note: Potentiometric Contours after Naftz, 1996
N
Lost Creek Uranium
In-Situ Recovery Project
Sweetwater County, WY
Figure 3.6-2
Potentiometric Surface,
Tertiary Aquifer System,
Great Divide Basin
0
2.5
5 Miles
No warranty is made by the BLM for use of the data for purposes not intended by BLM

The Battle Spring Formation is described as an arkosic fine- to coarse-grained sandstone with claystone and minor conglomerates. There are typically several water-bearing sands within the Battle Spring Formation. The Battle Spring aquifers are included in the Tertiary aquifer system, as defined by Collentine et al. (1981).

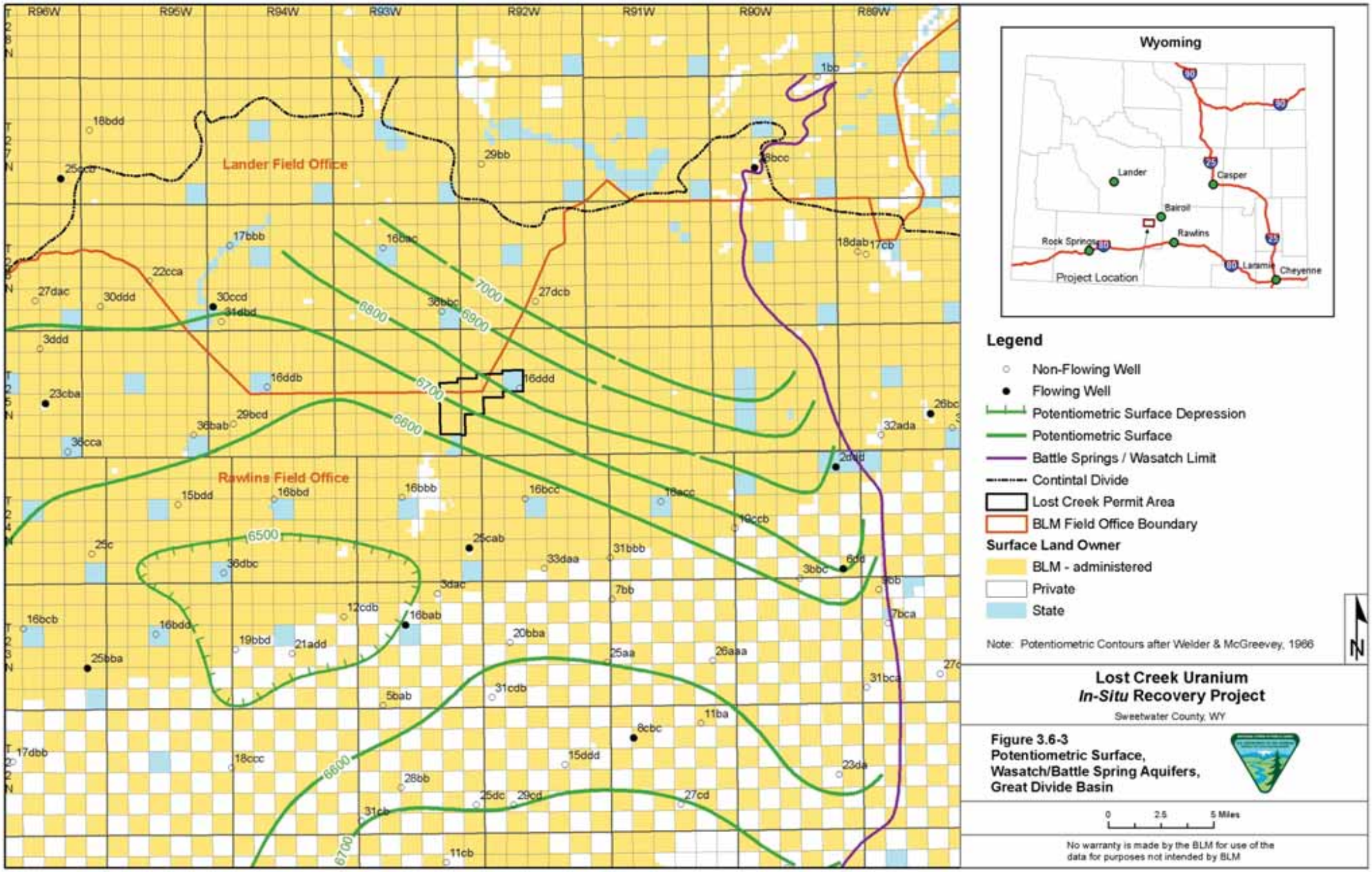
Groundwater within the Battle Spring aquifers is typically under confined conditions, although locally unconfined conditions exist. The potentiometric surface within the Battle Spring aquifers is usually within 200 feet of the ground surface (Welder and McGreevy, 1966). Most wells drilled for water supply in this unit are less than 1,000 feet deep. The potentiometric surface map of Wasatch and Battle Spring aquifers (**Figure 3.6-3**) indicates groundwater movement toward the center of the Basin (Welder and McGreevy, 1966). From the Permit Area, the potentiometric surface dips to the southwest at approximately 50 feet per mile (ft/mile) (a hydraulic gradient of 0.01 feet per foot [ft/ft]). The hydraulic gradient becomes steeper near the margins of the Basin, where recharge to the aquifer is occurring.

Wells completed in the Battle Spring aquifers typically yield 30 to 40 gpm; but yields as high as 150 gpm are possible. Pump tests conducted on 26 wells completed within the Battle Spring aquifers resulted in transmissivity values ranging from 3.9 to 423 ft^2/d, although most wells were less than 67 ft^2/d. Specific capacity was less than one gallon per minute per foot for 23 of the 26 wells tested (Collentine, et al., 1981).

3.6.1.6 Undifferentiated Tertiary and Quaternary Sediments

Undifferentiated Tertiary and Quaternary units above the Battle Spring/Wasatch Formations can be sources of water supply; but wells in the northeastern portion of the Basin are rare and generally limited to the margins of the Basin, where the Battle Spring Formation is not present. Commonly, along the margins of the Basin, hydrostratigraphic units younger than the Battle Spring/Wasatch have been deposited on rocks of Cretaceous age or older. Water supply wells along the margins of the Basin are often completed in both the older hydrostratigraphic units and Tertiary and Quaternary sediments. Water quality within these units tends to be variable and available resources of good quality water are limited.

The undifferentiated Tertiary units consist of interbedded claystone, sandstone and conglomerate, with the coarser grained facies providing suitable groundwater resources where present. The undifferentiated Tertiary units are absent within the Permit Area and are not discussed further.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6700
6600
6500
Wyoming
Lander
Casper
Bairoil
Rawlins
Rock Springs
Laramie
Cheyenne
Project Location
Legend
Non-Flowing Well
Flowing Well
Potentiometric Surface Depression
Potentiometric Surface
Battle Springs / Wasatch Limit
Contintal Divide
Lost Creek Permit Area
BLM Field Office Boundary
Surface Land Owner
BLM - administered
Private
State
Note: Potentiometric Contours after Welder & McGreevey, 1966
N
Lost Creek Uranium
In-Situ Recovery Project
Sweetwater County, WY
Figure 3.6-3
Potentiometric Surface,
Wasatch/Battle Spring Aquifers,
Great Divide Basin
0
2.5
5 Miles
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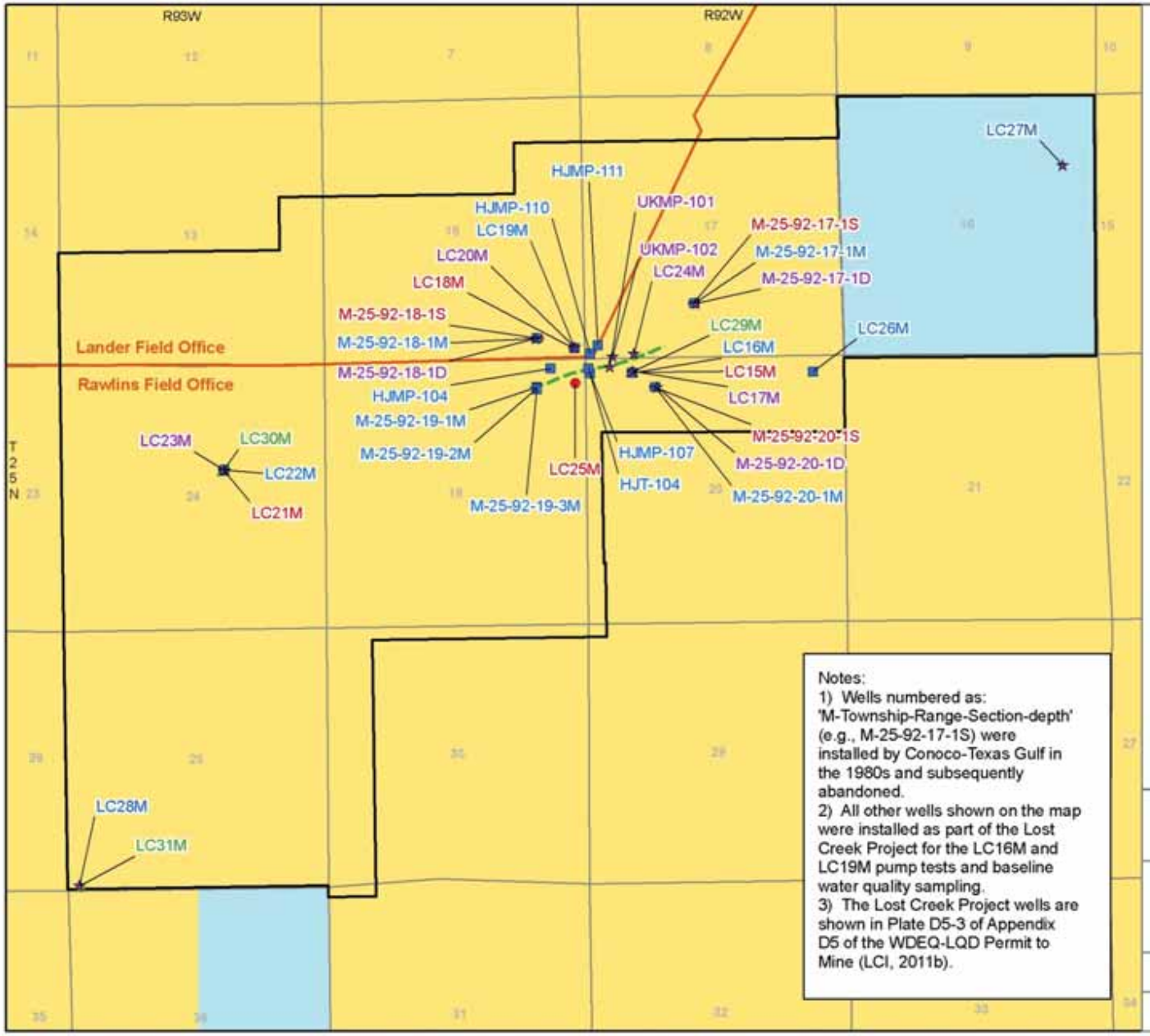
data for purposes not intended by BLM

The undifferentiated Quaternary units consist of clay, silt, sand, gravel and conglomerates that are poorly consolidated to unconsolidated (Welder and McGreevy, 1966). These units represent windblown, alluvial and lake deposits. Where present, these deposits can provide acceptable yields of groundwater of relatively good quality. Thin deposits of Quaternary sediments are present within surface drainages in the Permit Area but are usually above the water table and unsaturated. Therefore, Quaternary sediments are not an important groundwater source in the vicinity of the Project and are not described further.

3.6.2 Site Groundwater Hydrology

LCI has collected lithologic, water level, water quality, and pump test data as part of its ongoing evaluation of hydrologic conditions for the Permit Area and, most recently, for MU1. In addition to LCI's data, historic data collected for Conoco were used to support this evaluation (Hydro-Search, Inc., 1982). Drilling and installation of borings and monitor wells would continue to provide additional data to further refine the site hydrologic conceptual model and provide detailed operating information for each mine unit. Water level measurements, both historic and recent, provide data to assess potentiometric surface, hydraulic gradients and inferred groundwater flow directions for the aquifers of interest at the Permit Area. Long-term pump test data conducted by LCI and several shorter-term pump tests (Hydro-Engineering, 2007), as well as the pump tests conducted for Conoco (Hydro-Search, Inc., 1982), were used to evaluate hydrologic properties of the aquifers of interest. The pump test data were used to assess hydraulic characteristics of the confining units, and to evaluate impacts to the hydrologic system of the Fault through the Permit Area.

Figure 3.6-4 shows the locations of the historic Conoco (or Texasgulf) monitor wells (the M-25-92 series), and it shows the locations of the existing monitor wells that were used for baseline data collection and in the LC16M and LC19M pump tests. **Table 3.6-1** provides completion data for the monitor wells currently in use. Attachment D6-3 of the WDEQ-LQD Permit to Mine (LCI, 2011b) includes well completion logs for those wells. Plate D5-3 in Appendix D5 of the WDEQ-LQD Permit to Mine shows the locations of all the existing monitor wells in the Permit Area. **Figure 3.6-5** shows the monitor well locations for MU1; and **Table 3.6-2** is a list of those wells.



Notes:
1) Wells numbered as: 'M-Township-Range-Section-depth' (e.g., M-25-92-17-1S) were installed by Conoco-Texas Gulf in the 1980s and subsequently abandoned.
2) All other wells shown on the map were installed as part of the Lost Creek Project for the LC16M and LC19M pump tests and baseline water quality sampling.
3) The Lost Creek Project wells are shown in Plate D5-3 of Appendix D5 of the WDEQ-LQD Permit to Mine (LCI, 2011b).

Legend

Monitor Wells

- DE Horizon
- LFG Horizon
- HJ Horizon
- UKM Horizon
- Lost Creek Fault
- Lost Creek Permit Area
- BLM Field Office Boundary

Surface Land Owner

- BLM - administered
- State

N

Lost Creek Uranium
***In-Situ* Recovery Project**
Sweetwater County, WY

Figure 3.6-4
Early Lost Creek
Monitor Well Locations

0 0.5 1 Miles

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Table 3.6-1 Permit Area Monitor Well Data (Page 1 of 4)

Well Name	Easting (feet)	Northing (feet)	Completion Zone	Ground Surface Elevation (ft amsl)	Measure Point Elevation (ft amsl)	Total Depth (feet)	Top Underreamed Zone (ft bgs)	Bottom Underreamed Zone (ft bgs)	Total Underreamed thickness (feet)
HJT-106	744,221	534,573	DE	6933.14	6935.14	162	142	162	20
HJT-107	745,230	534,833	DE	6942.69	6944.34	163	133	163	30
LC29M	744,547	534,837	DE	6935.11	6936.86	171	140	164	24
LC30M	736,276	532,836	DE	6925.10	6927.40	236	196	236	40
LC31M	733,380	524,434	DE	6804.55	6805.83	191	150	190	40
MB-1	736,248	535,851	DE	6984.39	6985.89	300	240	280	40
MB-7	753,266	538,981	DE	6983.38	6984.88	140	80	125	45
MB-10	743,348	535,293	DE	6939.20	6940.70	190	130	160	30
HJMO-102	742,549	534,762	FG	6933.89	6934.56	330	290	330	40
HJMO-103	742,646	535,101	FG	6935.29	6936.29	330	296	326	30
HJMO-101	743,281	534,988	LFG	6904.24	6905.45	326	295	326	31
HJMO-104	742,897	534,899	LFG	6939.51	6940.76	328	296	326	30
HJMO-105	742,953	535,074	LFG	6936.84	6938.00	326	300	323	23
HJMO-106	743,168	535,258	LFG	6941.00	6941.75	336	296	326	30
HJMO-107	743,697	534,790	LFG	6936.86	6937.86	370	339	369	30
HJMO-108	743,461	535,298	LFG	6950.64	6951.64	333	305	333	28
HJMO-109	743,904	534,825	LFG	6937.79	6938.95	379	345	370	25
HJMO-110	743,675	535,194	LFG	6945.92	6947.13	330	300	330	30
HJMO-111	743,825	535,371	LFG	6949.38	6950.46	330	303	333	30
HJMO-112	744,375	534,674	LFG	6933.76	6935.51	350	305	350	45
HJMO-113	744,265	534,805	LFG	6936.06	6936.97	362	318	356	38
HJMO-114	744,979	534,676	LFG	6939.09	6940.75	360	324	360	36
LC15M	744,532	534,820	LFG	6935.13	6936.55	350	286	340	54
LC18M	743,368	535,316	LFG	6948.43	6949.03	350	290	332	42
LC21M	736,277	532,850	LFG	6925.00	6927.13	410	375	398	23
LC25M	743,397	534,601	LFG	6935.00	6936.52	380	316	369	53
MB-2	436,298	535,858	LFG	6985.42	6986.92	460	410	450	40

Table 3.6-1 Permit Area Monitor Well Data (Page 2 of 4)

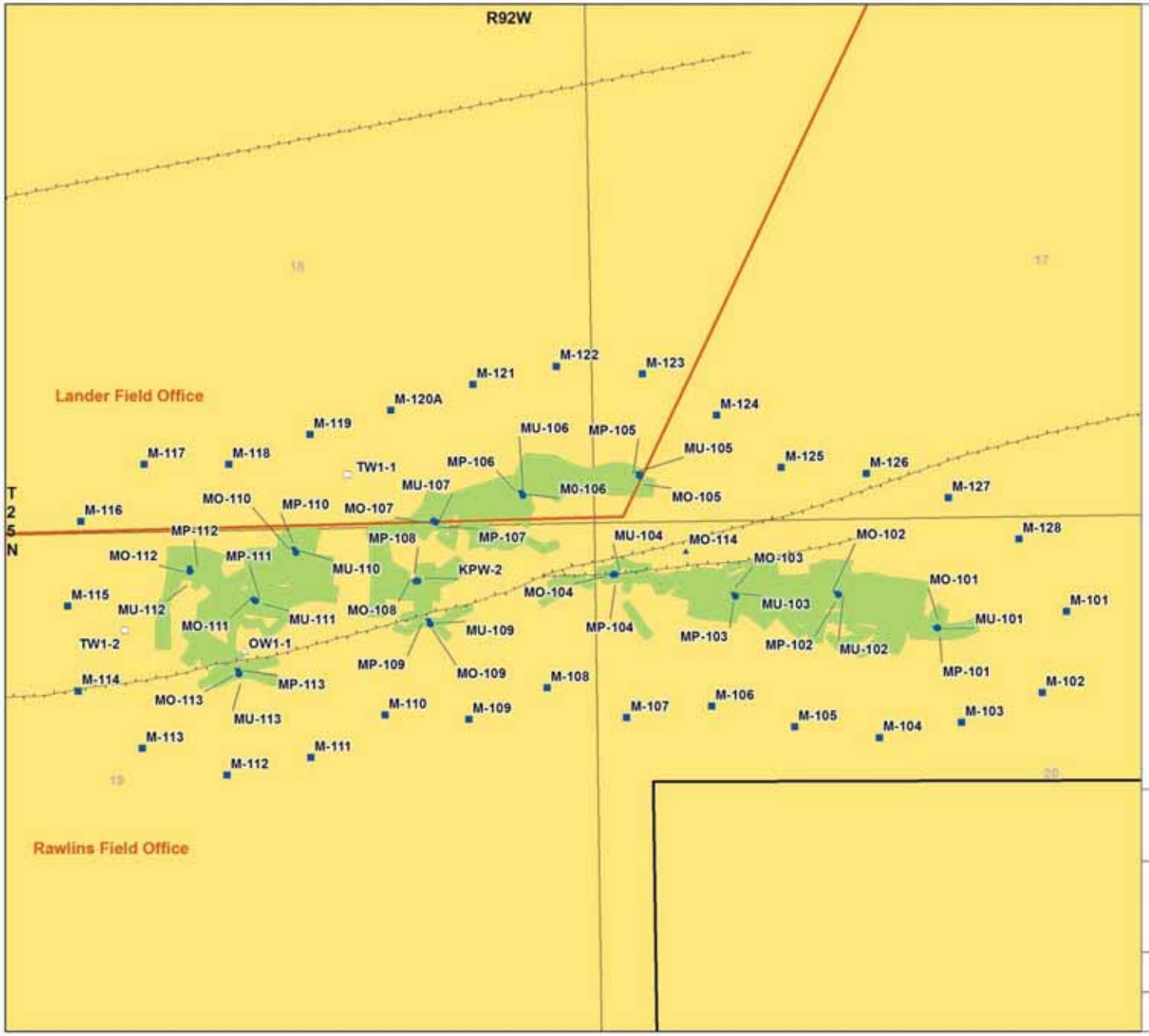
Well Name	Easting (feet)	Northing (feet)	Completion Zone	Ground Surface Elevation (ft amsl)	Measure Point Elevation (ft amsl)	Total Depth (feet)	Top Underreamed Zone (ft bgs)	Bottom Underreamed Zone (ft bgs)	Total Underreamed thickness (feet)
MB-5	733,337	524,466	LFG	6803.54	6805.04	330	305	325	20
MB-8	753,316	538,987	LFG	6984.00	6985.50	280	230	260	30
HJMP-101	743,287	534,998	HJ	6903.70	6904.58	490	438	465	27
HJMP-102	742,559	534,755	HJ	6934.15	6936.15	440	405	435	30
HJMP-103	742,652	535,109	HJ	6935.08	6936.49	432	392	432	40
HJMP-104	742,886	534,897	HJ	6939.04	6941.04	430	402	430	28
HJMP-105	742,933	535,073	HJ	6936.84	6937.38	460	425	463	38
HJMP-106	743,166	535,267	HJ	6940.20	6941.29	480	430	480	50
HJMP-107	743,684	534,802	HJ	6936.81	6938.45	464	423	460	37
HJMP-108	743,466	535,311	HJ	6951.12	6952.20	436	400	434	34
HJMP-109	743,895	534,829	HJ	6937.89	6939.10	512	478	512	34
HJMP-110	743,682	535,184	HJ	6945.81	6947.01	476	431	476	45
HJMP-111	743,836	535,365	HJ	6948.99	6949.49	440	393	440	47
HJMP-112	744,385	534,668	HJ	6934.32	6935.48	400	370	400	30
HJMP-113	744,273	534,797	HJ	6935.26	6937.26	462	416	462	46
HJMP-114	744,976	534,687	HJ	6940.18	6941.01	460	408	460	52
HJT-101	742,561	534,610	HJ	6937.12	6937.56	478	437	477	40
HJT-102	742,886	534,696	HJ	6937.82	6939.15	430	390	417	27
HJT-103	743,180	534,670	HJ	6937.56	6938.22	450	423	450	27
HJT-104	743,653	534,892	HJ	6937.48	6940.15	460	410	460	50
HJT-105	744,423	535,024	HJ	6937.45	6938.87	850	407	438	31
LC16M	744,549	534,818	HJ	6934.73	6936.15	472	410	467	57
LC19M	743,383	535,317	HJ	6949.32	6950.52	463	412	463	51
LC22M	736,292	532,850	HJ	6924.01	6926.06	592	504	585	81
LC26M	748,203	534,832	HJ	6952.96	6955.67	436	376	431	55
UKMO-101	744,086	534,943	HJ	6940.19	6942.28	487.4	465	485	20
UKMO-102	744,205	535,134	HJ	6940.24	6940.79	420	377	408	31
UKMO-103	744,501	535,556	HJ	6949.28	6950.53	438	417	445	28

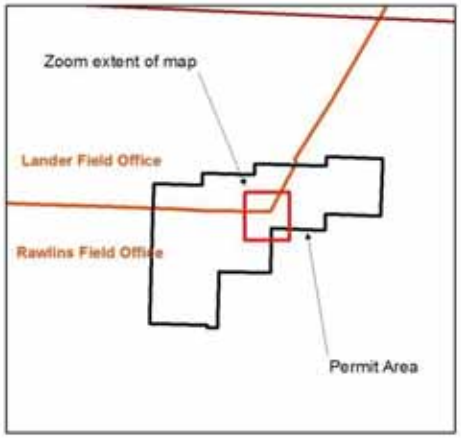
Table 3.6-1 Permit Area Monitor Well Data (Page 3 of 4)

Well Name	Easting (feet)	Northing (feet)	Completion Zone	Ground Surface Elevation (ft amsl)	Measure Point Elevation (ft amsl)	Total Depth (feet)	Top Underreamed Zone (ft bgs)	Bottom Underreamed Zone (ft bgs)	Total Underreamed thickness (feet)
MB-3B	736,348	535,854	HJ	6985.88	6987.38	600	540	552	12
							562	587	25
MB-6	733,376	524,466	HJ	6803.40	6804.90	440	380	405	25
MB-9	753,281	539,034	HJ	6984.82	6986.31	400	340	370	30
HJMU-101	743,277	531,997	UKM	6903.50	6904.71	535	499	535	36
HJMU-102	743,476	535,299	UKM	6934.72	6935.35	600	495	525	30
HJMU-103	742,657	535,098	UKM	6935.06	6936.06	850	500	540	40
HJMU-104	742,891	534,907	UKM	6939.01	6940.51	550	512	550	38
HJMU-105	742,942	535,076	UKM	6936.37	6937.58	548	502	542	40
HJMU-106	743,159	535,258	UKM	6940.59	6941.75	547	500	546	46
HJMU-107	743,686	534,788	UKM	6936.84	6937.88	855	550	580	30
HJMU-108	743,476	535,299	UKM	6949.97	6951.51	850	510	540	30
HJMU-109	743,905	534,835	UKM	6933.92	6939.38	850	524	574	50
HJMU-110	743,685	535,195	UKM	6945.97	6947.56	850	492	532	40
HJMU-111	743,841	535,374	UKM	6948.93	6950.08	853	507	545	38
HJMU-112	744,386	534,676	UKM	6934.18	6935.35	802	525	560	35
HJMU-113	744,277	534,807	UKM	6935.16	6936.99	800	524	555	31
HJMU-114	744,966	534,678	UKM	6939.10	6940.43	557	525	553	28
LC17M	744,548	534,838	UKM	6935.32	6936.90	575	529	565	36
LC20M	743,383	535,331	UKM	6949.27	6950.64	543	511	543	32
LC23M	736,292	532,835	UKM	6924.41	6926.80	634	595	630	35
LC24M	744,566	535,200	UKM	6942.33	6944.33	542	478	531	53
LC27M	753,260	539,018	UKM	7010.00	7012.16	477	433	456	23
LC28M	733,364	524,437	UKM	6804.15	6805.19	563	502	557	55
UKMP-101	744,090	534,929	UKM	6940.18	6941.74	575	540	572	32
UKMP-102	744,204	535,145	UKM	6940.51	6942.10	498	485	505	20

Table 3.6-1 Permit Area Monitor Well Data (Page 4 of 4)

Well Name	Easting (feet)	Northing (feet)	Completion Zone	Ground Surface Elevation (ft amsl)	Measure Point Elevation (ft amsl)	Total Depth (feet)	Top Underreamed Zone (ft bgs)	Bottom Underreamed Zone (ft bgs)	Total Underreamed thickness (feet)
UKMP-103	744,487	535,558	UKM	6949.73	6950.84	537	496	537	41
MB-4	736,398	535,868	UKM	6985.77	6987.27	680	610	640	30
UKMU-101	744,101	534,931	MKM	6939.87	6941.87	850	608	630	22
UKMU-102	744,191	535,143	MKM	6940.62	6942.62	583	545	570	25
UKMU-103	744,488	535,546	MKM	6948.75	6950.92	850	558	590	32





Legend

- Lost Creek Fault
- MU1 Proposed Pattern Area
- HJ Trend Well
- UKM Observation Well
- Perimeter Monitor Well
- Production Zone Monitor Well
- Overlying Monitor Well
- Underlying Monitor Well
- Lost Creek Permit Area
- BLM Field Office Boundary

Surface Land Owner

- BLM - administered

N

Lost Creek Uranium *In-Situ* Recovery Project

Sweetwater County, WY

Figure 3.6-5
Mine Unit 1 Monitor, Observation, & Trend Well Locations

0 0.05 0.1 Miles

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Table 3.6-2 Mine Unit 1 Monitor, Observation and Trend Wells

Monitor Ring (M) Wells and Trend Well (TW) [1]		Overlying Aquifer Monitor (MO) Wells	Underlying Aquifer Monitor (MU) Wells and Observation Well (OW)	Production Zone Monitor (MP) Wells
M-101	M-116	MO-101	MU-101	MP-101
M-102	M-117	MO-102	MU-102	MP-102
M-103	M-118	MO-103	MU-103	MP-103
M-104	M-119	MO-104	MU-104	MP-104
M-105	M-120A [2]	MO-105	MU-105	MP-105
M-106	M-121	MO-106	MU-106	MP-106
M-107	M-122	MO-107	MU-107	MP-107
M-108	M-123	MO-108	KPW-2 [4]	MP-108
M-109	M-124	MO-109	MU-109	MP-109
M-110	M-125	MO-110	MU-110	MP-110
M-111	M-126	MO-111	MU-111	MP-111
M-112	M-127	MO-112	MU-112	MP-112
M-113	M-128	MO-113	MU-113	MP-113
M-114	TW1-1	MO-114 [3]	OW1-1	---
M-115	---	---	---	---

[1] Detailed monitor well information (e.g., well depths, screened intervals) provided in Attachment MU1 2-1 of the WDEQ-LQD MU1 documents (LCI, 2011b).

[2] Well M-120 failed the MIT, was properly abandoned and was replaced with well M-120A.

[3] Well MO-114 was added to this list to ensure adequate monitoring near the Fault and associated splinter fault.

[4] Well MU-108 failed the MIT, was properly abandoned and replaced with well KPW-2, which was originally used as a pump test well within the same horizon as and 17 feet from well MU-108.

3.6.2.1 Hydrostratigraphic Units

As previously discussed in **Section 3.3**, the primary uranium production zone is identified as the HJ Horizon in the Battle Springs Formation. The HJ Horizon is subdivided into the Upper (UHJ), Middle (MHJ) and Lower (LHJ) Sands. The HJ Horizon is bounded above and below by aerially extensive confining units identified as the Lost Creek Shale and the Sage Brush Shale, respectively. Overlying the Lost Creek Shale is the FG Horizon. The deepest sand in the FG Horizon, the Lower FG (LFG) Sand, is the overlying aquifer to the HJ Horizon. Beneath the Sage Brush Shale is the KM Horizon. The uppermost sand within the KM Horizon, designated the Upper KM (UKM) sand, is a secondary production zone and also the underlying aquifer to the HJ Horizon. The No Name Shale unit

separates the UKM and Middle KM (MKM) Sand. The shallowest occurrence of groundwater within the Permit Area occurs within the DE Horizon, which is above the FG Horizon. A brief description of each hydrostratigraphic unit, from deepest to shallowest, is provided below and illustrated on a geophysical log on **Figure 3.3-3**.

DE Horizon

The DE Horizon is the shallowest occurrence of groundwater within the Permit Area, although the horizon is not saturated in all portions of the Permit Area. The depth to groundwater in the DE horizon has been measured from approximately 155 feet to 257 feet below ground surface; however some of the monitor wells were occasionally dry during the monitoring events. The DE Horizon consists of a sequence of sands and discontinuous clay/shale units. In the southern portion of the Permit Area, sands of the DE Horizon coalesce with sands of the FG Horizon. The top of the unit ranges from 100 to 200 ft bgs (**Figure 3.3-3**).

FG Horizon

The top of the FG Horizon occurs at depths of approximately 250 to 300 ft bgs on the north side of the Fault and 275 to 350 ft bgs on the south side of the Fault within the Permit Area. The FG Horizon is subdivided into the Upper (UFG), Middle (MFG) and Lower (LFG) Sands (**Figure 3.3-3**). The total thickness of the FG Horizon is approximately 100 feet. The basal unit in the FG Horizon, the LFG Sand, ranges from 20 to 50 feet thick within the Permit Area. The LFG Sand is designated as the overlying aquifer for the HJ Horizon.

Lost Creek Shale

Underlying the FG Sands is the Lost Creek Shale. The Lost Creek Shale appears continuous across the Permit Area, ranging from five to 45 feet in thickness. Typically, this unit has a thickness of ten to 25 feet. The Lost Creek Shale is the confining unit between the overlying aquifer (LFG Sand) and the HJ Horizon (**Figure 3.3-3**). An isopach of the shale thickness is included as Plate D5-2a in the WDEQ-LQD Permit to Mine (LCI, 2011b). The confining characteristics of the Lost Creek Shale have been demonstrated with a pump test.

HJ Horizon

The HJ Horizon is the primary target for uranium production at the Project. For purposes of uranium ISR operations, the HJ Horizon has been subdivided into three Sands: the Upper HJ (UHJ), Middle HJ (MHJ) and the Lower (LHJ) Sand (**Figure 3.3-3**). These sands are generally composed of coarse-grained arkosic sands with thin lenticular intervals of fine sand, mudstone and siltstone. The bulk of the uranium mineralization is present in the MHJ Sand. The total thickness of the HJ Horizon ranges from 100 to 160 feet, averaging approximately 120 feet.

The top of the HJ Horizon ranges from approximately 300 to 450 ft bgs within the Permit Area. The three sands are generally separated by thin clayey units that are not laterally extensive and, based on pump test results, do not act as confining units to prevent groundwater movement vertically between the HJ Sands. The underlying aquifer to the HJ Horizon is the UKM Sand. An isopach of the shale thickness is included as Plate D5-2b in the WDEQ-LQD Permit to Mine (LCI, 2011b).

Sage Brush Shale

Beneath the HJ Horizon is the Sage Brush Shale, at depths ranging from 450 to 550 ft bgs. The Sage Brush Shale is laterally extensive and ranges from five to 75 feet in thickness (**Figure 3.3-3**). An isopach of the shale thickness is included as Plate D5-2c in the WDEQ-LQD Permit to Mine (LCI, 2011b). The Sage Brush Shale is the lower confining unit to the HJ Production Zone. The confining characteristics of this unit have been demonstrated through pump tests.

UKM Sand

The UKM Sand is present beneath the Sage Brush Shale. The UKM Sand is the upper member of the KM Horizon and is generally a massive coarse sandstone with lenticular fine sandstone intervals. The UKM Sand is the underlying aquifer to the HJ Horizon but is also a potential production zone within the Permit Area. The UKM Sand is typically 30 to 60 feet thick but can reach over 75 feet in thickness (**Figure 3.3-3**). An isopach of the shale thickness is included as Plate D5-2d in the WDEQ-LQD Permit to Mine (LCI, 2011b). The top of the UKM Sand is usually between 450 and 600 ft bgs within the Permit Area.

No Name Shale

The No Name Shale at the base of the UKM Sand has not yet been fully characterized. The top of the unit is approximately 480 to 650 ft bgs. This unit is generally 10 to 30 feet thick (**Figure 3.3-3**).

3.6.2.2 Potentiometric Surfaces

Potentiometric surfaces for the DE, LFG, HJ, and UKM Horizons in 2008 are illustrated as contour maps in **Figure 3.6-6** through **Figure 3.6-9**. Table D6-6 in Appendix D6 of the WDEQ-LQD Permit to Mine (LCI, 2011b) lists static water level data recorded in 1982, 2006, 2007, and 2008. Based on the potentiometric surface maps, groundwater flow is to the west-southwest within the Permit Area, generally consistent with the regional flow system.

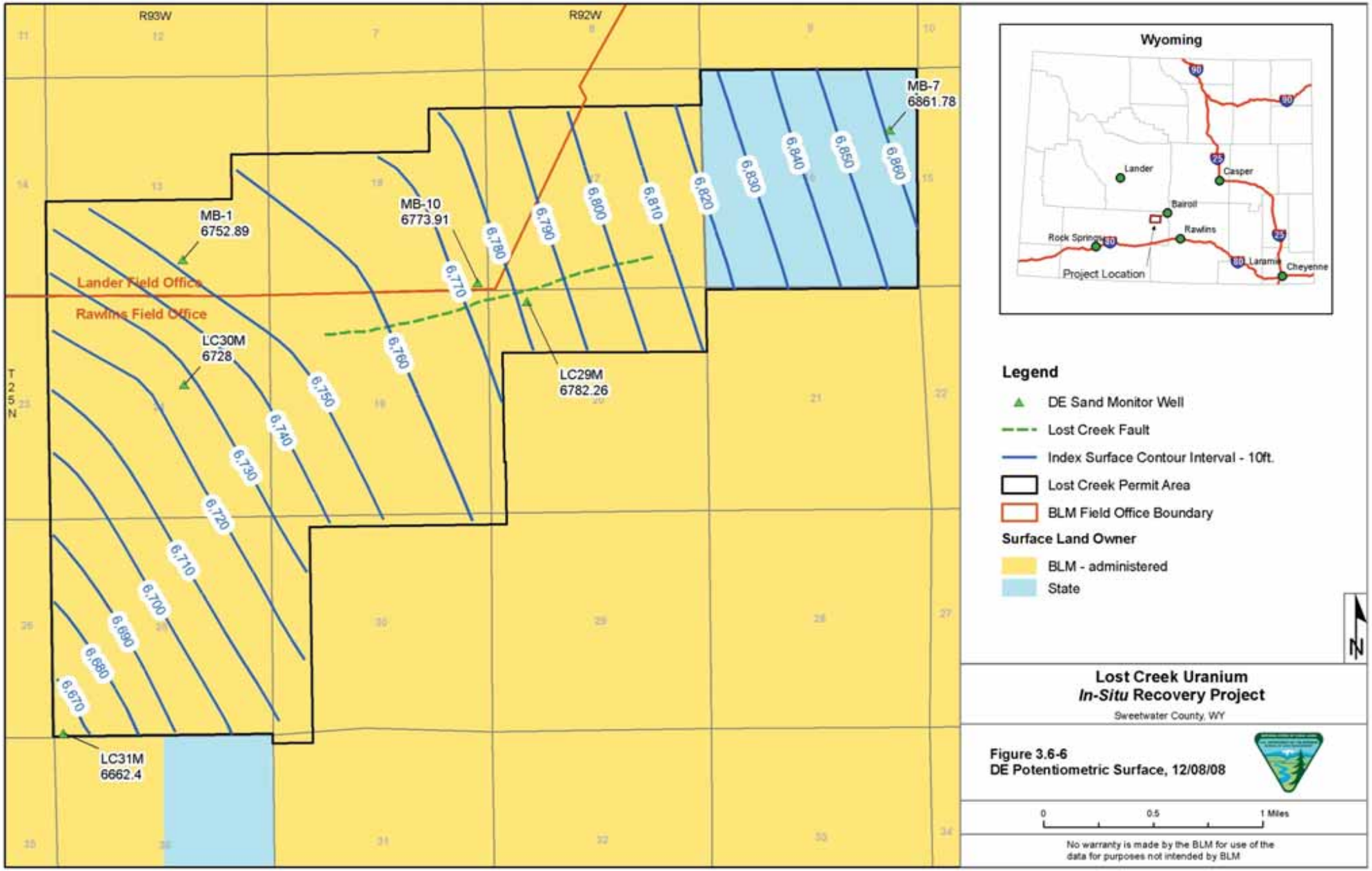

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Figure 3.6-6
DE Potentiometric Surface, 12/08/08

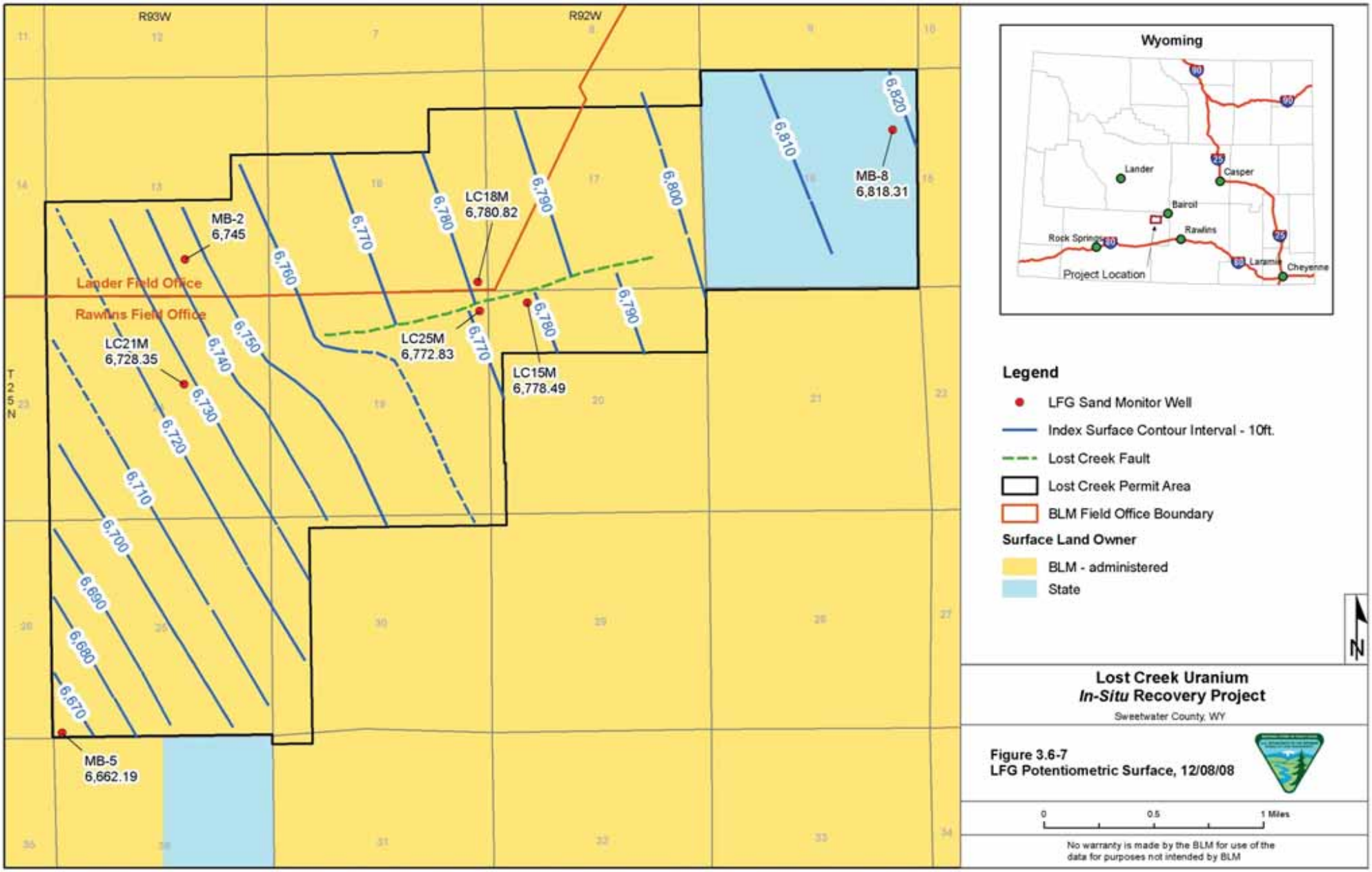

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Figure 3.6-7
LFG Potentiometric Surface, 12/08/08

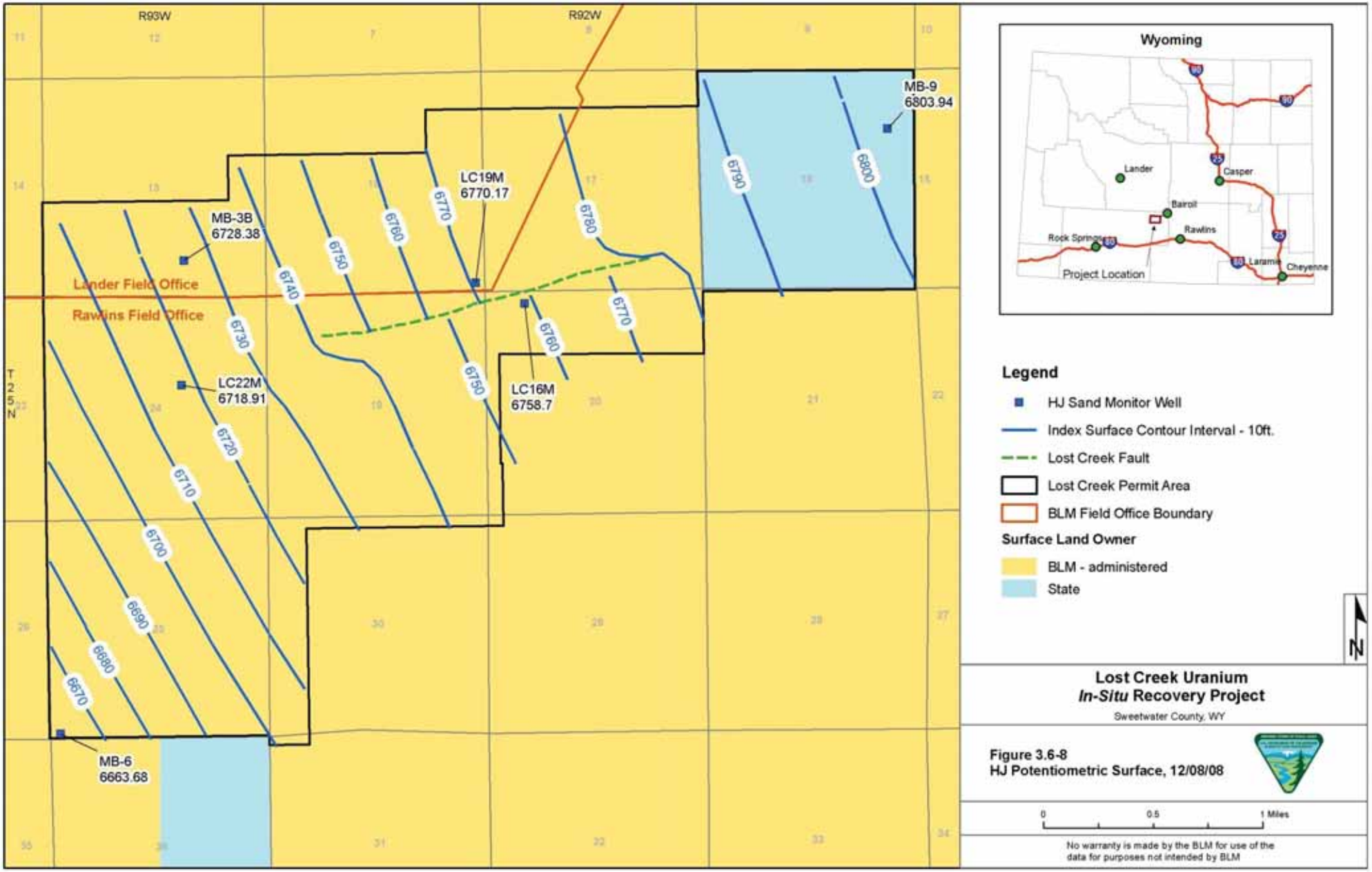

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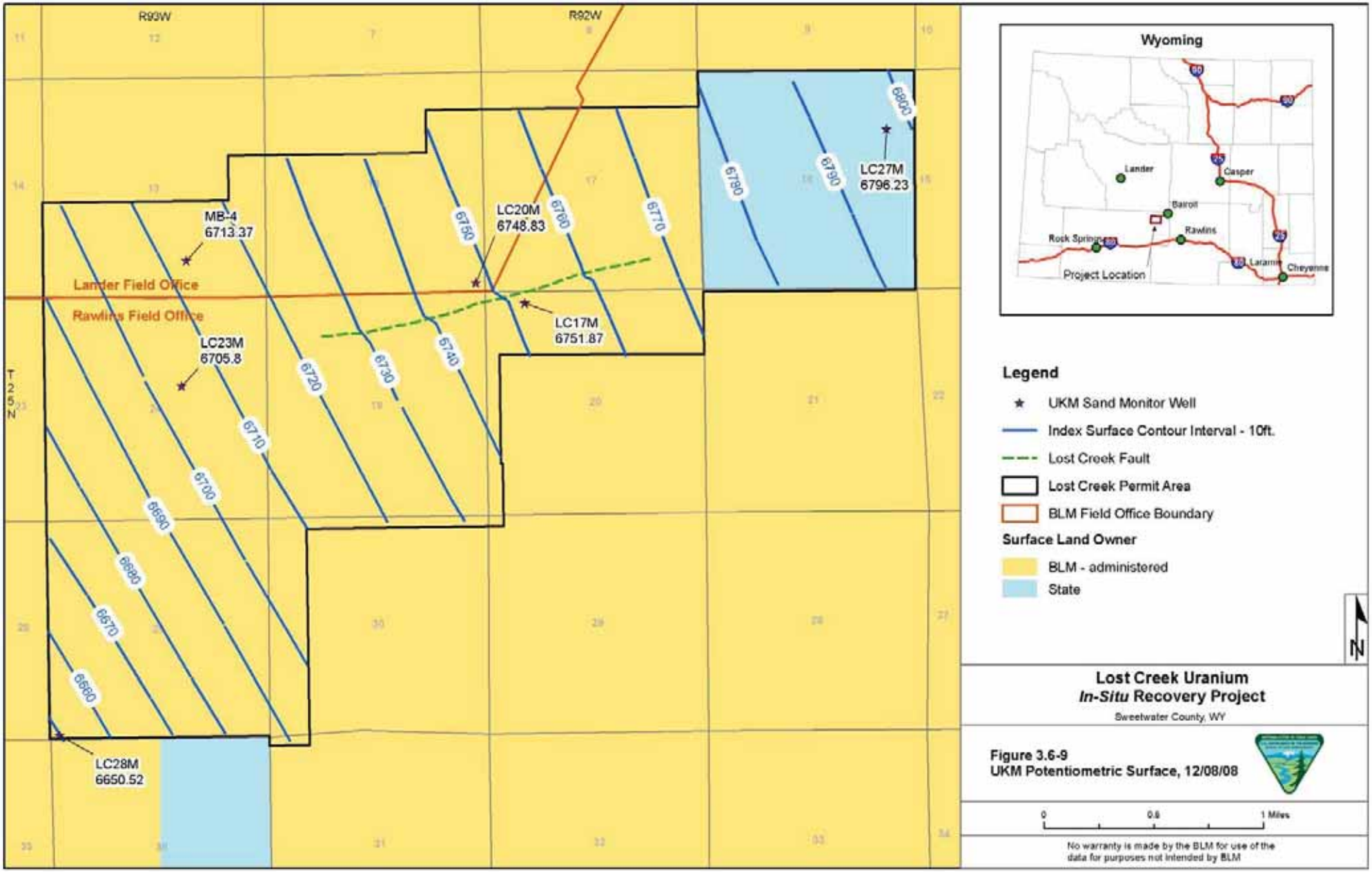
Figure 3.6-8
HJ Potentiometric Surface, 12/08/08


R93W
R92W
T 25 N
Lander Field Office
Rawlins Field Office
MB-4
6713.37
LC23M
6705.8
LC20M
6748.83
LC17M
6751.87
LC27M
6796.23
LC28M
6650.52
6660
6670
6680
6690
6700
6710
6720
6730
6740
6750
6760
6770
6780
6790
6800
Wyoming
Lander
Casper
Bairoil
Rawlins
Rock Springs
Laramie
Cheyenne
Project Location
Legend
UKM Sand Monitor Well
Index Surface Contour Interval - 10ft.
Lost Creek Fault
Lost Creek Permit Area
BLM Field Office Boundary
Surface Land Owner
BLM - administered
State
N
Lost Creek Uranium
In-Situ Recovery Project
Sweetwater County, WY
Figure 3.6-9
UKM Potentiometric Surface, 12/08/08
0
0.5
1 Miles
No warranty is made by the BLM for use of the data for purposes not intended by BLM

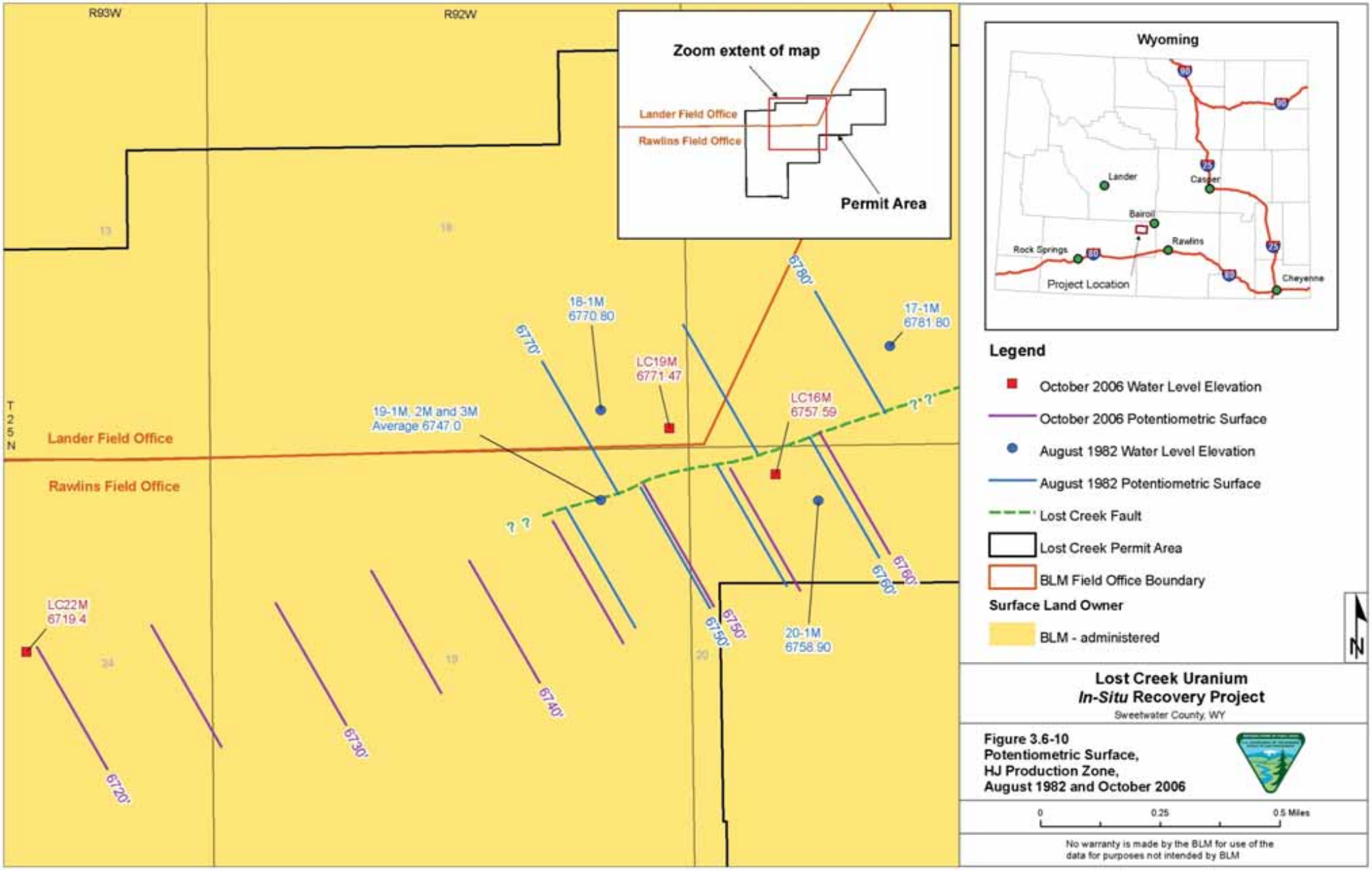
Based on the water level data collected for the HJ Horizon in the vicinity of the Fault, it is evident that the Fault provides a significant hydraulic barrier to groundwater flow. The potentiometric surface on the north side of the Fault is 5 to 15 feet higher than on the south side. The difference in hydraulic head across the Fault becomes less to the northeast. HJ Horizon water level data from 1982 and 2006 are shown on **Figure 3.6-10**. There are an insufficient number of data points to accurately represent the potentiometric surface for both those measurement periods. However, the data illustrate the difference in water levels within the HJ Horizon across the Fault.

The steep gradient observed in the potentiometric surface from the north to the south side of the Fault is most likely a manifestation of a lower permeability transition area associated with a fault smear zone and/or secondary faulting and fracturing near the Fault. This is consistent with regional groundwater flow impacted by lower permeability zones studied and modeled by Freeze (1969). Although limited groundwater leakage occurs across the Fault (as demonstrated during the long-term pump tests), the majority of groundwater flow on both sides of the Fault appears to be generally parallel to the Fault, to the west-southwest. Based on the potentiometric surface map, groundwater is inferred to flow to the west-southwest, generally consistent with the regional flow system.

The potentiometric surface for the overlying (LFG) aquifer indicates a similar groundwater flow direction as in the HJ aquifer, towards the west-southwest (**Figure 3.6-7**). The barrier effect of the Fault is also evident within this shallower hydrostratigraphic unit, with an observed difference of six to eight feet of hydraulic head across the Fault. Potentiometric surface data for the underlying (UKM) aquifer also indicate a generally west-southwest direction of groundwater flow (**Figure 3.6-9**). However, the impacts of the Fault are not as evident in this hydrostratigraphic unit, with little, if any, difference in hydraulic head across the Fault.

Hydraulic Gradients

The horizontal hydraulic gradients across the Permit Area were estimated from the December 2008 potentiometric surface maps and are summarized in **Table 3.6-3**. The gradients are similar in all the aquifers and range from about 0.003 to 0.007 ft/ft on both sides of the Fault.



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***In-Situ* Recovery Project**
Sweetwater County, WY

Figure 3.6-10
Potentiometric Surface,
HJ Production Zone,
August 1982 and October 2006

Table 3.6-3 Horizontal Hydraulic Gradients

	Distance (feet)	Head Upgradient	Head Downgradient	Head Difference (feet)	Hydraulic Gradient (foot/foot)
DE North Side of Fault	21000	6860	6710	150	0.0071
DE South Side of Fault	12500	6780	6690	90	0.0072
LFG North Side of Fault	21500	6820	6710	110	0.0051
LFG South Side of Fault	14000	6780	6680	100	0.0071
HJ North Side of Fault	20500	6800	6700	100	0.0049
HJ South Side of Fault	13500	6760	6680	80	0.0059
UKM North Side of Fault	20500	6790	6680	110	0.0054
UKM South Side of Fault	12700	6750	6670	80	0.0063

Vertical hydraulic gradients were determined in December 2008 by measuring water levels in closely grouped wells completed in different hydrostratigraphic units, and the results are summarized in **Table 3.6-4**. Vertical hydraulic gradients range from -0.04 to 0.37 ft/ft between the DE, LFG, HJ and UKM aquifers and consistently indicate decreasing hydraulic head with depth. The vertical gradients indicate the potential for groundwater flow is downward. A downward potential is indicative of an area of recharge, as opposed to an upward potential that is normally indicative of an area of groundwater discharge. A downward gradient is consistent with the structural and stratigraphic location of the Project with regard to Great Divide Basin.

3.6.2.3 Aquifer Testing

Aquifer properties for the Battle Spring aquifers within the Permit Area have been calculated from tests conducted for Conoco in the early 1980s and more extensive tests conducted for LCI in 2006, 2007, and 2008. The aquifer characteristics calculated from these tests are summarized in **Table 3.6-5**. The primary purpose of the tests conducted prior to 2008 was to determine aquifer characteristics, including transmissivity, storativity, hydraulic conductivity, and the potential for communication between aquifers. In addition to determining aquifer characteristics, the 2008 test collected information specific to operation of MU1, including: hydrologic communication between the HJ pumping well and the surrounding HJ monitor wells; the influence of the Fault within MU1, and the degree of hydrologic communication between the production zone and the overlying and underlying aquifers in MU1. Testing similar to that conducted in 2008 for MU1 would be conducted for each of the other mine units.

Table 3.6-4 Vertical Hydraulic Gradients (Page 1 of 4)

Well ID	Easting (feet)	Northing (feet)	Completion Zone	Measure Point Elevation (ft msl) [1]	Top Underreamed Interval (ft bgs) [2]	Bottom Underreamed Interval (ft bgs) [2]	Midpoint Underreamed Interval (ft bgs) [3]	Date of Measurement	Depth to Water (ft bgs)	Water Level Elevation (ft msl)	Vertical Hydraulic Gradient (foot/foot)
West Central Well Group (North side of Fault)											
MB-10	743347.83	535293	DE	6942.66	130	170	150	NM	NM	NM	- [4]
LC18M	743368	535316	LFG	6948.97	290	332	311	10/25/2006	167.32	6781.65	-
LC19M	743383	535317	HJ	6950.02	412	463	438	10/25/2006	179.05	6770.97	0.08
LC20M	743383	535331	UKM	6950.52	511	543	527	10/25/2006	202.84	6747.68	0.26
MB-10	743347.83	535293	DE	6942.66	130	170	150	NM	NM	NM	-
LC18M	743368	535316	LFG	6948.97	290	332	311	6/27/2007	168.04	6780.93	-
LC19M	743383	535317	HJ	6950.02	412	463	438	6/27/2007	180.08	6769.94	0.09
LC20M	743383	535331	UKM	6950.52	511	543	527	6/27/2007	202.36	6748.16	0.24
MB-10	743347.83	535293	DE	6942.66	130	170		NM	NM	NM	-
LC18M	743368	535316	LFG	6948.97	290	332	311	11/21/2007	168.11	6780.86	-
LC19M	743383	535317	HJ	6950.02	412	463	438	11/21/2007	181.41	6768.60	0.10
LC20M	743383	535331	UKM	6950.52	511	543	527	11/21/2007	204.2	6746.31	0.25
MB-10	743347.83	535293	DE	6942.66	130	170	150	12/8/2008	168.75	6,773.91	-
LC18M	743368	535316	LFG	6948.97	290	332	311	12/8/2008	168.15	6,780.82	-0.04
LC19M	743383	535317	HJ	6950.02	412	463	438	12/8/2008	179.85	6,770.17	0.08
LC20M	743383	535331	UKM	6950.52	511	543	527	12/8/2008	201.69	6,748.83	0.24

Table 3.6-4 Vertical Hydraulic Gradients (Page 2 of 4)

Well ID	Easting (feet)	Northing (feet)	Completion Zone	Measure Point Elevation (ft msl) [1]	Top Underreamed Interval (ft bgs) [2]	Bottom Underreamed Interval (ft bgs) [2]	Midpoint Underreamed Interval (ft bgs) [3]	Date of Measurement	Depth to Water (ft bgs)	Water Level Elevation (ft msl)	Vertical Hydraulic Gradient (foot/foot)
East Central Well Group (South of Fault)											
LC29M	744547	534837	DE	6937.55	140	164	152	10/25/2006	154.87	6,782.68	-
LCM15	744546	534823	LFG	6936.55	286	340	313	10/25/2006	160.34	6,776.21	0.04
LCM16	744562	534820	HJ	6936.15	410	467	438.5	10/25/2006	178.79	6,757.36	0.15
LCM17	744562	534840	UKM	6936.90	529	565	547	10/25/2006	185.34	6,751.56	0.05
LC29M	744547	534837	DE	6937.55	140	164	152	11/21/2007	155.14	6,782.41	-
LCM15	744546	534823	LFG	6936.55	286	340	313	11/21/2007	157.94	6,778.61	0.02
LCM16	744562	534820	HJ	6936.15	410	467	438.5	11/21/2007	178.78	6,757.37	0.17
LCM17	744562	534840	UKM	6936.90	529	565	547	11/21/2007	186.96	6,749.94	0.07
LC29M	744547	534837	DE	6937.55	140	164	152	12/8/2008	155.94	6,781.61	-
LCM15	744546	534823	LFG	6936.55	286	340	313	12/8/2008	158.06	6,778.49	0.02
LCM16	744562	534820	HJ	6936.15	410	467	438.5	12/8/2008	177.45	6,758.70	0.16
LCM17	744562	534840	UKM	6936.90	529	565	547	12/8/2008	185.03	6,751.87	0.06
West Well Group (South of Fault; Projected)											
LC30M	736276	532836	DE	6927.40	196	236	216	10/25/2006	199.02	6,728.38	-
LC21M	736277	532850	LFG	6927.13	375	398	387	10/25/2006	199.05	6,728.08	0.00
LC22M	736292	532850	HJ	6926.06	504	585	544.5	10/25/2006	206.66	6,719.40	0.06
LC23M	736292	532835	UKM	6926.80	595	630	612.5	10/25/2006	220.33	6,706.47	0.19
LC30M	736276	532836	DE	6927.40	196	236	216	12/8/2008	199.40	6,728.00	-
LC21M	736277	532850	LFG	6927.13	375	398	387	12/8/2008	198.78	6,728.35	0.00
LC22M	736292	532850	HJ	6926.06	504	585	544.5	12/8/2008	207.15	6,718.91	0.06
LC23M	736292	532835	UKM	6926.80	595	630	612.5	12/8/2008	221.00	6,705.80	0.19

Table 3.6-4 Vertical Hydraulic Gradients (Page 3 of 4)

Well ID	Easting (feet)	Northing (feet)	Completion Zone	Measure Point Elevation (ft msl) [1]	Top Underreamed Interval (ft bgs) [2]	Bottom Underreamed Interval (ft bgs) [2]	Midpoint Underreamed Interval (ft bgs) [3]	Date of Measurement	Depth to Water (ft bgs)	Water Level Elevation (ft msl)	Vertical Hydraulic Gradient (foot/foot)
Northwest Well Group (North of Fault)											
MB-1	736245.85	535848.56	DE	6985.90	240	280	260	12/8/2008	233.01	6,752.89	-
MB-2	736301.85	535855.26	LFG	6986.92	410	450	430	12/8/2008	241.92	6,745.00	0.05
MB-3	736348.85	535849.86	HJ	6987.38	540	580	560	12/8/2008	259.00	6,728.38	0.13
MB-4	736395.85	535867.36	UKM	6987.27	630	660	645	12/8/2008	273.90	6,713.37	0.18
Southwest Well Group (South of Fault)											
LC31M	733380	524434	DE	6806.05	150	190	170	12/8/2008	143.65	6,662.40	-
MB-5	733337.91	524460.9	LFG	6805.04	305	325	315	12/8/2008	142.85	6,662.19	0.00
MB6	733380.91	524464.1	HJ	6804.90	380	405	392.5	12/8/2008	141.22	6,663.68	-0.02
LC28M	733364	524437	UKM	6805.56	502	557	529.5	12/8/2008	155.04	6,650.52	0.10
East Well Group (North of Fault; Projected)											
MB-7	753265.78	538975.75	DE	6984.88	80	125	102.5	11/17/2008	123.33	6,861.55	-
MB-8	753316.78	538979.75	LFG	6985.50	240	270	255	12/8/2008	167.19	6,818.31	0.28
MB-9	753280.78	539026.25	HJ	6986.32	340	370	355	12/8/2008	182.38	6,803.94	0.14
LC27M	753260	539018	UKM	6987.38	433	456	444.5	12/8/2008	191.15	6,796.23	0.09
Conoco Northeast Wells											
M-25-92-17-1S	745785	536224	LFG	6966.20	* [5]	*	334	8/18/1982	*	6792.90	-
M-25-92-17-1M	745813	536223	HJ	6966.70	*	*	422	8/18/1982	*	6781.80	0.13
M-25-92-17-1D	745837	536222	UKM	6967.40	*	*	516	8/18/1982	*	6761.60	0.21

Table 3.6-4 Vertical Hydraulic Gradients (Page 4 of 4)

Well ID	Easting (feet)	Northing (feet)	Completion Zone	Measure Point Elevation (ft msl) [1]	Top Underreamed Interval (ft bgs) [2]	Bottom Underreamed Interval (ft bgs) [2]	Midpoint Underreamed Interval (ft bgs) [3]	Date of Measurement	Depth to Water (ft bgs)	Water Level Elevation (ft msl)	Vertical Hydraulic Gradient (foot/foot)
Conoco Central Wells											
M-25-92-18-1S	742648	535513	LFG	6939.30	*	*	340	8/18/1982	*	6778.00	-
M-25-92-18-1M	742623	535515	HJ	6940.00	*	*	413	8/18/1982	*	6770.80	0.10
M-25-92-18-1D	742596	535517	UKM	6938.70	*	*	608	8/18/1982	*	6740.60	0.15
Conoco Southeast Wells											
M-25-92-20-1S	744998	534521	LFG	6934.50	*	*	341	8/18/1982	*	6776.40	-
M-25-92-20-1M	745023	534520	HJ	6934.90	*	*	388	8/18/1982	*	6758.90	0.37
M-25-92-20-1D	745048	534519	UKM	6935.00	*	*	522	8/18/1982	*	6751.80	0.05

[1] ft amsl - feet above mean sea level

[2] ft bgs - feet below ground surface

[3] Vertical hydraulic gradient is calculated from middle of underreamed interval in overlying aquifer to middle of underreamed interval in underlying aquifer. A positive number indicates a downward potential.

[4] Dash (-) indicates no overlying aquifer.

[5] Asterisk (*) indicates values were not reported by HydroSearch, Inc (1982)

Table 3.6-5 Summary of Aquifer Characteristics

Hydrostratigraphic Unit	Thickness (feet) [typical]	Porosity [1]	Transmissivity [2] (gpd/ft)		Transmissivity [2] (ft^2/d)		Storativity		Horizontal Hydraulic Conductivity [3] (feet/day)		Vertical Hydraulic Conductivity [4]	
			N of Fault [5]	S of Fault [5]	N of Fault	S of Fault	N of Fault	S of Fault	N of Fault	S of Fault	cm/sec	ft/day
DE	0 to 120 [40]	0.28	NM [6]	10 to 1100	NM [6]	1.3 to 147	NM	ND [7]	NM	0.03 to 3.7	- [8]	- [8]
Upper No Name Shale	0 to 50 [5 to 15]	NA [9]	NA	NA	NA	NA	NA	NA	NA	NA	-	-
FG Horizon (includes LFG, MFG and UFG)	30 to 150 [50]	0.28	30 to 90	120 to 300	4 to 12	16 to 40	ND	ND	0.08 to 0.24	0.3 to 0.8	-	-
Lost Creek Shale	5 to 45 [10 to 25]	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.6E-06 to 5.4E-05	0.016 to 0.15
HJ Horizon (includes LHJ, MHJ and UHJ)	100 to 160 [120]	0.28	220 to 2700	365 to 1820	29 to 361	49 to 243	6.6E-05 to 1.5E-04	3.5E-05 to 9.1E-04	0.2 to 3.0	0.4 to 2.0	-	-
Sage Brush Shale	5 to 75 [20 to 30]	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.1E-07 to 1.4E-06	0.0009 to 0.004
UKM	20 to 75 [50]	0.28	520 to 860	195 to 700	70 to 115	26 to 94	ND	ND	1.4 to 2.3	0.5 to 1.9	-	-

1982 Testing

In 1982, Hydro-Search, Inc. conducted two 25-hour tests within the HJ Horizon. Both pump tests were conducted at a rate of 30 gpm and on the south side of the Fault. There was no reported response in the HJ aquifer north of the Fault. Monitor wells in the overlying (LFG) and underlying (UKM) aquifers did not show any effects from the pump test. The monitor well locations are shown on **Figure 3.6-4**.

2006 Testing

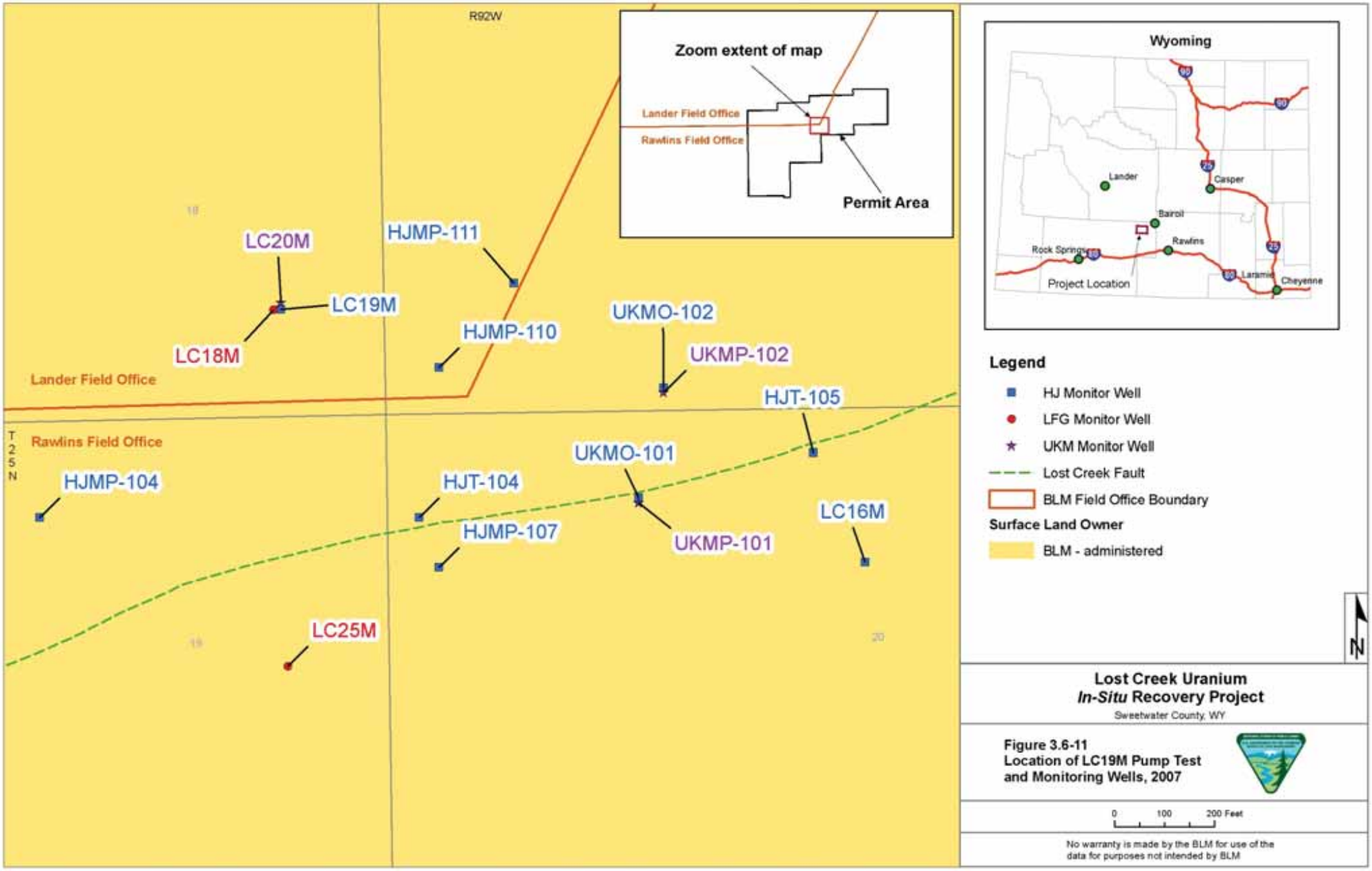
Hydro-Engineering (2007) conducted several short-term single-well pump tests and three longer multi-well pump tests in October 2006. The single-well tests ranged from 30 minutes to five hours in duration at rates from 0.67 to 14 gpm. The long-term tests were from 20 to 45 hours long at rates of 15 to 19 gpm. Each of the long-term tests was conducted in HJ well completions. The monitor well locations are shown on **Figure 3.6-4**. None of the HJ tests indicated significant communication (less than 0.2 feet draw down) with the overlying or underlying aquifers. The slope inflection point at approximately 150 minutes after the pump start indicated that a boundary (the Fault) was encountered and that the Fault is generally acting as a barrier to flow. There was also no indication of hydraulic communication across the Fault in any of the pump tests. Hydro-Engineering concluded that the Fault acts as a hydraulic barrier.

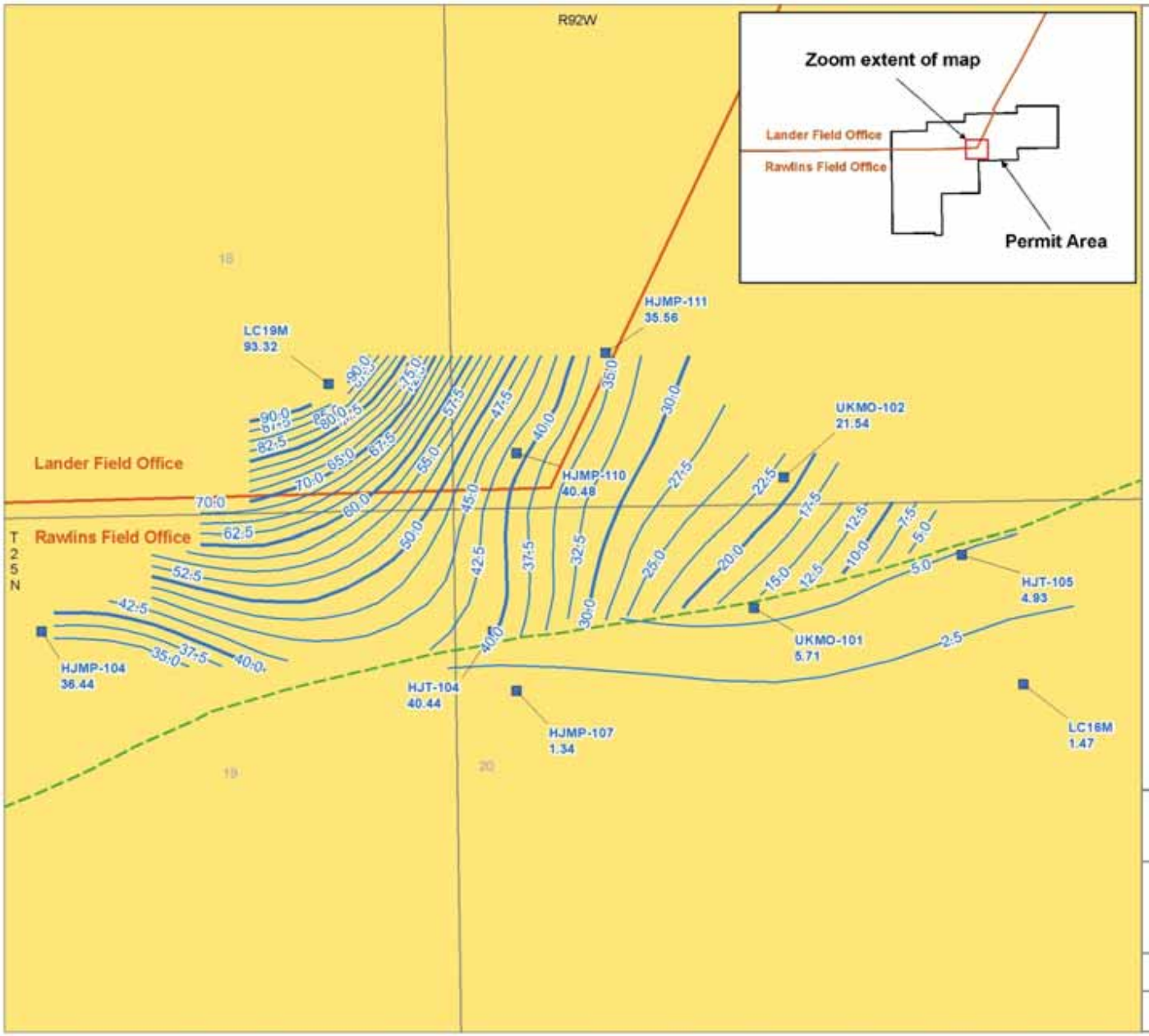
2007 Testing

In 2007, Petrotek Engineering Corporation conducted two long-term pump tests in the HJ aquifer at Wells LC19M and LC16M, one located on each side of the Fault. Pre-pumping monitoring was performed several days in advance of the tests to establish baseline conditions and to evaluate barometric effects. HJ monitor wells on both sides of the Fault and within distances likely to be impacted by the pump tests were included as observation wells. Observation wells in the overlying (LFG) and underlying (UKM) aquifers near the pumping wells and across the Fault were also monitored during the tests.

LC19M Test

The first pump test, with LC19M as the pumping well, was conducted to evaluate aquifer properties on the north side of the Fault. The locations of the wells monitored during the test are shown on **Figure 3.6-11**. The average pumping rate during the test was 42.9 gpm. Maximum drawdown in the pumping well was 93.3 feet. Monitoring was continued after pump shut-in to record recovery from the LC19M test. Drawdown at the end of the test in the HJ aquifer is shown on **Figure 3.6-12**. A detailed discussion of the LC19M test is included in Attachment D6-2a of Appendix D6 of the WDEQ-LQD Permit to Mine (LCI, 2011b).


R92W
Zoom extent of map
Lander Field Office
Rawlins Field Office
Permit Area
LC20M
LC19M
LC18M
HJMP-111
HJMP-110
UKMO-102
UKMP-102
HJT-105
Lander Field Office
T 25 N
Rawlins Field Office
HJMP-104
HJT-104
UKMO-101
HJMP-107
UKMP-101
LC16M
LC25M
Wyoming
Lander
Casper
Bairoil
Rawlins
Rock Springs
Laramie
Cheyenne
Project Location
Legend
HJ Monitor Well
LFG Monitor Well
UKM Monitor Well
Lost Creek Fault
BLM Field Office Boundary
Surface Land Owner
BLM - administered
N
Lost Creek Uranium
In-Situ Recovery Project
Sweetwater County, WY
Figure 3.6-11
Location of LC19M Pump Test
and Monitoring Wells, 2007
0
100
200 Feet
No warranty is made by the BLM for use of the
data for purposes not intended by BLM



Legend

- HJ Monitor Well
- Drawdown Contour (feet)
- Lost Creek Fault
- BLM Field Office Boundary

Surface Land Owner

- BLM - administered

N

Lost Creek Uranium
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Sweetwater County, WY

Figure 3.6-12
Drawdown in the HJ Aquifer at the End of the LC19M Pumping Test, 2007

0 100 200 Feet

No warranty is made by the BLM for use of the data for purposes not intended by BLM

The response of the overlying and underlying aquifers during the pump test was small (e.g., on the order of 0.2 to 0.5 feet); but the water level responses did correspond to the start and stop of pumping from LC19M in the HJ Horizon. The underlying/overlying responses appear to be relatively consistent, regardless of distance from the pumping well, the hydrostratigraphic interval monitored, or the location relative to the Fault. These water level changes suggest potential impacts from off-site pumping or background trends that, because of distance from the monitor wells, are manifested at multiple locations at the same or similar times. As previously stated, a declining trend in water level elevations was observed prior to the start of the test. Most of the wells showed an initial inverted response (increase in water level) at the start of the test and then resumed a gradual downward trend during the test. This phenomenon was also observed and noted by Hydro-Engineering during the 2006 pump tests. It is possible that some of the drawdown response could be caused by: 1) pumping in the drilling water well (LC1) that is completed in both the DE and FG Horizons; 2) communication across multiple sands due to the nature of the Fault distance from the pumping well location; 3) communication due to juxtapositioning of hydrostratigraphic units across the Fault; or 4) leakage through the confining shale, or any combination of these. While LCI has aggressively pursued re-plugging of historic wells and continues to do so, it is also possible that some of the communication could be related to abandoned wells.

Responses in observation wells across the Fault were negligible relative to the magnitude of drawdown observed in monitor wells located on the same side of the Fault as the pumping well. The impact of the Fault on groundwater flow can be clearly seen from the responses recorded in a pair of observation wells that were placed on either side of the Fault, within 100 feet of each other. Well HJT104, located on the north side of the Fault and completed in the HJ Horizon, had a maximum drawdown of 40.5 feet at the end of the LC19M test. Well HJMP107 (south of the Fault) in the HJ Horizon had a net decrease of 1.4 feet from the beginning of the test to the end of pumping at LC19M. At least a portion of that change is attributable to a declining trend in water levels that was observed in all monitor wells prior to the start of the test. The reason for the background trend observed has not been identified; however, it might be a result of offset pumping (e.g., LCI's first two water supply wells that are screened over multiple sands).

LC16M Test

A second long-term pump test was conducted to evaluate aquifer properties on the south side of the Fault. The locations of the wells monitored during the test are shown on **Figure 3.6-13**. The average pumping rate during the test was 37.4 gpm. Maximum drawdown in the pumping well was 69.3 feet. Monitoring was continued after pump shut-in to record recovery from the test. Drawdown near the end of the test in the HJ aquifer is shown on **Figure 3.6-14**. A detailed

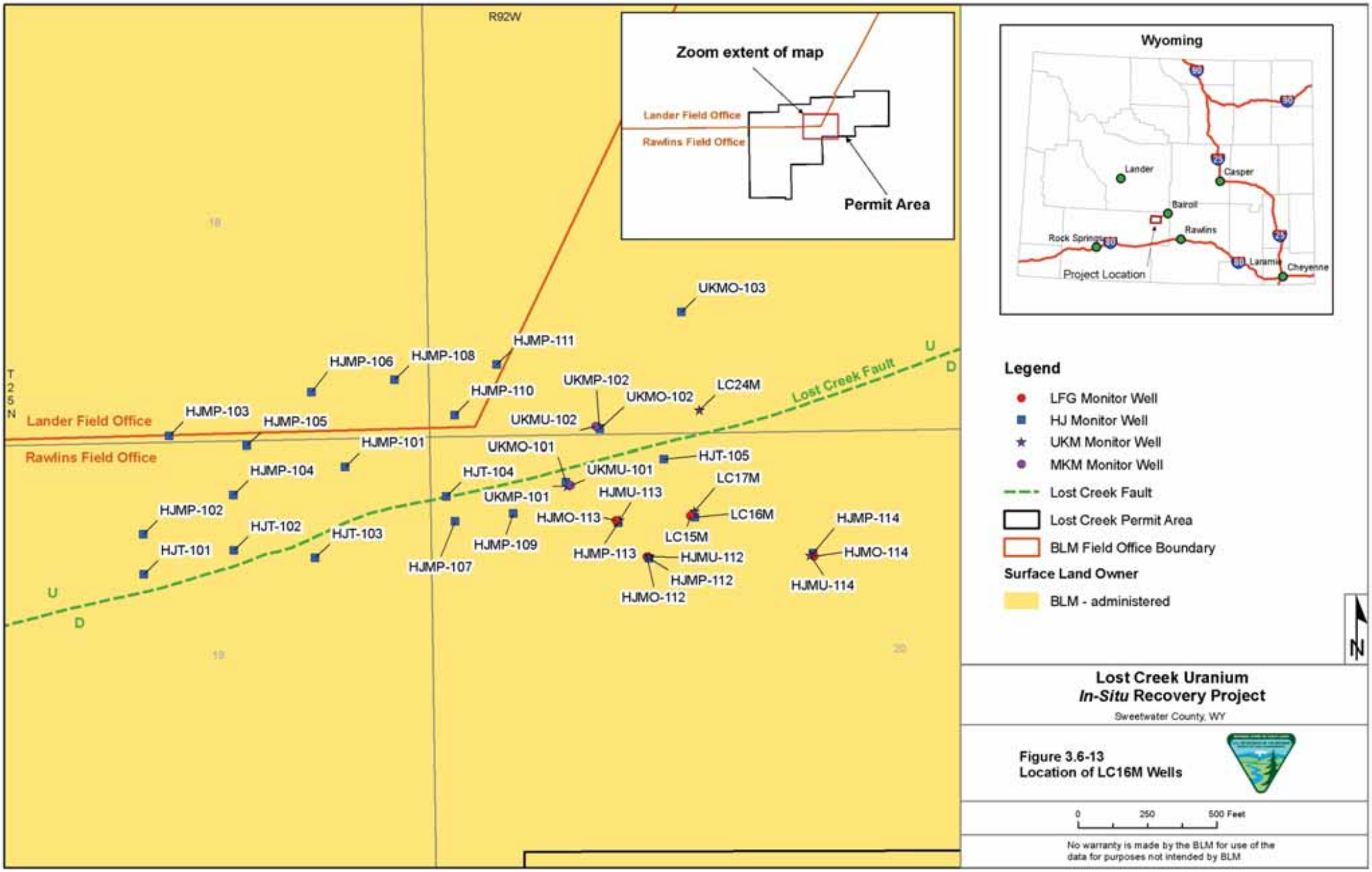
discussion of the LC16M test is included in Attachment D6-2b of Appendix D6 of the WDEQ-LQD Permit to Mine (LCI, 2011b).

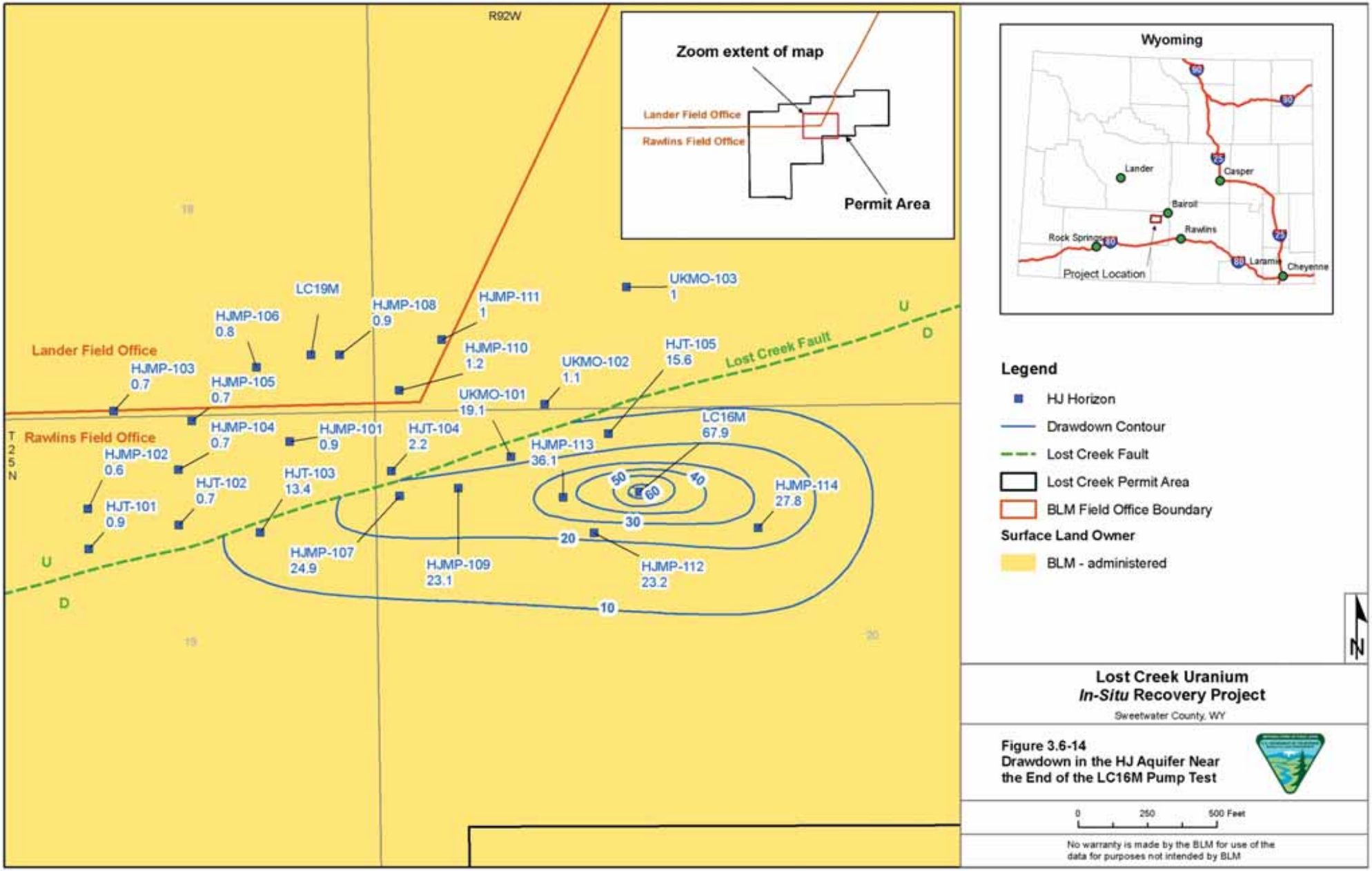
As in the LC19M pump test, the response of the overlying and underlying aquifers during the LC16M pump test was small (e.g., less than one foot in the LFG and less than two feet in the UKM); but the water level responses were coincident with the start and stop of pumping from LC16M. The response was slightly more pronounced in the UKM and occurred on both sides of the Fault.

The data from this test appear consistent with the first pump test, showing that the Fault, while not impermeable, is a significant barrier to groundwater flow. The same wells, located about 100 feet apart and across the Fault from one another (HJMP107 and HJT104), that were evaluated during the LC19M test were evaluated during the LC16M test. Well HJMP107, located on the same side of the Fault as the pumping well, had nearly 25 feet of drawdown near the end of the test. Well HJT104, located approximately 100 feet north of Well HJMP107 and north of the Fault, had approximately 2.2 feet of drawdown at the end of pumping.

2008 Testing

Two pump tests were conducted within MU1 due to the faulting that bisects the mine unit from west-southwest to east-northeast. The north pump test was conducted on the north side of the Fault (and associated splinter fault) in November 2008, and the south pump test was conducted on the south side of the Fault (and associated splinter fault) in December 2008. Both pump tests were conducted in the HJ Horizon, with monitoring of the overlying and underlying aquifers as well. The locations of the wells monitored during the 2008 testing are shown on **Figure 3.6-5**. The additional information collected from the two pump tests did not significantly alter the information on the aquifer characteristics attained from previous pump tests. This information is discussed in detail in Attachment MU1 2-1 of the WDEQ-LQD MU1 documents (LCI, 2011b).


R92W
T25N
Zoom extent of map
Lander Field Office
Rawlins Field Office
Permit Area
Wyoming
Lander
Casper
Bairoil
Rawlins
Rock Springs
Laramie
Cheyenne
Project Location
Lander Field Office
Rawlins Field Office
Lost Creek Fault
U
D
UKMO-103
HJMP-111
HJMP-106
HJMP-108
HJMP-110
UKMP-102
UKMO-102
LC24M
HJMP-103
HJMP-105
UKMU-102
HJMP-101
UKMO-101
HJT-105
HJMP-104
HJT-104
UKMU-101
LC17M
HJMU-113
UKMP-101
HJMP-102
HJMO-113
LC16M
HJMP-114
HJT-102
HJT-103
LC15M
HJMP-109
HJMP-113
HJMU-112
HJMO-114
HJT-101
HJMP-107
HJMP-112
HJMU-114
HJMO-112
Legend
LFG Monitor Well
HJ Monitor Well
UKM Monitor Well
MKM Monitor Well
Lost Creek Fault
Lost Creek Permit Area
BLM Field Office Boundary
Surface Land Owner
BLM - administered
N
Lost Creek Uranium
In-Situ Recovery Project
Sweetwater County, WY
Figure 3.6-13
Location of LC16M Wells
0
250
500 Feet
No warranty is made by the BLM for use of the data for purposes not intended by BLM



Lost Creek Uranium
***In-Situ* Recovery Project**

Sweetwater County, WY

Figure 3.6-14
Drawdown in the HJ Aquifer Near the End of the LC16M Pump Test