ALLIANT ENERGY
Interstate Power and Light Company
Sutherland Generating Station

CCR SURFACE IMPOUNDMENT

SAFETY FACTOR ASSESSMENT

Report Issued: March 05, 2018
Revision 0

HARD HAT SERVICES™
Engineering, Construction and Management Solutions

EXECUTIVE SUMMARY

This Safety Factor Assessment (Report) is prepared in accordance with the requirements of the United States Environmental Protection Agency (USEPA) Solid Waste Management System – Disposal of Coal Combustion Residual (CCR) from Electric Utilities (40 CFR Parts 257 and 261), also known as the CCR Rule.

This Report assesses the safety factors of each CCR unit at Sutherland Generating Station in Marshalltown, Iowa in accordance with §257.73(b), §257.73(e), and §257.100(a) of the CCR Rule. For purposes of this Report, "CCR unit" refers to existing and inactive CCR surface impoundments.

Primarily, this Report is focused on assessing if each CCR surface impoundment achieves the minimum safety factors, which include:

- Static factor of safety under long-term, maximum storage pool loading condition,
- Static factor of safety under the maximum surcharge pool loading condition,
- Seismic factor of safety; and,
- Post-Liquefaction factor of safety for embankments constructed of soils that have susceptibility to liquefaction.

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1 INTRODUCTION

The owner or operator of the Coal Combustion Residual (CCR) unit must conduct an initial and periodic safety factor assessments to determine if each CCR surface impoundment achieves the minimum safety factors, which include:

- Static factor of safety under long-term, maximum storage pool loading condition,
- Static factor of safety under the maximum surcharge pool loading condition,
- Seismic factor of safety; and,
- Post-Liquefaction factor of safety for embankments constructed of soils that have susceptibility to liquefaction.

This Report has been prepared in accordance with the requirements of §257.73(b), §257.73(e), and §257.100(a) of the CCR Rule.

1.1 CCR Rule Applicability

The CCR Rule requires a periodic safety factor assessment by a qualified professional engineer (PE) for existing and inactive CCR surface impoundments with a height of 5 feet or more and a storage volume of 20 acre-feet or more; or the CCR surface impoundment has a height of 20 feet or more.

1.2 Safety Factor Assessment Applicability

The Sutherland Generating Station (SGS) in Marshalltown, Iowa (Figure 1 & Figure 2) has four inactive CCR surface impoundments, of which only one meets the applicability within Section 1.1. The CCR surface impoundments are identified as follows:

- SGS North Primary Pond
- SGS South Primary Pond
- SGS Main Pond
- SGS Polishing Pond

Only the SGS Main Pond meets the requirements of §257.73(b)(1) and/or §257.73(b)(2) and is subject to the periodic safety factor assessment requirements of §257.73(e) and

§257.100(a) of the CCR Rule. The SGS North Primary Pond, SGS South Primary Pond, and SGS Polishing Pond do not have an embankment height of 5 feet or more, and do not have a storage volume of 20 acre-feet or more. Thus, these ponds are not subject to the periodic safety factor assessment requirements.

2 FACILITY DESCRIPTION

SGS is located east of the City of Marshalltown and approximately one-half mile west of the Iowa River in Marshall County, at 3001 East Main Street, Marshalltown, Iowa.

SGS was a fossil-fueled electric generating station consisting of three steam turbine electric generating units and three combustion turbine units. SGS initiated operations in 1954. From 1954 to 2012 sub-bituminous coal was the primary fuel for producing steam. As of the end of 2012, SGS ceased using coal and modified facility operations to use natural gas as the primary fuel source. SGS ceased natural gas generation as of June 22, 2017 and retired. The external combustion turbines, located west of the main generating station, continue operations and are now associated with the nearby Marshalltown Generating Station.

When coal was the primary fuel for producing steam, a by-product of CCR was produced. The CCR at SGS is categorized into two types, bottom ash and precipitator fly ash.

The precipitator fly ash at SGS was collected by electrostatic precipitators and conveyed dry to a temporary on-site storage area. The precipitator fly ash was then transported off-site for beneficial reuse. If the dry conveying system malfunctioned, an emergency by-pass system would utilize water to sluice the precipitator fly ash from the generating plant to the CCR surface impoundments.

The bottom ash at SGS was sluiced from the generating plant to the CCR surface impoundments. Other influent flows that previously discharged into the CCR surface impoundments consisted of cooling tower blow down water, air compressor cooling water, boiler blow down water, storm water runoff from the former coal pile storage area, and other low-volume waste water streams from the generating plant via a basement sump pump.

General Facility Information:

State CCR Impoundment ID	64-UDP-02-15
Date of Initial Facility Operations	1954
NPDES Permit Number:	IA 6469103
Facility Title V Operating Permit:	98-TV-010R2
Latitude / Longitude:	42°2′51″N 92°51′35″W
Site Coordinates:	Section 32, Township 84 North, Range 17 West

2.1 SGS North Primary Pond and SGS South Primary Pond

The SGS North Primary Pond and SGS South Primary Pond, Figure 2, are located east of the generating plant and west of the SGS Main Pond. The two CCR surface impoundments are incised. The two CCR surface impoundments historically received sluiced bottom ash from the generating plant prior to SGS ceasing coal burning activities. The majority of the CCR that was sluiced from the generating plant settled out in the two primary CCR surface impoundments. The two primary CCR surface impoundments were dredged on a weekly basis with a long-reach excavator. The dredged CCR was stockpiled adjacent to the CCR surface impoundments for dewatering prior to transporting to a temporary stockpile area using a front-end loader. The CCR was then transported off-site for beneficial reuse or to a permitted landfill.

Process flows into the SGS North Primary Pond and SGS South Primary Pond ceased at the time of the facility retirement. The influent during rainfall events included surface water runoff from the former coal pile storage area that is pumped into the impoundments by the lift pumps, Figure 2. The water in the SGS South Primary Pond, in addition to discharging through the corrugated metal pipe, can overflow into a high-density polyethylene corrugated pipe, which discharges into the west end of the SGS Main Pond.

The SGS North Primary Pond and SGS South Primary Pond both have a surface area of approximately 0.25 acres each.

2.2 SGS Main Pond

The SGS Main Pond, Figure 2, is located east of the generating plant and east of the SGS North Primary Pond and SGS South Primary Pond. The SGS Main Pond receives influent flows from the SGS North Primary Pond and SGS South Primary Pond, as well as storm water runoff from the surrounding area. The SGS North Primary Pond discharges into the northwest corner of the SGS Main Pond, while the overflow pipe from the SGS South Primary Pond discharges into the west end of the SGS Main Pond.

The water within the SGS Main Pond flows around a series of intermediate berms to improve suspended solids settlement prior to discharging into the southern end of the SGS Polishing Pond, which is located north of the SGS Main Pond. The water in the SGS Main Pond discharges into the SGS Polishing Pond via a concrete mixing channel located in the northeast corner of the SGS Main Pond, Appendix B. Since SGS ceased coal burning activities, the water within the SGS Main Pond has receded below the invert elevation of the concrete mixing channel at 861.9 feet. Therefore, water no longer discharges into the SGS Polishing Pond during normal conditions.

The SGS Main Pond has a surface area of approximately 4.8 acres and has an embankment height of approximately 8 feet from the crest to the toe of the downstream slope. The top elevation of the embankment is elevation 865 feet. From the July 14, 2017 Annual Inspection Report, the total volume of impounded CCR and water within the SGS Main Pond is approximately 34,000 cubic yards.

2.3 SGS Polishing Pond

The SGS Polishing Pond, Figure 2, is located east of the generating plant and north of the SGS Main Pond. The SGS Polishing Pond receives influent flows from the SGS Main Pond, as well as storm water runoff from the surrounding area. The water in the SGS Main Pond discharges into the SGS Polishing Pond via a concrete mixing channel located in the northeast corner of the SGS Main Pond. Since SGS ceased coal burning activities the SGS Polishing Pond no longer receives normal inflow from the SGS Main Pond and the water elevation in the pond has receded well below the invert elevation of the influent concrete mixing channel. The water that previously discharged into the SGS Polishing Pond discharged through the facility's National Pollutant Discharge Elimination System (NPDES) Outfall 001, which consists of a Parshall flume and flow metering equipment, Figure 2. The invert elevation of the Parshall flume is 861.3 feet. The water that flows through NPDES Outfall 001 discharges into an outfall pond, which overflow drains towards the east into the Iowa River. The overflow drain is a 2-foot diameter corrugated steel riser pipe with a rim elevation at elevation 860.5 feet.

The SGS Polishing Pond has a surface area of approximately 1.2 acres. The storage volume of the CCR surface impoundment is negligible. The embankment on the east side of the CCR surface impoundment has a crest elevation of 865 feet and maximum height above outside grade of eight feet.

3 SAFETY FACTOR ASSESSMENT- §257.73(e)

This Report documents if each CCR surface impoundment achieves the minimum safety factors, which are identified on the table below.

Safety Factor Assessment	Minimum Safety Factor
Static Safety Factor Under Maximum Storage Pool Loading	1.50
Static Safety Factor Under Maximum Surcharge Pool Loading	1.40
Seismic Safety Factor	1.00
Post-Liquefaction Safety Factor	1.20

3.1 Safety Factor Assessment Methods

The safety factor assessment is completed with the two-dimensional limit-equilibrium slope stability analyses program STABL5M (1996)[1]. The program analyzes many potential failure circles or block slides by random generation of failure surfaces using the toe and crest search boundaries set for each analysis. The solution occurs by balancing the resisting forces along the failure plane due to the Mohr-Columb failure strength parameters of friction angle and cohesion. The gravity driving forces are divided by the resisting forces to produce a safety factor for the slope. The minimum of hundreds of searches is presented as the applicable safety factor.

There are both total stress and effective stress friction angle and cohesion values for clay. For the total stress case, clay has only cohesion. For effective stress, clay has both cohesion and friction angle. When clay receives a load that is applied only briefly (i.e., earthquake or high water), it responds as a total stress soil. For long term loadings such as normal water elevation, the clay resistance to failure is based on effective stress parameters. The total stress parameters for compacted and stiff clay yield a conservative answer for safety factor. Since the clay at the toe of the embankments is soft clay,

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[1] STABL User Manual by Ronald A. Siegal, Purdue University, June 4, 1975 and STABL5 – The Spencer Method of Slices: Final Report by J. R. Carpenter, Purdue University, August 28, 1985

estimates of the effective stress strength for the clay at the toe is used for the normal operating water elevation in the SGS Main Pond and the total stress parameters for the clay components in the embankments and toe clay are used for the impacts from earthquake and high water which are short term loads.

3.1.1 Soil Conditions in and under the impoundments

The outer embankments of the CCR surface impoundment were constructed in 1955. The embankments were constructed by excavating clay present in the CCR surface impoundment area and using the clay from the interior of the single CCR surface impoundment to build embankments with a top elevation of 865. The bottom of the CCR surface impoundment is lower than the surrounding ground surface, Appendix A, and the embankments are constructed of black clay (Zook clay), Appendix B.

SGS is located in the alluvial outwash formations of the Iowa River. Deep soil borings by TEAM Services west of the CCR surface impoundments and by Black & Veatch south of the CCR surface impoundments indicate that sand is present below elevation 850. The TEAM Services and Black & Veatch boring logs and locations are provided in Appendix C. The top elevation of the sand in each boring, Figure 2, is tabularized below (Boring BV-7 is approximately 900 feet down the valley). The density of the sand immediately below the Zook clay is loose to medium dense.

Soil Boring	Boring Depth (Ft.)	Sand Depth (Ft.)	Surface Elevation (Ft.)	Sand Top Elevation (Ft.)
B-1	48	8.0	859.3	851
B-2	80	8.0	859.7	852
B-3	40.5	8.5	859.9	851
BV-6	80.5	7.0	856.6	850
BV-7	80.5	8.0	855.9	848

The general soil stratigraphy in Iowa is windblown Loess on the surface with glacial till below the loess. In some locations the loess is eroded away and in river valleys the till is also totally or partially eroded and overlain by alluvial soils. The Marshall County Soil

Survey, Appendix B, indicates that Zook clay is some of the finest textured soils derived from alluvial deposition and is found in the lower parts of bottom lands below alluvial benches that divide the bottomland of river valleys from the loess deposits. The USGS topographic quadrangle “Marshalltown Southeast” indicates that the natural ground surface adjacent to the CCR surface impoundments is between elevations 855-860. The USGS elevation range is consistent with the June 2012 critical cross-section survey results shown in Appendix D.

The generalized soil conditions at the embankments is compacted Zook clay from the top elevation at 865 (feet) to elevation 857-855 (assuming some topsoil was stripped prior to compacting the embankment), undisturbed Zook clay to elevation 850 and loose to medium dense alluvial sand below that elevation. The Zook clay prior to construction of the embankments was approximately 8-feet thick and was exposed to desiccation and bottom drainage after deposition. In addition to the natural drainage and desiccation, the undisturbed Zook clay below the embankments has been surcharge loaded by as much as 8-feet of compacted embankment for over 50 years further consolidating the clay under the embankment. The pocket penetrometer results from the borings shown in Appendix A indicate that the underlying Zook clay is over consolidated. Zook clay at the toe of the embankment slopes is assumed to be normally consolidated since the area is normally saturated and is not expected to show significant dessication.

The strength properties of the embankment for compacted or over consolidated Zook clay, normally consolidated Zook clay and the underlying sand are tabularized below. The underlying sand immediately below the clay is assigned a friction angle of 28° which represents a loose sand. The normally consolidated clay is assigned an effective stress friction angle of 24° with no cohesion based on the relationship of friction angle to plasticity index[2] reported in Appendix B for Zook clay. For the embankment clay, the effective stress friction angle and cohesion are the average values reported for compacted high plasticity (CH) clay by the United States Bureau of Reclamation[3]. The total stress cohesion values for the embankment clay are based on the minimum values measured from the borings taken in the embankments and summarized in Appendix E. The total stress cohesion for the normally consolidated clay was selected to represent a soft clay formation.

Soil Type	Effective Stress		Total Stress	
	Friction Angle	Cohesion (psf)	Friction Angle	Cohesion (psf)
Embankment Clay	25	400	0	1000
Soft Clay	24	0	0	250
Sand	28	N/A	28	N/A

3.1.2 Design Water Surface in Impoundments Maximum Normal Pool and Maximum Pool Under Design Inflow Storm

The SGS Main Pond receives storm water from the former coal pile storage area. For normal pool elevation and for pool elevation during the seismic safety factor analysis, the normal water elevation is assumed to be 859 feet as shown on the May of 2016 topographic map, Figure 2.

The maximum pool under the design inflow storm is based on the results of the Inflow Design Flood Control Plan. The inflow flood is routed through the SGS Main Pond with the CCR surface impoundment full to the overflow invert elevation of 861.9 feet. The assumption is based on site observations of back flooding caused by the flood stage of the adjacent Iowa River and provides a true test of the CCR surface impoundment

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[2] Kenney, T.C., 1959, Discussion, Journal of Soil Mechanics and Foundations Division, ASCE, Vol 85, No. SM3. Pp. 66-79

[3] USBM, "Design of Small Dams", 1977

outflow hydraulics. The maximum elevation in the CCR surface impoundment under the flood conditions with the 100-year design storm is water elevation 863.5 feet.

3.1.3 Selection of Seismic Design Parameters and Description of Method

The design earthquake ground acceleration is selected from the United States Geologic Survey (USGS) detailed seismic design maps based on the latitude and longitude of the SGS. The peak ground acceleration (PGA) value is selected for a 2% probability of exceedance in 50 years (2,500 year return period) as required by §257.53 and §257.100(a). The site soils are clay with cohesion greater than 1,000 psf, or predominantly medium dense sand to bedrock at elevation 615 feet, Appendix C. The site class as defined in the 2009 International Building Code 1613.5.5 is Site Class D for the soil profile above the bedrock. For Site Class D the ground surface PGA for slope stability and liquefaction assessment is 0.048g, Appendix F.

3.1.4 Liquefaction Assessment Method and Parameters

Certain soils may have zero effective stress (liquefaction) during an earthquake or from static shear of a saturated embankment slope. Soils that will liquefy include loose or very loose uniform fine sand or silt, and low plasticity clay (plastic index (PI) of less than 12). The native clay and embankment both have PI higher than 12 and are stiff and medium stiff in consistency. The river valley sand is predominantly medium dense and located at least 10 feet below the toe of the embankments.

None of the soil types at SGS is susceptible to liquefaction and no analysis of liquefaction potential is required for the embankments.

3.2 SGS Main Pond

Various locations were surveyed in June 2012 to determine the critical cross-section as shown on Figure 2. The overall height of the embankments is similar, and the steepest slope is at the westernmost of the three sections. At this location, top of the embankment is at elevation 865 feet and outside face of the embankment is at a 1.8 horizontal to 1 vertical slope. The toe of the embankment is at elevation 857 feet for a total embankment height of 8 feet. The inside slope of the embankment has a benched cut likely produced during removal of CCR and exposed by the reduced water elevation in the CCR surface impoundment. Safety factor analysis was completed for a range of failure surfaces that start on the embankment crest and exit to the south of the embankment toe.

3.2.1 Static Safety Factor Assessment Under Maximum Storage Pool Loading - §257.73(e)(1)(i) and §257.100(a)

Analysis of both circular and block sliding surfaces, Appendix F, shows a minimum factor of safety of 2.2. The minimum safety factor is a block failure surface passing along the sand and embankment clay interface.

3.2.2 Static Safety Factor Assessment Under Maximum Surcharge Pool Loading - §257.73(e)(1)(ii) and §257.100(a)

The SGS Main Pond will contain the 100 year return period design storm through a combination of storage in the CCR surface impoundment above overflow invert of 861.9 feet and discharge to the SGS Polishing Pond. The maximum surcharge pool elevation is 863.5 feet at the peak of the storm. Analysis for both circular and block sliding surface, Appendix F, shows a minimum factor of safety of 3.4. The minimum safety factor is a circular surface passing through the sand under the embankment with an exit 25-feet south of the embankment toe.

3.2.3 Seismic Safety Factor Assessment - §257.73(e)(1)(iii) and §257.100(a)

The SGS Main Pond was assigned a pseudo-static earthquake coefficient equal to 0.048 g acceleration and a vertical downward component equal to $^{2}/_{3}$ of the horizontal component (0.032 g) as recommended by Newmark[4]. Analysis for both a circular and block sliding surface, Appendix F, shows a minimum factor of safety of 2.7. The minimum is for the circular sliding surface through the sand under the embankment.

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[4] Newmark, N. M. and W. J. Hall, "Earthquake Spectra and Design", EERI Monograph, Earthquake Engineering Research Institute, Berkeley, California, 1982

3.2.4 Liquefaction Safety Factor Assessment - §257.73(e)(1)(iv) and §257.100(a)

The SGS Main Pond foundation and embankment soils are not susceptible to liquefaction, see Section 3.1.4.

4 RESULTS SUMMARY

The results of the safety factor assessment indicate that the SGS Main Pond embankments meet the requirements of §257.73(e) and §257.100(a). The results are:

	Static Stability Normal Water Elevation	Static Stability Flood Water Elevation	Pseudo Static Earthquake with Normal Water Elevation	Liquefaction Potential	Post-Earthquake Static Stability Normal Water Elevation
Required Safety Factor	1.5	1.4	1.0		1.2
SGS Main Pond	2.2	3.4	2.7	no	

5 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

To meet the requirements of 40 CFR §257.73(e)(2) and §257.100(a), I Mark W. Loerop hereby certify that I am a licensed professional engineer in the State of Iowa; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable requirements in 40 CFR §257.73(b), §257.73(e), and §257.100(a).

By:____________________

Name: MARK LOEROP

Date: MARCH 5, 2018

MARK W. LOEROP
22197

FIGURES

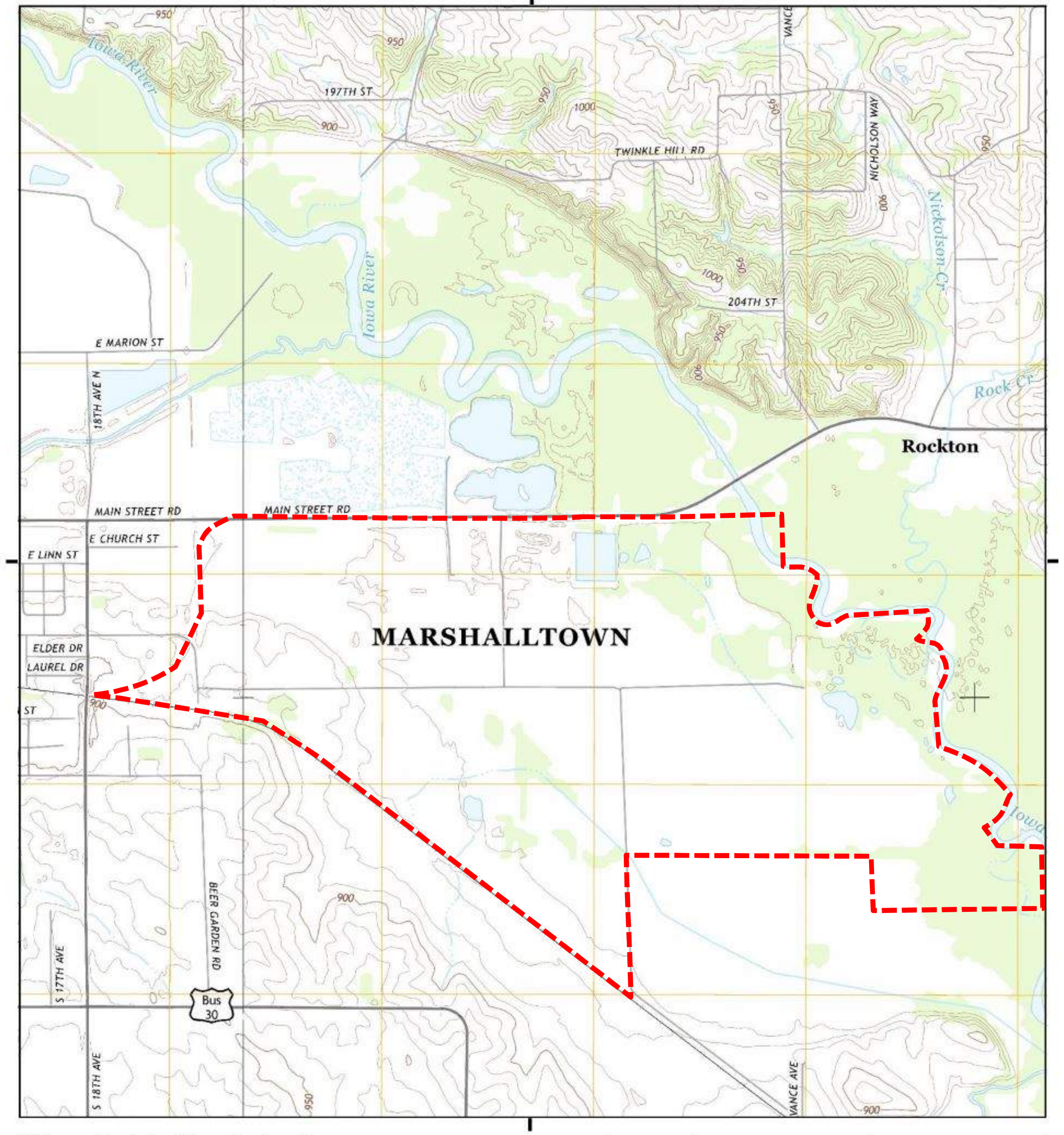
Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Safety Factor Assessment

EDR

Historical Topo Map

2013



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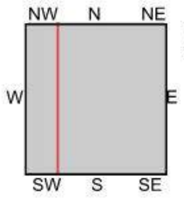

TP, Le Grand, 2013, 7.5-minute
W, Marshalltown, 2013, 7.5-minute

SITE NAME:	Sutherland Generating Station
ADDRESS:	3001 East Main Street Road Marshalltown, IA 50158
CLIENT:	Environmental Site Assessors

N

5087055 - 1 page 4

Historical Aerial Photo

┅ Approximate Property Boundary

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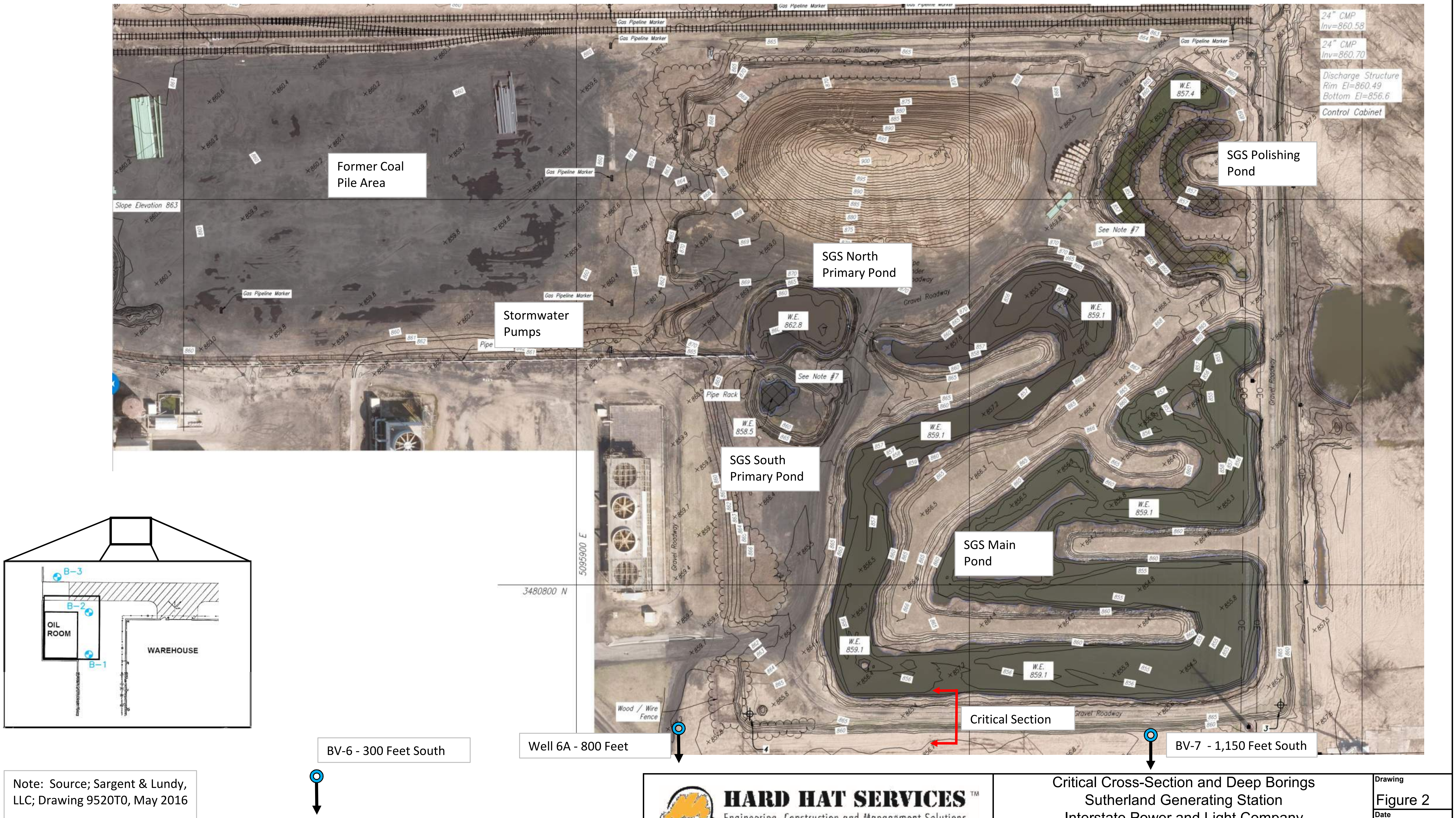
Site Location
Sutherland Generating Station
Interstate Power and Light Company

Drawing
Figure 1
Date
1/22/2018



Note: Source; Sargent & Lundy, LLC; Drawing 9520T0, May 2016

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Critical Cross-Section and Deep Borings
Sutherland Generating Station
Interstate Power and Light Company

Drawing
Figure 2

Date
1/22/2018

APPENDIX A – Pond Configuration, Sample Locations and Boring Logs

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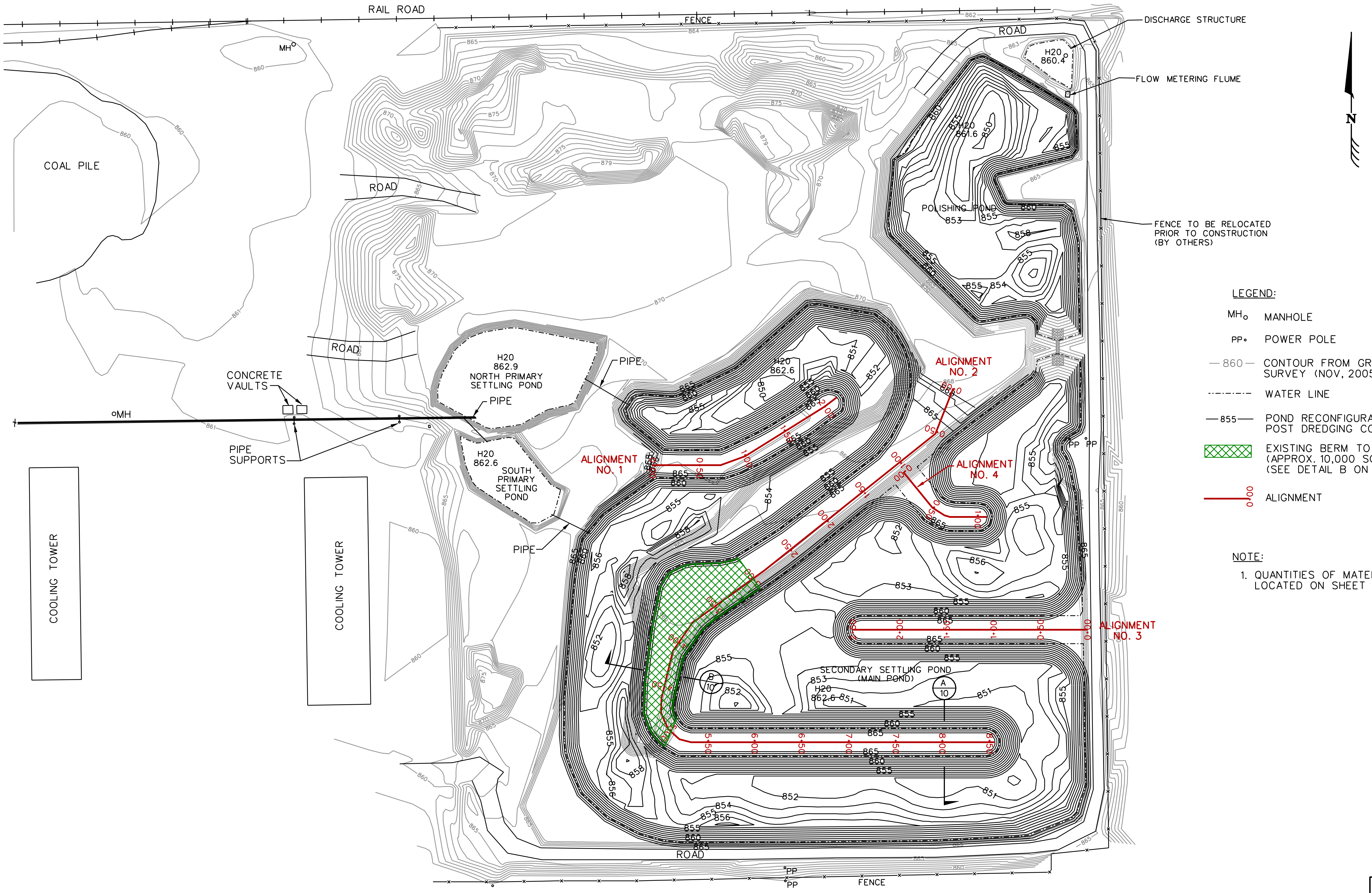
Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Safety Factor Assessment



LEGEND:

MH○	MANHOLE
PP∘	POWER POLE
— 860 —	CONTOUR FROM GROUND SURVEY (NOV, 2005)
—·—·—	WATER LINE
— 855 —	POND RECONFIGURATION AND POST DREDGING CONTOURS
▨	EXISTING BERM TO BE STABILIZED (APPROX. 10,000 SQ FT) (SEE DETAIL B ON SHEET 10)
—0+00—	ALIGNMENT

NOTE:

1. QUANTITIES OF MATERIALS ARE LOCATED ON SHEET 12.

DRAWING NUMBER:
1-2060-0-D-C5001-003

REV	DATE	BY	DESCRIPTION

SCALE:
0 50 100
SCALE IN FEET

DESIGNED: M. Loerop
DRAWN: HHSI
CHECKED: T. Blair

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Engineering, Construction and Management Solutions

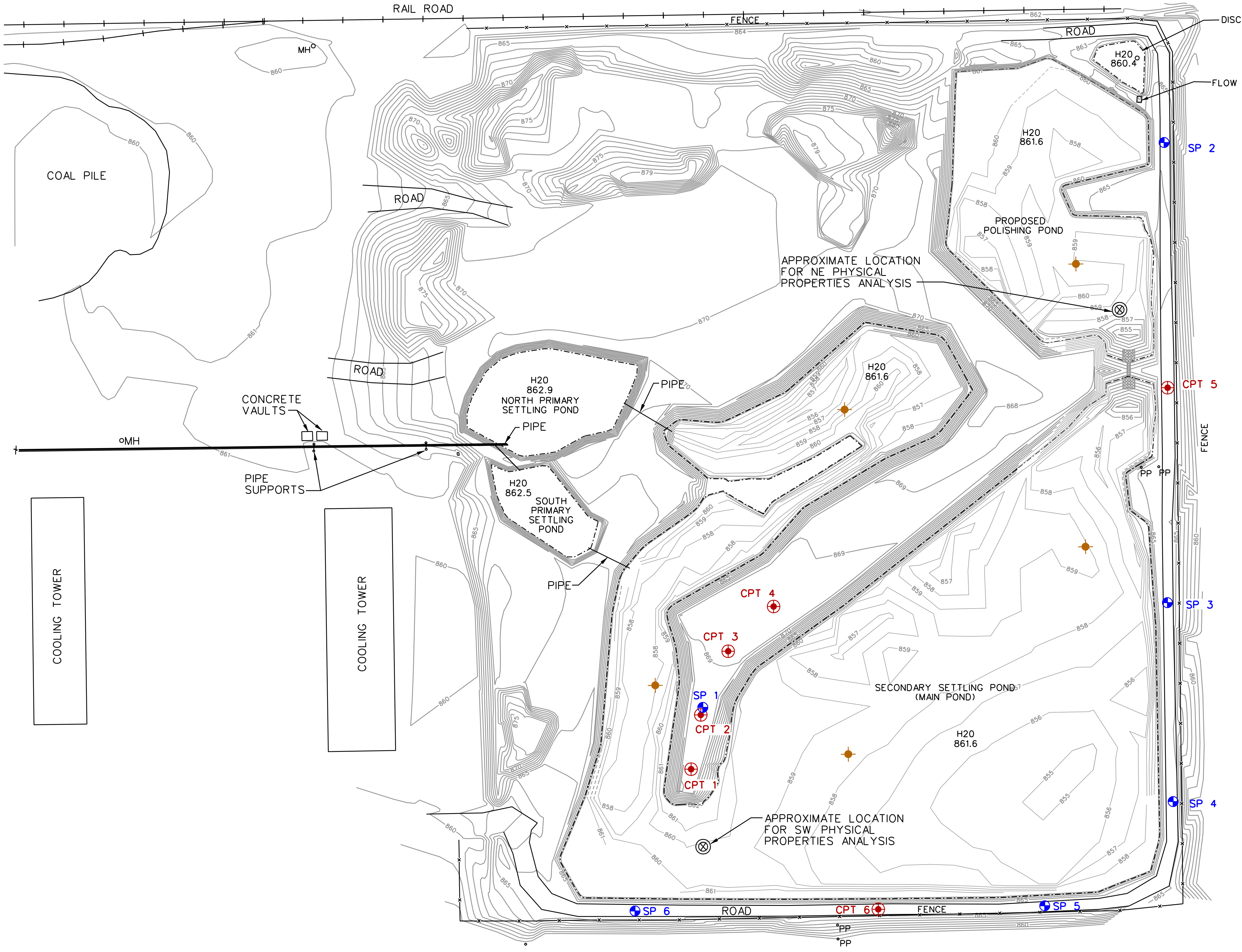
940 E. Diehl Rd, Suite 150
Naperville, IL 60563
(630) 637-9470

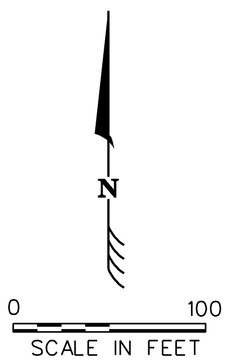
CLIENT:
INTERSTATE POWER & LIGHT
SUTHERLAND GENERATING STATION

TITLE:
PHASE 2
SETTLING POND RECONFIGURATION

SHEET
3

...\reconfiguration.dgn
4/19/2006





LEGEND:

●	SOIL PROBE LOCATION
●	CONE PENETRATION TEST LOCATION
✦	COMPOSITE SAMPLE LOCATION
MH○	MANHOLE
PP○	POWER POLE
— 860 —	CONTOUR FROM GROUND SURVEY (NOV, 2005)
-·-·-·-	WATER LINE

NOTES:

1. CONE PREPARATION TESTS WERE CONDUCTED TO A DEPTH OF 15' OR UNTIL REFUSAL.
2. SOIL PROBES WERE COMPLETED WITH A SPLIT SPOON SAMPLER TO A DEPTH OF 15' OR UNTIL REFUSAL.
3. SAMPLING ACTIVITIES WERE CONDUCTED ON 3-14-06.
4. ALL FIVE COMPOSITE SAMPLE LOCATIONS WERE PLACED IN A FIVE GALLON BUCKET. IT WAS MIXED FOR 15 MINUTES, SAMPLED, AND SENT TO THE LABORATORY FOR TOTAL METALS AND SFLP ANALYSIS.

DRAWING NUMBER:

REV	DATE	BY	DESCRIPTION

SCALE:
0 50 100
SCALE IN FEET

DESIGNED: M. Loerop
DRAWN: HHSI
CHECKED: T. Blair

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940 E. Diehl Rd, Suite 150
Naperville, IL 60563
(630) 637-9470

CLIENT:
INTERSTATE POWER & LIGHT
SUTHERLAND GENERATING STATION

TITLE:
GEOTECHNICAL AND SEDIMENT SAMPLE TEST LOCATIONS

FIGURE
1

$FILEABBREVS
$DATES

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

PROJECT: Alliant Energy

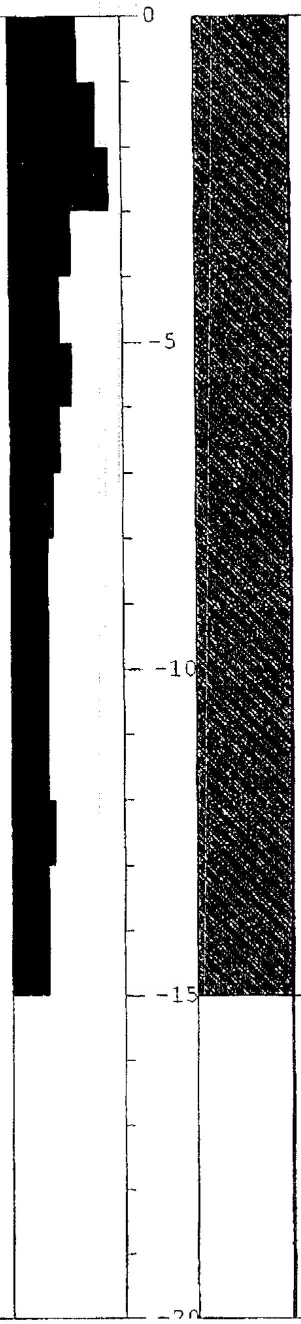
COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SP2*

page 1 of 2

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Mark Lorep*
DATE BEGAN: *3-14-06*
DATE FINISHED: *3-14-06*
GROUND SURFACE ELEVATION: *NOT MEASURED*

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS	POCKET PENETROMETER HISTOGRAM	DEPTH IN FEET	PROFILE	DESCRIPTION
				0		0		CLAY; brown;; low to high plasticity; moist; trace sand and gravel.
				2.75				
				3.5				
	GP 1	5'/5'						
				4.0				
				2.5				
						-5		
				2.0				
				2.5				
	GP 2	2'/5'						
				1.5				
				1.5		-10		
				1.75				
	GP 3	5'/5'						
				1.5				
				1.5		-15		Bottom of boring @ 15.0'. Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.
						-20		



CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

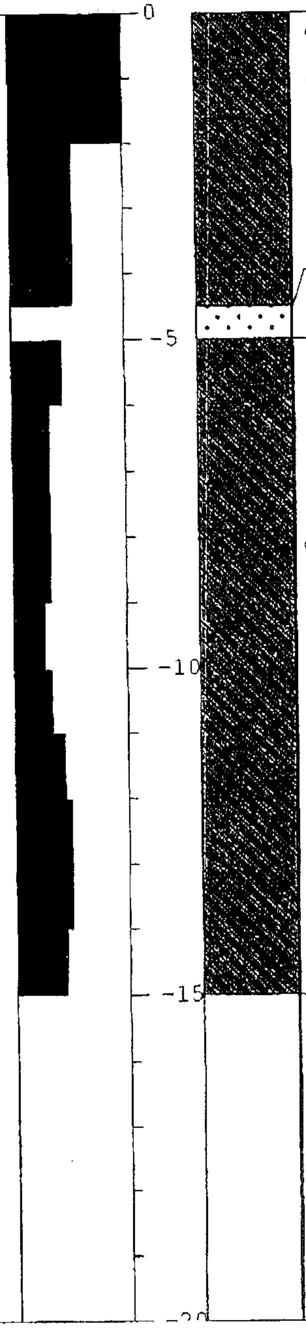
PROJECT: Alliant Energy

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SP3*

page 1 of 2

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Mark Lorep*
DATE BEGAN: *3-14-06*
DATE FINISHED: *3-14-06*
GROUND SURFACE ELEVATION: *NOT MEASURE*



DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS	DEPTH IN FEET	DESCRIPTION
				0	0	CLAY; yellowish brown to black; non-plastic to low plasticity; moist; trace ash, sand and gravel.
				4.5		
				4.5		
	GP 1	5'/5'				
				2.5		
						SAND; yellow; poorly graded; medium grained; moist.
					-5	CLAY; olive; low plasticity; moist; some sand.
				2.0		
				1.5		
	GP 2	2'/5'				@ 8' grades some organic matter
				1.5		
					-10	
				1.25		
				1.5		@11' organic matter grades out
				2.0		
	GP 3	5'/5'		2.25		@ 13' grades olive
				2.25		
					-15	
				2.0		
						Bottom of boring @ 15.0'. Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.
					-20	

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

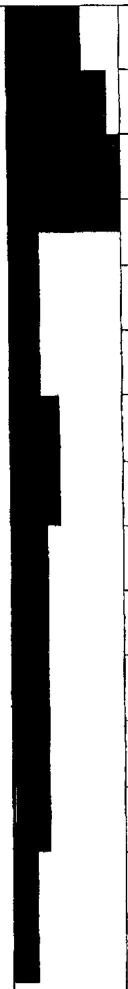
PROJECT: Alliant Energy

COORDINATES: *N NOT SURVEYED*
E NOT SURVEYED

BORING NO.: *SP4*

page 1 of 2

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Mark Lorep*
DATE BEGAN: *3-14-06*
DATE FINISHED: *3-14-06*
GROUND SURFACE ELEVATION: *NOT MEASURED*



DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS	DEPTH IN FEET	DESCRIPTION
				0	0	CLAY; yellowish brown to black; non-plastic to low plasticity; moist; trace ash, sand and gravel.
				3.0		
				4.0		
	GP 1	5'/5'				
				4.5		
				1.25	-5	CLAY; olive; low plasticity; moist; some sand.
				1.25		
				2.0		
	GP 2	2'/5'				@ 8' grades some organic matter
				2.0		
				1.5	-10	
						@11' organic matter grades out
				1.5		
	GP 3	5'/5'				@ 13' grades olive
				1.5		
				1.0		
				1.0	-15	
						Bottom of boring @ 15.0'. Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.
					-20	

CABENO

Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

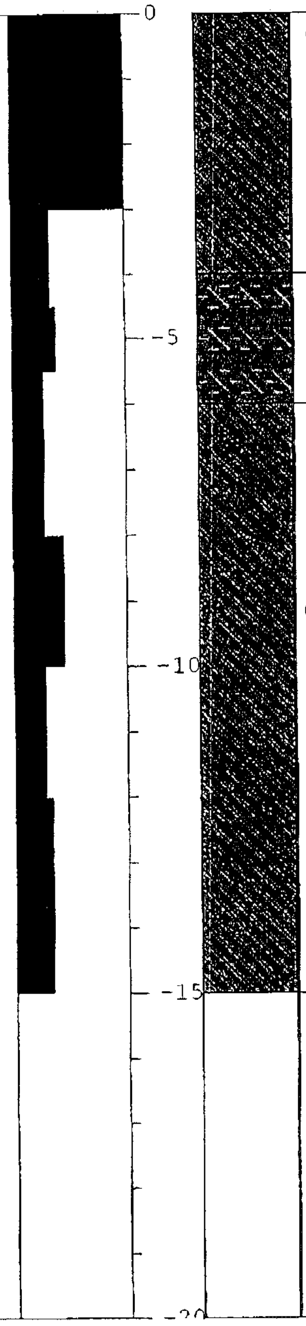
PROJECT: Alliant Energy

COORDINATES: *N NOT SURVEYED* *E NOT SURVEYED*

BORING NO.: *SP5*

page 1 of 2

LOGGED BY: *John Noyes*
EDITED BY: *John Noyes*
CHECKED BY: *Mark Lorep*
DATE BEGAN: *3-14-06*
DATE FINISHED: *3-14-06*
GROUND SURFACE ELEVATION: *NOT MEASURED*



DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS	POCKET PENETROMETER HISTOGRAM	DEPTH IN FEET	PROFILE	DESCRIPTION
				0		0		CLAY; brown; low plasticity; moist; trace sand and gravel.
				>4.5				
				>4.5				
	GP 1	5'/5'						
				>4.5				
								CLAY & ASH; black; non-plastic to low plasticity; moist.
				1.5		-5		
				1.75				
								CLAY; olive; low plasticity; moist; trace sand and gravel.
				1.25				
	GP 2	2'/5'		1.25				
								@ 9' grades black
				2.0		-10		
								@11' grades olive
				1.25				
	GP 3	5'/5'		1.5				
				1.5				
				1.5		-15		
								Bottom of boring @ 15.0'.
								Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.
						-20		

CABENO
Environmental Field Services, LLC

BORING LOG

CLIENT: Hard Hat

PROJECT: Alliant Energy

COORDINATES: N NOT SURVEYED
E NOT SURVEYED

BORING NO.: SP6

page 1 of 2

LOGGED BY: John Noyes
EDITED BY: John Noyes
CHECKED BY: Mark Lorep
DATE BEGAN: 3-14-06
DATE FINISHED: 3-14-06
GROUND SURFACE ELEVATION: NOT MEASURED

DEPTH TO WATER WHILE DRILLING	SAMPLE NO. AND TYPE	SAMPLE RECOVERY	SAMPLE INFROMATION	POCKET PENETROMETER READINGS	POCKET PENETROMETER HISTOGRAM	DEPTH IN FEET	PROFILE	DESCRIPTION
				0		0	▨	CLAY; brown; low plasticity; moist; trace sand and gravel.
				> 4.5				
				> 4.5				
	GP 1	5'/5'		> 4.5				
				2.5		-5		
				2.5				
				1.75				
	GP 2	2'/5'		2.5				
								@ 9' grades some organic material
				2.25		-10		
								@11' organic material grades out
				1.75				
	GP 3	5'/5'		2.5				
				2.25				
				2.0		-15		
								Bottom of boring @ 15.0'. Boring advanced W/ Geoprobe Model 6610 using 60" Macrocore sampling system.
						-20		

DESCRIPTION

APPENDIX B – Soil Survey of Marshall County, Iowa

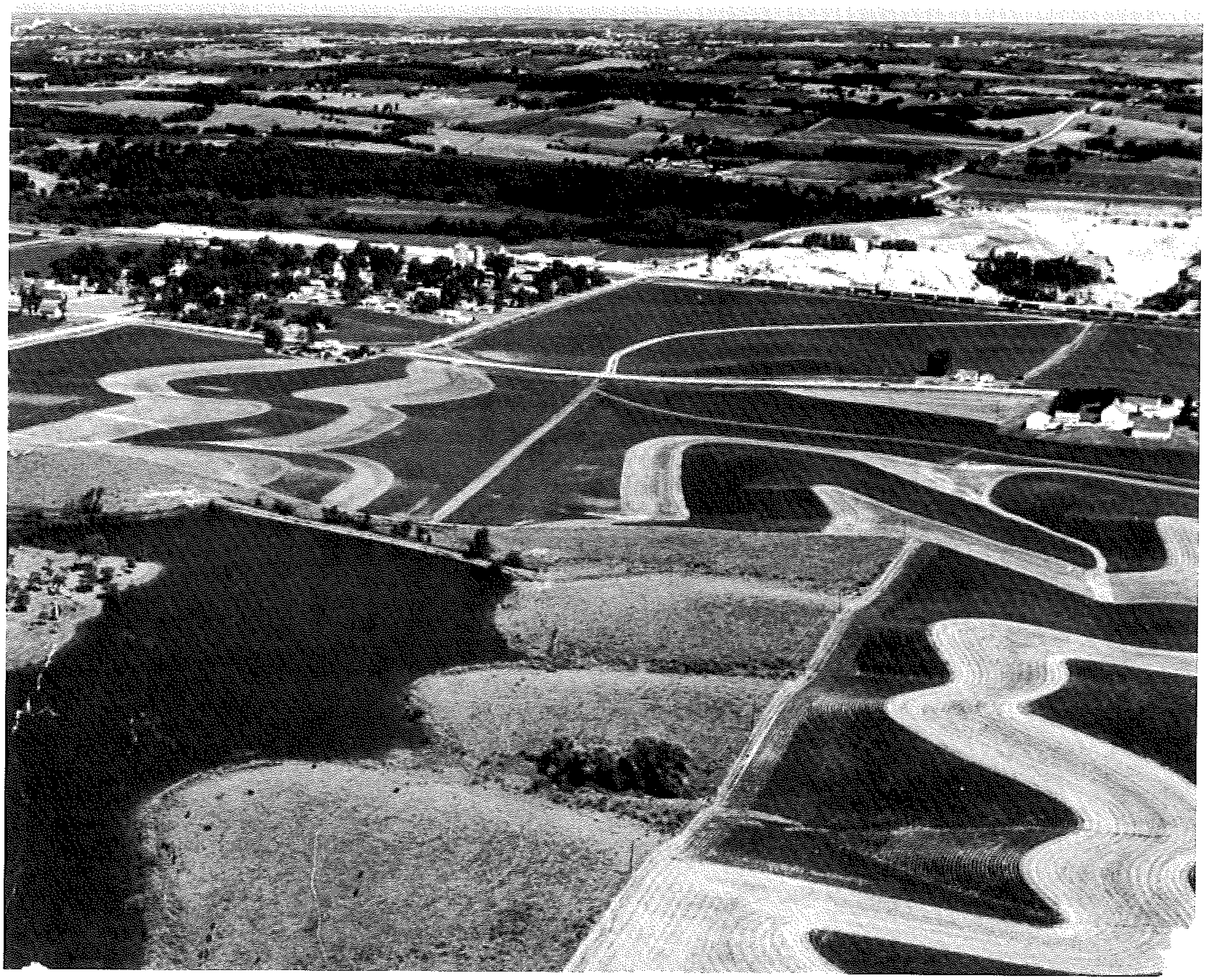
Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Safety Factor Assessment

Soil Survey of

Marshall County, Iowa

United States Department of Agriculture, Soil Conservation Service
in cooperation with the
Iowa Agriculture and Home Economics Experiment Station
Cooperative Extension Service, Iowa State University
and Department of Soil Conservation, State of Iowa



general soil map units

The general soil map at the back of this publication shows broad areas, called soil associations, that have a distinctive pattern of soils, relief, and drainage. Each soil association on the general soil map is a unique natural landscape. Typically, a soil association consists of one or more major soils and some minor soils. It is named for the major soils. The soils making up one association can occur in other associations but in a different pattern.

The general soil map can be used to compare the suitability of large areas for general land uses. Areas of suitable soils can be identified on the map. Likewise, areas where the soils are not suitable can be identified.

Because of its small scale, the map is not suitable for planning the management of a farm or field or for selecting a site for a road or building or other structure. The soils in any one association differ from place to place in slope, depth, drainage, and other characteristics that affect management.

1. Colo-Lawson-Zook association

Nearly level, poorly drained and somewhat poorly drained, silty soils formed in alluvium; on bottom lands and alluvial fans

This association consists of nearly level soils on flood plains and fans along major streams and in river valleys. These soils are subject to flooding. In places near the natural water course, the flood plains are severely dissected, and water stands in old channels.

This association makes up 10 percent of the county. It is about 29 percent Colo soils, 13 percent Lawson soils, 10 percent Zook soils, and 48 percent soils of minor extent (fig. 2).

Colo soils, on flood plains and alluvial fans, are nearly level and are poorly drained. Typically, the surface layer is black silty clay loam about 11 inches thick. The subsurface layer is black silty clay loam about 26 inches thick. The next layer is very dark gray silty clay loam about 14 inches thick. The substratum to a depth of about 60 inches is light brownish gray silty clay loam.

Lawson soils, on first and second bottoms, are nearly level and are somewhat poorly drained. Typically, the surface layer is black silty clay loam about 6 inches thick. The subsurface layer is black and very dark brown silty clay loam in the upper part and very dark grayish brown silty clay loam in the lower part. The substratum to a depth of about 60 inches is dark grayish brown silty clay loam.

Zook soils, on low flood plains, are nearly level and are poorly drained. Typically, the surface layer is black silty clay loam about 9 inches thick. The subsurface layer is black silty clay loam and silty clay about 31 inches thick. The subsoil to a depth of about 60 inches is very dark gray and grayish brown, friable silty clay loam.

Soils of minor extent in this association are the Ackmore, Hanlon, Lawler, Nevin, Nodaway, Saude, and Wiota soils. The poorly drained and somewhat poorly drained Ackmore soils and moderately well drained Nodaway and Hanlon soils are on broad flood plains and bottom lands near the natural stream channel. In addition, Ackmore and Nodaway soils are on alluvial fans near tributaries. The somewhat poorly drained Lawler soils and well drained Saude soils are on stream benches and outwash plains. The somewhat poorly drained Nevin soils are on high bottoms and low stream benches. The well drained and moderately well drained Wiota soils are on stream benches.

Most areas of this association are used for cultivated crops. Channeled and dissected areas of the flood plain are used for pasture and trees. The main enterprise is growing cash grain crops. The soils are well suited to cultivated crops if they are adequately drained and protected from flooding. They are poorly suited to building site development and sanitary facilities.

Corn, soybeans, oats, hay, and pasture grow well on the soils of this association. The organic matter content and the available water capacity of these soils are high. The main concerns of management are improving drainage and protecting the soils from flooding. These soils can be drained by tile and surface drains if adequate outlets are available. Diversions, levees, and channel improvements help to provide flood protection and control runoff from adjacent areas.

2. Muscatine-Tama-Garwin association

Nearly level and gently sloping, somewhat poorly drained, well drained, and poorly drained, silty soils formed in loess; on uplands

This association consists of wide areas of nearly level soils on divides and gently sloping soils on side slopes. The landscape is mostly gently undulating and undulating.

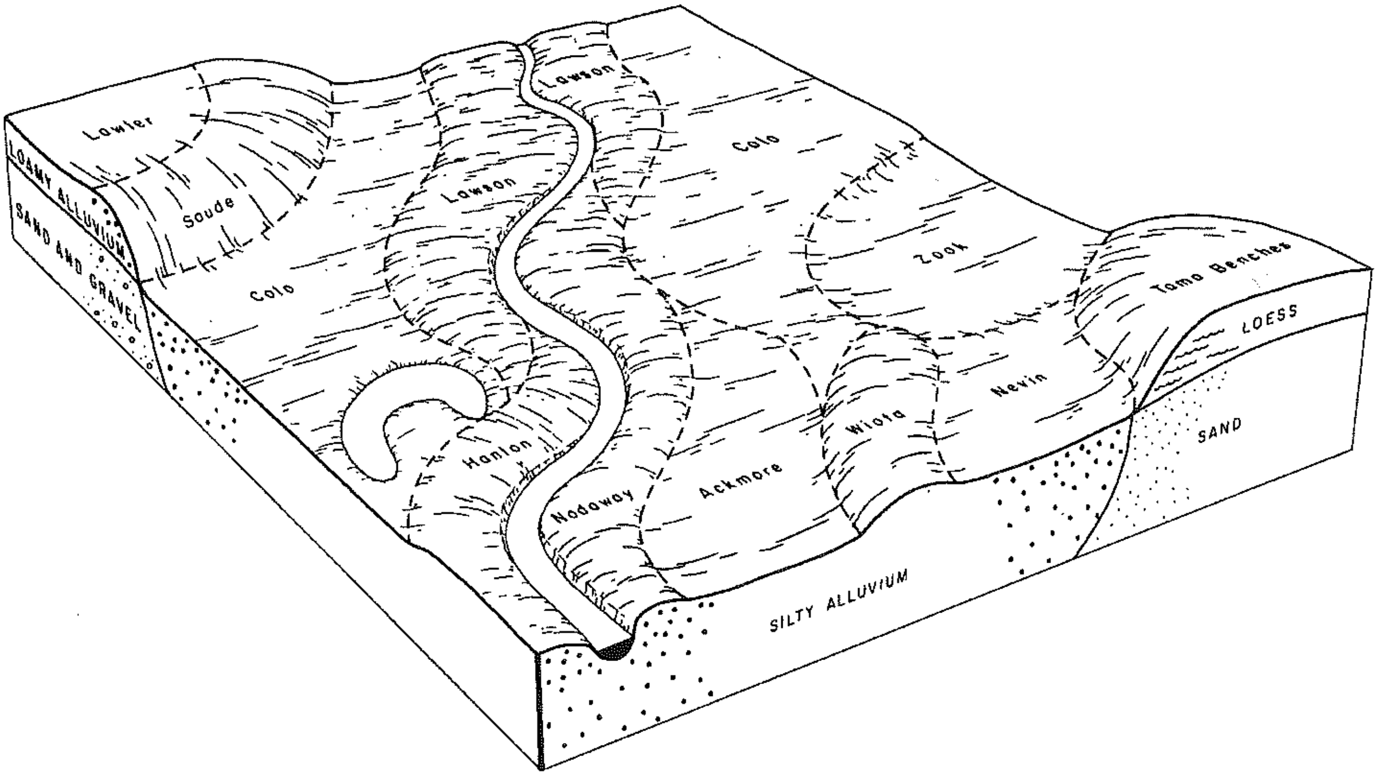


Figure 2.—Typical pattern of soils and parent material in the Colo-Lawson-Zook soil association.

This association makes up about 21 percent of the county. It is about 43 percent Muscatine soils, 38 percent Tama soils, 13 percent Garwin soils, and 6 percent soils of minor extent.

Muscatine soils, on moderately wide divides, are very gently sloping and are somewhat poorly drained. Typically, the surface layer is black silty clay loam about 9 inches thick. The subsurface layer is black and very dark brown silty clay loam about 10 inches thick. The subsoil is silty clay loam about 27 inches thick. It is very dark grayish brown and dark grayish brown in the upper part and mottled grayish brown and light olive brown in the lower part. The substratum to a depth of about 60 inches is grayish brown, mottled silty clay loam.

Tama soils, on broad convex ridgetops and side slopes, are nearly level and gently sloping and are well drained. Typically, the surface layer is very dark brown silty clay loam about 7 inches thick. The subsurface layer is very dark brown and very dark grayish brown silty clay loam about 9 inches thick. The subsoil is friable silty clay loam about 31 inches thick. It is brown in the upper part, yellowish brown in the middle part, and dark yellowish brown and yellowish brown in the lower part. The substratum to a depth of about 60 inches is yellowish brown, mottled silty clay loam.

Garwin soils, on wide divides and concave heads of drainageways, are nearly level and are poorly drained. Typically, the surface layer is black silty clay loam about 8 inches thick. The subsurface layer is black and very dark gray silty clay loam about 9 inches thick. The subsoil is friable silty clay loam about 26 inches thick. It is dark gray and gray in the upper part and mottled olive gray in the lower part. The substratum to a depth of about 60 inches is light olive gray, mottled silty clay loam.

The soils of minor extent in this association are the Colo, Ely, Harpster, and Sperry soils. The poorly drained Colo soils are in upland drainageways. The somewhat poorly drained Ely soils are on foot slopes. The poorly drained, calcareous Harpster soils are on wide divides and at the heads of drainageways. The very poorly drained Sperry soils are in slight depressions on wide divides.

Most areas of this association are used for row crops (fig. 3). The main enterprise is growing cash grain crops. These soils are well suited to all cultivated crops commonly grown in the county.

Corn, soybeans, oats, and hay grow well on the soils of this association. The available water capacity is high to very high. The organic matter content of these soils is moderate to high. The main concerns of management are controlling erosion and improving drainage.

phosphorus, and low in available potassium. This soil has good tilth.

Most areas of this soil are in cropland. This soil is well suited to cultivated crops, hay, and pasture if protected from run-on water and if tile outlets are available. It is poorly suited to sanitary facilities and building site development.

This soil is well suited to corn and soybeans if drainage is adequate. Open drains and tile outlets are necessary to adequately drain this soil. This soil generally occurs as small areas within larger areas of better drained soils. Areas of this soil are subject to flooding because of runoff from adjoining soils. Return of all crop residue helps to maintain tilth.

This Vesser soil is in capability subclass IIw.

54—Zook silty clay loam, 0 to 2 percent slopes. This nearly level, poorly drained soil is on flood plains. Areas of this soil are subject to occasional flooding. Typical areas are broad and irregular in shape and range from 5 to more than 100 acres.

Typically, the surface layer is black silty clay loam about 9 inches thick. The subsurface layer is black silty clay loam and silty clay about 31 inches thick. The subsoil is very dark gray and grayish brown, friable silty clay loam to a depth of about 60 inches. Some areas have about 12 inches of silt loam overwash.

Included with this soil in mapping are small depressional areas that are high in organic matter content. These areas contain marsh vegetation. Marsh areas pond water for long periods and are not cultivated. These areas make up 5 percent of this map unit.

Permeability of this Zook soil is slow, and surface runoff is slow to very slow. The available water capacity is high. This soil has a seasonal high water table. The content of organic matter in the surface layer is 5 to 7 percent. The surface layer is slightly acid or neutral, and the subsoil is medium acid to mildly alkaline, low in available phosphorus, and very low in available potassium. This soil has poor tilth.

Most areas of this soil are in cropland. This soil is well suited to cultivated crops if adequately drained and if protected from flooding. It is poorly suited to sanitary facilities and building site development.

This soil is well suited to corn and soybeans if drainage is adequate. Areas can be drained by tile and surface drains if adequate outlets are available. Diversions, levees, and channel improvements are used to control flooding and runoff from adjacent areas. Artificial drainage improves the timeliness of field operations and helps to improve tilth.

This Zook soil is in capability subclass IIw.

55—Nicollet loam, 1 to 3 percent slopes. This very gently sloping, somewhat poorly drained soil is on slightly convex or plane, sloping ground moraines that have low relief. In places, this soil is on toe slopes or in the upper part of drainageways. Individual areas are irregular in shape and range from 5 to 40 acres.

Typically, the surface layer is black loam about 8 inches thick. The subsurface layer is loam about 12 inches thick. It is black in the upper part and very dark gray in the lower part. The subsoil is friable clay loam about 13 inches thick. It is dark grayish brown with dark yellowish brown mottles in the upper and middle parts and dark grayish brown and mottled in the lower part. The substratum to a depth of about 60 inches is grayish brown, mottled loam.

Included with this soil in mapping are a few small areas of Webster and Okoboji soils that are poorly drained or very poorly drained. These soils are on lower areas and have a heavier textured subsoil. The Okoboji soils pond water. These soils make up 5 to 10 percent of this map unit.

Permeability of this Nicollet soil is moderate, and surface runoff is slow. This soil has a seasonal high water table. The available water capacity is high. The surface layer is slightly acid or neutral, and the subsoil is slightly acid or medium acid. The content of organic matter is about 5 to 6 percent in the surface layer. The subsoil is very low in available phosphorus and very low to low in available potassium. This soil has good tilth.

Most areas of this soil are cultivated. This soil is well suited to cultivated crops, hay, and pasture. It is poorly suited to sanitary facilities and moderately suited to building site development.

This soil is well suited to corn and soybeans. If the soil is used for cultivated crops, there is a very slight hazard of erosion on the more sloping areas. Adequate drainage for the fluctuating water table may be beneficial. Conservation tillage, a practice that leaves crop residue on the surface throughout the year, helps to prevent soil loss caused by wind erosion. Returning crop residue helps to maintain good tilth.

If used for pasture or hay, overgrazing or grazing when the soil is wet causes surface compaction and decreased infiltration. Proper stocking rates, pasture rotation, timely deferment of grazing, and restricted use during wet periods help to keep the pasture and soil in good condition.

This Nicollet soil is in capability class I.

62D2—Storden loam, 9 to 14 percent slopes, moderately eroded. This strongly sloping, well drained soil is on convex side slopes of the uplands. Typically, the slopes are short. Individual areas are long and narrow and range from 10 to 20 acres.

Typically, the surface layer is light yellowish brown and dark grayish brown, calcareous loam. The substratum to a depth of about 60 inches is calcareous loam. The upper part is light yellowish brown, the middle part is pale brown, and the lower part is light brownish gray.

Included with this soil in mapping are a few small areas that contain more sand and gravel and are droughty. They make up 5 to 10 percent of the map unit.

Permeability of this Storden soil is moderate, and surface runoff is rapid. The available water capacity is roots; few worm channels; slightly acid; gradual smooth boundary.

A13—13 to 18 inches; very dark gray (10YR 3/1) light silty clay loam, very dark grayish brown (10YR 3/2) kneaded, dark grayish brown (10YR 4/2) dry; moderate very fine and fine subangular blocky structure; friable; few fibrous roots; few worm channels; slightly acid; gradual smooth boundary.

A3—18 to 26 inches; very dark grayish brown (10YR 3/2) and dark brown (10YR 3/3) silty clay loam, very dark gray (10YR 3/1) coatings on peds, brown (10YR 5/3) dry; moderate fine subangular blocky structure; friable; few fibrous roots; few worm channels; slightly acid; gradual smooth boundary.

B2t—26 to 37 inches; brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) coatings on peds; weak medium prismatic structure parting to moderate medium subangular blocky; friable; thin discontinuous clay films; few fibrous roots; few worm channels; slightly acid; gradual smooth boundary.

B3—37 to 49 inches; brown (10YR 4/3) silty clay loam; weak medium prismatic structure parting to weak medium subangular blocky; friable; thin discontinuous silt coats; few fibrous roots; few worm channels; slightly acid; gradual smooth boundary.

C—49 to 60 inches; yellowish brown (10YR 5/4) silty clay loam; few fine faint grayish brown (10YR 5/2) mottles; massive; friable; thin discontinuous silt coats; few fibrous roots; slightly acid.

The solum ranges from 36 to 60 inches in thickness. The mollic epipedon ranges from 18 to 32 inches in thickness.

The A horizon is 25 to 32 percent clay. Reaction ranges from slightly acid to strongly acid. The B horizon is brown (10YR 4/3) or dark yellowish brown (10YR 4/4). The C horizon is silt loam or silty clay loam and is stratified in some pedons.

Zook series

The Zook series consists of poorly drained soils on flood plains commonly adjacent to foot slopes and bench escarpments. Permeability is slow. Zook soils formed in silty alluvium that is less than 15 percent sand. Native vegetation was prairie grasses. Slope ranges from 0 to 2 percent.

Zook soils are similar to Colo soils and are commonly adjacent to Bremer and Nevin soils. Colo soils have less clay in the solum. Bremer soils have thinner A horizons and less clay in the B horizon. They are on second bottoms or low stream benches. Nevin soils have thinner A horizons, are somewhat poorly drained, and are on high second bottoms and low stream benches.

Typical pedon of Zook silty clay loam, 0 to 2 percent slopes, 1,040 feet south and 198 feet east of the northwest corner of sec. 20, T. 84 N., R. 18 W.

Ap—0 to 9 inches; black (N 2/0) silty clay loam, black (N 2/0) dry; weak fine granular structure; friable; common fibrous roots; neutral; abrupt smooth boundary.

A12—9 to 18 inches; black (N 2/0) heavy silty clay loam, black (N 2/0) dry; moderate very fine subangular blocky structure; friable; few fibrous roots; neutral; gradual smooth boundary.

A13—18 to 25 inches; black (N 2/0) light silty clay, black (N 2/0) dry; moderate very fine and fine subangular blocky structure; firm; few fibrous roots; slightly acid; gradual smooth boundary.

A31—25 to 32 inches; black (10YR 2/1) light silty clay, dark gray (10YR 4/1) dry; weak medium prismatic structure parting to fine and medium subangular blocky; firm; few fibrous roots; slightly acid; gradual smooth boundary.

A32—32 to 40 inches; black (10YR 2/1) heavy silty clay loam, dark gray (10YR 4/1) dry; weak medium prismatic structure parting to fine and medium subangular blocky; firm; few fibrous roots; slightly acid; gradual smooth boundary.

B2g—40 to 48 inches; very dark gray (10YR 3/1) silty clay loam; weak medium prismatic structure parting to weak fine subangular blocky; friable; few fibrous roots; slightly acid; gradual smooth boundary.

B3g—48 to 60 inches; grayish brown (2.5Y 5/2) silty clay loam; few fine distinct strong brown (7.5YR 5/6) mottles; weak medium prismatic structure; friable; few fibrous roots; neutral.

The solum ranges from 45 to 64 inches in thickness. The entire solum is 5 to 15 percent sand and below a depth of 16 inches, it is 38 to 46 percent clay.

The A horizon ranges from 30 to 40 inches in thickness. It is black (10YR 2/1, N 2/0) silty clay loam or silty clay. The A horizon is 32 to 42 percent clay. Reaction ranges from neutral to medium acid. The B and C horizons are very dark gray (10YR 3/1), dark gray (10YR to 5Y 4/1), gray (5Y 5/1), or grayish brown (2.5Y 5/2).

formation of the soils

This section discusses the factors of soil formation and relates these factors to the soils in Marshall County.

factors of soil formation

Soil is produced by the action of soil-forming processes on materials deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by the physical and mineralogical composition of the parent material; the climate under which the soil material has accumulated and existed since accumulation; the plant and animal life on and in the soil; the relief, or lay of the land; and the length of time the forces of soil development have acted on the soil materials (*8*).

Climate and vegetation are the active factors in the formation of soil. They act on the parent material and slowly change it into a natural body that has genetically related horizons. The effects of climate and vegetation are conditioned by relief. The parent material also affects the kind of profile that can be formed and, in extreme cases, determines it almost entirely. Finally, time is needed for the changing of the parent material into a soil. It may be much or little, but some time is always required for horizon differentiation. A long period generally is required for the development of distinct horizons.

The factors of soil formation are so closely interrelated in their effects on the soil that few generalizations can be made regarding the effect of any one unless conditions are specified for the other four. Many of the processes of soil development are unknown.

parent material and its geologic origin

Most of the soils in Marshall County developed from loess (windblown materials), glacial till (ice-laid materials), and alluvium (water-laid materials). A few areas of eolian sand are along the Iowa River and Minerva and Honey Creeks. Parent materials in most places are built up like layers of a cake. These layers can be observed in road cuts and in places on side slopes. In this county, parent material was important in developing the general character of the soil profile.

The major Pleistocene deposits of pre-Wisconsin age are either Kansan drift, Nebraskan drift, or both. The different drifts, or tills, are not readily differentiated in Marshall County. The glacial till ranges from none to over 300 feet in thickness.

Soils developed on the Kansan till plain during the Yarmouth and Sangamon interglacial ages. This soil development was before loess deposition. On nearly level interstream divides, the soils were strongly weathered and had a gray plastic subsoil called gumbotil. This gumbotil remains; it is several feet thick and very slowly permeable. The Clarinda soils developed in this gumbotil (*15*).

Geologic erosion has cut into and below the Yarmouth-Sangamon paleosol and into the Kansan till and older deposits. On the surface formed by this erosion, there is a stone line on top of till and erosional sediment called pedisediment. Soils that have a red clayey subsoil developed in the pedisediment, stone line, and subjacent till. This period of erosion and soil formation is called Late Sangamon. The Adair soils formed in the Late Sangamon paleosols (*9*).

The Kansan till is exposed mostly in hilly areas. The unweathered till is firm, calcareous clay loam. It contains pebbles, boulders, and sand as well as silt and clay. The soils that formed in Kansan till during the Yarmouth and Sangamon ages were covered by loess. Geologic erosion has removed the loess and paleosols on many side slopes. In these places, the till is only slightly weathered at the surface and has been exposed only during the Wisconsin State of the Quaternary period (*15*). Shelby, Gara, and Lindley soils formed in slightly weathered glacial till.

Glacial till is exposed in many rolling areas in the northeastern part of Marshall County. The till in this part of the county was truncated during the early part of loess deposition in the Wisconsin age. The truncated till surface is called the Iowan Erosion Surface (*15*).

The Iowan Erosion Surface is multi-leveled. Several levels of summits occur in a gradual progression from the stream valleys toward the low crests that mark the drainage divides. Other features typical of the Iowan Erosion Surface are erratics and paha. Erratics are large boulders partially buried or lying on the surface. Paha are prominent elongated ridges and are oriented in a distinct northwest-southeast direction. The core of the paha is an erosional remnant of the Kansan till, but the Yarmouth-Sangamon paleosol is intact (*16*). The paha are capped with thick loess or sand and loess.

The Iowan Erosion Surface is about 15 to 60 feet lower than the adjacent Kansan surface. The loess cap on the summits thins on shoulders and side slopes. Dinsdale soils formed in thin loess and glacial till.

The glacial till is less than 100 feet thick in most of the Iowan Erosion Surface areas. Geologic erosion has reworked the glacial till on hillslopes. Liscomb soils formed in loamy surface sediment and glacial till.

Loess of Wisconsin age covers most of Marshall County and is an extensive parent material. It consists mainly of silt and clay particles that have been deposited by wind. Variations in the loess are related to the distance from the source of loess. The source of loess in Marshall County is probably the bottom lands to the northwest and the Iowa River. The major deposits of loess in Marshall County are older than 14,000 years (*15*).

On the stable upland divides of the Kansan till plain, the loess is about 21 feet thick. Killduff, Tama, Muscatine, Garwin and Sperry soils are formed in loess on this landform. On the Iowan Surface, the loess is about 12 feet thick. Tama, Muscatine, Garwin, Sperry, and Harpster soils formed in loess on this landscape. Dinsdale soils formed in both loess and glacial till.

Along the rivers, loess deposits are twice as thick on both the Kansan plain and Iowan Surface. Downs, Fayette, Tama, and Killduff soils formed in this loess. Some of the high stream benches along the major streams and rivers are covered with loess deposits as thin as 7 feet. Tama, Muscatine, and Downs soils formed in this loess.

A glacial till lies above the loess in the western part of Marshall County. This till is part of the Bemis moraine system of the Des Moines Lobe. The till is of Cary age, a subdivision of the Wisconsin Glacial Stage. The evidence for the geologic youth of the Cary Glaciation is the lack of deep weathering, the unleached calcareous till at a shallow depth, the poorly developed surface drainage, and many closed depressions (*15*).

Two major erosional and depositional episodes in recent time have modified the Cary till surface. The initial relief has been reduced by the movement of material from hill summits to depressions and lowland areas. The sediment on hillslopes has selectively sorted from the summits to the toe slopes and into the depressions (*15*). Clarion, Nicollet, Webster, Canisteo, Harps, Lester, and Storden soils formed in the Cary glacial drift.

Alluvium consists of sediment that has been removed and laid down by water. As it moves, this sediment is sorted to some extent, but only in a few places is it as well sorted as the loess. Also, alluvium does not have the wide range of particle sizes that occurs in glacial drift. Because the alluvium in Marshall County is derived from loess and glacial drift, it is largely a mixture of silt and clay, silt and sand, or sand and gravel.

Alluvial sediment is the parent material for the soils on flood plains, on low benches, and in long drainageways. As the river overflows its channels and the water spreads over the flood plains, coarse textured material, such as sand and coarse silt, are deposited first. As the floodwater continues to spread, it moves more slowly, and finer textured sediment is deposited. After the flood has passed, the finest particles, or clay, settle from the water that is left standing in the lowest part of the flood plain. The Hanlon, Spillville, Nodaway, and Lawson soils commonly are closest to the stream channel and are coarser textured than the other soils on flood plains. The Ackmore, Coland, and Colo soils are on upland drainageways as well as on the flood plains of larger streams. Colo soils are extensive. Zook soils commonly are on the lower part of the bottom land and are one of the finest textured soils derived from alluvium in the county.

Alluvial stream benches are intermediate in elevation between the flood plains and the loess-covered benches. The Wiota, Nevin, Koszta, and Bremer soils formed in the silty alluvium on this landform. The Saude, Waukee, Lawler, and Hanska soils formed in loamy-over-sandy alluvium on these benches.

Sediment that has accumulated at the foot of the slope on which it originated is called colluvium or local alluvium. The Ely, Judson, Terril, and Vesser soils formed in the sediment on the foot slopes. Downslope from these soils is alluvial sediment carried in to the area from distant sources.

A secondary topographic form associated with alluvial plains is sand dunes. Fine sand is blown by the wind from stream channel and flood plain surfaces to higher elevations (*12*). Accumulations of dune sand are found on low stream benches, on high loess-covered benches, and upland fringing the leeward side of valleys. Dickinson, Sparta, and Chelsea soils are formed in eolian sand that is more than 5 feet thick.

climate

The soils in Marshall County have been developing under a midcontinental, subhumid climate for the past 5,000 years. The morphology and properties of most of the soils indicate that this climate was similar to the present climate. From 6,500 to 16,000 years ago, however, the climate probably was cool and moist and conducive mostly to the growth of forest vegetation.

The influence of the general climate in a region is modified by local conditions in or near the developing soils. For example, soils on south-facing slopes formed under a microclimate that is warmer and drier than the average climate of nearby areas. The low-lying, poorly drained soils on bottom lands formed under a wetter and colder climate than that in most areas around them. These local differences influence the characteristics of the soil and account for some of the differences among soils in the same climatic region.

vegetation and animal life

Many changes in climate and vegetation have taken place in Iowa during the past 28,000 years (*14*). The period between 28,000 to 11,000 years ago was dominated by coniferous forest with a transitional period of birch and alder. Deciduous forest dominated 11,000 to

9,000 years ago. A very dry period occurred between 9,000 to 3,200 years ago, with prairie vegetation dominating. Trees, especially oak, have invaded the prairie since 3,200 years ago, but the prairie still dominates.

For the past 5,000 years, the soils of Marshall County appear to have been influenced by two main kinds of vegetation—prairie grasses and trees. Big bluestem and little bluestem were the main prairie grasses. The main trees were deciduous, mainly oak, hickory, ash, elm, and maple.

The effects of vegetation on soils similar to those in Marshall County have been studied recently. Evidence shows that vegetation shifted while soils developed in areas bordering both trees and grasses. The morphology of the Downs, Sparta, Gara, and Lester soils reflect the influence of both trees and grasses. The Chelsea, Fayette, and Lindley soils formed under the influence of trees (*11*). Grasses influenced the development of the Tama, Muscatine, Garwin, Clarion, Colo, Dickinson, Killduff, Shelby, and Zook soils and the remaining minor soils in the county.

In most places, the soils that formed under trees are lighter colored, are more acid, and have a thinner surface layer that is lower in organic matter content than soils that formed under grasses. The soils in the county that formed under shifting vegetation or mixed grasses and trees have properties that are intermediate between the properties of soils formed under grasses and those of soils formed under trees.

Animals, such as earthworms and burrowing animals, help to keep the soil open and porous. Bacteria and fungi decompose the vegetation, thus releasing nutrients for plant food.

relief

Relief also may cause important differences among soils. It indirectly influences soil development through its effect on drainage. In Marshall County, the soils range from level to very steep. In many areas of the bottom lands, the nearly level soils are frequently flooded and have a permanently or periodically high water table. In depressions, water soaks into the nearly level soils that are subject to flooding. Much of the rainfall runs off the steep soils or uplands.

Level soils are on the broad upland flats and on the stream bottoms. The very steepest soils in the county are generally on slopes near the major streams and their tributaries. The intricate pattern of upland drainageways indicates that in most of the county the landscape has been modified by geological processes.

Generally, the soils in Marshall County that formed where the seasonal water table was well below the subsoil have a subsoil that is yellowish brown. Examples of such soils are the Clarion, Dickinson, Downs, Killduff, Shelby, and Tama soils. The Lawler, Muscatine, Nevin, and similar soils formed where the seasonal water table fluctuated and was periodically high. The Garwin, Webster, and similar soils formed where the seasonal water table is high and have a subsoil that is dominantly grayish. The Colo, Garwin, Webster, Zook and similar soils developed under prairie grasses and have a high water table. These poorly drained soils contain more organic matter in the surface layer than do well drained soils formed under prairie grasses. Clay accumulates in the subsoil of such soils as Sperry soils that are slightly depressional or nearly level. This is because a large amount of water enters the soils and carries clay particles downward. Sperry soils are called claypan soils because they have a hard layer where the greatest amount of clay accumulates.

The Killduff, Shelby, Tama, and similar soils that have wide slope ranges have some properties that change as slope increases. Two of these properties are the depth to carbonates and the thickness of the surface layer. Depth to carbonates is shallow where slopes are steepest. The surface layer becomes thin in stronger sloping soils.

time

Time is required for a soil to develop. An older and more strongly developed soil shows well defined genetic horizons. A soil with less development shows no horizons, or only weakly defined ones. Most soils on the flood plains are of this kind because these materials have not been in place long enough for distinct horizons to develop.

As an example, the effects of time can be seen by the increase of clay in the subsoil. A high clay content in the subsoil compared to that in the surface soil indicates a high degree of soil profile development has taken place. This can be important because soils with a high clay content in the subsoil generally have poorer drainage.

Material is generally removed from soils on steep slopes before there has been time for a thick profile with strong horizons to develop. Also, much of the water runs off the slopes rather than through the soil material, so that even though the material has been in place for a long time, the soil may exhibit little development.

Most of the parent materials in Marshall County are thousands of years old. The present land surface and many soils are much younger because of recent geologic erosion (*15*).

The oldest soils in Marshall County are those formed in loess on upland summits and on nearly level, loess-covered stream benches. The Garwin, Harpster, Muscatine, Sperry, and Tama soils might be as old as 14,000 years (*13*). The Clarion and other soils that formed in Cary glacial drift are as young as 3,000 years. The Liscomb and other strongly sloping soils on the Iowan Erosion Surface area are as young as or younger than 2,000 years. The Shelby and other strongly sloping or steeper soils on the Kansan till plain are as young as or younger than 6,800 years. Soils formed in alluvium and eolian sand are only a few thousand years old or less. The Wiota, Saude, and other soils that formed in materials on stream benches are the oldest alluvial soils. The Colo, Hanlon, Spillville, and other soils that formed in materials on the flood plains are younger than Wiota and Saude soils. The Dickinson, Sparta, and Chelsea soils are of an age intermediate between Hanlon and Wiota soils. Two soils that formed in alluvium, Nodaway and Ackmore soils, are less than 125 years old.

man's influence on the soil

Important changes take place if the soil is cultivated. Some of these changes have little effect on productivity; others have a drastic effect. Changes caused by erosion generally are most apparent. On many of the cultivated soils in the county, particularly the gently rolling to hilly soils, part or all of the original surface layer has been lost through sheet erosion. In some places, shallow to deep gullies have formed.

A study of eroded soils in Iowa, including Marshall County, was started in 1974 by the Iowa Cooperative Soil Survey. Soil descriptions and laboratory data of selected sites are available. Initial results show a lower organic matter content in eroded soils.

Nodaway and Ackmore soils formed in stratified silt loam alluvium on alluvial fans and flood plains. This alluvium has been deposited on the bottom during the past 125 years of cultivation. Many sloping soils have lost topsoil through water erosion to form these recent flood plain deposits. About 23 percent of the soils in Marshall County are eroded.

In many continuously cultivated fields, the granular structure that was apparent when the grassland was undisturbed is no longer present. In these fields the surface tends to bake and harden when it dries. Fine textured soils that have been plowed when too wet tend to puddle and are less permeable than similar soils in undisturbed areas. Poor seedling emergence and root penetration result in these areas.

Man has done much to increase the productivity of the soils and to reclaim areas not suitable for crops. He has made large areas of bottom land suitable for cultivation by digging drainage ditches and constructing diversions and dikes. Broad flats and nearly level soils, such as Garwin and Webster soils, have been greatly improved for cultivation by installing some kind of drainage system. By adding commercial fertilizers, man has counteracted deficiencies in plant nutrients and has made some soils more productive than they were in their natural state.

processes of horizon differentiation

Horizon differentiation is caused by four basic kinds of change—additions, removals, transfers, and transformation in the soil system (*18*). Each of these four kinds of change affects many substances that compose soils, such as organic matter, soluble salts, carbonates, sesquioxides, or silicate clay materials. In general, these processes tend to promote horizon differentiation, but some tend to offset or retard it. These processes and the changes brought about proceed simultaneously in soils, and the ultimate nature of the profile is governed by the balance of these changes within the profile.

An accumulation of organic matter is an early step in the process of horizon differentiation in most soils. Soils in Marshall County range from very high to very low in the amount of organic matter that has accumulated in their surface layers. Some soils that were formerly quite high in organic matter content are now low because of erosion. The accumulation of organic matter has been an important process in the differentiation of soil horizons in Marshall County.

The process through which substances are removed from parts of the soil profile is important in the differentiation of soil horizons. The movement of calcium carbonates and bases downward in soils is an example. All the soils in the county, except Canisteo, Harps, Harpster, and Storden soils, have been leached free of calcium carbonates in the upper part of their profile. Some soils have been so strongly leached that they are strongly acid or very strongly acid even in their subsoil.

Phosphorus is removed from the subsoil by plant roots and transferred to other parts of the plant. It is then returned to the surface layer in the plant residue. These processes affect the forms and distribution of phosphorus in the profile.

The translocation of silicate clay minerals is another important process. The clay minerals are carried downward in suspension in percolating water from the surface layer. They accumulate in the subsoil in pores and root channels and as clay films. In Marshall County, this process has had an influence on the profiles of many of the soils. In other soils, the clay content of the horizons are not markedly different and other evidence of clay movement is minimal.

Another kind of transfer that is minimal in most soils, but occurs to some extent in very clayey soils, is that brought about by shrinking and swelling. This causes cracks to form and incorporates some material from the surface layer into lower parts of the profile. Clarinda soils are examples of soils with potential for this kind of physical transfer.

Transformations are physical and chemical. For example, soil particles are weathered to smaller sizes. The reduction of iron is another example of a transformation. This process is called gleying and involves the saturation of the soil with water for long periods in the presence of organic matter. It is characterized by the presence of ferrous iron and gray colors. Gleying is associated with poorly drained soils, such as the Garwin soils. Reductive extractable iron, or free iron, is normally lower in somewhat poorly drained soils, such as Muscatine soils (*20*). Still another kind of transformation is the weathering of the primary apatite mineral present in soil parent materials to secondary phosphorous compounds.

geologic profile of Marshall County

Marshall County has a gently undulating to rolling and steep landscape. It is mainly dissected by the Iowa River and the North Skunk River. Clear Creek, the three Timber Creeks, Linn Creek and three Minerva Creeks, and the two Asher Creeks are the principal interior streams (*4*).

The broad upland areas are dominated by loess at the surface. The soils formed in loess, such as the Muscatine and Tama soils, are the most productive soils in Marshall County and in Iowa. Strongly sloping to steep soils, such as the Shelby soils, formed in glacial till and till-derived materials. These soils are on slopes that descend to the major streams. Along the bottom of the streams are complex patterns of alluvium and related areas of wind-reworked sands. In the western part of the county are Clarion soils formed in Wisconsin glacial till.

Although the unconsolidated materials dominate the present land surface, such bedrock as limestone and sandstone is exposed locally. All the bedrock material would be exposed if the unconsolidated materials were removed. However, the surface exposed would not be flat but would exhibit landforms much like the present surface. There are bedrock valleys and ridges which can affect water movement within the overlying unconsolidated materials.

Bedrock is exposed in about 21 different sections in Marshall County. In most places the natural outcrops are small. The bedrock exposed in Marshall County is primarily of Mississippian and Pennsylvanian age (*7*). The general rock types are mostly dolomite and sandstone. The dolomite is quarried and provides stone for aggregate, road surfacing, and agstone. Some coal measure shales are exposed by Honey Creek.

Information collected during the drilling of wells and test holes is available for over 180 wells in Marshall County (*6*). Detailed information is available for many of these wells. Some of these wells are drilled into rocks that are aquifers. Three distinct levels of rocks that are aquifers occur in Marshall County (*5*).

TABLE 15.--ENGINEERING INDEX PROPERTIES--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Frag- ments > 3 inches	Percentage passing sieve number--				Liquid limit	Plas- ticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
51 Vesser	0-17	Silt loam	CL	A-6	0	100	100	98-100	95-100	30-40	10-20
	17-28	Silt loam	CL	A-6	0	100	100	98-100	95-100	30-40	10-20
	28-60	Silty clay loam	CL, CH	A-7	0	100	100	98-100	95-100	40-55	20-30
54 Zook	0-18	Silty clay loam	CH, CL	A-7	0	100	100	95-100	95-100	45-65	20-35
	18-60	Silty clay, silty clay loam.	CH	A-7	0	100	100	95-100	95-100	60-85	35-55
55 Nicollet	0-20	Loam	OL, ML, CL	A-6, A-7	0	95-100	95-100	85-98	55-85	35-50	10-25
	20-33	Clay loam, loam	CL	A-6, A-7	0-5	95-100	95-100	80-95	55-80	35-50	15-25
	33-60	Loam	CL, ML	A-6, A-4	0-5	95-100	90-100	75-90	50-75	30-40	5-15
62D2 Storden	0-8	Loam	ML, CL	A-4, A-6	0-5	95-100	95-100	70-85	55-70	30-40	5-15
	8-60	Loam	CL-ML, CL	A-4, A-6	0-5	95-100	85-97	70-85	55-70	20-40	5-15
63C, 63E Chelsea	0-8	Loamy fine sand	SM, SP-SM	A-2-4	0	100	100	65-80	10-35	---	NP
	8-60	Fine sand, sand, loamy sand.	SP, SM, SP-SM	A-3, A-2-4	0	100	100	65-80	3-15	---	NP
65F, 65G Lindley	0-7	Loam	CL-ML, CL	A-4, A-6	0	95-100	90-100	85-95	50-65	15-30	5-15
	7-50	Clay loam, loam	CL	A-6, A-7	0	95-100	90-100	85-95	55-75	30-45	15-25
	50-60	Loam, clay loam	CL	A-6	0	95-100	90-100	85-95	50-70	30-40	15-25
88 Nevin	0-24	Silty clay loam	CL, OL	A-6, A-7	0	100	100	100	90-95	35-45	10-20
	24-47	Silty clay loam	CL	A-7	0	100	100	95-100	90-95	40-50	20-30
	47-60	Silty clay loam, silt loam.	CL	A-7	0	100	100	95-100	90-95	40-50	20-30
93D2*, 93E2*:											
Shelby	0-7	Loam	CL	A-6	0	95-100	85-95	75-90	55-70	30-40	10-20
	7-45	Clay loam	CL	A-6, A-7	0-5	90-95	85-95	75-90	55-70	30-45	15-25
	45-60	Clay loam	CL	A-6, A-7	0-5	90-95	85-95	75-90	55-70	30-45	15-25
Adair	0-6	Clay loam	CL	A-6	0	95-100	80-95	75-90	60-80	30-40	10-20
	6-60	Silty clay, clay, clay loam.	CL, CH	A-7	0	95-100	80-95	70-90	55-80	40-55	20-30
95 Harps	0-18	Loam, clay loam	CL, CH	A-6, A-7	0-5	100	95-100	80-90	65-80	30-55	15-35
	18-43	Loam, clay loam, sandy clay loam.	CL, CH	A-6, A-7	0-5	95-100	95-100	80-90	65-80	30-60	15-35
	43-60	Loam	CL	A-6	0-5	95-100	90-100	70-80	50-75	25-40	10-25
107 Webster	0-20	Silty clay loam	CL, CH	A-7, A-6	0-5	100	95-100	85-95	70-90	35-60	15-30
	20-39	Clay loam, silty clay loam, loam.	CL	A-6, A-7	0-5	95-100	95-100	85-95	60-80	35-50	15-30
	39-60	Loam, sandy loam, clay loam.	CL	A-6	0-5	95-100	90-100	75-85	50-75	30-40	10-20
118 Garwin	0-17	Silty clay loam	CL, CH	A-7	0	100	100	100	95-100	45-55	20-30
	17-60	Silty clay loam	CH, CL	A-7	0	100	100	100	95-100	45-55	25-35
119 Muscatine	0-19	Silty clay loam	CL	A-7	0	100	100	100	95-100	40-50	15-25
	19-60	Silty clay loam	CL	A-7	0	100	100	100	95-100	40-50	20-30
120, 120B, 120C, 120C2, 120D2, 120E2 Tama	0-16	Silty clay loam	ML	A-6, A-7	0	100	100	100	95-100	35-50	10-20
	16-47	Silty clay loam	CL	A-7	0	100	100	100	95-100	40-50	15-25
	47-60	Silty clay loam, silt loam.	CL	A-6, A-7	0	100	100	100	95-100	35-45	15-25
122 Sperry	0-22	Silt loam	CL	A-6	0	100	100	100	95-100	30-40	10-20
	22-37	Silty clay loam, silty clay.	CH	A-7	0	100	100	100	95-100	50-65	25-35
	37-60	Silty clay loam, silt loam.	CL	A-7	0	100	100	100	95-100	40-50	20-30
133 Colo	0-11	Silty clay loam	CL, CH	A-7	0	100	100	90-100	90-100	40-60	15-30
	11-60	Silty clay loam	CL, CH	A-7	0	100	100	90-100	90-100	40-55	20-30

See footnote at end of table.

TABLE 16.--PHYSICAL AND CHEMICAL PROPERTIES OF SOILS--Continued

Soil name and map symbol	Depth	Clay	Moist bulk density	Permeability	Available water capacity	Soil reaction	Shrink-swell potential	Erosion factors		Wind erodibility group	Organic matter
								K	T		
	In	Pct	G/cm^3	In/hr	In/in	pH					Pct
54	0-18	32-38	1.30-1.35	0.2-0.6	0.21-0.23	5.6-7.3	High	0.28	5	7	5-7
Zook	18-60	36-45	1.30-1.45	0.06-0.2	0.11-0.13	5.6-7.8	High	0.28			
55	0-20	24-35	1.15-1.25	0.6-2.0	0.17-0.22	5.6-7.3	Moderate	0.24	5	6	5-6
Nicollet	20-33	24-35	1.25-1.35	0.6-2.0	0.15-0.19	5.6-7.8	Moderate	0.32			
	33-60	22-28	1.35-1.45	0.6-2.0	0.14-0.19	7.4-7.8	Low	0.32			
62D2	0-8	18-27	1.35-1.45	0.6-2.0	0.20-0.22	7.4-8.4	Low	0.28	5	4L	.5-2
Storden	8-60	18-27	1.35-1.65	0.6-2.0	0.17-0.19	7.4-8.4	Low	0.37			
63C, 63E	0-8	8-15	1.50-1.55	6.0-20	0.10-0.15	5.6-7.3	Low	0.17	5	2	<.5
Chelsea	8-60	5-10	1.55-1.70	6.0-20	0.06-0.08	5.1-5.5	Low	0.17			
65F, 65G	0-7	18-27	1.20-1.40	0.6-2.0	0.16-0.18	4.5-7.3	Low	0.32	5	6	.5-1
Lindley	7-50	25-35	1.50-1.75	0.2-0.6	0.14-0.18	4.5-6.5	Moderate	0.32			
	50-60	18-32	1.75-1.85	0.2-0.6	0.12-0.16	6.1-7.8	Moderate	0.32			
88	0-24	26-29	1.30-1.35	0.6-2.0	0.21-0.23	5.6-7.3	Moderate	0.32	5	7	4-6
Nevin	24-47	30-35	1.30-1.40	0.6-2.0	0.18-0.20	6.1-6.5	Moderate	0.43			
	47-60	25-36	1.40-1.45	0.6-2.0	0.18-0.20	6.6-7.3	Moderate	0.43			
93D2*, 93E2*:											
Shelby	0-7	24-27	1.50-1.55	0.6-2.0	0.20-0.22	5.6-7.3	Moderate	0.28	5	6	.5-2
	7-45	30-35	1.55-1.75	0.2-0.6	0.16-0.18	5.6-7.8	Moderate	0.28			
	45-60	30-35	1.75-1.85	0.2-0.6	0.16-0.18	6.6-8.4	Moderate	0.37			
Adair	0-6	27-35	1.45-1.50	0.2-0.6	0.17-0.19	5.6-7.3	Moderate	0.32	2	6	1-3
	6-60	38-50	1.50-1.60	0.06-0.2	0.13-0.16	5.1-6.5	High	0.32			
95	0-18	25-35	1.35-1.40	0.6-2.0	0.19-0.21	7.9-8.4	Moderate	0.24	5	4L	4-6
Harps	18-43	18-32	1.40-1.50	0.6-2.0	0.17-0.19	7.9-8.4	Moderate	0.32			
	43-60	20-26	1.50-1.70	0.6-2.0	0.17-0.19	7.9-8.4	Moderate	0.32			
107	0-20	26-36	1.35-1.40	0.6-2.0	0.19-0.21	6.6-7.3	Moderate	0.24	5	6	6-7
Webster	20-39	25-35	1.40-1.50	0.6-2.0	0.16-0.18	6.6-7.8	Moderate	0.32			
	39-60	18-29	1.50-1.70	0.6-2.0	0.17-0.19	7.4-8.4	Moderate	0.32			
118	0-17	30-35	1.30-1.35	0.6-2.0	0.21-0.23	5.6-7.3	High	0.28	5	7	6-7
Garwin	17-60	28-34	1.28-1.35	0.6-2.0	0.18-0.20	6.1-7.3	High	0.28			
119	0-19	28-30	1.30-1.35	0.6-2.0	0.22-0.24	5.1-7.3	Moderate	0.28	5	6	5-6
Muscatine	19-60	30-34	1.28-1.35	0.6-2.0	0.18-0.20	5.1-7.3	Moderate	0.43			
120, 120B, 120C, 120C2, 120D2, 120E2	0-16	24-29	1.25-1.30	0.6-2.0	0.22-0.24	5.1-7.3	Moderate	0.32	5	7	1-5
Tama	16-47	28-34	1.30-1.35	0.6-2.0	0.18-0.20	5.1-6.0	Moderate	0.43			
	47-60	22-28	1.35-1.40	0.6-2.0	0.18-0.20	5.6-7.3	Moderate	0.43			
122	0-22	18-22	1.35-1.40	0.6-2.0	0.22-0.24	5.6-7.3	Moderate	0.28	5	6	3-4
Sperry	22-37	38-45	1.40-1.45	0.06-0.2	0.14-0.16	5.1-6.5	High	0.43			
	37-60	26-34	1.45-1.50	0.2-0.6	0.19-0.21	5.6-6.5	High	0.43			
133	0-11	27-32	1.28-1.32	0.6-2.0	0.21-0.23	5.6-7.3	High	0.28	5	7	5-7
Colo	11-60	30-35	1.25-1.35	0.6-2.0	0.18-0.20	6.1-7.3	High	0.28			
133+	0-11	20-26	1.25-1.30	0.6-2.0	0.22-0.24	6.6-7.3	Moderate	0.28	5	6	3-5
Colo	11-60	30-35	1.25-1.35	0.6-2.0	0.18-0.20	6.1-7.3	High	0.28			
133B	0-11	27-32	1.28-1.32	0.6-2.0	0.21-0.23	5.6-7.3	High	0.28	5	7	5-7
Colo	11-60	30-35	1.25-1.35	0.6-2.0	0.18-0.20	6.1-7.3	High	0.28			
135	0-40	27-35	1.40-1.50	0.6-2.0	0.20-0.22	6.1-7.3	High	0.28	5	7	5-7
Coland	40-60	27-35	1.40-1.50	0.6-2.0	0.20-0.22	6.1-7.3	High	0.28			

See footnote at end of table.

APPENDIX C – Deep Soil Borings

Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Safety Factor Assessment

BLACK & VEATCH

BORING LOG

BORING NO. BV-6
SHEET 1 OF 3

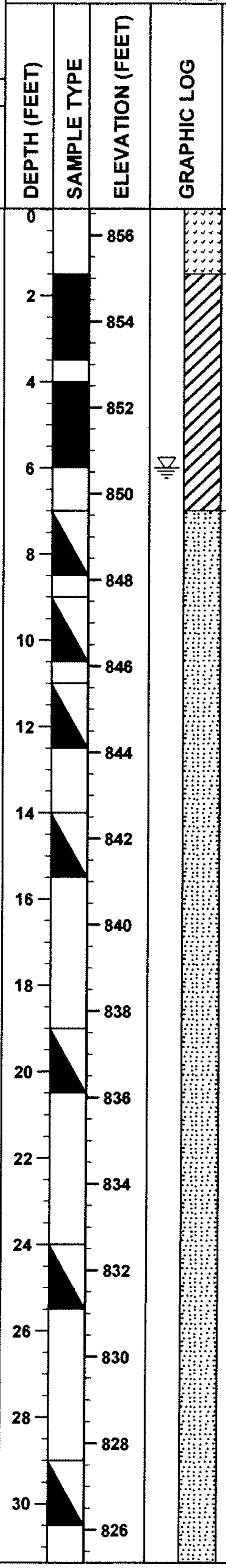
CLIENT	PROJECT	PROJECT NO.
Interstate Power & Light	Sutherland Station	145491

PROJECT LOCATION	COORDINATES		GROUND ELEVATION (DATUM)	TOTAL DEPTH
Marshalltown, Iowa	N 3479395.0'	E 5095039.0'	856.6 ft (MSL)	80.5 (feet)

SURFACE CONDITIONS	COORDINATE SYSTEM	DATE START	DATE FINISHED
Flat, grassy marsh, standing water, offset 28' south	State Plane	04/13/07	04/14/07

LOGGED BY	CHECKED BY	APPROVED BY
R. S. Edwards VB SE	V. Bhadriraju VB	E. Meyer Em

SOIL SAMPLING						
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY
ROCK CORING						
CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD
TW	1	-	-	-	-	1.6
TW	2	-	-	-	-	1.5
SPT	3	3	3	5	8	1.5
SPT	4	3	5	7	12	0.7
SPT	5	5	7	8	15	0
SPT	6	6	4	4	8	0
SPT	7	9	7	7	14	0
SPT	8	5	4	3	7	0.7
SPT	9	9	10	15	25	0.8



CLASSIFICATION OF MATERIALS

Silty CLAY; dark gray; moist; low plasticity; (TOPSOIL)

1.5

CLAY; yellow-brown; moist; high plasticity

grading gray w/some brown mottling

7.0

SAND; brownish-yellow; loose; wet; medium to coarse grained; well graded; rounded

grading medium dense

grading loose

grading medium dense

grading loose

grading medium dense; medium to fine grained; rounded to subrounded; w/rounded cobbles

REMARKS

Boring advanced w/4-1/4" ID hollow stem auger. SPT performed w/ automatic hammer.

Water encountered @ 6' during drilling.

Below 11.5' continued w/ 2-15/16" tricone roller bit using bentonite mud as drilling fluid.

Driller reports cobbles.

BORING LOG

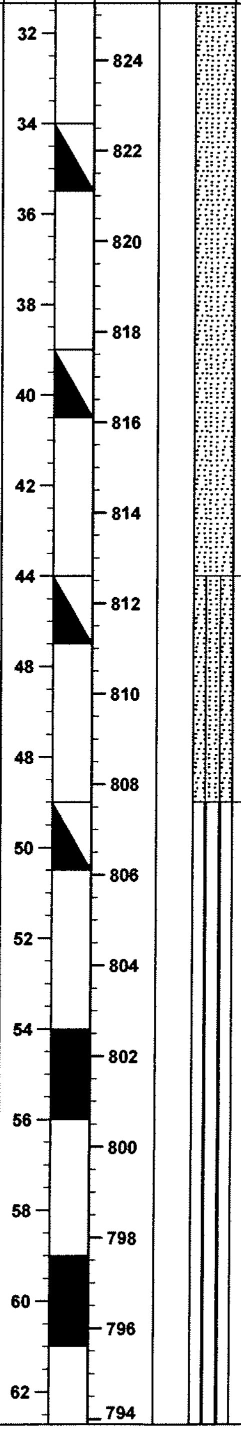
BORING NO. BV-6

SHEET 2 OF 3

CLIENT Interstate Power & Light
PROJECT Sutherland Station
PROJECT NO. 145491
PROJECT LOCATION Marshalltown, Iowa
COORDINATES N 3479395.0' E 5095039.0'
GROUND ELEVATION (DATUM) 856.6 ft (MSL)
TOTAL DEPTH 80.5 (feet)
SURFACE CONDITIONS Flat, grassy marsh, standing water, offset 28' south
COORDINATE SYSTEM State Plane
DATE START 04/13/07
DATE FINISHED 04/14/07
LOGGED BY R. S. Edwards VB for SE
CHECKED BY V. Bhadriraju VB
APPROVED BY E. Meyer EM

SOIL SAMPLING						
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY
ROCK CORING						
CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD
SPT	10	8	11	11	22	0.5
SPT	11	6	6	5	11	0.8
SPT	12	3	6	7	13	0.8
SPT	13	6	13	12	25	1.4
TW	14	-	-	-	-	0
TW	16	-	-	-	-	0

DEPTH (FEET) | SAMPLE TYPE | ELEVATION (FEET) | GRAPHIC LOG



CLASSIFICATION OF MATERIALS

grading fine to coarse grained; fine to coarse, angular gravel

36.7' to 37.3' gravel lense

44.0

Silty SAND; dark gray; medium dense; wet; fine grained; poorly graded

49.0

SILT; dark gray; very stiff; moist; low plasticity; w/trace sand (Glacial Till)

REMARKS

Gravel lense based on drilling resistance.

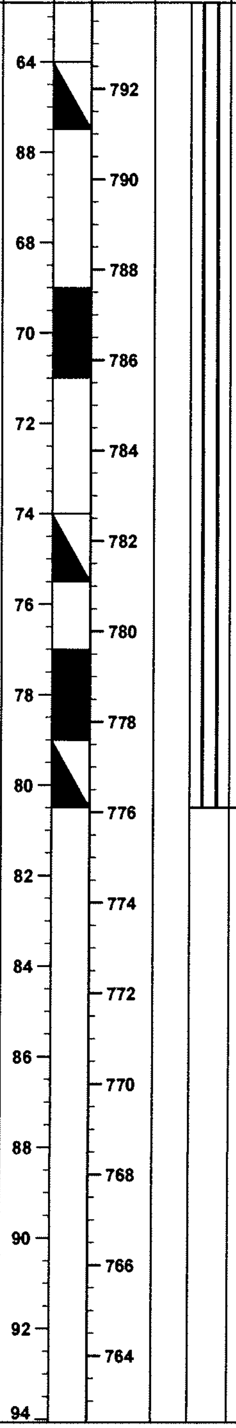
TW 14 recovered w/split spoon.
PP = 1.5 tsf

BLACK & VEATCH

BORING LOG

BORING NO. BV-6
SHEET 3 OF 3

CLIENT Interstate Power & Light	**PROJECT** Sutherland Station		**PROJECT NO.** 145491
PROJECT LOCATION Marshalltown, Iowa	**COORDINATES** N 3479395.0' E 5095039.0'	**GROUND ELEVATION (DATUM)** 856.6 ft (MSL)	**TOTAL DEPTH** 80.5 (feet)
SURFACE CONDITIONS Flat, grassy marsh, standing water, offset 28' south	**COORDINATE SYSTEM** State Plane	**DATE START** 04/13/07	**DATE FINISHED** 04/14/07
LOGGED BY R. S. Edwards VB for SE	**CHECKED BY** V. Bhadriraju VB	**APPROVED BY** E. Meyer EM	



SOIL SAMPLING SAMPLE TYPE / ROCK CORING CORE SIZE	SAMPLE NUMBER / RUN NUMBER	SET 6 INCHES / RUN LENGTH	2ND 6 INCHES / RUN RECOVERY	3RD 6 INCHES / RQD RECOVERY	N VALUE / PERCENT RECOVERY	SAMPLE RECOVERY / RQD	CLASSIFICATION OF MATERIALS	REMARKS
SPT	18	6	8	8	16	1.4		PP = 1.5 to 2.0 tsf
TW	18A	-	-	-	-	0	grading stiff	TW 18A recovered w/split spoon. PP = 1.75 tsf
SPT	19	7	9	10	19	1.4	grading very stiff	PP = 2.25 tsf
								PP = 3.0 tsf
TW	20	-	-	-	-	1.0		
SPT	21	8	9	9	18	1.0		PP = 2.5 tsf
								Bottom of boring @ 80.5'. Water level not recorded. Boring backfilled w/ cement bentonite grout on 04/14/07.

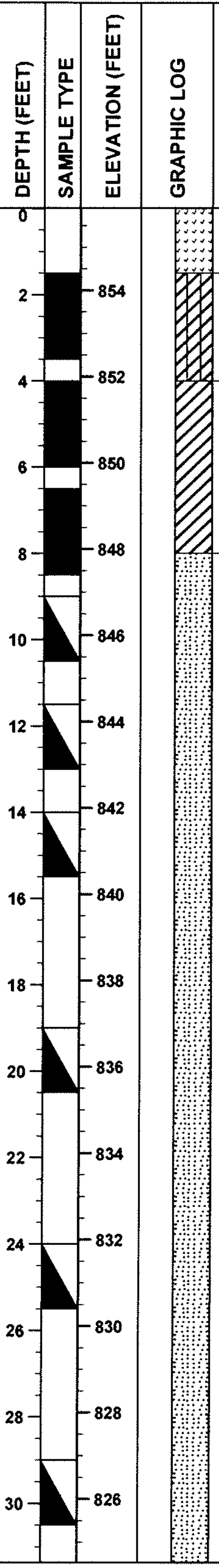
BLACK & VEATCH

BORING LOG

BORING NO. BV-7
SHEET 1 OF 3

CLIENT Interstate Power & Light	**PROJECT** Sutherland Station	**PROJECT NO.** 145491

PROJECT LOCATION Marshalltown, Iowa	**COORDINATES** N 3479095.0' E 5097105.0'	**GROUND ELEVATION (DATUM)** 855.9 ft (MSL)	**TOTAL DEPTH** 80.5 (feet)
SURFACE CONDITIONS Agricultural field off access road	**COORDINATE SYSTEM** State Plane	**DATE START** 04/11/07	**DATE FINISHED** 04/12/07
LOGGED BY R. S. Edwards VB for SE	**CHECKED BY** V. Bhadriraju VB	**APPROVED BY** E. Meyer Em	



SOIL SAMPLING						
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY
ROCK CORING						
CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD
TW	1	-	-	-	-	1.5
TW	2	-	-	-	-	1.5
TW	3	-	-	-	-	1.5
SPT	4	2	3	3	6	1.0
SPT	5	5	4	5	9	0.8
SPT	6	6	7	7	14	0.6
SPT	7	5	4	2	6	0.8
SPT	8	3	4	4	8	1.4
SPT	9	8	10	10	20	1.3

CLASSIFICATION OF MATERIALS

Silty CLAY; dark gray; moist; low plasticity (TOPSOIL)

1.5

Silty CLAY; dark gray; moist; low plasticity

4.0

CLAY; gray-brown; mottled; moist; high plasticity

8.0

SAND; yellow-brown; loose; wet; fine to medium grained; well graded; w/rounded to subrounded gravel

grading medium dense

grading loose

grading w/cobbles

grading medium dense; cobbles grade out

REMARKS

Boring advanced w/4-1/2" ID hollow stem auger. SPT performed w/ automatic hammer.

Below 4' continued w/ 2-15/16" tricone roller bit using bentonite mud as drilling fluid.

Driller reports cobbles @ 23.4'.

BLACK & VEATCH

BORING LOG

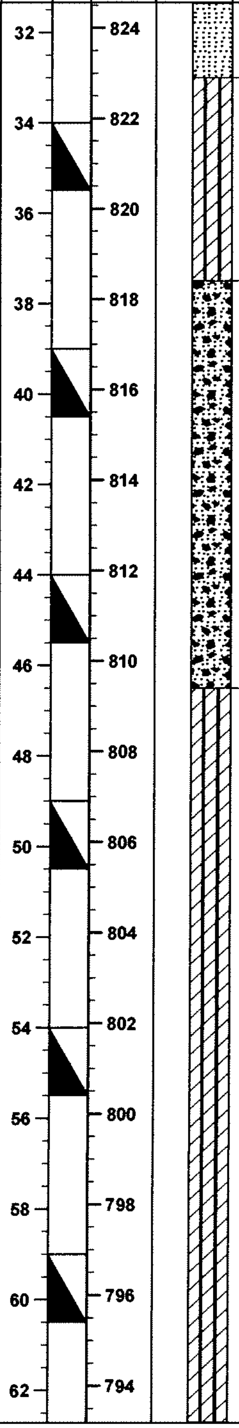
BORING NO. BV-7
SHEET 2 OF 3

CLIENT	PROJECT	PROJECT NO.
Interstate Power & Light	Sutherland Station	145491

PROJECT LOCATION	COORDINATES		GROUND ELEVATION (DATUM)	TOTAL DEPTH
Marshalltown, Iowa	N 3479095.0'	E 5097105.0'	855.9 ft (MSL)	80.5 (feet)

SURFACE CONDITIONS	COORDINATE SYSTEM	DATE START	DATE FINISHED
Agricultural field off access road	State Plane	04/11/07	04/12/07

LOGGED BY	CHECKED BY	APPROVED BY
R. S. Edwards VB SE	V. Bhadriraju VB	E. Meyer



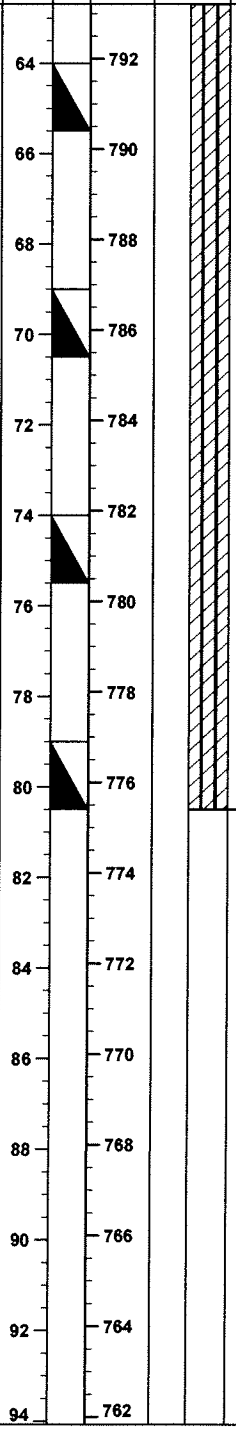
SOIL SAMPLING: SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	DEPTH (FEET)	CLASSIFICATION OF MATERIALS	REMARKS
ROCK CORING: CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD			
							33.0	Clayey SILT; dark gray; stiff; moist; low plasticity	
SPT	10	4	4	5	9	2.0			PP = 1.0 tsf
							37.5	Gravelly SAND; gray; medium dense; wet; medium to coarse grained; poorly graded; angular	
SPT	11	17	4	7	11	0			
SPT	12	37	31	16	47	1.8		grading dense	
							46.5	Clayey SILT; dark gray; very stiff; moist; low plasticity; w/trace angular sand; (Glacial Till)	
SPT	13	9	12	13	25	1.7			PP = 4.5 tsf
SPT	14	8	16	17	33	1.4		grading hard	PP = 4.5 tsf
SPT	15	13	14	13	27	1.0		grading very stiff	PP = 2.5 tsf Below 60' continued w/ 4-1/4" ID hollow stem auger.

BLACK & VEATCH

BORING LOG

BORING NO. BV-7
SHEET 3 OF 3

CLIENT Interstate Power & Light
PROJECT Sutherland Station
PROJECT NO. 145491
PROJECT LOCATION Marshalltown, Iowa
COORDINATES N 3479095.0' E 5097105.0'
GROUND ELEVATION (DATUM) 855.9 ft (MSL)
TOTAL DEPTH 80.5 (feet)
SURFACE CONDITIONS Agricultural field off access road
COORDINATE SYSTEM State Plane
DATE START 04/11/07
DATE FINISHED 04/12/07
LOGGED BY R. S. Edwards VB for SE
CHECKED BY V. Bhadriraju VB
APPROVED BY E. Meyer



SOIL SAMPLING								
SAMPLE TYPE	SAMPLE NUMBER	SET 6 INCHES	2ND 6 INCHES	3RD 6 INCHES	N VALUE	SAMPLE RECOVERY	CLASSIFICATION OF MATERIALS	REMARKS
ROCK CORING								
CORE SIZE	RUN NUMBER	RUN LENGTH	RUN RECOVERY	RQD RECOVERY	PERCENT RECOVERY	RQD		
SPT	16	8	13	14	27	1.2		PP = 3.75 tsf
SPT	17	8	12	13	25	1.2		PP = 4.0 tsf
SPT	18	9	13	12	25	2.0		PP = 3.0 tsf
SPT	19	9	11	12	23	2.0		PP = 3.0 tsf
								Bottom of boring @ 80.5'. Water level not recorded. Boring backfilled w/ cement bentonite grout on 04/12/07.

LOG OF BORING NO. 1

Page 1 of 2

OWNER	ARCHITECT/ENGINEER
SITE Marshalltown, Iowa	PROJECT Sutherland Air Heater Building

Approx. Surface Elev.: 859.3 ft.

GRAPHIC LOG		DESCRIPTION	
▩	2.0	Fill -- SAND, with gravel and coal debris, very dark gray	857.3
⁘	3.0	Fine SAND	856.3
▧	8.0	Lean CLAY, trace sand and ferrous staining, dark grayish brown and yellowish brown, medium stiff	▽ 851.3
⁘	12.0	Silty fine to medium SAND, yellowish brown, very loose	847.3
⁘	27.0	Silty fine to coarse SAND, trace gravel. dark grayish brown, very loose	832.3
⁘		Fine to coarse SAND, trace gravel and silt, light brownish gray. medium dense	

DEPTH (ft.)	USCS SYMBOL	SAMPLES NUMBER	TYPE	RECOVERY	SPT -N BLOWS / FT.	TESTS MOISTURE, %	DRY DENSITY PCF	UNCONFINED STRENGTH PSF
	SP	1	AS			8.4		
			HS					
	CL	2	SS	12"	3	28.2		1500*
5			HS					
	SP	3	SS	10"	1	17.2		
10			HS					
	SP	4	SS	1"	1	13.2		
15			HS					
	SP	5	SS	1"	1			
20			HS					
	SP	6	SS	0"	1			
25			HS					
	SP	7	SS	14"	12	11.2		
30			HS					
	SP	8	SS	11"	16	13.5		
35								

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

Calibrated Hand Penetrometer*

WATER LEVEL OBSERVATIONS		
WL	▽ 8'	WD ▼
WL		
WL		

TEAM Services, Inc.

BORING STARTED	11-13-07		
BORING COMPLETED	11-13-07		
RIG	Rig 112	FOREMAN	MG
APPROVED	RED	JOB #	1-2125

LOG OF BORING NO. 1

Page 2 of 2

OWNER	ARCHITECT/ENGINEER
SITE Marshalltown, Iowa	PROJECT Sutherland Air Heater Building

GRAPHIC LOG	DESCRIPTION	DEPTH (ft.)	USCS SYMBOL	SAMPLES				TESTS		
				NUMBER	TYPE	RECOVERY	SPT - N BLOWS / FT.	MOISTURE, %	DRY DENSITY PCF	UNCONFINED STRENGTH PSF
⁘	Fine to coarse SAND, trace gravel and silt, light brownish gray, medium dense 38.0 821.3				HS					
⁘	Silty fine to coarse SAND, trace gravel and ferrous staining, olive gray, medium dense		SP	9	SS	17"	14	15.0		
⁘		40			HS					
⁘			SP	10	SS	18"	19	14.1		
⁘	46.0 813.3	45			HS					
▨	Sandy lean CLAY, trace gravel, very dark gray, very stiff 48.0 811.3		CL	11	SS	18"	19	10.7		7500*
	Bottom of Boring									

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

Calibrated Hand Penetrometer*

WATER LEVEL OBSERVATIONS		
WL	∇ 8'	WD ▼
WL		
WL		

TEAM Services, Inc.

BORING STARTED	11-13-07		
BORING COMPLETED	11-13-07		
RIG	Rig 112	FOREMAN	MG
APPROVED	RED	JOB #	1-2125

LOG OF BORING NO. 2

Page 1 of 3

OWNER

ARCHITECT/ENGINEER

SITE
Marshalltown, Iowa

PROJECT
Sutherland Air Heater Building

DESCRIPTION

Approx. Surface Elev.: 859.7 ft.

Fill -- Lean CLAY, trace sand, gravel, and organic matter, very dark brown

2.0 — 857.7

Lean CLAY, trace sand and ferrous staining, dark gray, stiff

8.0 — 851.7

Silty fine to medium SAND, yellowish brown, loose ∇

12.0 — 847.7

Silty fine to coarse SAND, trace gravel, light yellowish brown, loose

17.0 — 842.7

Silty fine to coarse SAND, trace gravel and ferrous staining, light olive brown, medium dense

-- color change to gray @ 22'

-- becomes loose @ 28'

-- color change to grayish brown, becomes medium dense @ 32'

DEPTH (ft.)	USCS SYMBOL	SAMPLES NUMBER	TYPE	RECOVERY	SPT - N BLOWS / FT.	TESTS MOISTURE, %	DRY DENSITY PCF	UNCONFINED STRENGTH PSF
	CL	1	AS			19.1		
			HS					
	CL	2	SS	12"	5	22.4		2500*
5			HS					
	SP	3	SS	16"	5	17.7		
10			HS					
	SP	4	SS	13"	4	14.5		
15			HS					
	SP	5	SS	12"	13	6.4		
20			HS					
	SP	6	SS	14"	10	12.6		
25			HS					
	SP	7	SS	10"	7	11.8		
30			HS					
	SP	8	SS	8"	20	10.1		
35								

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

Calibrated Hand Penetrometer*

WATER LEVEL OBSERVATIONS		
WL	∇ 9'	WD ▼
WL		
WL		

TEAM Services, Inc.

BORING STARTED	11-13-07		
BORING COMPLETED	11-13-07		
RIG	Rig 112	FOREMAN	MG
APPROVED	RED	JOB #	1-2125

LOG OF BORING NO. 2

Page 2 of 3

OWNER

ARCHITECT/ENGINEER

SITE
Marshalltown, Iowa

PROJECT
Sutherland Air Heater Building

GRAPHIC LOG	DESCRIPTION
	Silty fine to coarse SAND, trace gravel and ferrous staining, grayish brown, medium dense
	43.0 … 816.7
	Sandy lean CLAY, trace gravel, very dark gray, very stiff

DEPTH (ft.)	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY	SAMPLES SPT - N BLOWS / FT.	TESTS MOISTURE, %	TESTS DRY DENSITY PCF	TESTS UNCONFINED STRENGTH PSF
			HS					
	SP	9	SS	10"	15	10.7		
40			HS					
	CL	10	SS	16"	13	12.4		
45			HS					
	CL	11	SS	8"	20	12.7		
50			HS					
	CL	12	SS	18"	20	10.9		
55			HS					
	CL	13	SS	18"	16	11.8		
60			HS					
	CL	14	SS	18"	19	12.5		
65			HS					
	CL	15	SS	18"	21	12.4		
70								

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

Calibrated Hand Penetrometer*

WATER LEVEL OBSERVATIONS

WL	∇ 9'	WD ▼
WL		
WL		

TEAM Services, Inc.

BORING STARTED	11-13-07		
BORING COMPLETED	11-13-07		
RIG	Rig 112	FOREMAN	MG
APPROVED	RED	JOB #	1-2125

LOG OF BORING NO. 2

Page 3 of 3

OWNER	ARCHITECT/ENGINEER
SITE Marshalltown, Iowa	PROJECT Sutherland Air Heater Building

GRAPHIC LOG	DESCRIPTION	DEPTH (ft.)	USCS SYMBOL	SAMPLES				TESTS		
				NUMBER	TYPE	RECOVERY	SPT - N BLOWS / FT.	MOISTURE, %	DRY DENSITY PCF	UNCONFINED STRENGTH PSF
▨					HS					
▨			CL	16	SS	18"	21	12.3		
▨		75			HS					
▨	-- becomes hard @ 77'									
▨			CL	17	SS	18"	29	12.3		
▨	80.0 779.7	80								
	Bottom of Boring									

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

Calibrated Hand Penetrometer*

WATER LEVEL OBSERVATIONS		
WL	∇ 9'	WD ▼
WL		
WL		

TEAM Services, Inc.

BORING STARTED	11-13-07		
BORING COMPLETED	11-13-07		
RIG	Rig 112	FOREMAN	MG
APPROVED	RED	JOB #	1-2125

LOG OF BORING NO. 3

Page 1 of 2

OWNER	ARCHITECT/ENGINEER
SITE Marshalltown, Iowa	PROJECT Sutherland Air Heater Building

Approx. Surface Elev.: 859.9 ft.

GRAPHIC LOG	DESCRIPTION	Depth	Elev.
▩	Fill -- Lean CLAY, with sand, trace gravel, organic matter, and coal debris, very dark brown	3.0	856.9
▨	Lean CLAY, trace sand and ferrous staining, dark gray and olive brown, medium stiff	8.5	851.4
░	Silty fine to medium SAND, dark yellowish brown, very loose ∇	12.0	847.9
░	Silty fine to coarse SAND, trace gravel, light yellowish brown, medium dense -- color change to gray @ 23' -- color change to grayish brown @ 28' -- becomes dense @ 33'		

DEPTH (ft.)	USCS SYMBOL	SAMPLES				TESTS		
		NUMBER	TYPE	RECOVERY	SPT - N BLOWS / FT.	MOISTURE, %	DRY DENSITY PCF	UNCONFINED STRENGTH PSF
	CL	1	AS			5.6		
			HS					
5	CL	2	SS	13"	6	24.4		1500*
			HS					
10	SP	3	SS	10"	3	18.1		
			HS					
15	SP	4	SS	11"	11	16.4		
			HS					
20	SP	5	SS	9"	16	18.2		
			HS					
25	SP	6	SS	8"	19	13.7		
			HS					
30	SP	7	SS	12"	16	9.9		
			HS					
35	SP	8	SS	10"	35	16.0		

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

Calibrated Hand Penetrometer*

WATER LEVEL OBSERVATIONS		
WL	∇ 10' WD	▼
WL		
WL		

TEAM Services, Inc.

BORING STARTED	11-13-07		
BORING COMPLETED	11-13-07		
RIG	ATV	FOREMAN	DC
APPROVED	RED	JOB #	1-2125

LOG OF BORING NO. 3

Page 2 of 2

OWNER	ARCHITECT/ENGINEER
SITE **Marshalltown, Iowa**	PROJECT **Sutherland Air Heater Building**

GRAPHIC LOG	DESCRIPTION	DEPTH (ft.)	USCS SYMBOL	SAMPLES				TESTS		
				NUMBER	TYPE	RECOVERY	SPT - N BLOWS / FT.	MOISTURE, %	DRY DENSITY PCF	UNCONFINED STRENGTH PSF
	Silty fine to coarse SAND, trace gravel, grayish brown, dense				HS					
	40.0 819.9	40	SP	9	SS	9"	37	15.6		
	40.5 Sandy lean CLAY, trace gravel, very dark gray, very stiff 819.4									
	Bottom of Boring									

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: IN-SITU, THE TRANSITION MAY BE GRADUAL.

Calibrated Hand Penetrometer*

WATER LEVEL OBSERVATIONS		
WL	∇ 10' WD	▼
WL		
WL		

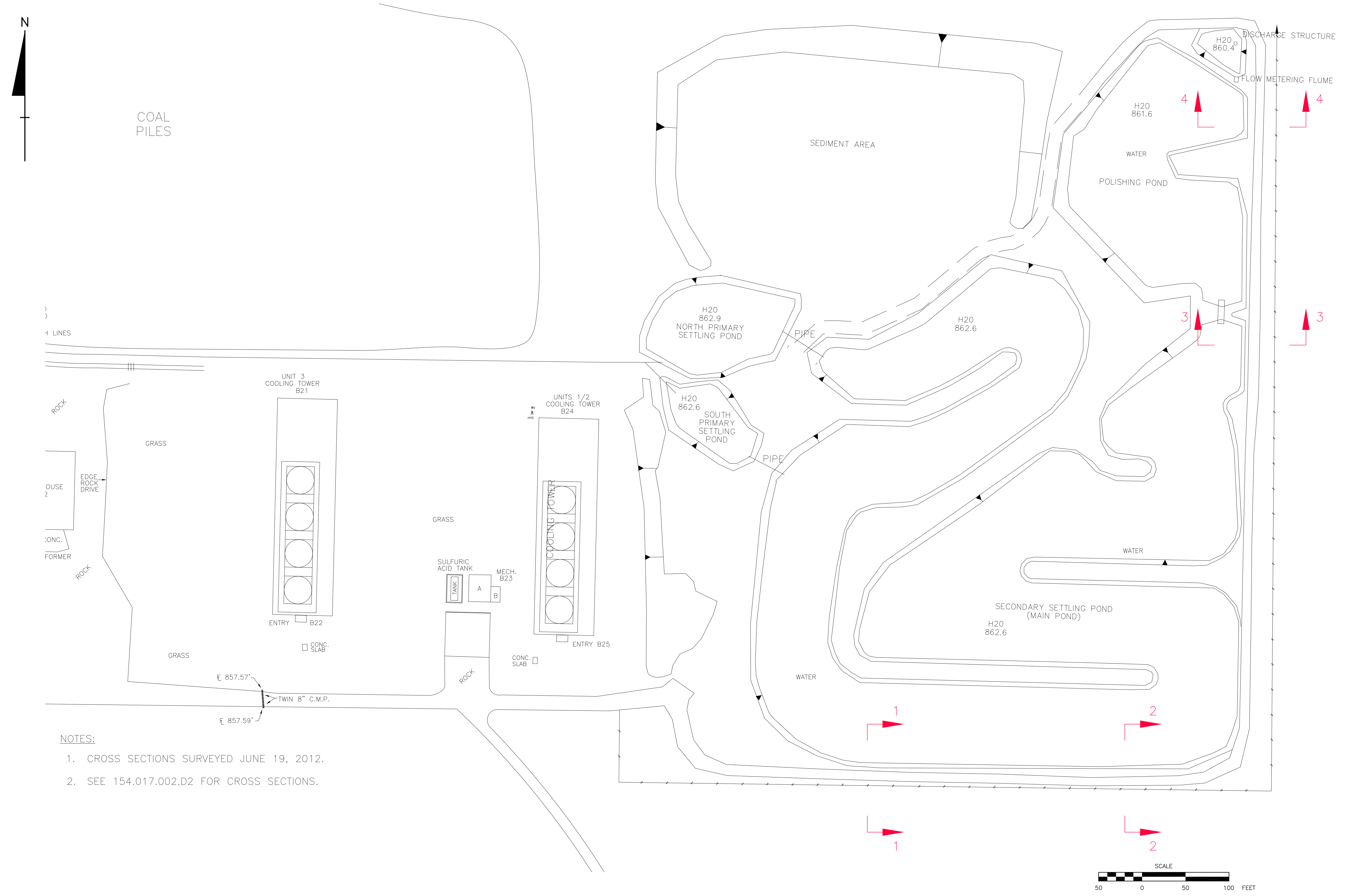
TEAM Services, Inc.

BORING STARTED	**11-13-07**		
BORING COMPLETED	**11-13-07**		
RIG	**ATV**	FOREMAN	**DC**
APPROVED	**RED**	JOB #	**1-2125**

APPENDIX D – June 2012 Critical Cross-Section Surveys

Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Safety Factor Assessment



NOTES:

1. CROSS SECTIONS SURVEYED JUNE 19, 2012.
2. SEE 154.017.002.D2 FOR CROSS SECTIONS.

REV	DATE	BY	DESCRIPTION
5			
4			
3			
2			
1			

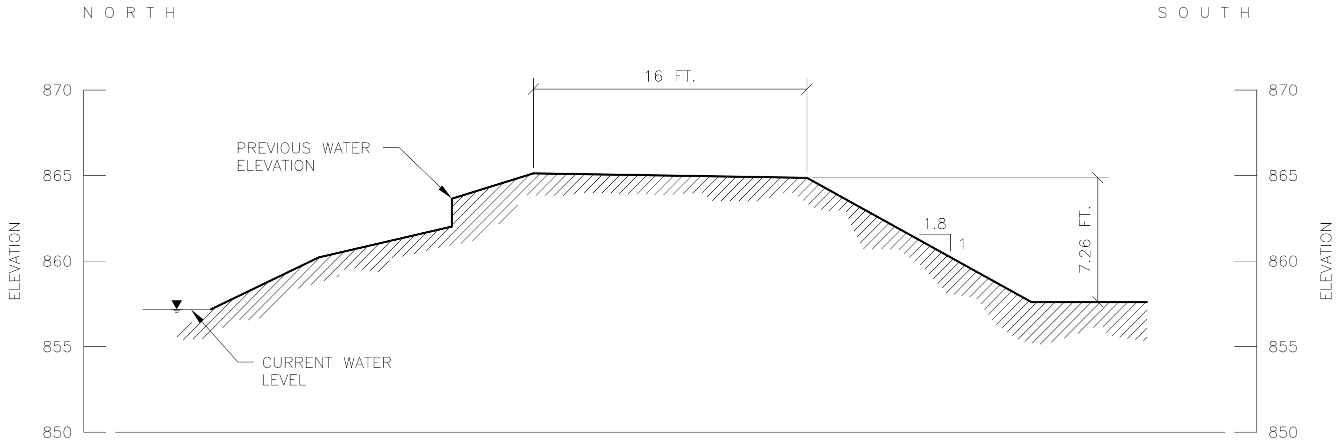
www.aetherdbs.com

SCALE: AS SHOWN
DATE: 06-26-2012
DRAWN BY: M___A___M
CHKD. BY:
APPROVED:

CLIENT / LOCATION
INTERSTATE POWER & LIGHT COMPANY
SUTHERLAND GENERATING STATION
MARSHALLTOWN, IOWA

DRAWING DESCRIPTION
CROSS SECTION LOCATIONS

JOB 154.017.002
SHT. SHEET 1
DWG. 154.017.002.D1



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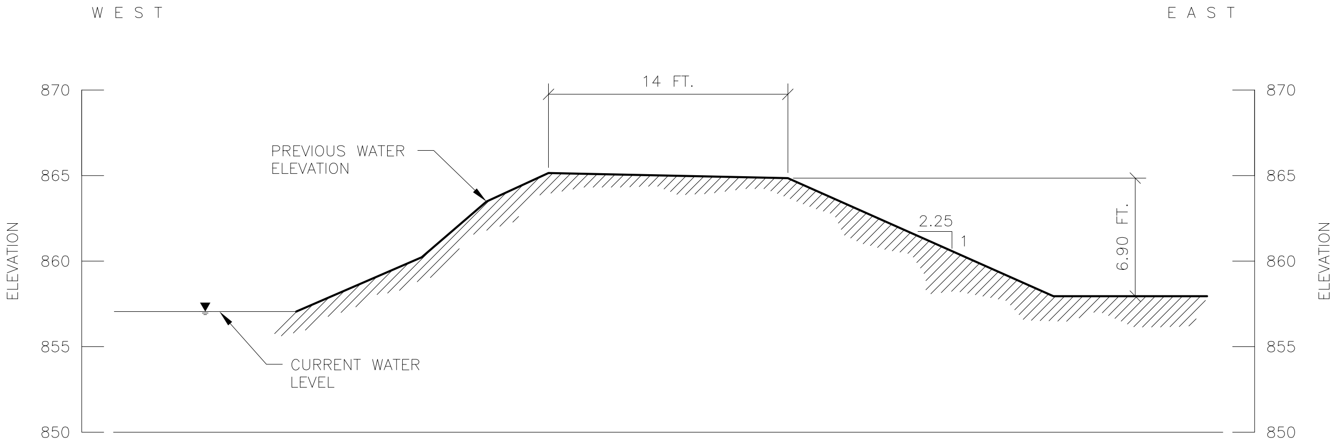
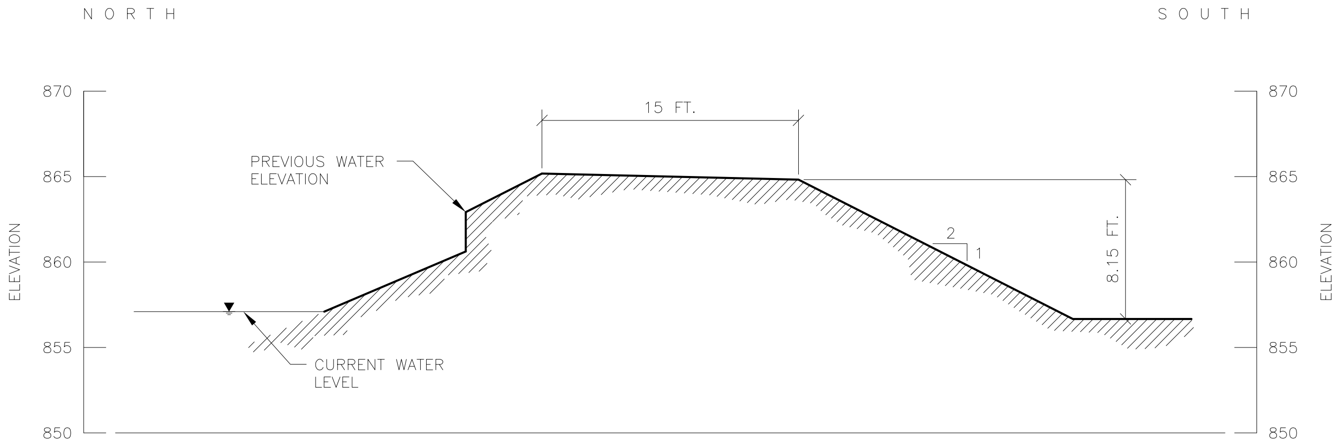
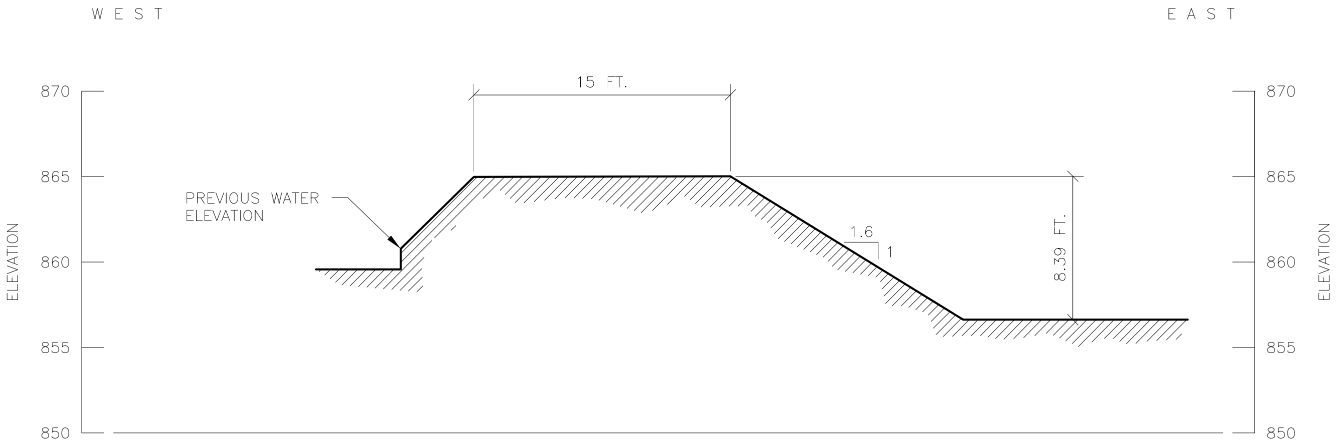


LOCATION 3



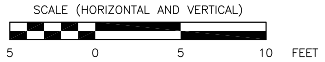
LOCATION 2



LOCATION 4

NOTES:

1. CROSS SECTIONS SURVEYED JUNE 19, 2012.



REV	DATE	BY	DESCRIPTION
5			
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SCALE: AS SHOWN
DATE: 06-26-2012
DRAWN BY: M A M
CHKD. BY:
APPROVED:

CLIENT / LOCATION
INTERSTATE POWER & LIGHT COMPANY
SUTHERLAND GENERATING STATION
MARSHALLTOWN, IOWA

DRAWING DESCRIPTION
CROSS SECTIONS

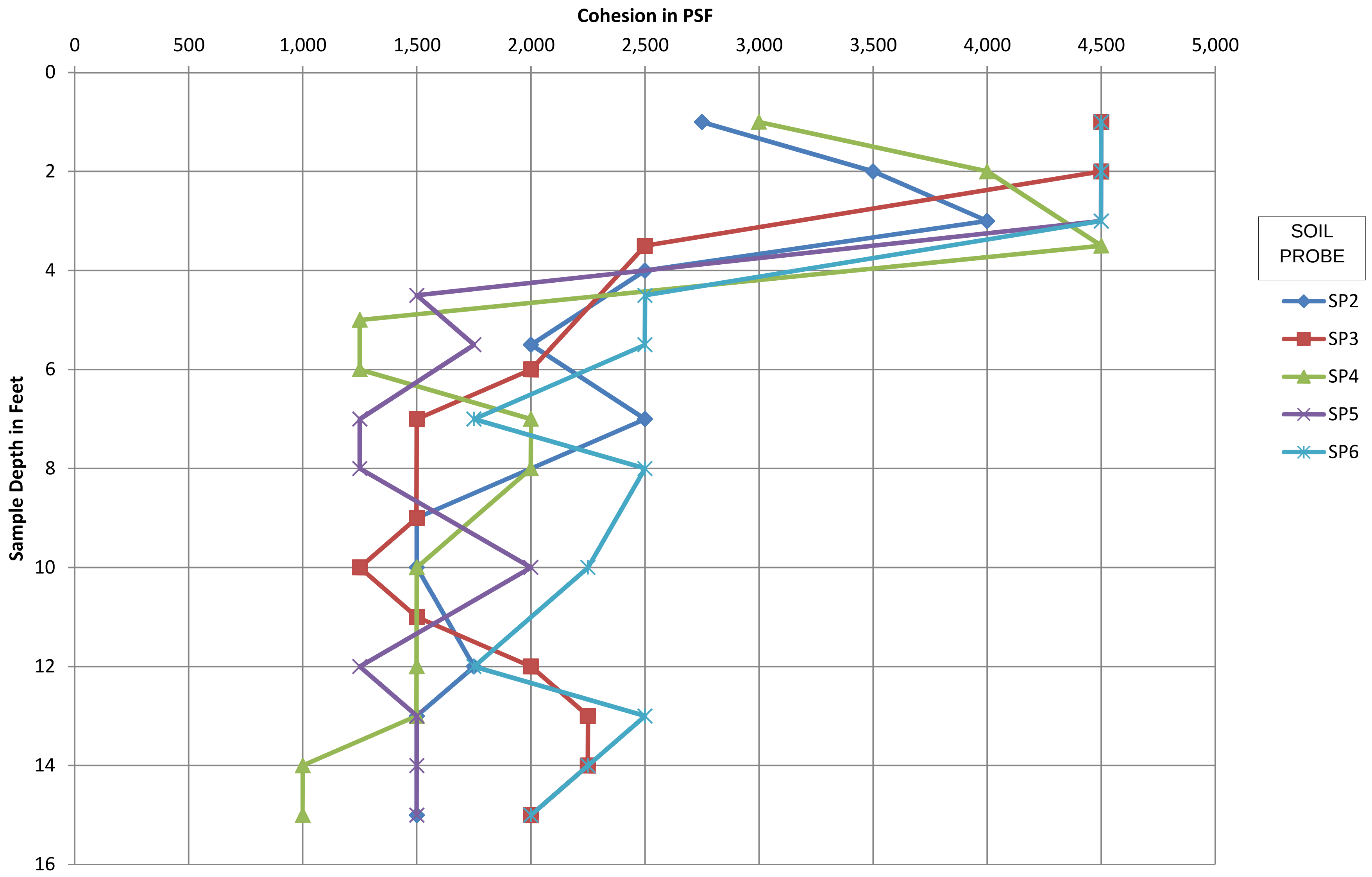
JOB 154.017.002
SHT. SHEET 2
DWG. 154.017.002.D2

APPENDIX E – Summary of Pocket Penetrometer Results

Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Safety Factor Assessment

Pocket Penetrometer Results (Presented as Cohesion)



APPENDIX F – USGS Probable Ground Acceleration

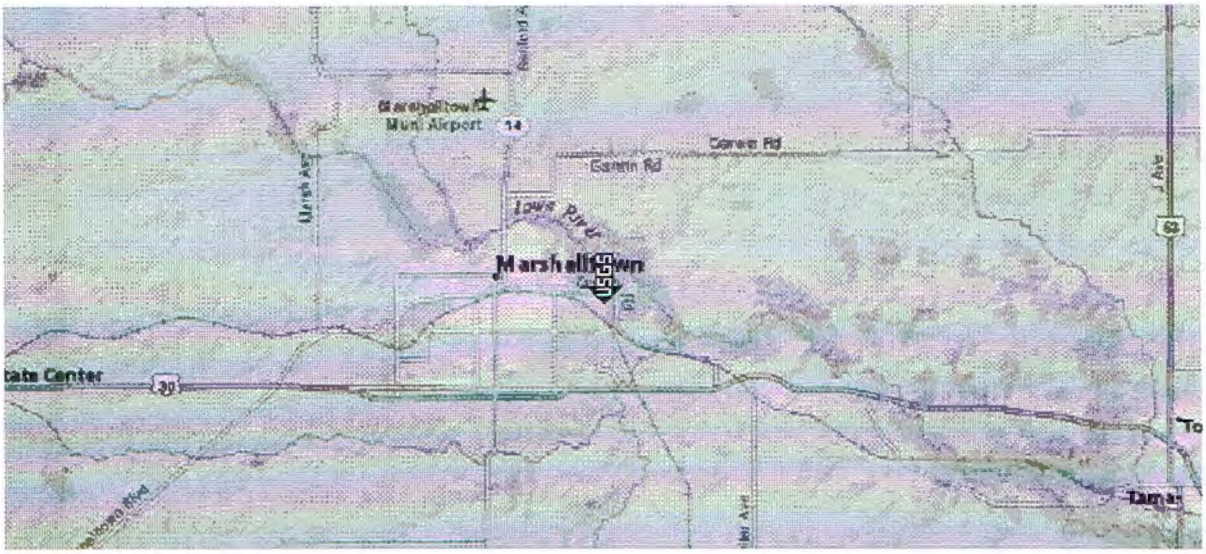
Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

Safety Factor Assessment

USGS Design Maps Summary Report

User–Specified Input

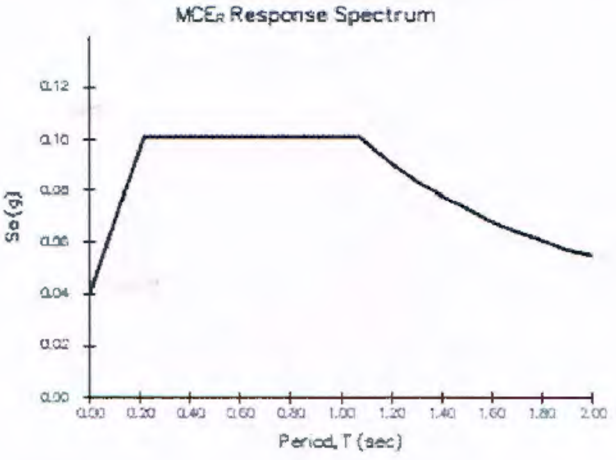
Report Title	Sutherland Generating Station Mon December 4, 2017 14:59:29 UTC
Building Code Reference Document	ASCE 7-10 Standard (which utilizes USGS hazard data available in 2008)
Site Coordinates	42.0475°N, 92.8597°W
Site Soil Classification	Site Class D – "Stiff Soil"
Risk Category	I/II/III

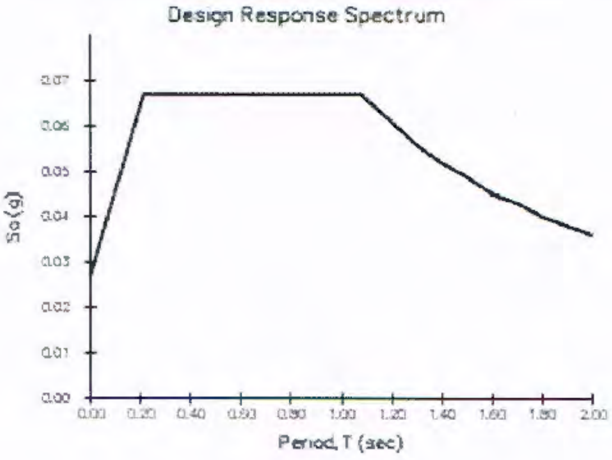


USGS–Provided Output

$S_S =$ 0.063 g	$S_{MS} =$ 0.101 g	$S_{DS} =$ 0.067 g
$S_1 =$ 0.045 g	$S_{M1} =$ 0.109 g	$S_{D1} =$ 0.073 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.


MCE$_R$ Response Spectrum


Design Response Spectrum

For PGA_M, T_L, C_{RS}, and C_{R1} values, please view the detailed report.

Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

From Figure 22-7 [4] PGA = 0.030

Equation (11.8–1): $PGA_M = F_{PGA}PGA = 1.600 \times 0.030 = 0.048$ g

Table 11.8–1: Site Coefficient F_{PGA}

Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of PGA

For Site Class = D and PGA = 0.030 g, F_{PGA} = 1.600

Section 21.2.1.1 — Method 1 (from Chapter 21 – Site-Specific Ground Motion Procedures for Seismic Design)

From Figure 22-17 [5] $C_{RS} = 0.910$

From Figure 22-18 [6] $C_{R1} = 0.851$

Section 11.6 — Seismic Design Category

Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

VALUE OF S_{DS}	**RISK CATEGORY**		
	I or II	**III**	**IV**
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D	D	D

For Risk Category = I and S_{DS} = 0.067 g, Seismic Design Category = A

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

VALUE OF S_{D1}	**RISK CATEGORY**		
	I or II	**III**	**IV**
$S_{D1} < 0.067g$	A	A	A
$0.067g \le S_{D1} < 0.133g$	B	B	C
$0.133g \le S_{D1} < 0.20g$	C	C	D
$0.20g \le S_{D1}$	D	D	D

For Risk Category = I and S_{D1} = 0.073 g, Seismic Design Category = B

Note: When S_1 is greater than or equal to 0.75g, the Seismic Design Category is **E** for buildings in Risk Categories I, II, and III, and **F** for those in Risk Category IV, irrespective of the above.

Seismic Design Category ≡ "the more severe design category in accordance with Table 11.6-1 or 11.6-2" = B

Note: See Section 11.6 for alternative approaches to calculating Seismic Design Category.

References

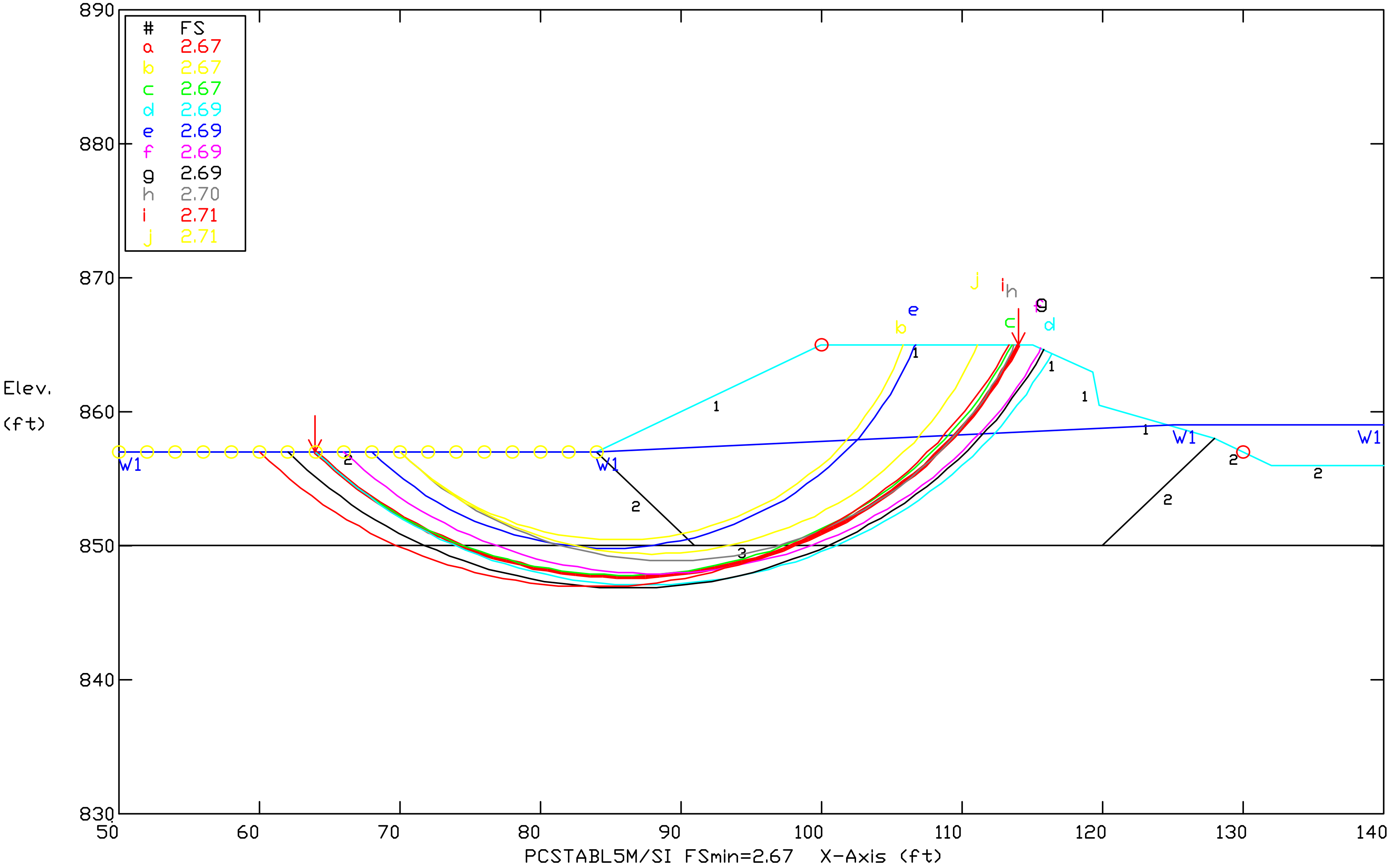
1. *Figure 22-1*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-1.pdf
2. *Figure 22-2*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-2.pdf
3. *Figure 22-12*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-12.pdf
4. *Figure 22-7*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-7.pdf
5. *Figure 22-17*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-17.pdf
6. *Figure 22-18*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-18.pdf

APPENDIX G – Slope Stability Analysis Results

Alliant Energy
Interstate Power and Light Company
Sutherland Generating Station
Marshalltown, Iowa

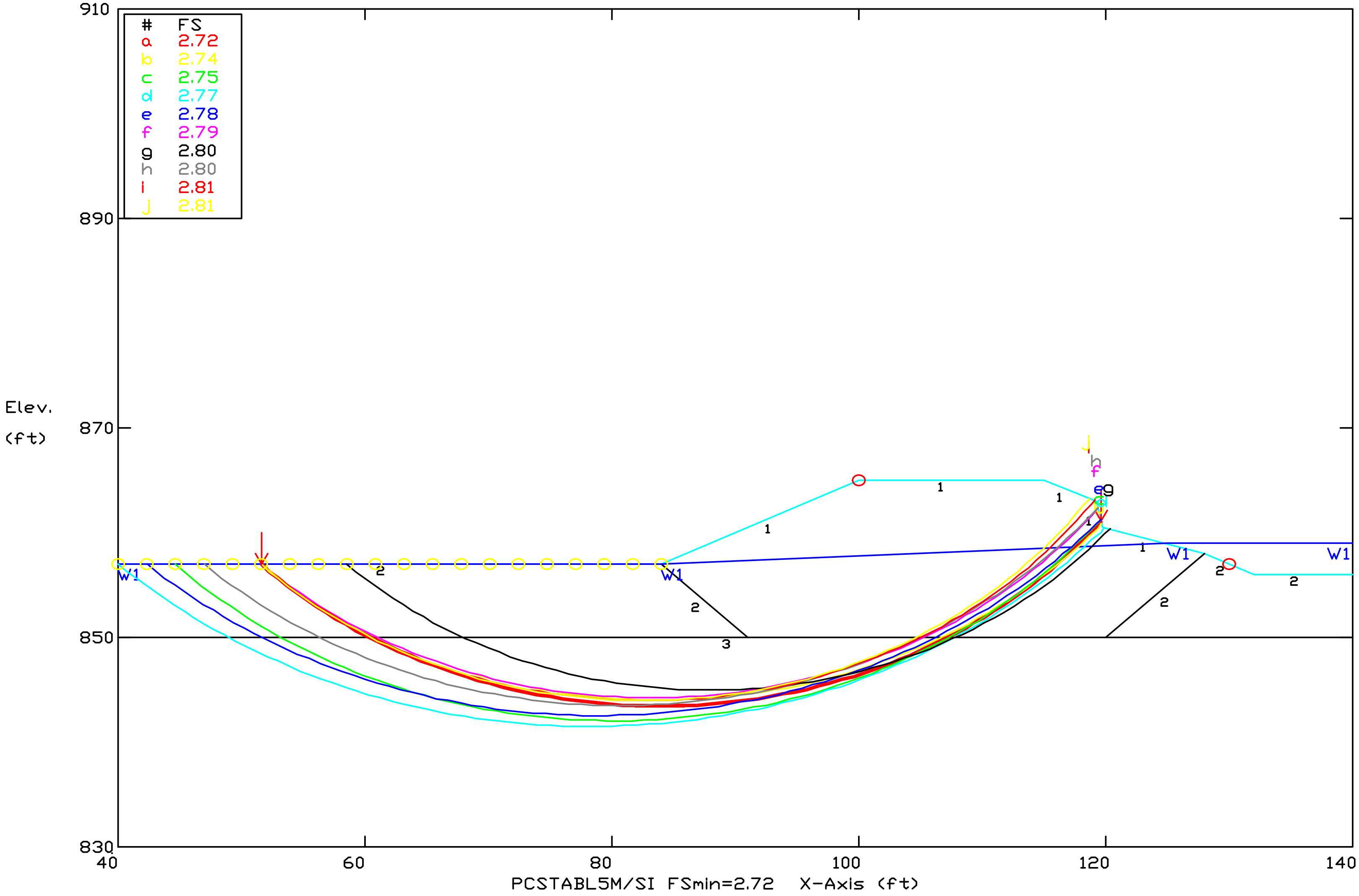
Safety Factor Assessment

Alliant Energy - Marshalltown, Iowa Static Case w Water @ 859.0'
Ten Most Critical. E:MARSH60.PLT 12-05-17 10:16am



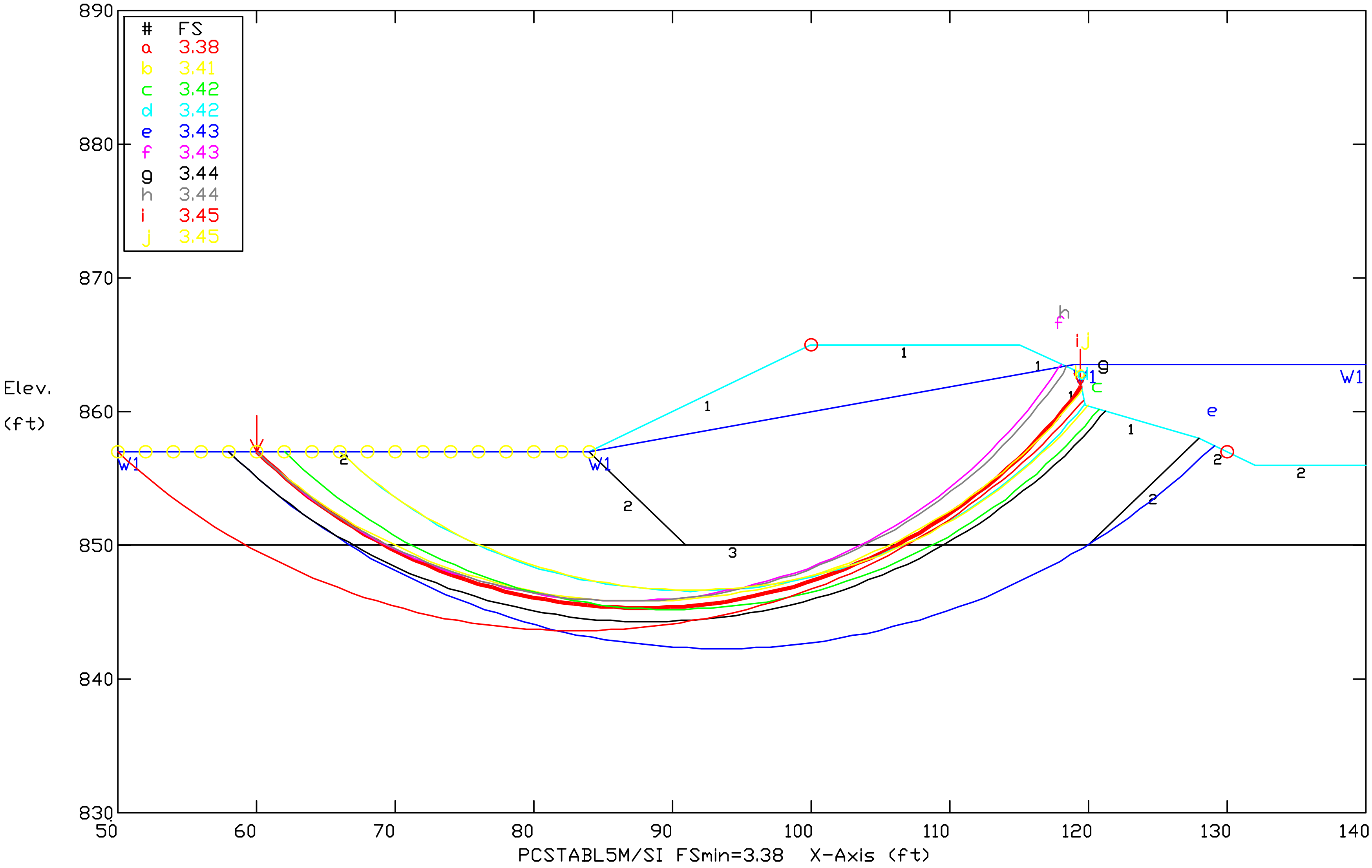
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	120	120	400	25	0	0	W1
2 NC Clay	100	110	0	24	0	0	W1
3 Sand	120	120	0	28	0	0	W1

Alliant Energy - Marshalltown, Iowa Earthquake Case w Water @ 859.0'
Ten Most Critical. E:MARSH61.PLT 12-05-17 10:45am



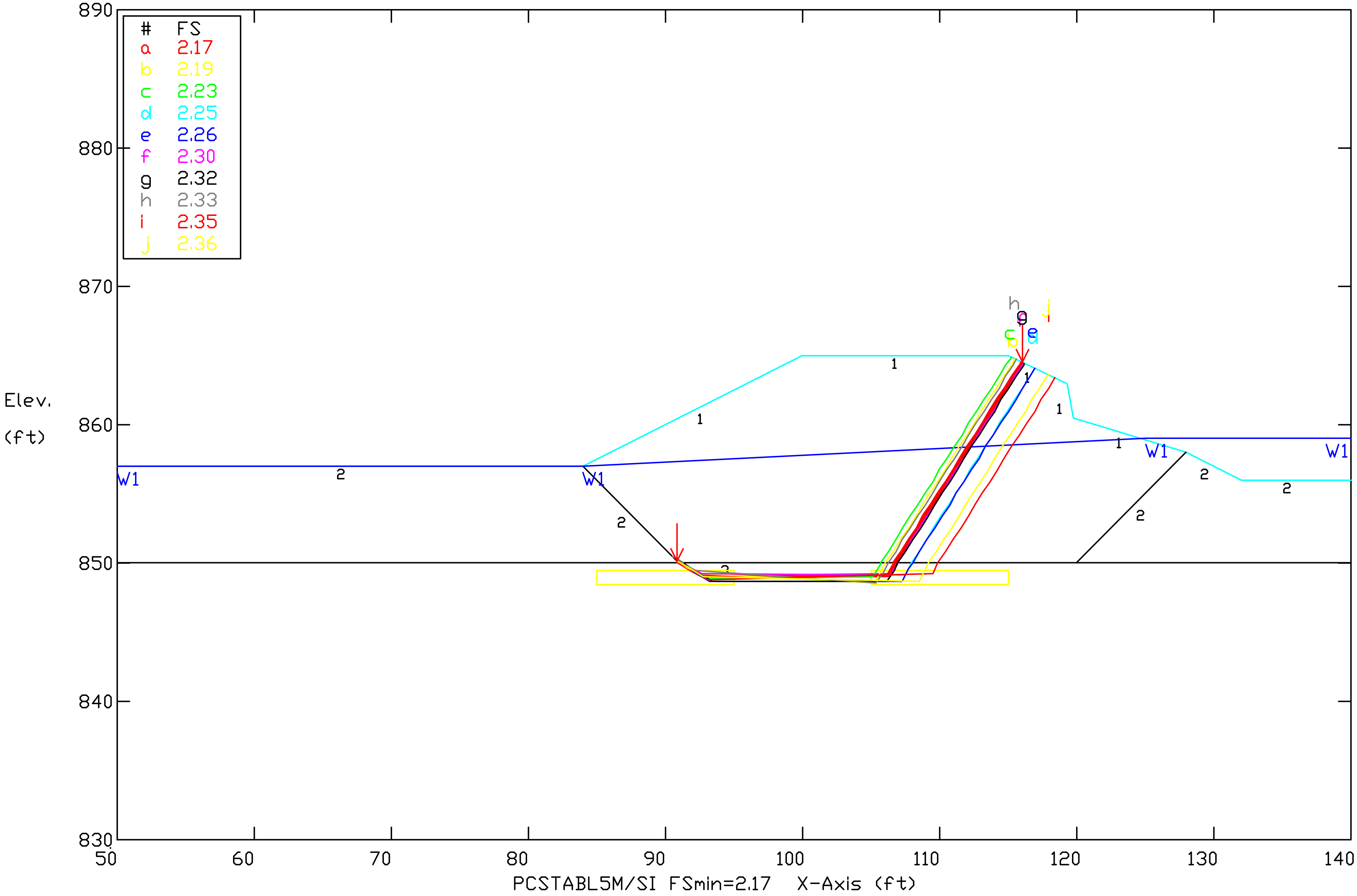
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	120	120	1000	0	0	0	W1
2 NC Clay	100	110	250	0	0	0	W1
3 Sand	120	120	0	28	0	0	W1

Alliant Energy - Marshalltown, Iowa Static Case w Water @ 863.5'
Ten Most Critical. E:MARSH62.PLT 12-05-17 10:51am



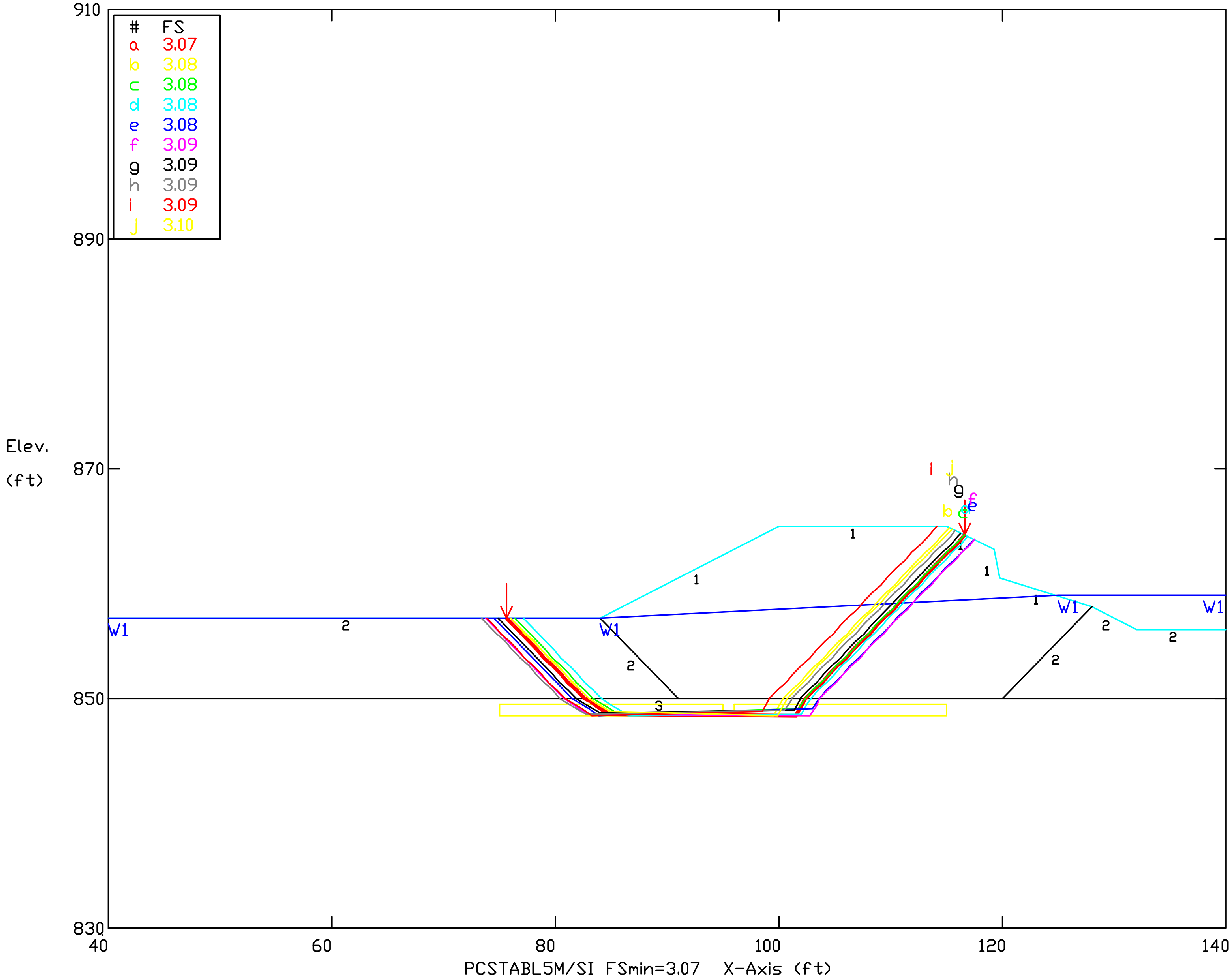
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	120	120	1000	0	0	0	W1
2 NC Clay	100	110	250	0	0	0	W1
3 Sand	120	120	0	28	0	0	W1

Alliant Energy - Marshalltown, Iowa Static Case w Water @ 859.0'
Ten Most Critical. E:MARSH60B.PLT 12-06-17 11:01am



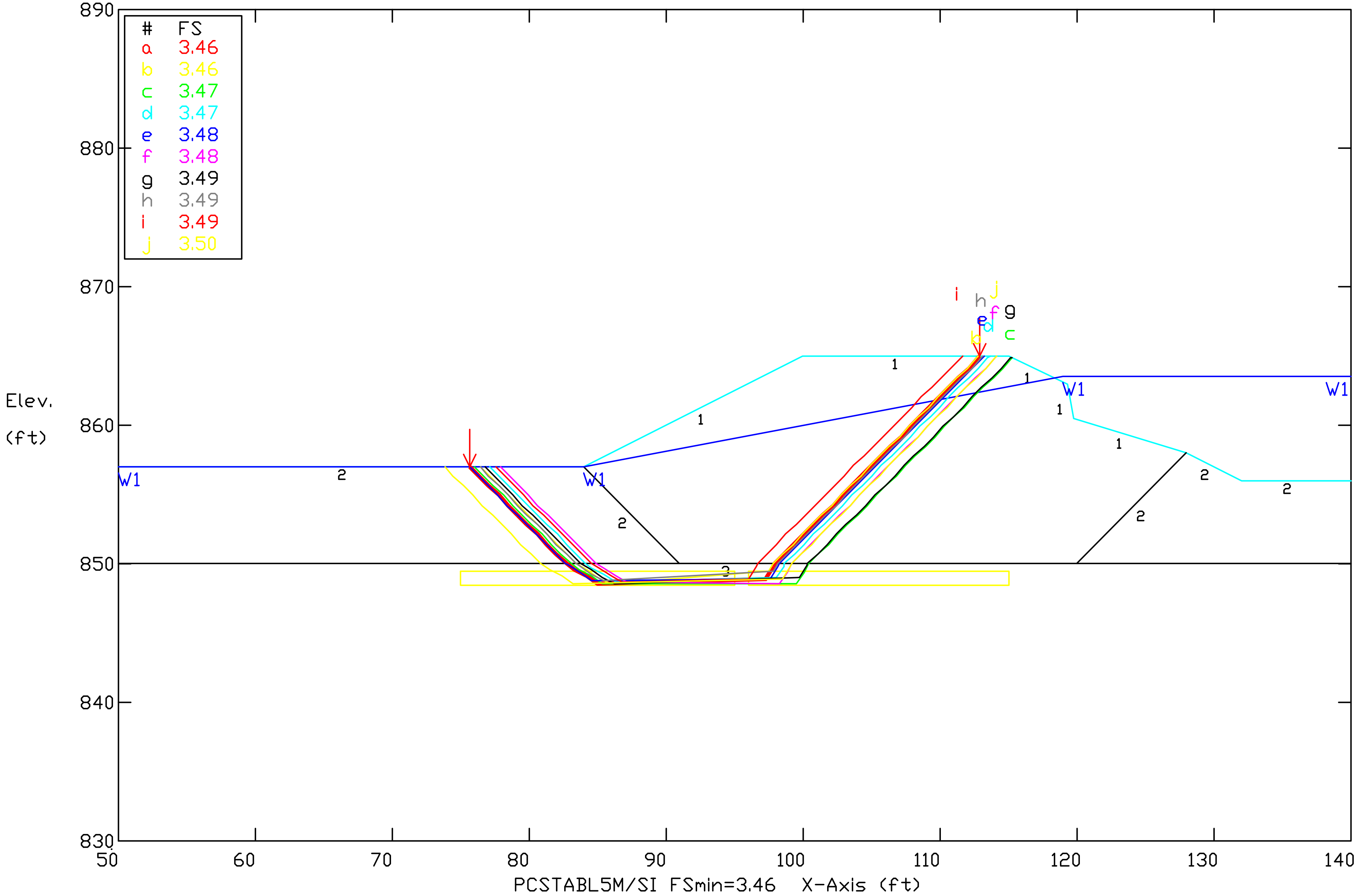
Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	120	120	400	25	0	0	W1
2 NC Clay	100	110	0	24	0	0	W1
3 Sand	120	120	0	28	0	0	W1

Alliant Energy - Marshalltown, Iowa Earthquake Case w Water @ 859.0'
Ten Most Critical. E:MARSH61B.PLT 12-06-17 10:11am



Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	120	120	1000	0	0	0	W1
2 NC Clay	100	110	250	0	0	0	W1
3 Sand	120	120	0	28	0	0	W1

Alliant Energy - Marshalltown, Iowa Static Case w Water @ 863.5'
Ten Most Critical. E:MARSH62B.PLT   12-06-17   10:12am



Soil Type No. Label	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1 Dike	120	120	1000	0	0	0	W1
2 NC Clay	100	110	250	0	0	0	W1
3 Sand	120	120	0	28	0	0	W1