LC EAST
HYDROLOGIC PUMP TEST PLAN
KM AND L HORIZONS

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LC EAST PROJECT

SWEETWATER COUNTY, WY

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1.0 INTRODUCTION

The purpose of this work plan is to describe the objectives and procedures for conducting regional pump tests in the KM and L Horizons. The test focus is on defining the vertical hydraulic connection between the KM Horizon and the underlying L Horizon in the LC East (LCE) Project area. Another key objective of these tests is to establish the L Horizon hydrologic characteristics, which have not previously been defined in the LCE area. This information is required input for permit completion purposes.

The 2013 LCE pump tests fully established the hydrologic relationship between the FG, HJ and KM Horizons. Accordingly, a re-assessment of those relationships will not be revisited as part of this test plan. As stated above, this pump test plan focuses on defining the relationship between the KM, L, M, and N Horizons in LCE.

1.1 Background

Significant mineralization has been identified in the KM Horizon in LCE. Lost Creek ISR plans to develop and extract uranium from proposed mine units completed in the KM Horizon of the Battle Spring Formation via ISR. Production from the KM Horizon will occur at various locations in the LC East Project area (see resource areas on **Figure 1-1**).

The KM, L, and M Horizons have been demonstrated to be in limited hydraulic communication in the Lost Creek Permit area. This is based on the results of testing and stratigraphic analysis detailed in the following reports: *Lost Creek Hydrologic Test, Composite KLM Horizon Regional Pump Test, October 2011* and *Lost Creek Hydrologic Test, Composite KLM Horizon 5-Spot Testing, October 2012* [Petrotek]. Since the nature of Battle Spring Formation depositional environment remains consistent throughout the area, it is presumed that similar hydrologic communication exists within the LCE Project area as well.

1.2 Test Objectives

The pump test objectives are to:

- Determine representative hydrologic aquifer parameters for the L Horizon;
- Evaluate the degree of vertical hydraulic communication between KM Horizon and the underlying L Horizon;
- Develop vertical hydraulic control parameters for the K-Shale. This data is required input into, and calibration of, a particle tracking model; and
- Generate L Horizon background water quality data.

2.0 SITE CHARACTERIZATION

2.1 Stratigraphy

In the LC East Amendment area, the top 1,200 feet from surface of the Battle Spring Formation represents the interval of interest. Within this interval, the stratigraphy has been sub-divided into several thick stratigraphic **"Horizons"** (e.g. HJ, KM, L, M, N, etc.). Horizons are dominated by sands and separated from each other by **"Named Shales"** of regional extent (**Figure 2-1**). Each horizon, however, is in actuality the composite of numerous "sands" which are in turn separated by numerous unnamed shales within the horizon. The extent of unnamed shales varies considerably. They may be quite areally extensive, or may be only of local extent. Note also that the term "shale" is used herein rather loosely, as it commonly may include considerable amounts of siltstone or fine grained sand in addition to the typical mudstone and claystone.

Horizons of primary interest are further subdivided into "**Sub-Horizons**" (e.g., LFG, UHJ, and UKM). Criteria for establishing sub-horizons are based largely on a combination of continuity of sand packages and continuity of associated mineral horizons. Vertical boundaries between sub-horizons are established somewhat arbitrarily and may or may not coincide with the presence of an intervening shale.

The resulting system of stratigraphic nomenclature is illustrated in the Stratigraphic Profile on **Figure 2-1**. This nomenclature is internal to Ur-Energy, and is not recognized officially by the geological community. The foundation for this system has been carried over, with some modification, from that established by Conoco Minerals during its early exploration activities in the region and subsequently adopted by Texasgulf during its tenure with the property. Nomenclature terms from surface downward to the KM Horizon were inherited from previous operators; below that the terms were derived by Lost Creek ISR LLC.

Note that in the last few years Ur-Energy has abandoned the use of the term "Sand" in favor of the term "Horizon" to describe the major stratigraphic units. It is believed that the term "Sand" can be misleading in recognition of the fact that any substantial stratigraphic interval consists not only of sand facies but also contains a considerable number of interbedded shales which yields hydrogeological characteristics significantly different than an interval consisting only of sand. Also note that the boundaries between horizons (i.e. Named Shales) have been established on a relatively arbitrary basis and don't necessarily reflect patterns or breaks in sedimentary or depositional characteristics. As a result, the system of nomenclature as illustrated on **Figure 2-1** should be viewed essentially and simply as a cataloguing tool for stratigraphic organization.

Overlying Confining Unit: Sagebrush Shale

The most notable shales are the Lost Creek Shale (LCS) and Sagebrush Shale (SBS) in that they exhibit a high degree of regional continuity and confinement. Locally however, they may display considerably complexity showing variable lithology and inter-fingering with adjacent sands above and below, which often results in dramatic changes in the thickness of the shales within short

horizontal distances. This is evident in the thickness isopach maps in the LC East Amendment (Plates D5-3a and D5-3c).

The SBS represents the boundary between the HJ Horizon and the underlying KM Horizon. It is laterally extensive and virtually continuous throughout the LC East Amendment area. Depth to the top of the SBS within the LC East Amendment area ranges from a maximum of 510 feet in the northern parts of Section 20 to 100 feet in northernmost portions of the Amendment area. Thickness varies from 2 to 30 feet.

KM Horizon Production Zone and Underlying Horizons

The uranium mineral trend which dominates the LC East Amendment area is referred to as the East Mineral Trend (EMT). Within the EMT the HJ Horizon and the KM Horizon represent the primary hosts to mineralization. Note that nomenclature for the KM was modified in recent years. Initially, and at the time of the original Lost Creek Mine Permit, the KM Horizon was assigned three sub-horizons: the Upper KM (UKM), the Middle KM (MKM) and the Lower KM (LKM). As additional drilling results became available over time it became apparent that the KM is better described as having only two sub-horizons, underlain by the K-Shale. Consequently, the MKM designation was abandoned and replaced by the LKM such that the current nomenclature employs only the UKM and LKM. Both the UKM and the LKM sub-horizons host mineralization. A shale unit referred to as the No Name Shale (NNS) commonly divides the two sub-horizons of the KM, but it is not always present.

In general, the character and lithology of the KM is similar to that of the HJ Horizon. Depth to the top of the KM Horizon ranges from approximately 510 feet in the northern parts of Section 20 to about 100 feet in the far northern portions of the Amendment area. Thickness ranges from approximately 100 to 130 feet. A thickness isopach map for the KM Horizon is presented as Plate D5-3d in the LC East Amendment application.

The K-Shale represents the basal boundary of the KM Horizon, separating it from the underlying L Horizon. Likewise, the LM-Shale separates the L Horizon from the underlying M Horizon. These shale units may show continuity over large areas, however regional continuity has not been confirmed due to sparsity of drilling data that extends deep enough. Commonly, they represent a series of inter-fingered layers of claystone, mudstone, and siltstone (see Plate D5-2b in Amendment Application). Thus, they cannot be considered truly confining units on a regional scale. However, due to the inter-fingering nature and low permeability of these units, test results confirm that they limit (attenuate with depth) and/or restrict vertical flow. Previous pump tests have evaluated these as potential lower aquitards to the KM Production Zone.

MN-Shale and N Horizon

The MN-Shale is a zone of interfingered layers of mudstone, siltstone, and shale that separates the M Horizon from the deeper N Horizon (**Figure 2-1**). It ranges from approximately 10 to 40 feet thick, with a typical thickness of about 10 to 20 feet. Similar to the above shales, regional continuity of the MN-Shale is not certain due to a lack of geologic drill data. As a result, the MN-Shale is not considered at this time to be a true regionally confining unit. However, the MN-Shale does appear to

limit and/or restrict vertical flow due to the inter-fingering of finer grained and lower permeability units.

Beneath the MN-Shale is the N Horizon and, based on limited data, the total thickness of the N Horizon is approximately 100 feet. No isopach maps have been constructed for this aquifer due to the limited number of borings that have penetrated through the entire N Horizon.

2.2 Hydrogeology

The results of HJ and KM Horizon pump tests, conducted throughout the Lost Creek and LC East project sites, indicate very little to no hydraulic communication between these two horizons. Furthermore, the same findings are applicable to the FG and HJ Horizons. The degree of hydraulic separation between the KM Horizon and the underlying L Horizon has yet to be established in the LCE Project area, and is the focus of this study.

The fact that Lost Creek ISR has been operating for almost three years without a substantiated excursion is confirmation that the intervening shaley layers are effective aquitards, and adequately control the vertical migration of mining fluids.

2.3 Previous Testing

As part of the LC East regional hydrologic characterization activities for NRC License and LQD Permit to Mine applications, Lost Creek ISR performed two HJ Horizon pump tests and three KM Horizon pump tests in 2013. The test results were presented as Attachment D6-4 in the LC East Permit Amendment titled *Lost Creek East Regional Hydrologic Pump Tests, September – December 2013*.

The findings indicated that there was no apparent hydraulic communication between the HJ and KM Horizons in any of the five pump test areas; additionally, there was no obvious hydraulic communication with the underlying N Horizon. There were no intermediate L Horizon wells in the LCE area to monitor.

No L Horizon monitor wells were installed as it was originally thought the N Horizon would serve as the underlying aquifer due to the established hydraulic connection observed between the KM, L and M Horizons. This hydraulic communication had been recognized by Petrotek during their 2009, 2011 and 2012 pump testing programs (see **Section 8**, References). However, subsequent modeling of the KM Horizon (Petrotek 2016) has demonstrated that the vertical migration of lixiviant can be controlled by the K-Shale and other ancillary low permeable layers while operating in a balanced mode with a minor bleed. Accordingly, Lost Creek ISR now believes that the L Horizon can best serve as the underlying aquifer, hence the need to establish aquifer characteristics and water quality data as described in the following sections.

3.0 TEST WELLS

3.1 Existing LCE Test Well Locations

The well clusters used in the 2013 pump test program are shown on **Figure 3-1**. Each pump test well cluster included one or more wells completed in the FG, HJ, and KM Horizons. It was originally intended that an N Horizon well be constructed at each cluster, but the Central N Horizon well turned out to actually be an M Horizon completed well when a more detailed stratigraphic correlation was performed. In addition, observation well clusters were installed adjacent to or between the pump test clusters as shown on **Figure 3-1**. Well Completion Reports were included as Appendix A in the *Lost Creek East Regional Hydrologic Pump Tests, September – December 2013*. Existing KM, M and N Horizon well information related to location, construction, completion interval, and initial water levels are provided in **Table 3-1** of this document.

3.2 Proposed L Horizon Well Location and Completion Information

Well Locations

Lost Creek ISR proposes to install two L Horizon wells at each of the three existing pump test clusters. The proposed L Horizon well locations are shown on **Figure 3-2**. One well will be partially penetrating and designed exactly as an underlying monitor well would be during actual wellfield operation. The new well will be located approximately 50 to 150 feet from the KM Horizon pumped well. The second L Horizon well at each cluster will be fully penetrating and used for an L Horizon pump test well, and as an observation well for the KM Horizon test. The distance between the two L Horizon wells will be at least two times the L Horizon aquifer thickness in order to negate the partial penetration effect.

Well Completion

New L Horizon wells will be constructed with 4.5-inch inside diameter PVC, SDR-17 casing (a typical well design is shown on **Figure 3-3**). The casing annulus will be filled via pressure grouting of cement back to the surface. The cement plug remaining inside the casing will be drilled out and the well deepened to its final completion depth using a 4.25-inch diameter drill bit. The open-hole interval beneath the casing will be underreamed to approximately 8-inches. A well screen insert assembly consisting of 3.5-inch outside diameter PVC well screen with 0.020-inch slots will be hung on a double K-pack system and installed within the casing to the desired depth (**Figure 3-3**).

The wells will be developed using standard water well techniques including but not limited to: air lifting, pumping, swabbing, and surging. All test and observation wells must pass an MIT before being utilized.

Proposed well completion data for L Horizon test and observation wells are also shown on **Table 3-1** in **blue** lettering. E-logs for the nearest N Horizon well was used to pick the L Horizon completion intervals (E-logs provided in **Appendix A**). The proposed screen interval for the partially penetrating wells are positioned near the top of the L Horizon just beneath an obvious low permeable layer. The rationale for selecting the screen interval on fully penetrating wells is based on choosing the largest sand package present between the K-Shale and LM-Shale layers.

4.0 PUMP TEST SCHEME AND SEQUENCING

The 2013 LCE pump tests fully established the hydrologic relationship between the FG, HJ and KM Horizons. Accordingly, a re-assessment of those relationships will not be revisited as part of this test plan. This pump test plan focuses on defining the relationship between the KM, L, M and N Horizons in LCE. The following section details the proposed pump test scheme and methods planned for implementing the 2016 test. Details of testing are summarized below.

4.1 Test Scheme

The KM Horizon hydrologic tests will be conducted in a manner designed to meet the objectives outlined in **Section 1.2**.

The general testing procedures will be as follows:

- All KM and L Horizon wells used in the pump tests will be developed by using standard water well techniques including but not limited to: air lifting, pumping, swabbing, and surging prior to conducting pump tests;
- In-Situ LevelTROLL® data-logging transducers (vented) will be installed in nearby KM, L, M, and N Horizon observation wells to record changes in water levels during pumping (well identified in **Section 5.1**). The water level changes in the more distant observation wells may be manually measured using an e-line. Lost Creek staff will verify transducer setting depths and head readings against manual water level measurements;
- LevelTROLL transducers will measure and record pre-test background water levels and barometric pressure for a period of time prior to the commencement of testing to ensure stability (largely due to the proximity of active ISL mining patterns);
- Water levels and barometric pressure will be recorded throughout the pre-test, pumping, and recovery periods; and
- Recovery monitoring will commence upon test termination and continue until baseline conditions are re-established or nearly so.

4.2 Pump Test Equipment and Sequencing

Equipment

Aquifer testing will be performed utilizing a Grundfos 60S100-18 (10 hp), 460V, 3-phase electrical submersible pump (or equivalent) powered by a portable diesel generator. The pump will be set approximate 10 feet above the well screen assembly to allow for the maximum amount of drawdown.

Flow from the pump will be controlled via a manual ball valve placed at the terminus of a wellhead metering assembly. The metering assembly will included a 1.5-inch NU FLO MCII turbine meter. The meter displays total flow (in gallons) and instantaneous flow rate (in gallons per minute [gpm]).

Discharge water will be land applied approximately 150 feet down-gradient via a 2-inch high-density polyethylene (HDPE) pipe.

Water levels will be measured and recorded with In-Situ Level TROLL® pressure transducer dataloggers. The pressure rating for the transducers will range from 32 to 100 psi, and programmed to record depth to water measurements at specific time intervals during all phases of testing (pre-test background monitoring, pumping, and recovery periods).

Pump Test Sequencing

LC ISR plans to start by testing (pumping from) the KM Horizon in the northern most cluster first, then proceed southward to each successive test cluster. Once all KM Horizon clusters have been tested, then the L Horizon will be tested commencing with the northern-most cluster. This sequencing approach is intended to provide sufficient time for the KM aquifer to recover before stressing the lower L Horizon. If, however, the KM aquifer has not adequately recovered, then additional time will be allotted for recovery before starting the L Horizon test.

4.3 Pumping Rate and Test Duration

Background Monitoring

Approximately one week prior to initiating the pump testing programs, background monitoring of water levels in the KM and L Horizons will be collected hourly, via pressure transducers, to establish that conditions are static.

Pumping Rates

The KM Horizon 2013 pump test discharge rates ranged from 40 to 60 gpm resulting in pump well water level declines that ranged from 26 to 94 feet. These pumping rates were sustainable for the three to seven day pump test periods. Accordingly, LC ISR anticipates replicating these pumping rates during the 2016 KM Horizon pump tests, but reserves the right to pump at lower rates if conditions warrant.

Prior to starting the long-term L Horizon tests, step-rate tests will be conducted to establish sustainable pumping rates. Based on the step-rate test results, a pumping rate will be selected that best meets the test objectives. The pumping rate will be recorded on a logarithmic scale, meaning closely spaced time intervals in the beginning becoming progressively further spaced apart later into the test period.

Test Duration

Each pumping well will be started and flow maintained at a constant rate (or as constant as possible) for the duration of the test. Water level data will be recorded on the logarithmic scale programed into the pressure transducer by the manufacturer. Based on the 2013 LCE test results, it is anticipated that the test duration will last approximately two days or until the desired effect(s) is (are) observed. This means that if drawdown is observed in the underlying L Horizon when the KM

Horizon is pumped, then the test will continue until a sufficient trend (data) is generated to analyze.

Barring unexpected variations in hydrogeologic properties, a "cause and effect" minimum drawdown response of 1.0 to 2.0 feet will be considered "significant" with respect to demonstrating hydraulic communication between the pumping well and the corresponding observation well(s).

5.0 PUMP TEST MONITORING

5.1 Observation Well Monitoring

The following is the proposed horizon-specific summary of water level monitoring by location and completion interval:

- North Cluster **KM Horizon** Pump Test – 7 wells, including:
  - M-KM9 – pumped well
  - M-KM8 and M-KM10 – observation wells
  - M-L6 and M-L7 – observation wells
  - M-N4 and M-N5A – observation wells
- Central Cluster **KM Horizon** Pump Test – 7 wells, including:
  - M-KM7 – pumped well
  - M-KM8 and LC27M (KM Horizon) – observation wells
  - MB-11 (L Horizon) – observation well
  - M-L8 and M-L9 – observation wells
  - M-N3 (actually an M well) – observation well
- Southern Cluster **KM Horizon** Pump Test – 8 wells, including:
  - M-KM4A – pumped well
  - M-KM5A, M-KM6 and M-KM11A – observation wells
  - M-L10 and M-L11 – observation wells
  - M-N2 and M-N6 – observation wells
- North Cluster **L Horizon** Pump Test – 7 wells, including:
  - M-L7 – pumped well
  - M-KM8, M-KM9 and M-KM10 – observation wells
  - M-L6 – observation well
  - M-N4 and M-N5A – observation wells
- Central Cluster **L Horizon** Pump Test – 6 wells, including:
  - M-L9 – pumped well
  - M-KM8 and LC27M (KM Horizon) – observation wells
  - M-L8 – observation well
  - MB-11 (L Horizon) – observation well
  - M-N3 (actually an M well) – observation well
- Southern Cluster **L Horizon** Pump Test – 8 wells, including:

- M-L11 – pumped well
- M-KM4A, M-KM5A, M-KM6 and M-KM11A – observation wells
- M-L10 – observation well
- M-N2 and M-N6 – observation wells

In addition to monitoring water levels in the above-referenced wells, some periphery wells completed in the KM, L and N Horizons may also be monitored to assess the radius of influence generated by the test.

Lost Creek personnel will collect daily downloads after instrument installation for review and QA/QC for all phases of hydrologic testing.

5.2 Barometric Pressure Monitoring

An In-Situ BaroTROLL® will be installed approximately one week prior to initiating the testing programs and used to measure barometric pressure during all test phases including recovery. The data collection interval will be hourly. If significant variations in water levels attributable to barometric pressure change are noted, then data may require correction to factor out that effect.

6.0 L HORIZON BASELINE WATER QUALITY SAMPLING

Water samples will be collected from L Horizon pump test wells (M-L7, M-L9 and M-L11) near the end of each test and submitted to a commercial analytical laboratory for Guideline 8 analyses. Quarterly samples will be collected thereafter until one years' worth of data has been compiled.

7.0 DATA ANALYSIS AND REPORTING

Conventional analytical techniques (i.e., log-log, semi-log, and distance-drawdown methods developed by Theis, Jacob, and Cooper and Jacob, respectively) will be used, as appropriate, to evaluate the aquifer response to pumping and to assess the KM and L Horizon hydraulic characteristics. Theis recovery analyses will be performed on the pumping well, and as appropriate on some of the monitoring wells. Other analytical methods (e.g., Hantush, Neuman, etc.) may be employed for the monitoring wells, if warranted. The analyses may be performed using the Schlumberger Aquifer Test software package or done manually.

Following the completion of field activities and data analysis, a report that fully discusses the pump test objectives, procedures and results will be prepared by LC ISR, LLC and submitted to NRC and WDEQ/LQD in support of Lost Creek's LC East Amendment application. The report will include discussions of: 1) geologic data/setting, 2) monitor and pump well construction specifications, 3) pre-test water-level trends, 4) KM and L aquifer hydrogeologic characteristics, 5) KM and L Horizon water-level responses when the corresponding aquifer is stressed, and 6) the K-Shale vertical hydraulic conductivity characteristics.

8.0 REFERENCES

Petrotek Engineering Corporation, 2009. Lost Creek Regional Hydrologic Testing – Mine Unit 1, North and South Tests; prepared for Lost Creek ISR, LLC October 2009.

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