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PERFORMANCE OF THE GROUT CURTAIN AT THE KENTUCKY RIVER LOCK AND DAM NO. 8

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THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering in the College of Engineering at the University of Kentucky

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ABSTRACT OF THESIS

PERFORMANCE OF THE GROUT CURTAIN AT THE KENTUCKY

RIVER LOCK AND DAM NO. 8

Karst bedrock conditions and deterioration of the lock and dam structures have resulted in significant leakage through, underneath, and around Lock and Dam No. 8 on the Kentucky River. During severe droughts, the water surface in Pool No. 8 has been observed to drop below the crest of the dam, resulting in water supply shortages and water quality issues for surrounding communities reliant on the pool. Presently, the primary purpose of Lock and Dam No. 8 is water supply. Pool No. 8 is currently where the cities of Nicholasville (Jessamine County, KY) and Lancaster (Garrard County, KY) draw their water. Due to the age and condition of the structures, and the criticality of the retained water supply, the project Owner commissioned a replacement dam to be built. One major component of the replacement dam was a foundation improvement program. The foundation improvement program was designed to address the karst bedrock conditions at the site. The foundation improvements included a secant pile cutoff wall and a double-row grout curtain. The grout curtain at Lock and Dam No. 8 was evaluated based on the metrics presently available.

KEYWORDS: Karst, Grout Curtain, Lock, Dam, Kentucky River, Seepage

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1 Problem Statement

1.1 Grout Curtains in Karst Environments

Moneymaker (1968) stated that "Solution cavities are almost invariably present in the foundations and abutments at dam sites in limestone and carbonate rock." Lock and Dam No. 8 is founded on primarily limestone bedrock with interbedded shale partings and is not an exception to Moneymaker's claim. As Weaver and Bruce (2007) point out, the reservoir leakage in limestone foundations depends on the stage and extent that dissolution has occurred, joint orientation, and bedding plane orientation. It should be noted that while not all limestones are cavernous, minor dissolution activities along bedding planes and joints can lead to the need for an extensive grouting program (Weaver and Bruce, 2007). Deere (1981) suggested that cavernous karstic features are often infilled with clays and silts; and therefore, will not take large grout quantities during treatment. Deere also pointed out that karstic limestone features may be structurally or lithologically driven but will almost certainly be highly unpredictable and erratic.

Grouting in karst environments to reduce seepage is common practice and is historically proven. As Deere pointed out, karst conditions are unpredictable and erratic. This presents a significant challenge to designers. While design guidance and installation methods are available to designers, a successful grout curtain in karst environments will be designed and installed based on the site specific karstic conditions. The remainder of this study focuses on the extent of karstic dissolution of the foundation bedrock at Lock and Dam No. 8, how these karstic conditions influenced the design and installation methods, and the performance of the grout curtain at Lock and Dam No. 8.

The objective of this study is to evaluate the performance of the installed double-row grout curtain at Lock and Dam No. 8. To fully evaluate the grout curtain, this study will also present the site specific geological and geotechnical information at the Lock and Dam No. 8 site, discuss the design methodology for the grout curtain to account for karstic foundation features, and review the grout curtain installation records.

1.2 General Project Description

Lock and Dam No. 8 on the Kentucky River is located in Garrard and Jessamine Counties, Kentucky, approximately 139.9 river miles upstream of its confluence with the Ohio River. The facility was originally constructed between the years of 1898 and 1900 to support an increasing demand of commercial traffic along the Kentucky River. Refer to Figure 1 for a project location map.

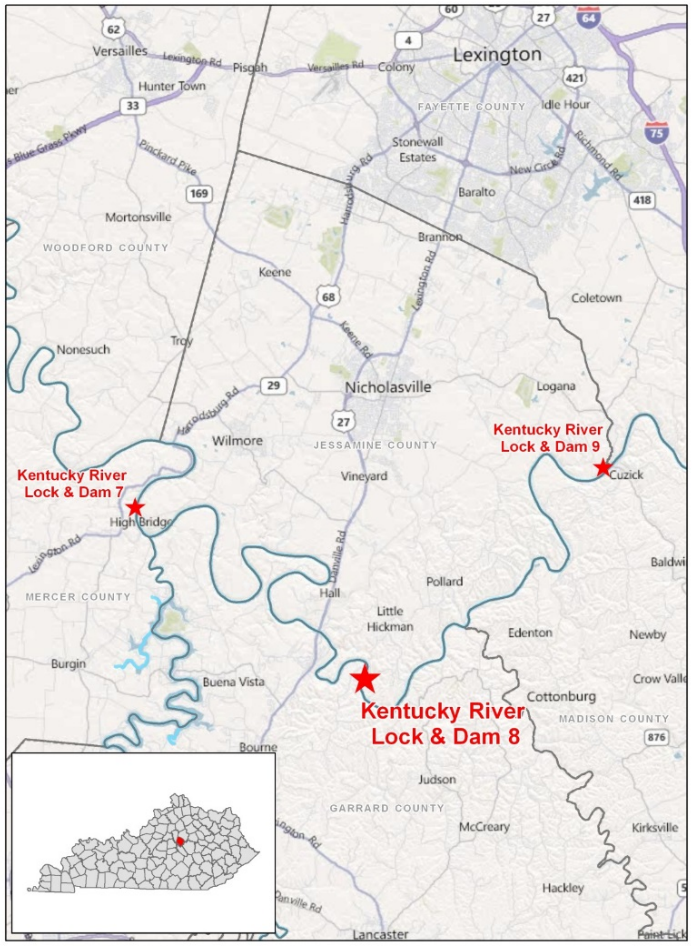

Figure 1 Project Location Map

Prior to the renovation efforts that began in July 2013, Lock and Dam No. 8 was comprised of a fixed-crest overflow dam (rock-filled timber crib structure capped with concrete), a stone masonry navigation lock with a bulkhead wall, and other ancillary structures. An aerial photograph of Lock and Dam No. 8 is presented in Figure 2. While numerous repairs have been performed at the facility throughout its 111 years of operation, the condition of the dam, lock structure, lock gates, ancillary structures, and mechanical components has deteriorated significantly.

Figure 2 Aerial Photograph of Lock and Dam No. 8

Presently, the primary purpose of Lock and Dam No. 8 is water supply. Pool No. 8 is currently where the cities of Nicholasville (Jessamine County, KY) and Lancaster (Garrard County, KY) draw their water.

1.3 Existing Conditions and New Dam Design

Karst bedrock conditions (as discussed in Section 3), and deterioration of the lock and dam structures have resulted in significant leakage through, underneath and around the facility. During severe droughts, the water surface in Pool No. 8 has been observed to drop below the crest of the dam, resulting in water supply shortages and water quality issues for surrounding communities reliant on the pool. An aerial image of the project site displaying the major facility components is shown in Figure 3.

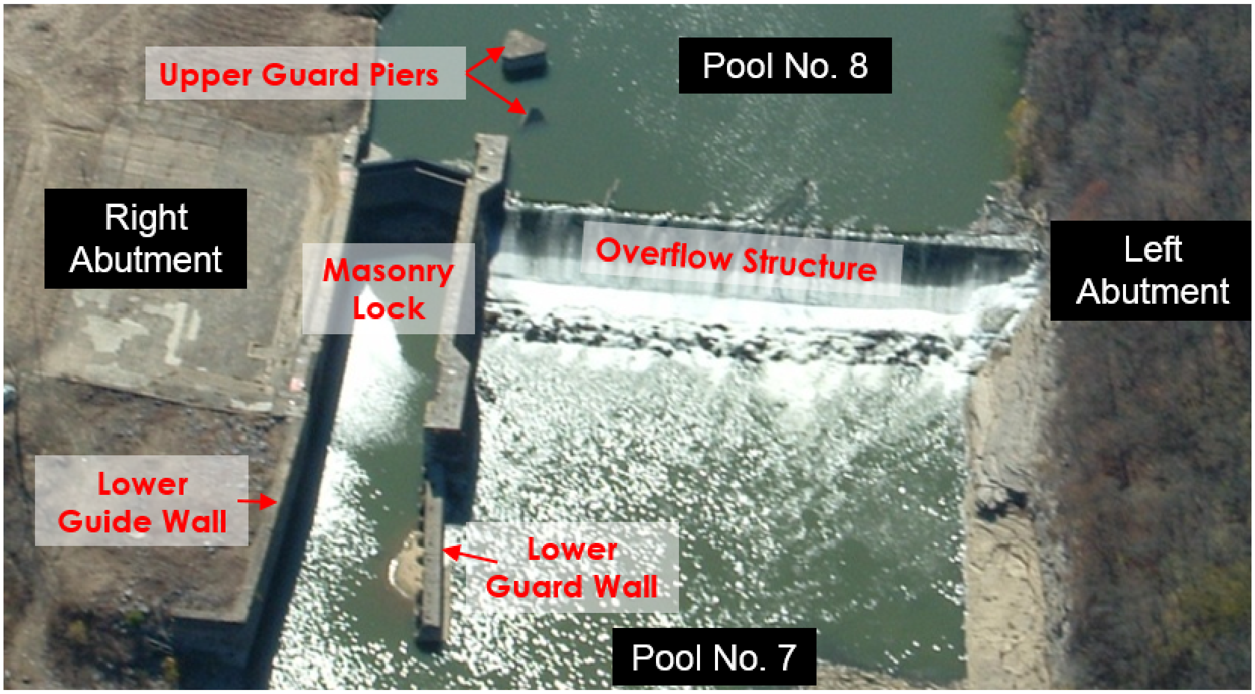

Figure 3 Lock and Dam No. 8 Site Features

Due to the age and condition of the structures, and the criticality of the retained water supply, the project Owner commissioned a replacement dam to be built. The major components of the new dam design include:

- A new dam structure located immediately upstream of the existing facility. The new dam is a cellular concrete gravity dam. The new dam ties into the river lock wall on east and into a steep sloping rock face on the west abutment.
- Foundation improvements to address karst bedrock conditions at the site. This included a secant pile cutoff wall and a double-row grout curtain. Details of the foundation bedrock conditions are discussed in Section 3 and the grout curtain program is discussed in Section 4.
- Modifications within the lock chamber to allow water conveyance during drought conditions and the addition of scour protection elements to prevent erosion of the lock chamber's upper sill.
- Site grading to reduce soil pressures behind the existing Upper Guide Wall structure and improve drainage on the eastern abutment. See Figure 4 for the location of the Upper Guide Wall in relation to other project components.

A three-dimensional rendering of the various renovation components of the new dam is displayed in Figure 4.

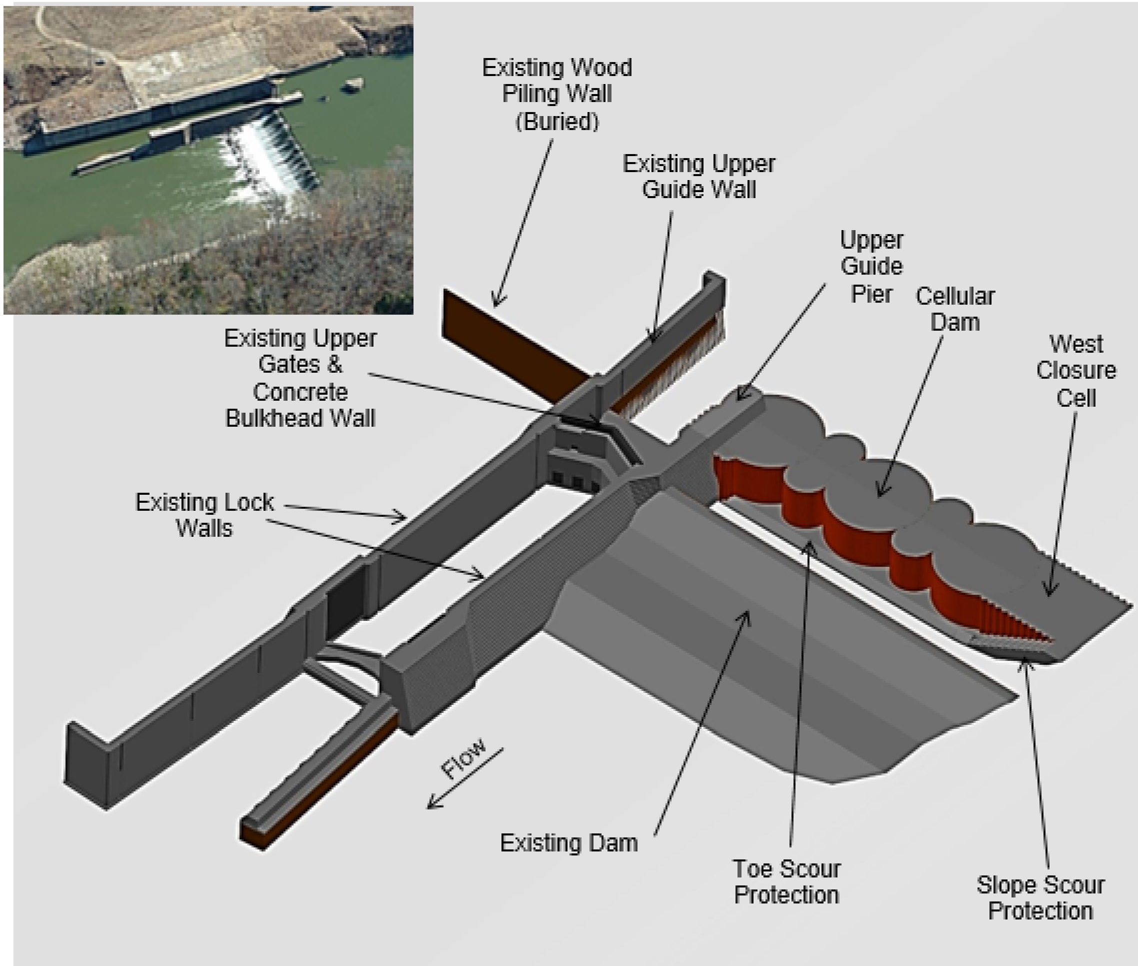

Figure 4 Rendering of Renovation Components (looking upstream)

1.4 Objectives of Study

The objective of this study is to evaluate the testing data collected during the installation of the grout curtain, and the available pre-and-post-construction piezometric data, to assess the efficiency of the grout curtain.

2 KARST TERRAIN AT LOCK AND DAM NO. 8

Every karst climate is different and will be influenced by many different factors. For example: La Angostura Dam in Mexico was founded on clayey, limestone and was treated with a double row grout curtain (Marsal, 1974), while Spruce Run Dam in Pennsylvania was also constructed on non-cavernous limestone required a triple-line grout curtain to successfully address the foundation seepage (McGavock, 1968).

Closer to the project site discussed in this study, Moneymaker (1968) reported that Kentucky Dam encountered karst foundation conditions including a large vertical solution feature. The foundation at Kentucky Dam was treated with a concrete cutoff and conventional grouting.

Similar karst challenges were encountered at Wolf Creek Dam in Jamestown, Kentucky. Erich (2013) concluded that the concentrated seepage that began to cause problems at Wolf Creek Dam was ascribed to the karstified limestone foundation and high hydraulic head. Several remediation efforts have been performed at Wolf Creek Dam, include an emergency grouting program from 1968 to 1970, the construction of a barrier wall in the 1970s, and the more recent renovations including a new 980,000 square feet barrier wall. A double line grout curtain was installed on either side of the barrier wall to temporarily block seepage.

Rough River Dam located in Falls of Rough, Kentucky, has also experienced issues with solution features within the foundation bedrock at the site. Ailstock (2015) points out that as part of the original construction, grouting was performed at each abutment, but beginning in 2003 a sinkhole developed near the downstream rock toe which was repaired later in 2006 and 2007. Solution features within the limestone bedrock were exposed during modifications to the Stilling Basin at Rough River Dam in 2008. These features were filled with concrete and the Stilling Basin modification construction continued.

Karstic conditions are highly variable and so are the consequences associated with the features. Similarly, the approach to treat karst features varies depending on the extent of karstic dissolution.The remaining sections of this report focus on how these various factors were considered to treat the karstic limestone foundation at Lock and Dam No. 8. The focus of this study is on how the site specific geologic conditions were considered in the design, the field installation procedures, treatment observations, and analysis of the results. The geologic conditions at Lock and Dam No. 8 are discussed in detail in Section 3, and the history of remedial actions taken to address karstic issues at the facility are presented in Table 1.

Table 1. Summary of Karst Mitigation Actions

Year	Event
1943 – 1944	Treatment of bedrock features in the lower portion of the Lock Chamber.
1985	Concrete repairs to Lock Chamber floor (bedrock).
2002	Left Abutment leakage repairs (grout bags, drilling and grouting).

3 GEOLOGIC CONDITIONS

3.1 REGIONAL GEOLOGY

Based on the available geologic mapping, the Lock and Dam No. 8 project site is underlain by the Grier Limestone Member of the Lexington Limestone Group. According to the U.S. Geological Survey (USGS) Geologic Map of the Buckeye Quadrangle (1970), the Grier Limestone Member consists of gray, fossiliferous limestone with minor amounts of interbedded shale and micro-grained limestone. The referenced mapping also describes the bedding as very irregular to even, with chert nodules in some locales. The structural contours drawn on the base of the Calloway Creek Limestone Group indicate that rock in the vicinity of the site dips less than one-degree to the south-southeast. The referenced geologic mapping is presented in Figure 5.

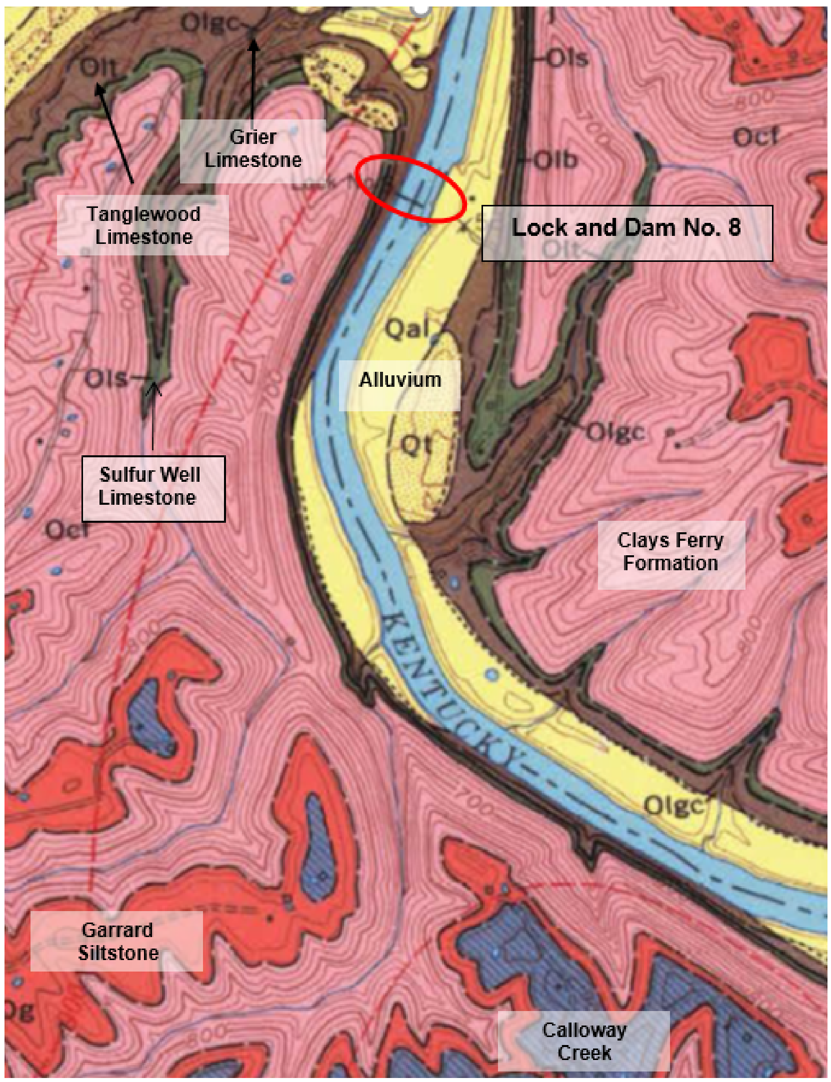

Figure 5 Geologic Quadrangle (USGS) of the Project Site

The project site is located on the downthrown side of the Kentucky River Fault Zone approximately 1.5 miles southeast of the project site. Vertical displacements near the project site along the fault are on the order of 50 feet. The Kentucky River Fault System, now inactive, is one of the major structural geology features of Kentucky. The fault system can be described as a narrow band of normal faults and grabens trending north-northeast from Casey County to Jessamine County, thence curving east-northeast to Montgomery County. The general sense of the displacement is down to the southeast with the throw up to 600 feet.

3.2 Site Geology

Karst bedrock conditions have been a challenge at the project site dating back to the early 1900's. Numerous karst features and fissures in the bedrock are documented at the site within historical documents, particularly within the floor of the lock chamber, lower guide wall footprint and at the west (left) abutment of the existing dam. United States Army Corps of Engineers (USACE) drawings from 1913, as presented in Figure 6, depict as-constructed conditions of the upstream 20 feet of the lower guide wall structure. These as-constructed drawings identify three fissures within the footprint of the lower guide wall structure.

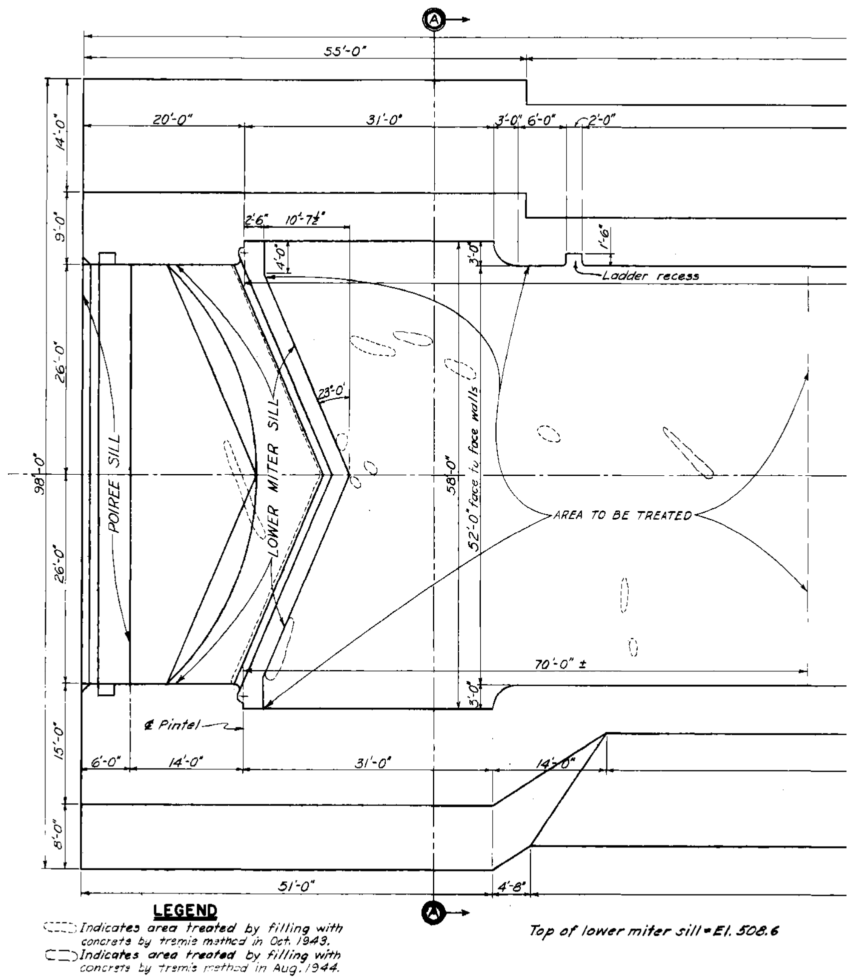

Figure 6 Lock Chamber Features Identified for Treatment (USACE, 1950)

The largest of these fissures is estimated to be near 30 feet in length by scaling the historic drawing. The drawing also indicates the bottom of the largest fissure is near elevation 490 feet, which is approximately 9 feet below the top of rock elevation. The largest fissure is oriented in a northeasterly direction, while smaller fissures were oriented in a northwesterly direction.

USACE drawings from 1950 identify areas in the chamber floor reported to have been treated in 1943 and 1944. In general, the identified features coincide with subsequent underwater observations and dive inspections in 1985, 1989, 1997 and 2001. Similar to fissures documented in the foundation of the lower guide structure, the general orientation of the features is in a northeasterly direction. During operation of the lock chamber, several of these features have been observed to be hydraulically connected to the lower pool and are particularly active during chamber filling activities.

In addition to historic observations within the lock chamber, karst features and jointing has been observed and treated on numerous occasions in the left abutment. A small rock shelter can be observed in the downstream west (left) abutment rock outcrop, approximately 350 feet downstream of the existing dam. Approximate dimensions of the rock shelter are three feet wide, two feet tall and 20 feet deep. The rock shelter is also oriented in a northeasterly direction from the opening in the rock outcropping. A photograph of the rock shelter is presented in Figure 7.

Figure 7 Rock Shelter Located in the Downstream Left Abutment Outcrop

Other evidence of karst topography at the site includes a small sinkhole observed on the Jessamine County side of the property during the geotechnical study. Approximate dimensions of the sinkhole are five feet in diameter and four feet deep. A photograph of the sinkhole is also presented in Figure 8.

Figure 8 Sinkhole Observed Near the Site Entrance

3.3 FIELD MEASURED I-ANGLES

A geologic reconnaissance was performed in June 2011 in support of the renovation design. The area of study was located on the Garrard County side of the river, immediately downstream of the left abutment of the existing dam (Figure 9).

Figure 9 Geologic Reconnaissance Area of Study

The length of the study area was approximately 400 feet, and the elevations ranged from above the crest of the dam (i.e., above elevation 530.8 feet) to just above the tailwater elevation on the date of study (i.e., approximately below elevation 513 feet). Rock outcrops, including near vertical highwalls and several benches of varying elevation, were observed during the reconnaissance.

Exposed rock outcroppings were limestone and were described as light gray, fine grained to microcrystalline, thin to medium-bedded, and hard, with shale partings throughout. The shale partings were described as dark gray, silty, laminated, and soft to moderately hard. This description is generally consistent with the USGS geologic mapping information for the Grier Limestone Member of the Lexington Limestone Group, which is the predominant geologic unit at the site, and is representative of both the outcrops and the foundation of the dam. Figure 10 presents a closer view of the highwall and benches immediately downstream of the left abutment of the dam.

Figure 10 Geologic Reconnaissance – Highwall and Benches Downstream Along Left Abutment

3.3.1 Measurement Location

Field i-angle measurements were taken along five survey lines, established at various elevations and horizontal locations along the rock outcrop at the downstream left abutment of the existing dam. All lines were oriented roughly in the direction of potential sliding (i.e., upstream to downstream) for the proposed dam. Two lines (Lines 1 and 2) were on the rock highwall and the remaining three lines (Lines 3, 4, and 5) were on near-horizontal benches. Elevations of the lines ranged from 513 to 526 feet. For comparison, the crest of the existing dam is 530.8 feet and the base of the dam is near 500 feet. (Stantec, 2011)

A sixth line (also oriented roughly upstream to downstream) was surveyed to estimate the overall apparent dip of the bedding planes exposed along the outcrop. Two points, roughly 360 feet apart, were marked along a single bedding plane and were surveyed. At this distance, any localized surface roughness effects should be negligible.

3.3.2 Measurement Methodology

Measurements of field i-angles employed two different techniques. The measurement technique for Lines 1 and 2 consisted of taking vertical offset measurements at specified step intervals along a tightly stretched horizontal string line. The string line was installed by nailing each end into the rock face and establishing the horizontal line using a bubble level. A single bedding plane was then marked at two-foot horizontal intervals. At each interval, the vertical distance (up or down) was measured from the string line to the bedding plane. Lines 1 and 2 were 30 and 24 feet in length, respectively.

The measurement technique for Lines 3, 4, and 5 consisted of direct measurement of horizontally exposed bedding planes using a self-zeroing laser level and straight edges of varying lengths. An inherent assumption of the measurements taken on the bench is that a single bedding plane is represented along the bench. Each line was typically 20 to 30 feet long and was marked in two-foot increments. Two-foot, four-foot, six-foot, and eight-foot straight edges (2X4 lumber) were then placed along the survey line and the angle (deviation from horizontal) was measured by placing the self-zeroing level on the straight edge. The straight edge was progressively moved along the line and readings taken every two feet (e.g., the eight-foot readings would be taken at zero to eight feet, two to ten feet, four to 12 feet, and so forth).

3.3.3 Measurement Results

The field i-angles can be calculated based on the data from Lines 1 and 2, or measured directly from Lines 3, 4, and 5. In order to consider general trends and reduce bias that may occur from one particular survey line, it is preferred to view the entire data set for all five lines. Figure 11 presents the i-angles from all five lines as a function of step length. The sign convention was such that positive angles indicate apparent dip in the upstream direction.

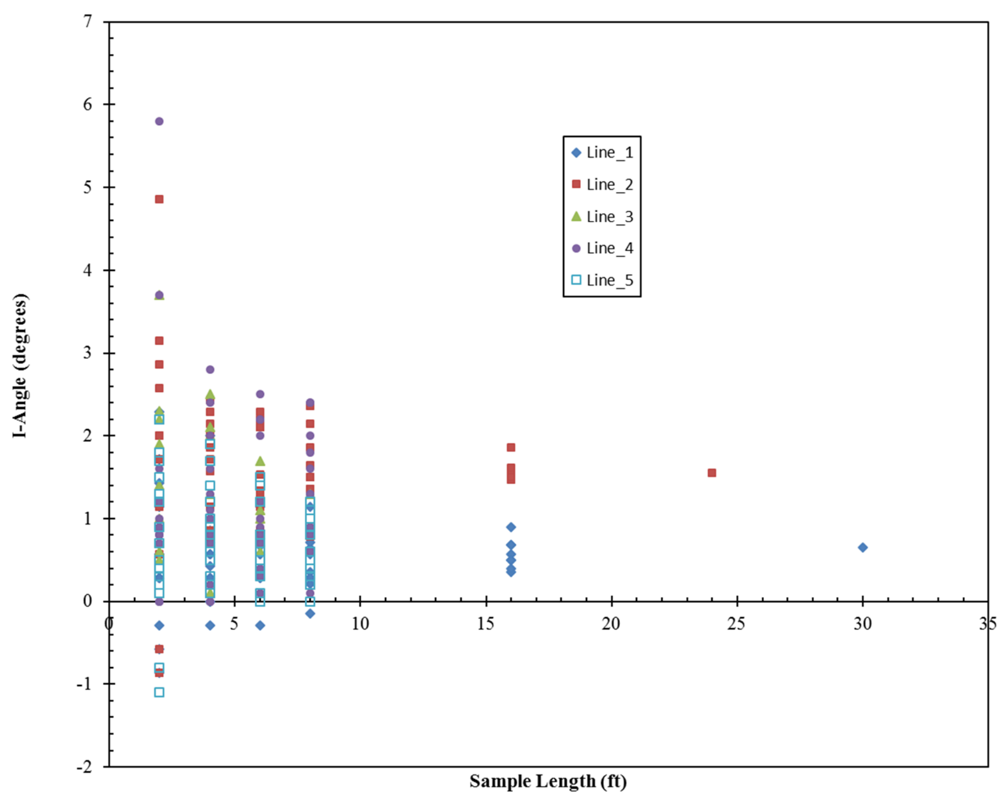

Figure 11 i-Angle vs. Step Length Plot

Lines 1 and 2 produced data points at each two-foot increment, thus i-angles could be computed for any multiple of two, up to the full length of the survey line. For graphical presentation purposes, i-angles from Lines 1 and 2 were calculated at two, four, six, eight, 16, 24 (full length of Line 2), and 30-foot (full length of Line 1) step lengths. It is assumed that the asperities (or waviness) are symmetric about a line that marks the overall dip of the bedding plane (which must later be separated out from the actual i-angle). Thus, positive and negative i-angle measurements can be considered together. Lines 3, 4, and 5 provide direct measurements of the two, four, six, and eight-foot i-angles. Again, the overall dip of the bedding planes must later be separated out from the actual i-angle.

As would be expected, shorter sample lengths lead to greater variation and larger (i.e., steeper) i-angles. As step length increases, the i-angles decrease, approaching a steady-state value equal to the overall apparent dip of the bedding planes. Based on surveyed elevations along Line 6, the overall apparent dip of the bedding planes is approximately one-degree in the upstream direction.

As discussed previously, selection of the first-order i-angle for use in deriving the design friction angle is a subjective process with no definitive guidance. Assuming that a representative step length is used, the actual i-angle will tend to be driven by the higher measured values (omitting any perceived outliers). For step lengths of roughly 16 feet or less, the upper bound of field measured i-angles generally varies from two to three degrees. Adjusting for the overall apparent dip of one-degree, the actual i-angle generally varies from one to two degrees. For design purposes, a first-order i-angle of one-degree was used. This selection is consistent with visual observations of the rock outcrop, which indicate that the large scale bedding is relatively planar (i.e., very little large scale roughness or waviness) and dips slightly in the upstream direction.

3.4 Joint Orientation and Spacing

3.4.1 Measurement Locations

Fracture mapping (orientation, spacing, etc.) was performed at the rock outcrop at the downstream left abutment of the existing dam. Steeply inclined (near-vertical) fractures were observed on the rock highwall (above Lines 1 and 2 from i-angle mapping), as well as on a near-horizontal bench (near Line 5 from i-angle mapping). It should be noted that in many cases, the fractures were partially obscured by vegetation or weathered rock surfaces. Additionally, the original excavation, blasting, and quarrying process that created the outcrop produced many fractures that are not indicative of the regional fracture patterns.

3.4.2 Measurement Methodology

Strike and dip of observed fractures were measured using a Brunton Compass. Fracture spacing was measured using a steel or cloth tape.

3.4.3 Measurement Results

On the highwall above i-angle Line 1, two predominant fracture sets were observed. The first set had strikes ranging from N32W to N41W, dips of 88 to 89 degrees (from horizontal), and horizontal spacing (perpendicular distance between fractures) of approximately 32 feet. The second set had strikes ranging from N54E to N56E, dips of 86 to 88 degrees, and horizontal spacing of approximately 17 feet.

On the highwall above i-angle Line 2, two predominant fractures were observed, although the horizontal spacing could not be estimated due to limited exposure of the fractures. The first fracture had a strike of N42W and dip of 88 degrees. The second fracture had a strike of N69E and dip of 90 degrees. These orientations are fairly similar to those observed above Line 1, and both exhibit general strike orientations similar to feature orientations recorded in the lock chamber and lower guide wall footprint from previous dive inspections, as discussed in Section 3.2.

Two sets of more closely spaced fractures were observed on the bench near Line 5. This observation was unique and did not appear to be representative of other portions of the outcrop. The fracture patterns may indicate an individual rock layer with more brittle behavior (i.e., a stiffer material that tends to fracture more often) than the remainder of the exposed outcrop. The first set had strikes ranging from N4W to N11E, dips of 87 to 90 degrees, and horizontal spacing of roughly three feet. The second set had strikes ranging from N49E to N65E, dips of 84 to 89 degrees, and horizontal spacing of approximately one-foot.

3.5 Site Investigation

3.5.1 Pre-Construction Borings

A subsurface exploration program (locations, depths, orientation, inclination, type of sampling, etc.) was developed by Stantec to support the design of the new lock and dam structures, as well as the foundation improvement program. According to Weaver and Bruce in *Dam Foundation Grouting* (2007), "exploratory drilling is most important feature of subsurface exploration for design of a grouting program at a 'typical' dam site." Information obtained from the geological reconnaissance was used to assist development of the program. The program consisted of thirty inclined and vertical borings positioned across the site, as shown on the boring layout drawing in Appendix A. The type, orientation and location of borings are identified on the boring layout drawing. General boring locations can be divided into the following groups:

- Seven borings were located on the right abutment; including one through the lock land wall, three through the esplanade, and three upstream of the esplanade.
- Two borings were located in the upper lock approach.
- Eighteen borings were located upstream of the existing dam within or near the footprint of the proposed dam. These borings were advanced from a floating plant (barge).
- Three borings were located in the west (left) abutment within or near the footprint of the proposed dam.

Vertical borings were used to obtain sediment and rock core samples for laboratory testing. Target coring depths for these borings were a minimum of ten feet with additional depth of drilling as deemed necessary in the field based on the subsurface conditions encountered in the field. A total of ten vertical borings were planned as part of the exploration. Four vertical borings were positioned on the right abutment with one boring through the lock land wall and thee borings in the esplanade. One of these borings was positioned in an attempt to intercept a potential cutoff wall at the upstream end of the lock land wall. The remaining vertical borings were located within the confines of the Kentucky River. With the exception of one vertical boring near the river lock wall, all vertical river borings were positioned near the centerline alignment (designated at Baseline A, approximately 25 feet upstream of the upstream end of the river lock wall) of the new dam.

Inclined borings were incorporated into the exploration program to intercept steeply inclined geological site features in the rock such as joints, fractures, fissures, etc. No sediment or rock samples were obtained from inclined borings for laboratory testing. Boring inclination for land borings was targeted at 30 degrees, while inclination for river borings was targeted at 15 degrees. The general coring depth of inclined borings was targeted at 50 linear feet with the exception of one boring into the left abutment that was targeted at 60 linear feet. The depth of drilling was extended in certain borings as deemed necessary in the field based on the subsurface conditions encountered. Orientation (i.e., azimuth) of inclined borings was determined from fracture set strikes measured during the geological reconnaissance (Section 3.4). In general, two lines of inclined borings were positioned both upstream (approximately 35 feet upstream of Baseline A) and downstream (approximately 25 feet downstream of Baseline A) of the new dam footprint. Spacing between borings on the lines of inclined borings ranged between ten to 30 feet. Target orientation of the upstream line of inclined borings was in a N57E direction, while the downstream line of borings was oriented in a N33W direction. Drafted boring logs and profiles along the dam baseline are presented in Appendix A. The drafted boring logs include RQD values, recovery percentages, unconfined compressive strength results, and unit weights.

3.5.1.1 Pre-construction Drilling Methods

Vertical borings were advanced through the soil or sediment overburden with 4.25-inch inside diameter (ID) hollow stem augers. Boring locations on the esplanade were pre-cored to 12 inches in diameter with a thin wall coring apparatus for the depth of esplanade masonry stone or concrete to accommodate the nine-inch outside diameter (OD) of the augers. Standard penetration testing (SPT) and split-spoon sampling was performed on 2.5-foot intervals within the soil or sediment overburden using a 140-pound automatic hammer. SPTs and sampling were performed to provide an indication of soil consistency and obtain samples for laboratory testing. Recovered samples were placed in labeled glass jars after visual classification and measurement of recovery were performed. Inclined borings were also advanced with steel casing with no soil or sediment sampling occurring in these borings.

Upon refusal of the auger or split-spoon sampler, flush-jointed, steel casing was driven or spun into the borehole until the casing was seated into rock. Vertical borings utilized six-inch casing to accommodate PQ-size (approximately 3.3-inch ID) coring equipment, while inclined borings utilized four-inch casing to accommodate NQ-size (approximately 1.8-inch ID) coring equipment. Split-barrel coring equipment using water as the drilling fluid and coolant were utilized in both vertical and inclined boring applications. Rock coring was generally performed in five-foot intervals for vertical (PQ-size) borings and ten-foot intervals for inclined (NQ-size) borings. Water loss occurred on several borings and is identified on boring logs.

Upon rock core retrieval, the rock core was photographed and logged while still in half of the split-barrel coring equipment. After the rock core had been photographed and logged, the core was wrapped in plastic sleeves and placed in wooden core boxes. Core boxes were packed with saw dust as necessary to reduce rolling or sliding of rock core within the box. The core boxes were stored at the site and transported to Stantec's Lexington, Kentucky office on a weekly basis.

At completion of drilling activities, as-drilled boring locations were recorded with a survey-grade GPS system. Top of casing, top of ground or barge deck elevations and location were recorded for each boring. As-drilled orientation of inclined borings was located by surveying an off-set point in the direction of drilling. Borings were backfilled with cement-bentonite grout, pumped utilizing a tremie tube.

3.5.1.2 Pre-construction Subsurface Exploration Results

Key information from the pre-construction subsurface exploration is summarized in Table 2.

Table 2. Pre-construction Boring Summary

Boring	Surface Elevation[2]	Top of Rock Elevation	Bottom of Boring Elevation	Inclination (from Vertical)	Bearing	SPT Sampling	Average RQD Value	Rock Coring Size
B-1	549.7	500.1	445.0	30˚	N 33˚ W	N	87	NQ
B-2	549.8	500.9	436.7	31˚	S 57˚ W	N	66	NQ
B-3	543.6	499.5	489.1	0˚	--	Y	64	PQ
B-4	549.1	501.0	490.6	0˚	--	Y	36	PQ
B-5	539.9	500.3	489.5	0˚	--	N	68	PQ
B-6	543.8	500.0	490.0	0˚	--	Y	67	PQ
B-7	540.6	499.9	489.6	0˚	--	Y	62	PQ
B-8	534.6	499.1	487.4	0˚	--	Y	60	PQ
B-9	534.6	500.3	450.8	14˚	N 80˚ E	N	69	NQ
B-10[1]	Terminated prior to encountering top of rock.							
B-11	533.9	499.4	450.3	14˚	N 61˚ E	N	79	NQ
B-12	533.9	499.6	450.3	14˚	N 63˚ E	N	53	NQ
B-13	536.4	499.3	475.4	0˚	--	Y	20	PQ
B-14	535.3	500.6	451.8	14˚	N 56˚ E	N	47	NQ
B-15	536.1	500.8	452.3	14˚	N 58˚ E	N	60	NQ
B-16	535.1	500.7	467.8	0˚	--	Y	84	PQ
B-17	534.8	502.0	452.0	15˚	N 56˚ E	N	51	NQ
B-18	536.6	506.8	453.9	15˚	N 55˚ E	N	39	NQ
B-19	537.5	521.7	458.9	15˚	N 70˚ W	N	73	NQ
B-20	535.2	517.8	493.5	0˚	--	Y	39	PQ
B-21	534.2	500.0	477.0	0˚	--	N	88	PQ
B-22	536.6	506.4	473.9	0˚	--	Y	91	PQ
B-23	534.3	521.5	470.0	15˚	N 27˚ W	N	83	NQ
B-24	533.4	504.3	454.8	15˚	N 27˚ W	N	84	NQ
B-25	533.6	501.3	450.6	15˚	N 27˚ W	N	81	NQ
B-26	533.7	500.5	450.0	15˚	N 28˚ W	N	64	NQ
B-27	533.7	499.6	450.2	15˚	N 28˚ W	N	78	NQ
B-28	533.3	499.1	450.1	15˚	N 24˚ E	N	31	NQ
B-29	534.3	499.0	477.4	0˚	--	Y	54	NQ
B-30	534.0	499.6	477.2	0˚	--	N	78	PQ

3.5.2 Additional Cell No. 2 Subsurface Exploration

Discussed later in Section 4.2.2, the grout curtain holes were advanced by means of percussion drilling. During the installation of the grout curtain in Cell No. 2, void features were encountered. The percussion drilling methods limited the information and the ability to further characterize the subsurface conditions. As a result, concurrent with the grout curtain installation in Cell 2, additional geotechnical cores were performed to gain a better understanding of the extents of the feature and the subsurface conditions surrounding the feature. Eight additional cores (C1 through C8, shown in red in Figure 12) were performed in October 2015. Three cores were performed along the axis of the dam (which was coaxial with the original Secant Pile Wall design), two were performed upstream of the axis, and three were performed downstream of the axis. The additional core locations relative to the grout curtain borings and the dam are shown in Figure 12.

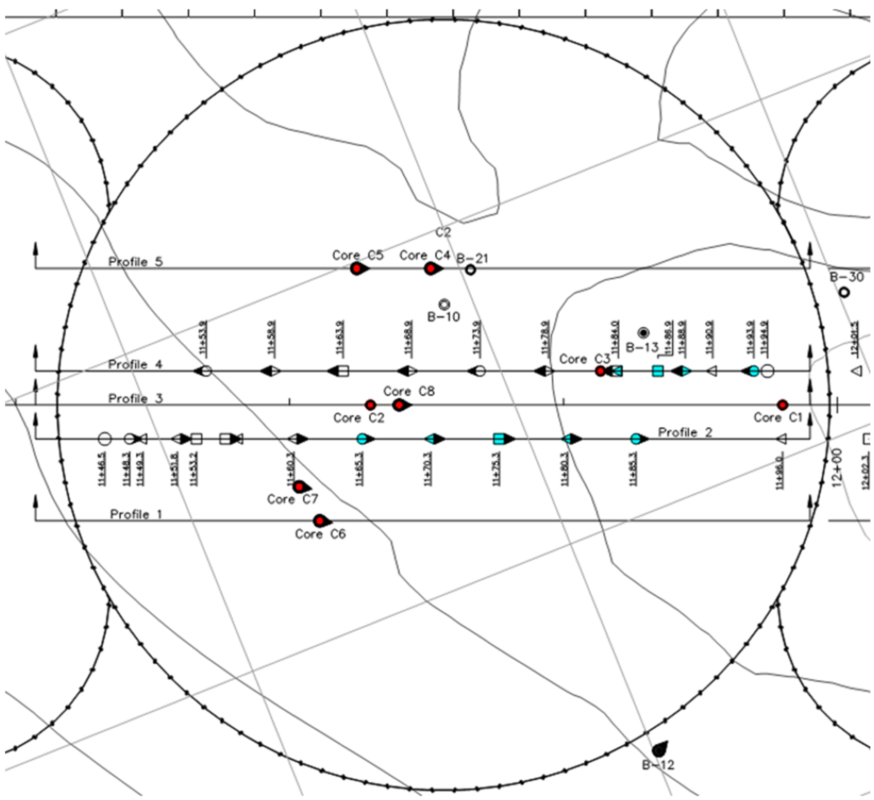

Figure 12 Additional Core Holes in Cell No. 2

The cores indicated that the feature was not as wide as the observations reported during grout curtain installation. It was determined that the percussion method of drilling and the relatively thin drill string diameter caused the drill string to divert from its intended inclination when the decreased bit resistance was encountered in the feature. The drill string trended toward the vertical as it was advanced through the feature. This made it seem like the feature was much wider than anticipated when the intended borehole inclination was assumed.

In general, the additional coring showed that the location and width of the feature was consistent with the original assumptions with lower quality bedrock around the feature. In addition, it appeared that the feature narrowed in the upstream portion of Cell 2. Eight additional vertical core borings were performed along a revised secant pile wall alignment. The intent of the additional core borings was to better define the feature and extents of lower quality bedrock directly underneath the new footprint and shorten the wall length if possible to economize the design. Locations of the additional cores (S2 through S9) are shown in blue in Figure 13, along with the final Secant Pile Wall design.

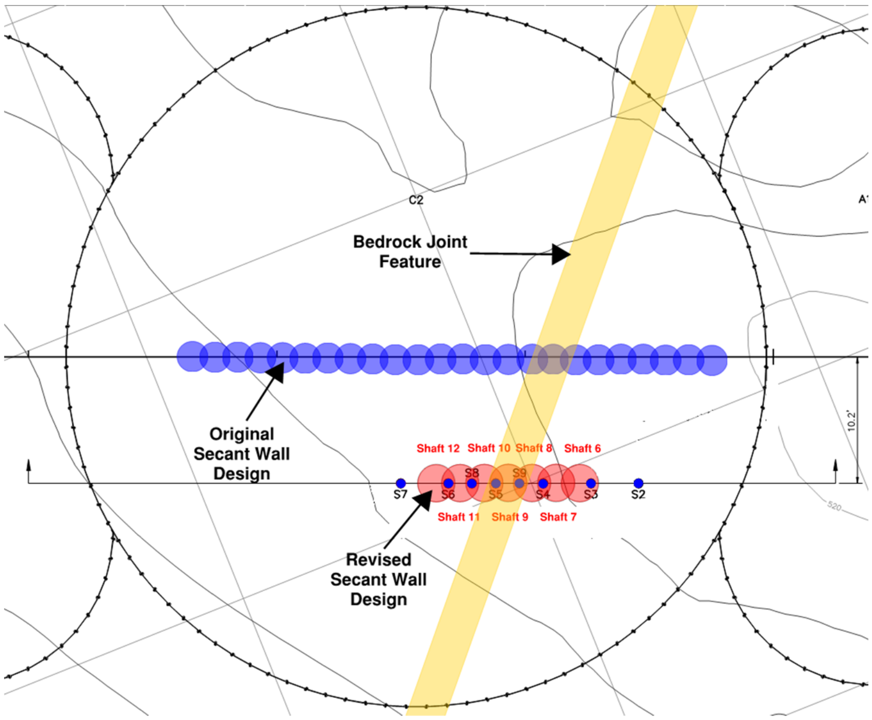

Figure 13 Final Secant Pile Wall Layout

3.6 Pressure Testing

Pressure testing was performed in all pre-construction borings with the exception of B-10, which experienced mechanical complications and was aborted prior to performing rock coring. Pressure testing was conducted in a down-stage manner. As defined by Houlsby (1990), this type of pre-design pressure testing is referred to as exploratory testing. Pressure testing equipment consisted of a water valve, control valve, water meter, pressure gauge and single-stage packer, all connected in series with a water line. Pressure testing was performed in a phased approach and is consistent with guidance found in *Construction and Design of Cement Grouting* (Houlsby, 1990). This method consists of using five pressure increments for a particular test length. The pressure increments are performed in the following sequence: low-moderate-peak-moderate-low. The five pressure runs are performed immediately after each other and were performed for a total of five minutes per run.

Peak stage pressures were determined from a combination of guidance from several publications. A one-pound per square inch (psi) per foot of depth guideline was used to determine target peak pressures. Peak pressures were calculated from the top of overburden or sediment in a given borehole location. Inclined boring linear footage was converted to vertical depth prior to calculating a target peak pressure. Once the peak pressure was calculated, the low and moderate target pressures were determined consistent with Houlsby's methodology. For example, low and moderate target pressures for a peak target pressure of 40 psi would be ten psi and 22 psi, respectively.

The general pressure testing procedure consists of coring to a pre-determined depth or bottom of test length. Once coring was completed and coring equipment was withdrawn from the borehole, an inflatable single-stage packer was positioned and inflated at the top of the test length. Water was then pumped into the test interval until the desired stage pressure was achieved. The desired pressure was maintained for a specified time interval (five minutes) by either adding water or bleeding water from the system. Volume of water (either added or subtracted), actual pressures and time interval were recorded for each phase of the test.

A total of 105 pressure tests were performed as part of the Lock and Dam No. 8 pre-construction subsurface exploration program. The average test length was 9.4 vertical feet with maximum and minimum test lengths of 6.7 and 12 vertical feet, respectively. A Badger water meter with a 40-gallon per minute capacity was used to measure water volume takes during testing. Target peak pressures were not obtainable in multiple borings due to high water takes. In these boreholes, only three testing increments were performed (low-moderate-low) and the inability to reach target peak pressure was noted.

Testing was consistent with the lugeon test method, which is widely accepted and is a "pump-in" test where the volume of water taken in a test length section is measured during specified time intervals. Results of these tests provide an indication of the radial permeability of the interval. The test method was derived by Lugeon in 1933 and the related unit of permeability calculated from field measurements has been named after him. These calculated permeabilities in conjunction with other factors are then used to determine whether the foundation rock requires improvement.

3.6.1 Lugeon Values

After completion of pressure testing, lugeon values for each pressure increment (low-moderate-peak-moderate-low) of each test were calculated. A lugeon unit is defined as one liter of water taken per meter of test length per minute at 150 psi. In English units, a lugeon unit is equal to 0.0107620 cubic feet of water per foot of test length per minute at 142 psi. Equation 1 was used to determine the lugeon value for each pressure increment of each test performed.

$$\text{Lugeon} = \left(\frac{v/\ell}{t}\right)\left(\frac{142\text{psi}/P}{C}\right) \qquad \textbf{Equation 1}$$

Variables in Equation 1 are as follows: *v* is the volume of water taken during the test in cubic feet (ft^3), ℓ is the length of the test interval in linear feet, t is the time interval of each test increment in minutes, P is the actual pressure of the test in psi, and C is the conversion factor equal to 0.0107620 ft^3/ft/min.

The lugeon test and subsequent calculation of lugeon values has a maximum sensitivity in low permeability situations (Houlsby, 1990). Houlsby (1990) recommends the following guidance related to meaningful variations in lugeon values.

- Between one and five, each variation of one unit is meaningful.
- Between five and ten, meaningful increments are two units.
- Between ten and 15, meaningful increments are five units.
- Between 15 and 50, meaningful increments are ten units.
- Between 50 and 100, meaningful increments are 30 units.
- It is meaningless to distinguish lugeon values above 100 units as all values above this level have the same relative significance. Recommended practice is to quote these values as greater than 100 lugeons.

Lugeon values greater than zero are indicative of flow through fractures, joints and/or other features within the rock mass, while a lugeon value of zero is indicative of tight rock with no measured flow through rock features. Calculated lugeon values for the pressure increments performed during the exploration program ranged between zero and greater than 100.

For reference, a plot of water take in gallons versus Lugeon values for a representative water-pressure test performed over five minutes over a stage length of 10 feet for various pressures is presented in Figure 14.

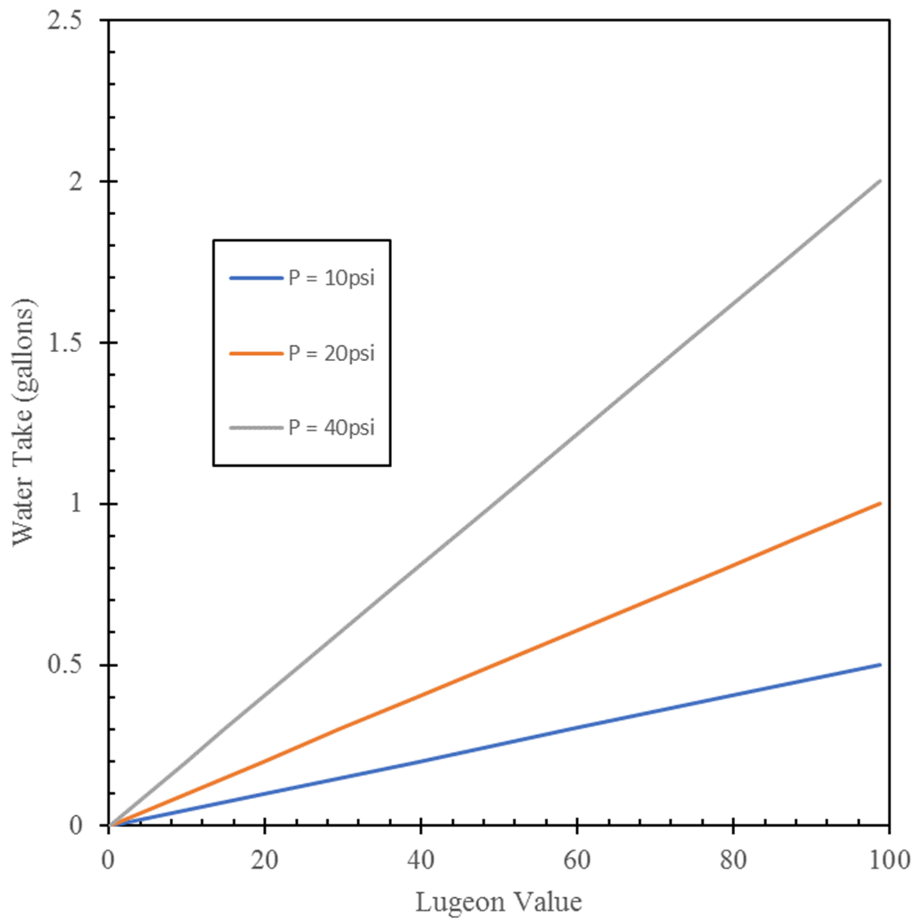

Figure 14 Water Take vs Lugeon Values Plot

3.6.2 Flow Regimes

Calculated lugeon values from the five pressure testing increments of each test were used to estimate flow regimes and select a representative lugeon value for the test length. Flow regimes and representative lugeon values were determined using guidance from Houlsby (1990) and are as follows:

- *Laminar Flow:* The lugeon values for all five test pressure increments are at or near the same value. The representative lugeon value can be equal to the average of the five individual values or any one of the individual values may be used. This flow regime is typically indicative of finer cracks within the rock mass.

- *Turbulent Flow:* The lugeon values decrease as the pressure increases to the peak value then increases as the pressure returns to the lowest pressure. There is a sense of symmetry to the lugeon values over the five increments. This flow regime is indicative of wider cracks with fast flow rates. The representative lugeon value should be set equal to the lowest lugeon value at the peak pressure.

- *Dilation:* The lugeon values remain near or at a similar value for the moderate and low pressures, but increases during the peak pressure. This scenario indicates the peak pressure has resulted in the opening of features due to the compression of softer material surrounding the features or the closure of parallel features. The representative lugeon value for this flow regime should be set equal to the lowest pressure stage or the moderate pressure stage if these values are less than the lowest pressure.

- *Wash-out:* The lugeon values steadily increase through the five pressure test increments. This scenario indicates material within the void space of the feature(s) is being removed allowing more water to pass through the feature(s), or the water-pressure results in rock dilation and fallen debris prevents the feature(s) from closing. The representative lugeon value for this flow regime should be equal to the final low pressure value.

- *Void Filling:* The lugeon values steadily decrease through the five pressure test increments. This scenario indicates the rock feature(s) are being filled and that water cannot progress further. The lowest measured lugeon value is representative of this flow regime.

Estimating the flow regime for a specific pressure test can be subjective, as the progression of lugeon values for a given test may be difficult to associate with a definitive flow regime.

3.6.3 Results

A total of 105 pressure tests were performed on 29 borings during the subsurface exploration program. A summary of assigned flow regimes and range of representative lugeon values are presented in Table 3.

Table 3. Summary of Flow Regimes and Representative Lugeon Values

Flow Regime	Number of Pressure Tests Resulting in this Flow Regime	Representative Lugeon Value Range
Laminar	51	0 to 38
Turbulent	15	9 to >100
Dilation	29	0 to 12
Wash-Out	4	12 to >100
Void-Filling	6	2 to 14

Further breakdowns of assigned representative lugeon values are as follows:

- 65 tests were assigned a lugeon value between zero and one,
- ten tests were assigned a lugeon value between two and three,
- six tests were assigned a lugeon value between four and five,
- three tests were assigned a lugeon value between six and ten,

- four tests were assigned a lugeon value between 11 and 15,
- six tests were assigned a lugeon value between 16 and 50,
- and 11 tests were assigned a lugeon value greater than or equal to 100 (included in this is a test assigned a lugeon value of 98).

The majority of pressure tests (80 out of 105) were assigned either laminar or dilation flow regimes. Representative lugeon values for these tests ranged between zero and 38 with the large majority of these tests (76 out of 80) assigned lugeon values between zero and five. In general, these flow regimes are synonymous with low water takes, high RQD percentages and few rock defects.

Turbulent flow regimes were assigned to pressure tests performed in three general locations on the site and are typically associated with significant defects identified in the rock mass structure. Within the right abutment and upper approach, this flow regime occurred along the upper test length intervals (approximate elevations 498 to 489 feet) for borings B-1, B-2, B-3, B-4, B-6, B-7 and B-9. The test length for each of these borings intercepted water-stained features, vertical fractures and highly fractured zones. Another group of borings riverward of the lock river wall were also identified to have turbulent flow regimes. In this grouping, this regime occurred in borings B-11, B-12, B-13, B-28 and B-29 to a depth of about 25 feet (approximate elevation 475 feet). Numerous deficiencies were observed in each of these borings and include highly fractured zones, water-stained features, voids, vertical fractures and highly weathered shale seams. This flow regime was also assigned to the upper test length interval (approximate elevation 518 to 508 feet) of boring B-23. In plan view, this boring is the closest to the left abutment of the existing dam. With the exception of boring B-8, this flow regime occurred in locations where water staining was observed.

Wash-out flow regimes were assigned to pressure tests performed in three locations (four separate borings). These locations include the lock land wall (boring B-5), riverward of the lock land wall (boring B-12), and within the left abutment (boring B-19 and B-20) of the proposed dam footprint. With the exception of boring B-12, which is in the vicinity of boring B-13, water-stained features were present in each of the test length increments assigned wash-out flow regimes.

Void-filling flow regimes were assigned to pressure tests in four borings (B-16, B-21, B-23 and B-28). This flow regime occurred between 475 to 500 feet with the exception of boring B-28 where the flow regime occurred between 450 to 460 feet. Records for each water-pressure test performed in a pre-construction boring is included in Appendix B.

3.7 Laboratory Testing

3.7.1 Soil Testing

Soil Nos. 1 through 5, described in Section 3.8.1, were classified based on laboratory testing of representative composite samples taken from borings at the right abutment. No laboratory testing was performed on Soil No. 6 as particle sizes were too large for the split-spoon sampler. Classification tests included Particle Size Analysis (ASTM D 422), Atterberg Limits (D 4318), Natural Moisture Content (D 2216) and Engineering Classification of Soils (D 2487) testing was performed on split-spoon samples taken in each soil type found at the right abutment. Engineering classifications are referenced to the Unified Soil Classification System (USCS). Some specimens were combined to form composite samples, if additional quantity of material was needed or samples were similar in nature.

Soil No. 1 was classified as a silty, clayey gravel with a USCS classification of GC-GM. Approximately 34 percent of the soil particles (by weight) were finer than the No. 200 sieve and approximately 35 percent of the particles were larger than the No. 4 sieve. Atterberg limit results from tested samples resulted in a liquid limit of 25, a plastic limit of 18, and a plasticity index of seven. Natural moisture content for this soil type ranged between 10 and 22 percent, with an average value of 15 percent.

Soil No. 2 was classified as a sandy, lean clay with a USCS classification of CL. On average, about 54 percent of the particles were finer than the No. 200 sieve. Atterberg limit results from three samples resulted in liquid limits of 28, 22, and 30; plastic limits of 20, 17, and 20; and plasticity indices of eight, five, and ten. Natural moisture content for this soil type ranged between 19 and 30 percent, with an average value of 23 percent.

Soil No. 3 was classified as a silty sand with a USCS classification of SM. Approximately 43 percent of the particles in this soil type were finer than the No. 200 sieve. The sample was found to be non-plastic. Natural moisture content ranged between seven and 18 percent, with an average value of 14 percent.

Soil No. 4 was visually classified as a sandy, lean clay (CL) to a clayey sand (SC). No further testing was performed on this soil type.

Soil type No. 5 is representative of the sediment observed within the river channel and was classified as a silty, clayey gravel with sand (GC-GM). On average, about 40 percent of the particles were larger than the No. 4 sieve with approximately 20 percent of the particles finer than the No. 200 sieve. Atterberg limit results from one sample resulted in a liquid limit of 24, a plastic limit of 17, and a plasticity index of seven. Natural moisture content testing was not performed on these samples. (Stantec, 2011)

3.7.2 Rock Testing

3.7.2.1 Methodology

Cores of the limestone and shale rock were subjected to unconfined compressive strength testing (ASTM D 5607) and direct shear testing (ASTM D 5607). Prior to unconfined compressive strength testing, the prepared cylinders were weighed to allow calculation of their unit weight.

The bedrock has many fractures and/or interfaces where sliding could occur, such as along natural fractures in the bedrock. A proper assessment of the stability of the structures requires consideration of the strength that can be mobilized at the interfaces along these joints. Direct shear tests are well suited to measuring the strength of intact or jointed interfaces in these materials. The data are used in conjunction with the field scale geometry of the bedding surfaces (or joints between blocks) to establish appropriate strength parameters for use in stability analyses.

The nature and influence of non-planar fracture surfaces can be very different at the scale of the lab test relative to the scale of the structures being evaluated. In general, lab test specimens tend to over predict field strengths when the fracture surfaces are rough because the rough surface has a relatively greater contribution to resistance in the lab test. Due to the natural and expected variation in laboratory test results, a complimentary approach has been used to aid in the interpretation and selection of representative shear strength parameters for the project. This approach considers the available sliding resistance to be derived from two components; the resistance available along a smooth planar surface, and the additional resistance available due to the non-planar characteristics of the fracture. The first part can be estimated by running shear tests on artificial saw cut rock surfaces (i.e., smooth sawn surfaces). The second part (the 1st order i-angle; Section 3.3) is estimated for the site based on the surface roughness (or waviness) of the bedding planes relative to the scale of the sliding mass (e.g., the base width of the dam).

The normal stresses used to conduct the tests were extended to values representative of stresses that can be expected below the base of the structures. Both peak and post-peak strengths were recorded. Each specimen was subjected to multi-stage shear testing. That is, an initial test was run at a specific normal stress to obtain peak and post-peak shear strengths. Subsequently, the specimen was reset and sheared again under a different normal stress. This generated a post-peak strength for the new normal stress. A peak stress was recorded only at the first normal stress stage and typically each specimen was sheared at three different normal stresses. In some instances (especially for sawn surface tests) a strong peak strength followed by a lower post-peak strength was not observed. In these cases, only the post-peak strengths were reported. In between stages, the interface was observed to confirm that the surface was not degrading or polishing to the point that subsequent tests would not be representative. (Stantec, 2011)

3.7.2.2 Results

The limestone (with shale partings) rock was subjected to the following laboratory tests: direct shear natural fracture (DSNF), direct shear sawn surface (DSSS), unconfined compressive strength, and unit weight.

The direct shear strength of the limestone bedrock and the shale partings was tested along natural fractures (i.e., bedding planes where each side of the plane has already been physically detached from the other) and smooth sawn surfaces (horizontal cuts made in the laboratory). Natural fractures were generally along the weaker shale partings, rather than in the parent limestone material. Thus, only the shale partings could be tested along natural fractures. Both limestone and shale were tested on smooth sawn surfaces generated in the laboratory.

Friction and cohesion values were estimated for peak and post-peak conditions using best-fit methods. Note that neither of these conditions were necessarily used for design purposes.

Table 4. Direct Shear Tests on Limestone with Shale Partings

Material or Interface	Condition	Number of Specimens	Peak Friction Angle (degrees)	Peak Cohesion (psi)	Post-Peak Friction Angle (degrees)	Post-Peak Cohesion (psi)
Shale Parting	Natural Fracture	6	59	0	48	0
Shale Parting	Sawn Surface	6	N/A	N/A	26	0
Limestone	Sawn Surface	3	N/A	N/A	30	0

Unconfined compressive strength tests were performed on the limestone to evaluate the bearing strength, which may affect stability analyses that include an examination of loads that could crush or fail the foundation. Three tests were performed on the limestone member, with an average unconfined compressive strength of 11,200 psi.

Wet (saturated surface dry (SSD)) unit weights were estimated for the unconfined compressive strength specimens. SSD refers to the condition of a sample in which surfaces of the particle are saturated, but the inter-particle voids are otherwise dry. The average unit weight for limestone was 167 pounds per cubic foot (pcf).

3.8 SUMMARY OF SITE CONDITIONS

3.8.1 Site Soil Conditions

Six predominant soil types were identified at the site. Four were located along the right abutment, and two were within the river channel. Soil No. 1 was observed in borings B-3 and B-7 from the ground surface (near elevation 542 feet) to an approximate elevation of 526 feet. This soil type was described in general to be silty, clayey gravel, light brown to light gray in color, moist, and very soft to very stiff in consistency. SPT blow counts (N_{SPT}) for this soil type ranged from two to 18, with an average value of seven. This soil type may be representative of backfill material for the lock and guide wall structure during original construction.

Soil No. 2 was observed in borings B-3, B-4, B-6 and B-7. With the exception of boring B-4, this soil type was in general observed between elevations 525 and 500 feet. This soil type was observed to be between elevations 545 and 510 feet in boring B-4. This soil type was described in general to be a sandy, lean clay, predominately gray in color, moist, and very soft to hard in consistency. N_{SPT} for this soil type ranged from weight of hammer (WH) to 44, with an average value of four. This soil type may be representative of the native soil, as it is located at lower elevations near areas (i.e., adjacent to the lock wall) where excavation would likely not have been necessary and comprises the majority of boring B-4 where minimal excavation for construction would likely have been necessary.

Soil No. 3 was only observed in boring B-6 from elevation 535 (directly beneath the esplanade) to 520 feet. This soil type was in general observed to be a silty sand, light gray in color, moist, and soft to very stiff in consistency. N_{SPT} for this soil type ranged from four to 24, with an average value of ten. This boring and soil type is in the immediate vicinity of a proposed cutoff wall structure (USACE, 1913) at the upstream end of the lock land wall extending 50 feet into the abutment. The top elevation of the cutoff wall is depicted as 534.5 feet on the historic drawing. While construction of this cutoff wall structure has not been verified, this soil type may be representative of backfill materials from this effort.

Soil No. 4 was observed in B-4 and B-6 and was located within ten feet of the top of rock, between elevations 510 to 500 feet. This soil type was in general observed to be a sandy, lean clay or a clayey sand, brown to gray in color, wet, and soft too stiff in consistency. N_{SPT} for this soil type ranged from six to 14, with an average value of ten. This soil type may also be representative of native soil materials as it is unlikely that excavation to support construction was performed at this depth and distance from the lock structure.

Soil No. 5 was observed within the river channel. The soil type was in general described to be a silty, clayey gravel with sand, brown to gray in color, wet, and very soft to hard in consistency. N_{SPT} for this soil type ranged from two to 34, with an average value of ten. While not retrieved during sampling operations, numerous cobbles and obstructions were encountered at several locations. This is anticipated given that numerous earthen and rock fill cofferdam structures have been constructed upstream of existing facilities to support construction and repairs throughout the years of service.

Soil No. 6 was also encountered within the river channel; however, this soil type was unable to be sampled due to particle sizes larger than the split-spoon sampler. Similar to Soil No. 5, this material may be the result of previous cofferdam structures constructed upstream of existing facilities. This soil type is assumed to consist predominately of boulders and cobbles.

3.8.2 Site Bedrock Conditions

In general, the recovered rock coring consists of interbedded limestone (75 to 90 percent) shale (ten to 25 percent), fitting the typical rock types expected in the Grier Limestone member, as described previously in Section 4.1. In general, the limestone can be described as light gray, thin to medium-bedded, microcrystalline, hard, weathered, with several shale partings and shaley zones. The limestone contained fractured zones water staining on many of the fracture planes. The shale is dark gray, laminated to thin-bedded, very soft to soft, and fresh to severely weathered. In general, shale seams range between zero and 0.2 feet in thickness across the majority of the site with a slight increase in thickness up to 0.4 feet in the upper portion of rock cores taken at the left abutment. The following is an overview of subsurface rock conditions at the site.

The proposed dam is planned to be located upstream of the existing dam. The proposed dam footprint will likely occur within 25 feet downstream to 35 feet upstream of Baseline A. Top of rock across the footprint of the proposed dam site is relatively planar with elevations ranging between 499.0 and 502.0 feet. The rock surface is relatively planar with the lowest elevation of 499.0 occurring slightly riverward of the lock river wall. The top of rock surface slopes from the right and left abutment toward the lowest rockline elevation near the lock river wall are estimated at one and two percent, respectively. The rockline begins to transition upward approximately 80 feet from the left abutment (distance from shoreline at normal pool). A total of seven borings are located within this transition and identify two distinct rockline slopes. An approximate 7.3(H):1(V) slope occurs between 80 and 50 feet of the abutment, while a steeper approximate 1.5(H):1(V) slope occurs between the 50 feet and the left abutment shoreline. Dip across the proposed dam footprint is near level to dipping slightly downstream. Dip measured across borings B-14 to B-26 and B-11 to B-29 are 0.2 percent and 0.5 percent in the downstream direction, respectively. This is contrary to visual observations of the downstream rock outcropping and the measured dip of one-degree in the upstream direction (Section 5.1.4).

Rock Quality Designation (RQD) values are a rough measurement of the degree of jointing or fracture in a rock mass and is a borehole recovery percentage incorporating only pieces of solid core that are longer than four inches in length measured along the centerline of the core. Calculated RQD values for the site ranged between zero and 100 percent. Lower RQD values at the site are primarily a result of numerous bedding planes, fractured and weathered shale zones. In general, with a few exceptions, rock with a RQD less than 50 percent is located within the upper five to 13 feet of rock. Exceptions to this generality include borings B-13, B-28 and B-18. These borings are discussed below in further detail.

Borings B-1 through B-9 exhibit several similar subsurface rock characteristics. Borings B-1 through B-7 was located on the right abutment, while borings B-8 and B-9 were located in the upper approach. Water staining of horizontal bedding planes was observed in borings B-1, B-2, B-3, B-5, B-8 and B-9 and occurred within 2.9 vertical feet of each other between elevations 494.3 and 491.4 feet. Complete or partial drilling water loss occurred in borings B-2 and B-9 at or near the elevation of observed water staining. Core loss of 0.2 feet was observed in B-1 and is judged to have also occurred near the elevation of water staining. A photograph within B-1 from a down-hole camera near elevation 492 feet is presented in Figure 15. The photograph appears to be of a horizontal opening in the bedrock with partial collapse of the surrounding rock mass (boring B-1 is inclined 30 degrees). Core loss of 0.4 feet was also observed in boring B-2 between elevations 490 and 480 feet with complete loss of drilling water return.

With the exception of boring B-4, numerous localized fractured zones and vertical fractures were identified in the top 13 feet of rock in borings B-1 through B-9. Boring B-8, which is located approximately 16 feet upstream of the upstream end of the lock river wall, contained three distinct vertical fractures ranging between 0.9 to 1.5 feet in length. Small vertical fractures ranging between 0.1 to 0.3 feet in length were also identified in borings B-3 and B-7. Localized fractured zones in these borings ranged between 0.1 to 0.6 feet. A photograph of a localized fractured zone in boring B-7 from a down-hole camera near elevation 498.5 feet is presented in Figure 15. Portions of the surrounding core wall may have collapsed into the borehole after coring equipment was extracted.

With the exception of borings B-13, B-28 and borings in their immediate vicinity, borings along the proposed dam footprint (borings B-10 through B-30) exhibit similar subsurface characteristics. In general, these borings exhibit characteristics of higher-quality rock with the majority of RQD values exceeding 75 percent. Exceptions to this are within the top five to 13 feet of rock and boring B-18, which has RQD values below 50 for a depth of 25 feet. Few defects (fractured zones, water staining, weathered shale seams, etc.) are observed in recovered core samples for these borings and appear to be isolated occurrences. A small grouping of fractured zones and vertical fractures are located within the top five feet of rock on borings B-19, B-20 and B-23 in the left abutment.

Two significant voids with observed drops in the drill rods were encountered in borings B-13 and B-28 within the top eight feet of rock. Boring B-13 is located approximately 40 feet from the center of lock river wall near the centerline (25 upstream of the upstream lock wall end) of the proposed dam site, while boring B-28 is located approximately 20 feet from the center of the lock river wall in line with the upstream end of the lock walls. In boring B-13, a 1.4-foot void was encountered between elevations 497.1 and 495.7 feet. In boring B-28, a 3.0-foot void was encountered between elevations 496.0 to 493.0 feet. In both borings, complete or partial loss of drilling water occurred when voids were encountered. Gray drilling fluid return occurred in boring B-28 when the void was encountered indicating the void may be partially filled with highly weathered shale, clay or sediment. After coring through the void in B-28, the steel casing was driven and seated into the bottom of the void near elevation 493.0 feet. Another 50 percent loss of drilling water occurred during the following core run with a measured 0.5-foot loss of core. While these two features may or may not be hydraulically connected, boring B-28 is at an approximate bearing of N66E from boring B-13. This is a similar orientation to features documented in the floor of the lock chamber, as well as joint sets in the left abutment. Previously documented features in the lock chamber are located in a general northeasterly direction from borings B-13 and B-28.

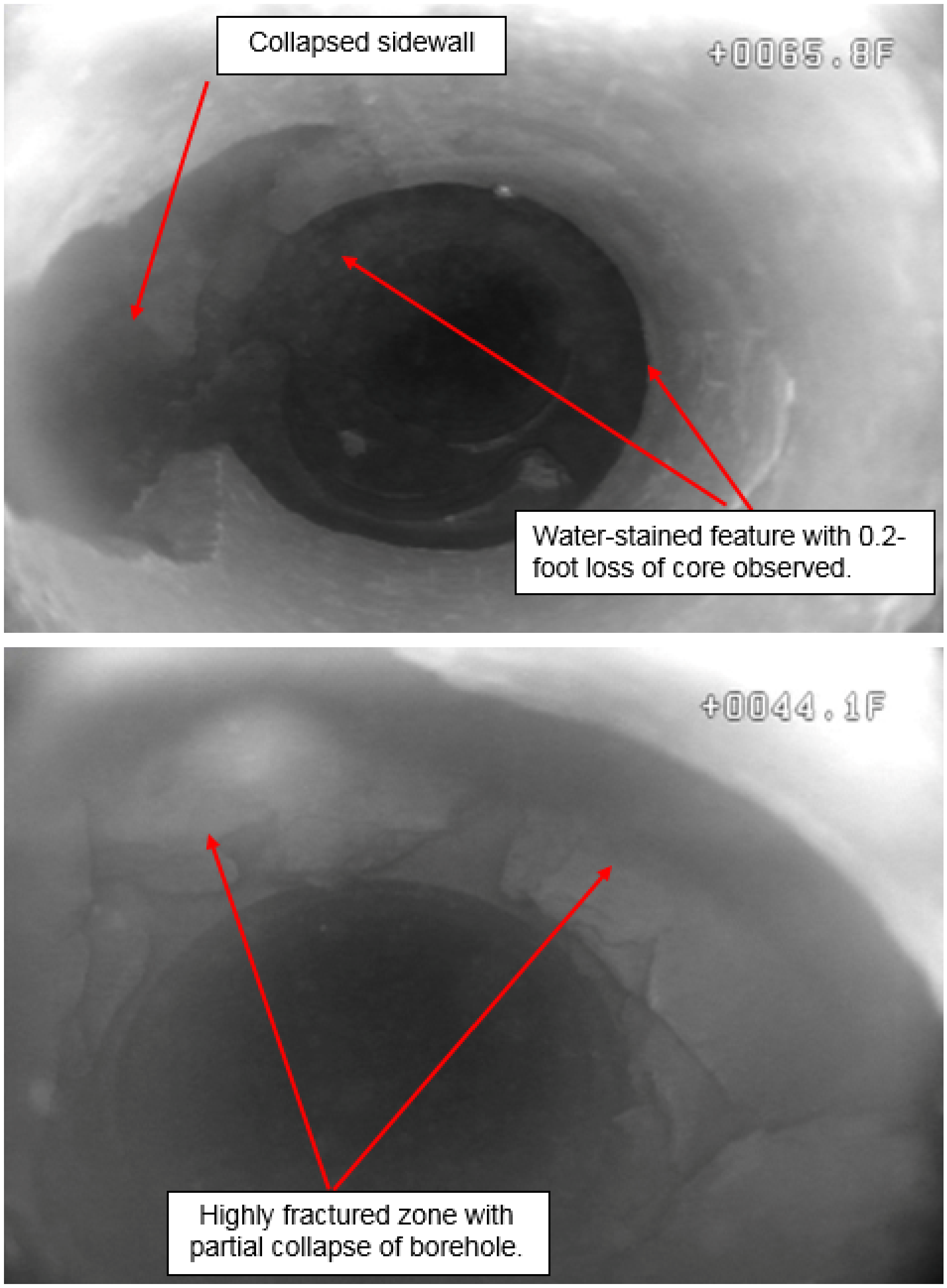

Figure 15 Top – Down-hole Camera Photograph of B-1 Near Elevation 492 Feet (2011). Bottom – Down-hole Camera Photography of B-7 Near Elevation 498.5 Feet (2011)

In addition to encountered voids, borings B-13 and B-28 contain numerous fractured zones, water staining and weathered shale seams throughout the depth of the borehole. RQD values for boring B-13 ranged between zero and 40 percent, while boring B-28 ranged between zero and 57 percent. Numerous weathered shale seams were identified in boring B-28 ranging between elevations 493 to 470 feet. These weathered shale seams are indicative of in place weathering, which usually occurs in defects in the rock mass. Weathering of shale seams may also be indicative of weathering due to the movement of water through discontinuities in the rock mass. Although to a much lesser degree, several localized fractured zones and vertical fractures were also identified in borings B-12, B-27, B-29 and B-30, which are within the immediate vicinity of borings B-13 and B-28. (Stantec, 2011)

3.8.3 Site Regions

For the purposes of summarizing data from the historical document review, site and geological reconnaissance, geotechnical investigation, and laboratory testing; the dam site has been divided up into four regions. The regions are presented in Figure 16 and include: Region 1 – right abutment and upper approach, Region 2 – eastern portion of the proposed dam footprint, Region 3 – western portion of the proposed dam footprint, and Region 4 – left abutment of the proposed dam footprint. The following discussions provide a brief summary of observations and collected data for each region described above.

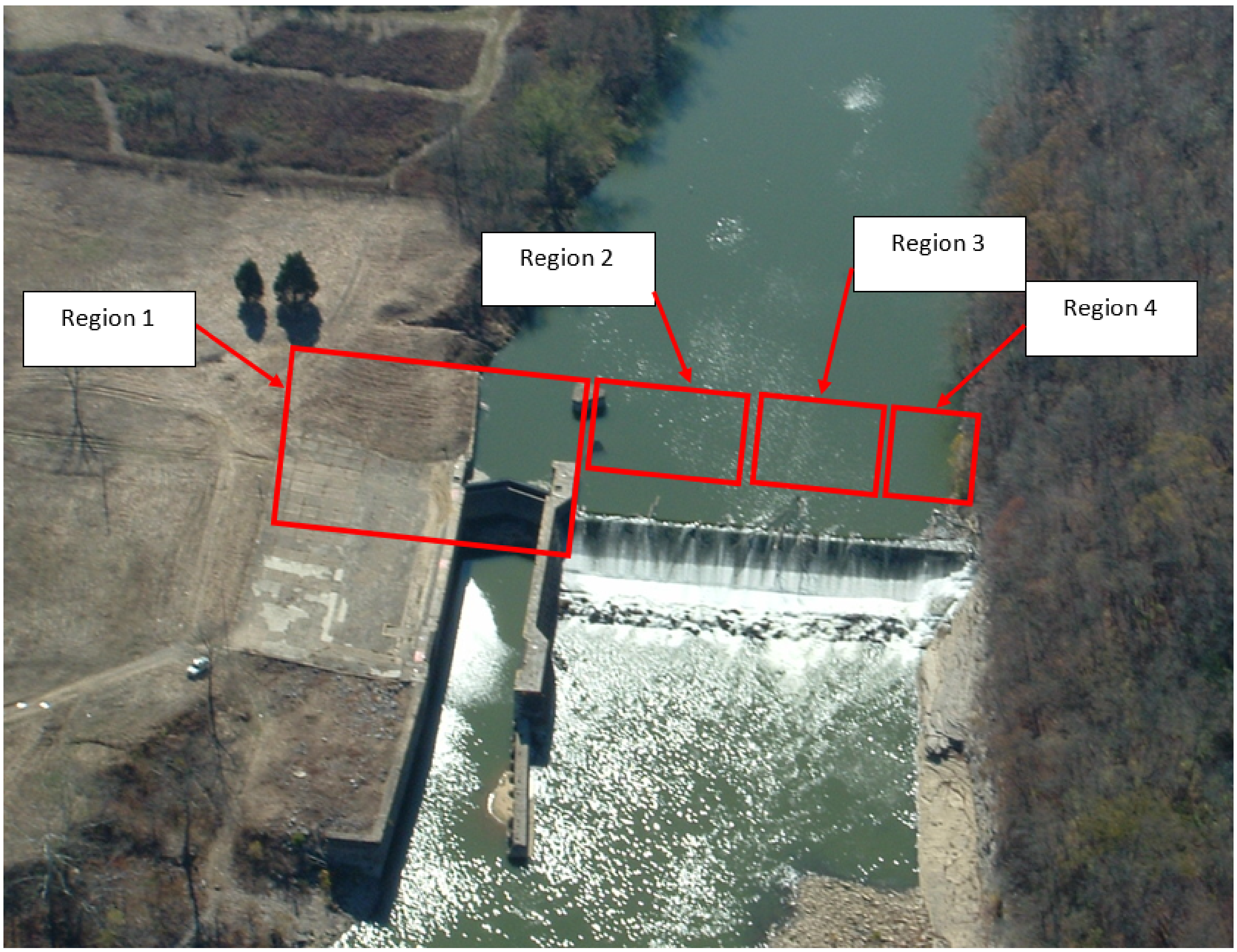

Figure 16 Regions of Similar Subsurface Characteristics

3.8.3.1 Region 1 - Right Abutment and Upper Approach

In general, Region 1 extends from the lock river wall to the eastern limits of the esplanade and from 25 downstream to 35 feet upstream of Baseline A. Existing structures in this region include the lock walls, upper sill, concrete bulkhead wall, upper guide wall and the esplanade. The masonry lock walls and upper sill are founded on rock and consist of hand-laid sandstone masonry blocks with mortar. A concrete bulkhead wall was constructed immediately downstream of the upper gates and is founded on the masonry upper sill. Headward erosion and scouring of the downstream face of the upper sill have resulted in slight undermining of the bulkhead wall (0.1 to 0.2 feet). Spalling of masonry facing stones was also observed along the interior faces of the lock walls within the chamber. The upper guide wall is a concrete wall founded on wood piling to an unknown depth. Measurements of the wall face during site reconnaissance indicate the wall is tilting (0.6 degrees from vertical) towards the upper approach. Upper guard piers are in progressive states of failure; the downstream pier has failed riverward and the upstream pier appears to be leaning towards the upper approach.

Historically, leakage through, underneath and around the lock structure has been an issue prompting many assessments and facility repairs throughout the service of the facility. USACE drawings from 1913 propose the construction of a cutoff wall structure along the upper face of the lock land wall and extending into the right abutment approximately 65 feet from the lock wall face. While implementation of this repair has not been verified, it serves as an indication of historic seepage issues at the right abutment. In addition, several underwater assessments of the lock chamber have been performed at the site. Observations from these assessments include fissures in the lower lock chamber floor, crevices beneath the lock walls and observed hydraulic connections to the lower pool. Leakage issues through the upper gates and culvert filling valves were addressed in 2001 with the construction of a bulkhead wall and installation of culvert inlet cover plates.

Borings within this region include B-1 through B-9 with three borings located within the limits of the esplanade, three borings east of the upper guide wall, one boring in the lock land wall and two borings in the upper approach. Four soil types were identified within the right abutment with two soil types identified within the confines of the river channel. Top of rock in this region ranges between elevations 499.1 to 501.0 feet and slopes at an approximate one percent slope towards the lock river wall. In general, RQD percentages for the rock mass in this region were less than 50 percent in the top thirteen feet of rock and increased to above 75 percent below this point with a few exceptions. Numerous deficiencies in the rock were observed within the top thirteen feet of rock. These include water-stained features, highly fractured zones and many vertical fractures. Water-stained, horizontal fractures were observed in six of the nine borings and ranged between elevations 494.3 and 491.4 feet. Complete or partial drilling fluid loss and loss of rock core were observed in multiple borings. Three distinct vertical fractures ranging from 0.9 to 1.5 feet in length were observed in boring B-8, which is located immediately upstream of the lock river wall. No significant rock defects were observed in recovered cores below elevation 487 feet.

Pressure testing results in this region correlated with calculated RQDs and observed features within the rock mass. High water takes, turbulent and washout flow regimes, and high lugeon values were associated with the top thirteen feet of rock. Representative lugeon values for the top thirteen feet of rock range between 6 and greater than 100. However, the average lugeon value above elevation 487 feet for this region is near 67. Laminar and dilation flow regimes with low water takes and low representative lugeon values (below five) occurred below elevation 487 feet. (Stantec, 2011)

3.8.3.2 Region 2 – Eastern Portion of Proposed Dam Footprint

Region 2 is defined between stations 11+80 and 12+70 of Baseline 'A' within the proposed dam site footprint (25 feet downstream to 35 feet upstream of Baseline A). Borings within this region include B-10 through B-13 and B-27 through B-30. Three borings were located along the downstream edge of the proposed dam footprint, while four borings were located along the centerline and two borings were located along the upstream edge. In general, RQD percentages were lower within this region. With the exception of borings B-11, B-27 and B-30, RQD percentages were calculated to be less than 50 percent for the top 25 feet of rock in this region. RQDs below this elevation were calculated to be 60 percent or greater. Top of rock in this region is planar and ranges between elevations 499.0 to 499.6 feet.

Two voids with observed drops in the drill rods during performance of coring were encountered in borings B-13 and B-28 (vertical thickness of 1.4 feet and 3.0 feet, respectively) within eight feet of the top of rock. Complete or partial loss of drilling fluids was observed when each void was encountered with gray return water observed initially in boring B-28. While these two features may or may not be hydraulically connected, boring B-28 is in a northeasterly direction from B-13. This orientation is consistent with strikes measured in the rock outcropping on the left abutment and the orientation of documented fissures in the floor of the lock chamber and lower guide wall footprint. Numerous other deficiencies were also observed in B-13, B-28 and the surrounding borings. These include many highly fractured zones, several vertical or inclined fractures and water-stained features. Numerous weathered shale seams were also observed in the upper 30 feet of rock in boring B-28.

High water takes during pressure testing corresponded with identified defects in the rock mass and occurred to a depth of 25 feet below top of rock. Turbulent and washout flow regimes were assigned for pressure tests performed within the direct vicinity of significant features such as voids, highly fractured zones and water staining. With the exception of boring B-27, representative lugeon values for this region to a depth of 25 feet below top of rock generally ranged between nine and greater than 100. Laminar, dilation and void filling flow regimes with low water takes and low representative lugeon values occurred below elevation 475 feet. (Stantec, 2011)

3.8.3.3 Region 3 – Western Portion of Proposed Dam Footprint

Region 3 is defined between stations 10+50 and 11+70 of Baseline ‘A’ within the proposed dam site footprint. In general, this region is associated with high quality rock. RQDs for this region followed the general site pattern, with RQDs lower than 50 percent in the top ten to thirteen feet of rock and increased to above 65 percent below this depth with a few exceptions. Few defects in the rock mass were observed and judged to be isolated occurrences. Pressure testing for this region was associated with low water takes, laminar, dilation and void filling flow regimes, and low representative lugeon values. With the exception of the upper pressure test in boring B-14 (representative lugeon value of 12), representative lugeon values for this region were determined to be between zero and four. Top of rock in this region sloped towards the lock river wall at an approximate two percent slope. (Stantec, 2011)

3.8.3.4 Region 4 - Left Abutment

Region 4 is defined between stations 10+00 and 10+50 of Baseline ‘A’ and consists of the left abutment of the proposed dam footprint. Seepage and leakage through the left abutment of the existing dam has historically been an issue. Repair efforts have consisted of the installation of grout bags along the upstream interface and grouting of shallow karst and joint features. An existing rock shelter measuring approximately three feet wide, two feet tall and 20 feet in depth is located about 350 downstream of the existing dam. Top of rock in this region is sloping upward towards the left abutment at an approximate 1.5(H):1(V) slope.

Borings within this region consist of B-19, B-20, B-22 and B-23. Lower RQD percentages are associated in the rock mass above elevation 505 feet with several water-stained features, highly fractured zones and vertical fractures observed. Rock below elevation 505 feet was observed to be of high quality, with RQDs above 86 percent with no features observed. Turbulent and washout flow regimes were associated with pressure tests performed above elevation 505 feet and correspond to lower RQD percentages and high water takes. Representative lugeon values for these tests ranged between 13 and greater than 100. Pressure tests performed below elevation 505 feet were associated with laminar and dilation flow regimes, low water takes and low representative lugeon values (zero to five).

4 GROUT CURTAIN PROGRAM

4.1 GROUT CURTAIN DESIGN

Grout curtains are a foundation improvement technique installed for facilities founded on fractured rock where underseepage is a concern. Grout curtains are common components of concrete gravity dams when it is necessary to install a vertical barrier ("curtain") to address near-horizontal groundwater flow (seepage) in foundation material where excavation is not feasible.

A grout curtain is installed in rock through the pressure injection of pumpable grout into open boreholes. The boreholes are planned, spaced, and drilled with the intent of intersecting joints, fractures, and discontinuities within the foundation rock that may be seepage pathways. The performance of the grout curtain is evaluated by the rock mass permeability of the targeted bedrock following installation. Following the installation of the grout curtain, there should be less underseepage through the foundation rock as compared to the pre-installation condition. The design drawings for the grout curtain at Lock and Dam No. 8 are presented in Appendix C. The remainder of this section discusses in detail the design considerations of the grout curtain at Lock and Dam No. 8.

4.1.1 Geological Considerations

The design of the grout curtain at Lock and Dam No. 8 began with a thorough understanding of the unique geologic conditions at the site. First, the historic documentation, repair efforts, and studies were reviewed to help narrow the focus of the pre-design geotechnical exploration and geological reconnaissance. Refer to Section 3.2 for discussions regarding the site geology, including historical observations.

The geological reconnaissance helped identify the strike, dip, and orientation of the bedrock and visible features at the site. The information collected in the geological reconnaissance was leveraged to determine the design orientation of the grout holes. The goal in laying out the holes is intersect the most features within the bedrock that pose risk to underseepage. From the geological reconnaissance, it was determined that the bedding at the site was nearly horizontal which included some isolated clay seams and open bedding plans. The orientation of observed features and discontinuities was near vertical.

The geotechnical exploration provided insight on the subsurface conditions along the alignment of the proposed new dam. The boring logs and pressure testing data from each borehole were reviewed to assess the permeability of the foundation bedrock across the site. While the boring logs identified discontinuities within the foundation bedrock (such as karst features), the pressure testing data provided an indication of the hydraulic conductivity and connectivity between discontinuities in the foundation bedrock. Refer to Section 3.5 for details regarding the geotechnical exploration at Lock and Dam No. 8, and Section 3.6 for the associated pressure testing data.

The foundation rock at Lock and Dam No. 8 can generally be described as limestone with interbedded shale partings. While several karst features have been historically documented at the project site, most the foundation is best described as a soluble limestone with some solution activity along joints and bedding planes. Moneymaker (1968) points out that "Solution cavities are almost invariably present in the foundations and abutments at dam sites in limestones and carbonate rocks" as reported in *Dam Foundation Grouting* (Weaver and Bruce, 2007). According to Weaver and Bruce, relatively minor solution activities in these types of geologic environments can warrant extensive grouting programs.

4.1.2 Alignment, Spacing, and Orientation

The alignment of the grout curtain at Lock and Dam No. 8 extends across the river channel and into each abutment. The grout curtain was designed to follow the alignment of the pool retaining features of the new Lock and Dam No. 8 structure. Specifically, the grout curtain begins on the east (right) abutment and extends across the upper approach near the upper sill within the lock chamber, then turns upstream along the lock river wall, across the lock wall connection cell along the centerline of the new dam continuing all the way to the west (left) abutment. Unlike the floodplain geometry of the east (right) abutment, the west (left) abutment consists of a steep sloping rockline that is densely vegetated above the crest of the proposed new dam. The geometry of the west (left) abutment prevented the design of the grout curtain to extend up the abutment, as designed on the east (right) abutment. As a result, a fan layout was designed to extend the grout curtain into the left abutment that consisted of tightly spaced grout holes that were advanced at initially near horizontal angles and successively installed at steeper inclinations (from the horizontal).

The grout curtain at Lock and Dam No. 8 consists of two parallel rows. The alignment of both rows follows project Baseline A, Baseline B, and Baseline C. The upstream and downstream row of the grout curtain are spaced five feet apart along the designed alignment. The upstream row was designed and installed 2.5 feet upstream (right of Baseline C), and the downstream row was installed 2.5 feet downstream (left of Baseline C). The borings within the two rows are oriented in opposite directions. This double row technique is the modern-day standard for large projects (Bruce 2013).

The grout curtain was designed in accordance with spilt-spacing methods. Split-spacing refers to the procedure of locating an additional grout hole between two previously grouted holes. This design approach allows for adjustments to be made in the field based on the real-time results of the installation of previous holes. The general method for installing a grout curtain designed using split-spacing criteria is first, primary holes are installed, then intermediate holes referred to as secondary holes, then additional holes called tertiary, quaternary, and so on can be installed to achieve closure. Based on the subsurface conditions at the project site, a primary-secondary spacing of ten feet was specified for the length of the grout curtain. This means that at any single location along the extents of the grout curtain, the maximum spacing between two grout holes will be ten feet. In the foundation bedrock beneath Cell No. 2, significant features were encountered in the geotechnical exploration. As a result, tertiary holes were specified in the design that reduced the maximum grout hole spacing to five feet.

The grout holes were designed at an inclination of 15 degrees from vertical as allowed by construction constraints (i.e. access limitations, permanent structures, sheet piling cells, etc.). Grout holes that were unable to be installed at this inclination were installed as vertical holes. The inclination of 15 degrees was selected because of the orientation of the jointing as determined during the geologic reconnaissance (Section 3.4). The bedding at the project site was determined to be near horizontal with near vertical jointing. Therefore, it was determined that the 15-degree inclination provided the greatest possibility to intersect joints, karst features, and other foundation bedrock discontinuities. Houlsby (1990) stated that in the case where jointing is horizontal and vertical inclined holes are preferred. Houlsby (1990) added that vertical holes in this geologic setting may miss many vertical cracks; and therefore, may not be as efficient as inclined grout holes. Some in the industry have gone as far as to say angled holes are “necessary” to ensure upstream-downstream oriented joints are intersected and treated (Bruce 2013).

The upstream and downstream rows of the grout curtain were inclined in opposite directions to help reduce the potential for un-grouted windows within the grout curtain. Figure 17 presents an orientation and inclination graphic of the double row curtain at Lock and Dam No. 8. Detail (a) shows a typical grout curtain layout in a main cell, (b) and (c) presents section views of the downstream and upstream grout curtain rows, respectively. Detail (d) demonstrates the installation condition of both grout curtain rows installed at opposing inclinations.

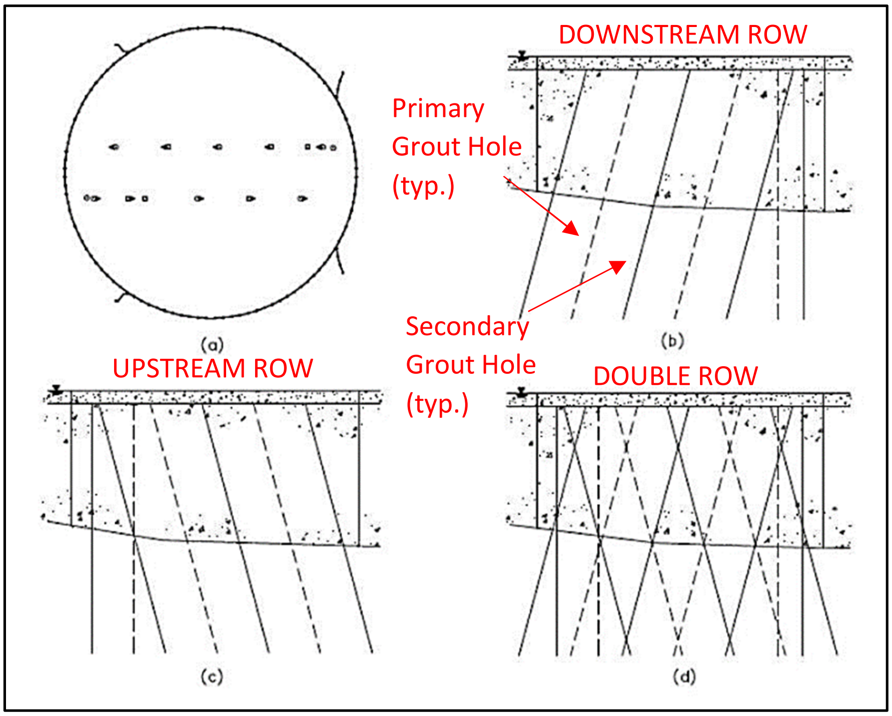

Figure 17. Grout Curtain Orientation and Inclinations (Webster and Hacker, 2016)

4.1.3 Design Depth

The design depth of the grout curtain was determined based on the results of rock core observations and hydraulic water-pressure testing results from the pre-construction (2011) geotechnical exploration. Along the length of the grout curtain, two tip elevations were specified for the borings. The specified tip elevations in the design were EL. 465 and EL. 480. The deeper specified tip elevations (EL. 465) are located in Cell No. 1, Arc Cell A1-2, and Cell No. 2 because of foundation bedrock conditions revealed in the pre-construction (2011) geotechnical exploration. At these section of the grout curtain, weathering of bedrock cores was observed at greater depths, as well as great permeability values from the water-pressure tests. As a reference, Drawings A45 through A48 show a profile view of the grout holes with the specified design tip elevations along the alignment of the grout curtain.

This methodology is consistent with the approach proposed by Donald A. Bruce (2013) in *Specialty Construction Techniques for Dam and Levee Remediation*, which states that “The depth of the curtain should be based on geology and seepage assessments and not based on the structure height." Weaver and Bruce (2007) in *Dam Foundation Grouting* concluded that the exploratory holes prior to designing a grout curtain should be based on the depth to a relatively impermeable zone as opposed to the planned height of the structure.

Another approach to designing the depth of a grout curtain is to consider the height of the dam. Weaver and Bruce (2007) cite the formula the U.S. Bureau of Reclamation (USBR) uses which is presented in Equation 2.

$$D = (H/3) + C \qquad \textbf{Equation 2}$$

Where D is the depth of the grout hole in feet, H is the height of the dam above the grout hole, and C is a constant varying from 25 to 75 based on the rock mass permeability. Weaver and Bruce (2007) also state that Szaly (1976) points out that construction of grout curtains produces significant improvements only if the curtain is tied into more impervious rock; otherwise, the seepage quantity will not be reduced. In conclusion, this alternate approach may be successful in only controlling the seepage path length, and therefore protecting the integrity of the dam structure (Weaver and Bruce, 2007).

4.2 Curtain Installation Procedures

4.2.1 Curtain Sections

In general, the installation of the grout curtain followed the progression of the construction of the new dam. After the cell infill (tremie concrete) had been placed within each circular sheet pile cell, the foundation treatment began shortly thereafter. The grout curtain was installed in the sections listed below from east to west (right to left):

- East Bank (Baseline D): Region 1
- Lock Wall Connection Cell (Baseline C): Region 2
- Cell No. 1 (Baseline C and Baseline A): Region 2
- Arc Cell No. A1-2 (Baseline A): Region 2
- Cell No. 2 (Baseline A): Region 2
- Arc Cell No. A2-3 (Baseline A): Region 3
- Cell No. 3 (Baseline A): Region 3
- West Closure Cell (Baseline A): Region 4
- West Bank Fan (Baseline A): Region 4

The upstream row of each segment along the grout curtain alignment was installed first. Then the downstream row of the grout curtain was installed in that segment. This approach was specified in the design to help reduce hydrostatic pressures on the downstream row of the grout curtain during installation. Essentially, the upstream row served as a shield for the downstream row during installation.

For each section of the grout curtain, the primary grout holes of the upstream curtain were installed first. Then, the secondary holes were installed, and if deemed necessary based on water-pressure testing information, tertiary grout holes were installed. This process was repeated for the downstream row once the upstream row was completed.

water-pressure testing information, tertiary grout holes were installed. This process was repeated for the downstream row once the upstream row was completed.

4.2.2 Drilling Methods

Each grout hole was drilled using a down-the-hole pneumatically powered percussion hammer drill. During the advancement of the drill string in each hole, the driller maintained a rock log that was developed based on drilling observations, the rate of advancement of the drill string, and cuttings washed to the top of the hole. Once a grout hole had been advanced to its target depth, the drilling log was reviewed by the on-site engineer, and the foundation improvement contractor's foreman. The on-site engineer then selected depth intervals for water-pressure testing (Lugeon tests) and prescribed the appropriate system for testing (single-packer or double-packer). Each grout hole was advanced by means of upstage drilling unless subsurface conditions warranted downstage drilling (e.g., loss of drilling water, borehole collapse, etc.).

4.2.3 Grout Hole Testing

Lugeon test intervals were typically performed over depth intervals ranging from eight- to twelve-feet. These test intervals fall within guidelines provided in *Dam Foundation Grouting* (Bruce and Weaver, 2007) which recommends test intervals of preferably three- to five-meters. In the event a subsurface feature (i.e. a void, joint, etc.) was encountered during the drilling process, the on-site engineer sometime selected to isolate this feature in a smaller test interval. A Lugeon test was then performed on each prescribed interval. Each lugeon test consisted of applying water at low pressure, a moderate pressure, a peak pressure, back to the moderate pressure, and then back down to the low pressure. The pressure conditions were held for a five-minute interval and were performed immediately following the previous pressure. During the five-minute time interval, the quantity of water that segment of the hole "took" was monitored and recorded on an Automated Grouting and Data Collection System. The peak, moderate, and low pressures were determined using the same methodology as the pre-construction pressure testing discussed in Section 3.6. While the exploratory testing data was used to help design the alignment, layout, spacing, and orientation, the data acquired from the pressure tests discussed in this section was used to determine the grout mix to be used, grouting stages, and to identify connectivity with other grout holes. Houlsby (1990) refers to this step prior to grouting as the grout hole testing phase.

The bottom interval of each grout hole was tested with a single-packer system, and the remaining intervals were tested using a double-packer system. Each system consisted of one (single) or two (double) inflatable bladder(s) that when inflated isolated the interval of interest for the introduction of water. Two connections were made to each packer: one for compressed air to inflate the packer and one for the water source. The single- and double-packer pressure testing systems are the most common throughout the grouting industry (Bruce, 2013).

Houlsby (1990) recommends that each pressure increment be maintained for ten minutes before switching to the next pressure increment. This time interval was specified to ensure that any crack dilation, wash out, or rock movement would occur and provide an accurate representation of permeability. However, other components of the dam construction were held up until the completion of each grout curtain section. For example, each cell received two reinforcing mats and a concrete cap after the installation of the grout curtain. Therefore, these activities could not be completed until that grout curtain section was installed. Due to the limited construction season on the Kentucky River due to the high-water conditions during the winter months, the time interval for each pressure increment was reduced to five minutes as described above. This adjustment was contingent upon observation of the real-time flow and pressure data from the Automated Grouting Data Collection System.

Once the pressure testing was complete, the data was reviewed to establish the plan for grouting that hole. The pressure testing data was specifically reviewed for Lugeon values, total water take, and zones of greater permeability within the grout hole. Utilizing this data, the on-site engineer selected which grout mix to start with, and if single-stage or multi-stage grouting would be most appropriate for that grout hole. Once, the grouting plan for that hole had been agreed upon, the grout process began.

4.2.4 Grout Mixes

Three high mobility cement-based balanced-stable grout mixes were utilized in the grouting program at Lock and Dam No. 8: Mix A, Mix B, and Mix C. Virtually all rock grouting for dams is performed using cement-based grouts (Bruce 2013). Bruce specifically recommends the use of balanced-stable grout mixes by saying “Balanced-stable grouts are easily formulated, do not require significant and sometimes any additional costs, and result in higher-quality grout curtains. For these reasons balanced-stable grout should be specified for all high mobility grouting projects.” Balanced-stable grouts consist of cement, water, and admixtures, and have replaced neat cement grouts as the norm in the grouting industry because of their reduced propensity to bleed and pressure filtrate. (Bruce 2013)

The components of each mix consisted of water, pre-hydrated bentonite, cement, super plasticizers, and viscosity modifiers (as necessary). The properties of each mix are presented below in Table 5.

Table 5. Grout Mixes

Grout Mix	W/C Ratio	Marsh Funnel Time (sec.)	Density (pcf)	Pressure Filtration Coefficient (Kpf)	Bleed (%)	Final Set Time (hrs.)
Mix A	1.32	36	89.9	0.06	0.8	15
Mix B	1.03	43	94.2	0.06	0.8	12
Mix C	0.75	65	101.7	0.06	0.4	9

Immediately following batching, and prior to injection down a grout hole, certain properties were tested in the field using a mud balance, Marsh funnel, and a graduated cylinder. The pressures, flow rates, and total grout take volume were monitored in the field using the Automated Grouting and Data Collection System. A small construction trailer was setup on-site to house the Automated Data and Grouting Data Collection System. The on-site engineer and the foundation improvement contractor’s geologist and superintendent monitored the grouting data for each grout hole in real time. Adjustments between grout mixes were selected in the field based on the data presented and recorded by the Automated Grouting and Data Collection System. For example, if the on-site engineer observed the pressure and grout flow rate remaining constant in a hole after 100 gallons of Mix A had been injected down a hole, the on-site engineer would likely propose switching to a more viscous Mix B. Each hole was grouted until the refusal criteria was achieved. The design defined refusal as a grout flow rate of 0.75 gallons-per-minute (gpm) held for five-minutes at the maximum pressure specified for the stage being grouted. The maximum pressure for each stage was the same maximum pressure used in the pressure test for that stage.

According to Bruce (2007), the specified value for refusal criteria for grout holes varies widely in North America. Typical ranges for refusal criteria range from near zero to a more traditional value of 0.75 gpm. Bruce (2013) goes on to state that, “Specifying absolute zero take is not recommended as this requirement exceeds the accuracy of flow measuring equipment. However, a very low stage refusal criterion such as 0.1 gpm over a period of five-minutes or less is recommended”. The grout flow rate criteria specified in the design at Lock and Dam No. 8 (0.75 gpm) is not as stringent as the criteria recommended by Bruce, but it falls within the typical range throughout the grouting industry.

4.2.5 Automated Grouting and Data Collection System

The design specified the use of an Automated Grouting and Data Collection System to help facilitate the processing of data quickly and efficiently in the field. The Automated Grouting and Data Collection System consisted of three major components: a pressure gauge, a flow sensor, and the Cinaut Manufacture and Control System, by Jean Lutz SA Civil Engineering Instruments. The Automated Grouting and Data Collection System was used to pressure test (Lugeon test) and grout each grout hole.

The pressure gauge and flow sensor were located at the grout header and measured gauge pressure and flow on a one-second time interval. This data was collected and transmitted to the Cinaut 15 through a serial data connection. The Cinaut instrument was used to plot the measured data by the pressure and flow sensors in real time and produce reports to quickly analyze the data. The Cinaut instrument had eight inputs that receive direct data from flow, volume, and pressure sensors on the grout and water injection instrumentation.

During pressure testing, the screen on board the Cinaut 15 instrument displayed in real time the following metrics:

- Hole location and depth
- Test start time and date
- Water-pressure (measured directly by the pressure sensor)
- Water flow rate (measured directly by flow sensor)
- Lugeon value (calculated by the Cinaut software from pressure, flow rate, elapsed time, and depth interval). This equation is presented in Equation 1 in Section 3.6.1.

During grouting operations, the screen on board the Cinaut 15 instrument displayed in real time the following metrics:

- Hole location and depth
- Gauge pressure (measured directly by the pressure sensor)
- Injection rate (measured directly by flow sensor)
- Cumulative grout volume injected (calculated by the Cinaut software from flow rate and elapsed time)
- Apparent Lugeon value (calculated by the Cinaut software from pressure, flow rate, elapsed time, and depth interval)

All the information described above was then included in a report generated by the Cinaut 15 instrument. See Figure 18 for the setup of the Cinaut 15 instrument during grouting operations.

An example of the grouting records collected during construction for a grout hole at Lock and Dam No. 8 is presented in Appendix D. The tabulated results of the grout hole testing and grout injection of each grout hole is presented in Appendix E.

Figure 18. Automated Grouting and Data Collection System Operation

4.3 Performance Testing

Following the installation of a section of the grout curtain, verification cores were core drilled and then water-pressure tested to verify the effectiveness of the grout curtain prior to closing that section. The number of verification cores for a section depended on the length of that particular segment. For example, the section within Arc Cell A1-2 had one verification core while the section of the grout curtain within Cell No. 1 had two verification cores.

Each verification hole was core drilled and logged by a licensed geologist. The verification holes were then pressure tested consistent with the methods described previously. Due to the inability to measure the effectiveness of the installation process against other metrics, the pressure testing data collected at this stage is vital in assessing and guiding the performance of the work (Bruce, 2013). The design criteria for the maximum permeability of the foundation bedrock at Lock and Dam No. 8 was selected as three Lugeons. This performance criteria was selected based on the site geology, financial constraints, the perceived value of water loss through seepage or uncontrolled flow during times of severe drought, and anticipated frequency of severe drought events (Webster and Hacker, 2016).

Therefore, the Lugeon values from the verification holes were then compared to this criterion. If the Lugeon values of the verification cores satisfied this criterion that section of the grout curtain was closed. In the event the criterion was not satisfied, split-spacing between grout holes would have been executed to attempt to further reduce the permeability within the foundation bedrock. No section along the grout curtain at Lock and Dam No. 8 required split-spacing criteria based on the results of the verification holes. This is an indication that the design spacing, depth, orientation, and grout mixes were sufficient to satisfy the design criteria. Appendix G includes the tabulated automated test data from the pressure testing and grouting of the verification holes and grout holes for each section of the grout curtain.

Houlsby (1990) developed general guidelines to help in determining acceptable foundation permeability criteria. The guidelines he developed began with the work of Lugeon (1933). As a consultant, Lugeon worked on the principle that grouting is necessary where the permeability exceeds one-Lugeon for dams over 100 feet high and three-Lugeons for those less than 100 feet. In regard to seepage, Houlsby (1990) recommends that if the water is of "precious" value an acceptable foundation permeability of one-Lugeon and if the water is worth the cost of intensive grouting an acceptable foundation permeability of two- to three-Lugeons. In addition to the seepage concerns, dam stability should be considered. Houlsby (1990) recommends a Lugeon value of three to prevent piping of foundation materials. In general, the selected design permeability of three-Lugeons is consistent with Lugeon's principles and Houlsby's guidelines.

James Warner, P.E. (2004) lists some challenges with selecting the appropriate cutoff criteria for grout curtains in his book *Practical Handbook of Grouting.* Warner states that in designing a grout curtain, "One must thus consider both the nature of the defects and the amount of reduction reasonably required. Calling for a greater reduction in seepage than is rationally required will virtually always come at a high price." The balancing act between cost and seepage cutoff is common throughout the industry. Both Warner (2004) and Houlsby (1990) seem to suggest the solution to this challenge is to assess the value of the water that will be lost due to seepage, and then set the closure criteria based on that consideration.

The location of the verification hole(s) was selected by the on-site engineer based on the pressure testing and grouting data from the upstream and downstream row of the curtain along a particular section. Generally, the areas within a section that demonstrated the highest foundation permeability were selected for verification testing. This study considers 11 total verification cores (Note: the verification core water-pressure testing data for Cell No. 1 was not available at the time of this study).

5 Observation and Interpretation of Data

Analysis of the observed subsurface data was performed for the various stages of the project including the pre-construction geotechnical data, the data obtained during the grout curtain installation, post-installation performance testing data, and piezometric data. These various analyses are included in the following subsections.

5.1 Analysis of Pre-Construction Geotechnical Data

As discussed in Section 3.5, a pre-construction geotechnical exploration was performed to assist in the design of the foundation improvement program. The geotechnical exploration included rock core borings and staged pressure tests. Specifically, an analysis of the RQD and the Lugeon values obtained from the pre-construction geotechnical exploration is the focus of this section.

For each of the pre-construction borings, the average RQD value was computed. This value was computed by weighting the RQD value for each individual core run over the total depth of reported RQD values for that boring. RQD values were only considered within the elevations of interest (i.e. some boring were advanced deeper than the design tip elevation of the grout curtain. RQD values were considered from the top of rock elevation to approximately elevation 480 feet across the site, except within an area of Region 2 (STA. 11+40 to STA. 12+60).

Similarly, an average Lugeon value was computed for each pre-construction boring. The average Lugeon value was computed by weighting the Lugeon value of each stage tested over the total depth of the boring that was water-pressure tested.

The average RQD and average Lugeon values were plotted along Baseline A (see Figure 19). This plot demonstrates the elevated Lugeon values in Regions 1 and 2, as previously discussed. However, Figure 19 also demonstrates that there is not a direct relationship between RQD and Lugeon values (i.e. low RQD values do not translate to low Lugeon values and vice-versa).

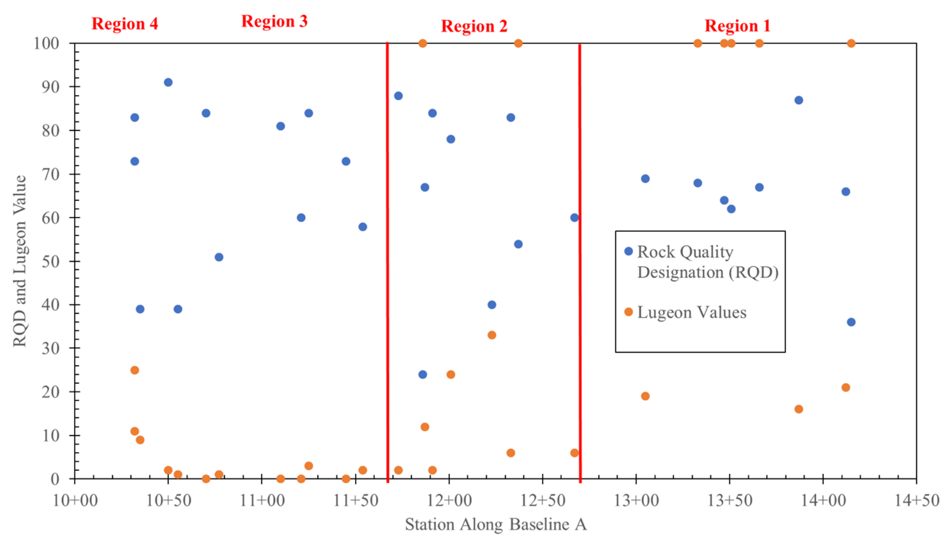

Figure 19. RQD and Lugeon Values Along Baseline A

To further investigate the relationship between RQD and Lugeon values, a plot of RQD-versus-Lugeon values was created (see Figure 20). Figure 20 further demonstrates that these two metrics (RQD and Lugeon values) used to characterize subsurface conditions are not directly related. For example, from Figure 20 we clearly see that a maximum Lugeon value of 100 was observed for rock that possessed an average weighted RQD value of 24 and 68. Two vastly different values of RQD share the same Lugeon value further confirming that additional factors at Lock and Dam No. 8 beyond RQD are influencing the foundation permeability recorded in the pre-construction water-pressure tests.

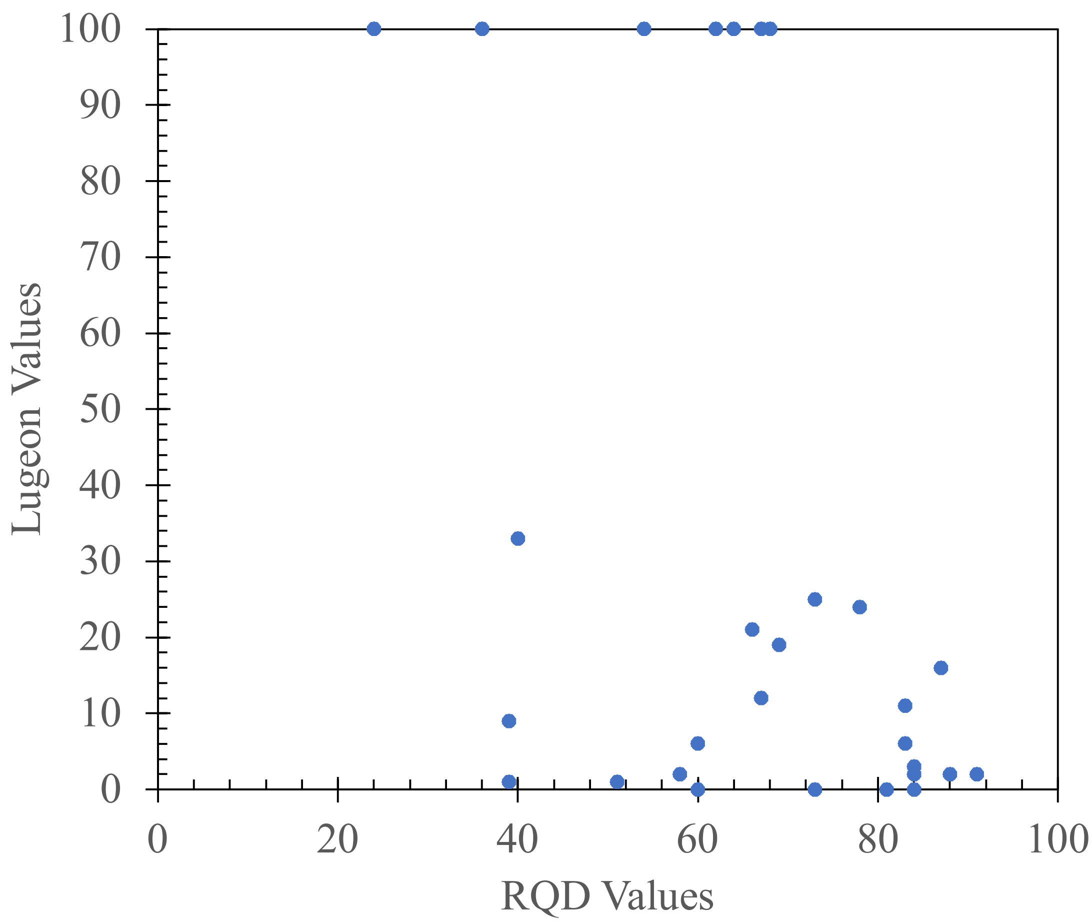

Figure 20. RQD-vs-Lugeon Values

A statistical analysis of these findings was performed and is presented in Table 6 for the entire site and for each region across the site.

Table 6. Statistical Analysis

Analysis Region	RQD Values			Lugeon Values			Correlation Coefficient
	MIN	MAX	MEAN	MIN	MAX	MEAN	
Entire Site	24	91	66	0	100	31	-0.42
Region 1	36	87	65	16	100+	70	-0.55
Region 2	24	88	64	2	100+	32	-0.76
Region 3	39	84	66	0	3	1	-0.04
Region 4	39	83	72	2	25	12	-0.14

It is apparent from Table 6 that the mean RQD values across the site are nearly uniform. The mean RQD value for all pre-construction borings across the site was 66. When the RQD data was subdivided into the four regions identified in Section 3.8.3, the mean RQD values across the site ranged from 64 to 72, indicating uniformity in the RQD value across regions and throughout the foundation bedrock at Lock and Dam No. 8. On the other hand, the mean Lugeon value of all the water-pressure test across the site was 31, while the range between regions was 1 to 70. While RQD values across the site demonstrated smaller variations across the site, Lugeon values fluctuated substantially throughout the four regions.

More specifically, as discussed in Section 3.8.3, Regions 1 and 2 have more documented karstic conditions and problems. Table 6 presents the statistical correlation coefficient between RQD and Lugeon values from the pre-construction values. The closer the correlation coefficient is to -1, the relationship between the variables follows a negative correlation (i.e. as RQD decreases, Lugeon values increase). The closer the correlation coefficient is to 0, the more the two variables display independence of each other. The correlation coefficients for all regions demonstrated a negative correlation. The correlation coefficients in Regions 1 and 2 are closest to -1, while the correlation coefficients for Regions 3 and 4 are near 0. This statistical analysis demonstrates a closer correlation between the RQD values and Lugeon values in Regions 1 and 2. However, the relationship between RQD and Lugeon values breaks down in Regions 3 and 4.

RQD values are a direct reflection of the extent of weather, fracturing, jointing, and dissolution of the subsurface rock sampled. The slightly higher mean RQD values in Regions 3 and 4 are indicative of this. The extent of karstic dissolution and weathering in Regions 1 and 2 results in an increase of interconnectivity of bedrock discontinuities; thus, resulting in a stronger negative correlation.

5.2 Analysis of Grout Curtain Installation Data

The double-row grout curtain was installed in accordance with the methodology described in Section 4.2. Following the drilling of a grout hole and prior to grouting, the hole was water-pressure tested (see Section 4.2.3). This section analyzes the results of the grout curtain installation bedrock permeability data in comparison to the pre-construction water-pressure testing data, as well as the total grout takes (volume in gallons) considering the Lugeon values of the grout hole water-pressure test.

The pre-construction geotechnical exploration included water-pressure tests within 29 rock core borings. During construction, each grout hole was water-pressure tested following drilling and prior to grout injection. The pre-construction water-pressure testing data was used to design the various components of the grout curtain, such as, depth and spacing, while the water-pressure testing data obtained in each grout hole was used to identify cross-hole communication, grouting stages, and which grout mix to use.

In general, the Lugeon values collected from the pre-construction geotechnical exploration were consistent with the data collected during construction. The relationship between the Lugeon values is demonstrated in Figure 21. Figure 21 plots the Lugeon values along Baseline A for both the pre-construction tests and the grout hole tests. Both data sets demonstrate more variable and generally higher Lugeon values in Regions 1 and 2. Similarly, Regions 3 and 4 demonstrate generally lower Lugeon values. However, higher Lugeon values were noted in Region 4 further into the left abutment in the grout hole water-pressure testing data than observed in the pre-construction data. This likely occurred because the pre-construction core borings did not extend as far into the left abutment as the grout holes. The grout holes advanced into the left abutment were advanced at inclinations of up to 55 degrees where karst features were encountered and could be observed in the rock outcrops along the left bank.

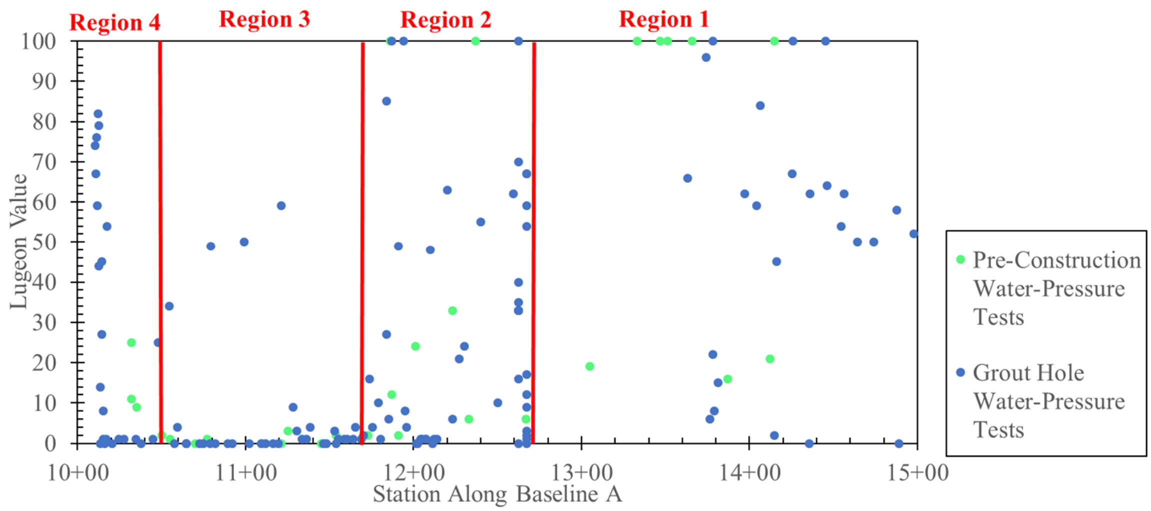

Figure 21. Pre-Construction and Grout Curtain Installation Lugeon Values

Figure 21 also demonstrates isolated occurrences of high Lugeon values in the grout hole installation data that were not observed in the pre-construction data. This is indicative of the sporadic nature of the karstic dissolution of the limestone bedrock across the project site throughout all four regions. The high Lugeon values collected in the grout hole testing in Regions 1 and 2 were observed in the pre-construction data likely because the extent of karstic dissolution was more severe in these regions (see Section 3.8.3). However, the higher Lugeon values observed in Regions 3 and 4 were not observed in the pre-construction borings because the extent of karstic dissolution of the foundation bedrock was not as extensive in these regions. Rather isolated karst features within the bedrock were encountered in the grout holes due to the high volume of grout holes in comparison to the pre-construction borings. Although the karst features observed in Regions 3 and 4 were not as extensive in terms of dissolution, these features still demonstrate high permeability values than observed in the pre-construction borings.

In addition to the comparison of the pre-construction Lugeon values and the grout hole Lugeon values, the grout hole Lugeon values were compared to the total grout hole takes recorded during construction. On Figure 22 the Lugeon values and total grout take (volume in gallons) are plotted along Baseline A for each grout hole of the grout curtain.

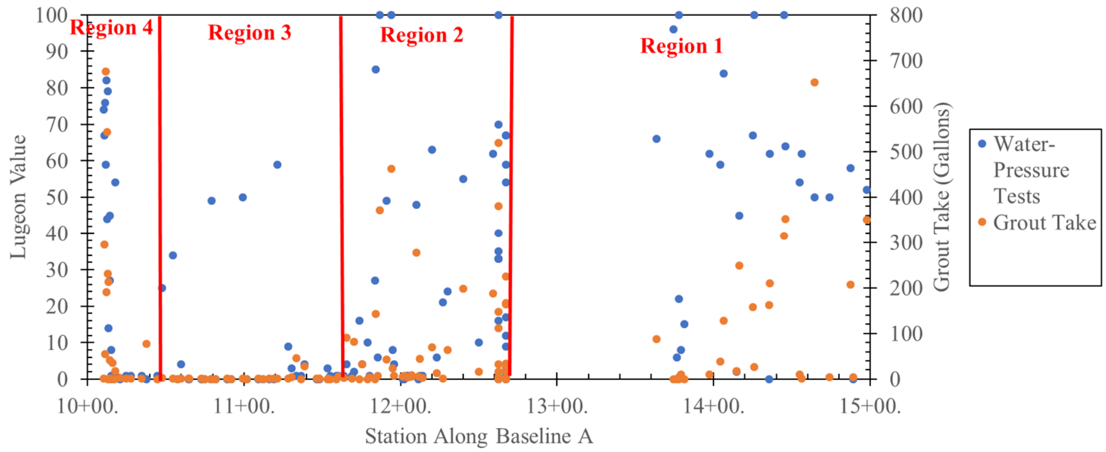

Figure 22. Lugeon Values and Total Grout Takes

Generally, Figure 22 shows that higher Lugeon values typically translated to higher injected grout takes. Figure 23 presents the total grout take in gallons for each grout mix (A, B, and C) along with the associated Lugeon value of each grout hole.

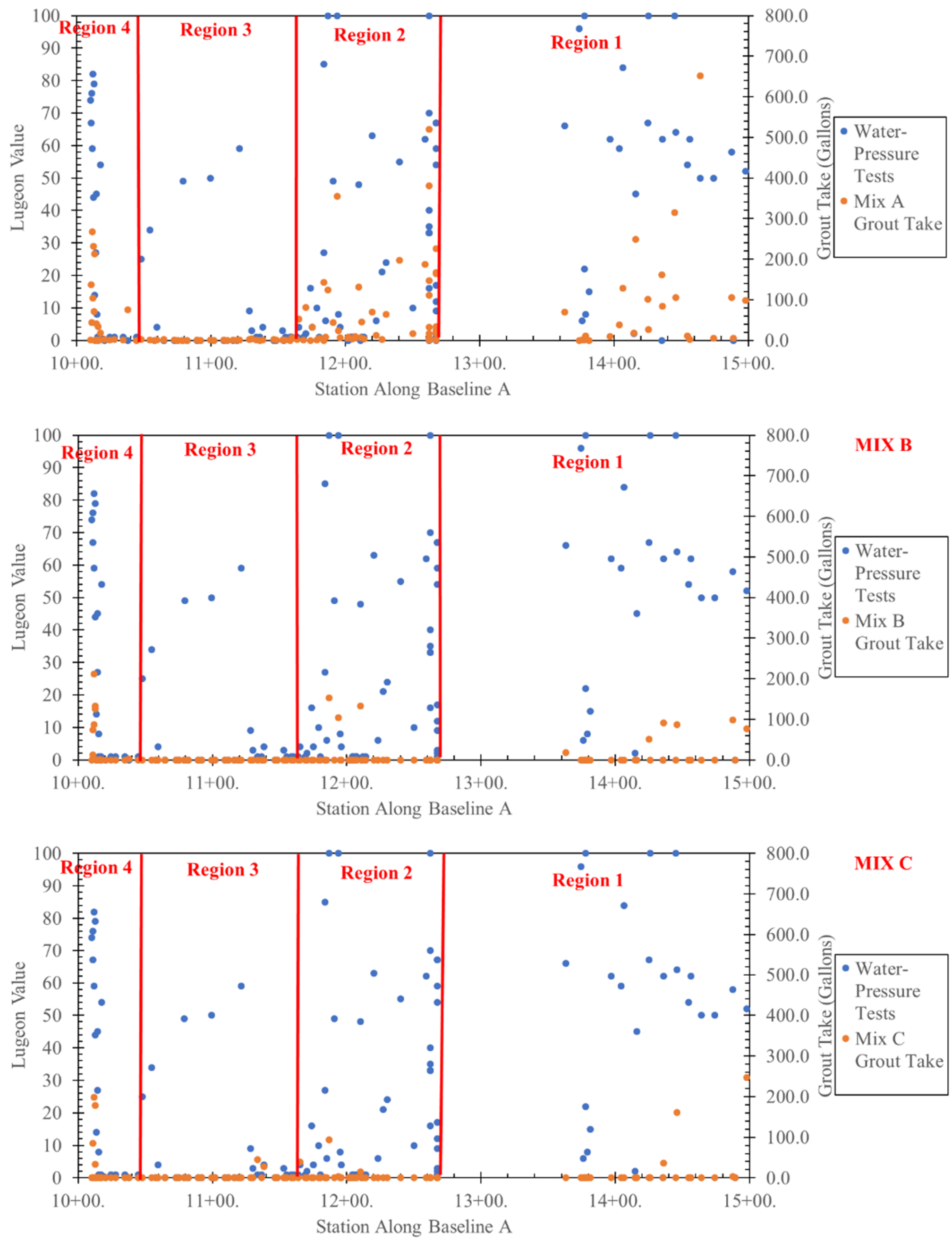

Figure 23. Total Grout Takes of Each Grout Mix

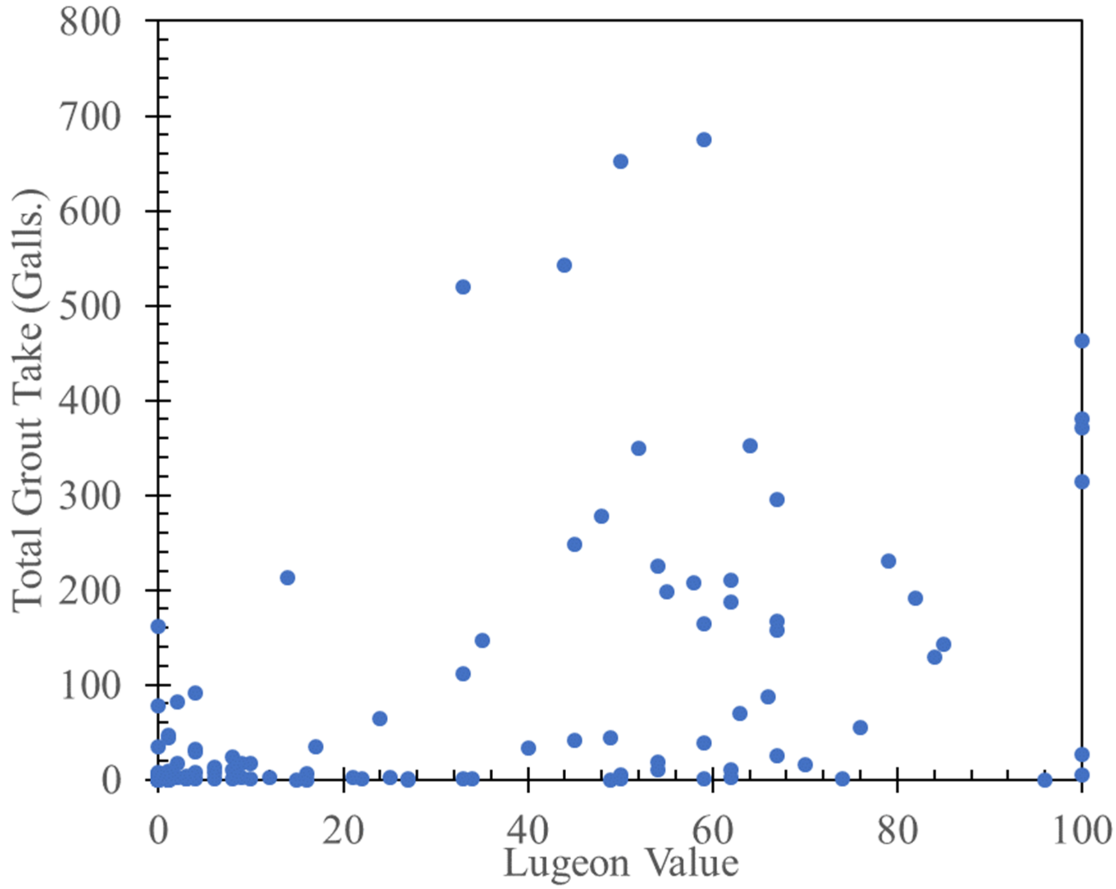

Figure 24. Total Grout Take vs. Lugeon Value

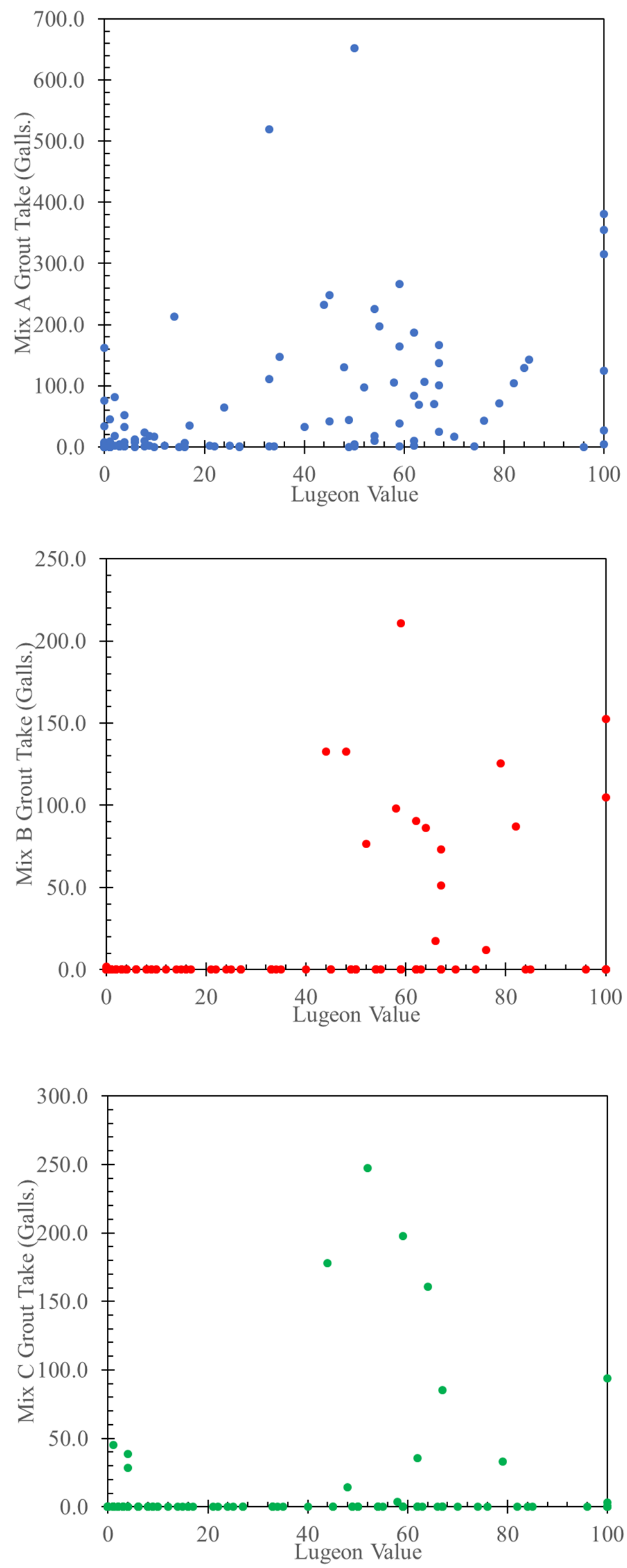

Figure 25. Grout Mix Take vs. Lugeon Value

The correlation coefficient between the Lugeon values and resulting total grout take within a grout holes is 0.53. This demonstrates a positive correlation between the two data sets (i.e. high Lugeon values translate to high grout takes). However, the correlation is not as strong as expected. As shown in Figure 24, high Lugeon values did not always translate to high volumes of grout injection. Based on the subsurface conditions encountered at the site, this is likely the result of two factors. First, many of the karst features were observed to be infilled with alluvial soil deposits which included clays, silts, sands, and gravels. Figure 25 plots each individual grout mix take versus Lugeon values to provide additional comparison for each individual grout mix.

The Lugeon tests is performed using water and depending on the gradation characteristics of the alluvial soils infilling the discontinuities, water may flow through easily, while the more viscous, denser grout may not. Due to the infilling of the bedrock discontinuities at Lock and Dam No. 8, high Lugeon values did not always result in higher grout takes. Second, this analysis does not consider which grout mix was used in grouting. Throughout construction, the decision of which grout mixes used to treat a hole was based upon the water-pressure test data. Therefore, a hole with a high Lugeon value may result in a low grout take if Mix C (most viscous mix used at Lock and Dam No. 8) was injected. However, if Mix A or Mix B were used in a similar hole the grout take may be significantly higher.

5.3 Analysis of Performance Testing Data

As discussed in Section 4.2.3, prior to grouting, each grout hole was water-pressure tested. Following the installation of the grout curtain, verification cores were drilled and subsequently water-pressure tested to determine if the closure criteria (average Lugeon value of 3) had been achieved. A comparative analysis between the initial Lugeon values of the grout holes and the verification cores will serve as an indicator of the efficiency of the design (depth, spacing, alignment, and orientation), and the success of the installation (grout mixes, grouting pressures, and quality execution).

The average permeability of the foundation bedrock at the Lock and Dam No. 8 project site was determined to be 31-Lugeons. This average permeability of the bedrock at Lock and Dam No. 8 was determined from the water-pressure testing of 4,665-linear feet of grout holes prior to the installation of the grout curtain. The Lugeon value observed in each grout hole prior to grouting and the Lugeon value of each performance verification core is plotted in Figure 26.

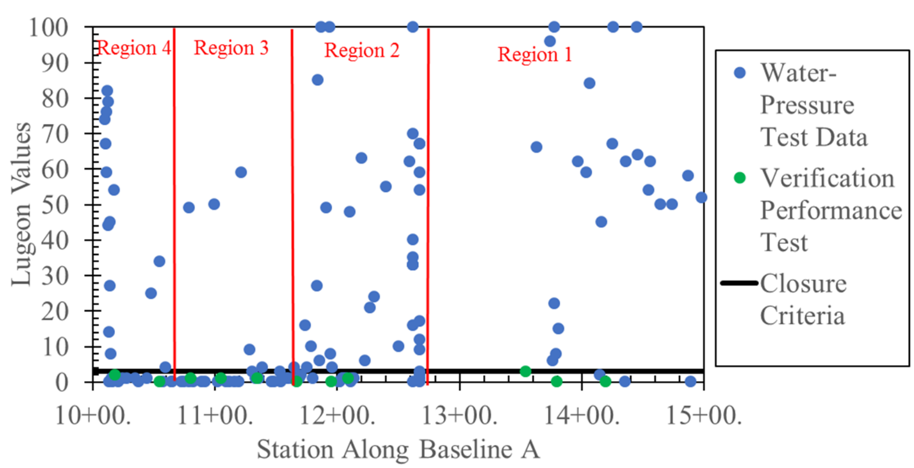

Figure 26. Lugeon Values Summary

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5.4 Analysis of Piezometric Data

Prior to construction, eight piezometers were installed along the east (right) bank along Baseline D. The piezometers were open-standpipes that were screened in the foundation bedrock. Each open-standpipe piezometer received an in-situ Level Logger that was set to continuously record piezometric data every hour. That continuous log of piezometric data is stored on the instrument's internal memory for download at any time. Each piezometer is screened in the foundation bedrock (limestone). The piezometric data from six piezometers will be assessed to evaluate the efficiency of the grout curtain at Lock and Dam No. 8. Stantec performed well maintenance on the instruments on May 9, 2017, and after bailing out the riser of piezometer B-2, concerns arose that the piezometer may have been grouted and or damaged during installation of the grout curtain. Additionally, piezometer B-5 was damaged during construction. Therefore, piezometers B-2 and B-5 were not included in the assessment of the piezometric data at Lock and Dam No. 8.

Piezometers B-6, B-7, and B-8 were installed 15 feet upstream of Baseline D, which is 12.5 feet upstream of the upstream row of the grout curtain. Piezometers B-1, B-3, and B-4 were installed 15 feet downstream of the Baseline D, which is 12.5 feet downstream of the downstream row of the grout curtain. Figure 27 presents a plan view of the piezometers installed at Lock and Dam No. 8 along Baseline D.

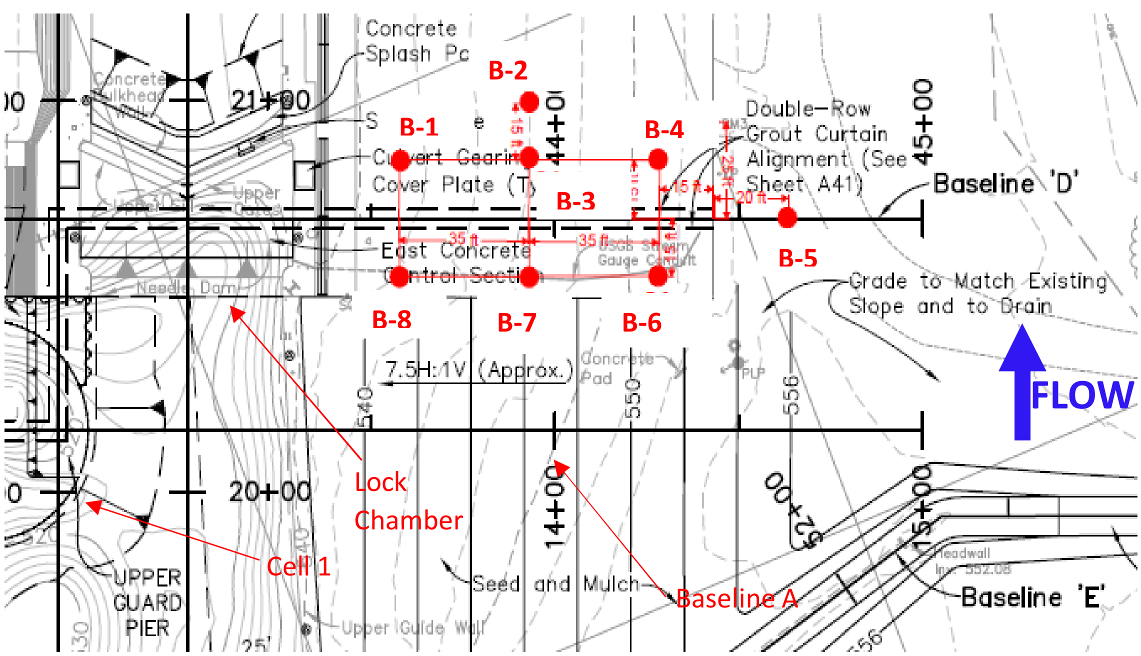


Figure 27. Piezometer Layout

The piezometers at Lock and Dam No. 8 are installed at the eastern edge of the grout curtain. At the edge of the grout curtain, there are three-dimensional seepage effects on the piezometric data that are not considered in this study. For example, groundwater from the east bank impacts the piezometric conditions at the location of the installed piezometers. Those effects are assumed to impact each instrument uniformly and cancel out when making relative comparisons between instruments before and after installation of the grout curtain.

The pre-construction piezometric data for each piezometer was assessed between the dates of December 18, 2013, through August 4, 2014. This range of data was collected prior to any installation of the grout curtain at Lock and Dam No. 8 (which began on August 6, 2014) and represents the pre-curtain piezometric conditions at each instrument location. Piezometric data for the post-curtain condition for each instrument was assessed between May 23, 2017, through August 16, 2017. Figure 28 presents the post-curtain installation data for each piezometer analyzed.

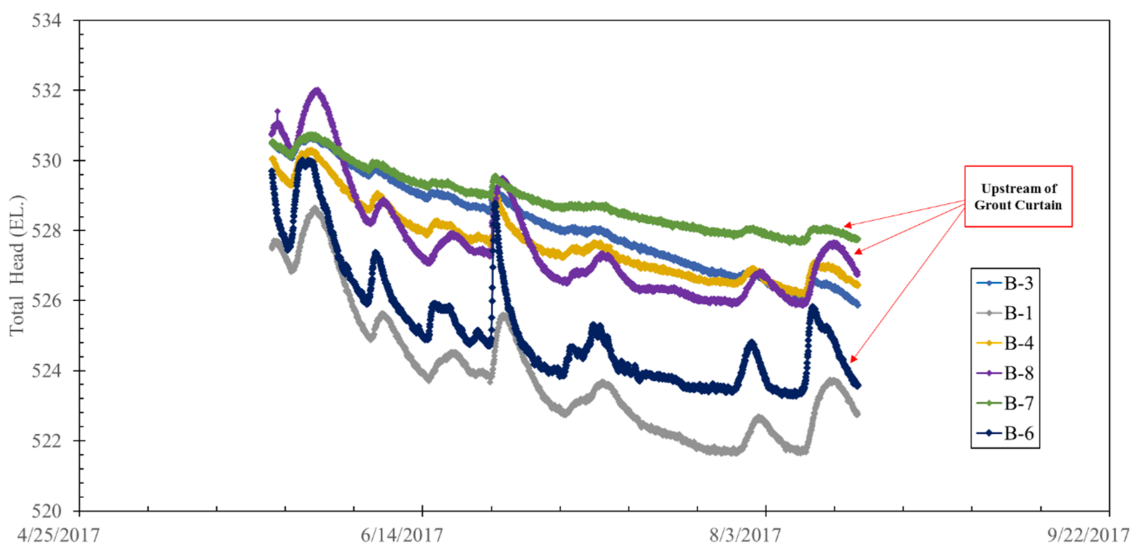


Figure 28. Post-Curtain Piezometer Data

In general, Figure 28 shows a total head drop across the grout curtain. Piezometers B-1 and B-3 show lower total head conditions than piezometers B-8 and B-7 which are located directly downstream on the downstream side of the grout curtain, respectively. However, piezometer B-4 shows higher total head conditions than piezometer B-6 and piezometer B-4 is located directly downstream on the downstream side of the grout curtain. This phenomenon is likely due to three-dimensional seepage effects from the right abutment. Piezometers B-4 and B-6 are located furthest up the right abutment from the river.

A plot of total elevation head versus headwater was plotted for each instrument during each time interval. This plot allowed for comparison of total head readings for each piezometer for similar headwater conditions between the pre-curtain condition and post-curtain condition. Total elevation head versus headwater plots are shown in Figure 29 for each piezometer.

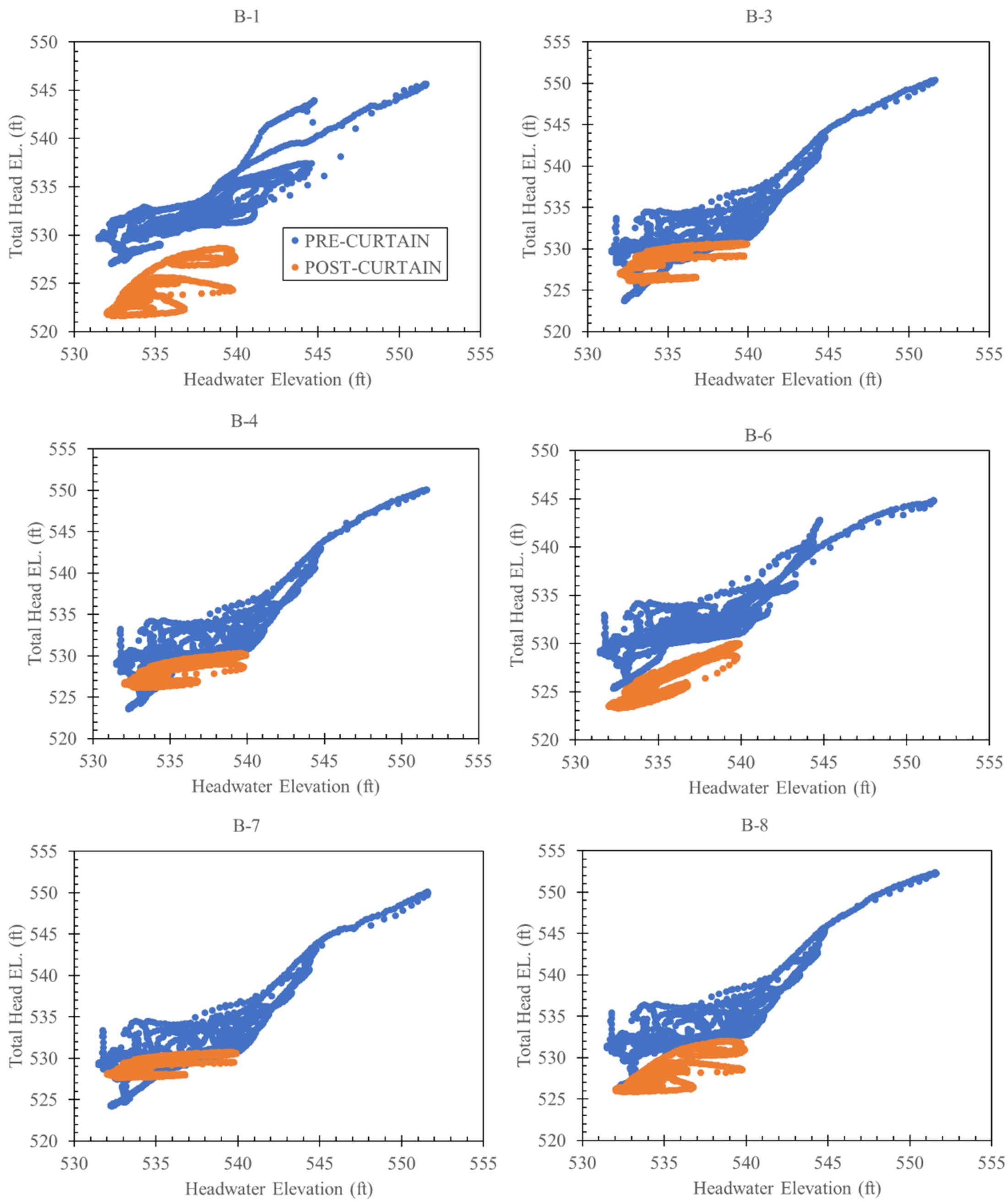


Figure 29. Piezometer Total Head vs. Headwater

Each piezometer assessed showed a reduction in observed total head values for similar headwater conditions following the installation of the grout curtain. This indicates that the grout curtain reduces the total head at each piezometer location for various pool conditions. Conclusions from the review of each plot in Figure 29 are presented in Table 7.

Table 7. Piezometric Data Comparison

Piezometer	Observations Pre-Curtain vs. Post-Curtain
B-1	Approximate reduction of five- to seven-feet in total head
B-3	Slight reduction in total head
B-4	Slight reduction in total head
B-6	Approximate reduction of five- to six-feet in total head
B-7	Slight reduction in total head
B-8	Approximate reduction of one- to four-feet in total head

To elaborate on the trends observed in the plot for each piezometer presented in Figure 29 and discuss in Table 7, a portion of the piezometric data collected from piezometer B-1 was used to create a similar plot. A total head versus headwater plot was developed for piezometer B-1 during a time interval in which the headwater fluctuated from approximate elevation 535 to elevation 541. This plot is presented in Figure 30.

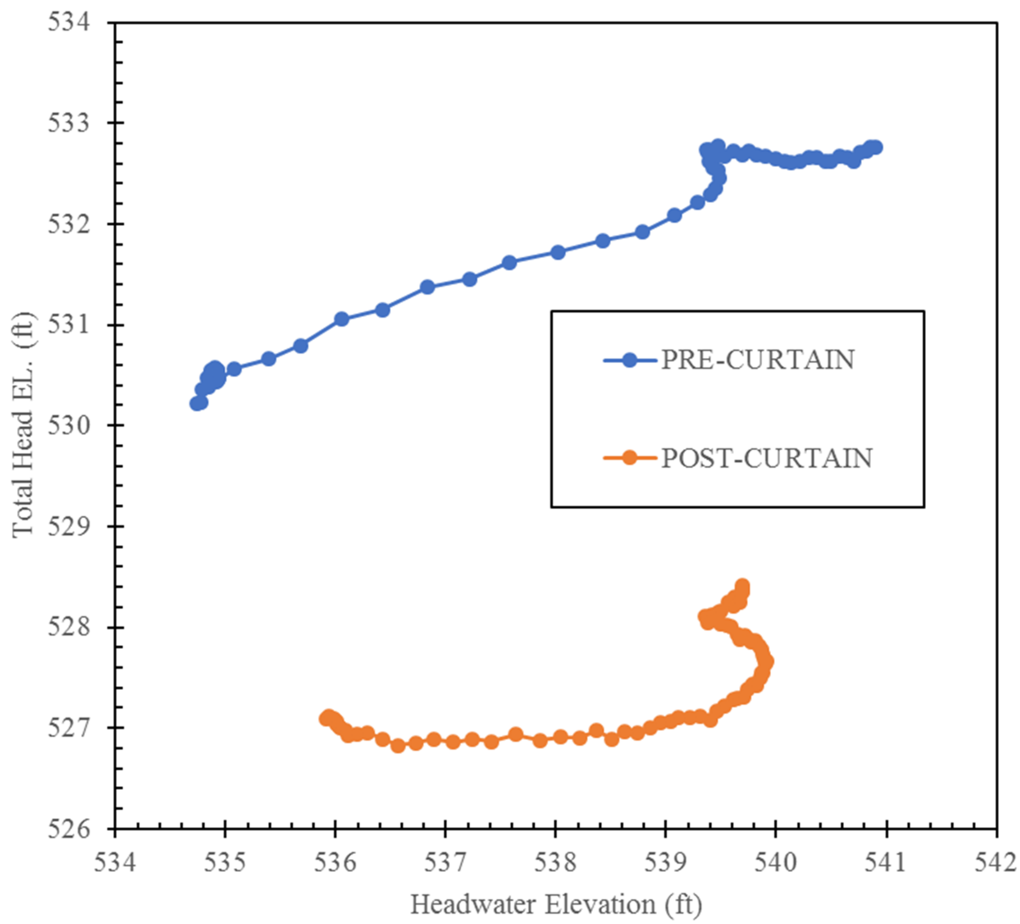


Figure 30. Selected Data from B-1

Consistent with the trends summarized in Table 7, Figure 30 demonstrates that for similar headwater conditions, total head measurements within piezometer B-1 have been reduced by the installation of the grout curtain.

Figure 30 demonstrates the general trend observed in all piezometers for the pre-curtain condition that as headwater elevation increases so does the total head reading at the piezometer inclination. The steeper the slope of the data, the greater the connection between headwater and observed total head at that piezometer location. For example; a 1:1 slope of the data points would suggest a direct connection between headwater and total head. As shown in Figure 30, the slope of the pre-curtain data is generally steeper than the piezometer data points for similar headwater conditions in the post-curtain condition. This suggests that the grout curtain reduced the influence headwater has on the total head condition at this piezometer location.

6 DESIGN EVALUATION

The components of the grout curtain, the design and the installation requirements, are discussed in Section 4. Each of these components will be evaluated in the following sections.

6.1 GEOLOGICAL CONSIDERATIONS

The original design of the foundation improvement program at Lock and Dam No. 8 included a high mobility grout curtain, a low-mobility grout treatment of a specified area with Cell No. C2, and a secant pile cutoff wall within Cell No. C2 consisting of 23 30-inch diameter concrete shafts. The foundation improvement program was designed from review of the document historical karst issues, an on-site geological reconnaissance, and a pre-construction geotechnical exploration. Section 4.1.1 discusses the impacts the geological considerations had on the design. Both the historical information review and the geological reconnaissance are limited by the amount of information available. However, the pre-construction geotechnical exploration used to develop the final design can be optimized the constructed product.

During construction at Lock and Dam No. 8 two components of the foundation improvement program were significantly modified based on the subsurface conditions encountered during installation of the high-mobility grout curtain. Construction modifications are typical in karst environments because karst behavior is unpredictable and often concealed. The low-mobility grout treatment was completely removed from the scope of work and the secant pile cutoff wall was reduced from 23 shafts to seven shafts and re-aligned upstream. The modifications of the secant pile cutoff wall is shown is shown in Figure 13.

The extent of karstic dissolution in the regions where the low-mobility grout treatment and the secant pile cutoff wall was more severe than other areas across the site. Specifically, the low-mobility grout treatment was designed to treat karstic dissolution around a principal joint within the foundation bedrock of Cell No. C2, and the secant pile cutoff was designed to cutoff seepage through the principal joint.

As discussed in Section 5.2, many of the discontinuities within the foundation bedrock were infilled with alluvial soils deposited by the river. The low-mobility grout treatment was removed from project scope during construction because of this infilling effect. The low-mobility grout was denser and more viscous than the high-mobility grout used in the curtain and would not have been able to flow through the alluvial soils within the bedrock discontinuities.

The principal joint within the foundation of Cell No. C2 was encountered in two pre-construction borings. Based on the rock core from these two borings the secant pile cutoff wall was designed. Historical information of this feature along the alignment of the new dam was not available because the feature was concealed beneath the river.

The modifications discussed above were incorporated into new dam based on additional information collected during the installation of the grout curtain. While the low-mobility grout treatment was entirely excluded from construction, the secant pile cutoff wall was re-designed during construction. The additional information provided information regarding the subsurface conditions that were not evident from the pre-construction geotechnical exploration alone.

6.2 Alignment, Spacing, and Orientation

The evaluation of the grout curtain design alignment, spacing, and orientation is best supported by the analysis included in Section 5. Specifically, the performance testing data and piezometric data confirm the proficiency of the designed alignment, spacing, and orientation of the grout curtain.

The alignment of the grout curtain was laid out to follow the water retaining structures of the new dam and was limited by constructability issues within an active river environment. The spacing and orientation of the grout holes was determined by the geologic conditions at the project site. The alignment, spacing, and orientation of the grout curtain at Lock and Dam No. 8 were selected with the objective of reducing the bedrock permeability of the site to three-Lugeons or less. This metric was accomplished with the designed alignment, spacing, and orientation (see Section 5.3). Piezometric conditions were also reduced as indicated by the piezometric data collected from the right abutment (see Section 5.4).

In summary, the available metrics at Lock and Dam No. 8 indicate that the designed alignment, spacing, and orientation of the grout curtain was satisfactory.

6.3 Design Depth

The depth of the grout curtain at Lock and Dam No. 8 extended to two different elevations: EL. 480 and EL 465. The bottom elevation of the grout curtain was designed based on the subsurface, geologic conditions encountered along that section of the grout curtain in the pre-construction geotechnical data. This methodology of designing grout curtains is widely accepted as discussed in Section 4.1.3.

An alternative approach to designing the bottom elevation of a grout curtain and is also discussed in Section 4.1.3. This method determines the depth of the grout curtain based on the structural height of the dam and is used by the USBR. This equation is not valid at Lock and Dam No. 8 because of the subsurface conditions at the site. The formula incorporates the structural height of the dam into the calculation to reduce the hydraulic gradient beneath the dam. However, Lock and Dam No. 8 is founded on limestone bedrock and material erosion resulting from high hydraulic gradients is not a failure mode of concern. At Lock and Dam No. 8 the objective of the grout curtain is to reduce foundation seepage to support the retention of Pool No. 8.

In this particular case, the depth of the grout curtain must vary to accomplish that goal. While the structural height of the new dam is uniform across the site, the depth of karstic dissolution in the foundation bedrock varies. In order to support adequate pool retention, the depths of the grout curtain must vary to support these conditions. The design depth and selected approach are optimal for the conditions encountered at Lock and Dam No. 8, as well as the objectives of the grout curtain. A plot comparing the different depths that would have been determined from the two proposed methodologies discussed in Section 4.1.3 is included in Appendix F.

6.4 Curtain Installation Procedures

The grout curtain at Lock and Dam No. 8 was installed in general accordance with the procedures outline in Section 4.2. Prior to setting up to drill a grout hole, the depth, alignment, spacing, and orientation of that particular hole were predetermined by the design. However, the grouting stages within a hole and the grout mixes injected in the hole were determined in the field based on the grout hole testing described in Section 4.2.3.

In the field, the Engineer required the grouting Contractor to wash each hole after drilling and prior to water-pressure testing as well. The hole was washed with water until the return water was clear and free of sediments. The washing of the grout holes became increasingly important as the infilling of bedrock discontinuities was encountered in grout holes across the site. Washing each grout hole would help remove the fine-grained soil particles from the discontinuities prior to water-pressure testing and grouting. This procedure allowed for a more representative measure of the bedrock permeability because the infilling is a short-term condition because of the active marine environment of the river. Additionally, the washing of the fine-grained alluvial materials from bedrock discontinuities allowed for grout to flow through the discontinuities and treat the features as designed.

Although not specifically specified, grout hole washing was a critical step in adequately treating the foundation bedrock at Lock and Dam No. 8.

7 DISCUSSIONS AND CONCLUSIONS

The available metrics at Lock and Dam No. 8 indicate that the grout curtain is successfully cutting off seepage as the design intended (refer to Section 5). Specifically, the analysis of the performance verification core holes and piezometric data suggest the grout curtain is performing as intended. The following recommendations are derived from the design, installation, and evaluated performance of the grout curtain at Lock and Dam No. 8.

The pre-construction geotechnical exploration at Lock and Dam No. 8 is discussed in detail in Section 3.5.1. In total, 30 borings were advanced along the new dam alignment and abutments that were utilized to design the grout curtain. However, additional rock core borings would have been beneficial to help characterize the extent of karstic dissolution in Region 2, specifically in the foundation of Cell No. C2. This location received significant modifications from the original design based on the subsurface conditions encountered in the installation of the grout curtain. As discussed in Section 6.1, the low-mobility grout treatment was removed from the construction scope and the secant pile cutoff wall was significantly reduced.

In the design of grout curtains and other foundation improvement components, thorough characterization of the karstic features is essential in the installation of a seepage cutoff and successful completion of the project. Karst conditions are problematic and terrifying to Owners throughout this region. However, thorough geotechnical exploration of significant karst features helps reduce and alleviate the risks and problems of construction in karst environments. A more focused geotechnical exploration of the karst conditions identified in Region 2, specifically additional rock core borings and downhole camera footage, would have been valuable in designing the foundation improvement features and reducing the potential for change orders to the Owner. While it may be impossible to fully characterize the degree of dissolution of karstic features in limestone rock, this case demonstrates that the more information available the more power and control the designer has over these conditions.

The piezometers at Lock and Dam No. 8 have recorded valuable piezometric information along the right abutment. This information has been used to monitor the performance of the grout curtain at Lock and Dam No. 8 since construction completion (see Section 5.4). These piezometers were installed by the design Engineer for this exact purpose. However, these piezometers are spatially and geographically limited. These piezometers only provide piezometric information along one location of the grout curtain and suffer from the three-dimensional effects of seepage from the abutment. In order to evaluate the full performance of a grout curtain, adequate piezometric instrumentation should be installed upstream and downstream of the grout curtain along the extents (abutment-to-abutment) of the curtain. Specifically, piezometers should be installed along sections (upstream-to-downstream) where the seepage regime may change. For example, to fully understand the piezometric conditions in the foundation bedrock at Lock and Dam No. 8 following the grout curtain, a section of piezometers would be recommended at the following locations in addition to the right abutment:

- Left Abutment
- Typical Section of the Dam
- Section through Region 2 (near secant pile cutoff wall)

The addition of these piezometers would provide a thorough understanding of the piezometric conditions across the site of the as-constructed condition. This information would be useful in identifying potential seepage windows in the curtain, long term monitoring, and identifying development of new karst features.

Grout hole washing was executed and implemented in the field based on the subsurface conditions encountered at Lock and Dam No. 8. This process was a critical aspect of the grout curtain installation. This process proved so significant that it is recommended to be specified in the curtain installation procedures for similar projects. In active river environments, karst discontinuities within the bedrock will be subject to various degrees of infilling over time. Eliminating the temporary infilling conditions with a more permanent grout treatment is essential for the seepage cutoff. Designers should include requirements for washing that dictate durations of hole washing, methods (air, water, etc.), and criteria for completion of washing. This process control provides an additional measure of quality check for the designer on the installed grout curtain.

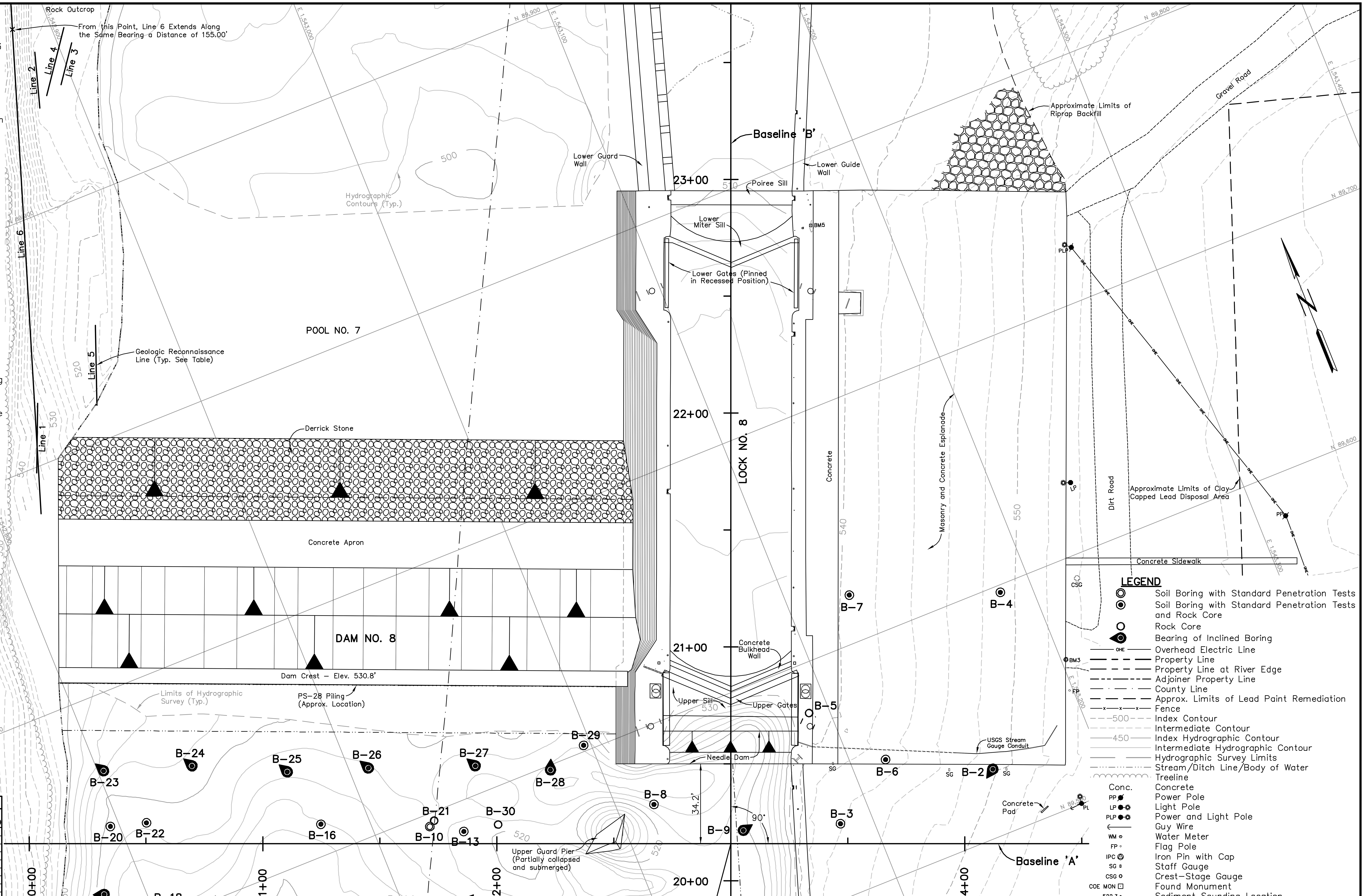
Karst conditions are problematic for engineers, designers, and owners for many reasons, but mainly because karstic dissolution is hard to characterize, unpredictable, and often concealed. While designers and engineers should make all efforts to fully characterize karst conditions, on the other hand, they must also remain flexible throughout the construction process. Additional subsurface information is collected throughout the installation of grout curtains. This information may provide a confidence boost or reveal previously unknown conditions. When this happens, designers and engineers, must not remain loyal to design, but rather remain loyal to goal of seepage cutoff. This requires designers and engineers to interpret the additional information from construction immediately and in real-time. Designers and engineers must remain flexible throughout construction to modifications that new information may require. This proved critical at Lock and Dam No. 8 and resulted in the reduction of construction scope.

While limited metrics are presently available to evaluate the efficiency of the grout curtain at Lock and Dam No. 8, the evaluations discussed in Sections 5.3 and 5.4 indicate that the grout curtain is effective in reducing the seepage pressure underneath the dam. The ultimate metric of efficiency for the grout curtain at Lock and Dam No. 8 will be the performance of the new facility during severe drought conditions.

APPENDIX A – PRE-CONSTRUCTION BORING PLAN AND DRAFTED LOGS

NOTES:

1. Horizontal coordinates are based on the Kentucky State Plane Coordinate System, North Zone, North American Datum of 1983 (NAD83). Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88). Many historic drawings are often referenced to the Kentucky River Datum (KRD) or the National Geodetic Vertical Datum of 1929 (NGVD29). At Lock and Dam No. 8, elevations based on KRD can be converted to NAVD88 by subtracting 2.5 feet, while elevations based on NGVD29 can be converted to NAVD88 by subtracting 0.5 feet.
2. The property shown hereon is subject to all easements, covenants, and restrictions, reorded and/or unrecorded. Stantec Consulting Services Inc. makes no guarantee with respect to the existence of such restrictions. Boundary monuments were located in the field as indicated. Boundary lines have been extended to normal pool.
3. Existing site features, dimensions, and topography were obtained from site mapping developed by Stantec Consulting Services Inc. between the dates of May 4, 2011 and July 6, 2011. Hydrographic information (stream bed contouring) was developed by Stantec Consulting Services Inc. on July 5 and 6, 2011 using a mapping grade GPS locator device and sonar equipment. The surface of the stream bed has likely changed since performance of the hydrographic survey.
4. Because of the long project history, undocumented repair efforts and lack of as-built information, not all site features may be accurately reflected.
5. Some mechanical components and buried utilities have not been located and are not shown hereon.



LEGEND

- Soil Boring with Standard Penetration Tests
- Soil Boring with Standard Penetration Tests and Rock Core
- Rock Core
- Bearing of Inclined Boring
- OHE — Overhead Electric Line
- Property Line
- Property Line at River Edge
- Adjoiner Property Line
- County Line
- Approx. Limits of Lead Paint Remediation
- x — Fence
- 500 — Index Contour
- Intermediate Contour
- 450 — Index Hydrographic Contour
- Intermediate Hydrographic Contour
- Hydrographic Survey Limits
- Stream/Ditch Line/Body of Water
- Treeline
- Conc. — Concrete
- PP — Power Pole
- LP — Light Pole
- PLP — Power and Light Pole
- Guy Wire
- WM — Water Meter
- FP — Flag Pole
- IPC — Iron Pin with Cap
- SG — Staff Gauge
- CSG — Crest-Stage Gauge
- COE MON — Found Monument
- 522.3 • — Sediment Sounding Location

GEOLOGIC RECONNAISSANCE

	Northing	Easting	Elev. (Ft.)
Line 1	89,797.6	1,542,823.3	525.8
	89,825.1	1,542,834.8	526.1
Line 2	89,942.0	1,542,882.7	515.5
	89,964.9	1,542,889.6	516.1
Line 3	89,947.9	1,542,894.8	513.7
	89,962.8	1,542,905.6	513.8
Line 4	89,945.9	1,542,887.4	513.7
	89,970.1	1,542,905.0	514.0
Line 5	89,814.9	1,542,858.1	519.9
	89,846.9	1,542,870.1	520.6
Line 6	89,780.8	1,542,818.6	525.6
	90,124.6	1,542,933.3	530.1

BASELINE LOCATION TABLE

Baseline	Station	Northing	Easting
'A'	9+00.00	89,688.9	1,542,668.5
'A'	15+00.00	89,465.5	1,543,225.3
'B'	18+00.00	89,339.7	1,542,959.4
'B'	24+00.00	89,896.6	1,543,182.7

BORING LOCATION TABLE

Boring No.	Northing	Easting	Elev. (Ft.)	Orientation	Inclination (from Vert.)
B-1	89,477.6	1,543,108.8	549.7	N 33° W	30°
B-2	89,527.9	1,543,155.5	549.8	S 57° W	31°
B-3	89,530.5	1,543,086.4	543.6	N/A	N/A
B-4	89,596.9	1,543,186.6	549.1	N/A	N/A
B-5	89,579.4	1,543,091.5	539.9	N/A	N/A
B-6	89,548.8	1,543,114.5	543.8	N/A	N/A
B-7	89,619.9	1,543,126.3	540.6	N/A	N/A
B-8	89,567.8	1,543,015.4	534.6	N/A	N/A
B-9	89,543.3	1,543,046.8	534.2	N 80° E	14°
B-10	89,594.7	1,542,923.0	533.7	N/A	N/A
B-11	89,532.9	1,542,964.8	533.9	N 61° E	14°
B-12	89,558.6	1,542,925.4	533.9	N 63° E	14°
B-13	89,587.4	1,542,935.7	536.4	N/A	N/A
B-14	89,566.1	1,542,893.0	535.3	N 56° E	14°
B-15	89,580.6	1,542,864.2	536.1	N 58° E	14°
B-16	89,613.0	1,542,880.2	535.1	N/A	N/A
B-17	89,598.7	1,542,823.0	534.8	N 56° E	15°
B-18	89,604.1	1,542,801.7	536.6	N 55° E	15°
B-19	89,619.6	1,542,783.0	537.5	N 70° W	15°
B-20	89,645.6	1,542,796.3	535.2	N/A	N/A
B-21	89,596.4	1,542,925.7	534.2	N/A	N/A
B-22	89,641.3	1,542,811.2	535.6	N/A	N/A
B-23	89,668.7	1,542,802.4	534.3	N 27° W	15°
B-24	89,656.7	1,542,838.3	533.4	N 27° W	15°
B-25	89,639.1	1,542,875.2	533.6	N 27° W	15°
B-26	89,627.7	1,542,907.9	533.7	N 28° W	15°
B-27	89,611.6	1,542,950.7	533.7	N 28° W	15°
B-28	89,598.0	1,542,979.9	533.3	N 24° E	15°
B-29	89,602.5	1,542,997.0	534.3	N/A	N/A
B-30	89,584.7	1,542,950.4	534.0	N/A	N/A

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE

2011 BORING LAYOUT

DRAWING NO. **3 OF 18**

DRAWN BY BFS

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A & E FILE NO. 175561026

DATE NOV., 2011

COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
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SCALE 1" = 20'

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NOTES:

1. Datum is the North American Vertical Datum of 1988 (NAVD88).
2. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend" for boring log legend.

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

2011 LOGS OF BORINGS

COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
FINANCE AND ADMINISTRATION CABINET
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SCALE: 1"=5'
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LOGS OF BORINGS

SCALE: 1"=5' (VERT. ONLY)

NOTES:

1. Datum is the North American Vertical Datum of 1988 (NAVD88).
2. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend" for boring log legend.

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE

2011 LOGS OF BORINGS

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SCALE 1"=5'

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LOGS OF BORINGS

SCALE: 1"=5' (VERT. ONLY)

NOTES:

1. Datum is the North American Vertical Datum of 1988 (NAVD88).
2. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend" for boring log legend.

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

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2011 LOGS OF BORINGS

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SCALE 1"=5'

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LOGS OF BORINGS
SCALE: 1"=5' (VERT. ONLY)

NOTES:

1. Datum is the North American Vertical Datum of 1988 (NAVD88).
2. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend" for boring log legend.

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE

2011 LOGS OF BORINGS

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SCALE 1"=5'

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LOGS OF BORINGS

SCALE: 1"=5' (VERT. ONLY)

NOTES:

1. Datum is the North American Vertical Datum of 1988 (NAVD88).
2. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend" for boring log legend.

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
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2011 LOGS OF BORINGS

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SCALE: 1"=5' (VERT. ONLY)

NOTES:

1. Datum is the North American Vertical Datum of 1988 (NAVD88).
2. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend" for boring log legend.

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE

2011 LOGS OF BORINGS

DRAWING NO. 12 OF 18

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SCALE 1"=5'

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LOGS OF BORINGS
SCALE: 1"=5' (VERT. ONLY)

NOTES:

1. Datum is the North American Vertical Datum of 1988 (NAVD88).
2. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend" for boring log legend.

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE	**2011 LOGS OF BORINGS**	DRAWING NO. **13 OF 18**
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PROFILE – BASELINE 'A' – STA. 10+00 TO STA. 12+90
SCALE: 1" = 10'

NOTES:

1. Some site features and dimensions were obtained from digital images of drawings prepared by the United States Army Corps of Engineers. Because of the long project history, undocumented repair efforts and lack of as-built information, not all site features may be accurately reflected hereon. Dimensions of portions of structures below water or the ground surface are based on boring results and/or interpretation of historical drawings and were not field verified. Utilities, electrical wiring, and mechanical components are not shown.
2. Elevations shown hereon are referenced to the North American Vertical Datum of 1988 (NAVD88). Elevations from historical drawings were converted to NAVD88 and have not been field verified.
3. The boring logs and related information shown on this drawing depict approximate subsurface conditions only at the specific boring locations noted and at the time of drilling. Conditions at other locations may differ from conditions occurring at boring locations. Also, the passage of time may result in a change in the subsurface conditions at any boring location. Correlations shown between borings are generally based on straight line interpolation or data from historical drawings. Actual conditions between borings are unknown and may differ from those shown.
4. See Sheet 3 of 18, "Lock and Dam No. 8, 2011 Boring Layout", for locations of sections and profiles.
5. See Sheets 7 of 18 through 13 of 18, "Lock and Dam No. 8, 2011 Logs of Borings", for detailed descriptions of borings. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend", for boring log legend.
6. Upper and lower pool levels represent crest elevations of Dam No. 8 and Dam No. 7, respectively.
7. Hydrographic information (stream bed contouring) was developed by Stantec Consulting Services Inc. on July 5 and 6, 2011 using a mapping grade GPS locator device and sonar equipment. The surface of the stream bed has likely changed since the performance of the hydrographic survey.
8. Inclined borings shown on the drawings are skewed from actual inclinations.

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE	BASELINE 'A' PROFILE STATION 10+00 TO STATION 12+90	DRAWING NO. 14 OF 18
DRAWN BY BFS	COMMONWEALTH OF KENTUCKY KENTUCKY RIVER AUTHORITY	SCALE AS SHOWN
CHECKED BY DAG/ALW	FINANCE AND ADMINISTRATION CABINET DEPARTMENT FOR FACILITIES MANAGEMENT DIVISION OF ENGINEERING	REVIEWED DIV. OF ENGR.
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DATE NOV., 2011	Stantec	ENGR. FILE NO. –

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1/15 PROFILE – BASELINE 'A' – STA. 12+90 TO STA. 14+50

SCALE: 1" = 10'

NOTES:

1. Some site features and dimensions were obtained from digital images of drawings prepared by the United States Army Corps of Engineers. Because of the long project history, undocumented repair efforts and lack of as-built information, not all site features may be accurately reflected hereon. Dimensions of portions of structures below water or the ground surface are based on boring results and/or interpretation of historical drawings and were not field verified. Utilities, electrical wiring, and mechanical components are not shown.
2. Elevations shown hereon are referenced to the North American Vertical Datum of 1988 (NAVD88). Elevations from historical drawings were converted to NAVD88 and have not been field verified.
3. The boring logs and related information shown on this drawing depict approximate subsurface conditions only at the specific boring locations noted and at the time of drilling. Conditions at other locations may differ from conditions occurring at boring locations. Also, the passage of time may result in a change in the subsurface conditions at any boring location. Correlations shown between borings are generally based on straight line interpolation or data from historical drawings. Actual conditions between borings are unknown and may differ from those shown.
4. See Sheet 3 of 18, "Lock and Dam No. 8, 2011 Boring Layout", for locations of sections and profiles.
5. See Sheets 7 of 18 through 13 of 18, "Lock and Dam No. 8, 2011 Logs of Borings", for detailed descriptions of borings. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend", for boring log legend.
6. Upper and lower pool levels represent crest elevations of Dam No. 8 and Dam No. 7, respectively.
7. Hydrographic information (stream bed contouring) was developed by Stantec Consulting Services Inc. on July 5 and 6, 2011 using a mapping grade GPS locator device and sonar equipment. The surface of the stream bed has likely changed since the performance of the hydrographic survey.
8. Inclined borings shown on the drawings are skewed from actual inclinations.

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RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE

BASELINE 'A' PROFILE
STATION 12+90 TO STATION 14+50

DRAWING NO. **15 OF 18**

DRAWN BY BFS

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DATE NOV., 2011

COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
FINANCE AND ADMINISTRATION CABINET
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SCALE AS SHOWN

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1/16 PROFILE – BASELINE 'B'
SCALE: 1" = 10'

NOTES:

1. Some site features and dimensions were obtained from digital images of drawings prepared by the United States Army Corps of Engineers. Because of the long project history, undocumented repair efforts and lack of as-built information, not all site features may be accurately reflected hereon. Dimensions of portions of structures below water or the ground surface are based on boring results and/or interpretation of historical drawings and were not field verified. Utilities, electrical wiring, and mechanical components are not shown.
2. Elevations shown hereon are referenced to the North American Vertical Datum of 1988 (NAVD88). Elevations from historical drawings were converted to NAVD88 and have not been field verified.
3. The boring logs and related information shown on this drawing depict approximate subsurface conditions only at the specific boring locations noted and at the time of drilling. Conditions at other locations may differ from conditions occurring at boring locations. Also, the passage of time may result in a change in the subsurface conditions at any boring location. Correlations shown between borings are generally based on straight line interpolation or data from historical drawings. Actual conditions between borings are unknown and may differ from those shown.
4. See Sheet 3 of 18, "Lock and Dam No. 8, 2011 Boring Layout", for locations of sections and profiles.
5. See Sheets 7 of 18 through 13 of 18, "Lock and Dam No. 8, 2011 Logs of Borings", for detailed descriptions of borings. See Sheet 4 of 18, "Lock and Dam No. 8, 2011 Soil Summary and Legend", for boring log legend.
6. Upper and lower pool levels represent crest elevations of Dam No. 8 and Dam No. 7, respectively.
7. Hydrographic information (stream bed contouring) was developed by Stantec Consulting Services Inc. on July 5 and 6, 2011 using a mapping grade GPS locator device and sonar equipment. The surface of the stream bed has likely changed since the performance of the hydrographic survey.
8. Inclined borings shown on the drawings are skewed from actual inclinations.

FOR INFORMATION ONLY

NOT FOR CONSTRUCTION

Section or Detail No.
Sheet Where Shown
REFERENCE KEY

REVISIONS	DATE
1	
2	
3	
4	
5	
6	
7	
8	
9	

RENOVATION OF KENTUCKY RIVER LOCK & DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE
DRAWN BY BFS
CHECKED BY DAG/ALW
A & E FILE NO. 175561026
DATE NOV., 2011

BASELINE 'B' PROFILE
COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
Stantec

DRAWING NO. 16 OF 18
SCALE AS SHOWN
REVIEWED DIV. OF ENGR.
For Intent Only
ENGR. FILE NO. –

AGENCY AUTHORIZED AGENT — Approved for Program Concept Only — DATE
DIVISION OF ENGINEERING — Approved for Program Concept Only — DATE

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APPENDIX B – PRE-CONSTRUCTION PRESSURE TESTING RESULTS

Stantec

Project	175561026		
Sheet No.	1 of 1	**Date**	6/21/2011
Hole #	B-1	**Rig #**	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	549.7 ft NAVD88	**Crew**	G. Thompson, K. Hicks
	Lock 8 Road, Jessamine County, KY	**Top of Rock Elev. (ft.)**	500.1 ft	**Inspector**	A. Smith
Boring Size	NQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	23.4 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
				Clock Times																	
Top Elev	Bottom Elev	Required	Actual	Start	End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
		5	5	9:20	9:25	10	10	50375.8	50391.8	16	23.40		Unable to maintain target pressure	16	2.138889	8.5	5	10	66		
		5	5	9:33	9:38	20	20	50385.2	50401.2	16			of 38 and 50 psi	16	2.138889	8.5	5	20	33		
497.1	488.6	5	5	9:39	9:44	10	10	50432.8	50441.3	8.5		23.50		8.5	1.136285	8.5	5	10	35	33	Group B Turbulent Flow
		5	5	11:06	11:11	20	20	50434.8	50436.6	1.8				1.8	0.240625	8.9	5	20	4		
		5	5	11:12	11:17	38	38	50449	50458.1	9.1				9.1	1.216493	8.9	5	38	10		
488.6	479.7	5	5	11:32	11:37	50	50	50462	50482.2	20.2				20.2	2.700347	8.9	5	50	16	0	Group C Dilation
		5	5	11:37	11:42	38	38	50482.7	50484.8	2.1				2.1	0.280729	8.9	5	38	2		
		5	5	11:43	11:48	20	20	50484.8	50484.9	0.1				0.1	0.013368	8.9	5	20	0		
		5	5	12:48	12:53	20	20	50492.7	50492.7	0	23.80			0	0	8.6	5	20	0		
		5	5	12:53	12:58	38	38	50493.4	50493.7	0.3				0.3	0.040104	8.6	5	38	0		
479.7	471.1	5	5	12:58	1:03	50	50	50495.6	50514.9	19.3				19.3	2.580035	8.6	5	50	16	0	Group C Dilation
		5	5	1:03	1:08	38	38	50516.9	50522.8	5.9				5.9	0.788715	8.6	5	38	6		
		5	5	1:08	1:13	20	20	50523.6	50523.9	0.3		23.70		0.3	0.040104	8.6	5	20	1		
		5	5	2:06	2:11	20	19	50520.6	50520.6	0	24.00			0	0	8.8	5	19	0		
		5	5	2:12	2:17	38	37	50522	50523.6	1.6				1.6	0.213889	8.8	5	37	2		
471.1	462.3	5	5	2:18	2:23	50	49	50537	50567.1	30.1				30.1	4.023785	8.8	5	49	25	0	Group C Dilation
		5	5	2:26	2:31	38	38	50570	50580.5	10.5				10.5	1.403646	8.8	5	38	11		
		5	5	2:31	2:36	20	20	50580.6	50580.6	0		24.10		0	0	8.8	5	20	0		
		5	5	3:43	3:48	20	20	50580	50580	0	28.10			0	0	8.6	5	20	0		
		5	5	3:50	3:55	38	39	50581	50582.6	1.6				1.6	0.213889	8.6	5	39	2		
462.3	453.7	5	5	3:55	4:00	50	50	50585.4	50609.7	24.3				24.3	3.248438	8.6	5	50	20	0	Group C Dilation
		5	5	4:01	4:05	38	39	50611.9	50616.6	4.7				4.7	0.628299	8.6	5	39	5		
		5	5	4:06	4:11	20	20	50615.5	50615.5	0		24.10		0	0	8.6	5	20	0		
		5	5	5:05	5:10	20	20	50613	50613	0	24.20			0	0	8.7	5	20	0		
		5	5	5:10	5:15	38	38	50614.4	50619.8	5.4				5.4	0.721875	8.7	5	38	6		
453.7	445.0	5	5	5:16	5:21	50	50	50623.4	50654.2	30.8				30.8	4.117361	8.7	5	50	25	0	Group C Dilation
		5	5	5:21	5:26	38	39	50656.2	50667.6	11.4				11.4	1.523958	8.7	5	39	12		
		5	5	5:26	5:31	20	20	50666.8	50666.8	0		24.20		0	0	8.7	5	20	0		

Stantec

Project 175561026
Sheet No. 1 of 2 **Date** 6/23/2011
Hole # B-2 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Surface Elevation (ft.) 549.8 ft NAVD88
Top of Rock Elev. (ft.) 500.9 ft
Crew G. Thompson, K. Hicks
Inspector A. Smith
Boring Size NQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter
Test Method Lugeon Test
Static Water Level 24.0 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
				Clock Times																	
Top Elev	Bottom Elev	Required	Actual	Start	End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
496.7	488.2	5	5	3:46	3:51	10	11	50932	50979.6	47.6	dry			47.6	6.363194	8.5	5	11	180	43	Group B Turbulent Flow
		5	5	3:52	3:59	20	21	50973	51022.4	49.4				49.4	6.603819	8.5	5	21	98		
		5	5	4:00	4:05	30	30	51035	51066.3	31.3				31.3	4.184201	8.5	5	30	43		
		5	5	4:11	4:16	20	20	51066.5	51131.4	64.9				64.9	8.675868	8.5	5	20	135		
		5	5	4:18	4:23	10	11	51135	51153.5	18.5		dry		18.5	2.47309	8.5	5	11	70		
488.2	479.6	5	5	5:41	5:46	20	20	51148.1	51148.1	0	dry			0	0	8.6	5	20	0	0	Group C Dilation
		5	5	5:46	5:51	38	38	51148.9	51149	0.1				0.1	0.013368	8.6	5	38	0		
		5	5	5:51	5:56	50	50	51149.5	51150.7	1.2				1.2	0.160417	8.6	5	50	1		
		5	5	5:57	6:02	38	38	51150.7	51150.8	0.1				0.1	0.013368	8.6	5	38	0		
		5	5	6:02	6:07	20	20	51150.6	51150.6	0		dry		0	0	8.6	5	20	0		
479.6	471.0	5	5	8:18	8:23	10	10	51205	51206.6	1.6	23.20			1.6	0.213889	8.6	5	10	7	1	Group C Dilation
		5	5	8:23	8:28	20	21	51208.1	51231	22.9				22.9	3.061285	8.6	5	21	45		
		5	5	8:31	8:36	30	30	51235	51270.3	35.3				35.3	4.718924	8.6	5	30	48		
		5	5	8:37	8:42	20	20	51270.4	51286.8	16.4				16.4	2.192361	8.6	5	20	34		
		5	5	8:43	8:48	10	10	51287.1	51287.3	0.2		23.50		0.2	0.026736	8.6	5	10	1		
471.0	462.5	5	5	9:30	9:35	20	20	51285.1	51285.1	0	23.30			0	0	8.6	5	20	0	0	Group C Dilation
		5	5	9:36	9:41	38	37	51285.8	51286	0.2				0.2	0.026736	8.6	5	37	0		
		5	5	9:41	9:46	50	50	51286.7	51291.4	4.7				4.7	0.628299	8.6	5	50	4		
		5	5	9:47	9:52	38	37	51291.5	51291.8	0.3				0.3	0.040104	8.6	5	37	0		
		5	5	9:52	9:57	20	20	51290.4	51290.4	0		23.70		0	0	8.6	5	20	0		
462.5	453.9	5	5	11:23	11:28	20	20	51300.4	51300.5	0.1	22.70			0.1	0.013368	8.6	5	20	0	0	Group C Dilation
		5	5	11:28	11:33	38	38	51300.8	51314.4	13.6				13.6	1.818056	8.6	5	38	15		
		5	5	11:33	11:38	50	50	51317.1	51345.8	28.7				28.7	3.836632	8.6	5	50	23		
		5	5	11:38	11:43	38	39	51346.6	51365.1	18.5				18.5	2.47309	8.6	5	39	19		
		5	5	11:43	11:48	20	20	54356.4	54356.4	0		23.30		0	0	8.6	5	20	0		
453.9	445.3	5	5	12:34	12:39	20	20	51374.5	51374.9	0.4	22.90			0.4	0.053472	8.6	5	20	1	1	Group A Laminar Flow
		5	5	12:39	12:44	38	38	51394.7	51394.7	0				0	0	8.6	5	38	0		
		5	5	12:44	12:49	50	50	51395.4	51395.7	0.3				0.3	0.040104	8.6	5	50	0		
		5	5	12:49	12:53	38	37	51395.7	51395.7	0				0	0	8.6	5	37	0		
		5	5	12:53	12:58	20	21	51395.7	51395.7	0		23.40		0	0	8.6	5	21	0		

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Project	175561026
Sheet No.	2 of 2
Date	6/23/2011
Hole #	B-2
Rig #	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	549.8 ft NAVD88	**Crew**	G. Thompson, K. Hicks
	Lock 8 Road, Jessamine County, KY	**Top of Rock Elev. (ft.)**	500.9 ft	**Inspector**	A. Smith
Boring Size	NQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	24.0 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test	
445.3	436.7	5	5	1:42	1:47	20	20	51388	51388	0	23.30		
		5	5	1:47	1:52	38	39	51389	51389	0			
		5	5	1:52	1:57	50	50	51389.1	51389.9	0.8			
		5	5	1:57	2:02	38	38	51389.5	51389.6	0.1			
		5	5	2:02	2:07	20	20	51388.6	51388.6	0		23.70	

Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
0	0	8.6	5	20	0	1	Group A Laminar Flow
0	0	8.6	5	39	0		
0.8	0.106944	8.6	5	50	1		
0.1	0.013368	8.6	5	38	0		
0	0	8.6	5	20	0		

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Project 175561026
Sheet No. 1 of 1 **Date** 6/22/2011
Hole # B-3 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Boring Size PQ Wireline
Test Method Lugeon Test

Surface Elevation (ft.) 543.6 ft NAVD88
Top of Rock Elev. (ft.) 499.5 ft
Pump Capacity 30 - 40 gallons
Static Water Level 20.2 ft

Crew T. Caudill, E. Caudill
Inspector J. Adams
Meter Type Badger Meter
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test	
496.8	489.1	5	5			10	10	50000	50072.5	72.5	15.80	16.90	
		5	5			20	20	50102	50202.8	100.8			
		5	5			10	10	50220	50298.5	78.5			

Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
72.5	9.69184	7.7	5	10	332	>100	Group B Turbulent Flow
100.8	13.475	7.7	5	20	231		
78.5	10.49392	7.7	5	10	360		

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Project 175561026
Sheet No. 1 of 1 **Date** 6/29/2011
Hole # B-4 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Boring Size PQ Wireline
Test Method Lugeon Test

Surface Elevation (ft.) 549.1 ft NAVD88
Top of Rock Elev. (ft.) 501.0 ft
Pump Capacity 30 - 40 gallons
Static Water Level 13.0 ft

Crew T. Caudill, E. Caudill
Inspector J. Adams
Meter Type Badger Meter
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (ps		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
498.5	490.6	5	5			20	20	51700	51759.5	59.5		13.00		59.5	7.95399	7.9	5	20	133	>100	Group B Turbulent Flow
		5	5			30	30	51788	51874	86				86	11.4965	7.9	5	30	128		
		5	5			40	38	51945	52046	101				101	13.5017	7.9	5	38	119		
		5	5			30	30	52055	52146.5	91.5				91.5	12.2318	7.9	5	30	136		
		5	5			20	20	52153	52226.3	73.3				73.3	9.79878	7.9	5	20	164		

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Project 175561026
Sheet No. 1 of 1 **Date** 6/23/2011
Hole # B-5 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County , KY
Surface Elevation (ft.) 539.9 ft NAVD88
Crew T. Caudill, E. Caudill
Top of Rock Elev. (ft.) 500.3 ft
Inspector J. Adams
Boring Size PQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter
Test Method Lugeon Test
Static Water Level 6.5 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test	
501.5	489.5	5	5			20	21	50667	50673	6.2		6.50	
		5	5			38	38	50680	50702	22.3			
		5	5			50	50	50707	50741	33.5			
		5	5			38	38	50745	50770	25			
		5	5			20	20	50773	50787	14.1			

Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
6.2	0.828819	12.0	5	21	9	21	Group D Wash-Out
22.3	2.981076	12.0	5	38	17		
33.5	4.478299	12.0	5	50	20		
25	3.342014	12.0	5	38	19		
14.1	1.884896	12.0	5	20	21		

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Project 175561026
Sheet No. 1 of 1 **Date** 6/30/2011
Hole # B-6 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Surface Elevation (ft.) 543.8 ft NAVD88
Top of Rock Elev. (ft.) 500.0 ft
Crew T. Caudill, E. Caudill
Inspector J. Adams
Boring Size PQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter
Test Method Lugeon Test
Static Water Level 19.5 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test	
497.3	490.0	5	5			20	20	52334	52401.4	67.4	19.50		Gauge did not reach 40 psi.
		5	5			30	30	52415	52505.5	90.5			Extra test at 10psi was run.
		5	5			20	20	52527	52603.8	76.8			
		5	5			10	9	52611	52662.8	51.8			
		5	5										

Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
67.4	9.010069	7.3	5	20	163	>100	Group B Turbulent Flow
90.5	12.09809	7.3	5	30	146		
76.8	10.26667	7.3	5	20	186		
51.8	6.924653	7.3	5	9	278		
0	0	7.3	5	0			

Stantec

Project 175561026
Sheet No. 1 of 1 **Date** 6/27/2011
Hole # B-7 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY

Boring Size PQ Wireline

Test Method Lugeon Test

Surface Elevation (ft.) 540.6 ft NAVD88

Top of Rock Elev. (ft.) 499.9 ft

Pump Capacity 30 - 40 gallons

Static Water Level 26.4 ft

Crew T. Caudill, E. Caudill

Inspector J. Adams

Meter Type Badger Meter

Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
499.8	489.6	5	5			10	10	51410	51467.3	57.3		26.40		57.3	7.659896	10.2	5	10	198	>100	Group B Turbulent Flow
		5	5			20	20	51475	51559	84				84	11.22917	10.2	5	20	145		
		5	5			10	10	51567	51629.5	62.5				62.5	8.355035	10.2	5	10	216		

Stantec

Project 175561026
Sheet No. 1 of 1 **Date** 7/7/2011
Hole # B-8 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Surface Elevation (ft.) 534.6 ft NAVD88
Crew G. Thompson, M. Rigsby
Top of Rock Elev. (ft.) 499.1 ft
Inspector A. Smith
Boring Size PQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter
Test Method Lugeon Test
Static Water Level 2.8 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test	
496.4	487.4	5	5	9:15	9:20	12	13	52685.8	52687.9	2.1	2.80		
		5	5	9:20	9:25	18	18	52688.1	52690.5	2.4			
		5	5	9:26	9:31	27	27	52691.1	52694.8	3.7			
		5	5	9:32	9:37	18	18	52695.3	52697.9	2.6			
		5	5	9:37	9:42	12	12	52698.1	52700.2	2.1		2.80	

Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
2.1	0.280729	9.0	5	13	6	6	Group A Laminar Flow
2.4	0.320833	9.0	5	18	5		
3.7	0.494618	9.0	5	27	5		
2.6	0.347569	9.0	5	18	6		
2.1	0.280729	9.0	5	12	7		

Stantec

Project	175561026
Sheet No.	1 of 1
Date	7/11/2011
Hole #	B-9
Rig #	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	534.6 ft NAVD88	**Crew**	G. Thompson, M. Rigsby
	Lock 8 Road, Jessamine County, KY	**Top of Rock Elev. (ft.)**	500.3 ft	**Inspector**	A. Smith
Boring Size	NQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.7 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
497.0	489.3	5	5	10:55	11:00	12	12	52706.5	52764.3	57.8	1.70			57.8	7.726736	7.7	5	12	221	>100	Group B Turbulent Flow
		5	5	11:00	11:05	18	18	52768	52833.3	65.3				65.3	8.72934	7.7	5	18	166		
		5	5	11:05	11:10	22	21	52838	52913.1	75.1				75.1	10.03941	7.7	5	21	164		
		5	5	11:10	11:15	18	18	52917.5	52987.2	69.7				69.7	9.317535	7.7	5	18	177		
		5	5	11:15	11:20	12	12	52990	53051.4	61.4		1.70		61.4	8.207986	7.7	5	12	234		
489.3	479.6	5	5	12:32	12:37	12	12	53058.9	53061.3	2.4	17.10			2.4	0.320833	9.7	5	12	7	5	Group A Laminar Flow
		5	5	12:38	12:43	20	20	53063.2	53065.3	2.1				2.1	0.280729	9.7	5	20	4		
		5	5	12:43	12:48	33	33	53066.7	53071.4	4.7				4.7	0.628299	9.7	5	33	5		
		5	5	12:49	12:54	20	20	53071.8	53074.8	3				3	0.401042	9.7	5	20	5		
		5	5	12:54	12:59	12	12	53075	53076.5	1.5		17.10		1.5	0.200521	9.7	5	12	5		
479.6	470.0	5	5	1:37	1:42	12	12	53078.4	53081.4	3	17.50			3	0.401042	9.6	5	12	9	5	Group C Dilation
		5	5	1:42	1:47	25	25	53083.2	53085.4	2.2				2.2	0.294097	9.6	5	25	3		
		5	5	1:47	1:52	42	42	53087	53105.4	18.4				18.4	2.459722	9.6	5	42	16		
		5	5	1:52	1:57	25	25	53106.4	53111.2	4.8				4.8	0.641667	9.6	5	25	7		
		5	5	1:57	2:02	12	13	53111.5	53113.4	1.9		17.50		1.9	0.253993	9.6	5	13	5		
470.0	460.0	5	5	2:34	2:39	18	18	53117.4	53118.6	1.2	19.20			1.2	0.160417	10.0	5	18	2	1	Group C Dilation
		5	5	2:40	2:45	34	34	53119.7	53138.3	18.6				18.6	2.486458	10.0	5	34	19		
		5	5	2:45	2:50	50	50	53141.8	53180.7	38.9				38.9	5.200174	10.0	5	50	27		
		5	5	2:51	2:56	34	34	53184.2	53203.4	19.2				19.2	2.566667	10.0	5	34	20		
		5	5	2:56	3:01	18	18	53202.9	53203.5	0.6		17.30		0.6	0.080208	10.0	5	18	1		
460.0	450.3	5	5	4:08	4:13	18	19	53206.5	53207.8	1.3	17.80			1.3	0.173785	9.7	5	19	2	2	Group C Dilation
		5	5	4:13	4:18	34	34	53208.3	53231.7	23.4				23.4	3.128125	9.7	5	34	25		
		5	5	4:18	4:23	50	50	53233.4	53287.6	54.2				54.2	7.245486	9.7	5	50	39		
		5	5	4:24	4:29	34	34	53311.8	53341.6	29.8				29.8	3.983681	9.7	5	34	32		
		5	5	4:29	4:34	18	18	53343	53345.4	2.4		17.80		2.4	0.320833	9.7	5	18	5		

Stantec

Project 175561026
Sheet No. 1 of 1 **Date** 7/12/2011
Hole # B-11 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Boring Size NQ Wireline
Test Method Lugeon Test

Surface Elevation (ft.) 533.9 ft NAVD88
Top of Rock Elev. (ft.) 499.4 ft
Pump Capacity 30 - 40 gallons
Static Water Level 1.7 ft

Crew G. Thompson, M. Rigsby
Inspector A. Smith
Meter Type Badger Meter
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
497.1	489.3	5	5	11:00	11:05	12	11	53347.4	53351.1	3.7	1.20			3.7	0.494618	7.8	5	11	15	9	Group B Turbulent Flow
		5	5	11:05	11:10	20	20	53351.6	53356.3	4.7				4.7	0.628299	7.8	5	20	11		
		5	5	11:10	11:15	29	28	53356.5	53361.8	5.3				5.3	0.708507	7.8	5	28	9		
		5	5	11:15	11:20	20	20	53362.1	53366.6	4.5				4.5	0.601563	7.8	5	20	10		
		5	5	11:20	11:25	12	12	53366.8	53369.8	3		1.50		3	0.401042	7.8	5	12	11		
489.3	479.7	5	5	12:08	12:13	12	12	53370.8	53371.4	0.6	1.10			0.6	0.080208	9.6	5	12	2	1	Group A Laminar Flow
		5	5	12:13	12:18	22	22	53371.7	53372.3	0.6				0.6	0.080208	9.6	5	22	1		
		5	5	12:19	12:24	38	39	53372.7	53373.9	1.2				1.2	0.160417	9.6	5	39	1		
		5	5	12:24	12:29	22	22	53374.2	53374.9	0.7				0.7	0.093576	9.6	5	22	1		
		5	5	12:29	12"34	12	12	53375	53375.5	0.5		1.60		0.5	0.06684	9.6	5	12	2		
479.7	469.8	5	5	1:20	1:25	17	17	53378.5	53380.4	1.9	1.20			1.9	0.253993	9.9	5	17	4	3	Group A Laminar Flow
		5	5	1:25	1:30	33	33	53381.1	53383.8	2.7				2.7	0.360938	9.9	5	33	3		
		5	5	1:30	1:35	47	47	53384.3	53387.7	3.4				3.4	0.454514	9.9	5	47	3		
		5	5	1:36	1:41	33	33	53387.9	53390.4	2.5				2.5	0.334201	9.9	5	33	3		
		5	5	1:41	1:46	17	17	53390.8	53392.2	1.4		1.50		1.4	0.187153	9.9	5	17	3		
469.8	460.1	5	5	2:14	2:19	18	17	53392.4	53392.6	0.2	1.20			0.2	0.026736	9.7	5	17	0	0	Group A Laminar Flow
		5	5	2:20	2:25	34	34	53392.9	53393.2	0.3				0.3	0.040104	9.7	5	34	0		
		5	5	2:26	2:31	50	50	53393.4	53393.8	0.4				0.4	0.053472	9.7	5	50	0		
		5	5	2:31	2:36	34	34	53393.8	53394.2	0.4				0.4	0.053472	9.7	5	34	0		
		5	5	2:36	2:41	18	18	53394.3	53394.5	0.2		1.50		0.2	0.026736	9.7	5	18	0		
460.1	450.3	5	5	4:11	4:16	18	18	53395.6	53395.7	0.1	1.20			0.1	0.013368	9.8	5	18	0	0	Group C Dilation
		5	5	4:17	4:22	34	34	53395.9	53396.2	0.3				0.3	0.040104	9.8	5	34	0		
		5	5	4:22	4:27	50	50	53396.5	53399.8	3.3				3.3	0.441146	9.8	5	50	2		
		5	5	4:27	4:32	34	34	53399.9	53400.2	0.3				0.3	0.040104	9.8	5	34	0		
		5	5	4:32	4:37	18	18	53400.3	53400.3	0		1.40		0	0	9.8	5	18	0		

Stantec

Project	175561026
Sheet No.	1 of 1
Date	7/13/2011
Hole #	B-12
Rig #	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	533.9 ft NAVD88	**Crew**	G. Thompson, M. Rigsby
	Lock 8 Road, Jessamine County , KY	**Top of Rock Elev. (ft.)**	499.6 ft	**Inspector**	A. Smith
Boring Size	NQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.7 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
495.9	489.2	5	5	10:24	10:29	12	13	53402.3	53406.6	4.3	1.20			4.3	0.574826	6.7	5	13	17	11	Group B Turbulent
		5	5	10:29	10:34	20	19	53407	53411.7	4.7				4.7	0.628299	6.7	5	19	13		
		5	5	10:34	10:39	29	29	53412.2	53418.1	5.9				5.9	0.788715	6.7	5	29	11		
		5	5	10:44	10:49	20	20	53418.4	53423.1	4.7				4.7	0.628299	6.7	5	20	12		
		5	5	10:50	10:55	12	12	53423.4	53427.2	3.8		1.70		3.8	0.507986	6.7	5	12	17		
489.2	479.4	5	5	11:41	11:46	12	12	53428.3	53430.9	2.6	1.10			2.6	0.347569	9.8	5	12	8	12	Group D Wash-Out
		5	5	11:47	11:52	23	23	53431.9	53436.8	4.9				4.9	0.655035	9.8	5	23	8		
		5	5	11:52	11:57	38	38	53438.1	53446.7	8.6				8.6	1.149653	9.8	5	38	8		
		5	5	11:57	12:02	23	23	53447.4	53452.6	5.2				5.2	0.695139	9.8	5	23	8		
		5	5	12:02	12:06	12	12	53452.8	53456.7	3.9		1.60		3.9	0.521354	9.8	5	12	12		
479.4	469.7	5	5	12:55	1:00	16	16	53458.4	53459.2	0.8	1.10			0.8	0.106944	9.7	5	16	2	0	Group A Laminar Flow
		5	5	1:00	1:05	30	30	53459.6	53460.2	0.6				0.6	0.080208	9.7	5	30	1		
		5	5	1:06	1:11	48	48	53460.4	53460.9	0.5				0.5	0.06684	9.7	5	48	0		
		5	5	1:11	1:16	30	30	53460.9	53461.4	0.5				0.5	0.06684	9.7	5	30	1		
		5	5	1:17	1:22	16	16	53461.4	53461.7	0.3		1.60		0.3	0.040104	9.7	5	16	1		
469.7	460.1	5	5	2:03	2:08	18	18	53463.7	53463.9	0.2	1.10			0.2	0.026736	9.6	5	18	0	0	Group A Laminar Flow
		5	5	2:08	2:13	34	34	53464.5	53464.8	0.3				0.3	0.040104	9.6	5	34	0		
		5	5	2:13	2:18	50	50	53465.1	53465.6	0.5				0.5	0.06684	9.6	5	50	0		
		5	5	2:19	2:24	34	34	53465.6	53465.7	0.1				0.1	0.013368	9.6	5	34	0		
		5	5	2:24	2:29	18	18	53465.7	53465.7	0		1.60		0	0	9.6	5	18	0		
460.1	450.3	5	5	3:05	3:10	18	19	53467	53467.4	0.4	1.30			0.4	0.053472	9.8	5	19	1	0	Group C Dilation
		5	5	3:10	3:15	34	35	53467.8	53468.9	1.1				1.1	0.147049	9.8	5	35	1		
		5	5	3:16	3:21	50	50	53469	53472.9	3.9				3.9	0.521354	9.8	5	50	3		
		5	5	3:21	3:26	34	34	53473.2	53473.5	0.3				0.3	0.040104	9.8	5	34	0		
		5	5	3:26	3:31	18	18	53473.5	53473.6	0.1		1.60		0.1	0.013368	9.8	5	18	0		

Stantec

Project 175561026
Sheet No. 1 of 1 **Date** 7/25/2011
Hole # B-13 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Surface Elevation (ft.) 536.4 ft NAVD88
Crew G. Thompson, M. Rigsby
Top of Rock Elev. (ft.) 499.3 ft
Inspector J. Adams
Boring Size PQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter
Test Method Lugeon Test
Static Water Level 2.0 ft
Meter # 93428424

Test Section (ft) Top Elev	Test Section (ft) Bottom Elev	Time of Test (min) Required	Time of Test (min) Actual	Clock Times Start	Clock Times End	Gage Pressure (psi) Required	Gage Pressure (psi) Actual	Meter Reading (gal) Start of Test	Meter Reading (gal) End of Test	Meter Reading (gal) Total	Static Water Levels (ft) Pre-Test	Static Water Levels (ft) Post-Test	Notes	Total Test Take (gal)	Total Test Take (ft^3)	Test Interval (vertical ft)	Time (min)	Actual Pressure (psi)	Lugeon Value Each Test	Lugeon Value Representative for Tested Stage	Lugeon Value Group
494.9	485.4	5	5	1:47	1:52	15	15	54182	54277.5	95.5	1.60		Test ran with pressure higher than	95.5	12.76649	9.5	5	15	236	>100	Group B Turbulent Flow
		5	5	1:53	1:58	22	21	54300	54422.1	122.1			assigned	122.1	16.3224	9.5	5	21	216		
		5	5	1:59	2:04	45	44	54455	54632.7	177.7				177.7	23.75503	9.5	5	44	150		
		5	5	2:05	2:10	22	22	54655	54783.1	128.1				128.1	17.12448	9.5	5	22	216		
		5	5	2:11	2:16	15	15	54800	54898.5	98.5		1.70		98.5	13.16753	9.5	5	15	244		
485.4	475.4	5	5	4:08	4:13	12	11	55260	55346.5	86.5	1.70		st two 5 minute runs were perform	86.5	11.56337	10.0	5	11	277	>100	Group B Turbulent Flow
		5	5	4:14	4:19	23	23	55360	55490	130			est was stopped and pressure was	130	17.37847	10.0	5	23	199		
		5	5	4:20	4:25	40	40	55515	55691.2	176.2			adjusted and ran with appropriate	176.2	23.55451	10.0	5	40	155		
		5	5	4:26	4:31	23	24	55711.1	55849	137.9				137.9	18.43455	10.0	5	24	203		
		5	5	4:31	4:36	12	12	55860	55959	99		1.70		99	13.23438	10.0	5	12	291		

Stantec

Project 175561026
Sheet No. 1 of 1 **Date** 7/14/2011
Hole # B-14 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Boring Size NQ Wireline
Test Method Lugeon Test

Surface Elevation (ft.) 535.3 ft NAVD88
Top of Rock Elev. (ft.) 500.6 ft
Pump Capacity 30 - 40 gallons
Static Water Level 1.7 ft

Crew G. Thompson, M. Rigsby
Inspector A. Smith
Meter Type Badger Meter
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
		5	5	10:35	10:40	12	12	53478.4	53485.8	7.4	1.30			7.4	0.989236	7.3	5	12	30		
		5	5	10:40	10:45	15	15	53487.1	53497.8	10.7				10.7	1.430382	7.3	5	15	34		
497.8	490.5	5	5	10:46	10:51	23	23	53499.5	53525.8	26.3				26.3	3.515799	7.3	5	23	55	12	Group C Dilation
		5	5	10:51	10:56	15	15	53527.8	53534.3	6.5				6.5	0.868924	7.3	5	15	21		
		5	5	10:56	11:01	12	12	53534.5	53537.4	2.9		1.60		2.9	0.387674	7.3	5	12	12		
		5	5	12:11	12:16	12	12	53534.8	53535	0.2	1.30			0.2	0.026736	9.7	5	12	1		
		5	5	12:16	12:21	21	21	53535.3	53535.5	0.2				0.2	0.026736	9.7	5	21	0		
490.5	480.8	5	5	12:21	12:26	32	32	53535.6	53536.4	0.8				0.8	0.106944	9.7	5	32	1	0	Group A Laminar Flow
		5	5	12:26	12:31	21	21	53536.5	53536.7	0.2				0.2	0.026736	9.7	5	21	0		
		5	5	12:32	12:37	12	12	53536.7	53536.8	0.1		1.60		0.1	0.013368	9.7	5	12	0		
		5	5	1:32	1:37	13	13	53537.9	53538.5	0.6	1.20			0.6	0.080208	9.7	5	13	2		
		5	5	1:37	1:42	25	25	53538.6	53538.7	0.1				0.1	0.013368	9.7	5	25	0		
480.8	471.1	5	5	1:43	1:48	42	42	53538.8	53540.4	1.6				1.6	0.213889	9.7	5	42	1	0	Group A Laminar Flow
		5	5	1:49	1:54	25	25	53540.5	53540.7	0.2				0.2	0.026736	9.7	5	25	0		
		5	5	1:54	1:59	13	13	53540.7	53540.8	0.1		1.70		0.1	0.013368	9.7	5	13	0		
		5	5	2:48	2:53	18	18	53541.8	53541.8	0	1.40			0	0	9.7	5	18	0		
		5	5	2:53	2:58	34	34	53542.1	53542.4	0.3				0.3	0.040104	9.7	5	34	0		
471.1	461.4	5	5	2:58	3:03	50	50	53542.7	53544.2	1.5				1.5	0.200521	9.7	5	50	1	0	Group A Laminar Flow
		5	5	3:04	3:09	34	34	53544.2	53544.2	0				0	0	9.7	5	34	0		
		5	5	3:09	3:14	18	18	53544.2	53544.2	0		1.80		0	0	9.7	5	18	0		
		5	5	4:02	4:07	18	18	53544.5	53544.6	0.1	1.10			0.1	0.013368	9.6	5	18	0		
		5	5	4:07	4:12	34	34	53544.8	53545.3	0.5				0.5	0.06684	9.6	5	34	1		
461.4	451.8	5	5	4:12	4:17	50	50	53545.7	53550.9	5.2				5.2	0.695139	9.6	5	50	4	0	Group C Dilation
		5	5	4:18	4:23	34	34	53551	53551.2	0.2				0.2	0.026736	9.6	5	34	0		
		5	5	4:23	4:28	18	18	53551.2	53551.2	0		1.60		0	0	9.6	5	18	0		

Stantec

Project	175561026
Sheet No.	1 of 1
Date	7/18/2011
Hole #	B-15
Rig #	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	536.1 ft NAVD88	**Crew**	G. Thompson, M. Rigsby
	Lock 8 Road, Jessamine County, KY	**Top of Rock Elev. (ft.)**	500.8 ft	**Inspector**	A. Smith
Boring Size	NQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.7 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)		Clock Times		Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Start	End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
498.7	491.6	5	5	10:26	11:31	9	9	53551	53551.2	0.2	1.20			0.2	0.026736	7.1	5	9	1	0	Group A Laminar
		5	5	11:31	11:36	12	12	53551.2	53551.2	0				0	0	7.1	5	12	0		
		5	5	11:37	11:42	18	18	53551.3	53551.7	0.4				0.4	0.053472	7.1	5	18	1		
		5	5	11:42	11:47	12	12	53551.7	53551.7	0				0	0	7.1	5	12	0		
		5	5	11:47	11:52	9	9	53551.7	53551.7	0		1.60		0	0	7.1	5	9	0		
491.6	481.9	5	5	12:22	12:27	12	12	53551.7	53551.9	0.2	1.40			0.2	0.026736	9.7	5	12	1	0	Group A Laminar
		5	5	12:28	12:33	17	17	53551.9	53552	0.1				0.1	0.013368	9.7	5	17	0		
		5	5	12:33	12:38	27	26	53552.2	53552.4	0.2				0.2	0.026736	9.7	5	26	0		
		5	5	12:38	12:43	17	17	53552.4	53552.4	0				0	0	9.7	5	17	0		
		5	5	12:44	12:49	12	12	53552.4	53552.4	0		1.60		0	0	9.7	5	12	0		
481.9	472.2	5	5	1:24	1:29	12	12	53552.6	53552.7	0.1	1.20			0.1	0.013368	9.7	5	12	0	0	Group A Laminar
		5	5	1:29	1:34	22	22	53552.9	53553.1	0.2				0.2	0.026736	9.7	5	22	0		
		5	5	1:35	1:40	37	37	53553.3	53553.6	0.3				0.3	0.040104	9.7	5	37	0		
		5	5	1:45	1:50	22	22	53553.6	53553.6	0				0	0	9.7	5	22	0		
		5	5	1:50	1:55	12	12	53553.6	53553.6	0		1.50		0	0	9.7	5	12	0		
472.2	462.2	5	5	2:25	2:30	16	16	53553.8	53554	0.2	1.10			0.2	0.026736	10.0	5	16	0	0	Group C Dilation
		5	5	2:30	2:35	31	31	53554.3	53554.5	0.2				0.2	0.026736	10.0	5	31	0		
		5	5	2:35	2:40	47	47	53556.4	53570.8	14.4				14.4	1.925	10.0	5	47	11		
		5	5	2:41	2:46	31	31	53571.1	53571.3	0.2				0.2	0.026736	10.0	5	31	0		
		5	5	2:46	2:51	16	16	53571.3	53571.3	0		1.60		0	0	10.0	5	16	0		
462.2	452.3	5	5	3:26	3:31	18	18	53581.5	53581.7	0.2	1.20			0.2	0.026736	9.9	5	18	0	0	Group A Laminar
		5	5	3:31	3:36	34	34	53581.9	53582	0.1				0.1	0.013368	9.9	5	34	0		
		5	5	3:37	3:42	50	50	53582	53582.3	0.3				0.3	0.040104	9.9	5	50	0		
		5	5	3:42	3:47	34	34	53582.3	53582.3	0				0	0	9.9	5	34	0		
		5	5	3:48	3:53	18	18	53582.3	53582.3	0		1.70		0	0	9.9	5	18	0		

Stantec

Project 175561026
Sheet No. 1 of 1 **Date** 7/26/2011
Hole # B-16 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Surface Elevation (ft.) 535.1 ft NAVD88
Top of Rock Elev. (ft.) 500.7 ft
Crew G. Thompson, M. Rigsby
Inspector J. Adams

Boring Size PQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter

Test Method Lugeon Test
Static Water Level 1.7 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
497.0	488.0	5	5	12:06	12:11	10	10	55973.3	55974.8	1.5	1.70			1.5	0.200521	9.0	5	10	6	4	Group E Void Filling
		5	5	12:11	12:16	15	15	55975.1	55977.1	2				2	0.267361	9.0	5	15	5		
		5	5	12:17	12:22	20	20	55977.3	55979.6	2.3				2.3	0.307465	9.0	5	20	5		
		5	5	12:23	12:28	15	15	55979.9	55981.6	1.7				1.7	0.227257	9.0	5	15	4		
		5	5	12:28	12:33	10	10	55981.8	55983	1.2		1.70		1.2	0.160417	9.0	5	10	5		
488.0	477.8	5	5	1:47	1:52	10	10	55985.9	55987.4	1.5	1.70			1.5	0.200521	10.2	5	10	5	3	Group E Void Filling
		5	5	1:52	1:57	20	20	55988.5	55991	2.5				2.5	0.334201	10.2	5	20	4		
		5	5	1:57	2:02	30	30	55992.1	55995.2	3.1				3.1	0.41441	10.2	5	30	4		
		5	5	2:02	2:07	20	20	55995.5	55997.1	1.6				1.6	0.213889	10.2	5	20	3		
		5	5	2:07	2:12	10	10	55997.2	55998.1	0.9		1.70		0.9	0.120313	10.2	5	10	3		
477.8	467.8	5	5	3:27	3:32	10	10	56000.9	56002.1	1.2	1.70			1.2	0.160417	10.0	5	10	4	3	Group A Laminar
		5	5	3:32	3:37	25	25	56003.7	56005.9	2.2				2.2	0.294097	10.0	5	25	3		
		5	5	3:37	3:42	40	40	56007.2	56010.3	3.1				3.1	0.41441	10.0	5	40	3		
		5	5	3:42	3:47	25	25	56010.5	56012.7	2.2				2.2	0.294097	10.0	5	25	3		
		5	5	3:47	3:52	10	10	56012.8	56014.2	1.4		1.70		1.4	0.187153	10.0	5	10	5		

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Project 175561026
Sheet No. 1 of 1 **Date** 7/19/2011
Hole # B-17 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Surface Elevation (ft.) 534.8 ft NAVD88
Top of Rock Elev. (ft.) 502.0 ft
Crew G. Thompson, M. Rigsb
Inspector A. Smith

Boring Size NQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter

Test Method Lugeon Test
Static Water Level 1.7 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
		5	5	10:13	10:18	12	12	53583.3	53583.8	0.5	1.30			0.5	0.06684	8.6	5	12	2		
		5	5	10:18	10:23	14	14	53583.9	53584.5	0.6				0.6	0.080208	8.6	5	14	2		
499.3	490.7	5	5	10:24	10:29	23	23	53584.5	53585.8	1.3				1.3	0.173785	8.6	5	23	2	2	Group A Laminar
		5	5	10:29	10:34	14	14	53585.8	53586.4	0.6				0.6	0.080208	8.6	5	14	2		
		5	5	10:34	10:39	12	12	53586.4	53586.9	0.5		1.50		0.5	0.06684	8.6	5	12	2		
		5	5	11:38	11:43	12	12	53589	53589	0	1.20			0	0	9.8	5	12	0		
		5	5	11:43	11:48	21	21	53589	53589.1	0.1				0.1	0.013368	9.8	5	21	0		
490.7	480.9	5	5	11:48	11:53	32	32	53589.1	53589.4	0.3				0.3	0.040104	9.8	5	32	0	0	Group A Laminar
		5	5	11:53	11:58	21	21	53589.4	53589.4	0				0	0	9.8	5	21	0		
		5	5	11:59	12:04	12	12	53589.4	53589.4	0		1.50		0	0	9.8	5	12	0		
		5	5	12:31	12:36	13	13	53590.2	53590.3	0.1	1.30			0.1	0.013368	9.4	5	13	0		
		5	5	12:36	12:41	25	25	53590.6	53590.6	0				0	0	9.4	5	25	0		
480.9	471.5	5	5	12:41	12:46	42	42	53591.1	53592.2	1.1				1.1	0.147049	9.4	5	42	1	1	Group A Laminar
		5	5	12:47	12:52	25	25	53592.2	53592.8	0.6				0.6	0.080208	9.4	5	25	1		
		5	5	12:52	12:57	13	13	53592.8	53593.1	0.3		1.60		0.3	0.040104	9.4	5	13	1		
		5	5	1:52	1:57	18	18	53594.6	53594.8	0.2	1.10			0.2	0.026736	9.8	5	18	0		
		5	5	1:58	2:03	34	34	53595.2	53596.3	1.1				1.1	0.147049	9.8	5	34	1		
471.5	461.7	5	5	2:03	2:08	50	48	53596.4	53598.5	2.1				2.1	0.280729	9.8	5	48	2	1	Group A Laminar
		5	5	2:09	2:14	34	34	53598.5	53599	0.5				0.5	0.06684	9.8	5	34	1		
		5	5	2:14	2:19	18	18	53599.1	53599.4	0.3		1.70		0.3	0.040104	9.8	5	18	1		
		5	5	2:47	2:52	18	18	53600.8	53602	1.2	1.40			1.2	0.160417	8.6	5	18	3		
		5	5	2:52	2:57	34	34	53602.1	53603.2	1.1				1.1	0.147049	8.6	5	34	1		
461.7	452.0	5	5	2:58	3:03	50	48	53603.7	53610.4	6.7				6.7	0.89566	8.6	5	48	6	1	Group C Dilation
		5	5	3:03	3:08	34	34	53610.8	53612.1	1.3				1.3	0.173785	8.6	5	34	2		
		5	5	3:08	3:13	18	18	53612.1	53612.7	0.6		1.70		0.6	0.080208	8.6	5	18	1		

Stantec

Project 175561026
Sheet No. 1 of 1 **Date** 7/19/2011
Hole # B-18 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Surface Elevation (ft.) 536.6 ft NAVD88
Top of Rock Elev. (ft.) 506.8 ft
Crew G. Thompson, M. Rigsby
Inspector A. Smith

Boring Size NQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter

Test Method Lugeon Test
Static Water Level 1.8 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
		5	5	9:40	9:45	12	12	53613.1	53613.4	0.3	1.20			0.3	0.040104	11.0	5	12	1		
		5	5	9:45	9:50	14	14	53613.4	53613.6	0.2				0.2	0.026736	11.0	5	14	0		
503.3	492.3	5	5	9:50	9:55	24	24	53613.8	53614.4	0.6				0.6	0.080208	11.0	5	24	1	1	Group A Laminar
		5	5	9;55	10:00	14	14	53614.4	53614.6	0.2				0.2	0.026736	11.0	5	14	0		
		5	5	10:00	10:05	12	12	53614.6	53614.7	0.1		1.60		0.1	0.013368	11.0	5	12	0		
		5	5	10:41	10:46	12	12	53615.3	53615.4	0.1	1.30			0.1	0.013368	9.7	5	12	0		
		5	5	10:46	10:51	20	20	53615.6	53615.8	0.2				0.2	0.026736	9.7	5	20	0		
492.3	482.6	5	5	10:52	10:57	34	34	53616	53616.4	0.4				0.4	0.053472	9.7	5	34	0	0	Group A Laminar
		5	5	10:57	11:02	20	20	53616.4	53616.4	0				0	0	9.7	5	20	0		
		5	5	11:03	11:08	12	12	53616.4	53616.4	0		1.60		0	0	9.7	5	12	0		
		5	5	11:52	11:57	14	14	53617.4	53617.4	0	1.10			0	0	9.5	5	14	0		
		5	5	11:57	12:02	26	26	53617.6	53617.9	0.3				0.3	0.040104	9.5	5	26	0		
482.6	473.1	5	5	12:03	12:08	43	43	53618	53618.6	0.6				0.6	0.080208	9.5	5	43	1	0	Group A Laminar
		5	5	12:08	12:13	26	26	53618.6	53618.8	0.2				0.2	0.026736	9.5	5	26	0		
		5	5	12:13	12:18	14	14	53618.8	53618.9	0.1		1.40		0.1	0.013368	9.5	5	14	0		
		5	5	12:57	1:02	18	18	53619.6	53620.1	0.5	1.30			0.5	0.06684	9.8	5	18	1		
		5	5	1:02	1:07	34	34	53620.4	53621.3	0.9				0.9	0.120313	9.8	5	34	1		
473.1	463.3	5	5	1:07	1:12	50	50	53621.9	53632.4	10.5				10.5	1.403646	9.8	5	50	8	1	Group C Dilation
		5	5	1:12	1:17	34	34	53632.5	53634.2	1.7				1.7	0.227257	9.8	5	34	2		
		5	5	1:17	1:22	18	18	53634.2	53634.6	0.4		1.60		0.4	0.053472	9.8	5	18	1		
		5	5	3:15	3:20	18	18	53636.4	53637.2	0.8	1.40			0.8	0.106944	9.5	5	18	2		
		5	5	3:21	3:26	34	34	53637.5	53640	2.5				2.5	0.334201	9.5	5	34	3		
463.3	453.8	5	5	3:26	3:31	50	50	53641.3	53660.5	19.2				19.2	2.566667	9.5	5	50	14	2	Group C Dilation
		5	5	3:32	3:37	34	34	53663.9	53664.9	1				1	0.133681	9.5	5	34	1		
		5	5	3:37	3;42	18	18	53665	53665.5	0.5		1.70		0.5	0.06684	9.5	5	18	1		

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Project	175561026
Sheet No.	1 of 1
Date	7/21/2011
Hole #	B-19
Rig #	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	537.5 ft NAVD88	**Crew**	G. Thompson, M. Rigsby
	Lock 8 Road, Jessamine County, KY	**Top of Rock Elev. (ft.)**	521.7 ft	**Inspector**	A. Smith
Boring Size	NQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.8 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
		5	5	10:34	10:39	8	8	53662	53676.8	14.8	10.20			14.8	1.978472	9.8	5	8	67		
		5	5	10:40	10:45	10	10	53733	53781.3	48.3				48.3	6.456771	9.8	5	10	174		
517.3	507.5	5	5	10:45	10:50	15	15	53788	53847.2	59.2				59.2	7.913889	9.8	5	15	142	>100	Group D Wash Out
		5	5	10:51	10:56	10	10	53851.3	53901.6	50.3				50.3	6.724132	9.8	5	10	181		
		5	5	10:56	11:01	8	8	53904	53950	46		10.60		46	6.149306	9.8	5	8	207		
		5	5	11:52	11:57	12	12	53952.4	53952.5	0.1	10.20			0.1	0.013368	9.5	5	12	0		
		5	5	11:57	12:02	16	16	53952.8	53952.8	0				0	0	9.5	5	16	0		
507.5	498.0	5	5	12:03	12:08	25	25	53953	53953.5	0.5				0.5	0.06684	9.5	5	25	1	0	Group A Laminar
		5	5	12:08	12:13	16	16	53953.5	53953.6	0.1				0.1	0.013368	9.5	5	16	0		
		5	5	12:13	12:18	12	12	53953.6	53953.6	0		10.50		0	0	9.5	5	12	0		
		5	5	12:42	12:47	12	12	53955.5	53955.5	0	10.30			0	0	9.7	5	12	0		
		5	5	12:47	12:52	21	21	53955.8	53955.8	0				0	0	9.7	5	21	0		
498.0	488.3	5	5	12:52	12:57	34	34	53955.8	53955.9	0.1				0.1	0.013368	9.7	5	34	0	0	Group A Laminar
		5	5	12:57	1:02	21	21	53955.9	53955.9	0				0	0	9.7	5	21	0		
		5	5	1:02	1:07	12	12	53955.9	53955.9	0		10.70		0	0	9.7	5	12	0		
		5	5	1:53	1:58	14	14	53956.9	53956.9	0	10.10			0	0	10.0	5	14	0		
		5	5	1:58	2;03	27	22	53957.2	53957.5	0.3				0.3	0.040104	10.0	5	22	0		
488.3	478.3	5	5	2:03	2:08	44	44	53958.2	53973.3	15.1				15.1	2.018576	10.0	5	44	12	0	Group C Dilation
		5	5	2;08	2:13	27	26	53973.8	53974.6	0.8				0.8	0.106944	10.0	5	26	1		
		5	5	2:13	2:18	14	14	53974.6	53974.6	0		10.50		0	0	10.0	5	14	0		
		5	5	2:39	2:44	18	18	53975.2	53975.2	0	10.30			0	0	9.7	5	18	0		
		5	5	2:44	2:49	34	34	53975.7	53979.4	3.7				3.7	0.494618	9.7	5	34	4		
478.3	468.6	5	5	2:49	2:54	50	50	53972	54015.7	43.7				43.7	5.84184	9.7	5	50	32	0	Group C Dilation
		5	5	2:54	2:59	34	34	54017.3	54026.5	9.2				9.2	1.229861	9.7	5	34	10		
		5	5	2:59	3:04	18	18	54026.5	54026.5	0		10.70		0	0	9.7	5	18	0		
		5	5	3:47	3:52	18	18	54026.5	54026.8	0.3	10.40			0.3	0.040104	9.8	5	18	1		
		5	5	3:52	3:57	34	34	54028.4	54043.1	14.7				14.7	1.965104	9.8	5	34	16		
468.6	458.8	5	5	3:57	4:02	50	50	54065	54108	43				43	5.748264	9.8	5	50	31	1	Group C Dilation
		5	5	4:02	4:07	34	34	54112.8	54138.2	25.4				25.4	3.395486	9.8	5	34	27		
		5	5	4:07	4:12	18	18	54149.4	54149.6	0.2		10.40		0.2	0.026736	9.8	5	18	0		

Stantec

Project	175561026		
Sheet No.	1 of 1	**Date**	7/27/2011
Hole #	B-20	**Rig #**	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	535.2 ft NAVD88	**Crew**	G. Thompson, M. Rigsby
	Lock 8 Road, Jessamne County, KY	**Top of Rock Elev. (ft.)**	517.8 ft	**Inspector**	A. Smith
Boring Size	PQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.7 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
513.7	503.7	5	5	11:45	11:50	5	5	56022.1	56024	1.9	1.70			1.9	0.253993	10.0	5	5	13	13	Group D Wash Out
		5	5	11:50	11:55	10	10	56025.5	56030.6	5.1				5.1	0.681771	10.0	5	10	18		
		5	5	12:00	12:05	15	15	56031.5	56039.2	7.7				7.7	1.02934	10.0	5	15	18		
		5	5	12:05	12:10	10	10	56040	56045	5				5	0.668403	10.0	5	10	18		
		5	5	12:10	12:15	5	5	56045.8	56049.3	3.5		1.70		3.5	0.467882	10.0	5	5	25		
503.7	493.5	5	5	1:18	1:23	10	10	56051.6	56053.6	2	1.70			2	0.267361	10.2	5	10	7	5	Group A Laminar
		5	5	1:23	1:28	15	15	56054.6	56057	2.4				2.4	0.320833	10.2	5	15	6		
		5	5	1:28	1:33	20	20	56057.5	56060	2.5				2.5	0.334201	10.2	5	20	4		
		5	5	1:33	1:38	15	15	56060.3	56062.2	1.9				1.9	0.253993	10.2	5	15	4		
		5	5	1:38	1:43	10	10	56062.4	56063.6	1.2		1.70		1.2	0.160417	10.2	5	10	4		

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Project	175561026		
Sheet No.	1 of 1	**Date**	8/15/2011
Hole #	B-21	**Rig #**	CME 45T

Location	KY River Lock and Dam No. 8 Lock 8 Road, Jessamine County, KY	**Surface Elevation (ft.)**	534.2 ft NAVD88	**Crew**	G. Thompson, M. Rigsby
		Top of Rock Elev. (ft.)	500.0 ft	**Inspector**	A. Smith
Boring Size	PQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.6 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test	
497.2	487.2	5	5	10:59	11:04	12	12	57896.8	57898.9	2.1	1.40		
		5	5	11:04	11:09	21	21	57899.8	57902.7	2.9			
		5	5	11:09	11:14	30	30	57903.4	57907.5	4.1			
		5	5	11:15	11:20	21	21	57907.6	57909.5	1.9			
		5	5	11:20	11:25	12	12	57909.6	57910.9	1.3		1.60	
487.2	477.0	5	5	12:41	12:46	13	12	57914	57916	2	1.40		
		5	5	12:46	12:51	25	25	57917	57920.3	3.3			
		5	5	12:52	12:57	40	40	57920.2	57923.2	3			
		5	5	12:57	1:02	25	25	57923.3	57924.7	1.4			
		5	5	1:02	1:06	13	13	57925.1	57926	0.9		1.60	

Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
2.1	0.280729	10.0	5	12	6	3	Group E Void Filling
2.9	0.387674	10.0	5	21	5		
4.1	0.54809	10.0	5	30	5		
1.9	0.253993	10.0	5	21	3		
1.3	0.173785	10.0	5	12	4		
2	0.267361	10.2	5	12	6	2	Group E Void Filling
3.3	0.441146	10.2	5	25	5		
3	0.401042	10.2	5	40	3		
1.4	0.187153	10.2	5	25	2		
0.9	0.120313	10.2	5	13	2		

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Project 175561026
Sheet No. 1 of 1 **Date** 7/27/2011
Hole # B-22 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Surface Elevation (ft.) 536.6 ft NAVD88
Top of Rock Elev. (ft.) 506.4 ft
Crew G. Thompson, M. Rigsby
Inspector J. Adams
Boring Size PQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter
Test Method Lugeon Test
Static Water Level 1.7 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
503.1	494.1	5	5	11:20	11:25	10	10	56066.6	56066.7	0.1	1.70			0.1	0.013368	9.0	5	10	0	3	Group A Laminar
		5	5	11:25	11:30	15	15	56067.5	56068.8	1.3				1.3	0.173785	9.0	5	15	3		
		5	5	11:30	11:35	20	20	56069.1	56070.5	1.4				1.4	0.187153	9.0	5	20	3		
		5	5	11:35	11:40	15	15	56070.7	56072	1.3				1.3	0.173785	9.0	5	15	3		
		5	5	11:40	11:45	10	10	56072.1	56072.8	0.7		1.70		0.7	0.093576	9.0	5	10	3		
494.1	484.0	5	5	1:05	1:10	10	10	56076.3	56076.5	0.2	1.70			0.2	0.026736	10.1	5	10	1	1	Group A Laminar
		5	5	1:10	1:15	18	18	56078.1	56078.8	0.7				0.7	0.093576	10.1	5	18	1		
		5	5	1:15	1:20	28	28	56079.9	56080.5	0.6				0.6	0.080208	10.1	5	28	1		
		5	5	1:20	1:25	18	18	56080.6	56080.6	0				0	0	10.1	5	18	0		
		5	5	1:25	1:30	10	10	56080.6	56081.1	0.5		1.70		0.5	0.06684	10.1	5	10	2		
484.0	474.0	5	5	2:35	2:40	10	10	56084	56089.1	5.1	1.70			5.1	0.681771	10.0	5	10	18	3	Group A Laminar
		5	5	2:40	2:45	23	23	56089.3	56091.3	2				2	0.267361	10.0	5	23	3		
		5	5	2:45	2:50	40	38	56091.6	56094.5	2.9				2.9	0.387674	10.0	5	38	3		
		5	5	2:50	2:55	23	23	56095.4	56098	2.6				2.6	0.347569	10.0	5	23	4		
		5	5	2:55	3:00	10	10	56098.1	56099.7	1.6		1.70		1.6	0.213889	10.0	5	10	6		

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Project 175561026
Sheet No. 1 of 1 **Date** 8/4/2011
Hole # B-23 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY

Surface Elevation (ft.) 534.3 ft NAVD88

Top of Rock Elev. (ft.) 521.5 ft

Crew G. Thompson, M. Rigsby

Inspector A. Smith

Boring Size NQ Wireline

Pump Capacity 30 - 40 gallons

Meter Type Badger Meter

Test Method Lugeon Test

Static Water Level 1.7 ft

Meter # 93428424

Test Section (ft) Top Elev	Test Section (ft) Bottom Elev	Time of Test (min) Required	Time of Test (min) Actual	Clock Times Start	Clock Times End	Gage Pressure (psi) Required	Gage Pressure (psi) Actual	Meter Reading (gal) Start of Test	Meter Reading (gal) End of Test	Meter Reading (gal) Total	Static Water Levels (ft) Pre-Test	Static Water Levels (ft) Post-Test	Notes	Total Test Take (gal)	Total Test Take (ft^3)	Test Interval (vertical ft)	Time (min)	Actual Pressure (psi)	Lugeon Value Each Test	Lugeon Value Representative for Tested Stage	Lugeon Value Group
		5	5	12:41	12:46	8	8	57118.4	57127.5	9.1	1.40			9.1	1.216493	9.7	5	8	41		
		5	5	12:46	12:51	10	10	57128	57137	9				9	1.203125	9.7	5	10	33		
518.5	508.8	5	5	12:51	12:56	16	16	57138	57150.7	12.7				12.7	1.697743	9.7	5	16	29	29	Group B Turbulent
		5	5	12:56	1:01	10	10	57151	57159.9	8.9				8.9	1.189757	9.7	5	10	32		
		5	5	1:01	1:06	8	8	57160.1	57168.4	8.3		1.60		8.3	1.109549	9.7	5	8	38		
		5	5	1:37	1:42	12	12	57168.7	57177.8	9.1	1.40			9.1	1.216493	9.6	5	12	28		
		5	5	1:42	1:47	16	16	57178.8	57189.2	10.4				10.4	1.390278	9.6	5	16	24		
508.8	499.2	5	5	1:47	1:52	25	25	57190.1	57202.1	12				12	1.604167	9.6	5	25	18	14	Group E Void Filling
		5	5	1:52	1:57	16	16	57202.9	57211.1	8.2				8.2	1.096181	9.6	5	16	19		
		5	5	1:57	2:02	12	12	57211.4	57216.1	4.7		1.60		4.7	0.628299	9.6	5	12	14		
		5	5	2:39	2:44	12	12	57216.3	57216.4	0.1	1.30			0.1	0.013368	9.8	5	12	0		
		5	5	2:44	2:49	22	22	57216.8	57217	0.2				0.2	0.026736	9.8	5	22	0		
499.2	489.4	5	5	2:49	2:54	35	35	57217	57217.4	0.4				0.4	0.053472	9.8	5	35	0	0	Group A Laminar
		5	5	2:55	3:00	22	22	57217.4	57217.7	0.3				0.3	0.040104	9.8	5	22	0		
		5	5	3:00	3:05	12	12	57217.7	57217.7	0		1.70		0	0	9.8	5	12	0		
		5	5	3:35	3:40	14	14	57217.9	57218.5	0.6	1.50			0.6	0.080208	9.8	5	14	2		
		5	5	3:41	3:46	28	28	57218.5	57219.2	0.7				0.7	0.093576	9.8	5	28	1		
489.4	479.6	5	5	3:46	3:51	45	45	57219.2	57219.8	0.6				0.6	0.080208	9.8	5	45	0	0	Group A Laminar
		5	5	3:51	3:56	28	28	57219.8	57219.9	0.1				0.1	0.013368	9.8	5	28	0		
		5	5	3:56	4:01	14	12	57219.9	57219.9	0		1.60		0	0	9.8	5	12	0		
		5	5	4:32	4:37	18	18	57220.5	57221.6	1.1	1.20			1.1	0.147049	9.6	5	18	2		
		5	5	4:38	4:43	34	34	57221.9	57223.9	2				2	0.267361	9.6	5	34	2		
479.6	470.0	5	5	4:43	4:48	50	48	57224.5	57235.3	10.8				10.8	1.44375	9.6	5	48	8	2	Group C Dilation
		5	5	4:49	4:54	34	34	57236	57237.8	1.8				1.8	0.240625	9.6	5	34	2		
		5	5	4:54	4:59	18	18	57237.8	57238.2	0.4		1.50		0.4	0.053472	9.6	5	18	1		

Stantec

Project	175561026		
Sheet No.	1 of 1	**Date**	8/5/2011
Hole #	B-24	**Rig #**	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	533.4 ft NAVD88	**Crew**	G. Thompson, M. Rigsby
	Lock 8 Road, Jessamine County, KY	**Top of Rock Elev. (ft.)**	504.3 ft	**Inspector**	A. Smith
Boring Size	NQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.3 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
				Clock Times																	
Top Elev	Bottom Elev	Required	Actual	Start	End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
		5	5	9:05	9:10	12	12	57238.8	57238.9	0.1	1.00			0.1	0.013368	7.7	5	12	0		
		5	5	9:10	9:15	20	20	57239	57239.2	0.2				0.2	0.026736	7.7	5	20	0		
501.3	493.6	5	5	9:16	9:21	28	28	57239.3	57239.5	0.2				0.2	0.026736	7.7	5	28	0	0	Group A Laminar
		5	5	9:21	9:26	20	20	57239.5	57239.6	0.1				0.1	0.013368	7.7	5	20	0		
		5	5	9:26	9:31	12	12	57239.6	57239.6	0		1.30		0	0	7.7	5	12	0		
		5	5	10:08	10:13	12	12	57240.9	57241	0.1	1.00			0.1	0.013368	9.6	5	12	0		
		5	5	10:13	10:18	23	23	57241.2	57241.4	0.2				0.2	0.026736	9.6	5	23	0		
493.6	484.0	5	5	10:19	10:24	38	38	57241.4	57241.8	0.4				0.4	0.053472	9.6	5	38	0	0	Group A Laminar
		5	5	10:24	10:29	23	23	57241.8	57242	0.2				0.2	0.026736	9.6	5	23	0		
		5	5	10:29	10:34	12	12	57242	57242	0		1.30		0	0	9.6	5	12	0		
		5	5	11:11	11:16	16	16	57243	57243.5	0.5	1.10			0.5	0.06684	9.7	5	16	1		
		5	5	11:16	11:21	30	30	57243.7	57244.7	1				1	0.133681	9.7	5	30	1		
484.0	474.3	5	5	11:21	11:26	48	48	57244.9	57246	1.1				1.1	0.147049	9.7	5	48	1	1	Group A Laminar
		5	5	11:26	11:31	30	30	57246	57246.5	0.5				0.5	0.06684	9.7	5	30	1		
		5	5	11:32	11:37	16	16	57246.5	57246.9	0.4		1.30		0.4	0.053472	9.7	5	16	1		
		5	5	12:10	12:15	18	18	57247.1	57247.2	0.1	1.20			0.1	0.013368	9.7	5	18	0		
		5	5	12:15	12:20	34	34	57247.5	57247.9	0.4				0.4	0.053472	9.7	5	34	0		
474.3	464.6	5	5	12:21	12:26	50	50	57248	57263.7	15.7				15.7	2.098785	9.7	5	50	11	0	Group C Dilation
		5	5	12:27	12:32	34	34	57264.1	57264.8	0.7				0.7	0.093576	9.7	5	34	1		
		5	5	12:32	12:37	18	18	57264.8	57264.9	0.1		1.30		0.1	0.013368	9.7	5	18	0		
		5	5	1:04	1:09	18	18	57266.2	57266.8	0.6	1.10			0.6	0.080208	9.8	5	18	1		
		5	5	1:10	1:15	34	34	57266.9	57268.2	1.3				1.3	0.173785	9.8	5	34	1		
464.6	454.8	5	5	1:16	1:21	50	50	57268.6	57292.7	24.1				24.1	3.221701	9.8	5	50	17	0	Group C Dilation
		5	5	1:21	1:26	34	34	57293.3	57297.2	3.9				3.9	0.521354	9.8	5	34	4		
		5	5	1:27	1:32	18	18	57297.2	57297.4	0.2		1.30		0.2	0.026736	9.8	5	18	0		

Stantec

Project	175561026		
Sheet No.	1 of 1	**Date**	8/8/2011
Hole #	B-25	**Rig #**	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	533.6 ft NAVD 88	**Crew**	G. Thompson, M. Rigsby
	Lock 8 Road, Jessamine County, KY	**Top of Rock Elev. (ft.)**	501.3 ft	**Inspector**	A. Smith
Boring Size	NQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.6 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
497.8	489.2	5	5	10:49	10:54	12	12	57299	57299.1	0.1	1.30			0.1	0.013368	8.6	5	12	0	0	Group A Laminar
		5	5	10:54	10:59	17	17	57299.1	57299.3	0.2				0.2	0.026736	8.6	5	17	0		
		5	5	10:59	11:04	27	27	57299.3	57299.6	0.3				0.3	0.040104	8.6	5	27	0		
		5	5	11:05	11:10	17	17	57299.6	57299.9	0.3				0.3	0.040104	8.6	5	17	1		
		5	5	11:10	11:15	12	12	57299.9	57300	0.1		1.60		0.1	0.013368	8.6	5	12	0		
489.2	479.5	5	5	11:48	11:53	12	12	57300.7	57300.7	0	1.40			0	0	9.7	5	12	0	0	Group A Laminar
		5	5	11:53	11:58	22	22	57300.9	57301	0.1				0.1	0.013368	9.7	5	22	0		
		5	5	11:59	12:04	37	37	57301	57301.4	0.4				0.4	0.053472	9.7	5	37	0		
		5	5	12:04	12:09	22	22	57301.4	57301.5	0.1				0.1	0.013368	9.7	5	22	0		
		5	5	12:09	12:14	12	12	57301.5	57301.5	0		1.70		0	0	9.7	5	12	0		
479.5	469.7	5	5	12:44	12:49	15	15	57305.2	57305.2	0	1.30			0	0	9.8	5	15	0	0	Group A Laminar
		5	5	12:49	12:54	30	30	57353.3	57353.6	0.3				0.3	0.040104	9.8	5	30	0		
		5	5	12:54	12:59	47	46	57353.6	57354	0.4				0.4	0.053472	9.8	5	46	0		
		5	5	12:59	1:04	30	30	57354	57354.1	0.1				0.1	0.013368	9.8	5	30	0		
		5	5	1:05	1:09	15	15	57354.1	57354.1	0		1.60		0	0	9.8	5	15	0		
469.7	460.1	5	5	3:50	3:55	18	18	57354	57354.2	0.2	1.20			0.2	0.026736	9.6	5	18	0	0	Group A Laminar
		5	5	3:55	4:00	34	34	57354.5	57354.6	0.1				0.1	0.013368	9.6	5	34	0		
		5	5	4:01	4:06	50	50	57354.7	57355.1	0.4				0.4	0.053472	9.6	5	50	0		
		5	5	4:06	4:11	34	34	57355.1	57355.3	0.2				0.2	0.026736	9.6	5	34	0		
		5	5	4:11	4:16	18	18	57355.3	57355.3	0		1.50		0	0	9.6	5	18	0		
460.1	450.6	5	5	4:58	5:02	18	18	57355.3	57355.4	0.1	1.20			0.1	0.013368	9.5	5	18	0	0	Group A Laminar
		5	5	5:02	5:07	34	34	57355.9	57355.9	0				0	0	9.5	5	34	0		
		5	5	5:07	5:12	50	50	57356	57356.5	0.5				0.5	0.06684	9.5	5	50	0		
		5	5	5:12	5:17	34	34	57356.5	57356.7	0.2				0.2	0.026736	9.5	5	34	0		
		5	5	5:17	5:22	18	18	57356.7	57356.8	0.1		1.60		0.1	0.013368	9.5	5	18	0		

Stantec

Project	175561026		
Sheet No.	1 of 1	**Date**	8/9/2011
Hole #	B-26	**Rig #**	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	533.7 ft NAVD88	**Crew**	Thompson, M. Rigs
	Lock 8 Road, Jessamine County, KY	**Top of Rock Elev. (ft.)**	500.5 ft	**Inspector**	A. Smith
Boring Size	NQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.4 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
		5	5	10:34	10:39	12	12	57356.5	57356.7	0.2	1.20			0.2	0.026736	7.5	5	12	1		
		5	5	10:39	10:44	18	18	57356.8	57357.1	0.3				0.3	0.040104	7.5	5	18	1		
496.5	489.0	5	5	10:44	10:49	28	28	57357	57357.5	0.5				0.5	0.06684	7.5	5	28	1	1	Group A Laminar
		5	5	10:49	10:54	18	18	57357.5	57357.7	0.2				0.2	0.026736	7.5	5	18	1		
		5	5	10:55	11:00	12	12	57357.7	57357.8	0.1		1.40		0.1	0.013368	7.5	5	12	0		
		5	5	11:35	11:40	12	12	57357.3	57358.4	1.1	1.10			1.1	0.147049	9.6	5	12	3		
		5	5	11:40	11:45	22	22	57358.8	57359	0.2				0.2	0.026736	9.6	5	22	0		
489.0	479.4	5	5	11:46	11:51	38	38	57359.1	57359.9	0.8				0.8	0.106944	9.6	5	38	1	0	Group A Laminar
		5	5	11:51	11:56	22	22	57359.9	57360.1	0.2				0.2	0.026736	9.6	5	22	0		
		5	5	11:56	12:01	12	12	57360.1	57360.2	0.1		1.40		0.1	0.013368	9.6	5	12	0		
		5	5	12:28	12:33	16	16	57361	57361.2	0.2	1.30			0.2	0.026736	9.8	5	16	0		
		5	5	12:33	12:38	30	30	57361.5	57361.8	0.3				0.3	0.040104	9.8	5	30	0		
479.4	469.6	5	5	12:38	12:43	48	48	57362.1	57370.7	8.6				8.6	1.149653	9.8	5	48	6	0	Group C Dilation
		5	5	12:43	12:48	30	30	57370.8	57371.1	0.3				0.3	0.040104	9.8	5	30	0		
		5	5	12:49	12:54	16	16	57371.1	57371.2	0.1		1.40		0.1	0.013368	9.8	5	16	0		
		5	5	1:45	1:50	18	18	57372	57372.3	0.3	1.20			0.3	0.040104	9.7	5	18	1		
		5	5	1:50	1:55	34	34	57372.6	57373	0.4				0.4	0.053472	9.7	5	34	0		
469.6	459.9	5	5	2:01	2:01	50	48	57373.8	57395.3	21.5				21.5	2.874132	9.7	5	48	16	0	Group C Dilation
		5	5	2:06	2:06	34	34	57376.1	57378.7	2.6				2.6	0.347569	9.7	5	34	3		
		5	5	2:12	2:12	18	18	57378.7	57378.9	0.2		1.40		0.2	0.026736	9.7	5	18	0		
		5	5	2:48	2:53	18	18	57399.5	57400.1	0.6	1.30			0.6	0.080208	9.9	5	18	1		
		5	5	2:53	2:58	34	34	57400.5	57401.1	0.6				0.6	0.080208	9.9	5	34	1		
459.9	450.0	5	5	5:59	3:04	50	50	57405.5	57413.9	8.4				8.4	1.122917	9.9	5	50	6	1	Group C Dilation
		5	5	3:04	3:09	34	34	57413.8	57414.4	0.6				0.6	0.080208	9.9	5	34	1		
		5	5	3:09	3:14	18	18	57414.4	57414.5	0.1		1.40		0.1	0.013368	9.9	5	18	0		

Stantec

Project 175561026
Sheet No. 1 of 1 **Date** 8/10/2011
Hole # B-27 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Surface Elevation (ft.) 533.7 ft NAVD88
Top of Rock Elev. (ft.) 499.6 ft
Crew . Thompson, M. Rigsb
Inspector A. Smith
Boring Size NQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter
Test Method Lugeon Test
Static Water Level 1.4 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
		5	5	10:49	10:54	12	12	57415.4	57417.1	1.7	1.20			1.7	0.227257	7.2	5	12	7		
		5	5	10:55	11:00	21	20	57417.4	57419.1	1.7				1.7	0.227257	7.2	5	20	4		
496.3	489.1	5	5	11:01	11:06	29	29	57419.2	57421.3	2.1				2.1	0.280729	7.2	5	29	4	4	Group A Laminar
		5	5	11:06	11:11	21	21	57421.4	57422.8	1.4				1.4	0.187153	7.2	5	21	3		
		5	5	11:11	11:16	12	12	57422.9	57424.2	1.3		1.50		1.3	0.173785	7.2	5	12	5		
		5	5	11:52	11:57	12	12	57425.3	57426.2	0.9	1.40			0.9	0.120313	9.7	5	12	3		
		5	5	11:57	12:02	26	26	57426.7	57428	1.3				1.3	0.173785	9.7	5	26	2		
489.1	479.4	5	5	12:02	12:07	39	39	57428.3	57431.2	2.9				2.9	0.387674	9.7	5	39	3	2	Group A Laminar
		5	5	12:08	12:13	26	26	57431.4	57432.5	1.1				1.1	0.147049	9.7	5	26	2		
		5	5	12:13	12:18	12	12	57432.5	57432.8	0.3		1.50		0.3	0.040104	9.7	5	12	1		
		5	5	12:53	12:58	17	17	57432.9	57433	0.1	1.20			0.1	0.013368	9.9	5	17	0		
		5	5	15:58	1:03	33	33	57433.4	57433.6	0.2				0.2	0.026736	9.9	5	33	0		
479.4	469.5	5	5	1:03	1:08	49	49	57433.8	57434.5	0.7				0.7	0.093576	9.9	5	49	1	0	Group A Laminar
		5	5	1:08	1:13	33	33	57434.5	57434.7	0.2				0.2	0.026736	9.9	5	33	0		
		5	5	1:13	1:18	17	17	57434.7	57434.8	0.1		1.50		0.1	0.013368	9.9	5	17	0		
		5	5	2:04	2:09	18	18	57435.4	57435.9	0.5	1.10			0.5	0.06684	9.5	5	18	1		
		5	5	2:09	2:14	34	34	57436.2	57437	0.8				0.8	0.106944	9.5	5	34	1		
469.5	460.0	5	5	2:15	2:20	50	50	57437	57437.9	0.9				0.9	0.120313	9.5	5	50	1	1	Group A Laminar
		5	5	2:20	2:25	34	34	57437.9	57438.2	0.3				0.3	0.040104	9.5	5	34	0		
		5	5	2:25	2:30	18	18	57438.2	57438.3	0.1		1.40		0.1	0.013368	9.5	5	18	0		
		5	5	3:15	3:20	18	18	57448.1	57448.5	0.4	1.10			0.4	0.053472	9.8	5	18	1		
		5	5	3:21	3:26	34	34	57448.5	57449	0.5				0.5	0.06684	9.8	5	34	1		
460.0	450.2	5	5	3:26	3:31	50	50	57449.1	57449.7	0.6				0.6	0.080208	9.8	5	50	0	1	Group A Laminar
		5	5	3:31	3:36	34	34	57449.7	57450.1	0.4				0.4	0.053472	9.8	5	34	0		
		5	5	3:37	3:42	18	18	57450.1	57450.4	0.3		1.50		0.3	0.040104	9.8	5	18	1		

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Project 175561026
Sheet No. 1 of 1 **Date** 8/11/2011
Hole # B-28 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, Kentucky
Surface Elevation (ft.) 533.3 ft NAVD88
Top of Rock Elev. (ft.) 499.1 ft
Crew G. Thompson, M. Rigsby
Inspector A. Smith

Boring Size NQ Wireline
Pump Capacity 30 - 40 gallons
Meter Type Badger Meter

Test Method Lugeon Test
Static Water Level 1.7 ft
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
		5	5	11:22	11:27	12	12	57455.5	57508.1	52.6	53.20			52.6	7.031597	9.7	5	12	159		
		5	5	11:27	11:32	22	22	57517.7	57586.8	69.1				69.1	9.237326	9.7	5	22	114		
488.9	479.2	5	5	11:32	11:37	37	37	57594	57693.5	99.5				99.5	13.30122	9.7	5	37	98	98	Group B Turbulent Flow
		5	5	11:37	11:42	22	22	57697.5	57770.4	72.9				72.9	9.745313	9.7	5	22	121		
		5	5	11:42	11:47	12	12	57777	57833.6	56.6		54.60		56.6	7.566319	9.7	5	12	172		
		5	5	12:41	12:46	15	14	57852.5	57852.9	0.4	52.90			0.4	0.053472	9.6	5	14	1		
		5	5	12:46	12:51	30	30	57853.7	57854.1	0.4				0.4	0.053472	9.6	5	30	0		
479.2	469.6	5	5	12:51	12:56	47	47	57854.3	57854.9	0.6				0.6	0.080208	9.6	5	47	0	0	Group A Laminar
		5	5	12:56	1:01	30	30	57854.9	57855.2	0.3				0.3	0.040104	9.6	5	30	0		
		5	5	1:02	1:07	15	15	57855.2	57855.4	0.2		56.20		0.2	0.026736	9.6	5	15	0		
		5	5	1:49	1:54	18	18	57858.4	57859.3	0.9	53.10			0.9	0.120313	9.7	5	18	2		
		5	5	1:54	1:59	34	34	57859.8	57861.5	1.7				1.7	0.227257	9.7	5	34	2		
469.6	459.9	5	5	1:59	2:04	50	50	57861.7	57864.7	3				3	0.401042	9.7	5	50	2	1	Group A Laminar
		5	5	2:05	2:10	34	34	57865	57866.1	1.1				1.1	0.147049	9.7	5	34	1		
		5	5	2:10	2:15	18	18	57866.1	57866.7	0.6		56.90		0.6	0.080208	9.7	5	18	1		
		5	5	3:14	3:19	18	18	57870.1	57873.7	3.6	54.30			3.6	0.48125	9.7	5	18	7		
		5	5	3:21	3:26	34	34	57874.7	57879.5	4.8				4.8	0.641667	9.7	5	34	5		
459.9	450.2	5	5	3:26	3:31	50	50	57880	57886.2	6.2				6.2	0.828819	9.7	5	50	5	4	Group E Void Filling
		5	5	3:31	3:36	34	34	57887	57891	4				4	0.534722	9.7	5	34	4		
		5	5	3:36	3:41	18	18	57891.1	57893.4	2.3		56.70		2.3	0.307465	9.7	5	18	5		

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Project 175561026
Sheet No. 1 of 1 **Date** 8/1/2011
Hole # B-29 **Rig #** CME 45T

Location KY River Lock and Dam No. 8
Lock 8 Road, Jessamine County, KY
Boring Size PQ Wireline
Test Method Lugeon Test

Surface Elevation (ft.) 534.3 ft NAVD88
Top of Rock Elev. (ft.) 499.0 ft
Pump Capacity 30 - 40 gallons
Static Water Level 1.7 ft

Crew Thompson, M. Rig
Inspector J. Adams
Meter Type Badger Meter
Meter # 93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
495.2	487.7	5	5			10	10	56112	56189.8	77.8	1.70			77.8	10.40035	7.5	5	10	366	>100	Group B Turbulent
		5	5			15	15	56204	56292	88				88	11.76389	7.5	5	15	276		
		5	5			22	22	56304	56425.7	121.7				121.7	16.26892	7.5	5	22	260		
		5	5			15	15	56450.2	56554	103.8				103.8	13.87604	7.5	5	15	325		
		5	5			10	10	56570	56659	89		1.70		89	11.89757	7.5	5	10	419		
487.7	477.4	5	5			10	10	56676	56729.6	53.6	1.70			53.6	7.165278	10.3	5	10	184	100	Group B Turbulent
		5	5			20	20	56747	56824	77				77	10.2934	10.3	5	20	132		
		5	5			35	35	56844	56946	102				102	13.63542	10.3	5	35	100		
		5	5			20	20	56960	57041	81				81	10.82813	10.3	5	20	139		
		5	5			10	9	57048	57108.5	60.5		1.70		60.5	8.087674	10.3	5	9	230		

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Project	175561026
Sheet No.	1 of 1
Date	8/16/2011
Hole #	B-30
Rig #	CME 45T

Location	KY River Lock and Dam No. 8	**Surface Elevation (ft.)**	534.0 ft NAVD88	**Crew**	G. Thompson, M. Rigsby
	Lock 8 Road, Jessamine Couty, KY	**Top of Rock Elev. (ft.)**	499.6 ft	**Inspector**	A. Smith
Boring Size	PQ Wireline	**Pump Capacity**	30 - 40 gallons	**Meter Type**	Badger Meter
Test Method	Lugeon Test	**Static Water Level**	1.6 ft	**Meter #**	93428424

Test Section (ft)		Time of Test (min)				Gage Pressure (psi)		Meter Reading (gal)			Static Water Levels (ft)		Notes	Total Test Take		Test Interval	Time	Actual Pressure	Lugeon Value		
Top Elev	Bottom Elev	Required	Actual	Clock Times Start	Clock Times End	Required	Actual	Start of Test	End of Test	Total	Pre-Test	Post-Test		(gal)	(ft^3)	(vertical ft)	(min)	(psi)	Each Test	Representative for Tested Stage	Group
497.6	487.6	5	5	8:41	8:46	12	12	57932.2	57935.8	3.6	1.60			3.6	0.48125	10.0	5	12	11	9	Group A Laminar
		5	5	8:46	8:51	21	21	57936.1	57940.3	4.2				4.2	0.561458	10.0	5	21	7		
		5	5	8:51	8:56	31	31	57940.8	57947.5	6.7				6.7	0.89566	10.0	5	31	8		
		5	5	8:56	9:01	21	21	57947.9	57953.2	5.3				5.3	0.708507	10.0	5	21	9		
		5	5	9:02	9:07	12	12	57954.4	57958.4	4		1.60		4	0.534722	10.0	5	12	12		
487.6	477.2	5	5	10:14	10:19	13	12	57966.6	57969.8	3.2	10.90			3.2	0.427778	10.4	5	12	9	38	Group A Laminar
		5	5	10:19	10:24	25	25	57974.8	58008.5	33.7				33.7	4.505035	10.4	5	25	46		
		5	5	10:24	10:29	42	42	58013.1	58056.7	43.6				43.6	5.828472	10.4	5	42	35		
		5	5	10:29	10:34	25	24	58070.4	58099.5	29.1				29.1	3.890104	10.4	5	24	41		
		5	5	10:34	10:39	13	13	58100.9	58111.9	11		13.20		11	1.470486	10.4	5	13	29		

APPENDIX C – GROUT CURTAIN DESIGN DRAWINGS

GROUT HOLE LOCATION AND INFORMATION TABLE

Baseline	Top of Hole Station*	Offset**	Top of Hole Elev. (ft.)	Bottom of Hole Station	Bottom of Hole Elev. (ft.)	Azimuth	Inclination from Vertical (deg.)	Hole Type
A	10+10.8	2.5' US	533.4	9+63.9	516.1	338° 08' 43"	70	Primary
A	10+11.7	2.5' US	532.9	9+68.5	507.7	338° 08' 43"	60	Secondary
A	10+12.5	2.5' US	532.4	9+74.3	500.1	338° 08' 43"	50	Primary
A	10+13.4	2.5' US	531.9	9+81.4	493.4	338° 08' 43"	40	Secondary
A	10+14.3	2.5' US	531.4	9+89.4	487.9	338° 08' 43"	30	Primary
A	10+15.1	2.5' US	530.9	9+98.1	483.8	338° 08' 43"	20	Secondary
A	10+16.0	2.5' US	530.4	10+07.4	481.0	338° 08' 43"	10	Primary
A	10+17.2	2.5' US	530.2	10+17.2	480.0	--	0	Secondary
A	10+17.6	2.5' US	528.2	10+30.5	480.0	158° 08' 43"	15	Secondary
A	10+20.7	2.5' US	528.2	10+20.7	480.0	--	0	Primary
A	10+27.8	2.5' US	528.2	10+40.7	480.0	158° 08' 43"	15	Primary
A	10+37.8	2.5' US	528.2	10+50.7	480.0	158° 08' 43"	15	Secondary
A	10+47.8	2.5' US	528.2	10+60.7	480.0	158° 08' 43"	15	Primary
A	10+57.8	2.5' US	528.2	10+70.7	480.0	158° 08' 43"	15	Secondary
A	10+72.8	2.5' US	528.2	10+72.8	480.0	--	0	Primary
A	10+75.0	2.5' US	528.2	10+87.9	480.0	158° 08' 43"	15	Primary
A	10+78.8	2.5' US	528.2	10+78.8	480.0	--	0	Secondary
A	10+82.0	2.5' US	528.2	10+94.9	480.0	158° 08' 43"	15	Secondary
A	10+92.0	2.5' US	528.2	11+04.9	480.0	158° 08' 43"	15	Primary
A	11+02.0	2.5' US	528.2	11+14.9	480.0	158° 08' 43"	15	Secondary
A	11+12.0	2.5' US	528.2	11+24.9	480.0	158° 08' 43"	15	Primary
A	11+28.4	2.5' US	528.2	11+28.4	480.0	--	0	Secondary
A	11+30.3	2.5' US	528.2	11+47.2	465.0	158° 08' 43"	15	Secondary
A	11+36.4	2.5' US	528.2	11+36.4	480.0	--	0	Primary
A	11+46.5	2.5' US	528.2	11+46.5	465.0	--	0	Primary
A	11+48.3	2.5' US	528.2	11+65.3	465.0	158° 08' 43"	15	Primary
A	11+49.3	2.5' US	528.2	11+49.3	480.0	--	0	Tertiary
A	11+51.8	2.5' US	528.2	11+67.9	480.0	158° 08' 43"	15	Tertiary
A	11+53.2	2.5' US	528.2	11+53.2	465.0	--	0	Secondary
A	11+55.3	2.5' US	528.2	11+72.3	465.0	158° 08' 43"	15	Secondary
A	11+56.3	2.5' US	528.2	11+56.3	480.0	--	0	Tertiary
A	11+60.3	2.5' US	528.2	11+74.6	480.0	158° 08' 43"	15	Tertiary
A	11+65.3	2.5' US	528.2	11+82.3	465.0	158° 08' 43"	15	Primary
A	11+70.3	2.5' US	528.2	11+84.6	480.0	158° 08' 43"	15	Tertiary
A	11+75.3	2.5' US	528.2	11+92.3	465.0	158° 08' 43"	15	Secondary
A	11+80.3	2.5' US	528.2	11+93.6	480.0	158° 08' 43"	15	Tertiary
A	11+85.3	2.5' US	528.2	12+02.3	465.0	158° 08' 43"	15	Primary
A	11+96.0	2.5' US	528.2	11+96.0	480.0	--	0	Tertiary
A	12+02.3	2.5' US	528.2	12+02.3	465.0	--	0	Secondary
A	12+04.0	2.5' US	528.2	12+20.9	465.0	158° 08' 43"	15	Secondary
A	12+07.3	2.5' US	528.2	12+07.3	480.0	--	0	Tertiary
A	12+11.3	2.5' US	528.2	12+11.3	465.0	--	0	Primary
A	12+20.1	2.5' US	528.2	12+20.1	465.0	--	0	Primary
A	12+23.1	2.5' US	528.2	12+40.1	465.0	158° 08' 43"	15	Primary
A	12+27.1	2.5' US	528.2	12+27.1	465.0	--	0	Secondary
A	12+30.1	2.5' US	528.2	12+47.1	465.0	158° 08' 43"	15	Secondary
A	12+40.1	2.5' US	528.2	12+57.1	465.0	158° 08' 43"	15	Primary
A	12+50.1	2.5' US	528.2	12+67.1	465.0	158° 08' 43"	15	Secondary
A	12+67.5	2.5' US	528.2	12+67.5	465.0	--	0	Primary

* – Hole Identifier/Baseline Station (e.g. 10+10.9 = Sta. 10+10.9)

** – US = Upstream
DS = Downstream

GROUT HOLE LOCATION AND INFORMATION TABLE (CONT'D)

Baseline	Top of Hole Station*	Offset**	Top of Hole Elev. (ft.)	Bottom of Hole Station	Bottom of Hole Elev. (ft.)	Azimuth	Inclination from Vertical (deg.)	Hole Type
A	10+10.3	2.5' DS	534.1	9+62.0	521.2	338° 08' 43"	75	Primary
A	10+11.1	2.5' DS	533.6	9+65.8	512.5	338° 08' 43"	65	Secondary
A	10+12.0	2.5' DS	533.0	9+71.0	504.3	338° 08' 43"	55	Primary
A	10+12.8	2.5' DS	532.4	9+77.4	497.1	338° 08' 43"	45	Secondary
A	10+13.6	2.5' DS	531.8	9+84.9	490.9	338° 08' 43"	35	Primary
A	10+14.4	2.5' DS	531.3	9+93.3	486.0	338° 08' 43"	25	Secondary
A	10+15.3	2.5' DS	530.7	10+02.3	482.4	338° 08' 43"	15	Primary
A	10+24.6	2.5' DS	528.2	10+11.7	480.0	338° 08' 43"	15	Secondary
A	10+34.6	2.5' DS	528.2	10+21.7	480.0	338° 08' 43"	15	Primary
A	10+44.6	2.5' DS	528.2	10+31.7	480.0	338° 08' 43"	15	Secondary
A	10+54.6	2.5' DS	528.2	10+41.7	480.0	338° 08' 43"	15	Primary
A	10+59.6	2.5' DS	528.2	10+59.7	480.0	--	0	Primary
A	10+64.7	2.5' DS	528.2	10+64.7	480.0	--	0	Secondary
A	10+64.7	2.5' DS	528.2	10+51.7	480.0	338° 08' 43"	15	Secondary
A	10+79.2	2.5' DS	528.2	10+66.3	480.0	338° 08' 43"	15	Primary
A	10+89.3	2.5' DS	528.2	10+76.4	480.0	338° 08' 43"	15	Secondary
A	10+99.3	2.5' DS	528.2	10+86.4	480.0	338° 08' 43"	15	Primary
A	11+09.3	2.5' DS	528.2	10+96.4	480.0	338° 08' 43"	15	Secondary
A	11+16.3	2.5' DS	528.2	11+16.3	480.0	--	0	Secondary
A	11+19.3	2.5' DS	528.2	11+06.4	480.0	338° 08' 43"	15	Primary
A	11+21.3	2.5' DS	528.2	11+21.3	480.0	--	0	Primary
A	11+33.5	2.5' DS	528.2	11+33.5	480.0	--	0	Primary
A	11+38.5	2.5' DS	528.2	11+25.5	480.0	338° 08' 43"	15	Secondary
A	11+38.5	2.5' DS	528.2	11+38.5	480.0	--	0	Secondary
A	11+53.9	2.5' DS	528.2	11+36.9	465.0	338° 08' 43"	15	Primary
A	11+58.9	2.5' DS	528.2	11+44.6	480.0	338° 08' 43"	15	Tertiary
A	11+63.9	2.5' DS	528.2	11+46.9	465.0	338° 08' 43"	15	Secondary
A	11+68.9	2.5' DS	528.2	11+54.6	480.0	338° 08' 43"	15	Tertiary
A	11+73.9	2.5' DS	528.2	11+56.9	465.0	338° 08' 43"	15	Primary
A	11+78.9	2.5' DS	528.2	11+64.6	480.0	338° 08' 43"	15	Tertiary
A	11+83.9	2.5' DS	528.2	11+66.9	465.0	338° 08' 43"	15	Secondary
A	11+84.0	2.5' DS	528.2	11+84.0	480.0	--	0	Tertiary
A	11+86.9	2.5' DS	528.2	11+86.9	465.0	--	0	Secondary
A	11+88.9	2.5' DS	528.2	11+74.6	480.0	338° 08' 43"	15	Tertiary
A	11+90.9	2.5' DS	528.2	11+90.9	480.0	--	0	Tertiary
A	11+93.9	2.5' DS	528.2	11+76.9	465.0	338° 08' 43"	15	Primary
A	11+94.9	2.5' DS	528.2	11+94.9	465.0	--	0	Primary
A	12+01.5	2.5' DS	528.2	12+01.5	480.0	--	0	Tertiary
A	12+05.1	2.5' DS	528.2	12+05.1	465.0	--	0	Primary
A	12+07.1	2.5' DS	528.2	12+07.1	480.0	--	0	Tertiary
A	12+10.1	2.5' DS	528.2	12+10.1	465.0	--	0	Secondary
A	12+12.1	2.5' DS	528.2	11+95.1	465.0	338° 08' 43"	15	Secondary
A	12+14.0	2.5' DS	528.2	12+14.0	480.0	--	0	Tertiary
A	12+27.9	2.5' DS	528.2	12+10.9	465.0	338° 08' 43"	15	Primary
A	12+37.9	2.5' DS	528.2	12+20.9	465.0	338° 08' 43"	15	Secondary
A	12+47.9	2.5' DS	528.2	12+30.9	465.0	338° 08' 43"	15	Primary
A	12+57.9	2.5' DS	528.2	12+40.9	465.0	338° 08' 43"	15	Secondary
A	12+59.2	2.5' DS	528.2	12+59.2	465.0	--	0	Secondary
A	12+62.4	2.5' DS	528.2	12+62.4	465.0	--	0	Primary
A	12+67.9	2.5' DS	528.2	12+50.9	465.0	338° 08' 43"	15	Primary

* – Hole Identifier/Baseline Station (e.g. 10+10.9 = Sta. 10+10.9)

** – US = Upstream
DS = Downstream

GROUT HOLE LOCATION AND INFORMATION TABLE (CONT'D)

Baseline	Top of Hole Station*	Offset**	Top of Hole Elev. (ft.)	Bottom of Hole Station	Bottom of Hole Elev. (ft.)	Azimuth	Inclination from Vertical (deg.)	Hole Type
C	31+11.5	2.5' DS	528.2	31+28.2	465.0	21° 01' 71"	15	Secondary
C	31+21.5	2.5' DS	528.2	31+38.2	465.0	21° 01' 71"	15	Primary
C	31+39.0	2.5' DS	528.2	31+39.0	465.0	--	0	Secondary
C	31+45.8	2.5' DS	528.2	31+45.8	465.0	--	0	Primary
C	31+53.8	2.5' DS	528.2	31+53.8	465.0	--	0	Secondary
C	31+55.3	2.5' DS	539.8	31+75.4	465.0	21° 01' 71"	15	Primary
C	31+58.3	2.5' DS	539.8	31+58.3	465.0	--	0	Primary
C	31+68.3	2.5' DS	539.8	31+68.3	465.0	--	0	Secondary
C	31+72.5	2.5' DS	539.8	31+73.0	465.0	--	0	Secondary
C	31+17.7	2.5' US	528.2	31+17.7	465.0	--	0	Primary
C	31+25.7	2.5' US	528.2	31+25.7	465.0	--	0	Secondary
C	31+26.8	2.5' US	528.2	31+09.9	465.0	201° 01' 71"	15	Secondary
C	31+37.5	2.5' US	528.2	31+37.5	465.0	--	0	Secondary
C	31+43.7	2.5' US	528.2	31+43.7	465.0	--	0	Primary
C	31+44.5	2.5' US	528.2	31+27.6	465.0	201° 01' 71"	15	Primary
C	31+63.3	2.5' US	539.8	31+43.3	465.0	201° 01' 71"	15	Secondary
C	31+63.3	2.5' US	539.8	31+63.3	465.0	--	0	Secondary
C	31+67.5	2.5' US	539.8	31+67.0	465.0	--	0	Primary
C	31+73.3	2.5' US	539.8	31+53.3	465.0	201° 01' 71"	15	Primary
D	42+73.1	2.5' US	499.5	42+63.9	465.0	338° 08' 43"	15	Secondary
D	42+83.1	2.5' US	499.5	42+73.9	465.0	338° 08' 43"	15	Primary
D	42+93.1	2.5' US	499.5	42+83.9	465.0	338° 08' 43"	15	Secondary
D	43+03.1	2.5' US	499.5	42+93.9	465.0	338° 08' 43"	15	Primary
D	43+13.1	2.5' US	499.5	43+13.8	465.0	--	0	Primary
D	43+13.8	2.5' US	499.5	43+03.9	465.0	338° 08' 43"	15	Secondary
D	43+23.8	2.5' US	499.5	43+23.8	465.0	--	0	Secondary
D	43+31.8	2.5' US	539.8	43+31.8	465.0	--	0	Primary
D	43+50.2	2.5' US	539.7	43+30.2	464.8	338° 08' 43"	15	Secondary
D	43+60.6	2.5' US	541.1	43+40.2	465.0	338° 08' 43"	15	Primary
D	43+71.0	2.5' US	542.6	43+50.2	465.0	338° 08' 43"	15	Secondary
D	43+81.4	2.5' US	544.1	43+64.2	479.8	338° 08' 43"	15	Primary
D	43+91.8	2.5' US	545.6	43+74.2	480.0	338° 08' 43"	15	Secondary
D	44+02.2	2.5' US	547.1	43+84.2	480.0	338° 08' 43"	15	Primary
D	44+12.6	2.5' US	548.7	43+94.2	480.0	338° 08' 43"	15	Secondary
D	44+23.0	2.5' US	550.2	44+04.1	480.0	338° 08' 43"	15	Primary
D	44+33.4	2.5' US	551.7	44+14.1	480.0	338° 08' 43"	15	Secondary
D	44+34.9	2.5' US	551.9	44+34.9	480.0	--	0	Secondary
D	44+43.8	2.5' US	553.2	44+24.1	480.0	338° 08' 43"	15	Primary
D	42+74.4	2.5' DS	518.1	42+74.4	465.0	--	0	Primary
D	42+80.1	2.5' DS	518.1	42+94.3	465.0	158° 08' 43"	15	Primary
D	42+84.4	2.5' DS	518.1	42+84.4	465.0	--	0	Secondary
D	42+90.1	2.5' DS	518.1	43+04.3	465.0	158° 08' 43"	15	Secondary
D	43+00.0	2.5' DS	518.1	43+14.3	465.0	158° 08' 43"	15	Primary
D	43+10.1	2.5' DS	518.1	43+24.3	465.0	158° 08' 43"	15	Secondary
D	43+20.1	2.5' DS	518.1	43+34.3	465.0	158° 08' 43"	15	Primary
D	43+27.1	2.5' DS	518.1	43+41.3	465.0	158° 08' 43"	15	Secondary
D	43+31.3	2.5' DS	539.8	43+51.3	465.0	158° 08' 43"	15	Primary
D	43+42.5	2.5' DS	539.6	43+58.5	480.0	158° 08' 43"	15	Primary
D	43+50.5	2.5' DS	539.8	43+50.5	480.0	--	0	Secondary
D	43+52.4	2.5' DS	540.0	43+68.5	480.0	158° 08' 43"	15	Secondary
D	43+62.0	2.5' DS	541.5	43+78.5	480.0	158° 08' 43"	15	Primary
D	43+71.6	2.5' DS	542.9	43+88.4	480.0	158° 08' 43"	15	Secondary
D	43+81.3	2.5' DS	544.3	43+98.5	480.0	158° 08' 43"	15	Primary
D	43+90.9	2.5' DS	545.7	44+08.5	480.0	158° 08' 43"	15	Secondary
D	44+00.5	2.5' DS	547.0	44+18.5	480.0	158° 08' 43"	15	Primary
D	44+10.1	2.5' DS	548.5	44+28.4	480.0	158° 08' 43"	15	Secondary
D	44+19.8	2.5' DS	549.9	44+38.5	480.0	158° 08' 43"	15	Primary

* – Hole Identifier/Baseline Station (e.g. 10+10.9 = Sta. 10+10.9)

** – US = Upstream
DS = Downstream

REVISIONS	DATE
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RENOVATION OF KENTUCKY RIVER LOCK AND DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE
DRAWN BY BFS
CHECKED BY DAG/ALW
A & E FILE NO. 175561026
DATE AUGUST, 2012

FOUNDATION IMPROVEMENT PROGRAM
GROUT CURTAIN LOCATION TABLE
COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING

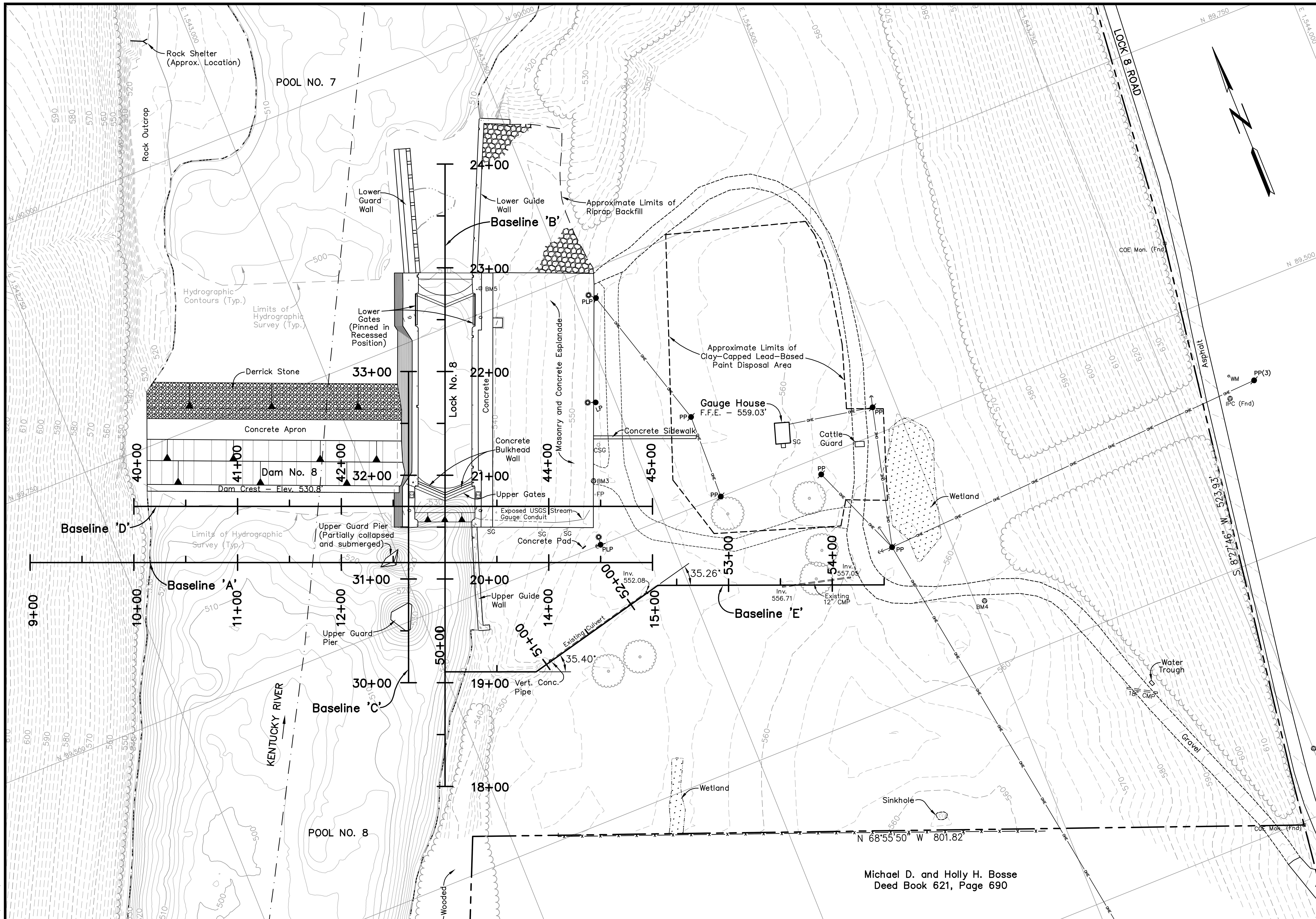
Stantec

DRAWING NO. A40
SCALE NO SCALE
REVIEWED DIV. OF ENGR.
For Intent Only
ENGR. FILE NO. C5RQ-084-RA08-00

AGENCY AUTHORIZED AGENT ________ Approved for Program Concept Only DATE ________

DIVISION OF ENGINEERING ________ Approved for Program Concept Only DATE ________

V:\1755\ACTIVE\175561026\GEOTECHNICAL\DRAWING\SHEET_FILES\100%\A40-61026C-209-GHT.DWG



NOTES:

1. Horizontal coordinates are based on the Kentucky State Plane Coordinate System, North Zone, North American Datum of 1983 (NAD83). Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88). Many historic drawings are often referenced to the Kentucky River Datum (KRD) or the National Geodetic Vertical Datum of 1929 (NGVD29). At Lock and Dam No. 8, elevations based on KRD can be converted to NAVD88 by subtracting 2.5 feet, while elevations based on NGVD29 can be converted to NAVD88 by subtracting 0.5 feet.
2. The property shown hereon is subject to all easements, covenants, and restrictions, recorded and/or unrecorded. Stantec Consulting Services Inc. makes no guarantee with respect to the existence of such restrictions. Boundary monuments were located in the field as indicated. Boundary lines have been extended to normal pool.
3. Existing site features, dimensions, and topography were obtained from site mapping developed by Stantec Consulting Services Inc. between the dates of May 4, 2011 and July 6, 2011. Hydrographic information (stream bed contouring) was developed by Stantec Consulting Services Inc. on July 5 and 6, 2011 using a mapping grade GPS locator device and sonar equipment. The surface of the stream bed has likely changed since performance of the hydrographic survey.
4. Because of the long project history, undocumented repair efforts and lack of as–built information, not all site features may be accurately reflected.
5. Some mechanical components and buried utilities have not been located and are not shown hereon. The Contractor shall locate and verify all mechanical components and buried utilities prior to construction.
6. The U.S. Geological Survey (USGS) operates a stream gauge sensor located near the Upper Guide Wall, and data collection and transmitting equipment located in the Gauge House. The sensor is connected to the Gauge House via a conduit that is partially exposed on the south end of the Esplanade, then travels underground following an unknown path.
7. Crest of Dam No. 8 is at elevation 530.8 feet NAVD88. Crest of Dam No. 7 is at elevation 512.5 feet NAVD88.

LEGEND

Overhead Electric Line
Property Line
Property Line at River Edge
County Line
Approx. Limits of Clay–Capped Lead–Based Paint Disposal Area
Fence
Index Contour
Intermediate Contour
Index Hydrographic Contour
Intermediate Hydrographic Contour
Hydrographic Survey Limits
Stream/Ditch Line/Body of Water
Treeline
Gravel Road
Dirt Road
PP Power Pole
LP Light Pole
PLP Power and Light Pole
Guy Wire
WM Water Meter
FP Flag Pole
IPC Iron Pin with Cap
SG Staff Gauge
CSG USGS Crest–Stage Gauge
COE MON. Corps of Engineers Monument
Rock Shelter
Wetland

BASELINE INTERSECTIONS

Sta. 12+64.92 'A' = Sta. 31+15.80 'C'
Sta. 13+00.00 'A' = Sta. 20+15.80 'B'
Sta. 19+10.50 'B' = Sta. 50+00.00 'E'
Sta. 20+70.00 'B' = Sta. 43+00.00 'D'
Sta. 31+70.00 'C' = Sta. 42+64.92 'D'

BASELINE LOCATION TABLE

Baseline	Station	Northing	Easting
'A'	9+00.00	89,688.87	1,542,668.45
'A'	15+00.00	89,465.52	1,543,225.33
'B'	18+00.00	89,339.68	1,542,959.37
'B'	24+00.00	89,896.55	1,543,182.72
'C'	30+00.00	89,445.55	1,542,964.04
'C'	33+00.00	89,723.99	1,543,075.71
'D'	40+00.00	89,701.95	1,542,781.44
'D'	45+00.00	89,515.82	1,543,245.50
'E'	50+00.00	89,442.23	1,543,000.50
'E'	50+87.85	89,409.53	1,543,082.04
'E'	52+31.71	89,443.22	1,543,221.90
'E'	54+50.00	89,362.44	1,543,424.69

NOTE: All Baseline intersection angles = 90°

25 0 50 100 FEET
GRAPHIC SCALE: 1" = 50'
CONTOUR INTERVAL = 2'
HYDRO. CONTOUR INTERVAL = 2'

REVISIONS	DATE
1	
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RENOVATION OF KENTUCKY RIVER LOCK AND DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE
EXISTING CONDITIONS AND BASELINE LAYOUT
DRAWING NO. A07
DRAWN BY BFS
COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
SCALE 1" = 50'
CHECKED BY DAG/ALW
A & E FILE NO. 175561026
REVIEWED DIV. OF ENGR.
DATE AUGUST, 2012
Stantec
For Intent Only
ENGR. FILE NO. C5RQ–084–RA08–00

AGENCY AUTHORIZED AGENT — Approved for Program Concept Only — DATE
DIVISION OF ENGINEERING — Approved for Program Concept Only — DATE

V:\1755\ACTIVE\175561026\GEOTECHNICAL\DRAWING\SHEET_FILES\100%\A07-61026C-202-EXC.DWG

NOTES:

1. Horizontal coordinates are based on the Kentucky State Plane Coordinate System, North Zone, North American Datum of 1983 (NAD83). Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88).
2. Existing site features, dimensions, and topography were obtained from site mapping developed by Stantec Consulting Services Inc. between the dates of May 4, 2011 and July 6, 2011. Hydrographic information (stream bed contouring) was developed by Stantec Consulting Services Inc. on July 5 and 6, 2011 using a mapping grade GPS locator device and sonar equipment. The surface of the stream bed has likely changed since performance of the hydrographic survey.
3. Because of the long project history, undocumented repair efforts and lack of as-built information, not all site features may be accurately reflected.
4. Some mechanical components and buried utilities have not been located and are not shown hereon. Contractor shall locate and verify all mechanical components and buried utilities prior to construction.
5. Crest of Dam No. 8 is at elevation 530.8 feet NAVD88. Crest of Dam No. 7 is at elevation 512.5 feet NAVD88.
6. Concrete Platform Extension, handrailing, and Sluice Gate Operating Mechanisms are not shown for clarity. These items are detailed on Sheet A30 "Plan – Concrete Bulkhead Wall Improvements".
7. Refer to Sheet A40 for grout hole stationing, offset, inclination, orientation and depth.
8. The CONTRACTOR shall incline grout holes as depicted on the Drawings.
9. Grout borings originating within the West Concrete Control Section shall be advanced 50 feet into rock and shall be inclined as shown on the Drawings.
10. Individual grout holes are not shown for clarity. See Sheets A42 through A44 for individual grout hole locations.

LEGEND

- ○ Primary Grout Hole, 0° Inclination
- Primary Grout Hole, 15° Inclination
- □ Secondary Grout Hole, 0° Inclination
- Secondary Grout Hole, 15° Inclination
- ◁ Tertiary Grout Hole, 0° Inclination
- Tertiary Grout Hole, 15° Inclination

GRAPHIC SCALE: 1" = 20'
CONTOUR INTERVAL = 2'
HYDRO. CONTOUR INTERVAL = 1'

REVISIONS	DATE
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RENOVATION OF KENTUCKY RIVER LOCK AND DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

FOUNDATION IMPROVEMENT PROGRAM
PLAN - GROUT CURTAIN SECTION LOCATIONS

COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING

Stantec

AS BUILT DATE
DRAWN BY BFS
CHECKED BY DAG/ALW
A & E FILE NO. 175561026
DATE AUGUST, 2012

DRAWING NO. A41
SCALE 1" = 20'
REVIEWED DIV. OF ENGR.
For Intent Only
ENGR. FILE NO. C5RQ-084-RA08-00

AGENCY AUTHORIZED AGENT — Approved for Program Concept Only — DATE
DIVISION OF ENGINEERING — Approved for Program Concept Only — DATE

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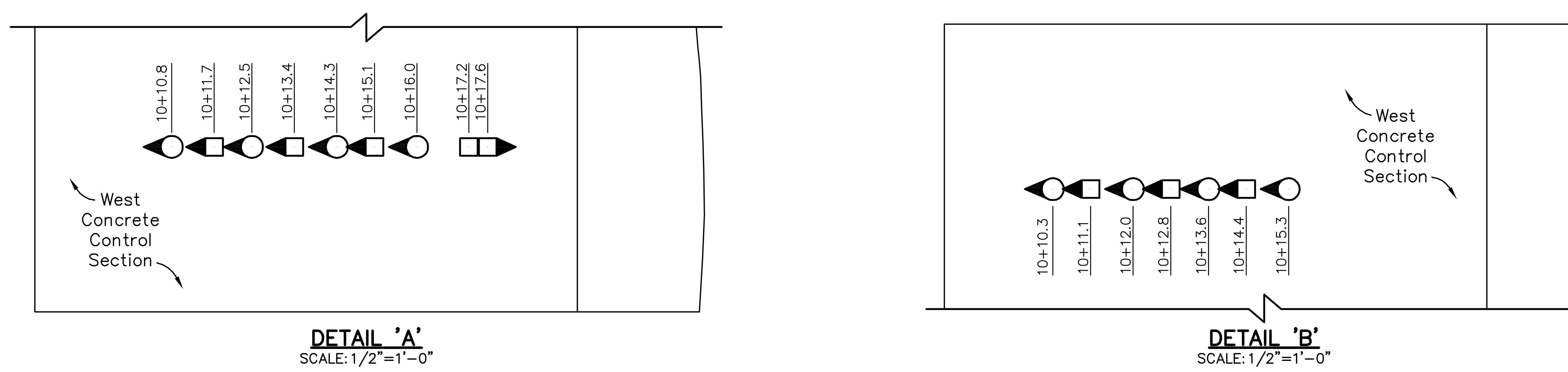
NOTES:

1. Refer to Sheet A40 for grout hole stationing, offset, inclination, orientation and depth.
2. The CONTRACTOR shall incline grout holes as depicted on the Drawings.
3. Grout borings originating within the West Concrete Control Section shall be advanced 50 feet and inclined as shown hereon.
4. Refer to Sheet A41 for general notes and layout.



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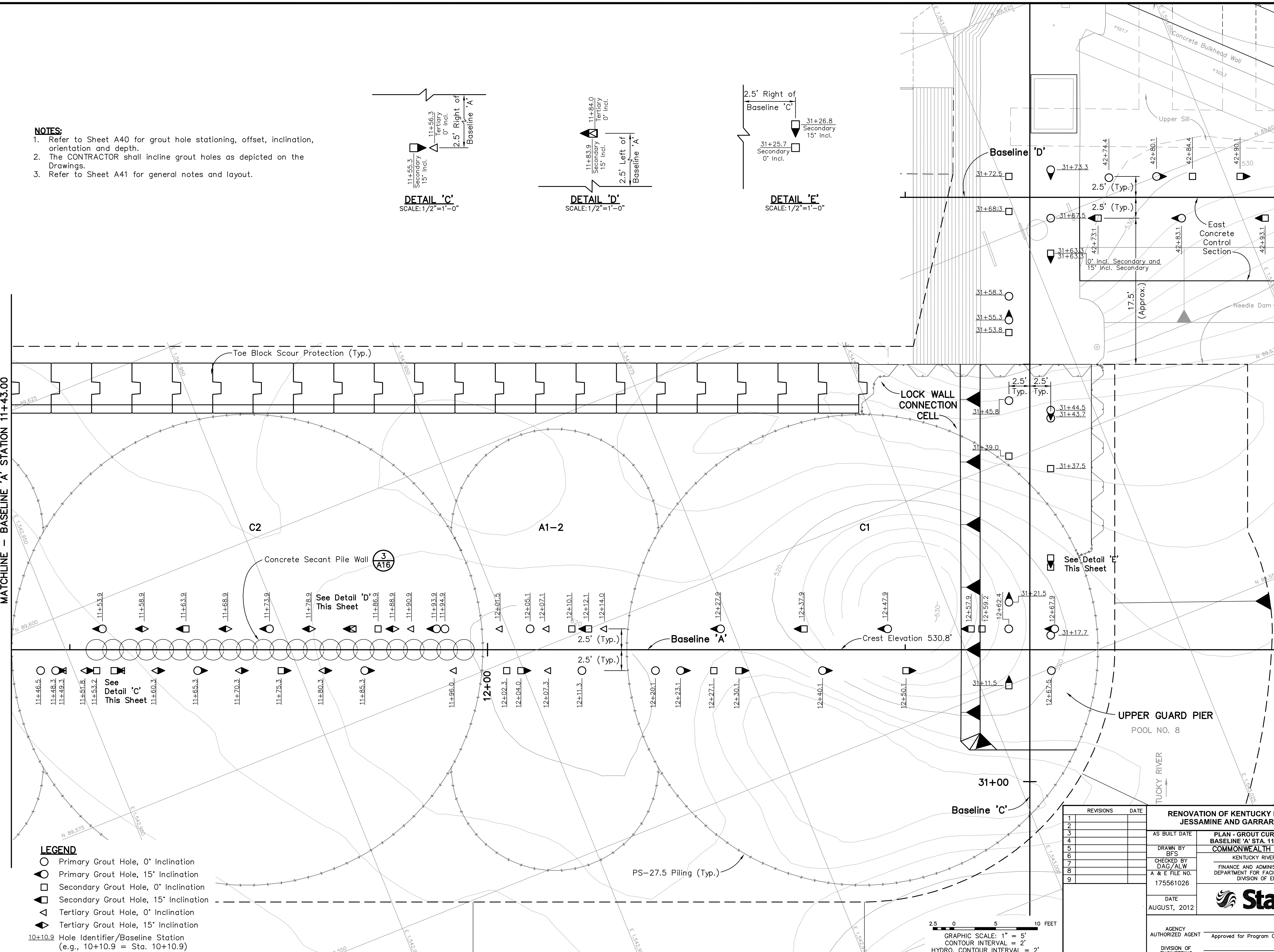
NOTES:
1. Refer to Sheet A40 for grout hole stationing, offset, inclination, orientation and depth.
2. The CONTRACTOR shall incline grout holes as depicted on the Drawings.
3. Refer to Sheet A41 for general notes and layout.



LEGEND
- ○ Primary Grout Hole, 0° Inclination
- Primary Grout Hole, 15° Inclination
- □ Secondary Grout Hole, 0° Inclination
- Secondary Grout Hole, 15° Inclination
- ◁ Tertiary Grout Hole, 0° Inclination
- Tertiary Grout Hole, 15° Inclination
- 10+10.9 Hole Identifier/Baseline Station (e.g., 10+10.9 = Sta. 10+10.9)

GRAPHIC SCALE: 1" = 5' (2.5, 0, 5, 10 FEET)
CONTOUR INTERVAL = 2'
HYDRO. CONTOUR INTERVAL = 2'

REVISIONS	DATE
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RENOVATION OF KENTUCKY RIVER LOCK AND DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

PLAN - GROUT CURTAIN LOCATIONS
BASELINE 'A' STA. 11+43 TO STA. 12+95

COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING

Stantec

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A & E FILE NO.: 175561026
DATE: AUGUST, 2012
DRAWING NO.: A43
SCALE: 1" = 5'
REVIEWED DIV. OF ENGR.
For Intent Only
ENGR. FILE NO.: C5RQ–084–RA08–00

AGENCY AUTHORIZED AGENT — Approved for Program Concept Only — DATE
DIVISION OF ENGINEERING — Approved for Program Concept Only — DATE

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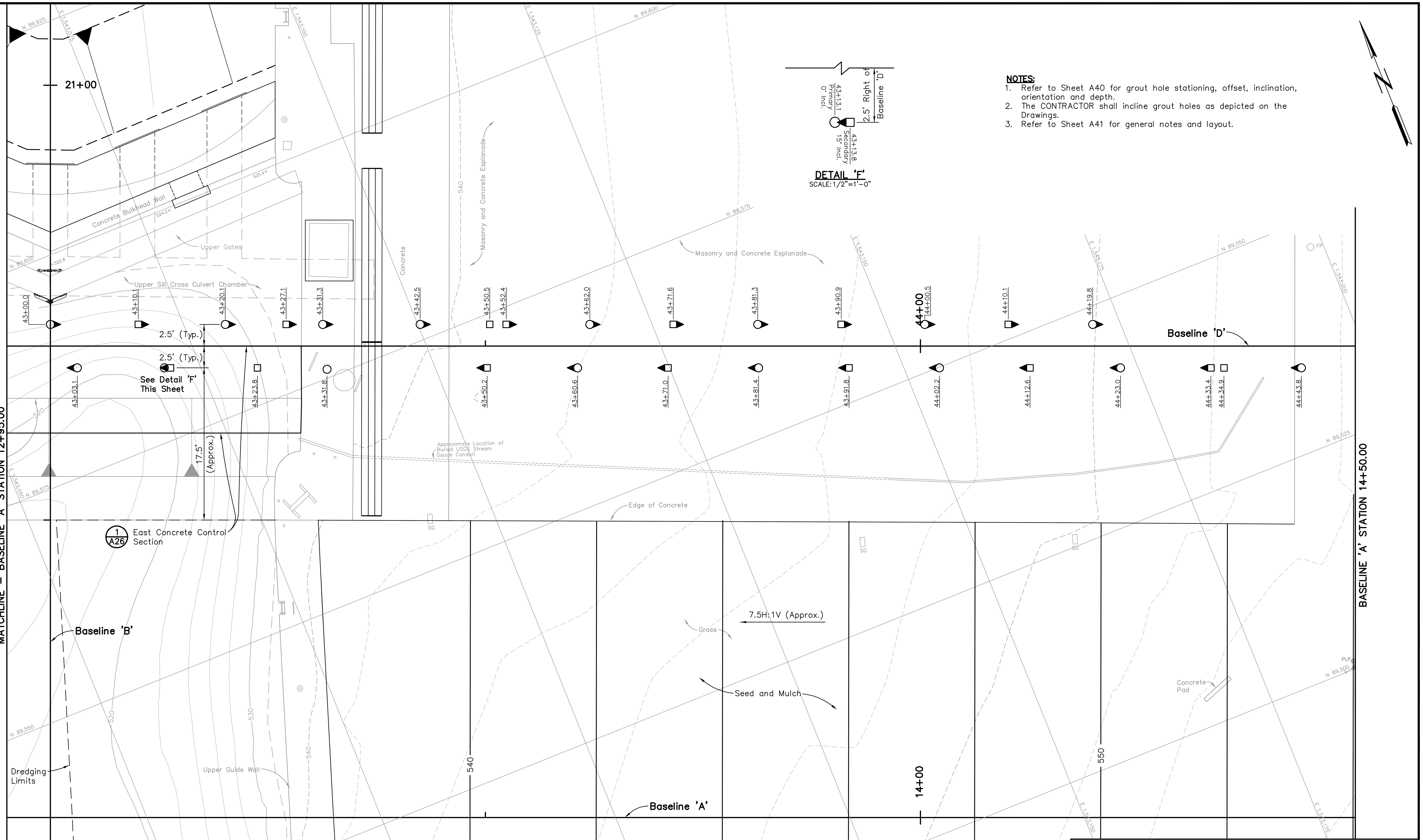

NOTES:

1. Refer to Sheet A40 for grout hole stationing, offset, inclination, orientation and depth.
2. The CONTRACTOR shall incline grout holes as depicted on the Drawings.
3. Refer to Sheet A41 for general notes and layout.

LEGEND

- Primary Grout Hole, 0° Inclination
- Primary Grout Hole, 15° Inclination
- Secondary Grout Hole, 0° Inclination
- Secondary Grout Hole, 15° Inclination
- Tertiary Grout Hole, 0° Inclination
- Tertiary Grout Hole, 15° Inclination
- 10+10.9 Hole Identifier/Baseline Station (e.g., 10+10.9 = Sta. 10+10.9)

GRAPHIC SCALE: 1" = 5' (2.5, 0, 5, 10 FEET)
CONTOUR INTERVAL = 2'
HYDRO. CONTOUR INTERVAL = 2'

REVISIONS	DATE
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RENOVATION OF KENTUCKY RIVER LOCK AND DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

PLAN - GROUT CURTAIN LOCATIONS
BASELINE 'A' STA. 12+95 TO STA. 14+50

COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING

Stantec

AS BUILT DATE
DRAWN BY: BFS
CHECKED BY: DAG/ALW
A & E FILE NO.: 175561026
DATE: AUGUST, 2012

DRAWING NO.: A44
SCALE: 1" = 5'
REVIEWED DIV. OF ENGR.
For Intent Only
ENGR. FILE NO.: C5RQ-084-RA08-00

AGENCY AUTHORIZED AGENT: Approved for Program Concept Only — DATE
DIVISION OF ENGINEERING: Approved for Program Concept Only — DATE

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1/A45 PROFILE – FOUNDATION GROUTING PROGRAM PARALLEL TO BASELINE 'A' – 2.5' UPSTREAM

SCALE: 1" = 10'

LEGEND

- Primary Grout Boring
- Secondary Grout Boring
- Tertiary Grout Boring

NOTES:

1. Refer to Sheet A40 for grout hole stationing, offset, inclination, orientation and depth.
2. The CONTRACTOR shall incline grout holes as depicted on the Drawings.
3. Grout borings originating within the West Concrete Control Section shall be advanced 50 feet and inclined as shown hereon.
4. Refer to Sheet A41 for general notes and layout.

Section or Detail No.
Sheet Where Shown

REFERENCE KEY

REVISIONS	DATE
1	
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RENOVATION OF KENTUCKY RIVER LOCK AND DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE

PROFILE - GROUT CURTAIN BASELINE 'A' - 2.5' U/S - STATION 9+60 TO STATION 12+80

DRAWING NO. A45

DRAWN BY BFS

COMMONWEALTH OF KENTUCKY
KENTUCKY RIVER AUTHORITY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING

SCALE AS SHOWN

CHECKED BY DAG/ALW

A & E FILE NO. 175561026

REVIEWED DIV. OF ENGR.

DATE AUGUST, 2012

Stantec

For Intent Only
ENGR. FILE NO.
C5RQ-084-RA08-00

AGENCY AUTHORIZED AGENT — Approved for Program Concept Only — DATE

DIVISION OF ENGINEERING — Approved for Program Concept Only — DATE

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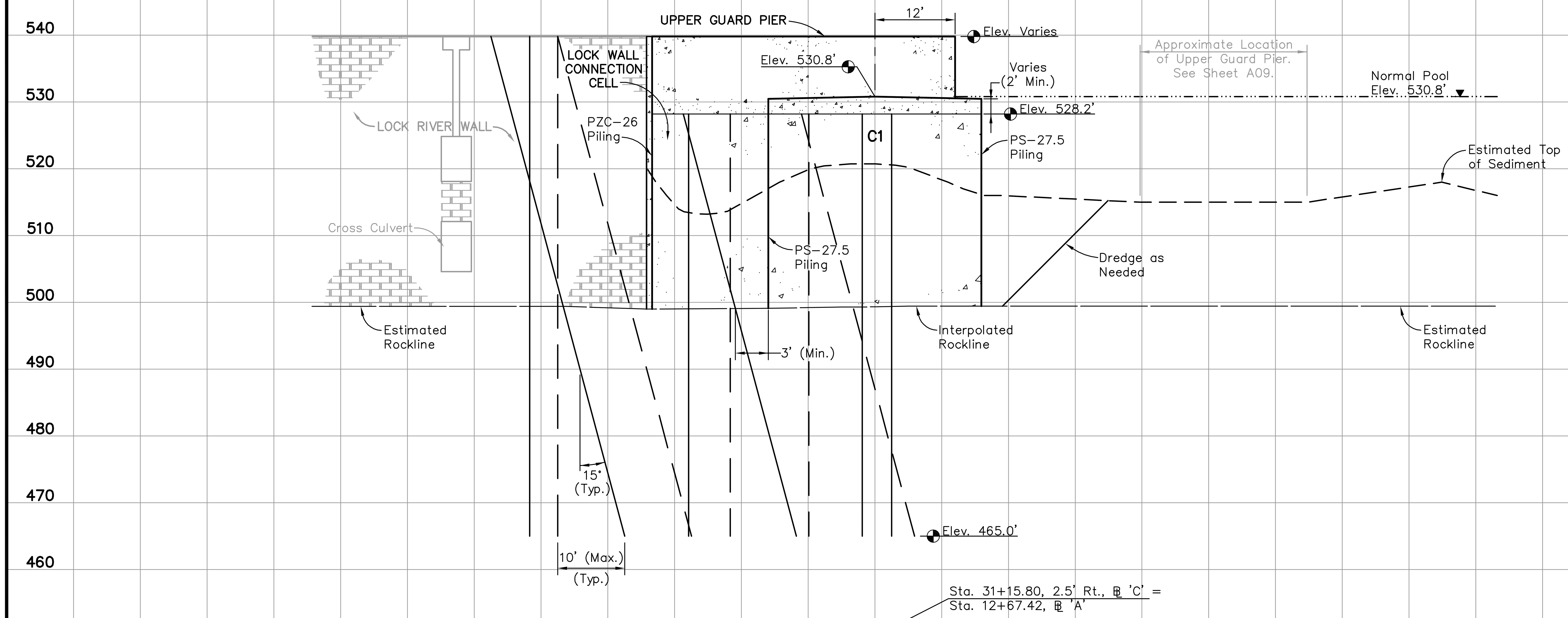
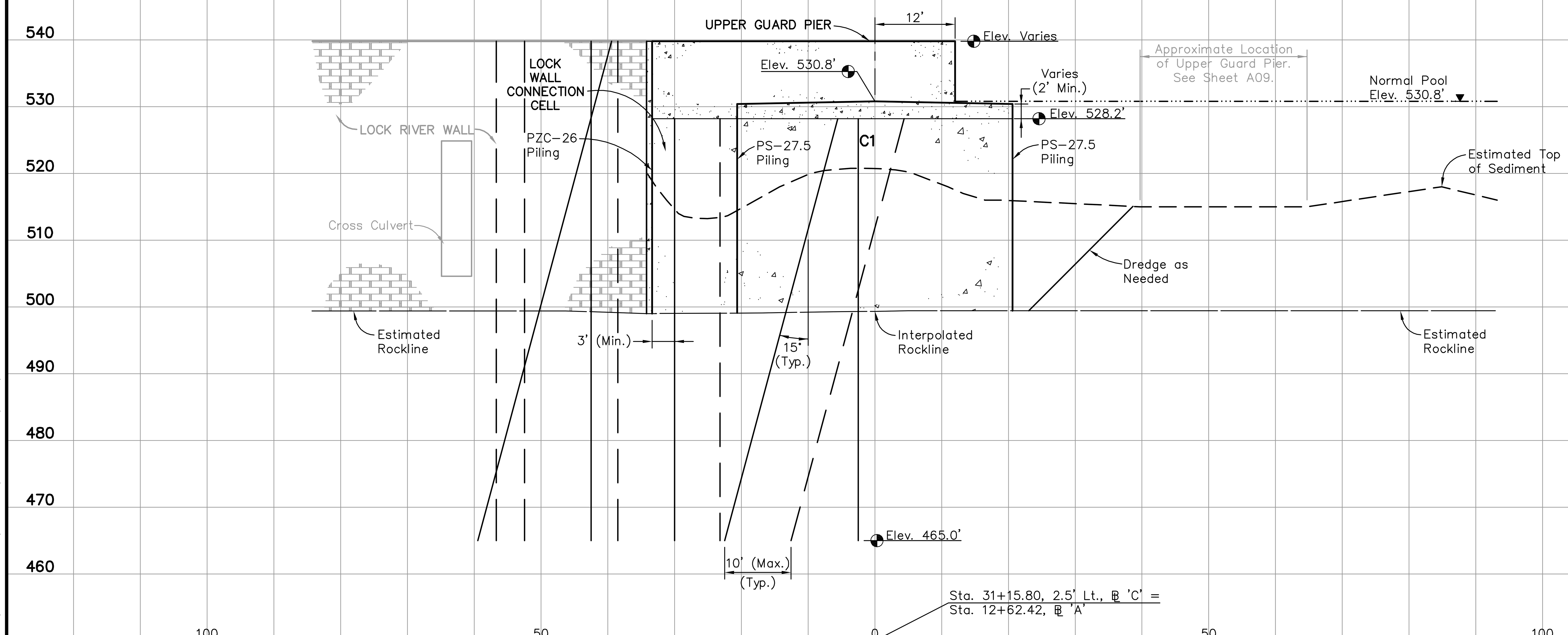


1
A47
PROFILE – FOUNDATION GROUTING PROGRAM
PARALLEL TO BASELINE 'C' – 2.5' UPSTREAM
SCALE: 1" = 10'



2
A47
PROFILE – FOUNDATION GROUTING PROGRAM
PARALLEL TO BASELINE 'C' – 2.5' DOWNSTREAM
SCALE: 1" = 10'

NOTES:

1. Refer to Sheet A40 for grout hole stationing, offset, inclination, orientation and depth.
2. The CONTRACTOR shall incline grout holes as depicted on the Drawings.
3. Refer to Sheet A41 for general notes and layout.

LEGEND

- ——— Primary Grout Boring
- —— —— Secondary Grout Boring
- – – – – Tertiary Grout Boring

REFERENCE KEY

Section or Detail No.
Sheet Where Shown

REVISIONS		DATE
1		
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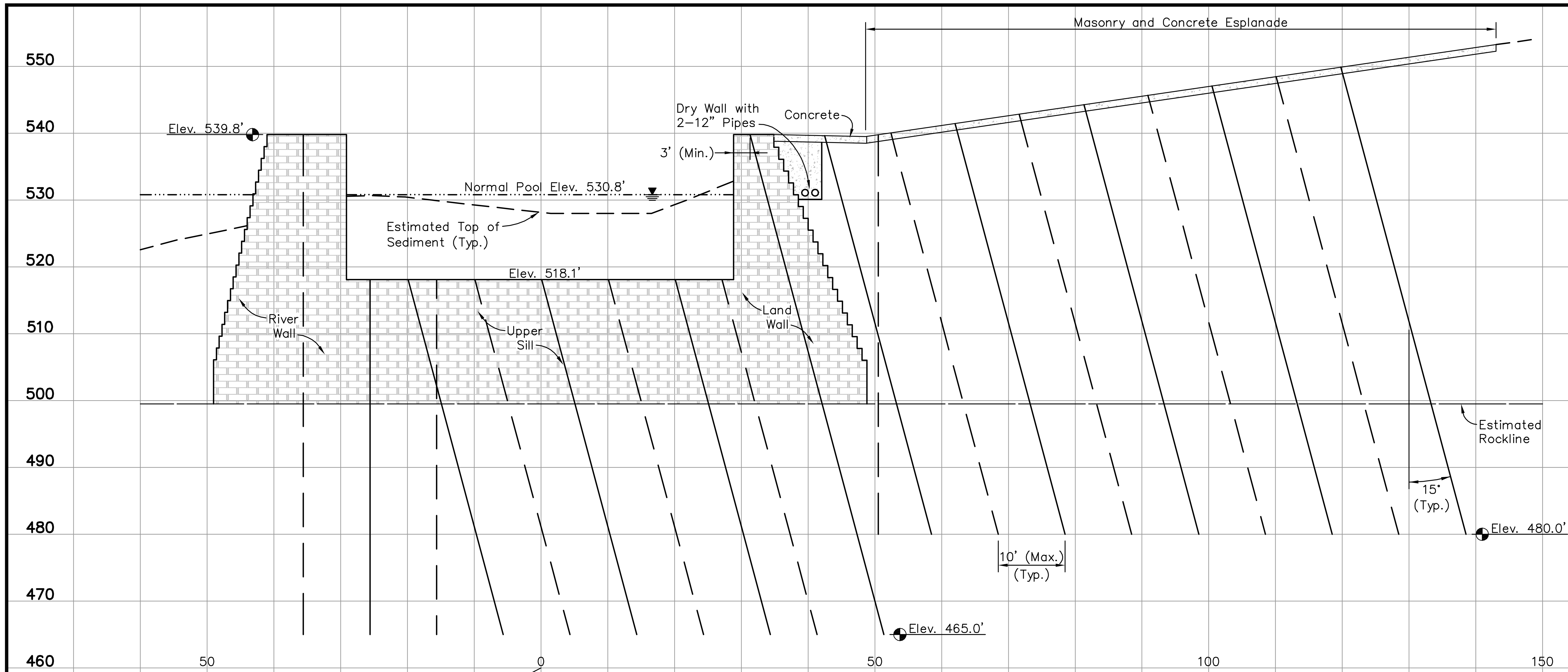
RENOVATION OF KENTUCKY RIVER LOCK AND DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE	PROFILE GROUT CURTAIN - BASELINE 'C'	DRAWING NO. A47
DRAWN BY BFS	COMMONWEALTH OF KENTUCKY KENTUCKY RIVER AUTHORITY	SCALE AS SHOWN
CHECKED BY DAG/ALW	FINANCE AND ADMINISTRATION CABINET DEPARTMENT FOR FACILITIES MANAGEMENT DIVISION OF ENGINEERING	REVIEWED DIV. OF ENGR.
A & E FILE NO. 175561026	Stantec	For Intent Only
DATE AUGUST, 2012		ENGR. FILE NO. C5RQ-084-RA08-00

AGENCY AUTHORIZED AGENT ______ Approved for Program Concept Only ______ DATE ______

DIVISION OF ENGINEERING ______ Approved for Program Concept Only ______ DATE ______



Sta. 20+73.00, ℄ 'B' = Sta. 43+00.00, ℄ 'D', 3' Lt.

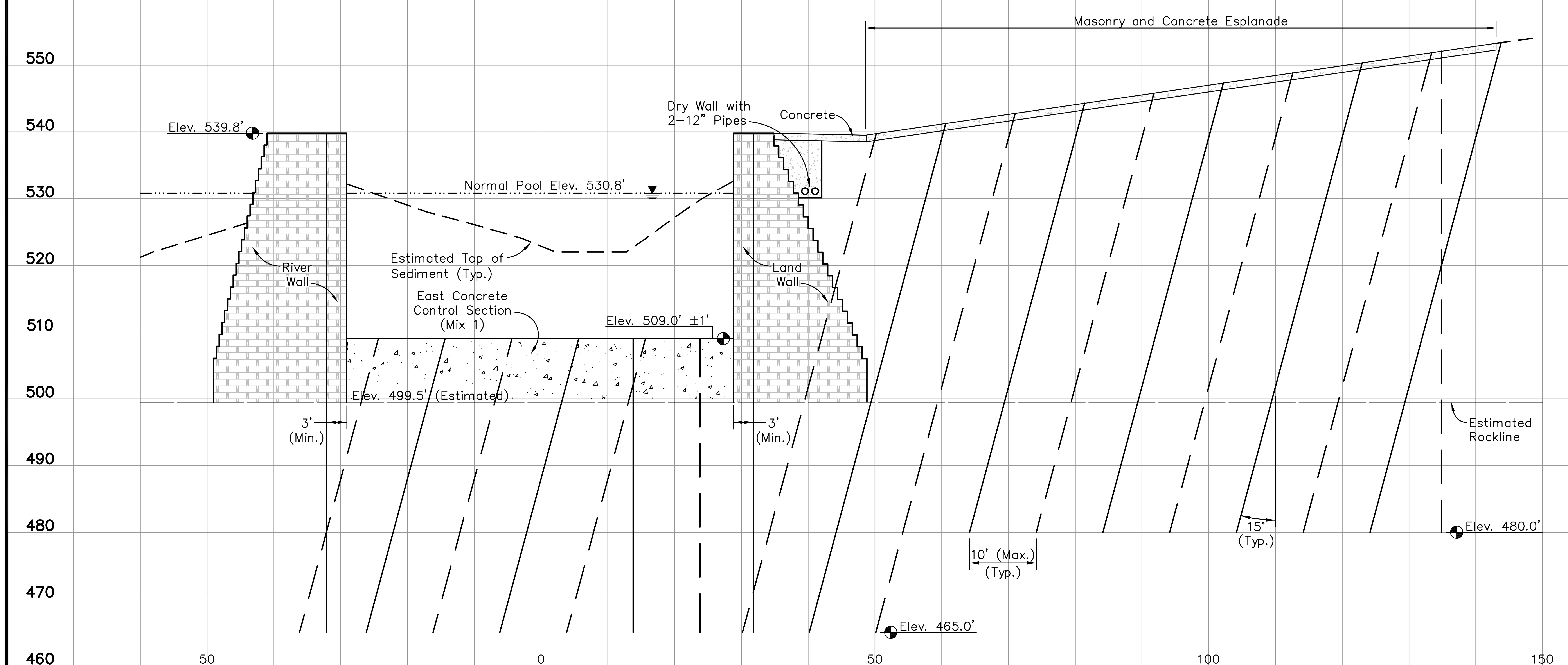
(1/A48) **PROFILE – FOUNDATION GROUTING PROGRAM PARALLEL TO BASELINE 'D' – 2.5' DOWNSTREAM**
SCALE: 1" = 10'

NOTES:

1. Refer to Sheet A40 for grout hole stationing, offset, inclination, orientation and depth.
2. The CONTRACTOR shall incline grout holes as depicted on the Drawings.
3. Refer to Sheet A41 for general notes and layout.

LEGEND

- ———— Primary Grout Boring
- —— —— Secondary Grout Boring
- – – – – Tertiary Grout Boring



Sta. 20+67.00, ℄ 'B' = Sta. 43+00.00, 3' Rt., ℄ 'D'

(2/A48) **PROFILE – FOUNDATION GROUTING PROGRAM PARALLEL TO BASELINE 'D' – 2.5' UPSTREAM**
SCALE: 1" = 10'

Section or Detail No.
Sheet Where Shown
REFERENCE KEY

REVISIONS		DATE
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RENOVATION OF KENTUCKY RIVER LOCK AND DAM NO. 8
JESSAMINE AND GARRARD COUNTIES, KENTUCKY

AS BUILT DATE	PROFILE GROUT CURTAINS - BASELINE 'D'	DRAWING NO. A48
DRAWN BY BFS	COMMONWEALTH OF KENTUCKY KENTUCKY RIVER AUTHORITY	SCALE AS SHOWN
CHECKED BY DAG/ALW	FINANCE AND ADMINISTRATION CABINET DEPARTMENT FOR FACILITIES MANAGEMENT DIVISION OF ENGINEERING	REVIEWED DIV. OF ENGR.
A & E FILE NO. 175561026	Stantec	For Intent Only ENGR. FILE NO. C5RQ-084-RA08-00
DATE AUGUST, 2012		

AGENCY AUTHORIZED AGENT — Approved for Program Concept Only — DATE
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APPENDIX D – GROUT RECORDS EXAMPLE

Job No: TQ 13-15

Drillers Rock Log

TERRAFIRM CONSTRUCTION, LLC

Date: 8-10-15

Project: Lock 8

Driller: PJ

Rig: 286

Hole #: AA1072B8 vert

Shift: Day

Helper: GP

Hole Angle	Time		Depth		Total		Remarks
	Start	Stop	From	To	Depth	Formation	
90°	8:50	10:10	0	28	48.2	cement	makeing
			28	50	50 ft	Rock	water!

Comments:

Terrafirm Construction, LLC

Kentucky Lock 8

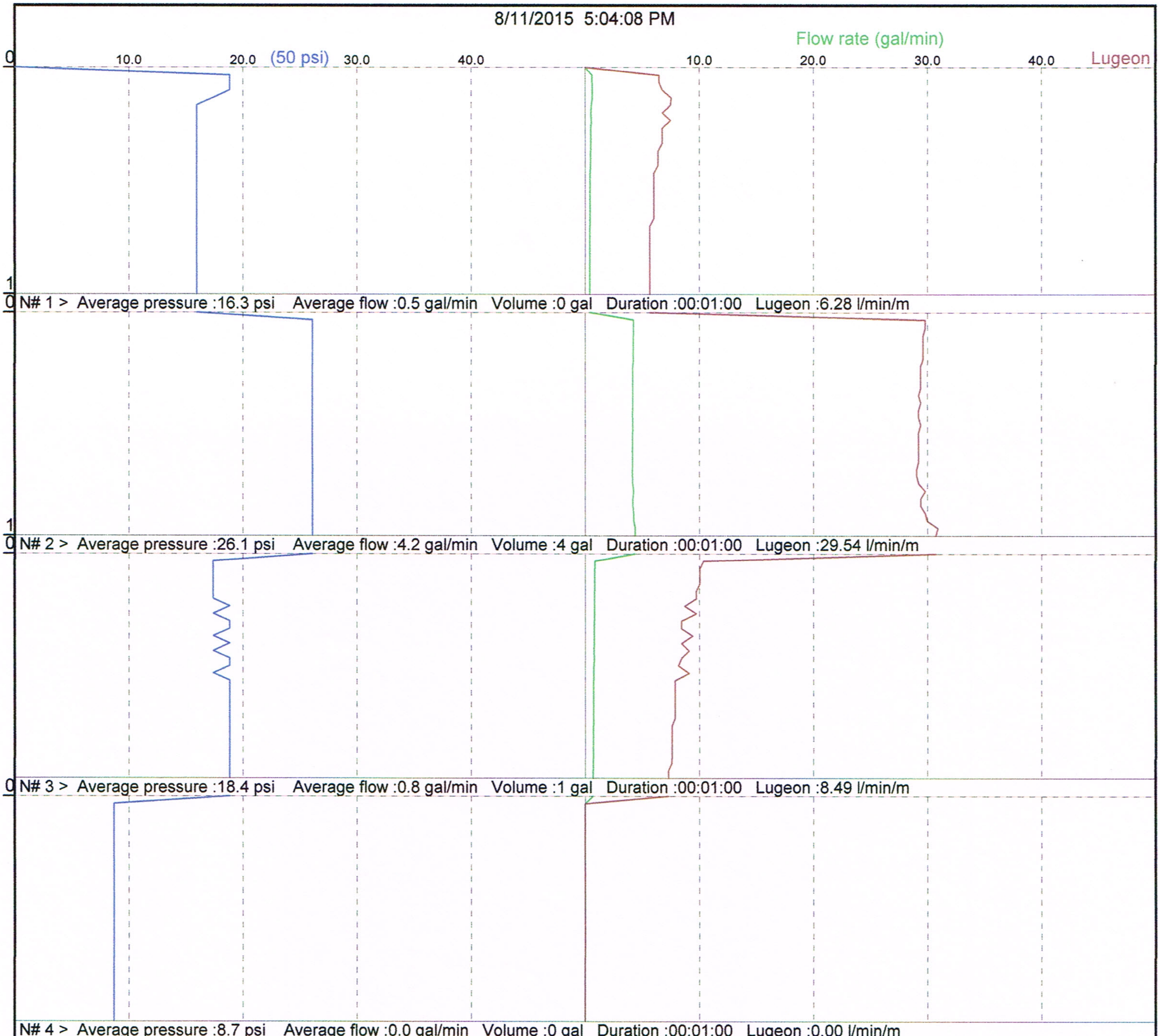
LUGEON TESTS

Pressure and flow in accordance to time

(Contract N#: 1845)

EXLGH 4.23/CINAUT

AU1072.8 test 2 (28.00-40.00 ft)

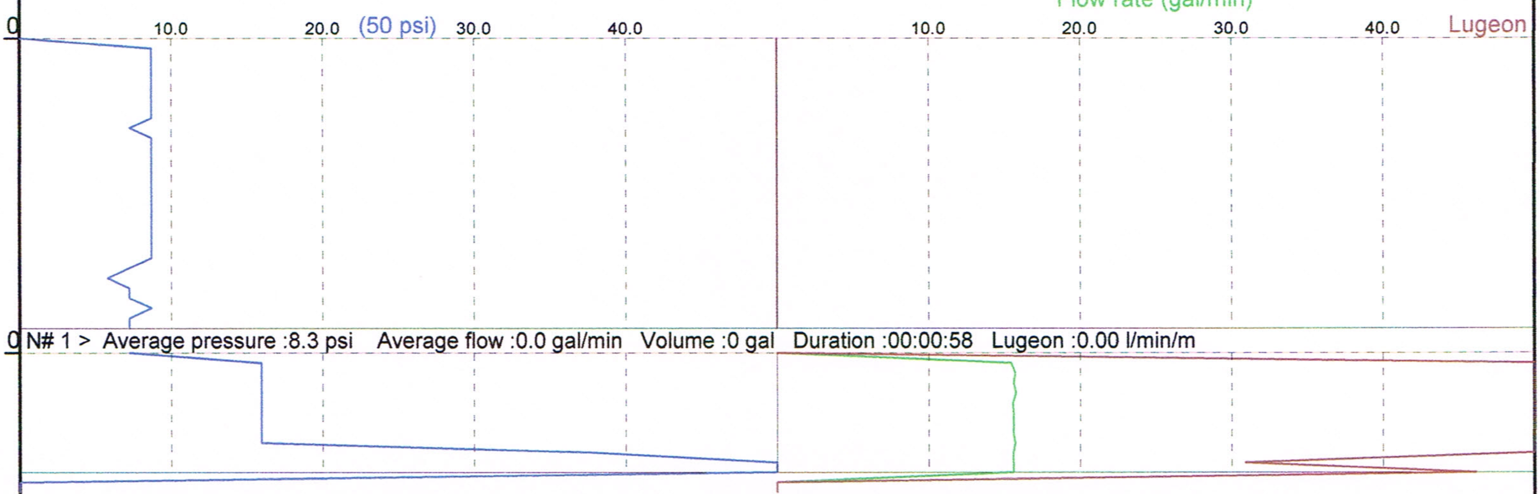


Terrafirm Construction, LLC	**Kentucky Lock 8** LUGEON TESTS Pressure and flow in accordance to time	(Contract N#: 1845)

EXLGH 4.23/CINAUT

AU1072.8 test 2 (28.00-40.00 ft)

8/11/2015 5:00:21 PM



N# 1 > Average pressure :8.3 psi Average flow :0.0 gal/min Volume :0 gal Duration :00:00:58 Lugeon :0.00 l/min/m

Terrafirm Construction, LLC

Kentucky Lock 8

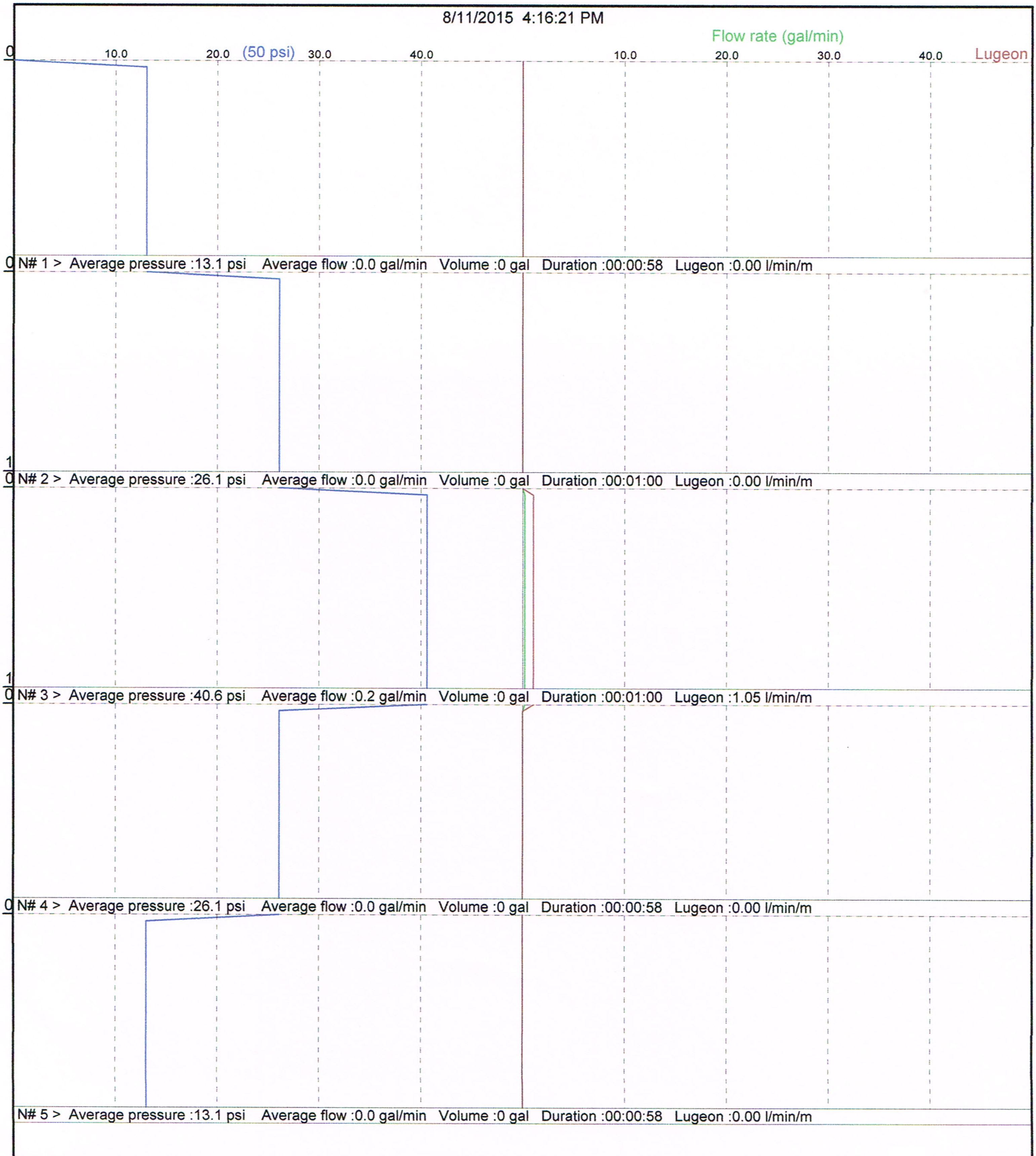
LUGEON TESTS

Pressure and flow in accordance to time

(Contract N#: 1845)

EXLGH 4.23/CINAUT

AU1072.8 test 1 (40.00-50.00 ft)



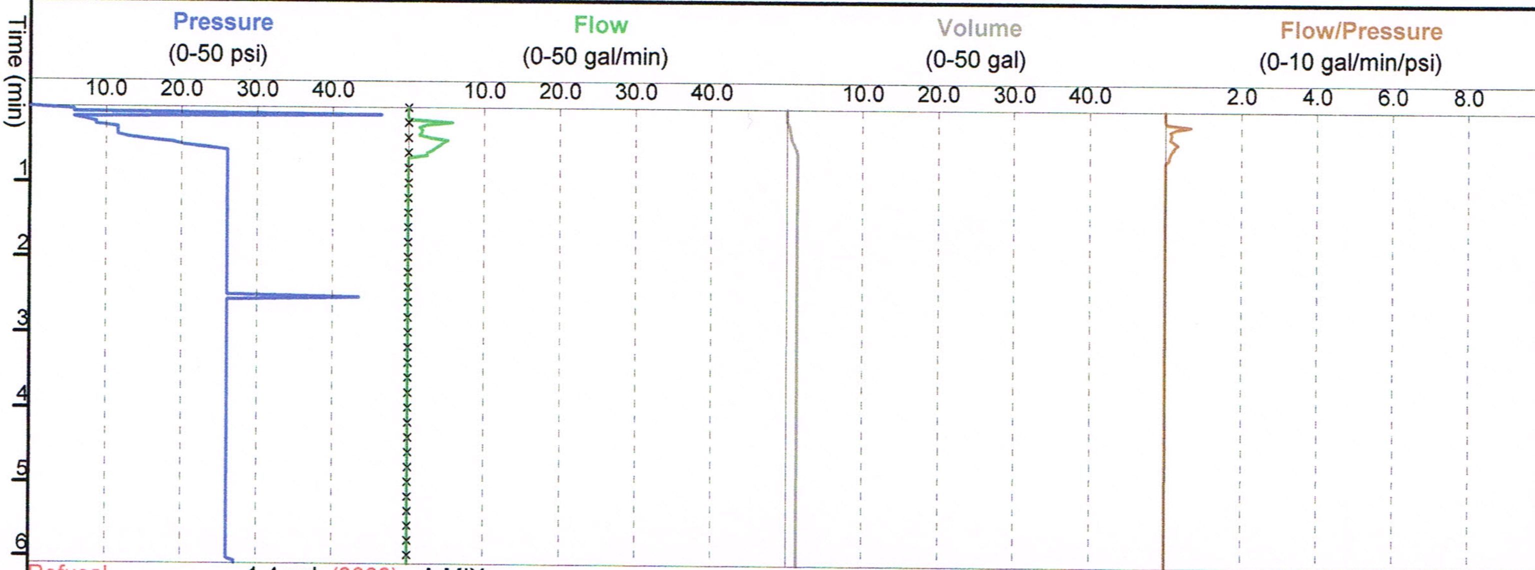
Terrafirm Construction, LLC	**Kentucky Lock 8** GROUTING Pressure and flow in accordance to time	(Contract N#: 1845)

1 cm = 1 min

EXPVD 4.88/CIPVD567

Borehole AU1072 stage 1 (28-50 ft)

08/11/15 6:00:39 PM



Refusal 1.4 gal (2000) A MIX

6:06:44 PM

APPENDIX E – GROUT CURTAIN INSTALLATION RECORDS

Verification Cores

Hole	Structure	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Values (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
V-1018.0	West Closure Cell	53.7	--	8.0 - 20.0	4.3, 5.8, 8.9, 5.8, 4.3	6, 8, 6, 6, 2	6	Laminar	Backfilled.						
				20.0 - 32.0	8.7, 16.2, 23.2, 16.0, 8.7	1, 1, 1, 0, 0	1	Laminar							
				32.0 - 44.0	11.3, 23.2, 33.4, 23.2, 12.2	0, 0, 0, 0, 0	0	Laminar							
				44.0 - 53.7	13.0, 30.5, 42.1, 30.5, 15.4	0, 0, 0, 0, 1	1	Laminar							
V-1055.0	West Closure Cell	50.8	--	24.8 - 50.8	4.3, 13.1, 22.3, 15.8, 7.9	0, 0, 0, 0, 0	0	Laminar	Backfilled.						
V-1	Esplanade	70	--	50.0 - 62.0	8.7, 16.0, 26.1, 16.0, 8.7	0, 0, 0, 0, 0	0	Laminar	Backfilled.						
				62.0 - 70.0	11.6, 23.2, 37.7, 23.2, 11.6	0, 0, 0, 0, 0	0	Laminar							
V-2	Esplanade	61.9	--	42.5 - 54.5	8.7, 16.0, 20.3, 13.1, 8.7	0, 0, 0, 0, 0	0	Laminar	Backfilled.						Hit steel at depth 18.0' and shifted hole 0.5' west.
				54.5 - 61.9	11.6, 20.3, 33.4, 18.9, 11.6	0, 0, 1, 0, 0	0	Laminar							
V-1105	Cell 3	50.8	--	27.6 - 50.8	8.7, 18.9, 26.2, 18.9, 8.6	1, 0, 0, 0, 0	1	Laminar	Backfilled.						
V-1080	Cell 3	50.8	--	26.0 - 38.0	8.7, 18.9, 30.5, 18.2, 5.8	0, 1, 0, 1, 0	1	Laminar	Backfilled.						Hit steel at depth 15.0' and shifted hole 0.5' west.
V-1209	A1-2	63.9	--	30.0 - 42.0	11.6, 23.2, 33.4, 20.3, 11.6	0, 0, 0, 0, 0	0	Laminar	Backfilled.						
				42.0 - 54.0	16.0, 30.6, 45.0, 30.5, 16.0	0, 1, 1, 0, 0	1	Laminar							
				54.0 - 63.9	20.3, 40.2, 48.9, 37.7, 18.9	0, 1, 1, 0, 0	1	Laminar							
V-1135	A2-3	63.3	--	28.0 - 63.3	9.5, 23.1, 31.3, 23.0, 8.7	1, 0, 1, 0, 0	1	Laminar	24.0 - 50.9	23.1	2.2	--	--	2.2	
V-1167	Cell 2	63.5	--	28.0 - 40.0	9.2, 18.5, 28.0, 18.5, 9.2	0, 12, 8, 0, 0	0	Dilation	11.0 - 50.9	10.6	1.8	--	--	1.8	Not Automated data, used manually recorded data
				40.0 - 52.0	13.3, 26.6, 40.0, 26.6, 13.3	0, 12, 10, 5, 0	0	Dilation							
				52.0 - 63.0	17.3, 34.6, 50.0, 34.6, 17.3	0, 10, 10, 7, 0	0	Dilation							
V-1195	Cell 2	63.3	--	28.0 - 40.0	11.6, 23.2, 30.5, 19.0, 11.0	0, 14, 9, 0, 0	0	Dilation	Backfilled.						
				40.0 - 52.0	15.9, 30.5, 42.1, 26.2, 16.0	0, 15, 10, 1, 0	0	Dilation							
				52.0 - 63.3	16.0, 37.7, 50.0, 34.3, 13.1	0, 12, 11, 2, 0	0	Dilation							
V-4300	Upper Approach	54.0 (Actually drilled depth = 54.0 - 9.0 = 45.0)	--	18.5 - 54.0	5	3	3	N/A	Backfilled						
V-SP9	Cell 2 (Secant Pile shaft 9)	53.0	--	Not Performend	Not Performed	N/A	N/A	N/A	45.0 - 53.0	45	69.9	--	-	--	Verification core obtained to determine if voids were present at interface. WPT not performed. Pressure grouted

West Closure Cell - Baseline A

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Values (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
AD1034.6P	50	15	26.0 - 38.0	8.7, 16.0, 26.1, 16.0, 8.2	0, 1, 0, 0, 0	1	Laminar	26.0 - 50.0	26	0.9	--	--	0.9	
			38.0 - 50.0	11.6, 23.2, 36.6, 23.2, 11.6	0, 0, 0, 0, 0	0	Laminar							
AD1059.6P	50	--	25.0 - 37.0	8.7, 16.0, 26.1, 16.0, 8.7	11, 10, 8, 9, 9	8	Turbulent	25.0 - 50.0	25	1.2	--	--	1.2	
			37.0 - 50.0	11.6, 23.2, 34.8, 23.2, 11.6	0, 0, 0, 1, 0	1	Laminar							
AD1024.6S	49.8	15	10.0 - 22.0	1.4, 3.4, 5.8, 2.7, 1.4	0, 0, 0, 0, 0	0	Laminar	10.0 - 49.8	7.5	0.7	--	--	0.7	
			22.0 - 34.0	4.3, 8.7, 16.0, 8.7, 4.3	0, 0, 0, 2, 0	1	Laminar							
			34.0 - 49.8	5.8, 16.0, 26.8, 18.9, 7.8	0, 1, 1, 0, 0	1	Laminar							
AD1054.6P	50	15	23.0 - 35.0	7.1, 13.1, 23.2, 13.1, 5.1	>100, >100, 76, >100, >100	76	Turbulent	23.0 - 50.0	23	1	--	--	1	Hit steel at depth 18.0' and shifted hole 0.5' west.
			35.0 - 50.0	11.5, 23.0, 35.0, 23.0, 11.5	0, 0, 0, 0, 0	0	Laminar							
AD1044.6S	49.5	15	17.0 - 29.0	4.3, 8.7, 13.1, 6.8, 4.3	0, >100, >100, 0, 0	0	Dilation	17.0 - 49.5	16.4	0.1	--	--	0.1	
			29.0 - 41.0	4.3, 16.0, 26.1, 15.8, 4.3	0, 0, 0, 1, 0	1	Laminar							
			41.0 - 49.5	11.6, 23.5, 37.7, 24.2, 11.6	0, 1, 0, 1, 0	1	Laminar							
AD1064.7S	50	15	28.0 - 40.0	5.8, 16.0, 23.4, 13.1, 5.8	0, 0, 0, 0, 0	0	Laminar	28.0 - 50.0	26	1.3	--	--	1.3	Hit steel at depth 15.0' and shifted hole 0.5' west.
			40.0 - 50.0	8.7, 23.2, 37.7, 23.2, 8.7	0, 0, 0, 0, 0	0	Laminar							
AD1064.8S	50	--	27.0 - 39.0	5.8, 16.0, 24.4, 13.1, 5.1	0, 0, 2, 0, 0	0	Dilation	28.0 - 50.0	27	1.7	--	--	1.7	
			39.0 - 50.0	11.6, 23.2, 37.7, 23.2, 15.9	1, 0, 0, 0, 0	1	Laminar							
AD1047.8P	50.9	15	24.0 - 36.0	8.7, 13.0, 21.4, 11.6, 7.9	57, 79, 55, >100, >100	55	Turbulent	24.0 - 50.9	23.1	2.2	--	--	2.2	
			36.0 - 50.9	11.6, 23.3, 34.6, 23.2, 9.4	0, 0, 0, 0, 0	0	Laminar							
AU1027.8P	50.9	15	11.0 - 23.0	4.3, 5.8, 8.7, 5.8, 3.0	0, 0, 0, 0, 0	0	Laminar	11.0 - 50.9	10.6	1.8	--	--	1.8	
			23.0 - 35.0	8.8, 11.6, 20.3, 11.6, 8.7	1, 0, 0, 0, 0	1	Laminar							
			35.0 - 50.9	11.6, 21.5, 33.6, 18.9, 11.6	0, 1, 0, 0, 0	1	Laminar							
AU1037.8S	50.1	15	15.0 - 27.0	4.7, 8.7, 13.1, 8.7, 4.3	0, >100, >100, >100, 0	0	Dilation	15.0 - 50.9	14.5	75.7	2	--	77.7	
			27.0 - 39.0	8.7, 16.0, 26.1, 16.0, 8.7	0, 0, 0, 0, 0	0	Laminar							
			39.0 - 50.9	11.6, 24.8, 37.7, 26.1, 11.6	0, 0, 0, 0, 0	0	Laminar							
AU1020.7P	54.4	--	18.0 - 54.4	4.3, 11.6, 16.0, 11.6, 4.4	0, 17, 17, 21, 0	0	Dilation	6.0 - 52.3	6	2.1	--	--	2.1	Hole was downstaged due to hole collapse at depth 18.0'.
AU1057.8S	51	15	23.0 - 35.0	8.7, 13.1, 23.0, 13.1, 8.7	1, 3, 2, 1, 0	1	Laminar	Backfilled.						
			35.0 - 51.0	11.7, 23.2, 33.4, 23.2, 11.6	0, 0, 1, 0, 0	0	Dilation							

West Bank Fan - Baseline A

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Values (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
AD1010.3P	50	75	8.0 - 33.0	1.4, 1.4, 4.3, 1.4, 1.4	0, 0, 63, 72, 57	57	Wash-Out	8.0 - 33.0	5.2	0.5	--	--	0.6	Hole was downstaged.
			33.0 - 50.0	1.4, 4.3, 8.7, 4.3, 1.4	0, >100, 98, >100, >100	98	Turbulent	33.0 - 50.0	10	0.1	--	--		
AD1012.0P	50	55	8.0 - 40.0	3.5, 4.4, 8.7, 4.5, 4.3	>100, >100, 77, >100, 94	77	Turbulent	8.0 - 40.0	14.3	53.6	--	--	191.3	Hole was downstaged.
			40.0 - 50.0	7.8, 16.0, 16.0, 16.0, 5.8	>100, >100, >100, >100, >100	>100	Turbulent	40.0 - 50.0	23	50.4	87.3	--		
AD1015.3P	50	15	8.0 - 50.0	0.0, 1.6, 4.3, 1.4, 0.0	1, 1, 1, 1, 0	1	Laminar	8.0 - 50.0	7.7	0	--	--	0	Hole was downstaged.
AD1013.4	52.3	40	3.0 - 16.0	1.4, 4.3, 4.3, 1.4, 0	0, >100, >100, 0, 0	0	Dilation	3.0 - 25.0	5	210.2	--	--	212.9	Hole was grouted in two stages based on subsurface features encountered during drilling.
			16.0 - 28.0	4.3, 8.7, 11.8, 8.7, 4.3	6, 5, 7, 6, 8	6	Laminar							
			28.0 - 40.0	4.3, 11.6, 20.2, 8.7, 4.3	75, 59, 51, 65, 74	51	Turbulent	25.0 - 52.3	20	2.7	--	--		
			40.0 - 52.3	5.8, 18.9, 29.8, 16.4, 7.7	0, 0, 0, 0, 0	0	Laminar							
AD1011.7S	53	60	3.0 - 15.0	8.9, 9.8, 10.1, 9.6, 8.9	0, >100, >100, >100, 0	0	Dilation	30.0 - 50.0	17	121.3	158.7	178.6	675.7	Hole was grouted in two stages based on subsurface features encountered during drilling.
			15.0 - 53.0	13.1, 14.5, 15.1, 15.0, 13.6	68, 62, 60, 60, 64	60	Turbulent	3.0 - 30.0	10	145.7	52.3	19.1		
			36.5 - 53.0	4.3, 4.3, 4.3,4.3, 4.3	>100, >100, >100, >100, >100	>100	Laminar							
AU1016.0P	52.3	10	6.0 - 18.0	4.0, 5.8, 2.9	0, >100, 0	0	Dilation	6.0 - 18.0	6	32.9	1.5	--	35	Hole was downstaged.
			18.0 - 52.3	4.3, 11.5, 16.0, 8.7, 4.3	0, 1, 15, 1, 0	0	Dilation	6.0 - 52.3	6	0.6	--	--		
AD1013.6P	51	35	6.0 - 51.0	1.6, 3.3, 4.9, 3.3, 1.6	0, 0, 5, 0, 0	0	Dilation	6.0 - 51.0	4.9	0	--	--	0	Hole was downstaged.
AU1017.2S	52.3	--	4.0 - 16.0	4.3, 4.3, 6.1, 4.3, 4.3	0, 1, 0, 0, 0	1	Laminar	4.0 - 52.0	12	0.2	--	--	0.2	Hole was downstaged.
			16.0 - 28.0	5.8, 11.6, 16.0, 11.6, 4.3	0, 0, 0, 0, 0	0	Laminar							
			28.0 - 40.0	5.8, 16.0, 27.6, 18.9, 5.8	0, 0, 1, 0, 0	0	Dilation							
			40.0 - 52.0	10.0, 23.2, 40.6, 28.1, 12.3	0, 0, 1, 1, 1	1	Laminar							
AD1010.8P	51.3	70	3.0 - 15.0	4.3, 4.3, 5.8, 4.3, 8.3	>100, >100, >100, >100, >100	>100	Laminar	30.0 - 51.3	15	55.9	61.6	85.4	295.9	Hole was grouted in two stages based on subsurface features encountered during drilling.
			15.0 - 51.0	4.3, 5.0, 8.7, 5.8, 4.5	69, 68, 52, 65, 73	52	Turbulent	3.0 - 51.3	18	81.3	11.7	--		
			38.0 - 51.0	4.3, 8.7, 11.4, 8.7, 4.3	90, 88, 80, 83, 90	80	Turbulent							
AD1012.5P	52	50	3.0 - 15.0	4.3, 5.7, 7.5, 4.3, 4.3	>100, >100, >100, >100, >100	>100	Laminar	40.0 - 52.0	30	89.7	124.2	177.9	542.8	Hole was grouted in two stages based on subsurface features encountered during drilling.
			15.0 - 27.0	8.7, 8.7, 13.1, 8.7, 6.3	5, 5, 5, 6, 6	5	Laminar							
			27.0 - 39.0	8.7, 13.1, 18.9, 13.1, 8.7	4, 3, 3, 3, 3	3	Laminar	3.0 - 52.0	10	142.4	8.6	--		
			39.0 - 52.0	10.3, 16.0, 13.9, 14.0, 11.6	54, 62, 68, 69, 72	65	Laminar							
AD1011.1S	50.3	65	30.0 - 50.0	2.4, 6.0, 11.6, 5.8, 3.4	81, 74, 60, 73, 74	60	Turbulent	30.0 - 50.0	25	43.3	11.9	--	55.3	Hole was grouted in two stages based on subsurface features encountered during drilling.
			3.0 - 50.0	1.4, 5.8, 8.7, 5.8, 1.4	0, >100, 83, >100, 0	83	Turbulent	2.0 - 30.0	10	0.1	--	--		
AD1012.8S	50.3	45	40.0 - 50.0	8.7, 16.0, 16.0, 16.0, 8.7	>100, >100, >100, >100, >100	>100	Laminar	28.0 - 50.0	28	71.8	125.6	32.9	#REF!	Hole was grouted in two stages based on subsurface features encountered
AD1017.6S	55.3	15	5.0 - 17.0	1.4, 1.4, 2.5, 1.4, 1.4	>100, >100, >100, >100, >100	>100	Turbulent	17.0 - 55.3	16.4	2.2	--	--	18	Hole was grouted in two stages based on subsurface features encountered during drilling.
			17.0 - 29.0	3.6, 8.7, 13.7, 8.7, 4.3	>100, 91, 78, 92, >100	78	Turbulent							
			29.0 - 41.0	10.1, 18.9, 26.2, 17.0, 4.5	79, 58, 45, 45, 57	45	Turbulent	6.6 - 17.0	5	15.8	--	--		
AD1015.1S	52.3	20	6.6 - 18.6	4.3, 5.5, 8.7, 4.3, 1.4	31, 33, 27, 40, >100	27	Turbulent	25.0 - 52.3	23	0.8	--	--	0.9	Hole was grouted in two stages based on subsurface features encountered during drilling.
			18.6 - 30.6	4.3, 11.6, 18.9, 11.6, 4.3	0, 0, 0, 1, 0	1	Laminar							
			30.6 - 42.6	8.7, 18.9, 29.5, 15.7, 9.0	0, 0, 0, 1, 0	1	Laminar	5.0 - 25.0	5	0.1	--	--		
			42.6 - 52.3	11.6, 26.1, 37.9, 23.6, 11.6	0, 0, 0, 0, 0	0	Laminar							
AD1014.3P	52.2	30	3.0 - 15.0	4.3, 4.6, 5.8, 4.3, 4.3	>100, >100, >100, >100, >100	>100	Laminar	3.0 - 52.2	15	1.1	--	--	1.1	
			15.0 - 27.0	4.3, 11.6, 16.0, 8.7, 4.3	5, 3, 3, 4, 1	3	Laminar							
			27.0 - 39.0	8.7, 16.0, 26.1, 16.0, 6.5	7, 8, 10, 8, 7	7	Dilation							
			39.0 - 52.0	13.1, 23.2, 33.4, 23.2, 12.3	1, 0, 1, 0, 0	1	Laminar							
AD1014.4S	50	25	4.0 - 16.0	4.3, 5.8, 8.7, 5.1, 2.3	>100, >100, >100, >100, >100	>100	Laminar	28.0 - 50.0	25	39.8	--	--	41.4	Hole was grouted in two stages based on subsurface features encountered during drilling.
			16.0 - 28.0	4.4, 11.6, 15.2, 11.6, 4.3	66, 48, 42, 44, 63	42	Turbulent							
			28.0 - 40.0	11.6, 18.5, 28.3, 18.5, 11.6	16, 29, 34, 30, 31	28	Laminar	4.0 - 28.0	10	1.6	--	--		
			40.0 - 50.0	11.6, 23.3, 37.7, 23.2, 11.6	4, 1, 0, 0, 0	1	Laminar							

Arc Cell A1-2 - Baseline A

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Values (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
AD1214.0T	57	--	30.0 - 42.0	11.6, 20.4, 34.6, 22.2, 11.6	1, 2, 5, 5, 0	0	Dilation	30.0 - 57.0	30	3.1	--	--	3.1	
			42.0 - 57.0	11.6, 30.9, 43.5, 30.5, 11.6	0, 1, 0, 0, 0	1	Laminar							
AD1210.1S	65.4	--	30.0 - 42.0	11.6, 18.9, 18.9, 18.9, 11.6	93, 83, 82, 82, 87	82	Turbulent	30.0 - 65.0	30	130.7	132.8	14.5	278	
			42.0 - 54.0	13.1, 26.1, 24.7, 23.2, 16.0	37, 52, 54, 56, 58	58	Wash-Out							
			54.0 - 65.0	22.3, 40.6, 54.3, 40.6, 19.6	0, 0, 1, 0, 0	0	Dilation							
AD1205.1S	67	--	30.0 - 42.0	10.6, 21.8, 32.8, 20.3, 11.5	0, 0, 0, 0, 0	0	Laminar	30.0 - 67.0	30	4.1	--	--	4.1	
			42.0 - 54.0	11.5, 30.5, 42.2, 30.0, 11.6	1, 1, 2, 2, 0	1	Laminar							
			54.0 - 67.0	18.9, 37.7, 51.5, 35.2, 18.9	1, 0, 1, 0, 0	1	Laminar							
AU1207.3T	55.6	--	30.0 - 42.0	8.7, 20.3, 30.6, 19.5, 9.0	4, 3, 3, 2, 2	2	Void Filling	30.0 - 55.0	30	9	--	--	9	
			42.0 -55.0	16.0, 30.5, 45.1, 30.5, 30.5	1, 1, 1, 1, 1	1	Laminar							
AU1202.3S	64.3	--	30.0 - 42.0	11.6, 16.4, 33.4, 20.3, 11.6	0, 1, 3, 1, 0	0	Dilation	30.0 - 64.0	30	7.5	--	--	7.5	
			42.0 - 54.0	16.0, 30.5, 47.9, 30.2, 15.1	0, 2, 3, 2, 1	0	Dilation							
			54.0 - 64.0	19.3, 40.3, 55.1, 40.6, 19.6	0, 0, 1, 0, 0	0	Dilation							
AU1211.3P	64.3	--	30.0 - 42.0	11.6, 28.8, 31.7, 23.2, 11.6	0, 0, 1, 0, 0	0	Dilation	30.0 - 64.0	30	6.4	--	--	6.4	
			42.0 - 54.0	16.0, 36.9, 45.0, 30.8, 16.0	0, 1, 2, 2, 0	0	Dilation							
			54.0 - 64.0	18.9, 37.7, 50.1, 40.6, 20.3	0, 0, 1, 1, 0	1	Laminar							
AD1201.5P	55.4	--	30.0 - 42.0	11.6, 23.2, 33.4, 23.2, 11.6	0, 0, 0, 1, 0	1	Laminar	30.0 - 55.0	30	5.7	--	--	5.7	
			42.0 - 55.0	16.1, 30.5, 46.3, 30.5, 16.0	0, 1, 2, 1, 0	0	Dilation							
AD1207.1T	55.4	--	30.0 - 42.0	11.6, 23.2, 33.4, 23.2, 11.6	0, 1, 2, 1, 0	0	Dilation	30.0 - 55.0	30	5.2	--	--	5.2	
			42.0 - 55.0	16.3, 31.4, 47.9, 30.5, 16.0	0, 1, 1, 1, 1	1	Laminar							
AU1204.0S	65.4	15	30.0 - 42.0	11.6, 23.2, 30.5, 23.1, 11.6	3, 3, 3, 3, 3	3	Laminar	30.0 - 65.0	35	4.5	--	--	4.5	
			42.0 - 54.0	15.6, 30.4, 44.9, 29.8, 13.1	0, 0, 1, 1, 0	0	Dilation							
			54.0 - 65.0	19.4, 36.6, 52.2, 37.7, 18.9	1, 1, 0, 0, 0	1	Laminar							
AD1212.1S	65.8	15	30.9 - 42.9	8.7, 19.8, 30.5, 18.9, 8.7	7, 9, 10, 6, 2	2	Dilation	30.9 - 65.8	30	44.7	--	--	44.7	
			42.9 - 54.9	11.6, 29.5, 45.0, 26.1, 11.6	7, 17, 20, 11, 1	1	Dilation							
			54.9 - 65.8	13.1, 35.6, 50.8, 34.8, 15.9	0, 0, 0, 0, 0	0	Laminar							

Arc Cell A2-3 - Baseline A

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Values (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
AD1133.5P	48.2	--	28.0 - 40.0	8.7, 16.0, 26.2, 18.9, 5.1	6, 0, 1, 1, 18	1	Turbulent	28.0 - 48.2	30	1.2	--	45.3	46.5	
			40.0 - 48.2	13.1, 26.1, 37.7, 23.2, 13.1	0, 0, 0, 0, 1	1	Laminar							
AU1136.4P	48.2	--	28.0 - 40.0	7.6, 18.9, 26.1, 16.1, 7.4	2, 0, 0, 1, 0	1	Laminar	Backfilled w/ Mix C grout by tremie method.						
			40.0 - 48.2	13.1, 26.1, 37.7, 26.1, 11.6	1, 1, 0, 0, 1	1	Laminar							
AD1138.5S	48.2	--	28.0 - 40.0	10.3, 20.7, 30.5, 16.1, 8.0	6, 2, 6, 0, 1	3	Laminar	28.0 - 48.2	28	0.2	--	--	0.2	
			40.0 - 48.2	13.1, 29.1, 40.3, 20.3, 13.1	19, 7, 5, 9, 15	5	Turbulent							
AD1138.5S	49.9	15	28.0 - 40.0	8.7, 19.4, 26.1, 16.0, 6.1	0, 1, 0, 0, 0	1	Laminar	28.0 - 49.9	28	0.2	--	28.3	28.5	
			40.0 - 49.9	12.7, 23.2, 36.8, 23.2, 15.1	17, 8, 5, 7, 12	5	Turbulent							
AU1128.4S	48.2	--	28.0 - 40.0	5.8, 16.0, 26.1, 15.9, 8.4	34, 9, 15, 15, 23	15	Turbulent	28.0 - 48.2	28	1.7	--	--	1.7	
			40.0 - 48.2	14.0, 26.2, 37.4, 26.1, 12.8	3, 1, 0, 0, 0	1	Laminar							
AU1130.3S	65.4	15	28.0 - 40.0	8.7, 16.0, 26.1, 16.0, 5.8	8, 4, 7, 4, 0	5	Laminar	28.0 - 65.4	28	3.8	--	--	3.8	
			40.0 - 52.0	10.9, 25.6, 33.0, 22.9, 11.6	5, 5, 6, 2, 0	4	Laminar							
			52.0 - 65.4	16.0, 32.3, 48.9, 28.8, 15.3	1, 1, 1, 1, 1	1	Laminar							

Cell 2 - Baseline A

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Values (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
AD1153.9P	65	15	28.0 - 40.0	8.7, 20.0, 27.6, 18.0, 8.7	0, 3, 4, 3, 0	0	Dilation	28.0 - 65.0	27	1.2	--	--	1.2	
			40.0 - 52.0	11.6, 23.2, 39.4, 26.1, 11.6	0, 0, 0, 1, 1	1	Laminar							
			52.0 - 65.0	13.1, 33.4, 49.2, 33.4, 13.1	0, 0, 0, 0, 0	0	Laminar							
AD1163.9S	65.4	15	28.0 - 40.0	9.1, 16.0, 26.1, 18.9, 11.6	0, 0, 0, 0, 0	0	Laminar	28.0 - 65.4	27	2.1	--	--	2.1	
			40.0 - 52.0	13.1, 25.4, 37.7, 23.2, 11.6	1, 1, 1, 0, 0	1	Laminar							
			52.0 - 65.4	18.9, 33.4, 49.4, 33.3, 16.0	0, 0, 0, 1, 0	1	Laminar							
AD1173.9P	65.6	15	28.0 - 40.0	11.6, 18.9, 27.4, 18.9, 11.6	>100, 63, 48, 66, >100	48	Turbulent	28.0 - 65.0	27	0	--	--	0	
			40.0 - 52.0	13.1, 26.1, 40.6, 26.1, 10.6	0, 2, 1, 1, 0	1	Laminar							
			52.0 - 65.6	16.0, 33.4, 52.2, 33.4, 15.3	0, 0, 0, 0, 0	0	Laminar							
AD1193.9P	65	15	28.0 - 50.0	11.6, 16.0, 26.1, 16.0, 8.7	>100, >100, >100, >100, >100	>100	Laminar	28.5 - 50.0	27	184	29.9	--	213.9	Soft material logged in hole from depth 30.0' - 65.0'. Hole then caved in and was backfilled as a result. TerraFirm redrilled hole and encountered grout and sand from depth 30.0 - 65.0' and lost drill rod down hole. Hole backfilled and abandoned. Replaced by grout hole AD1193.9PD.
			52.0 - 65.0	12.6, 30.5, 42.1, 30.5, 16.0	>100, >100, >100, >100, >100	>100	Laminar	Backfilled w/ Mix C after re-drilling and losing drill rod downhole.						
AD1194.9P	63	--	26.0 - 38.0	10.1, 17.2, 25.1, 18.9, 8.7	77, 24, 13, 18, 99	13	Turbulent	26.0 - 63.0	26	23.7	--	--	23.7	
			38.0 - 50.0	13.6, 26.1, 40.6, 26.1, 12.4	32, 15, 10, 13, 26	10	Turbulent							
			50.0 - 63.0	16.0, 33.4, 49.8, 33.4, 16.0	0, 1, 2, 2, 2	1	Laminar							
AD1193.9PD	65	15	28.0 - 35.0	8.7, 15.5, 26.1, 16.0, 8.7	>100, >100, >100, >100, >100	>100	Laminar	28.0 - 35.0	27	--	65.8	3.2	69	Sand, clay and river rock logged from depth 30.0' - 40.0'. Caved in at depth 35.0' and re-drilled.
AD1193.9PD (re-drilled)	65	15	28.0 - 40.0	8.8, 16.0, 26.1, 16.0, 8.7	>100, >100, 87, >100, >100	87	Turbulent	28.0 - 65.0	27	170.9	9.1	--	180	
			40.0 - 52.0	11.6, 23.3, 34.9, 23.2, 11.6	20, 16, 29, 48, 84	84	Wash-Out							
			52.0 - 65.0	16.0, 32.7, 48.7, 30.7, 13.2	0, 1, 0, 0, 0	1	Laminar							
AD1158.9T	55	15	28.0 - 40.0	8.7, 16.1, 26.1, 16.1, 8.7	3, 3, 3, 1, 1	2	Laminar	28.0 - 55.0	27	0.1	--	--	0.1	
			40.0 - 55.0	10.5, 23.2, 37.7, 23.2, 11.6	1, 0, 0, 0, 1	0	Turbulent							
AD1168.9T	55	15	28.0 - 40.0	8.7, 16.0, 26.1, 16.0, 8.7	3, 9, 9, 10, 2	2	Dilation	28.0 - 55.0	27	1.2	--	--	1.2	
			40.0 - 55.0	11.5, 26.1, 37.7, 26.1, 11.6	2, 1, 1, 0, 0	0	Void Filling							
AD1178.9T	65	15	28.0 - 40.0	8.7, 18.9, 27.5, 18.1, 8.7	86, 37, 30, 37, 80	30	Turbulent	28.0 - 65.0	27	0.3	--	--	0.3	
			40.0 - 52.0	11.6, 26.1, 37.7, 26.1, 11.6	0, 1, 0, 0, 0	1	Laminar							
			52.0 - 65.0	16.0, 33.4, 49.3, 33.4, 16.0	1, 0, 0, 0, 0	1	Laminar							
AD1183.9S	65	15	28.0 - 40.0	8.7, 18.7, 26.1, 16.0, 5.8	>100, >100, 74, 93, >100	74	Turbulent	28.0 - 65.0	27	0	--	--	0	
			40.0 - 52.0	11.6, 23.2, 37.7, 23.2, 11.6	12, 5, 7, 6, 11	7	Turbulent							
			52.0 - 65.0	16.0, 33.4, 49.1, 32.4, 16.0	0, 1, 1, 0, 0	1	Laminar							
AD1184.0T	38	--	28.0 - 38.0	6.0, 16.0, 27.1, 16.3, 5.8	>100, 94, 64, >100, >100	64	Turbulent	28.0 - 39.0	28	142.8	--	--	142.8	Sandy clay logged from depth 32.0' - 38.0'. TerraFirm elected not to advance the grout hole beyond depth 38.0' due to subsurface conditions.
AD1186.9S	65	--	28.0 - 40.0	10.1, 18.9, 27.1, 16.3, 8.7	>100, 81, 75, >100, >100	75	Turbulent	28.0 - 55.0	28	124.6	152.7	94	371.3	Wet grout, clay and sand logged from depth 30.0' - 40.0'. Clay/sand logged from depth 50.0' - 65.0'. Caved in at depth 55.0'.
			40.0 - 55.0	13.1, 26.1, 37.3, 24.9, 11.6	7, 8, 56, >100, >100	>100	Wash-Out							
AD1190.9T	63	--	28.0 - 40.0	8.8, 18.9, 25.9, 17.4, 8.7	>100, 66, 57, 81, >100	57	Turbulent	28.0 - 63.0	28	43.6	--	-	43.6	
			40.0 - 52.0	13.1, 27.3, 37.1, 26.1, 11.6	30, 24, 29, 39, 87	87	Wash-Out							
			52.0 - 63.0	17.6, 32.0, 47.8, 34.8, 16.0	0, 0, 0, 0, 0	0	Laminar							
AD1188.9T	101	15	Backfilled on October 8, 2015											Grout logged from depth 30.0' - 55.0' and mud/sand logged from depth 55.0' - 100.0' and rock logged from 100.0' - 101.0'.
AU1185.3P	65	15	28.0 - 40.0	7.5, 18.6, 26.1, 16.0, 8.7	44, 13, 10, 13, 14	10	Turbulent	28.0 - 65.0	27	7.4	--	-	7.4	
			40.0 - 52.0	11.6, 23.2, 39.2, 22.2, 11.2	19, 18, 22, 13, 6	6	Dilation							
			52.0 - 65.0	13.8, 33.4, 48.9, 31.5, 13.1	2, 0, 1, 0, 0	1	Laminar							
AU1146.5P	65	--	28.0 - 40.0	4.8, 18.1, 26.9, 16.0, 4.3	0, 0, 1, 0, 0	0	Dilation	28.0 - 64.9	28	1.8	--	-	1.8	
			40.0 - 52.0	8.7, 23.2, 40.7, 23.2, 9.6	0, 0, 3, 0, 0	0	Dilation							
			52.0 - 64.9	13.9, 30.5, 49.0, 30.5, 12.8	0, 0, 0, 0, 0	0	Laminar							
AU1148.3P	65	15	28.0 - 40.0	8.7, 18.9, 26.1, 16.0, 5.8	1, 1, 2, 0, 0	0	Dilation	28.0 -65.0	27	1.2	--	-	1.2	
			40.0 - 52.0	11.2, 23.2, 35.9, 20.3, 8.7	1, 1, 1, 0, 0	1	Laminar							
			52.0 - 65.0	16.0, 33.4, 47.9, 30.5, 13.1	0, 0, 0, 0, 0	0	Laminar							
AU1153.2S	65	--	28.0 - 40.0	8.7, 16.0, 26.1, 16.0, 5.8	5, 8, 9, 9, 9	8	Laminar	28.0 - 65.0	28	0.4	--	-	0.4	
			40.0 - 52.0	11.6, 26.1, 40.6, 26.1, 13.8	0, 0, 1, 0, 0	0	Dilation							
			52.0 - 65.0	17.9, 33.5, 52.2, 33.4, 16.0	1, 0, 1, 0, 0	1	Laminar							
AU1155.3S	65	15	28.0 - 40.0	8.7, 16.0, 26.5, 17.8, 8.7	3, 4, 4, 3, 3	3	Laminar	28.0 - 65.0	27	0.3	--	-	0.3	
			40.0 - 52.0	14.5, 26.1, 39.4, 26.1, 11.6	0, 0, 1, 0, 0	0	Dilation							
			52.0 - 65.0	16.0, 33.4, 49.3, 33.3.16.0	0, 0, 0, 0, 1	1	Laminar							
AU1165.3P	68	15	28.0 - 40.0	5.8, 18.9, 26.2, 16.0, 4.3	0, 4, 4, 4, 0	0	Dilation	50.0 - 65.0	48	51.9	--	38.9	90.8	Communication observed during WPT and grouting. Clay seam logged at depth 30.0' - 31.0' and a void/sand logged from depth 60.0' - 68.0'.
			40.0 - 52.0	11.6, 23.2, 34.5, 23.2, 11.6	0, 1, 16, 38, 6	12	Laminar							
			52.0 - 66.0	Communication w/ other holes prevented the collection of representative in-situ permeability testing data.										
AU1175.3S	65	15	28.0 - 40.0	8.7, 18.7, 26.7, 16.0, 8.7	6, 6, 6, 5, 4	5	Laminar	28.0 - 40.0	27	4.2	--	--	32.3	
			40.0 - 52.0	15.1, 26.1,37.7, 24.9, 11.5	5, 5, 7, 5, 2	2	Dilation	40.0 - 65.0	38	28.1	--	--		
			52.0 - 65.0	16.0, 34.8, 47.9, 31.7, 16.0	0, 1, 2, 5, 5	5	Wash-Out							
AU1160.3T	55	15	28.0 - 40.0	8.7, 17.2, 26.1, 16.0, 5.8	0, 5, 4, 3, 0	2	Laminar	28.0 - 55.0	27	6.5	--	--	6.5	
			40.0 - 55.0	11.6, 27.6, 41.1, 26.2, 11.6	0, 0, 0, 0, 0	0	Laminar							
AU1170.3T	55	15	28.0 - 40.0	6.0, 16.1, 23.2, 16.0, 4.7	0, 3, 9, 4, 5	0	Dilation	28.0 - 55.0	27	81.3	--	--	81.3	Gray clay/mud logged at depth 50.0 ' - 55.0'.
			40.0 - 55.0	12.4, 27.1, 40.5, 23.5, 9.2	7, 10, 11, 9, 4	4	Dilation							
AU1180.3T	55	15	28.0 - 55.0	16.5, 27.3, 16.0, 8.7	1, 2, 1, 0	1	Laminar	28.0 -55.0	27	4.8	--	--	4.8	Clay and grout logged from depth 30.0' - 55.0'.
AU1196.0T	70	--	28.0 - 40.0	8.7, 16.0, 26.1, 16.0, 5.9	11, 13, 16, 13, 7	7	Dilation	52.0 - 70.0	50	1.2	--	--	7.2	Small zone of clay logged from depth 58.0' - 60.0' and a soft zone (maybe void) logged from 60.0' - 70.0'.
			40.0 - 52.0	11.6, 29.5, 37.7, 26.1, 11.6	9, 9, 17, 12, 5	5	Dilation	28.0 - 70.0	27	6	--	--		
			52.0 - 70.0	16.0, 33.4, 50.6, 32.1, 15.7	1, 1, 1, 1, 0	1	Laminar							

Cell 3 - Baseline A

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Values (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
AD1079.2P	50.6	15	28.0 - 40.0	11.6, 19.0, 26.1, 21.0, 11.6	0, >100, 93, >100, >100	93	Turbulent	28.0 - 50.6	27	0	--	--	0	Artesian conditions observed in hole after completion of drilling.
			40.0 - 50.6	16.0, 26.1, 39.9, 27.6, 13.1	0.00, 0.00, 0.00, 0.00, 0.00	0	Laminar							
AD1099.3P	51.6	15	28.6 - 40.0	9.8, 18.9, 27.6, 20.2, 11.6	>100, >100, >100, >100, >100	>100	Laminar	28.6 - 51.5	27.6	1.4	--	--	1.4	Artesian conditions observed in hole after completion of drilling.
			40.0 - 51.5	16.0, 30.4, 40.6, 27.6, 14.9	0, 0, 1, 0, 0	0	Dilation							
AD1119.3P	50.3	15	29.0 - 41.0	6.2, 16.2, 26.7, 16.0, 7.9	0, 0, 2, 0, 0	0	Dilation	28.0 - 50.3	28	1.1	--	--	1.1	
			41.0 - 50.3	10.3, 23.4, 37.7, 23.2, 11.6	0, 0, 0, 0, 0	0	Laminar							
AD1121.3P	48.6	--	28.0 - 40.0	11.6, 20.3, 30.5, 20.3, 11.6	>100, >100, >100, >100, >100	>100	Laminar	28.0 - 48.6	28	1.2	--	--	1.2	
			40.0 - 48.6	16.0, 27.6, 42.1, 30.5, 16.0	1, 0, 1, 0, 0	1	Laminar							
AU1072.8P	50	--	28.0 - 40.0	8.3, 16.3, 26.1, 18.4, 8.7	0, 6, 30, 8, 0	0	Dilation	28.0 - 50.0	28	1.4	--	--	1.4	Artesian conditions observed in hole after completion of drilling.
			40.0 - 50.0	13.1, 26.1, 40.6, 26.1, 13.1	0, 0, 1, 0, 0	1	Laminar							
AU1112.0P	50	15	28.6 - 40.2	8.7, 18.9, 26.7, 18.9, 8.7	0, 0, 1, 0, 0	0	Dilation	BACKFILLED						Artesian conditions observed in hole after completion of drilling.
			40.2 - 50.0	11.6, 26.9, 40.6, 24.1, 11.6	0, 0, 0, 0, 0	0	Laminar							Hole backfilled, not pressure grouted due to low pressure test lugeon values.
AD1089.3S	50	15	29.3 - 41.3	8.7, 18.6, 26.1, 18.9, 8.7	0, 0, 5, 0, 0	0	Dilation	29.3 - 50.0	29	1.1	--	--	1.1	
			41.3 - 50.0	11.6, 26.1, 38.9, 23.2, 11.6	0, 1, 2, 0, 0	1	Laminar							
AU1102.0S	50	15	28.6 - 40.6	8.7, 18.9, 26.1, 18.9, 8.7	0, 0, 4, 0, 0	0	Dilation	BACKFILLED						Hole backfilled, not pressure grouted due to low pressure test lugeon values.
			40.6 - 50.0	12.2, 26.1, 40.6, 26.1, 12.5	0, 0, 0, 0, 0	0	Laminar							
AU1082.0S	50	15	28.6 - 40.6	8.7, 18.9, 26.7, 17.6, 8.7	0, 0, 0, 0, 0	0	Laminar	BACKFILLED						Artesian conditions observed in hole after completion of drilling.
			40.6 - 50.0	11.6, 26.1, 40.6, 26.1, 11.8	0, 0, 0, 0, 1	1	Laminar							
AU1078.8S	49.6	--	28.0 - 40.0	8.7, 18.9, 27.8, 18.5, 9.0	0, 0, 1, 0, 0	0	Dilation	BACKFILLED						Artesian conditions observed in hole after completion of drilling.
			40.0 - 49.6	11.8, 26.1, 40.6, 26.1, 11.6	0, 1, 1, 1, 0	1	Laminar							
AU1092.0P	50.1	15	28.6 - 40.6	8.5, 18.9, 26.1, 18.7, 6.0	0, 0, 3, 0, 0	0	Dilation	BACKFILLED						Artesian conditions observed in hole after completion of drilling.
			40.6 - 50.1	11.6, 26.1, 40.6, 26.1, 11.6	0, 0, 1, 0, 0	0	Dilation							
AD1116.3S	49.2	--	28.0 - 40.0	8.7, 18.9, 27.4, 17.6, 8.7	0, 0, 2, 0, 0	0	Dilation	28.0 - 49.2	28	0.8	--	-	0.8	
			40.0 - 49.2	11.6, 23.2, 38.6, 24.8, 11.6	1, 1, 1, 0, 0	1	Laminar							
AD1109.3S	50	15	29.0 - 41.0	8.7, 18.9, 27.1, 18.9, 8.7	0, 0, 3, 0, 0	0	Dilation	29.0 - 50.0	29	1.3	--	-	1.3	
			41.0 - 50.0	11.6, 23.2, 37.7, 23.4, 11.6	1, 1, 1, 1, 0	1	Laminar							
AU1075.0P	50.6	15	28.6 - 40.6	8.7, 18.4, 26.1, 16.1, 8.7	0, 0, 3, 0, 0	0	Dilation	BACKFILLED						Artesian conditions observed in hole after completion of drilling.
			40.6 - 50.6	11.9, 26.3, 40.6, 26.1, 11.6	0, 0, 1, 0, 0	0	Dilation							

Cell 1 - Baseline C

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Value (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
CD3111.5S	65.6	15	31.0 - 43.0	12, 18, 30, 18, 12	68, 43, 28, 44, 59	28	Turbulent	31.0 - 65.6	31	6.15	--	--	6.15	
			41.6 - 53.6	16, 25, 41, 25, 16	49, 36, 20, 28, 47	20	Turbulent							
			53.6 - 65.6	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar							
CD3121.5P	65.8	15	30.0 - 42.0	12, 18, 30, 18, 12	>100, >100, >100, >100, >100	>100	Laminar	30.0 - 65.3	29	--	--	--	147.1	Communication w/ CD3145.8P during grouting.
			41.3 - 53.3	16, 24, 40, 24, 16	7, 4, 3, 4, 7	3	Turbulent							WPT: Communication w/ AD1237.9S
			53.3 - 65.3	20, 30, 50, 30, 20	10, 7, 3, 7, 6	3	Turbulent							WPT: Communication w/ CD3145.8P. WPT: max 12 psi.achieved.
CD3139.0S	27	--	Abandoned											Hit steel twice in hole.
CU3117.7P	64.2	--	30.0 - 42.0	12, 18, 30, 18, 12	78, 51, 32, 42, 70	32	Turbulent	30.0 - 64.2	30	34.6	--	--	34.6	
			40.2 - 52.2	18, 24, 40, 24, 18	26, 22, 18, 22, 25	18	Turbulent							
			52.2 - 64.2	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar							
CU3123.7S	64.2	--	30.0 - 42.0	12, 18, 30, 18, 12	61, 35, 26, 41, 62	26	Turbulent	30.0 - 64.2	30	1.9	--	--	1.9	
			40.2 - 52.2	16, 24, 40, 24, 16	20, 14, 10, 13, 18	10	Turbulent							
			52.2 - 64.2	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar							
CU3125.7S	36	--	Abandoned											Broke rod at depth 16 feet down the hole.
CU3126.8S	65.9	15	31.0 - 43.0	12, 18, 30, 18, 12	50, 31, 22, 31, 42	22	Turbulent	31.0 - 69.5	30	17.4	--	--	17.4	
			41.9 - 53.9	16, 24, 40, 24, 16	3, 3, 3, 4, 4	4	Laminar							
			53.9 - 65.9	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar							
CU3137.5S	64.5	--	30.0 - 42.0	12, 18, 30, 18, 12	>100, >100, >100, >100, >100	>100	Laminar	30.0 - 64.5	30	--	--	--	163.8	WPT: Max of 19 psi achieved.
			40.5 - 52.5	16, 24, 40, 24, 16	22, 50, 56, 64, 76	76	Wash-Out							WPT: Max of 32 psi achieved.
			52.5 - 64.5	20, 30, 50, 30, 20	6, 4, 2, 5, 8	2	Turbulent							
CU3143.7P	64	--	30.0 - 42.0	12, 18, 30, 18, 12	>100, >100, >100, >100, >100	>100	Laminar	30.0 - 64.0	30	--	--	--	167.1	WPT: Max of 13 psi achieved.
			40.0 - 52.0	16, 24, 40, 24, 16	58, >100, >100, >100, >100	>100	Laminar							WPT: Max of 21 psi achieved.
			52.0 - 64.0	20, 30, 50, 30, 20	0, 0, 1, 1, 0	1	Laminar							

Cell 1 - Baseline A

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Value (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
AD1227.9P	65.6	15	27.0 - 39.0	10, 15, 26, 15, 10	0, 0, 0, 0, 0	0	Laminar	27.0 - 65.6	26		--		367.7	
			41.6 - 53.6	16, 24, 40, 24, 16	20, 20, 12, 15, 17	12	Turbulent							
			27.0 - 65.6	11, 16, 27, 16, 11	68, 46, 32, 44, 61	32	Turbulent							
AD1237.9S	65.8	15	53.8 - 65.8	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar	10.0 - 65.6	12	0	0	4.8	4.8	
AD1247.9P	65.5	15	41.5 - 53.5	16, 24, 40, 24, 16	7, 5, 5, 7, 9	5	Turbulent	28.0 - 65.8	27	15.1	--	--	36.2	
			53.5 - 65.5	20, 30, 50, 30, 20	51, 34, 22, 28, 38	22	Turbulent	5.0 - 65.8	10	--	16.4	--		
			--	--	--	--	--	33.0 - 65.8	32	--	--	4.7		
AD1257.9S	65.8	15	31.0 - 43.0	12, 18, 30, 18, 12	>100, >100, >100, >100, >100	>100	Laminar	31.0 - 65.8	30	--	--	--	226.5	WPT - Max. of 9 psi achieved.
			41.8 - 53.8	16, 25, 41, 25, 16	>100, >100, >100, >100, >100	>100	Laminar							WPT - Max. of 9 psi achieved.
			53.8 - 65.8	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar							
AD1259.2S	64.8	--	30.0 - 42.0	12, 18, 30, 18, 12	>100, >100, >100, >100, >100	>100	Laminar	30.0 - 64.8	30	--	--	--	187.3	WPT - Max. of 19 psi achieved.
			40.8 - 52.8	16, 25, 40, 25, 16	>100, 89, 85, 90, >100	85	Turbulent							WPT - Max. of 24 psi achieved.
			52.8 - 64.8	20, 30, 50, 30, 20	3, 2, 1, 0, 0	0	Void Filling							
AD1262.4P	64	--	26.0 - 38.0	10, 16, 26, 16, 10	67, >100, 89, >100, >100	89	Turbulent	30.0 - 64.0	30	32.94	--	--	32.94	
			40.0 - 52.0	16, 24, 40, 24, 16	4, 5, 7, 8, 10	10	Wash-Out							
			52.0 - 64.0	20, 30, 50, 30, 20	40, 30, 21, 26, 35	21	Turbulent							
AD1267.9P	65.6	15	29.6 - 41.6	12	Communication observed	--	--	10.0 - 65.6	12	--	--	--	138.04	
			41.6 - 53.6	16, 24, 40, 24, 16	0, 0, 0, 0, 0	0	Laminar							
			53.6 - 65.6	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar							
			10.0 - 65.6	12	>100 (Communication at interface with AD1237.9S)	>100	Laminar							
AU1220.1P	64.7	--	30.0 - 42.0	12, 18, 30, 18, 12	>100, >100, >100, >100, >100	>100	Laminar	30.0 - 64.7	30	69.5	--	--	69.5	
			40.7 - 52.7	16, 25, 40, 25, 16	>100, 88, 88, 88, >100	88	Turbulent							
			52.7 - 64.7	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar							
AU1223.1P	65.8	15	31.0 - 43.0	12, 18, 30, 18, 12	24, 16, 10, 14, 21	10	Turbulent	31.0 - 65.8	30	12.6	--	--	12.6	
			41.8 - 53.8	16, 24, 40, 24, 16	7, 6, 6, 6, 7	6	Turbulent							
			53.8 - 65.8	20, 30, 50, 30, 20	0, 1, 1, 1, 0	1	Laminar							
AU1227.1S	64.5	--	30.0 - 42.0	12, 18, 30, 18, 12	>100, 69, 62, 78, >100	62	Turbulent	30.0 - 64.5	30	1.9	--	--	1.9	
			40.5 - 52.5	16, 24, 40, 24, 16	0, 0, 1, 0, 0	0	Dilation							
			52.5 - 64.5	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar							
AU1230.1S	65.9	15	31.0 - 43.0	12, 18, 30, 18, 12	0, 0, 0, 0, 0	0	Laminar	31.0 - 65.9	30	64.5	--	--	64.5	
			53.9 - 65.9	20, 30, 50, 30, 20	0, 0, 1, 1, 0	1	Laminar							
AU1240.1P	65.9	15	31.0 - 43.0	12, 18, 30, 18, 12	>100, >100, >100, >100, >100	>100	Laminar	31.0 - 65.9	30		--		197.7	WPT - Max. of 21 psi achieved.
			41.9 - 53.8	16, 24, 40, 24, 16	95, 74, 63, 74, 98	63	Turbulent							WPT - Max. of 31 psi achieved.
AU1250.1S	65.9	15	31.0 - 43.0	12, 18, 30, 18, 12	21, 18, 16, 16, 19	16	Turbulent	31.0 - 65.9	30	16.7	--	--	16.7	
			41.9 - 53.9	16, 24, 40, 24, 16	12, 10, 14, 15, 12	13	Laminar							
			53.9 - 65.9	20, 30, 50, 30, 20	0, 1, 1, 0, 0	1	Laminar							
AU1267.5P	63.8	--	30.0 - 42.0	12, 18, 30, 18, 12	>100, >100, >100, >100, >100	>100	Laminar	30.0 - 63.8	30	24.9	--	--	24.9	WPT - Max. of 5 psi achieved.
			39.8 - 51.8	16, 24, 40, 24, 16	>100, >100, >100, >100, >100	>100	Laminar							WPT - Max. of 10 psi achieved.
			51.8 - 63.8	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar							Communication w/ AU1240.1P during grouting.

Lock River Wall - Baseline C

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Value (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
CD3153.8S	75	--	43.0 - 55.0	10	0	0	Laminar	43.0 - 75.0	10	0.5	--	--	0.5	
			51.0 - 63.0	9, 14, 23, 14, 9	>100, >100, >100, >100, >100	>100	Laminar							Max of 17 psi achieved during WPT
			63.0 - 75.0	14, 21, 35, 21, 14	0, 0, 0, 0, 0	0	Laminar							
CD3155.3P	77.7	15	44.5 - 56.5	10	0	0	Laminar	44.5 - 77.7	15	111.5	--	--	111.5	Missing Drill Log and Automated Records.
			53.7 - 65.7	9, 14, 23, 14, 9	0, 0, >100, >100, >100	>100	Laminar							
			65.7 - 77.7	14, 21, 35, 21, 14	0, 0, 0, 0, 0	0	Laminar							
CD3158.3P	75	--	43.0 - 55.0	10	>100	0	Laminar	43.0 - 49.7	13				519.8	
			51.0 - 63.0	11, 16, 27, 16, 11	93, 57, 25, 41, 100	>100	Laminar							Max of 17 psi achieved during WPT
			63.0 - 75.0	16, 23, 39, 23, 16	26, 35, 17, 25, 45	0	Laminar							
CD3168.3S	74.6	--	41.5 - 53.5	10	0	0	Laminar	41.5 - 74.6	15	1.3	--	--	1.3	
			53.5 - 65.5	8.7, 15.9, 18.9, 13.1, 8.7	0, 0, 0, 0, 0	0	Laminar							
			65.5 - 74.6	13.1, 23.2, 31.0, 20.5, 13.1	0, 0, 0, 0, 0	0	Laminar							
CD3172.5S	75	--	43.0 - 55.0	10	>100	>100	Laminar	63.0 - 75.0	39 10	14.6	--	--	16.4	
			51.0 - 63.0	11, 16, 27, 16, 11	>100, >100, >100, >100, >100	>100	Laminar	43.0 - 63.0		1.8				
			63.0 - 75.0	16, 23, 39, 23, 16	34, 20, 11, 17, 34	11	Turbulent							
CU3163.3S	77.7	15	43.1 - 55.1	11.6	0	0	Laminar	43.1 - 77.7	15	0.2	--	--	0.2	
			55.1 - 67.1	5.9, 13.2, 20.9, 13.1, 8.7	0, 0, 0, 0, 0	0	Laminar							
			67.1 - 77.7	11.3, 20.5, 33.4, 20.6, 11.6	1, 0, 0, 0, 0	1	Laminar							
CU3163.3S (Vertical)	75.7	0	41.2 - 53.2	8.7	1	1	Laminar	41.2 - 75.7	15	2.3	--	--	2.3	
			53.2 - 65.2	6.0, 16.0, 23.2, 13.3, 6.0	0, 0, 1, 1, 0	1	Laminar							
			65.2 - 75.7	11.6, 23.2, 33.5, 23.2, 11.6	0, 0, 0, 0, 0	0	Laminar							
CU3167.5P	74.9	--	41.1 - 53.1	11.5	4	4	Laminar	41.1 - 74.9	15	0.5	--	--	0.5	
			53.1 - 65.1	8.7, 16.0, 23.2, 13.1, 8.7	3, 4, 5, 6, 5	5	Laminar							
			65.1 - 74.9	8.9, 20.3, 33.4, 20.3, 11.6	1, 0, 0, 0, 0	1	Laminar							
CU3173.3P	78.9	15	42.5 - 54.5	11.6	4	4	Laminar	42.5 - 78.9	15	1.7	--	--	1.7	
			54.5 - 66.5	8.7, 16.0, 23.0, 16.0, 8.7	0, 0, 1, 0, 0	0	Dilation							
			66.5 - 78.9	16.0, 26.1, 33.4, 26.1, 16.0	0, 1, 1, 1, 0	1	Laminar							

Lock Wall Connection - Baseline C

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Value (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Grout Total Take (Gals.)	Remarks
CD3145.8P	63.6	--	30.0 - 63.6	12, 18, 30, 18, 12	>100, >100, >100, >100, >100	>100	Laminar	27.0 - 65.6	26	380.6	One stage WPT due to caving conditions at 35.0', small communication with AD1237.9S
CU3144.5P	66.2	15	31.0 - 43.0	12, 18, 30, 18, 12	0, 99, >100, >100, >100	>100	Wash-Out	31.0 - 66.2	30	225.5	communication with AD1237.9S
			42.2 - 54.2	16, 24, 40, 24, 16	16, 46, 55, 67, 62	62	Wash-Out				Max of 29 psi achieved during WPT
			54.2 - 66.2	20, 30, 50, 30, 20	0, 0, 0, 0, 0	0	Laminar				Communication w/ river observed during grouting

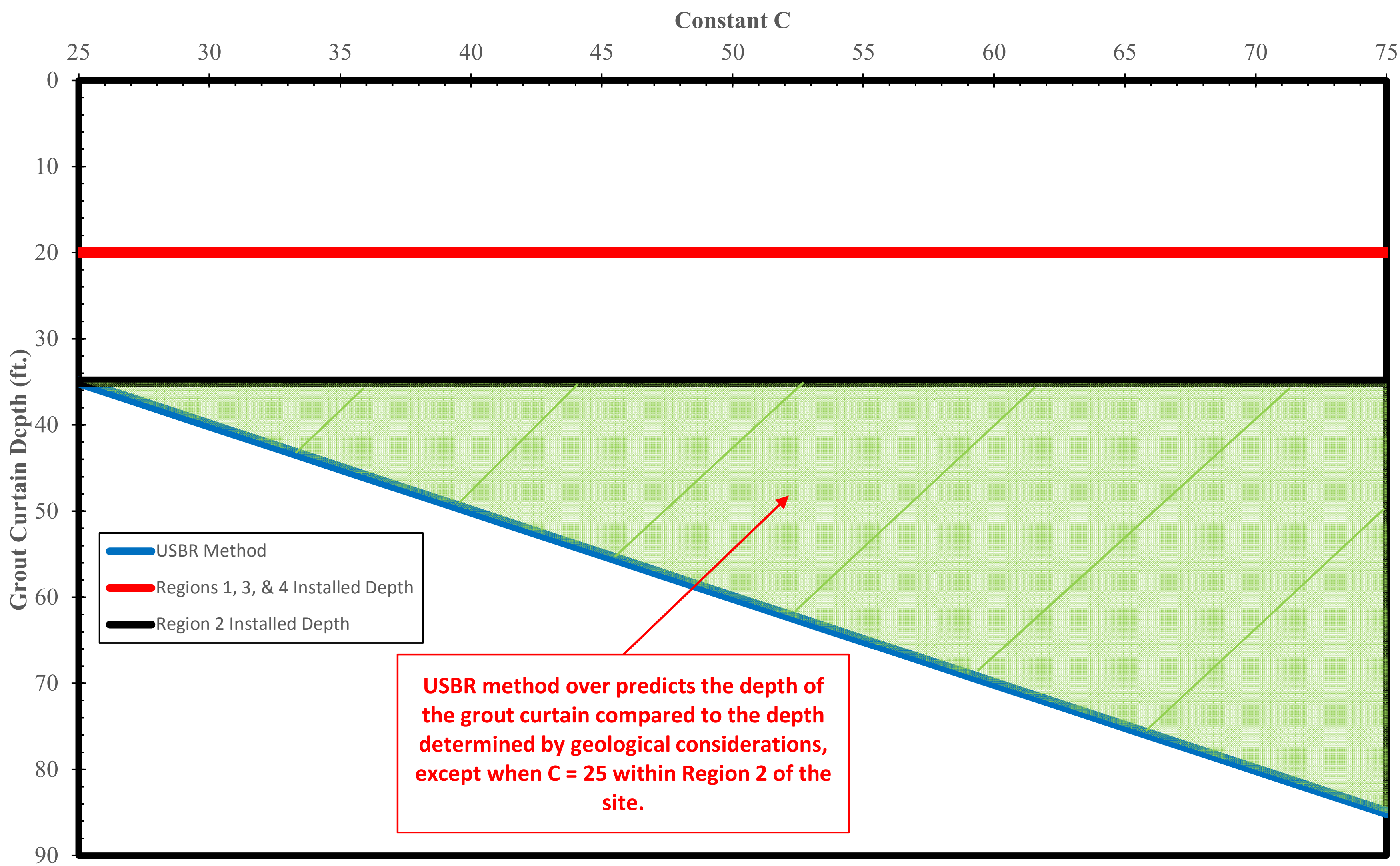
East Bank - Baseline D

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Value (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
DD4342.5P	62.0	15	43.0 - 55.0	11.6, 11.6, 16.0, 9.9, 5.8	0, 0, >100, >100, >100	>100	Wash-Out	43.0 - 62.0	22	9.7	--	--	9.7	
			50.0 - 62.0	8.7, 15.9, 26.1, 16.0, 8.7	48, 49, 24, 35, 81	24	Turbulent							
DD4350.5S	60.6	--	42.5 - 54.5	11.6, 11.6, 9.5, 8.6, 4.3	0, 0, >100, >100, 0	>100	Turbulent	42.5 - 60.6	23	38.3	--	--	38.3	WPT - Max. of 14 psi achieved.
			48.6 - 60.6	5.8, 11.6, 22.9, 11.6, 5.8	>100, 18, 17, 83, >100	17	Turbulent							
DD4352.4S	63.4	15	43.0 - 55.0	9, 13, 22, 13, 9	>100, >100, 67, >100, >100	67	Turbulent	43.0 - 63.4	22	128.9	--	--	128.9	
			51.4 - 63.4	12, 18, 30, 18, 12	40, 30, 68, >100, >100	>100	Wash-Out							
DD4362.0P	64.6	15	47.5 - 59.5	8.7, 4.7, 4.9, 4.3, 4.3	0, 0, 0, 0, 0	0	Laminar	47.5 - 64.6	25				248.6	WPT - Max. of 18 psi achieved.
			54.6 - 64.6	11.6, 16.0, 16.0, 15.4, 10.4	0, 0, >100, >100, >100	>100	Wash-Out							WPT - Max. of 4 psi achieved.
DD4371.6S	66.1	15	46.6 - 58.6	4.3, 9.8, 16.1, 8.7, 4.3	0, >100, >100, >100, 0	>100	Laminar	46.6 - 66.1	23	26.6	--	--	26.6	
			54.1 - 66.1	8.1, 13.1, 24.4, 13.1, 8.7	27, 4, >100, >100, >100	>100	Wash-Out							
DD4381.3P	67.4	15	49.0 - 53.0	8.7, 13.1, 25.9, 13.1, 8.7	77, >100, 54, 27, 0	0	Void Filling	49.0 - 53.0	27	0.1	--	--	0.1	Downstage grouting performed.
			47.5 - 67.4	6.8, 9.7, 6.5, 4.3, 4.3	0, 2, >100, 0, 0	0	Dilation	47.5 - 67.4	24				162	
DD4390.9S	68.3	15	48.5 - 60.5	5.8, 11.6, 18.9 11.6, 4.5	>100, >100, >100, >100, 0	>100	Laminar	48.5 - 68.3	24	--	--	--	314.9	
			56.3 - 68.3	8.9, 15.5, 27.2, 13.1 8.7	>100, >100, >100, >100, >100	>100	Laminar							
DD4400.5P	71.3	15	51.0 - 63.0	10.1, 13.1, 25.3, 13.1, 8.7	0, 65, 48, 82, >100	>100	Wash-Out	51.0 - 71.3	26	10.3	--	--	10.3	
			59.3 - 71.3	11.6, 16.0, 30.7, 16.0, 11.6	12, 9, 4, 5, 5	7	Laminar							
DD4410.1S	71.6	15	52.0 - 64.0	5.8, 11.6, 20.3, 11.6, 5.8	0, >100, >100, >100, >100	>100	Laminar	52.0 - 71.6	25	--	--	--	652	
			59.6 - 71.6	8.7, 16.0, 27.6, 14.4, 10.0	0, 0, 1, 0, 0	0	Dilation							
DD4419.8P	73.2	15	53.0 - 65.0	8.7, 13.1, 21.4, 13.4, 8.7	23, 20, 89, >100, >100	>100	Wash-Out	53.0 - 73.2	27	4.7	--	--	4.7	
			61.2 - 73.2	11.6, 17.2, 31.5, 16.0, 11.6	8, 6, 4, 3, 0	0	Void Filling							
DU4360.6P	79	15	45.0 - 57.0	5.8, 5.8, 13.1, 20.3, 13.1	4, 0, 0, 0, 0	0	Laminar	45.0 - 79.0	22.5	17.4	--	--	17.4	
			57.0 - 69.0	11.3, 23.2, 33.4, 21.0, 11.5	23, 0, 1, 0, 0	5	Laminar							
			69.0 - 79.0	15.4, 30.5, 46.5, 31.0, 15.5	4, 3, 2, 2, 3	2	Turbulent							
DU4371.0S	81	15	45.0 - 57.0	8.7, 14.1, 23.2, 13.1, 5.8	>100, >100, >100, >100, >100	>100	Laminar	45.0 - 82.0	22.5	101.21	51.06	--	157.3	
			58.0 - 70.0	11.6, 23.2, 26.1, 23.2, 11.6	>100, >100, >100, >100, >100	>100	Laminar							
			70.0 - 82.0	26.4, 33.4, 47.9, 30.5, 16.0	1, 0, 1, 1, 0	1	Laminar							
DU4381.8P	67	15	47.5 - 59.5	6.6, 8.7, 16.0, 23.2, 11.4	>100, 26, >100, >100, >100	>100	Laminar	47.5 - 67.0	0.0, 7.3, 17.2, 23	84	90.7	35.8	210.5	
			59.5 - 67.0	11.6, 23.2, 34.8, 23.2, 11.6	0, 2, 2, 2, 0	2	Laminar							
DU4391.8S	68	15	49.0 - 61.0	8.7, 16.0, 23.2, 16.0, 8.7	27, >100, >100, >100, >100	>100	Laminar	48.0 - 68.0	24	105.9	86.2	160.7	352.8	
			61.0 - 68.0	11.6, 24.0, 33.4, 22.7, 11.6	1, 1, 1, 3, 0	1	Laminar							
			62.0 - 70.0											
DU4412.6S	72	15	51.7 - 63.3					51.0 - 72.0	25.5	16.1	--	--	16.1	
			63.3 - 72.0	11.6, 23.2, 37.7, 24.7, 11.6	13, 9, 7, 8, 7	9	Laminar							
			64.5 - 73.0	11.6, 23.0, 37.7, 23.8, 11.6	10, 26, 13, 9, 0	0	Void Filling							
DU4433.4S	75	15	54.3 - 66.3	8.7, 16.0, 26.1, 16.0, 8.7	0, >100, 87, >100, >100	>100	Laminar	54.0 - 75.0	27	105.7	98.3	3.6	207.6	
			66.3 - 75.0	11.6, 23.2, 37.7, 23.2, 11.6	0, 3, 3, 1, 0	1	Laminar							
DU4434.9S	72.3	--	52.3 - 64.3	8.7, 16.0, 23.2, 16.0, 5.8	0, 0, 0, 0, 0	0	Laminar	52.0 - 72.3	26	4.5	--	--	4.5	
			64.3 - 72.3	8.7, 16.0, 37.7, 16.0, 8.7	4, 4, 1, 0, 0	0	Void Filling							
DU4443.8P	76	15	56.5 - 68.5	18.9, 26.9, 27.3, 18.9, 8.7	7, 20, 39, 46, >100	>100	Wash-Out	56.5 - 76.0	28	97.9	76.4	247.3	349.9	
			68.5 - 76.0	11.6, 26.1, 40.5, 26.1, 11.1	0, 0, 1, 0, 5	1	Laminar							

Upper Approach - Baseline D

Hole	Drilled Depth (feet)	Drilled Angle (Degrees)	Water Pressure Test Depths (feet)	Water Pressure Test Pressure (psi)	WPT Lugeon Value (l/m/min)	Reported Lugeon Value (l/m/min)	Flow Regime	Grout Stage (feet)	Grout Pressure (psi)	Mix A (Gals.)	Mix B (Gals.)	Mix C (Gals.)	Grout Total Take (Gals.)	Remarks
DD4274.4P	Hole abandoned - Lost drill steel in hole													Moved and drilled offset hole - See DD4274.4P offset
DD4274.4P Offset	54 (21.8 Core, 32.2 Perc.)	--	18.3 -28.3	8.7	26	26	--	18.3 - 54.0	10	4.2	--	--	4.2	
			28.3 - 38.3	4.4, 11.6, 18.0, 11.6, 4.3	0, 45, 35, 44, >100	>100	Wash-Out							
			38.3 - 48.3	8.7, 18.2, 26.2, 18.9, 8.7	>100, >100, 93, >100, >100	93	Turbulent							
			48.3 - 54.0	11.6, 23.2, 37.2, 23.2, 11.6	0, 0, 0, 0, 0	0	Laminar							
DU4275.6S	55.2 (21.5 Core, 33.7 Perc.)	15	21.5 - 31.5	10.8	18			21.5 - 55.2	10	0.2	--	--	0.2	
			31.5 - 41.5	5.8, 11.6, 19.8, 11.6, 4.3	33, 10, 9, 7, 9	7	Void Filling							
			41.5 - 55.2	8.7, 18.9, 27.6, 17.2, 8.7	0, 0, 0, 0, 0	0	Laminar							
DD4280.1P	55.5 (21.5 Core, 34.0 Perc.)	15	20.0 - 35.0	9	>100	>100	--	19.5 - 55.4	10	104.1	--	--	104.1	Air bubbles observed at DD4300P. Grout observed leaking through masonary near DD4320.1P.
			35.0 - 45.0	8.7, 13.5, 20.3, 12.1, 8.5	>100, >100, >100, >100, >100	>100	Turbulent							
			45.0 - 55.0	8.7, 21.0, 30.5, 19.5, 10.3	>100, >100, 85, >100, >100	85	Turbulent							
DD4284.4S	53.7 (21.3 Core, 32.4 Perc.)	--	18.3 - 28.3	8.7	45	45	--	18.3 - 54.0	10	6.7	--	--	6.7	
			28.3 - 38.3	4.3, 10.0, 16.4, 11.6, 4.3	0, 48, 33, 40, >100	>100	Wash-Out							
			38.3 - 48.3	8.7, 16.0, 26.1, 16.8, 7.7	99, 57, 31, 43, >100	31	Turbulent							
			48.3 - 53.6	11.6, 23.2, 35.9, 23.1, 11.6	0, 0 , 0, 0, 0	0	Laminar							
DU4285.6P	42.8	15	27.0 - 37.0	8.7	>100	>100	--	47.0 - 55.7	32	118.7	14.8		186.7	Upstaged
			37.0 - 47.0	5.8, 13.1, 23.2, 13.1, 5.8	>100, >100, >100, >100, >100	>100	Turbulent	--						
			47.0 - 55.7	8.7, 21.6, 30.5, 22.4, 8.7	>100, >100, >100, >100, >100	>100	Turbulent	27.0 - 55.7	13	52.9				2 grout set ups
DD4290.1S	55.8 (21.0 Core, 34.8 Perc.)	15	19.5 - 29.5	8.7	21	21	--	19.5 - 55.8	10	--	--	--	0	Hand log says 0.6 gal take. Automated log recoreded 0 gal take
			29.5 - 39.5	4.4, 11.6, 18.9, 11.6, 4.3	>100, 12, 8, 12, >100	8	Turbulent							
			39.5 - 49.5	8.7, 18.9, 26.1, 18.2, 8.7	23, 13, 13, 15, 26	13	Turbulent							
			49.5 - 55.8	11.6, 21.2, 35.1, 22.3, 11.6	0, 0, 0, 0, 0	0	Laminar							
DU4295.6S	46.6	15	15.0 - 25.0	4.3	>100	>100	--	15.0 - 55.6	5	2.3	--	--	2.3	
			25.0 - 35.0	4.3, 8.7, 9.7, 8.7, 4.3	>100, 24, 24, 16, 5	5	Void Filling							
			35.0 - 45.0	5.8, 14.9, 18.9, 13.7, 5.8	0, 0, 0, 0, 0	0	Laminar							
			45.0 - 55.6	8.7, 18.9, 30.5, 18.9, 10.6	0, 0, 0, 0, 0	0	Laminar							
DD4300.0P	55.7 (21.1 Core, 34.6	15	19.0 - 35.0	8.7	>100	>100	--	19.1 - 55.7	10	--	--	--	0	
			45.0 - 55.7	8.7, 19.2, 30.2, 19.8, 8.8	>100, >100, 91, >100, >100	91	Turbulent							
DU4305.6P	46.8	15	27.0 - 37.0	8.7	>100	>100	--	27.0 - 55.8	13	131.0	4.8	--	135.8	Communicated with DU4313.1P during WPT
			37.0 - 47.0	7.7, 16.0, 23.0, 16.0, 6.6	26, 16, 14, 15, 28	14	Turbulent							
DD4310.1S	55.5 (21.0 Core, 34.5 Perc.)	15	19.3 - 29.3	8.7	>100	>100	--	19.3 - 55.5	--	--	--	--	0	
			29.3 - 39.3	5.5, 10.4, 19.2, 12.7, 5.6	47, 2, >100, 25, 51	2	Dilation							
			39.3 - 55.3	8.7, 18.0, 26.1, 18.7, 8.7	0, 0, 0, 0, 0	0	Laminar							
DU4313.1P	45	--	26.0 - 36.0	9.1	>100	>100	--	26.0 - 54.0	13	52.2	--	--	52.2	
			36.0 - 46.0	5.8, 15.8, 20.4, 13.1, 5.8	3, 4, 3, 4, 0	3	Turbulent							
			46.0 - 54.0	11.6, 20.3, 30.5, 23.2, 13.1	1, 0, 2, 0, 0	0	Dilation							
DU4316.3S	46.8	15	15.0 - 25.0	4.3	12	12	--	15.0 - 55.6	5	--	--	--	0	Communicated with DU4295.6S during grouting
			25.0 - 35.0	5.3, 6.7, 10.9, 8.7, 4.2	>100, >100, >100, >100, >100	>100	Turbulent							
			35.0 - 45.0	8.7, 11.7, 18.9, 13.1, 5.8	54, 41, 22, 27, 97	22	Turbulent							
			45.0 - 55.8	8.8, 19.0, 30, 21, 10	3, 8, 4, 5, 10	10	Wash-Out							
DD4320.1P	55.8 (21.3 Core, 34.5 Perc.)	15	19.0 - 26.0	8.7	>100	>100		19.1 - 55.8	--	--	--	--	0	
			26.0 - 36.0	8.7, 8.7, 12.3, 8.7, 8.7	>100, >100, >100, >100, >100	>100	Turbulent							
			36.0 - 46.0	8.7, 16.0, 23.2, 16.0, 8.7	>100, >100, >100, >100 >100	>100	Turbulent							
			46.0 - 55.8	13.1, 26.3, 31.6, 26.1, 13.1	>100, >100, 84, >100, >100	84	Turbulent							
DU4323.8S	45	--	9.0 - 54.0	4.3	>100	>100	--	9.0 - 54.0	5	4.5	--	--	4.5	Automated & hard copy logs show interval for WPT and grouting to start at 7.0'. Starting depth changed to 9.0' (east concrete control section) to account for void space
DD4324.9T	40.8 (23.6 Core, 17.2	35	20.9 - 30.9	8.7	15	15	--	20.9 - 40.8	8.5	10.3	--	--	10.3	
			30.9 - 40.7	4.3, 8.7, 16.0, 11.6, 4.3	0, 0, 0, 0, 0	0	Laminar							
DD4322.2T	60.8 (21.3 Core, 39.5 Perc.)	30	19.9 - 29.9	8.7	18	18	--	19.9 - 60.8	10	0.3	--	--	0.3	
			29.9 - 39.9	4.3, 11.6, 16.0, 8.7, 4.3	3, 3, 3, 1, 0	0	Void Filling							
			39.9 - 49.9	8.7, 16.0, 23.3, 15.9, 8.7	24, 16, 15, 14, 7	7	Void Filling							
			49.9 - 60.8	9.1, 20.2, 31.5, 20.7, 11.1	0, 0, 1, 1, 0	0	Dilation							
DU4309.1T	31.9	50	15.0 - 25.0	4.4	14	14	--	15.0 - 40.0	6, 10, 10	70.1	17.6	--	88	Communicated with DU4316.3S during grouting
			25.0 - 40.0	4.3	>100	>100	--							Downstaged
DU4323.8T	36.3	10	15.0 - 25.0	4.3	35	35	--	15.0 - 45.4	5	0.4	--	--	0.4	
			25.0 - 35.0	4.3, 8.7, 11.6, 8.6, 4.3	12, 21, 26, 26, 32	32	Wash-Out							
			35.0 -45.4	4.5, 13.1, 20.5, 13.1, 5.8	0, 0, 2, 0, 0	0	Dilation							
DD4327.1S	55.5 (20.5 Core, 35.0 Perc.)	15	19.3 - 29.3	8.7	7	7	--	19.3 - 55.5	10	--	--	--	0	
			29.3 - 39.3	4.8, 11.8, 18.9, 11.6, 5.8	>100, 38, 28, 41, >100	28	Turbulent							Communicated with DD4310.1S during WPT
			39.3 - 55.5	10, 20, 30, 20, 10	0, 13, 22, 0, 0	13	Dilation							

APPENDIX F - Grout Curtain Depth Comparison Plot


Constant C
25
30
35
40
45
50
55
60
65
70
75
0
10
20
30
40
50
60
70
80
90
Grout Curtain Depth (ft.)
USBR Method
Regions 1, 3, & 4 Installed Depth
Region 2 Installed Depth
USBR method over predicts the depth of the grout curtain compared to the depth determined by geological considerations, except when C = 25 within Region 2 of the site.

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