LINER DESIGN DOCUMENTATION AND CERTIFICATION

LINER DESIGN DOCUMENTATION AND CERTIFICATION

Upstream Raise CCR Surface Impoundment
Coal Creek Station
Great River Energy

Submitted To: Great River Energy
Coal Creek Station
2875 Third Street SW
Underwood, North Dakota 58576

Submitted By: Golder Associates Inc.
44 Union Boulevard, Suite 300
Lakewood, Colorado 80228

October 13, 2016 **1649586**

Table of Contents

List of Appendices

1.0 INTRODUCTION

This report presents documentation and certification of the liner design for the Upstream Raise CCR Surface Impoundment (Upstream Raise) at Great River Energy's (GRE) Coal Creek Station (CCS). The Upstream Raise at CCS is an existing (i.e., received coal combustion residuals both before and after October 14, 2015) coal combustion residual (CCR) surface impoundment. This report addresses the requirements of 40 CFR Section §257.71, Liner Design Criteria for Existing CCR Surface Impoundments.

Coal Creek Station is located in McLean County, approximately 10 miles northwest of Washburn, North Dakota. The Upstream Raise comprises approximately 89 acres of composite lined footprint and is used as a combined dewatering and storage facility for CCRs including fly ash, bottom ash, and flue-gas desulfurization (FGD) material. The Upstream Raise consists of two connected underlying facilities: Ash Pond 92 and Southwest Section 16.

2.0 SUMMARY OF LINER DESIGN CRITERIA

The west side of the Upstream Raise (Ash Pond 92) includes approximately 55 acres of composite liner installed in 1989. The east side of the Upstream Raise (Southwest Section 16) includes approximately 34 acres of composite liner installed in three phases between 2005 through 2008 over historically placed CCRs/soil and the original Southwest Section 16 natural soil liner.

Regulation §257.71(a)(1) requires documentation that each existing CCR surface impoundment is constructed with one of the following liner systems.

- A liner consisting of a minimum of 2 feet of compacted soil with a hydraulic conductivity of no more than $1x10^{-7}$ centimeters per second (cm/sec).
- A composite liner that meets the requirements of §257.70(b), consisting of:
  - An upper component composed of at least a 30-mil geomembrane liner (GM) or 60-mil if using high density polyethylene (HDPE) installed in direct and uniform contact with the compacted soil or lower liner component, and
  - A lower component consisting of at least a 2-foot layer of compacted soil with a hydraulic conductivity less than or equal to $1x10^{-7}$ cm/sec.
- An alternative composite liner that meets the requirements of §257.70(c), consisting of:
  - An upper component composed of at least a 30-mil geomembrane liner (GM) or 60-mil if using high density polyethylene (HDPE) installed in direct and uniform contact with the compacted soil or lower liner component, and
  - A lower component, that is not a GM, with a liquid flow rate no greater than the liquid flow rate of 2 feet of compacted soil with a hydraulic conductivity of less than or equal to $1x10^{-7}$ cm/sec.

Additionally, composite liners and alternative composite liners must meet the following criteria regarding compatibility, engineering properties and installation, outlined in §257.70(b):

- Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeologic forces), physical contact with the CCR or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation;
- Constructed of materials that provide appropriate shear resistance of the upper and lower component interface to prevent sliding of the upper component including on slopes;
- Placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift; and
- Installed to cover all surrounding earth likely to be in contact with the CCR or leachate.

3.0 UPSTREAM RAISE LINER EVALUATION

The liner components for each side of the Upstream Raise are described below.

3.1 West Side (Ash Pond 92)

The west side of the Upstream Raise was lined in 1989 with a liner system consisting of an upper component of 40-mil thick HDPE geomembrane liner and a lower component of a minimum of 2 feet of compacted clay. At the time of construction, the west side of the Upstream Raise (Ash Pond 92) was referred to as the east half of the South Ash Pond. Construction quality assurance requirements and construction observations for the composite liner on the west side of the Upstream Raise (Ash Pond 92) are contained in the Foth & Van Dyke Construction Observation Report – East Half of South Ash Pond (Foth & Van Dyke 1990).

The minimum of 2-foot thick clay fill was placed in horizontal compacted lifts of no more than 6 inches in thickness and compacted to at least 98% maximum density as determined from a Standard Proctor (Foth & Van Dyke 1990). The thickness of the clay liner was surveyed to confirm that a minimum of 2 feet of material was placed. Testing conducted on the clay liner during construction consisted of grain size distribution, Proctor compaction curves, Atterberg limits, and field density and moisture testing.

Both “brown” clay and “gray” clay were used to construct the clay liner over the west side of the Upstream Raise. Laboratory hydraulic conductivity testing was conducted on 83 Shelby tube samples taken from the west side clay liner installation. Hydraulic conductivity testing of the “brown” clay liner materials provided a range in hydraulic conductivity results between $1x10^{-8}$ cm/sec and $1x10^{-7}$ cm/sec (Foth & Van Dyke 1990). Hydraulic conductivity testing of the “gray” clay liner materials provided a range in hydraulic conductivity results between $1x10^{-9}$ cm/sec and $1x10^{-7}$ cm/sec (Foth & Van Dyke 1990).

The liner system of the west side of the Upstream Raise meets and exceeds liner requirements outlined in §257.71(a)(1)(i). In addition to complying with the requirement to have a minimum of 2 feet of compacted soil with a hydraulic conductivity of no more than $1x10^{-7}$ cm/sec, the liner system has a 40-mil HDPE geomembrane liner in direct contact with the compacted clay layer.

3.2 East Side (Southwest Section 16)

Approximately 34 acres on the east side of the Upstream Raise was lined in three phases from 2005 through 2008 with a liner system consisting of an upper component of 60-mil thick linear low density polyethylene (LLDPE) geomembrane liner and a lower component of a minimum of 1 foot of compacted low hydraulic conductivity soil (LPS). This composite liner was constructed over the temporarily closed Southwest Section 16 facility that began operation in 1980 as the southwest corner of the East Ash Pond.

The original Southwest Section 16 facility (southwest corner of East Ash Pond), was constructed with a natural soil liner. Several geotechnical evaluations have been performed on foundation materials underlying the Southwest Section 16 facility including an evaluation of the pond bottom conditions completed in 1986 by E. A. Hickok & Associates (E.A. Hickok & Associates 1986) and subsurface field investigations performed by Golder between 2001 and 2003 (Golder 2004). These evaluations indicate that an approximately 15 to 30-foot thick layer of lean clay exists under the Southwest Section 16 facility from the base of CCR deposition down to a bedrock or sandy clay layer.

Between 1980 and 2005, CCR and site soils have been placed in the Southwest 16 footprint. This material consisted of a mix of fly ash, bottom ash, FGD material, and site soils. The co-mingled material was previously compacted and covered with a temporary soil cover in 1989 and after subsequent material placement events. In 2005, a large amount of the in-situ material was re-graded and re-compacted during development of the base grades and embankments for the east side of the Upstream Raise composite liner. A comparison between the approximate top of natural soil liner and the 2005 re-grade contours indicates an approximately 25 to 65-foot thick layer of comingled CCR and soil between the original natural soil liner and the new composite liner.

As completed, the liner system on the east side of the Upstream Raise (Southwest Section 16) consists of from top to bottom:

- An upper component consisting of a 60-mil LLDPE geomembrane liner
- A lower component consisting of:
  - 1 foot of compacted clay with a hydraulic conductivity of 7.1×10^{-8} cm/sec
  - Approximately 25 to 65 feet of stratified and compacted CCR materials with an equivalent estimated hydraulic conductivity of 1.3×10^{-7} cm/sec
  - Approximately 15 to 30 feet of natural clay liner with a hydraulic conductivity of 2.4×10^{-7} cm/sec

3.2.1 Alternative Composite Liner Demonstration – §257.70(c)

Per §257.70(c), the lower component of an alternative composite liner must have a liquid flow rate no greater than the liquid flow rate of 2 feet of compacted soil with a hydraulic conductivity of less than or equal to 1×10^{-7} cm/sec. Utilizing Darcy's law for gravity flow through porous media, a comparison between the alternative lower component and 2 feet of 1x10^{-7} cm/sec was performed for a range of heads expected over the east side of the Upstream Raise (Appendix A).

	Prescriptive (2 ft of 1x10^{-7}cm/sec)	**Alternative Lower Component**
h	q	q
ft	cm^3/sec/cm^2	cm^3/sec/cm^2
10	6.0E-07	1.9E-07
20	1.1E-06	2.2E-07
30	1.6E-06	2.6E-07
40	2.1E-06	3.0E-07
50	2.6E-06	3.3E-07
60	3.1E-06	3.7E-07
70	3.6E-06	4.1E-07
80	4.1E-06	4.4E-07
70	3.6E-06	4.1E-07
80	4.1E-06	4.4E-07
90	4.6E-06	4.8E-07

The comparative results indicate that the alternative lower component has a lower liquid flow rate than 2 feet of 1x10^{-7} cm/sec soil for the expected range of head.

The composite liner system installed on the east side of the Upstream Raise meets additional composite liner requirements outlined in §257.70(b):

- §257.70(b)(1) – The composite liner is constructed of competent materials with appropriate strength and meet the composite liner design requirements for CCR materials outlined in 40 CFR Section 257.71.
- §257.70(b)(2) –Based on design information and visual observations of the Upstream Raise composite liner constructed between 2005 and 2008, the composite liner system was constructed with soil-filled anchor trenches to provide shear resistance to movement of the liner system.
- §257.70(b)(3) – Embankments and subgrade materials (re-compacted CCR/soil) were designed to be compacted to at least 95% maximum density as determined from a Standard Proctor and were compacted to meet those specifications based on field testing. Based on this information and visual observations, embankment fill materials appear to have been compacted to densities sufficient for loading conditions expected at the Upstream Raise.
- §257.70(b)(4) – The composite liner was installed to cover surrounding earth that could come into contact with CCR material associated with the Upstream Raise.

The liner system of the east side of the Upstream Raise meets the liner requirements outlined in §257.71(c).

4.0 CERTIFICATION

The undersigned attest to the completeness and accuracy of this liner design documentation, and certify that the installed liner on the west and east sides of the Upstream Raise meet the requirements detailed in 40 CFR §257.71(a)(1), and that the Upstream Raise is a "lined" CCR surface impoundment.

GOLDER ASSOCIATES INC.

Todd Stong, PE
Associate and Senior Engineer

Craig Schuettpelz, PE
Senior Project Engineer

TS/CS/rjg

REGISTERED PROFESSIONAL ENGINEER
TODD J. STONG
PE-6144
DATE 10/13/2016
NORTH DAKOTA

5.0 REFERENCES

EPA. 2015. Environmental Protection Agency, Code of Federal Regulations Title 40 Part 257: Hazardous and Solid Waste Management System; *Disposal of Coal Combustion Residuals from Electric Utilities*. April.

Eugene A. Hickok & Associates. 1986. *Evaluation of Pond Bottom Conditions Southwest and West Portions of the East Ash Pond – Coal Creek Station*. July.

Foth & Van Dyke. 1990. *Construction Observation Report – East Half of South Ash Pond, Coal Creek Station, McLean County, North Dakota.* February.

Golder. 2004. *Geotechnical Investigation for Section 16 – Great River Energy Coal Creek Station*. August.

Golder. 2006. *Construction Quality Assurance Documentation and Certification – Southwest Section 16 – Phase I Upstream Raise Expansion Construction.* June.

Golder. 2007. *Construction Quality Assurance Documentation and Certification – Southwest Section 16 – Phase II Upstream Raise Expansion Construction.* March.

Golder. 2009. *Construction Quality Assurance Documentation and Certification – Southwest Section 16 – Phase III Upstream Raise Expansion Construction.* March.

APPENDIX A
ALTERNATIVE COMPOSITE LINER CALCULATION

1.0 OBJECTIVE

Compare the estimated liquid flow rate through the lower component of the east side of the Upstream Raise (Southwest Section 16) alternative composite liner to the estimated liquid flow rate through two feet of compacted soil with a hydraulic conductivity of 1 x 10^{-7} cm/sec.

2.0 METHOD

The liquid flow rate comparison is made using equation 1 from 40 CFR Section 257.70(c)(2), which is derived from Darcy's Law for gravity flow through porous media:

$$q = k\left(\frac{h}{t} + 1\right)$$

q = flow rate per unit area ($cm^3/sec/cm^2$)

k = hydraulic conductivity of the liner (cm/sec)

h = hydraulic head above the liner (cm)

t = thickness of the liner (cm)

3.0 ASSUMPTIONS

General

The hydraulic head above the liner (h) will vary across the east side of the Upstream Raise. The top of composite liner varies in elevation from elevation 1915 to 1938 feet, and the pool elevation varies from an approximate elevation of 1948 feet to 2001 feet as the Upstream Raise progresses. This results in hydraulic head above the liner between approximately 10 and 90 feet.

- h = 10 to 90 ft

Prescriptive Composite Liner Lower Component

- k = 1.0x10^{-7} cm/sec
- t = 2 ft

Alternative Composite Liner Lower Component

The lower component of the alternative composite liner is composed of three parts (from bottom to top):

Layer 1 – Natural Soil Liner

The original Southwest Section 16 facility (southwest corner of East Ash Pond), was constructed with a natural soil liner. Several geotechnical evaluations have been performed on foundation materials underlying the Southwest Section 16 facility including an evaluation of the pond bottom conditions completed in 1986 by E. A. Hickok & Associates (E.A. Hickok & Associates 1986) and subsurface field investigations performed by Golder between 2001 and 2003 (Golder 2004). Approximately 20 borings were performed across the floor of Southwest Section 16 by Golder (Figure 1). The borings indicate that an approximately 15 to 30-foot thick layer of lean clay exists under the facility from the base of CCR deposition down to bedrock or sandy clay layer. Site borings were used to identify the top of the natural soil liner and the approximate thickness of the liner (assuming bottom of natural soil liner based on boring information and/or estimated bedrock elevations).

Boring	Ground Elevation (ft)	Top of Clay Depth (ft)	Top of Clay Elevation (ft)	Bottom of Clay Elevation (ft)	Approximate Clay Thickness (ft)
BH-6	1925	49	1876	1850	26
BH-7	1922	55	1867	1850	17
BH-8	1924	49	1876	1848	28
BH-9	1946	75	1871	1851	20
BH-10	1949	78	1871	1852	19
SW16-1	1905	30	1875	1851	24
SW16-2	1912	38	1875	1857	18
SW16-3	1925	58	1868	1850	18
SW16-4	1910	34	1876	1847	29
SW16-5	1903	28	1875	1848	27
SW16-6	1918	49	1870	1851	19
SW16-7	1948	78	1870	1850	20
SW16-8	1943	68	1876	1856	20
SW16-9	1924	28	1896	1869	27
SW16-10	1944	60	1884	1860	24
SW16-11	1926	40	1886	1859	27
SW16-15	1905	23	1883	1864	18
SW16-16	1942	58	1884	1863	21
SW16-17	1923	43	1881	1860	21
SW16-18	1926	47	1879	1855	24
				Maximum	29
				Minimum	17

- t_1 = 15 ft (conservative value based on minimum estimated thickness)

Hydraulic conductivity of this natural soil liner has been measured through four field permeameters installed by E.A. Hickok and Associates in 1985, and laboratory testing of two Shelby tube samples collected by Golder in 2001 and 2002. Results of the testing indicate that the hydraulic conductivity of the natural soil liner is between 8×10^{-8} cm/sec and 5×10^{-7} cm/sec (E.A. Hickok & Associates 1986), with a geometric mean of 2.4×10^{-7} cm/sec.

Location	Hydraulic Conductivity cm/sec
Permeameter 18	2.0E-07
Permeameter 19	2.0E-07
Permeameter 20	5.0E-07
Permeameter 22	3.0E-07
BH-8 (61 ft bgl)	8.3E-08
SW16-8 (76 ft bgl)	3.9E-07
Geometric Mean	2.4E-07

- $k_1 = 2.4 \times 10^{-7}$ cm/sec

Layer 2 – Compacted CCR Materials and Soil

Between 1980 and 2005, CCR materials and site soils have been placed in the Southwest Section 16 footprint. This material has been compacted during placement, and in 2005, a large amount of the in-situ material was re-graded and re-compacted during development of the base grades for the east side of the Upstream Raise composite liner. Review of the 2005 subgrade contours, and the estimated top of natural soil liner suggest that there is approximately 25 to 65 feet of material within this compacted CCR/soil layer.

Boring	Top of Base Liner Elevation (ft)	Top of 2005 Subgrade Elevation (ft)	CCR/Soil Thickness (ft)
BH-6	1876	1941	65
BH-7	1867	1922	55
BH-8	1876	1930	54
BH-9	1871	1930	59
BH-10	1871	1934	64
SW16-3	1868	1932	65
SW16-4	1876	1934	58
SW16-7	1870	1923	53
SW16-8	1876	1928	53
SW16-10	1884	1917	33
SW16-11	1886	1914	28
SW16-16	1884	1922	38
SW16-18	1879	1915	36
		Min	28
		Max	65

- $t_2 = 25$ ft (conservative value based on minimum estimated thickness)

The stratified and compacted waste layer consists of native soil and comingled CCR material that is primarily a mix of fly ash, bottom ash, and flue gas desulfurization (FGD) material. Hydraulic conductivity tests on these various components range from 3×10^{-2} cm/sec to 3×10^{-8} cm/sec (Golder 2012). It is assumed that these various materials are both comingled and layered. Assuming stratification of the materials in equal amounts, the equivalent vertical hydraulic conductivity ($k_{v(equivalent)} = \Sigma t_i/\Sigma(t_i/k_i)$ is approximately 1.3 x 10^{-7} cm/sec.

Material Type	Hydraulic Conductivity cm/sec
Natural Soil (site wide)	3.2E-08
Fly Ash	3.6E-05
Bottom Ash	3.0E-02
FGD	8.0E-06
$kv_{(equivalent)}$	1.3E-07

- k_2 = 1.3 x 10^{-7} cm/sec

Layer 3 – Low Permeability Soil Liner

Between 2005 and 2008, the in-situ soil and CCR material was regraded and a low permeability soil (LPS) liner was placed over the regraded material before installation of a 60-mil linear low density polyethylene (LLDPE) geomembrane liner. Survey performed on the LPS liner system indicated an average thickness of 1.1 feet.

- t_3 = 1 ft

Laboratory hydraulic conductivity testing was performed on 13 samples collected from the LPS liner. The resulting hydraulic conductivity values ranged between 4x10^{-8} cm/sec and 1x10^{-7} cm/sec, with a geometric mean of 7.1x10^{-8} cm/sec.

Sample	Hydraulic Conductivity cm/sec
P3-#1	7.1E-08
P3-#2	7.7E-08
P3-#3	4.2E-08
P3-#4	1.0E-07
P1-#1	1.1E-07
P1-#2	8.8E-08
P1-#3	5.5E-08
P1-#4	5.9E-08
P1-#5	7.8E-08
P1-#6	6.0E-08
P2-#1	1.0E-07
P2-#2	9.1E-08
P2-#3	3.7E-08
Geometric Mean	7.1E-08

- k_3 = 7.1x10^{-8} cm/sec

Combined Lower Component Properties

These three layers make up the lower component of the alternative composite liner system under the east side of the Upstream Raise and have the following values for thickness and equivalent vertical hydraulic conductivity:

- t = 41 ft
- k = 1.5x10^{-7} cm/sec

4.0 CALCULATIONS/RESULTS

Based on the inputs described above, the flow rate per unit area estimated for the lower component of the alternative composite liner and for two feet of compacted soil with a hydraulic conductivity of 1x10^{-7} cm/sec was estimated.

	Prescriptive (2 ft of 1x10^{-7}cm/sec)	**Alternative Lower Component**
h	q	q
ft	cm^3/sec/cm^2	cm^3/sec/cm^2
10	6.0E-07	1.9E-07
20	1.1E-06	2.2E-07
30	1.6E-06	2.6E-07
40	2.1E-06	3.0E-07
50	2.6E-06	3.3E-07
60	3.1E-06	3.7E-07
70	3.6E-06	4.1E-07
80	4.1E-06	4.4E-07
90	4.6E-06	4.8E-07

The estimated liquid flow rate through the lower component of the alternative composite liner is less than the liquid flow rate through two feet of compacted soil with a hydraulic conductivity of 1 x 10^{-7} cm/sec.

5.0 REFERENCES

EPA. 2015. Environmental Protection Agency, Code of Federal Regulations Title 40 Part 257: Hazardous and Solid Waste Management System; *Disposal of Coal Combustion Residuals from Electric Utilities*. April.

Eugene A. Hickok & Associates. 1986. *Evaluation of Pond Bottom Conditions Southwest and West Portions of the East Ash Pond – Coal Creek Station*. July.

Golder. 2004. *Geotechnical Investigation for Section 16 – Great River Energy Coal Creek Station*. August.

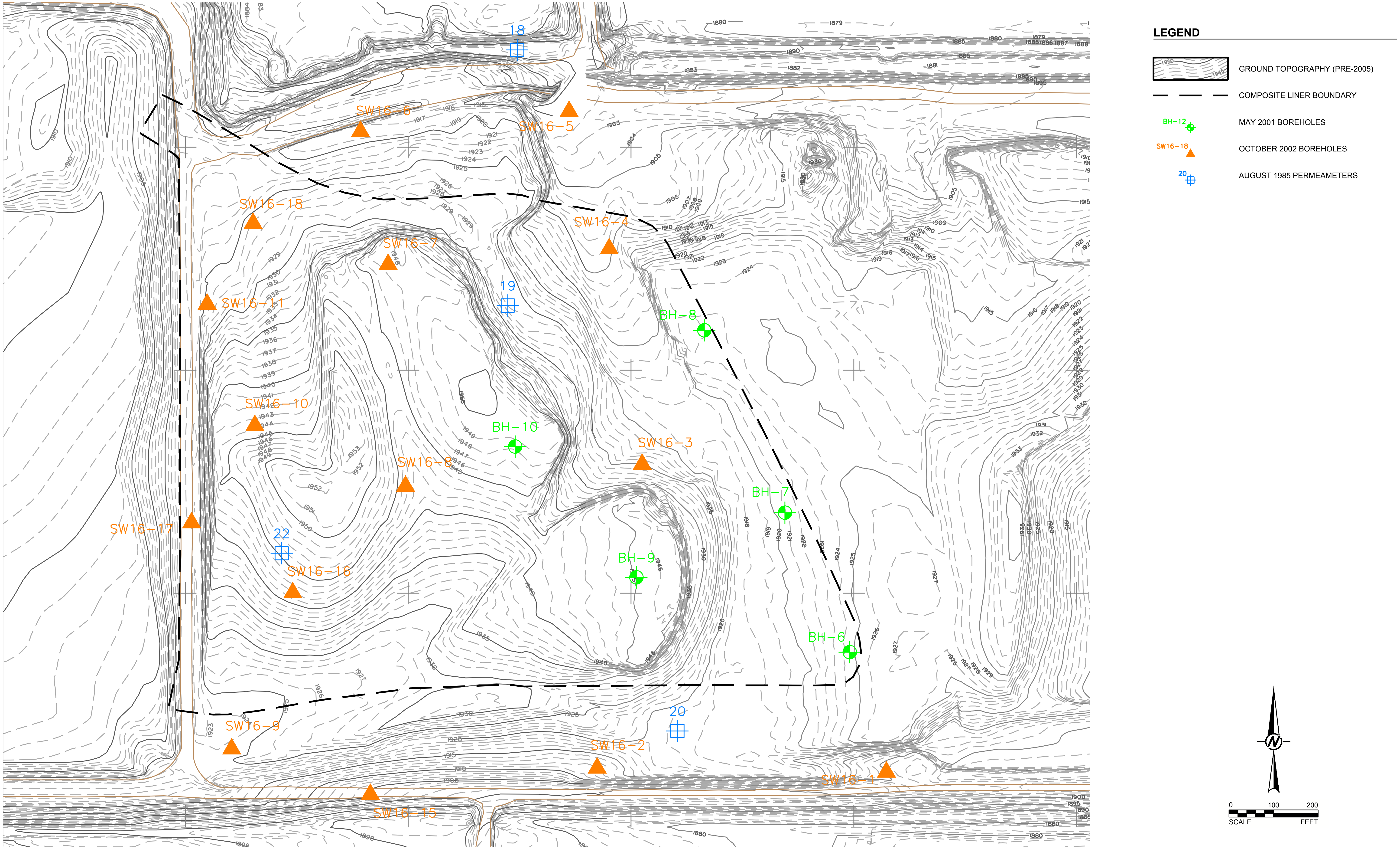
Golder. 2006. Construction Quality Assurance Documentation and Certification – Southwest Section 16 – Phase I Upstream Raise Expansion Construction. June.

Golder. 2007. Construction Quality Assurance Documentation and Certification – Southwest Section 16 – Phase II Upstream Raise Expansion Construction. March.

Golder. 2009. Construction Quality Assurance Documentation and Certification – Southwest Section 16 – Phase III Upstream Raise Expansion Construction. March.

GRE. 2012. *Permit Modification Document, Permit No. SP-033*. December.

FIGURE



GREAT RIVER ENERGY
SOUTHWEST SECTION 16
BORINGS AND PERMEAMETER LOCATIONS

FIGURE 1

Golder Associates

At Golder Associates we strive to be the most respected global group of companies specializing in ground engineering and environmental services. Employee owned since our formation in 1960, we have created a unique culture with pride in ownership, resulting in long-term organizational stability. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees now operating from offices located throughout Africa, Asia, Australasia, Europe, North America and South America.

Africa	+ 27 11 254 4800
Asia	+ 852 2562 3658
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Inc.
44 Union Boulevard, Suite 300
Lakewood, Colorado 80228 USA
Tel: (303) 980-0540
Fax: (303) 985-2080

Golder Associates