Coon Rapids Dam Fish Barrier and Improvements Preliminary Design

Addendum 1 – Recreational Pool during Construction

Minnesota Department of Natural Resources
St. Paul, Minnesota

Final
May 5, 2011

Stanley Consultants INC.

Table of Contents

Addendum 1 - Recreational Pool during Construction

LIST OF TABLES

Addendum 1 – Recreational Pool during Construction

A1.1 Background

Following submittal of the final report the DNR requested that additional consideration be given to the feasibility of maintaining the summer recreational pool (Elevation 830.1) throughout the construction period. Maintaining the recreational pool and avoiding a temporary pool drawdown during construction is desirable since it would a) provide a better barrier against invasive fish migration, and b) maintain the recreational function of the pool.

This addendum discusses the feasibility of maintaining the recreational pool during construction and issues that must be carried into preparation of final design and contract documents.

A1.2 Dam Operation and Pool Control

During Phase 1, the Anoka County side of the Dam would be reconstructed. All gates would remain operational until the Phase 1 upstream cofferdam is complete at which time, Inflatable Gates 1, 2 and 3 would no longer be needed, leaving Inflatable Gate 4 and the control gate to maintain the pool at the desired level. The combined effective[1] length of the five gates is 943 feet which will be reduced by 56 percent to 412 feet during Phase 1 construction. The reduction in spillway gate capacity results in two operational concerns: a) precise control of the desired pool level; and b) safe passage of high river flows.

Figure A-1 presents the spillway rating curve for the Phase 1 operational gates. As shown in the figure there is a potential gap in precise pool level control when river flows exceed approximately 9200 cfs. This flow represents the maximum flow at which the recreational pool (830.1) can be maintained with the control gate completely lowered and Inflatable Gate 4 partially lowered/deflated. As river flow increases beyond 9200 cfs the pool level will rise above 830.1 or Inflatable Gate 4 would be fully deflated and the pool would drop to

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[1] Total length minus pier widths.

approximately 824.0. This scenario assumes that past operation techniques are maintained during construction, i.e. inflatable gates are limited to three positions: fully raised, partially lowered, or fully lowered. The *partially lowered* position was established by the gate manufacturer as a precaution against wear and tear on the gate that would result from the formation and uncontrolled lateral oscillations of a *v-notch* that would form on the crest of the gate when flow is allowed to overtop the inflatable gate.

An option would be to abandon past inflatable gate operation techniques and attempt various degrees of gate inflation to better maintain the desired pool level. This scenario is shown as "modified ops" on Figure A-1 in the Figures Appendix. Long-term wear and tear on the gate would not be a concern since the gate would be decommissioned within the year, however a sudden failure of the gate would certainly be of concern. In addition, pool level control would certainly be less precise under this scenario.

The primary operator of Coon Rapids Dam indicated that in 2010, Gates 1, 3 and 4 were operated in this "modified" fashion to a certain degree, due to the desire to maintain Gate 2 inflated at all times in order to lessen the impact to the scour area downstream of the gate. Gates 1, 3 and 4 were operated as low as 2.10 psi which is the lowest setting currently allowed by the programmable logic controller (PLC). The operator added that the gates begin to vibrate violently at low pressures, a situation that is observable whenever the gates are inflated or deflated.

In order to determine how often construction season river flows exceed 9200 cfs, daily streamflow values over the last twenty years were analyzed. The construction season was assumed to be from June 1 through December 31 (214 calendar days). Results are presented in Table A-1 below.

Table A-1 Construction Season Streamflow Data

Year	No. Days > 9200 cfs	Year	No. Days > 9200 cfs
1989	2	1999	134
1990	37	2000	22
1991	95	2001	40
1992	13	2002	137
1993	128	2003	53
1994	68	2004	66
1995	118	2005	103
1996	66	2006	4
1997	70	2007	28
1998	94	2008	33
		Min =	2
		Mean =	66
		Max =	137

During Phase 2, the Hennepin County side of the Dam would be reconstructed. Approximately 380 feet of newly installed crest gates would be operational at this time and precise pool level control would be possible up to a river discharge of approximately 27,000 cfs.

A1.3 Dam Improvements

A1.3.1 Construction Sequencing.

The sequence of construction in the river would remain unchanged from that described in the original report. However, maintaining the recreational pool will require that some of the main spillway gates remain operational during construction thus adding complexity to the work required within the gate control building.

The control building houses four blowers (air compressors) to actuate the four inflatable gates, a hydraulic pumping unit (HPU) to actuate the control gate, and a combined control system module to monitor and operate all the gates. The blowers are piped to allow flow of compressed air from any blower to any of the four inflatable gates. Figure A-2 in the Figures Appendix shows the present mechanical layout of the control building.

The amount of work required within the control building will depend upon the type of replacement gate selected. If pneumatic gates are selected it is anticipated that a new control module would be required within the control building but that much of the remaining equipment and piping would remain as is. It is anticipated that the existing blowers could be re-used for the new gate system but the eventual gate manufacturer will weigh-in on this decision. Regardless, the switching-out of blowers should not prove problematic due to the previously discussed redundant piping/blower arrangement. It is anticipated that once the Phase 1 cofferdam is operational the southern two blowers would be removed from the control building leaving two blowers to actuate Gate 4. This newly vacated space would be occupied by a temporary control system to operate Gate 4 and the control gate. Once the temporary control system is functional the existing control system would be removed and replaced with a new control module. The temporary control system would be removed once the new module is operational.

If hydraulic gates are selected the control building will require major re-work including complete removal of the existing air system equipment and piping and replacement with additional HPU's and a new control module. Once again it is anticipated that once the Phase 1 cofferdam is operational the southern two blowers would be removed from the control building leaving two blowers to actuate Gate 4. In this case the vacated space would be occupied by two new HPU's and the control module to operate the new hydraulic gates. During Phase 2 remaining blowers and air piping would be removed and additional HPU's would be installed to operate the hydraulic gates.

A1.3.2 Cofferdam Design.

It was originally recommended that all gates would be lowered to draw down the upstream pool during construction and therefore, for preliminary design and cost estimating purposes this was assumed. The main reason for this is the risk associated with the scour protection construction activities taking place on the downstream side of the Dam. Additional analyses were conducted investigating cofferdam system requirements and associated costs for maintaining the "recreational pool" elevation of 830.1. This included both structural and geotechnical modeling to arrive at concept designs as well as the development of a cost estimate to determine the added cost of maintaining the high pool.

As was done in the previous analysis, an additional two feet of freeboard was added for each analysis case, thus, analyzing cofferdam systems with an upstream pool elevation of 832. As expected, the additional hydrostatic head imposed on the system changed the solution significantly. On the Anoka side, where alluvial sands are underlain by dense glacial till, the original cofferdam concept is still possible, however, the resisting (downstream) berm would need to be enlarged to provide additional counterforce. In addition, in order to control excessive deflections, a more robust sheet pile section (PZ 27) is required. Deflections in the model were limited to four inches.

CWALSHT was used to model two different failure modes for both the Anoka Side and the Hennepin Side soil conditions. Both high headwater and low headwater (reverse) conditions were modeled. In addition, the high headwater case was split into "usual" and "unusual" cases. "Usual" refers to headwater at elevation 830.1 whereas "unusual" refers to a headwater elevation of 832. Factors of safety of 1.5 and 1.25 are applied to the active soil pressures for the usual and unusual cases respectively. Factors of safety were referenced from EM 1110-2-2503. As was stated in the original report, the glacial till stratum is deeper on the Anoka side of the Dam (approximately elevation 775) and slopes up gradually towards the Hennepin side of the Dam until it reaches approximately elevation 815 on the Hennepin side.

Iterative analysis was conducted to determine the point along the dam at which the alluvial sands no longer have the depth required for adequate embedment of the sheet pile. The assumption was made that sheet pile could only be driven five feet into the dense glacial till. This is only an assumption and it is recommended that test piles be driven to see the actual drivability of the sheets into the glacial till stratum prior to construction. Because of the high counterforce berm required to control the high headwater cases, the low headwater (reverse) cases controlled the design due to the larger stickup and greater active earth pressures placed on the cantilevered wall. Low headwater was assumes as elevation 822. For the controlling load case (low headwater case failure toward upstream), it was determined that in order to mitigate excessive deflections and bending moments, the cantilever sheet pile (original proposed concept) is only viable for an embedment of 20 feet or greater (elevation 795). When this embedment is no longer available, an earthen or cellular solution is required. From the limited boring data available, it was determined that this point along the dam occurs approximately 500 feet from the Anoka side abutment, thus, cellular or earthen cofferdam is needed for the remaining 500 ft of Dam (approximately the entire half of the Dam nearest the Hennepin Side) . As indicated earlier, it may be a challenge to keep a constant recreational pool elevation using only the control gate and Inflatable Gate 4. All CWALSHT input and output as well as MathCAD sheets showing the scaled deflection and bending moment computations are provided in the Addendum 1 Computations Section following this report.

Cellular cofferdam analysis was conducted using methods outlined in EM 1110-2-2503 "Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures." From the analysis it was determined that a 20 ft diameter cellular structure is required. This solution would require that sheets be driven down to the glacial till stratum, thus relying on gravity to resist the forces imposed by the upstream pool.

In addition to the cantilevered sheet pile and cellular cofferdam concepts, full and partial earthen embankment concepts were investigated. It should be noted that these options depend on the willingness of regulatory agencies to allow the placement of fill material upstream of the cofferdam. If this option was chosen, all precautions would be taken to mitigate scour from occurring and from sediment to be carried downstream. This would include the placement of a geosythetic and riprap on the upstream face of the embankment. It should also be noted that the earthen embankment option would still require the driving of a sheet pile through the middle of the embankment to control seepage and mitigate uplift forces and dangerous working conditions during dewatering and excavation.

First, the full embankment section was modeled using SLOPE/W with Spencer's Method. Optimized circular failure surfaces were searched using specified entry and exit ranges. Required minimum factors of safety were taken from EM 1110-2-1913 for both "end of construction" and "Long-Term Steady State Seepage" cases. Required minimum factors of safety for these two conditions are assumed as 1.3 and 1.4 respectively.

Stability for the earthen embankment cofferdams was conducted with both "usual" and "unusual" High-pool headwater elevations (830.1 and 832 respectively). A drained "S-Case" condition of the upstream face during low headwater conditions (822) was also analyzed. For high headwater cases, the piezometric surface was assumed to drop along the sheet pile cutoff to the interior dewatered elevation. From the analysis, it was determined that a 3H:1V slope is required to meet the required minimum factors of safety.

A partial earthen cofferdam solution was also analyzed in which the earthen embankment was only raised to elevation 825 and a cantilevered sheet pile wall is driven through the center to elevation 832 (high pool elevation plus 2' freeboard). This condition also requires 3H:1V slopes for the embankment portion. This option was also evaluated in CWALSHT to check the deflections and bending moments of the cantilevered portion of the sheet pile wall. This option requires a more robust sheet pile section because it is being relied on for hydrostatic retention instead of just seepage mitigation (full embankment option). In this option, the upper exposed sheet pile interlocks would need to be sealed to prevent excessive seepage through the sheets. If sealing isn't an option, seepage could be mitigated through the use of a small drainage ditch or local sump pits.

All upstream cofferdam concepts for maintaining the recreational pool elevation are provided as Exhibits 07A and 07B in the Exhibits Appendix following this report.

A1.4 Construction Costs

Additional cofferdam costs as a result of the additional upstream pool elevation include the following:

- Costs associated with a more robust sheet pile section (Stage 1 - Anoka Side). This includes using a PZ 27 section instead of a PZ 22 section, adding an additional 5 pounds per square foot.
- Costs associated with a more robust counterforce embankment/berm (Anoka Side).

For the Hennepin Side (Stage 2), additional costs associated with one of the upstream concepts discussed in Section A1.3.2 include the following:

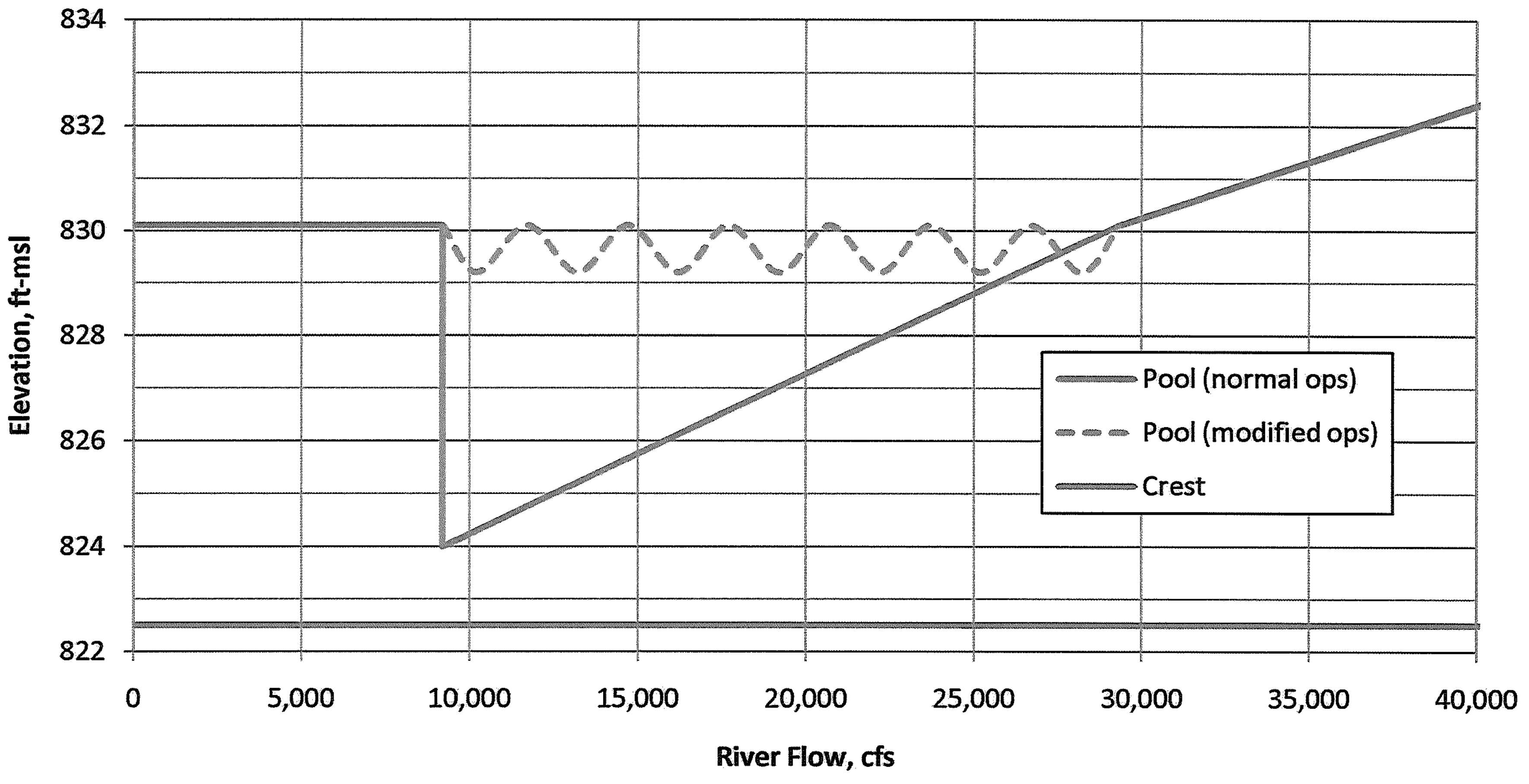
- Costs associated with the use of a cellular sheet pile cofferdam, double-wall sheet pile cofferdam, or earthen structure (Stage 2 - Hennepin Side).
- Costs associated with the use of a partial earthen embankment cofferdam with cantilevered sheet pile wall.
- Costs associated with the use of a full earthen embankment cofferdam with sheet pile cutoff.

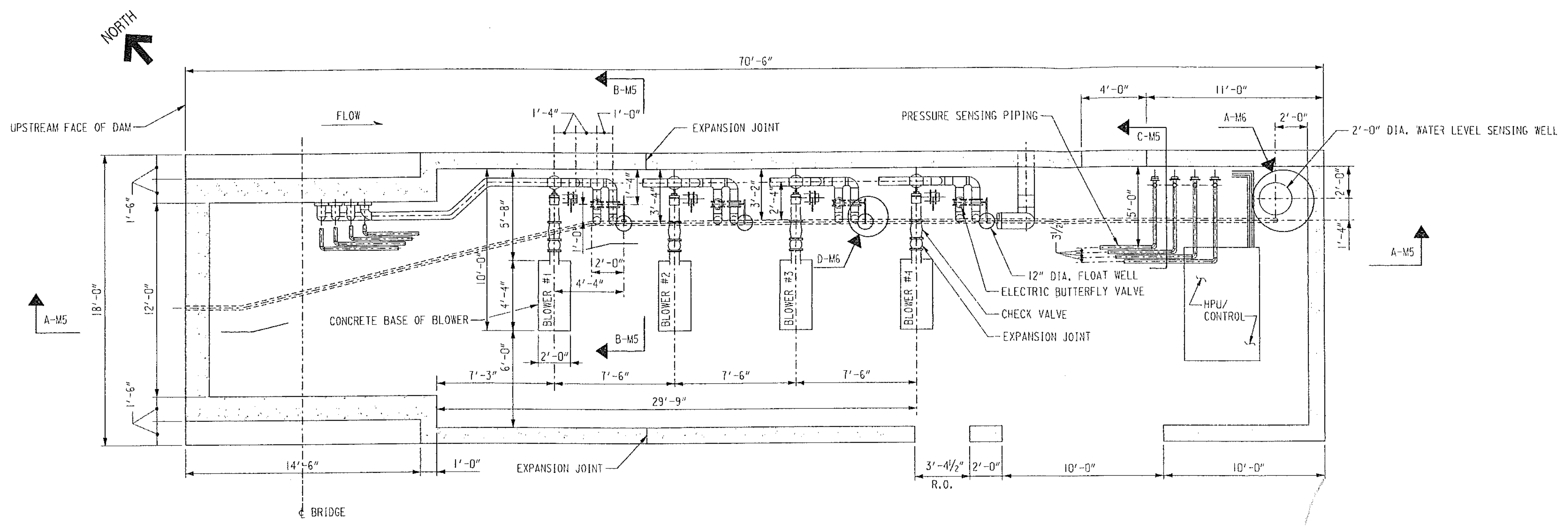
In addition to the extra costs incurred by increased material properties, it should also be noted that over the course of the last twelve months, the price of steel has increased drastically by nearly 50% from $0.90 to $1.00 per pound in 2010 to around $1.25 to $1.50 per pound in mid-2011. To "normalize" this increase to allow for proper perspective and comparison of the initial estimate and proposed alternative solutions, the same unit price values that were used in the original report were used for this addendum.

Addendum 1 Figures

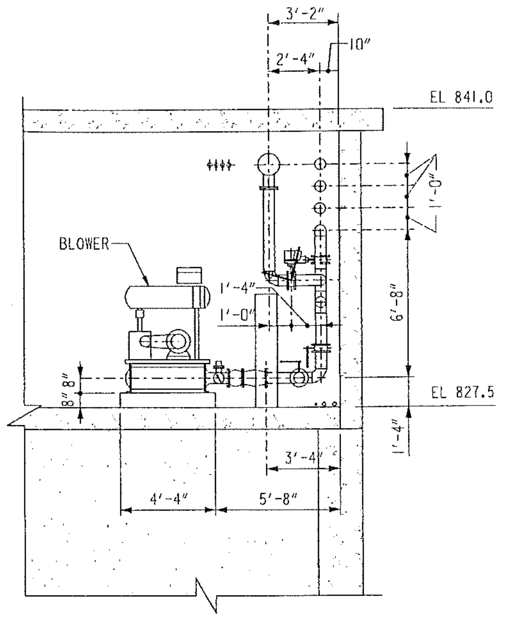
Figure A-1

Pool Operation: 830.1' Pool During Construction





CONTROL ROOM PIPING PLAN AT EL 838.0



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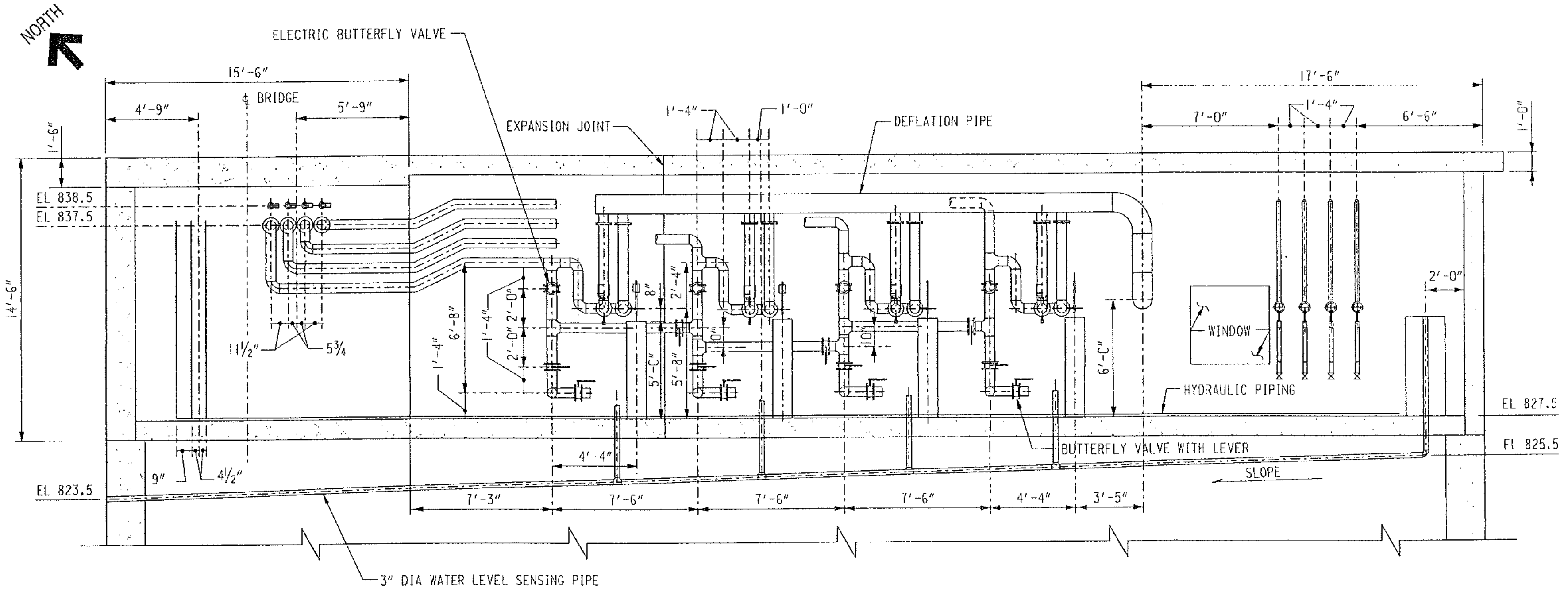

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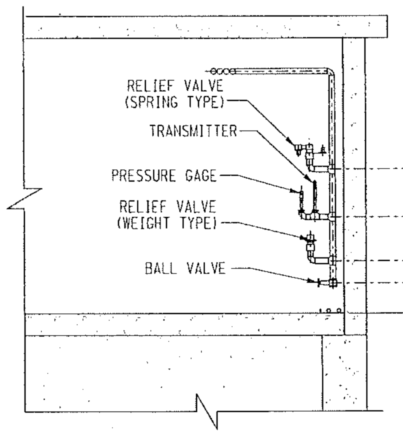


SECTION $\frac{\text{C-M5}}{\text{M5}}$

NOTE:

1. ALL AIR AND HYDRAULIC VALVES, GAGES, AND TRANSMITTERS LOCATED IN CONTROL BUILDING TO BE SUPPLIED BY CONTRACT 1 AND INSTALLED BY CONTRACT 2. ALL PIPING FURNISHED AND INSTALLED BY CONTRACT 2.

2. PIPE SLEEVE SEALS REQUIRED ALONG NORTH WALL FOR ALL PENETRATIONS.

THE ORIGINAL OF THIS DRAWING WAS CERTIFIED BY J.C. JOHNSON

DATE 3-23-95 REG NO 22020

AT FULL SIZE
0 1 2 3 IN
0 1 2 3 4 5 6 7 8 cm

NO.	REVISIONS	DRAWN	APPROVED	APPROVED	DATE	NO.	REVISIONS	DRAWN	APPROVED	APPROVED	DATE
						⚠	RECORD DRAWING	KMB			7/97

DESIGNED J.C. JOHNSON
DRAWN K. BURK
CHECKED K.A. PAULSON
APPROVED J.C. JOHNSON
APPROVED J.C. JOHNSON
DATE 3-23-95

STANLEY CONSULTANTS
INTERNATIONAL CONSULTANTS IN ENGINEERING, ARCHITECTURE, PLANNING, AND MANAGEMENT

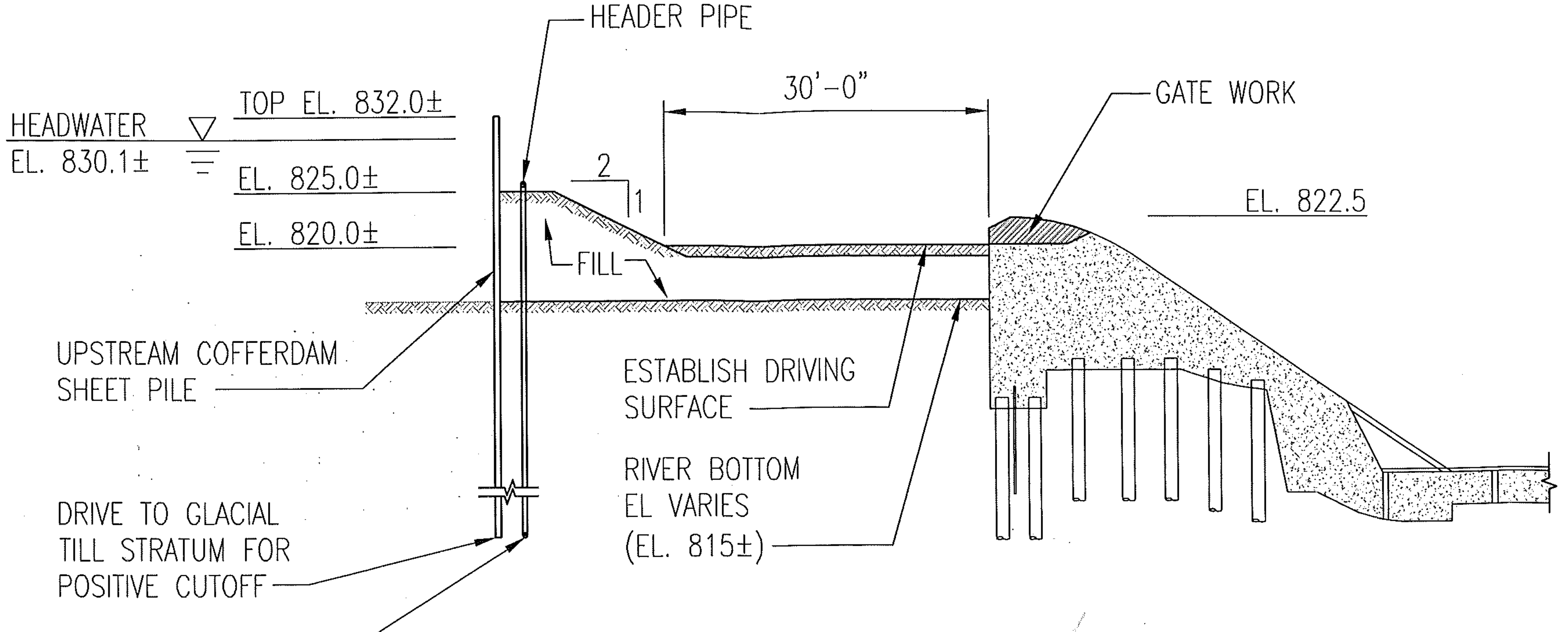
COON RAPIDS DAM REHABILITATION
SUBURBAN HENNEPIN
REGIONAL PARK DISTRICT

GATE SYSTEM CONTROL BUILDING -
PIPING PLAN AND SECTIONS

SCALE ¼" = 1'-0"
NO. 12305
M5
REV. 1

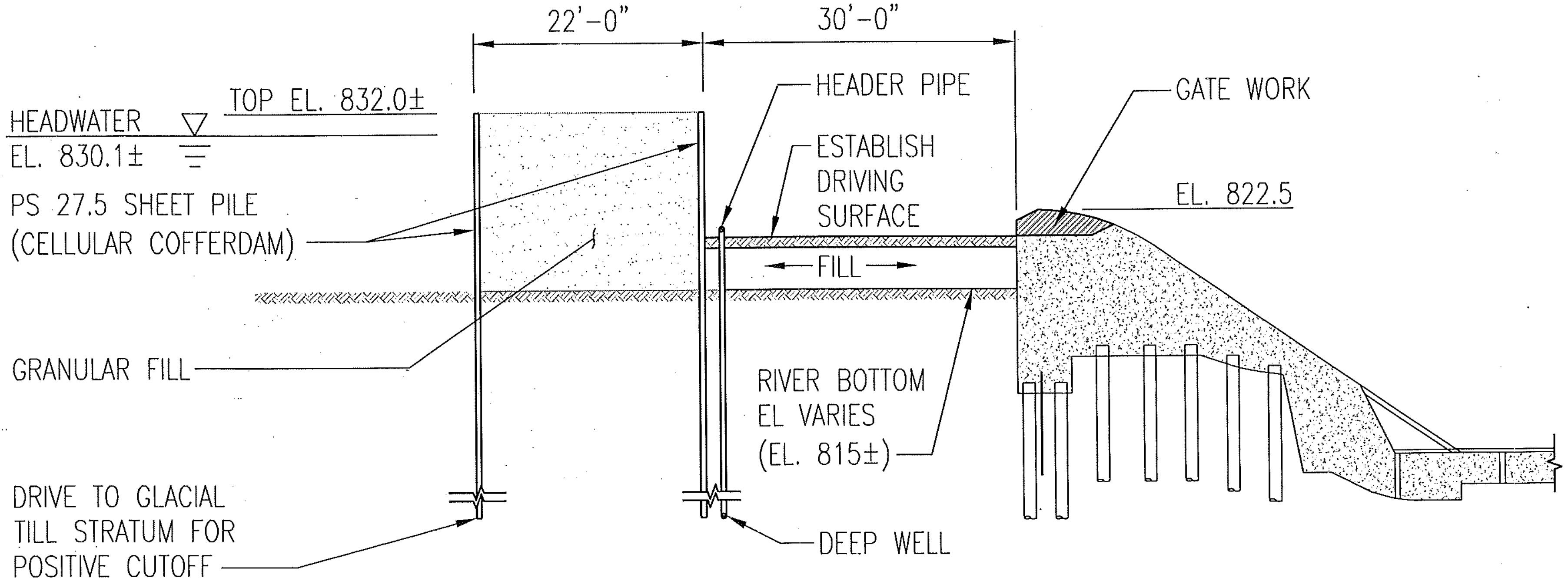
Addendum 1 Exhibits

Stanley Consultants INC.



CANTILEVERED SHEET PILE OPTION

SCALE: 1/16" = 1'-0"



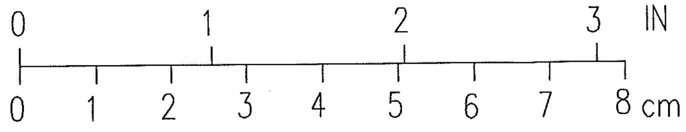
CELLULAR COFFERDAM OPTION

SCALE: 1/16" = 1'-0"

NOTES:

1. COFFERDAM CONCEPTS SHOWN ARE CONCEPTUAL AND SHOULD BE DESIGNED BY CONTRACTOR.
2. CANTILEVERED SHEET PILE OPTION SHOULD ONLY BE USED WHERE SHEET PILE EMBEDMENTS ARE POSSIBLE TO ELEVATION 795.0 OR DEEPER (PRIMARILY ANOKA SIDE).
3. CONCEPTS SHOWN ARE FOR MAINTAINING UPSTREAM POOL AT RECREATIONAL ELEVATION (EL. 820.1).

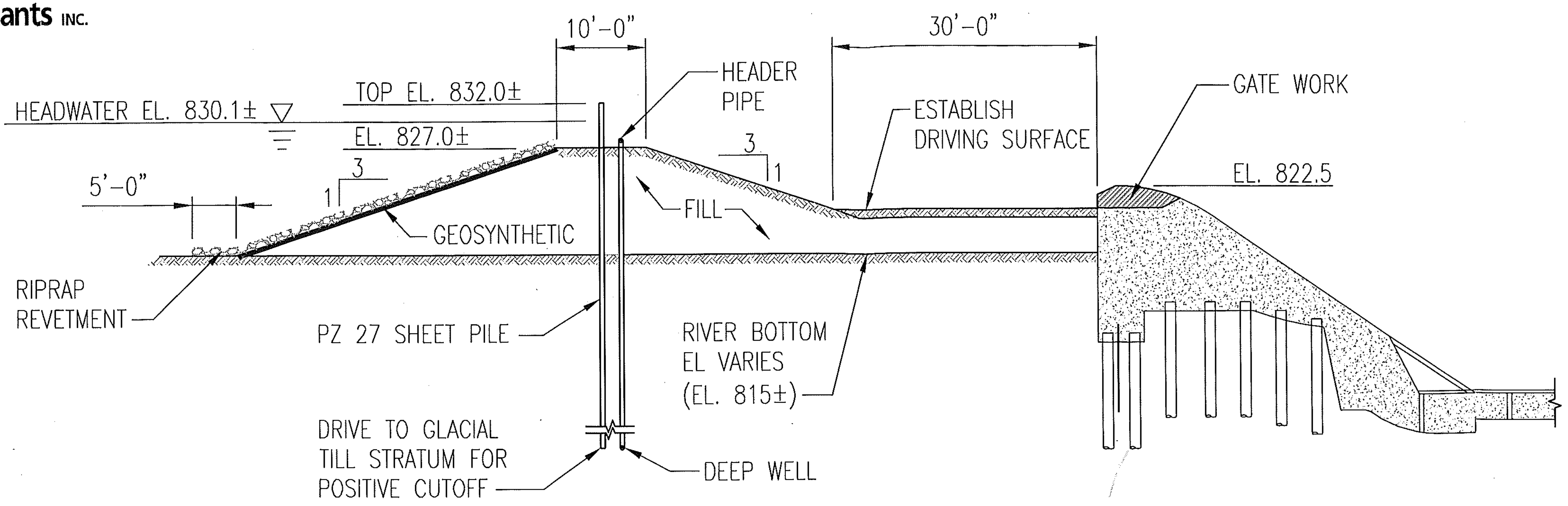
AT FULL SIZE



COON RAPIDS DAM
EXHIBIT 07A
REV: 1 04-05-11
UPSTREAM COFFERDAM CONCEPTS
FOR RECREATIONAL POOL

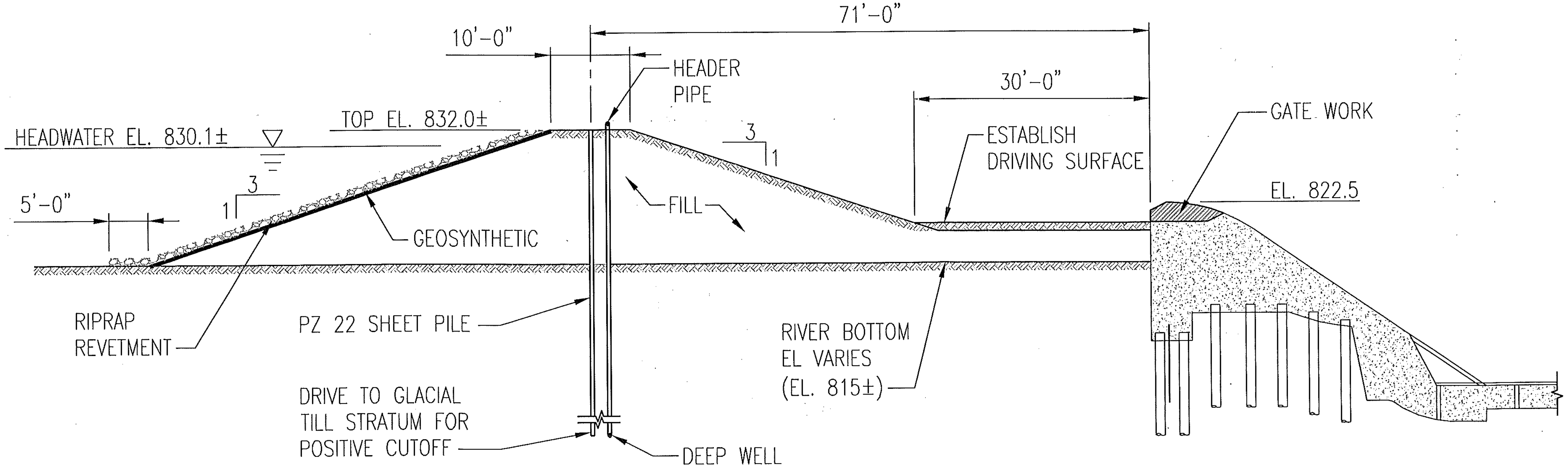
CADD B2-R3 © STANLEY CONSULTANTS Plot Date:4/5/2011 7:59:19 AM CADD File: EX-07A.dwg

Stanley Consultants INC.



PARTIAL EARTHEN EMBANKMENT OPTION

SCALE: 1/16" = 1'-0"



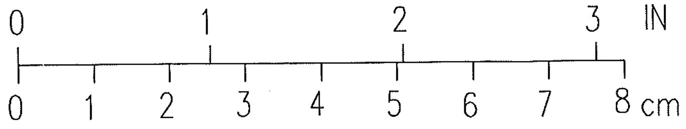
FULL EARTHEN EMBANKMENT OPTION

SCALE: 1/16" = 1'-0"

NOTES:

1. COFFERDAM CONCEPTS SHOWN ARE CONCEPTUAL AND SHOULD BE DESIGNED BY CONTRACTOR.
2. CONCEPTS SHOWN ARE FOR MAINTAINING UPSTREAM POOL AT RECREATIONAL ELEVATION (EL. 830.1).

AT FULL SIZE



COON RAPIDS DAM
EXHIBIT 07B
REV: 1 04-05-11
UPSTREAM COFFERDAM CONCEPTS
FOR RECREATIONAL POOL

CADD B2-R3 © STANLEY CONSULTANTS Plot Date:4/5/2011 7:59:27 AM CADD File: EX-07B.dwg

Addendum 1 Cost Worksheets

Stanley Consultants INC.

A Stanley Group Company
Engineering, Environmental and Construction Services - Worldwide

Created By: L. Karels **Date:** 7-Apr-11
Checked By: J. Jacks **Date:** 30-Mar-11

PROJECT NO. 23082
OPINION OF PROBABLE COST - ADDENDUM 1
UPSTREAM COFFERDAM COSTS FOR MAINTAINING RECREATIONAL POOL

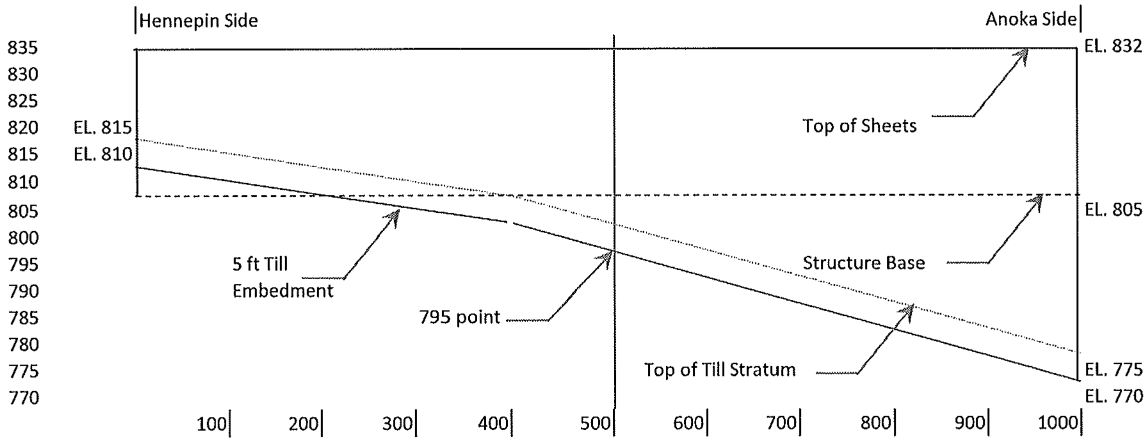
ITEM NO.	ITEM DESCRIPTION	UNIT	QUANTITY	UNIT COST	EXTENSION
Stage 1	***Cantilevered Sheet Pile Option***				
	PZ-27 Sheet Pile	SF	24750	$ 27	$ 668,250
	Cofferdam Fill	CY	6685	$ 25	$ 167,130
				Total	$ 835,380
Stage 2	***Cellular Sheet Pile Option***				
	PS 27.5 Sheet Pile	SF	55665	$ 28	$ 1,530,795
	Cofferdam Fill	CY	9328	$ 25	$ 233,212
				Total	$ 1,764,007
	Partial Earthen Embankment Option				
	PZ 27 Sheet Pile	SF	14750	$ 27	$ 398,250
	Cofferdam Fill	CY	12750	$ 25	$ 318,750
	Riprap	CY	1405	$ 60	$ 84,327
	Geosynthetic	SY	2108	$ 3	$ 5,270
				Total	$ 806,598
	Full Earthen Embankment Option				
	PZ 22 Sheet Pile	SF	14750	$ 22	$ 324,500
	Cofferdam Fill	CY	21731	$ 25	$ 543,287
	Riprap	CY	1991	$ 60	$ 119,464
	Geosynthetic	SY	2987	$ 3	$ 7,466
				Total	$ 994,717

	Stage 2 Option	**Costs**					
		Stage 1	*Stage 2*	*Total*	*Original Cost*	*Difference*	*% Increase*
Summary	Cellular Cofferdam	$ 835,380	$ 1,764,007	$ 2,599,387	$ 998,000	$ 1,601,387	160%
	Partial Earthen	$ 835,380	$ 806,598	$ 1,641,977	$ 998,000	$ 643,977	65%
	Full Earthen	$ 835,380	$ 994,717	$ 1,830,097	$ 998,000	$ 832,097	83%

Note: No Contingency, Underdeveloped Details, or fees added.

Sheet Pile Quantity Compuutations
Addnedum 1 - Recreational Upstream Pool EL. 830.1

Upstream Sheet Pile Profile



Stage 1:	QTY	UNITS	NOTES
Cantelliever Option	24750	SF	Only for Anoka Side (500 ft)

Stage 2:	QTY	UNITS	NOTES
Cellular	55665	SF	PS 27.5
Partial Earthen	14750	SF	PZ 27
Full Earthen	14750	SF	PZ 22

Cellular Comps:	QTY	UNITS	NOTES
Area	14750	SF	
Piles per Foot	2.3		USS Design Manual - Pg 68
Total Area	33925	SF	
Diameter	22	FT	
Perimeter	69.12	FT	
Avg Depth	802.5	ELEV	
Avg Height	29.5	FT	
No of Cells	22.73		
Sheet Width	19.69	IN	
	1.64	FT	
Area	**55665**		

Earth Fill Quantity Computations

Stage 1: Canteliever Option

	QTY	UNITS
Area	361	SF
Length	500	FT
Volume	180500	CF
	6685	**CY**

Stage 2:

Cellular	QTY	UNITS
Cell Ht	17	FT
Cell Dia	22	FT
Cell Area	380	SF
Cell Vol	6462	CF
No. Cells	23	
Bench Are	210	SF
Length	500	FT
Bench	105000	CF
Volume	3889	CY
Cell	146869	CF
Volume	5440	FCY
Total Vol.	**9328**	**CY**

Partial Earthen	QTY	UNITS
Area	689	SF
Length	500	FT
Volume	344250	CF
	12750	**CY**

Full Earthen	QTY	UNITS
Area	1174	SF
Length	500	FT
Volume	586750	CF
	21731	**CY**

Riprap Revetment Quantity Compuutations

Partial Earthen	QTY	UNITS
Width	38	FT
Depth	2	FT
Length	500	FT
Volume	**1405**	**CY**

Full Earthen	QTY	UNITS
Width	54	FT
Depth	2	FT
Length	500	FT
Volume	**1991**	**CY**

Geotextile Quantity Compuutations

Partial Earthen	QTY	UNITS
Width	38	FT
Length	500	FT
Area	**2108**	**SY**

Full Earthen	QTY	UNITS
Width	54	FT
Length	500	FT
Area	**2987**	**SY**

Addendum 1 Computations

Geotechnical and Structural Computations

Sheet Pile Cofferdam Structural Analysis

Upstream Cantilevered Cofferdam

Unusual Headwater Elevation (832)

Stanley Consultants INC.
Computed By: L. Karels
Checked by: J. Jacks
Approved by:
Filename: SheetPile_Wall_Case1_832.xmcd

Comp Date: 03/21/2011
Print Date: 3/25/2011
Print Time: 2:04 PM

Page No. _____.
Project No. 23082
Coon Rapids Dam
Upstream Cofferd
Preliminary De
Sheet 1 of 2

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 1 - Unusual Case - Surcharges Present

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

✓ ☑ ✓ ☑

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam for the proposed Coon Rapids Dam structural improvements. On Anoka side (existing apron side), alluvial sands are present to elevaton 775. Potential failure occuring from downstream to upstream during low headwater case (EL. 822).

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 2.93 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.84\, 10^{10} lbf \cdot in^3$

Wall Bottom Elevation: 794.26 ft

Required Penetraion: 20.74 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \quad I_{PZ} := 184.20 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 11.642 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_27} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_27} = 3.445 \cdot in$ < 4 in. OK

Using a PZ 22

$S_{PZ} := 18.1\text{in}^3$ $I_{PZ} := 84.38\text{in}^4$ $E = 29000\cdot\text{ksi}$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 19.425\cdot\text{ksi}$

Allowable Stress: $f_b := 0.5F_y$ $f_b = 25\cdot\text{ksi}$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_22} := \frac{\delta_{max}}{E\cdot I_{PZ}}$ $\delta_{PZ\_22} = 7.519\cdot\text{in}$ > 4 in. Need Larger Section

Conclusion

A PZ 27 (or equivalent) is adequte. Use PZ 27 (or equivalent).

```
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'FAILURE TOWARD UPSTREAM
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   832
SURFACE RIGHTSIDE   4    0    825
                  10    825
                  16    822
                  100    822
SURFACE LEFTSIDE   2    0    815
                  100    815
SOIL RIGHTSIDE  STRENGTHS   1
   120    120    27    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   120    120    27    0    0    0
WATER ELEVATIONS   62.4    822    822
VERTICAL STRIP  RIGHTSIDE   2    0    10    100
                     16    40    200
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                         TIME: 15:17:15

                            ****************
                            *  INPUT DATA  *
                            ****************

    I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'ANOKA SIDE - ALLUVIAL SANDS
    'FAILURE TOWARD UPSTREAM

   II.--CONTROL
      CANTILEVER WALL DESIGN
      FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
      FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

  III.--WALL DATA
      ELEVATION AT TOP OF WALL     = 832.00 FT.

   IV.--SURFACE POINT DATA

        IV.A.--RIGHTSIDE
           DIST. FROM     ELEVATION
           WALL (FT)        (FT)
              0.00         825.00
             10.00         825.00
             16.00         822.00
            100.00         822.00

        IV.B.--LEFTSIDE
           DIST. FROM     ELEVATION
           WALL (FT)        (FT)
              0.00         815.00
            100.00         815.00

    V.--SOIL LAYER DATA

      V.A.--RIGHTSIDE
           LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
           LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                 ANGLE OF         ANGLE OF                           <-SAFETY->
   SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->   <-FACTOR->
  WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE   ACT. PASS.
  (PCF)   (PCF)   (DEG)    (PSF)   (DEG)    (PSF)   (FT)  (FT/FT)
 120.00  120.00   27.00     0.00    0.00     0.00                   DEF  DEF

      V.B.--LEFTSIDE
           LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
           LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                 ANGLE OF         ANGLE OF                           <-SAFETY->
   SAT.   MOIST  INTERNAL  COH-     WALL    ADH-    <--BOTTOM-->   <-FACTOR->
  WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION   ELEV.  SLOPE   ACT. PASS.
  (PCF)   (PCF)   (DEG)    (PSF)   (DEG)    (PSF)   (FT)  (FT/FT)
 120.00  120.00   27.00     0.00    0.00     0.00                   DEF  DEF

   VI.--WATER DATA
      UNIT WEIGHT          = 62.40 (PCF)
      RIGHTSIDE ELEVATION = 822.00 (FT)
```

```
        LEFTSIDE ELEVATION   = 822.00 (FT)
        NO SEEPAGE

    VII.--VERTICAL SURCHARGE LOADS

        VII.A.--VERTICAL LINE LOADS
             NONE

        VII.B.--VERTICAL UNIFORM LOADS
                  NONE

        VII.C.--VERTICAL STRIP LOADS

             VII.C.1.--RIGHTSIDE
             <-DIST. FROM WALL->
               START        END       STRIP LOAD
                (FT)        (FT)        (PSF)
                0.00       10.00       100.00
               16.00       40.00       200.00

             VII.C.2.--LEFTSIDE
                  NONE

        VII.D.--VERTICAL RAMP LOADS
             NONE

        VII.E.--VERTICAL TRIANGULAR LOADS
             NONE

        VII.F.--VERTICAL VARIABLE LOADS
             NONE

  VIII.--HORIZONTAL LOADS
       NONE




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                          TIME: 15:17:17

                           **************************
                           *    SOIL PRESSURES FOR   *
                           * CANTILEVER WALL DESIGN *
                           **************************

    I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'ANOKA SIDE - ALLUVIAL SANDS
     'FAILURE TOWARD UPSTREAM

   II.--SOIL PRESSURES

        RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.
```

```
          LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                                <------NET------>
            NET      <---LEFTSIDE--->           (SOIL + WATER)        <--RIGHTSIDE--->
 ELEV.     WATER     PASSIVE    ACTIVE         ACTIVE    PASSIVE       ACTIVE    PASSIVE
 (FT)      (PSF)       (PSF)     (PSF)          (PSF)      (PSF)        (PSF)      (PSF)
 832.0      0.0         0.0       0.0            0.0        0.0          0.0        0.0
 831.0      0.0         0.0       0.0            0.0        0.0          0.0        0.0
 830.0      0.0         0.0       0.0            0.0        0.0          0.0        0.0
 829.0      0.0         0.0       0.0            0.0        0.0          0.0        0.0
 828.0      0.0         0.0       0.0            0.0        0.0          0.0        0.0
 827.0      0.0         0.0       0.0            0.0        0.0          0.0        0.0
 826.0      0.0         0.0       0.0            0.0        0.0          0.0        0.0
 825.0      0.0         0.0       0.0            0.0        0.0          0.0        0.0
 824.0      0.0         0.0       0.0           82.6      428.7         82.6      428.7
 823.0      0.0         0.0       0.0          127.7      662.5        127.7      662.5
 822.0      0.0         0.0       0.0          166.9      866.0        166.9      866.0
 821.0      0.0         0.0       0.0          194.3      792.5        194.3      792.5
 820.0      0.0         0.0       0.0          216.0      709.8        216.0      709.8
 819.0      0.0         0.0       0.0          237.6      847.3        237.6      847.3
 818.0      0.0         0.0       0.0          259.2      914.5        259.2      914.5
 817.0      0.0         0.0       0.0          280.8     1018.3        280.8     1018.3
 816.0      0.0         0.0       0.0          302.5     1145.0        302.5     1145.0
 815.0      0.0         0.0       0.0          324.1     1246.8        324.1     1246.8
 814.0      0.0       112.2      21.6          233.5     1345.9        345.7     1367.5
 813.0      0.0       224.5      43.3          142.9     1424.7        367.3     1468.0
 812.0      0.0       336.7      64.9           52.3     1506.0        389.0     1570.9
 811.4      0.0       401.4      77.4            0.0     1555.8        401.4     1633.1
 811.0      0.0       449.0      86.5          -38.4     1592.3        410.6     1678.8
 810.0      0.0       561.2     108.1         -129.0     1673.6        432.2     1781.8
 809.0      0.0       673.4     129.8         -226.6     1755.4        446.8     1885.2
 808.0      0.0       785.7     151.4         -321.4     1848.3        464.3     1999.6
 807.0      0.0       897.9     173.0         -426.2     1934.1        471.7     2107.1
 806.0      0.0      1010.1     194.6         -532.2     2015.3        478.0     2209.9
 805.0      0.0      1122.4     216.3         -627.9     2102.9        494.5     2319.2
 804.0      0.0      1234.6     237.9         -729.9     2194.6        504.7     2432.5
 803.0      0.0      1346.9     259.5         -829.9     2286.2        517.0     2545.8
 802.0      0.0      1459.1     281.1         -929.8     2329.9        529.3     2611.1
 801.0      0.0      1571.3     302.8        -1029.1     2302.1        542.2     2604.9
 800.0      0.0      1683.6     324.4        -1124.2     2301.4        559.4     2625.8
 799.0      0.0      1795.8     346.0        -1219.7     2374.8        576.2     2720.8
 798.0      0.0      1908.1     367.6        -1319.2     2471.5        588.9     2839.1
 797.0      0.0      2020.3     389.3        -1418.7     2558.7        601.6     2947.9
 796.0      0.0      2132.5     410.9        -1518.2     2626.1        614.3     3037.0
 795.0      0.0      2244.8     432.5        -1617.7     2702.0        627.0     3134.5
 794.0      0.0      2357.0     454.2        -1717.3     2796.5        639.7     3250.6
 793.0      0.0      2469.3     475.8        -1816.8     2890.9        652.5     3366.7
 792.0      0.0      2581.5     497.4        -1916.3     2979.8        665.2     3477.2
 791.0      0.0      2693.7     519.0        -2015.8     3048.3        677.9     3567.4
 790.0      0.0      2806.0     540.7        -2110.4     3121.6        695.6     3662.3
 789.0      0.0      2918.2     562.3        -2166.7     3214.5        751.5     3776.7
 788.0      0.0      3030.4     583.9        -2223.4     3307.3        807.0     3891.2
 787.0      0.0      3142.7     605.5        -2314.2     3400.1        828.5     4005.6
 786.0      0.0      3254.9     627.2        -2404.9     3492.9        850.1     4120.1
 785.0      0.0      3367.2     648.8        -2495.6     3585.7        871.6     4234.5
 784.0      0.0      3479.4     670.4        -2586.3     3657.8        893.1     4328.2
 783.0      0.0      3591.6     692.0        -2677.0     3727.7        914.7     4419.7
 782.0      0.0      3703.9     713.7        -2767.7     3817.7        936.2     4531.4
 781.0      0.0      3816.1     735.3        -2858.4     3909.4        957.7     4644.7
 780.0      0.0      3928.4     756.9        -2949.1     4001.0        979.3     4758.0
 779.0      0.0      4040.6     778.6        -3039.8     4092.7       1000.8     4871.2
 778.0      0.0      4152.8     800.2        -3130.5     4184.3       1022.4     4984.5
 777.0      0.0      4265.1     821.8        -3221.2     4276.0       1043.9     5097.8
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 776.0      0.0    4377.3    843.4   -3311.9    4367.7    1065.4    5211.1
 775.0      0.0    4489.5    865.1   -3402.6    4459.3    1087.0    5324.4
 774.0      0.0    4601.8    886.7   -3492.7    4551.0    1109.0    5437.7
 773.0      0.0    4714.0    908.3   -3581.0    4642.6    1133.0    5550.9
 772.0      0.0    4826.3    929.9   -3669.8    4719.4    1156.4    5649.3
 771.0      0.0    4938.5    951.6   -3760.5    4792.3    1178.0    5743.9
 770.0      0.0    5050.7    973.2   -3851.1    4879.8    1199.7    5853.0
 769.0      0.0    5163.0    994.8   -3941.7    4970.8    1221.3    5965.6
 768.0      0.0    5275.2   1016.4   -4032.3    5061.7    1242.9    6078.1
 767.0      0.0    5387.5   1038.1   -4122.9    5152.6    1264.5    6190.7
 766.0      0.0    5499.7   1059.7   -4213.5    5243.6    1286.2    6303.3
 765.0      0.0    5611.9   1081.3   -4304.1    5334.5    1307.8    6415.8
 764.0      0.0    5724.2   1102.9   -4394.7    5425.4    1329.4    6528.4
 763.0      0.0    5836.4   1124.6   -4485.4    5516.4    1351.1    6640.9
```

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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                              TIME: 15:17:18

                         ****************************
                         *  SUMMARY OF RESULTS FOR  *
                         *  CANTILEVER WALL DESIGN  *
                         ****************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'ANOKA SIDE - ALLUVIAL SANDS
    'FAILURE TOWARD UPSTREAM

  II.--SUMMARY

      RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

      LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

  WALL BOTTOM ELEV. (FT)      :      794.26
       PENETRATION (FT)       :       20.74

  MAX. BEND. MOMENT (LB-FT)   :  2.9366E+04
       AT ELEVATION (FT)      :      804.06

  MAX. SCALED DEFL. (LB-IN^3):  1.8437E+10
       AT ELEVATION (FT)      :      832.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELLASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.
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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                           TIME: 15:17:18

                      *****************************
                      * COMPLETE OF RESULTS FOR   *
                      *  CANTILEVER WALL DESIGN   *
                      *****************************

    I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'ANOKA SIDE - ALLUVIAL SANDS
    'FAILURE TOWARD UPSTREAM

   II.--RESULTS

                BENDING                              SCALED          NET
   ELEVATION     MOMENT          SHEAR             DEFLECTION      PRESSURE
     (FT)       (LB-FT)           (LB)             (LB-IN^3)        (PSF)
    832.00    0.0000E+00            0.            1.8437E+10          0.00
    831.00   -2.4447E-09            0.            1.7731E+10          0.00
    830.00   -2.4447E-09            0.            1.7025E+10          0.00
    829.00   -2.4447E-09            0.            1.6318E+10          0.00
    828.00   -2.4447E-09            0.            1.5612E+10          0.00
    827.00   -2.4447E-09            0.            1.4906E+10          0.00
    826.00    3.1432E-09            0.            1.4199E+10          0.00
    825.00   -2.4447E-09            0.            1.3493E+10          0.00
    824.00    1.3767E+01           41.            1.2787E+10         82.60
    823.00    1.0388E+02          146.            1.2081E+10        127.66
    822.00    3.2067E+02          294.            1.1374E+10        166.85
    821.00    7.0236E+02          474.            1.0669E+10        194.34
    820.00    1.2774E+03          679.            9.9646E+09        215.96
    819.00    2.0684E+03          906.            9.2626E+09        237.59
    818.00    3.0970E+03         1155.            8.5642E+09        259.22
    817.00    4.3849E+03         1425.            7.8712E+09        280.84
    816.00    5.9535E+03         1716.            7.1858E+09        302.47
    815.00    7.8247E+03         2030.            6.5107E+09        324.10
    814.00    1.0001E+04         2308.            5.8492E+09        233.48
    813.00    1.2411E+04         2497.            5.2050E+09        142.87
    812.00    1.4964E+04         2594.            4.5822E+09         52.26
    811.42    1.6466E+04         2609.            4.2345E+09          0.00
    811.00    1.7569E+04         2601.            3.9854E+09        -38.35
    810.00    2.0136E+04         2517.            3.4188E+09       -128.96
    809.00    2.2573E+04         2340.            2.8871E+09       -226.61
    808.00    2.4783E+04         2066.            2.3943E+09       -321.37
    807.00    2.6671E+04         1692.            1.9444E+09       -426.19
    806.00    2.8132E+04         1213.            1.5404E+09       -532.19
    805.00    2.9062E+04          633.            1.1850E+09       -627.88
    804.00    2.9364E+04          -46.            8.7968E+08       -729.93
    803.00    2.8936E+04         -826.            6.2502E+08       -829.87
    802.00    2.7678E+04        -1706.            4.2025E+08       -929.80
    801.00    2.5491E+04        -2685.            2.6316E+08      -1029.13
    800.00    2.2275E+04        -3762.            1.4998E+08      -1124.20
    799.57    2.0532E+04        -4260.            1.1312E+08      -1165.70
    799.00    1.7960E+04        -4800.            7.5130E+07       -746.13
    798.00    1.2910E+04        -5175.            3.1205E+07         -3.85
    797.00    7.8569E+03        -4808.            9.5894E+06        738.44
    796.00    3.5419E+03        -3698.            1.6565E+06       1480.72
    795.00    7.0762E+02        -1847.            5.7277E+04       2223.01
    794.26    0.0000E+00            0.            0.0000E+00       2771.83

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
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                         ELLASTICITY IN PSI TIMES PILE MOMENT
                         OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                         IN INCHES.

   III.--WATER AND SOIL PRESSURES

                                  <-------------SOIL PRESSURES-------------->
                  WATER           <----LEFTSIDE----->     <---RIGHTSIDE---->
 ELEVATION       PRESSURE         PASSIVE      ACTIVE      ACTIVE     PASSIVE
   (FT)           (PSF)            (PSF)        (PSF)       (PSF)      (PSF)
  832.00            0.                0.           0.          0.         0.
  831.00            0.                0.           0.          0.         0.
  830.00            0.                0.           0.          0.         0.
  829.00            0.                0.           0.          0.         0.
  828.00            0.                0.           0.          0.         0.
  827.00            0.                0.           0.          0.         0.
  826.00            0.                0.           0.          0.         0.
  825.00            0.                0.           0.          0.         0.
  824.00            0.                0.           0.         83.       429.
  823.00            0.                0.           0.        128.       663.
  822.00            0.                0.           0.        167.       866.
  821.00            0.                0.           0.        194.       792.
  820.00            0.                0.           0.        216.       710.
  819.00            0.                0.           0.        238.       847.
  818.00            0.                0.           0.        259.       915.
  817.00            0.                0.           0.        281.      1018.
  816.00            0.                0.           0.        302.      1145.
  815.00            0.                0.           0.        324.      1247.
  814.00            0.              112.          22.        346.      1367.
  813.00            0.              224.          43.        367.      1468.
  812.00            0.              337.          65.        389.      1571.
  811.42            0.              401.          77.        401.      1633.
  811.00            0.              449.          87.        411.      1679.
  810.00            0.              561.         108.        432.      1782.
  809.00            0.              673.         130.        447.      1885.
  808.00            0.              786.         151.        464.      2000.
  807.00            0.              898.         173.        472.      2107.
  806.00            0.             1010.         195.        478.      2210.
  805.00            0.             1122.         216.        495.      2319.
  804.00            0.             1235.         238.        505.      2432.
  803.00            0.             1347.         260.        517.      2546.
  802.00            0.             1459.         281.        529.      2611.
  801.00            0.             1571.         303.        542.      2605.
  800.00            0.             1684.         324.        559.      2626.
  799.57            0.             1732.         334.        567.      2667.
  799.00            0.             1796.         346.        576.      2721.
  798.00            0.             1908.         368.        589.      2839.
  797.00            0.             2020.         389.        602.      2948.
  796.00            0.             2133.         411.        614.      3037.
  795.00            0.             2245.         433.        627.      3135.
  794.26            0.             2357.         454.        640.      3251.
  793.00            0.             2469.         476.        652.      3367.
```

Stanley Consultants INC.
Computed by: L. Karels
Checked by: J. Jacks
Approved by:
Filename: SheetPile_Wall_Case2_832.xmcd

Comp Date: 03/21/2011
Print Date: 3/25/2011
Print Time: 2:04 PM

Page No. ______
Project No. 23082
Coon Rapids Dam
Upstream Cofferdam
Preliminary Design
Sheet 1 of 2

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 2 - Unusual Case

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

✓ ☑ ✓ ☑

Units:

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam for the proposed Coon Rapids Dam structural improvements. On Anoka side (existing apron side), alluviual sands are present to elevaton 775. Potential failure occuring from upstream to downstream during unusual headwater case (El. 832). Unusual headwater elevation is 2 ft above the high pool elevation (830.1) to account for freeboard.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 1.66 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 5.68\, 10^9 lbf \cdot in^3$

Wall Bottom Elevation: 805.42 ft

Required Penetration: 19.58 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \quad I_{PZ} := 184.20 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 6.596 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_27} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_27} = 1.063 \cdot in \quad f_b < 4$ in. OK.

Stanley Consultants INC.
Computed by: L. Karels
Checked by: J. Jacks
Approved by:
Filename: SheetPile_Wall_Case2_832.xmcd

Comp Date: 03/21/2011
Print Date: 3/25/2011
Print Time: 2:04 PM

Page No. _____.
Project No. 23082
Coon Rapids Dam
Upstream Coffer
Preliminary D
Sheet 2 of 2

Using a PZ 22

$S_{PZ} := 18.1\text{in}^3$ $\quad I_{PZ} := 84.38\text{in}^4$ $\quad E = 29000\cdot\text{ksi}$

Bending Stress: $\sigma_b := \dfrac{M}{S_{PZ}}$ $\quad \sigma_b = 11.006\cdot\text{ksi}$

Allowable Stress: $f_b := 0.5F_y$ $\quad f_b = 25\cdot\text{ksi}$ $\quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_22} := \dfrac{\delta_{max}}{E\cdot I_{PZ}}$ $\quad \delta_{PZ\_22} = 2.321\cdot\text{in}$ $\quad < 4$ in. OK

Conclusion

A PZ 22 (or equivalent) is adequate.

```
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'FAILURE TOWARD DOWNSTREAM
CONTROL  CANTILEVER  DESIGN  1.00  1.25
WALL   832
SURFACE RIGHTSIDE   2    0    825
                  100    825
SURFACE LEFTSIDE   4    0    825
                  10    825
                  16    822
                  100    822
SOIL RIGHTSIDE  STRENGTHS   2
   63    63    1    0    0    0    815   0
   120    120    27    0    0    0
SOIL LEFTSIDE  STRENGTHS   1
   120    120    27    0    0    0
WATER ELEVATIONS   62.4    832    822
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                           TIME: 15:02:48

                             ****************
                             *  INPUT DATA  *
                             ****************

      I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'ANOKA SIDE - ALLUVIAL SANDS
     'FAILURE TOWARD DOWNSTREAM

     II.--CONTROL
        CANTILEVER WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.25

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 832.00 FT.

     IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                0.00         825.00
              100.00         825.00

          IV.B.--LEFTSIDE
             DIST. FROM     ELEVATION
             WALL (FT)        (FT)
                0.00         825.00
               10.00         825.00
               16.00         822.00
              100.00         822.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                  ANGLE OF          ANGLE OF                           <-SAFETY->
  SAT.    MOIST   INTERNAL   COH-     WALL     ADH-   <--BOTTOM-->     <-FACTOR->
 WGHT.    WGHT.   FRICTION   ESION  FRICTION   ESION   ELEV.  SLOPE    ACT. PASS.
 (PCF)    (PCF)    (DEG)     (PSF)   (DEG)     (PSF)   (FT)  (FT/FT)
 63.00    63.00     1.00     0.00     0.00     0.00   815.00  0.00     DEF   DEF
120.00   120.00    27.00     0.00     0.00     0.00                    DEF   DEF

         V.B.--LEFTSIDE
             LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
             LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                  ANGLE OF          ANGLE OF                           <-SAFETY->
  SAT.    MOIST   INTERNAL   COH-     WALL     ADH-   <--BOTTOM-->     <-FACTOR->
 WGHT.    WGHT.   FRICTION   ESION  FRICTION   ESION   ELEV.  SLOPE    ACT. PASS.
 (PCF)    (PCF)    (DEG)     (PSF)   (DEG)     (PSF)   (FT)  (FT/FT)
120.00   120.00    27.00     0.00     0.00     0.00                    DEF   DEF

    VI.--WATER DATA
       UNIT WEIGHT          = 62.40 (PCF)
```

```
        RIGHTSIDE ELEVATION = 832.00 (FT)
        LEFTSIDE ELEVATION  = 822.00 (FT)
        NO SEEPAGE

    VII.--VERTICAL SURCHARGE LOADS
        NONE

   VIII.--HORIZONTAL LOADS
        NONE




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                         TIME: 15:02:51

                          **************************
                          *   SOIL PRESSURES FOR   *
                          * CANTILEVER WALL DESIGN *
                          **************************

    I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'ANOKA SIDE - ALLUVIAL SANDS
     'FAILURE TOWARD DOWNSTREAM

   II.--SOIL PRESSURES

       RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

       LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                        <------NET------>
          NET    <---LEFTSIDE--->       (SOIL + WATER)       <--RIGHTSIDE--->
ELEV.    WATER   PASSIVE   ACTIVE      ACTIVE   PASSIVE      ACTIVE   PASSIVE
(FT)     (PSF)    (PSF)    (PSF)        (PSF)    (PSF)        (PSF)    (PSF)
832.0      0.0      0.0      0.0          0.0      0.0          0.0      0.0
831.0     62.4      0.0      0.0         62.4     62.4          0.0      0.0
830.0    124.8      0.0      0.0        124.8    124.8          0.0      0.0
829.0    187.2      0.0      0.0        187.2    187.2          0.0      0.0
828.0    249.6      0.0      0.0        249.6    249.6          0.0      0.0
827.0    312.0      0.0      0.0        312.0    312.0          0.0      0.0
826.0    374.4      0.0      0.0        374.4    374.4          0.0      0.0
825.0    436.8      0.0      0.0        436.8    436.8          0.0      0.0
824.0    499.2    265.6     45.1        234.1    454.8          0.6      0.6
823.0    561.6    531.3     90.1         31.5    472.7          1.2      1.2
822.8    573.3    574.6     97.4          0.0    477.2          1.3      1.3
822.0    624.0    762.4    129.3       -136.6    496.5          1.7      1.9
821.0    624.0    924.4    156.8       -298.1    469.7          2.3      2.5
820.0    624.0   1051.9    178.4       -425.0    448.7          2.9      3.1
819.0    624.0    773.9    200.0       -146.5    427.7          3.5      3.7
818.0    624.0    660.8    221.7        -32.8    406.6          4.1      4.3
817.0    624.0    935.8    243.3       -307.2    385.6          4.6      4.9
816.0    624.0   1031.0    264.9       -401.8    364.6          5.2      5.6
815.0    624.0   1131.5    286.6       -498.2    378.9          9.2     41.5
```

```
 814.0    624.0    1238.1    308.2    -590.3    456.6      23.8    140.8
 813.0    624.0    1341.6    329.8    -672.1    562.5      45.5    268.3
 812.0    624.0    1444.7    351.4    -753.6    668.4      67.1    395.8
 811.0    624.0    1559.3    373.1    -846.5    774.3      88.8    523.3
 810.0    624.0    1668.5    394.7    -934.1    880.1     110.4    650.8
 809.0    624.0    1780.6    416.0   -1024.6    986.3     132.0    778.3
 808.0    624.0    1899.0    433.1   -1121.4   1096.7     153.6    905.8
 807.0    624.0    2010.4    446.9   -1211.1   1210.4     175.3   1033.3
 806.0    624.0    2132.6    464.8   -1311.7   1320.0     196.9   1160.8
 805.0    624.0    2253.1    481.6   -1410.5   1430.7     218.5   1288.4
 804.0    624.0    2363.9    493.4   -1499.8   1546.4     240.1   1415.9
 803.0    624.0    2486.3    505.2   -1600.5   1662.1     261.8   1543.4
 802.0    624.0    2617.2    521.9   -1709.8   1773.0     283.4   1670.9
 801.0    624.0    2738.7    540.2   -1809.7   1882.1     305.0   1798.4
 800.0    624.0    2850.2    553.9   -1899.6   1996.0     326.6   1925.9
 799.0    624.0    2970.1    566.2   -1997.8   2111.2     348.3   2053.4
 798.0    624.0    3099.2    578.5   -2105.3   2226.4     369.9   2180.9
 797.0    624.0    3228.4    590.8   -2212.8   2341.6     391.5   2308.4
 796.0    624.0    3357.5    603.1   -2320.4   2456.8     413.2   2435.9
 795.0    624.0    3486.6    621.0   -2427.9   2566.4     434.8   2563.4
 794.0    624.0    3601.7    639.4   -2521.3   2675.5     456.4   2690.9




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                          TIME: 15:02:54

                       ****************************
                       *   SUMMARY OF RESULTS FOR  *
                       *   CANTILEVER WALL DESIGN  *
                       ****************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'ANOKA SIDE - ALLUVIAL SANDS
    'FAILURE TOWARD DOWNSTREAM

  II.--SUMMARY

      RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

      LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

  WALL BOTTOM ELEV. (FT)      :      805.42
       PENETRATION (FT)       :       19.58

  MAX. BEND. MOMENT (LB-FT)   :  1.6672E+04
       AT ELEVATION (FT)      :      814.97

  MAX. SCALED DEFL. (LB-IN^3):   5.6862E+09
       AT ELEVATION (FT)      :      832.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELLASTICITY IN PSI TIMES PILE MOMENT
```

```
                  OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                  IN INCHES.



 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
 DATE: 21-MARCH-2011                                        TIME: 15:02:54

                         ****************************
                         * COMPLETE OF RESULTS FOR  *
                         *  CANTILEVER WALL DESIGN  *
                         ****************************

     I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'ANOKA SIDE - ALLUVIAL SANDS
     'FAILURE TOWARD DOWNSTREAM

    II.--RESULTS

                  BENDING                          SCALED          NET
    ELEVATION      MOMENT          SHEAR         DEFLECTION      PRESSURE
      (FT)        (LB-FT)           (LB)         (LB-IN^3)        (PSF)
      832.00    0.0000E+00            0.         5.6862E+09        0.00
      831.00    1.0400E+01           31.         5.3236E+09       62.40
      830.00    8.3200E+01          125.         4.9610E+09      124.80
      829.00    2.8080E+02          281.         4.5986E+09      187.20
      828.00    6.6560E+02          499.         4.2367E+09      249.60
      827.00    1.3000E+03          780.         3.8760E+09      312.00
      826.00    2.2464E+03         1123.         3.5175E+09      374.40
      825.00    3.5672E+03         1529.         3.1630E+09      436.80
      824.00    5.2806E+03         1864.         2.8147E+09      234.14
      823.00    7.2282E+03         1997.         2.4756E+09       31.48
      822.81    7.6025E+03         2000.         2.4134E+09        0.00
      822.00    9.2130E+03         1944.         2.1490E+09     -136.65
      821.00    1.1062E+04         1727.         1.8383E+09     -298.11
      820.00    1.2619E+04         1366.         1.5466E+09     -425.04
      819.00    1.3819E+04         1080.         1.2767E+09     -146.46
      818.00    1.4844E+04          990.         1.0307E+09      -32.76
      817.00    1.5772E+04          820.         8.1028E+08     -307.21
      816.00    1.6423E+04          466.         6.1708E+08     -401.81
      815.00    1.6672E+04           16.         4.5221E+08     -498.23
      814.00    1.6423E+04         -529.         3.1608E+08     -590.32
      813.00    1.5586E+04        -1160.         2.0824E+08     -672.13
      812.00    1.4076E+04        -1873.         1.2723E+08     -753.61
      811.85    1.3795E+04        -1984.         1.1752E+08     -767.16
      811.00    1.1856E+04        -2517.         7.0446E+07     -481.50
      810.00    9.1537E+03        -2831.         3.4076E+07     -147.05
      809.00    6.3048E+03        -2811.         1.3503E+07      187.40
      808.00    3.6433E+03        -2456.         3.8513E+06      521.84
      807.00    1.5036E+03        -1767.         5.7031E+05      856.29
      806.00    2.2020E+02         -744.         1.0783E+04     1190.74
      805.42    0.0000E+00            0.         0.0000E+00     1383.97

            NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                   ELLASTICITY IN PSI TIMES PILE MOMENT
                   OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                   IN INCHES.
```

```
III.--WATER AND SOIL PRESSURES

                              <-------------SOIL PRESSURES-------------->
                  WATER       <----LEFTSIDE----->     <---RIGHTSIDE---->
ELEVATION       PRESSURE      PASSIVE      ACTIVE     ACTIVE      PASSIVE
   (FT)           (PSF)        (PSF)        (PSF)      (PSF)       (PSF)
  832.00             0.           0.           0.         0.          0.
  831.00            62.           0.           0.         0.          0.
  830.00           125.           0.           0.         0.          0.
  829.00           187.           0.           0.         0.          0.
  828.00           250.           0.           0.         0.          0.
  827.00           312.           0.           0.         0.          0.
  826.00           374.           0.           0.         0.          0.
  825.00           437.           0.           0.         0.          0.
  824.00           499.         266.          45.         1.          1.
  823.00           562.         531.          90.         1.          1.
  822.81           573.         575.          97.         1.          1.
  822.00           624.         762.         129.         2.          2.
  821.00           624.         924.         157.         2.          2.
  820.00           624.        1052.         178.         3.          3.
  819.00           624.         774.         200.         3.          4.
  818.00           624.         661.         222.         4.          4.
  817.00           624.         936.         243.         5.          5.
  816.00           624.        1031.         265.         5.          6.
  815.00           624.        1131.         287.         9.         41.
  814.00           624.        1238.         308.        24.        141.
  813.00           624.        1342.         330.        45.        268.
  812.00           624.        1445.         351.        67.        396.
  811.85           624.        1461.         355.        70.        414.
  811.00           624.        1559.         373.        89.        523.
  810.00           624.        1669.         395.       110.        651.
  809.00           624.        1781.         416.       132.        778.
  808.00           624.        1899.         433.       154.        906.
  807.00           624.        2010.         447.       175.       1033.
  806.00           624.        2133.         465.       197.       1161.
  805.42           624.        2253.         482.       219.       1288.
  804.00           624.        2364.         493.       240.       1416.
```

Stanley Consultants INC.
Computed by: L. Karels
Checked by: J. Jacks
Approved by:
Filename: SheetPile_Wall_Case3_832.xmcd

Comp Date: 03/21/2011
Print Date: 3/25/2011
Print Time: 2:04 PM

Page No. ______.
Project No. 23082
Coon Rapids Dam
Upstream Cofferdam
Preliminary Design
Sheet 1 of 2

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 3 - Unusual Case - Surchages Present

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

✓ ☑ ✓ ☑

$k := 1000\cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110\cdot pcf \quad \gamma_{water} := 62.4\cdot pcf \quad \gamma_{conc} := 150\cdot pcf \quad f_c := 4\cdot ksi \quad f_y := 60\cdot ksi \quad F_y := 50\cdot ksi \quad E := 29000\cdot ksi$

$rpm := \frac{2\cdot\pi\cdot rad}{min} \quad cps := \frac{2\cdot\pi\cdot rad}{sec} \quad MPa := 10^6\cdot\frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam for the proposed Coon Rapids Dam structural improvements. On Hennepin side (existing stilling basin side), glacial till is shallow. Potential failure occuring from downstream to upstream during low headwater case (EL. 822).

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 1.76\times 10^4 lbf\cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 6.59\,10^9 lbf\cdot in^3$

Wall Bottom Elevation: 802.05 ft

Required Embedment: 12.95 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \qquad I_{PZ} := 184.20 in^4 \qquad E = 29000\cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \qquad \sigma_b = 6.993\cdot ksi$

Allowable Stress: $f_b := 0.5F_y \qquad f_b = 25\cdot ksi \qquad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_27} := \frac{\delta_{max}}{E\cdot I_{PZ}} \qquad \delta_{PZ\_27} = 1.234\cdot in$ < 4 in. OK.

Using a PZ 22

$S_{PZ} := 18.1\text{in}^3$ $\quad I_{PZ} := 84.38\text{in}^4$ $\quad E = 29000\cdot\text{ksi}$

Bending Stress: $\sigma_b := \dfrac{M}{S_{PZ}}$ $\quad \sigma_b = 11.669\cdot\text{ksi}$

Allowable Stress: $f_b := 0.5F_y$ $\quad f_b = 25\cdot\text{ksi}$ $\quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_22} := \dfrac{\delta_{max}}{E\cdot I_{PZ}}$ $\quad \delta_{PZ\_22} = 2.693\cdot\text{in}$ $\quad$ < 4 in. OK

Conclusion

A PZ 22 (or equivalent) is adequate.

```
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'FAILURE TOWARD UPSTREAM
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   832
SURFACE RIGHTSIDE   4    0     825
                  10    825
                  16    822
                  100    822
SURFACE LEFTSIDE   2    0     815
                  100    815
SOIL RIGHTSIDE  STRENGTHS   2
   120     120     27    0     0     0     815    0
   135     135     37    0     0     0
SOIL LEFTSIDE  STRENGTHS   1
   135     135     37    0     0     0
WATER ELEVATIONS   62.4    822     822
VERTICAL STRIP  RIGHTSIDE   2    0     10     100
                     16     40     200
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                          TIME: 15:18:19

                             ****************
                             *  INPUT DATA  *
                             ****************

       I.--HEADING
      'COON RAPIDS DAM
      'UPSTREAM COFFERDAM ANALYSIS
      'HENNEPIN SIDE - GLACIAL TILL
      'FAILURE TOWARD UPSTREAM

      II.--CONTROL
         CANTILEVER WALL DESIGN
         FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
         FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

     III.--WALL DATA
         ELEVATION AT TOP OF WALL    = 832.00 FT.

      IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                0.00        825.00
               10.00        825.00
               16.00        822.00
              100.00        822.00

         IV.B.--LEFTSIDE
            DIST. FROM     ELEVATION
            WALL (FT)        (FT)
                0.00        815.00
              100.00        815.00

       V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                   ANGLE OF          ANGLE OF                          <-SAFETY->
   SAT.    MOIST   INTERNAL   COH-     WALL     ADH-    <--BOTTOM-->   <-FACTOR->
  WGHT.    WGHT.   FRICTION   ESION  FRICTION   ESION   ELEV.  SLOPE   ACT. PASS.
  (PCF)    (PCF)    (DEG)     (PSF)    (DEG)    (PSF)   (FT)  (FT/FT)
 120.00   120.00    27.00     0.00     0.00     0.00   815.00   0.00    DEF  DEF
 135.00   135.00    37.00     0.00     0.00     0.00                    DEF  DEF

        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                   ANGLE OF          ANGLE OF                          <-SAFETY->
   SAT.    MOIST   INTERNAL   COH-     WALL     ADH-    <--BOTTOM-->   <-FACTOR->
  WGHT.    WGHT.   FRICTION   ESION  FRICTION   ESION   ELEV.  SLOPE   ACT. PASS.
  (PCF)    (PCF)    (DEG)     (PSF)    (DEG)    (PSF)   (FT)  (FT/FT)
 135.00   135.00    37.00     0.00     0.00     0.00                    DEF  DEF

     VI.--WATER DATA
        UNIT WEIGHT           = 62.40 (PCF)
```

```
        RIGHTSIDE ELEVATION = 822.00 (FT)
        LEFTSIDE ELEVATION  = 822.00 (FT)
        NO SEEPAGE

    VII.--VERTICAL SURCHARGE LOADS

        VII.A.--VERTICAL LINE LOADS
             NONE

        VII.B.--VERTICAL UNIFORM LOADS
                  NONE

        VII.C.--VERTICAL STRIP LOADS

             VII.C.1.--RIGHTSIDE
             <-DIST. FROM WALL->
               START       END       STRIP LOAD
               (FT)        (FT)        (PSF)
               0.00       10.00       100.00
              16.00       40.00       200.00

             VII.C.2.--LEFTSIDE
                  NONE

        VII.D.--VERTICAL RAMP LOADS
             NONE

        VII.E.--VERTICAL TRIANGULAR LOADS
             NONE

        VII.F.--VERTICAL VARIABLE LOADS
             NONE

  VIII.--HORIZONTAL LOADS
       NONE







PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                           TIME: 15:18:21

                           ***************************
                           *   SOIL PRESSURES FOR    *
                           * CANTILEVER WALL DESIGN  *
                           ***************************

    I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'FAILURE TOWARD UPSTREAM

   II.--SOIL PRESSURES

       RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.
```

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           LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                            <------NET------>
             NET      <---LEFTSIDE--->       (SOIL + WATER)      <--RIGHTSIDE--->
   ELEV.    WATER     PASSIVE    ACTIVE      ACTIVE   PASSIVE     ACTIVE   PASSIVE
   (FT)     (PSF)      (PSF)     (PSF)       (PSF)     (PSF)      (PSF)     (PSF)
   832.0      0.0        0.0       0.0         0.0       0.0        0.0       0.0
   831.0      0.0        0.0       0.0         0.0       0.0        0.0       0.0
   830.0      0.0        0.0       0.0         0.0       0.0        0.0       0.0
   829.0      0.0        0.0       0.0         0.0       0.0        0.0       0.0
   828.0      0.0        0.0       0.0         0.0       0.0        0.0       0.0
   827.0      0.0        0.0       0.0         0.0       0.0        0.0       0.0
   826.0      0.0        0.0       0.0         0.0       0.0        0.0       0.0
   825.0      0.0        0.0       0.0         0.0       0.0        0.0       0.0
   824.0      0.0        0.0       0.0        82.6     428.7       82.6     428.7
   823.0      0.0        0.0       0.0       127.7     662.5      127.7     662.5
   822.0      0.0        0.0       0.0       166.9     866.0      166.9     866.0
   821.0      0.0        0.0       0.0       194.3     792.5      194.3     792.5
   820.0      0.0        0.0       0.0       216.0     709.8      216.0     709.8
   819.0      0.0        0.0       0.0       237.6     847.3      237.6     847.3
   818.0      0.0        0.0       0.0       259.2     914.5      259.2     914.5
   817.0      0.0        0.0       0.0       280.8    1018.3      280.8    1018.3
   816.0      0.0        0.0       0.0       302.5    1145.0      302.5    1145.0
   815.0      0.0        0.0       0.0       265.8    1550.9      265.8    1550.9
   814.0      0.0      190.9      18.0        36.2    1997.0      227.2    2015.1
   813.8      0.0      231.2      21.8         0.0    2029.1      231.2    2050.9
   813.0      0.0      381.9      36.1      -135.5    2148.9      246.4    2185.0
   812.0      0.0      572.8      54.1      -306.5    2308.4      266.3    2362.6
   811.0      0.0      763.7      72.2      -479.0    2482.7      284.7    2554.9
   810.0      0.0      954.7      90.2      -652.0    2613.4      302.6    2703.6
   809.0      0.0     1145.6     108.3      -825.1    2702.7      320.5    2810.9
   808.0      0.0     1336.5     126.3      -998.1    2798.2      338.5    2924.5
   807.0      0.0     1527.5     144.3     -1172.0    2941.9      355.5    3086.2
   806.0      0.0     1718.4     162.4     -1350.9    3140.3      367.5    3302.7
   805.0      0.0     1909.3     180.4     -1534.4    3331.3      374.9    3511.8
   804.0      0.0     2100.3     198.5     -1711.3    3505.1      388.9    3703.6
   803.0      0.0     2291.2     216.5     -1894.5    3678.9      396.7    3895.4
   802.0      0.0     2482.1     234.5     -2081.4    3768.1      400.7    4002.7
   801.0      0.0     2673.1     252.6     -2255.9    3795.1      417.2    4047.7
   800.0      0.0     2864.0     270.6     -2432.0    3909.3      432.0    4179.9
   799.0      0.0     3054.9     288.7     -2612.6    4068.3      442.3    4357.0
   798.0      0.0     3245.9     306.7     -2793.2    4210.1      452.6    4516.9
   797.0      0.0     3436.8     324.8     -2973.9    4370.3      462.9    4695.0
   796.0      0.0     3627.7     342.8     -3154.5    4546.0      473.3    4888.8
   795.0      0.0     3818.7     360.8     -3335.1    4681.3      483.6    5042.2
   794.0      0.0     4009.6     378.9     -3515.7    4791.7      493.9    5170.6
   793.0      0.0     4200.5     396.9     -3696.4    4942.5      504.2    5339.4
   792.0      0.0     4391.5     415.0     -3874.4    5118.3      517.1    5533.2
   791.0      0.0     4582.4     433.0     -4048.1    5294.0      534.3    5727.0
   790.0      0.0     4773.3     451.0     -4223.0    5469.7      550.3    5920.8
   789.0      0.0     4964.3     469.1     -4400.8    5645.5      563.4    6114.6
   788.0      0.0     5155.2     487.1     -4578.6    5808.5      576.6    6295.6
   787.0      0.0     5346.1     505.2     -4756.4    5950.6      589.7    6455.8
   786.0      0.0     5537.1     523.2     -4921.8    6104.5      615.3    6627.8
   785.0      0.0     5728.0     541.3     -5056.1    6278.3      671.9    6819.6
   784.0      0.0     5918.9     559.3     -5198.9    6452.1      720.1    7011.4
   783.0      0.0     6109.9     577.3     -5368.6    6625.8      741.3    7203.2
   782.0      0.0     6300.8     595.4     -5538.2    6799.6      762.6    7395.0
   781.0      0.0     6491.7     613.4     -5716.3    6973.4      775.4    7586.8
   780.0      0.0     6682.7     631.5     -5899.6    7147.1      783.1    7778.6
   779.0      0.0     6873.6     649.5     -6076.0    7320.9      797.6    7970.4
   778.0      0.0     7064.5     667.6     -6249.0    7494.7      815.6    8162.2
```

```
  777.0      0.0     7255.5    685.6   -6421.9    7668.5     833.6     8354.0
  776.0      0.0     7446.4    703.6   -6594.8    7842.2     851.6     8545.9
  775.0      0.0     7637.3    721.7   -6767.8    8016.0     869.6     8737.7
  774.0      0.0     7828.3    739.7   -6940.7    8189.8     887.6     8929.5
  773.0      0.0     8019.2    757.8   -7113.6    8363.5     905.6     9121.3
  772.0      0.0     8210.2    775.8   -7286.6    8537.3     923.6     9313.1
  771.0      0.0     8401.1    793.8   -7459.5    8711.1     941.6     9504.9
  770.0      0.0     8592.0    811.9   -7632.4    8884.8     959.6     9696.7
  769.0      0.0     8783.0    829.9   -7805.4    9052.4     977.6     9882.3
  768.0      0.0     8973.9    848.0   -7978.3    9202.9     995.6    10050.9
  767.0      0.0     9164.8    866.0   -8151.2    9359.2    1013.6    10225.2
  766.0      0.0     9355.8    884.1   -8324.2    9532.1    1031.6    10416.1
  765.0      0.0     9546.7    902.1   -8497.1    9705.0    1049.6    10607.1
  764.0      0.0     9737.6    920.1   -8670.0    9877.9    1067.6    10798.0
  763.0      0.0     9928.6    938.2   -8843.0   10050.8    1085.6    10988.9




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                           TIME: 15:18:22

                       *****************************
                       *   SUMMARY OF RESULTS FOR  *
                       *   CANTILEVER WALL DESIGN  *
                       *****************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD UPSTREAM

  II.--SUMMARY

      RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

      LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

  WALL BOTTOM ELEV. (FT)      :       802.03
       PENETRATION (FT)       :        12.97

  MAX. BEND. MOMENT (LB-FT)   :   1.7563E+04
       AT ELEVATION (FT)      :       808.78

  MAX. SCALED DEFL. (LB-IN^3):    6.5936E+09
       AT ELEVATION (FT)      :       832.00

         NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                ELLASTICITY IN PSI TIMES PILE MOMENT
                OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                IN INCHES.
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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                        BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                   TIME: 15:18:22

                    *****************************
                    * COMPLETE OF RESULTS FOR   *
                    *  CANTILEVER WALL DESIGN   *
                    *****************************

    I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD UPSTREAM

   II.--RESULTS

                  BENDING                      SCALED        NET
   ELEVATION      MOMENT         SHEAR       DEFLECTION    PRESSURE
     (FT)         (LB-FT)        (LB)        (LB-IN^3)      (PSF)
    832.00      0.0000E+00          0.       6.5936E+09       0.00
    831.00      1.7462E-10          0.       6.2901E+09       0.00
    830.00      1.7462E-10          0.       5.9866E+09       0.00
    829.00      1.7462E-10          0.       5.6831E+09       0.00
    828.00      1.7462E-10          0.       5.3796E+09       0.00
    827.00      1.7462E-10          0.       5.0762E+09       0.00
    826.00      1.7462E-10          0.       4.7727E+09       0.00
    825.00      1.7462E-10          0.       4.4692E+09       0.00
    824.00      1.3767E+01         41.       4.1657E+09      82.60
    823.00      1.0388E+02        146.       3.8623E+09     127.66
    822.00      3.2067E+02        294.       3.5590E+09     166.85
    821.00      7.0236E+02        474.       3.2563E+09     194.34
    820.00      1.2774E+03        679.       2.9549E+09     215.96
    819.00      2.0684E+03        906.       2.6557E+09     237.59
    818.00      3.0970E+03       1155.       2.3601E+09     259.22
    817.00      4.3849E+03       1425.       2.0700E+09     280.84
    816.00      5.9535E+03       1716.       1.7874E+09     302.47
    815.00      7.8150E+03       2000.       1.5151E+09     265.82
    814.00      9.9101E+03       2151.       1.2564E+09      36.24
    813.79      1.0365E+04       2155.       1.2039E+09       0.00
    813.00      1.2051E+04       2102.       1.0149E+09    -135.49
    812.00      1.4057E+04       1881.       7.9408E+08    -306.55
    811.00      1.5755E+04       1488.       5.9756E+08    -479.03
    810.00      1.6975E+04        923.       4.2819E+08    -652.05
    809.00      1.7543E+04        184.       2.8806E+08    -825.07
    808.00      1.7285E+04       -728.       1.7813E+08    -998.08
    807.00      1.6030E+04      -1813.       9.7923E+07   -1172.01
    806.00      1.3601E+04      -3074.       4.5246E+07   -1350.92
    805.41      1.1560E+04      -3898.       2.5560E+07   -1458.55
    805.00      9.8414E+03      -4369.       1.5877E+07    -819.39
    804.00      5.3204E+03      -4416.       3.3982E+06     726.13
    803.00      1.5254E+03      -2917.       2.1759E+05    2271.65
    802.03      0.0000E+00          0.       0.0000E+00    3765.11

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELLASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.

  III.--WATER AND SOIL PRESSURES

                          <------------SOIL PRESSURES-------------->
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```
                 WATER       <----LEFTSIDE----->       <---RIGHTSIDE---->
ELEVATION       PRESSURE      PASSIVE     ACTIVE       ACTIVE      PASSIVE
  (FT)           (PSF)         (PSF)      (PSF)        (PSF)        (PSF)
 832.00            0.            0.         0.           0.           0.
 831.00            0.            0.         0.           0.           0.
 830.00            0.            0.         0.           0.           0.
 829.00            0.            0.         0.           0.           0.
 828.00            0.            0.         0.           0.           0.
 827.00            0.            0.         0.           0.           0.
 826.00            0.            0.         0.           0.           0.
 825.00            0.            0.         0.           0.           0.
 824.00            0.            0.         0.          83.         429.
 823.00            0.            0.         0.         128.         663.
 822.00            0.            0.         0.         167.         866.
 821.00            0.            0.         0.         194.         792.
 820.00            0.            0.         0.         216.         710.
 819.00            0.            0.         0.         238.         847.
 818.00            0.            0.         0.         259.         915.
 817.00            0.            0.         0.         281.        1018.
 816.00            0.            0.         0.         302.        1145.
 815.00            0.            0.         0.         266.        1551.
 814.00            0.          191.        18.         227.        2015.
 813.79            0.          231.        22.         231.        2051.
 813.00            0.          382.        36.         246.        2185.
 812.00            0.          573.        54.         266.        2363.
 811.00            0.          764.        72.         285.        2555.
 810.00            0.          955.        90.         303.        2704.
 809.00            0.         1146.       108.         321.        2811.
 808.00            0.         1337.       126.         338.        2925.
 807.00            0.         1527.       144.         355.        3086.
 806.00            0.         1718.       162.         367.        3303.
 805.41            0.         1830.       173.         372.        3425.
 805.00            0.         1909.       180.         375.        3512.
 804.00            0.         2100.       198.         389.        3704.
 803.00            0.         2291.       217.         397.        3895.
 802.03            0.         2482.       235.         401.        4003.
 801.00            0.         2673.       253.         417.        4048.
```

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 4 - Unusual Case

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

✓ ☑ ✓ ☑

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam for the proposed Coon Rapids Dam structural improvements. On Hennepin side (existing stilling basin side), glacial till is shallow.. Potential failure occuring from upstream to downstream during unusual headwater case (El. 832). Unusual headwater elevation is 2 ft above the high pool elevation (830.1) to account for freeboard.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 1.67 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 4.76\, 10^9 lbf \cdot in^3$

Wall Bottom Elevation: 807.69 ft

Required Penetration: 17.31 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \quad I_{PZ} := 184.20 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 6.636 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_27} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_27} = 0.891 \cdot in$ < 4 in. OK.

Stanley Consultants INC.
Computed by: L. Karels
Checked by: J. Jacks
Approved by:
Filename: SheetPile_Wall_Case4_832.xmcd

Comp Date: 03/21/2011
Print Date: 3/25/2011
Print Time: 2:04 PM

Page No. ______
Project No. 23082
Coon Rapids Dam
Upstream Cofferdam
Preliminary Design
Sheet 2 of 2

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $I_{PZ} := 84.38 in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 11.072 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_22} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_22} = 1.945 \cdot in$ < 4 in. OK

Conclusion

A PZ 22 (or equivalent) is adequate.

```
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'FAILURE TOWARD DOWNSTREAM
CONTROL  CANTILEVER  DESIGN  1.00  1.25
WALL   832
SURFACE RIGHTSIDE    2     0     827
                  100     827
SURFACE LEFTSIDE    4     0     825
                  10     825
                  16     822
                  100     822
SOIL RIGHTSIDE   STRENGTHS    2
   63     63     1     0     0     0     815    0
   135     135     37     0     0     0
SOIL LEFTSIDE   STRENGTHS    2
   120     120     27     0     0     0     815    0
   135     135     37     0     0     0
WATER ELEVATIONS    62.4     832     822
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                        BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                          TIME: 15:15:10

                          ****************
                          *  INPUT DATA  *
                          ****************

     I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD DOWNSTREAM

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.25

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 832.00 FT.

    IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM      ELEVATION
            WALL (FT)         (FT)
                0.00         827.00
              100.00         827.00

         IV.B.--LEFTSIDE
            DIST. FROM      ELEVATION
            WALL (FT)         (FT)
                0.00         825.00
               10.00         825.00
               16.00         822.00
              100.00         822.00

     V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                   ANGLE OF          ANGLE OF                          <-SAFETY->
  SAT.     MOIST   INTERNAL   COH-     WALL     ADH-   <--BOTTOM-->  <-FACTOR->
 WGHT.     WGHT.   FRICTION   ESION  FRICTION   ESION  ELEV.  SLOPE  ACT.  PASS.
 (PCF)     (PCF)    (DEG)     (PSF)    (DEG)    (PSF)  (FT)  (FT/FT)
  63.00    63.00     1.00      0.00     0.00     0.00 815.00   0.00   DEF   DEF
 135.00   135.00    37.00      0.00     0.00     0.00                 DEF   DEF

        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                   ANGLE OF          ANGLE OF                          <-SAFETY->
  SAT.     MOIST   INTERNAL   COH-     WALL     ADH-   <--BOTTOM-->  <-FACTOR->
 WGHT.     WGHT.   FRICTION   ESION  FRICTION   ESION  ELEV.  SLOPE  ACT.  PASS.
 (PCF)     (PCF)    (DEG)     (PSF)    (DEG)    (PSF)  (FT)  (FT/FT)
 120.00   120.00    27.00      0.00     0.00     0.00 815.00   0.00   DEF   DEF
 135.00   135.00    37.00      0.00     0.00     0.00                 DEF   DEF

   VI.--WATER DATA
```

```
          UNIT WEIGHT         = 62.40 (PCF)
          RIGHTSIDE ELEVATION = 832.00 (FT)
          LEFTSIDE ELEVATION  = 822.00 (FT)
          NO SEEPAGE

      VII.--VERTICAL SURCHARGE LOADS
          NONE

     VIII.--HORIZONTAL LOADS
          NONE




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                            TIME: 15:15:13

                            **************************
                            *   SOIL PRESSURES FOR   *
                            * CANTILEVER WALL DESIGN *
                            **************************

     I.--HEADING
      'COON RAPIDS DAM
      'UPSTREAM COFFERDAM ANALYSIS
      'HENNEPIN SIDE - GLACIAL TILL
      'FAILURE TOWARD DOWNSTREAM

    II.--SOIL PRESSURES

         RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

         LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                         <------NET------>
          NET      <---LEFTSIDE--->      (SOIL + WATER)       <--RIGHTSIDE--->
ELEV.    WATER    PASSIVE    ACTIVE     ACTIVE    PASSIVE     ACTIVE   PASSIVE
(FT)     (PSF)     (PSF)     (PSF)      (PSF)      (PSF)      (PSF)     (PSF)
832.0      0.0       0.0       0.0        0.0        0.0        0.0       0.0
831.0     62.4       0.0       0.0       62.4       62.4        0.0       0.0
830.0    124.8       0.0       0.0      124.8      124.8        0.0       0.0
829.0    187.2       0.0       0.0      187.2      187.2        0.0       0.0
828.0    249.6       0.0       0.0      249.6      249.6        0.0       0.0
827.0    312.0       0.0       0.0      312.0      312.0        0.0       0.0
826.0    374.4       0.0       0.0      375.0      375.0        0.0       0.0
825.0    436.8       0.0       0.0      438.0      438.0        0.6       0.6
824.0    499.2     265.6      45.1      235.3      456.0        1.2       1.2
823.0    561.6     531.3      90.1       32.6      474.0        1.7       1.9
822.8    573.7     576.1      97.7        0.0      478.6        2.3       2.5
822.0    624.0     762.4     129.3     -135.5      497.8        2.4       2.6
821.0    624.0     924.4     156.8     -296.9      470.9        2.9       3.1
820.0    624.0    1051.9     178.4     -423.9      449.9        3.5       3.7
819.0    624.0     773.9     200.0     -145.3      428.9        4.1       4.3
818.0    624.0     660.8     221.7      -31.6      407.9        4.6       4.9
817.0    624.0     935.8     243.3     -306.1      386.9        5.2       5.6
816.0    624.0    1031.0     264.9     -400.7      365.9        5.8       6.2
                                                                6.4       6.8
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 815.0   624.0   1532.4   234.9    -899.8    460.9    8.6     71.8
 814.0   624.0   2054.4   202.9   -1410.7    671.4   19.7    250.3
 813.0   624.0   2211.1   222.3   -1549.2    879.5   37.9    477.8
 812.0   624.0   2403.3   242.0   -1723.4   1087.5   55.9    705.4
 811.0   624.0   2582.1   260.0   -1884.2   1297.0   74.0    933.0
 810.0   624.0   2713.6   277.9   -1997.6   1506.7   92.0   1160.7
 809.0   624.0   2828.2   295.9   -2094.2   1716.4  110.0   1388.3
 808.0   624.0   2983.9   313.8   -2231.8   1926.1  128.1   1615.9
 807.0   624.0   3200.5   331.9   -2430.3   2135.7  146.1   1843.5
 806.0   624.0   3404.4   350.7   -2616.2   2344.4  164.2   2071.1
 805.0   624.0   3603.7   365.8   -2797.5   2556.9  182.2   2298.8
 804.0   624.0   3833.0   375.7   -3008.7   2774.6  200.3   2526.4
 803.0   624.0   4064.5   387.7   -3222.2   2990.3  218.3   2754.0
 802.0   624.0   4296.1   405.2   -3435.7   3200.4  236.3   2981.6
 801.0   624.0   4502.2   420.1   -3623.9   3413.1  254.4   3209.2
 800.0   624.0   4704.5   429.9   -3808.1   3631.0  272.4   3436.8
 799.0   624.0   4930.7   439.6   -4016.3   3848.9  290.5   3664.5
 798.0   624.0   5159.5   449.3   -4227.0   4066.8  308.5   3892.1
 797.0   624.0   5388.3   463.8   -4437.7   4279.9  326.5   4119.7
 796.0   624.0   5617.0   481.5   -4648.4   4489.8  344.6   4347.3
 795.0   624.0   5845.8   494.7   -4859.2   4704.3  362.6   4574.9
 794.0   624.0   6074.6   505.0   -5069.9   4921.6  380.7   4802.5
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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                          TIME: 15:15:13

                     ****************************
                     *   SUMMARY OF RESULTS FOR   *
                     *   CANTILEVER WALL DESIGN   *
                     ****************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD DOWNSTREAM

  II.--SUMMARY

       RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

       LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

  WALL BOTTOM ELEV. (FT)      :       807.69
       PENETRATION (FT)       :        17.31

  MAX. BEND. MOMENT (LB-FT)   :   1.6692E+04
       AT ELEVATION (FT)      :       815.20

  MAX. SCALED DEFL. (LB-IN^3):   4.7552E+09
       AT ELEVATION (FT)      :       832.00

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
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         ELLASTICITY IN PSI TIMES PILE MOMENT
         OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
         IN INCHES.



PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                          TIME: 15:15:13

                    ****************************
                    * COMPLETE OF RESULTS FOR  *
                    *  CANTILEVER WALL DESIGN  *
                    ****************************

    I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD DOWNSTREAM

   II.--RESULTS

                  BENDING                          SCALED
   ELEVATION      MOMENT          SHEAR          DEFLECTION        NET
     (FT)         (LB-FT)          (LB)          (LB-IN^3)       PRESSURE
                                                                  (PSF)
    832.00      0.0000E+00          0.           4.7552E+09        0.00
    831.00      1.0400E+01         31.           4.4348E+09       62.40
    830.00      8.3200E+01        125.           4.1143E+09      124.80
    829.00      2.8080E+02        281.           3.7941E+09      187.20
    828.00      6.6560E+02        499.           3.4744E+09      249.60
    827.00      1.3000E+03        780.           3.1558E+09      312.00
    826.00      2.2465E+03       1123.           2.8396E+09      374.98
    825.00      3.5680E+03       1530.           2.5272E+09      437.96
    824.00      5.2831E+03       1867.           2.2211E+09      235.30
    823.00      7.2336E+03       2001.           1.9242E+09       32.64
    822.81      7.6224E+03       2004.           1.8679E+09        0.00
    822.00      9.2224E+03       1949.           1.6398E+09     -135.49
    821.00      1.1077E+04       1733.           1.3713E+09     -296.95
    820.00      1.2640E+04       1372.           1.1218E+09     -423.88
    819.00      1.3847E+04       1088.           8.9422E+08     -145.30
    818.00      1.4881E+04        999.           6.9050E+08      -31.60
    817.00      1.5819E+04        831.           5.1248E+08     -306.05
    816.00      1.6481E+04        477.           3.6176E+08     -400.65
    815.00      1.6675E+04       -173.           2.3945E+08     -899.77
    814.00      1.5967E+04      -1328.           1.4583E+08    -1410.68
    813.76      1.5615E+04      -1664.           1.2788E+08    -1443.28
    813.00      1.3963E+04      -2602.           7.9605E+07    -1010.94
    812.00      1.0949E+04      -3331.           3.7361E+07     -445.59
    811.00      7.4902E+03      -3493.           1.3974E+07      119.76
    810.00      4.1509E+03      -3091.           3.5465E+06      685.11
    809.00      1.4966E+03      -2123.           3.9079E+05     1250.47
    808.00      9.2866E+01       -590.           1.3003E+03     1815.82
    807.69      0.0000E+00          0.           0.0000E+00     1991.08

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELLASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.

  III.--WATER AND SOIL PRESSURES
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                               <-------------SOIL PRESSURES-------------->
                     WATER     <----LEFTSIDE----->     <---RIGHTSIDE---->
  ELEVATION        PRESSURE     PASSIVE     ACTIVE      ACTIVE    PASSIVE
    (FT)             (PSF)       (PSF)       (PSF)       (PSF)     (PSF)
   832.00              0.          0.          0.          0.        0.
   831.00             62.          0.          0.          0.        0.
   830.00            125.          0.          0.          0.        0.
   829.00            187.          0.          0.          0.        0.
   828.00            250.          0.          0.          0.        0.
   827.00            312.          0.          0.          0.        0.
   826.00            374.          0.          0.          1.        1.
   825.00            437.          0.          0.          1.        1.
   824.00            499.        266.         45.          2.        2.
   823.00            562.        531.         90.          2.        2.
   822.81            574.        576.         98.          2.        3.
   822.00            624.        762.        129.          3.        3.
   821.00            624.        924.        157.          3.        4.
   820.00            624.       1052.        178.          4.        4.
   819.00            624.        774.        200.          5.        5.
   818.00            624.        661.        222.          5.        6.
   817.00            624.        936.        243.          6.        6.
   816.00            624.       1031.        265.          6.        7.
   815.00            624.       1532.        235.          9.       72.
   814.00            624.       2054.        203.         20.      250.
   813.76            624.       2091.        207.         24.      304.
   813.00            624.       2211.        222.         38.      478.
   812.00            624.       2403.        242.         56.      705.
   811.00            624.       2582.        260.         74.      933.
   810.00            624.       2714.        278.         92.     1161.
   809.00            624.       2828.        296.        110.     1388.
   808.00            624.       2984.        314.        128.     1616.
   807.69            624.       3200.        332.        146.     1844.
   806.00            624.       3404.        351.        164.     2071.
```

Sheet Pile Cofferdam Structural Analysis

Upstream Cantilevered Cofferdam

Usual Headwater Elevation (830.1)

Stanley Consultants INC.
Computed by: L. Karels
Checked by: J. Jacks
Approved by:
Filename: SheetPile_Wall_Case2_830.xmcd

Comp Date: 03/21/2011
Print Date: 3/25/2011
Print Time: 2:05 PM

Page No. ____
Project No. 23082
Coon Rapids Dam
Upstream Cofferdam
Preliminary Design
Sheet 1 of

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 2 - Usual Case

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

✓ ☑ ✓ ☑

$k := 1000 \cdot lbf$ $kpf := \frac{k}{ft}$ $ksf := \frac{k}{ft^2}$ $ksi := \frac{k}{in^2}$ $kcf := \frac{k}{ft^3}$ $ppf := \frac{lbf}{ft}$ $psf := \frac{lbf}{ft^2}$ $psi := \frac{lbf}{in^2}$ $pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\gamma_{water} := 62.4 \cdot pcf$ $\gamma_{conc} := 150 \cdot pcf$ $f_c := 4 \cdot ksi$ $f_y := 60 \cdot ksi$ $F_y := 50 \cdot ksi$ $E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam for the proposed Coon Rapids Dam structural improvements. On Anoka side (existing apron side), alluviual sands are present to elevaton 775. Potential failure occuring from upstream to downstream during usual headwater case (El. 830.1).

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 6.19 \times 10^3 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.28\,10^9 lbf \cdot in^3$

Wall Bottom Elevation: 810.32 ft

Required Penetration: 14.68 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3$ $I_{PZ} := 184.20 in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 2.46 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_27} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_27} = 0.24 \cdot in$ $f_b < 4$ in. OK.

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $I_{PZ} := 84.38 in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 4.104 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_22} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_22} = 0.523 \cdot in$ < 4 in. OK

Conclusion

A PZ 22 (or equivalent) is adequate.

```
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'ANOKA SIDE - ALLUVIAL SANDS
'FAILURE TOWARD DOWNSTREAM
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   832
SURFACE RIGHTSIDE    2     0    825
                   100    825
SURFACE LEFTSIDE    4     0    825
                   10     825
                   16     822
                   100     822
SOIL RIGHTSIDE   STRENGTHS    2
   63     63     1     0     0     0     815    0
   120     120     27     0     0     0
SOIL LEFTSIDE   STRENGTHS    1
   120     120     27     0     0     0
WATER ELEVATIONS    62.4    830.1    822
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                       BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                         TIME: 15:22:01

                          ****************
                          *  INPUT DATA  *
                          ****************

     I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'ANOKA SIDE - ALLUVIAL SANDS
    'FAILURE TOWARD DOWNSTREAM

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

   III.--WALL DATA
       ELEVATION AT TOP OF WALL    = 832.00 FT.

    IV.--SURFACE POINT DATA

        IV.A.--RIGHTSIDE
           DIST. FROM     ELEVATION
           WALL (FT)        (FT)
              0.00         825.00
            100.00         825.00

        IV.B.--LEFTSIDE
           DIST. FROM     ELEVATION
           WALL (FT)        (FT)
              0.00         825.00
             10.00         825.00
             16.00         822.00
            100.00         822.00

     V.--SOIL LAYER DATA

       V.A.--RIGHTSIDE
           LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
           LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                  ANGLE OF        ANGLE OF                          <-SAFETY->
  SAT.    MOIST   INTERNAL  COH-    WALL    ADH-   <--BOTTOM-->    <-FACTOR->
  WGHT.   WGHT.   FRICTION  ESION FRICTION  ESION  ELEV.   SLOPE   ACT.  PASS.
  (PCF)   (PCF)    (DEG)    (PSF)   (DEG)   (PSF)  (FT)   (FT/FT)
  63.00   63.00     1.00    0.00    0.00    0.00  815.00   0.00     DEF   DEF
 120.00  120.00    27.00    0.00    0.00    0.00                    DEF   DEF

       V.B.--LEFTSIDE
           LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
           LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                  ANGLE OF        ANGLE OF                          <-SAFETY->
  SAT.    MOIST   INTERNAL  COH-    WALL    ADH-   <--BOTTOM-->    <-FACTOR->
  WGHT.   WGHT.   FRICTION  ESION FRICTION  ESION  ELEV.   SLOPE   ACT.  PASS.
  (PCF)   (PCF)    (DEG)    (PSF)   (DEG)   (PSF)  (FT)   (FT/FT)
 120.00  120.00    27.00    0.00    0.00    0.00                    DEF   DEF

    VI.--WATER DATA
       UNIT WEIGHT          = 62.40 (PCF)
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     RIGHTSIDE ELEVATION = 830.10 (FT)
     LEFTSIDE ELEVATION  = 822.00 (FT)
     NO SEEPAGE

 VII.--VERTICAL SURCHARGE LOADS
     NONE

VIII.--HORIZONTAL LOADS
     NONE




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                          TIME: 15:22:04

                             *************************
                             *   SOIL PRESSURES FOR   *
                             * CANTILEVER WALL DESIGN *
                             *************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'ANOKA SIDE - ALLUVIAL SANDS
    'FAILURE TOWARD DOWNSTREAM

  II.--SOIL PRESSURES

       RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

       LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                        <------NET------>
         NET     <---LEFTSIDE--->       (SOIL + WATER)      <--RIGHTSIDE--->
ELEV.   WATER    PASSIVE   ACTIVE     ACTIVE    PASSIVE    ACTIVE    PASSIVE
(FT)    (PSF)     (PSF)    (PSF)      (PSF)      (PSF)      (PSF)     (PSF)
832.0     0.0       0.0      0.0        0.0        0.0        0.0       0.0
831.0     0.0       0.0      0.0        0.0        0.0        0.0       0.0
830.1     0.0       0.0      0.0        0.0        0.0        0.0       0.0
830.0     6.2       0.0      0.0        6.2        6.2        0.0       0.0
829.0    68.6       0.0      0.0       68.6       68.6        0.0       0.0
828.0   131.0       0.0      0.0      131.0      131.0        0.0       0.0
827.0   193.4       0.0      0.0      193.4      193.4        0.0       0.0
826.0   255.8       0.0      0.0      255.8      255.8        0.0       0.0
825.0   318.2       0.0      0.0      318.2      318.2        0.0       0.0
824.0   380.6     233.8     45.1      147.4      336.2        0.6       0.0
823.1   434.5     435.6     83.9        0.0      351.7        1.1       0.6
823.0   443.0     467.7     90.1      -23.5      354.2        1.2       1.1
822.0   505.4     671.1    129.3     -163.9      378.0        1.7       1.2
821.0   505.4     813.7    156.8     -306.0      351.1        2.3       1.8
820.0   505.4     926.0    178.4     -417.6      330.1        2.9       2.5
819.0   505.4    1038.2    200.0     -529.3      309.1        3.5       3.1
818.0   505.4     590.4    221.7      -80.9      288.1        4.1       3.7
817.0   505.4     648.0    243.3     -137.9      267.1        4.6       4.3
816.0   505.4     927.5    264.9     -416.8      246.0        5.2       4.9
```

```
 815.0     505.4     1017.4     286.6     -502.8      255.7        9.2      36.8
 814.0     505.4     1108.4     308.2     -579.2      321.2       23.8     124.0
 813.0     505.4     1195.8     329.8     -644.8      411.8       45.5     236.2
 812.0     505.4     1290.7     351.4     -718.1      502.4       67.1     348.4
 811.0     505.4     1389.5     373.1     -795.3      593.0       88.8     460.6
 810.0     505.4     1484.9     394.7     -869.1      683.6      110.4     572.9
 809.0     505.4     1584.9     416.0     -947.4      774.6      132.0     685.1
 808.0     505.4     1686.6     433.1    -1027.5      869.7      153.6     797.4
 807.0     505.4     1785.5     446.9    -1104.8      968.1      175.3     909.6
 806.0     505.4     1892.7     464.8    -1190.4     1062.4      196.9    1021.8
 805.0     505.4     1994.6     481.6    -1270.7     1157.9      218.5    1134.1
 804.0     505.4     2092.5     493.4    -1347.0     1258.3      240.1    1246.3
 803.0     505.4     2205.8     505.2    -1438.6     1358.8      261.8    1358.6
 802.0     505.4     2314.5     521.9    -1525.7     1454.3      283.4    1470.8
 801.0     505.4     2412.9     540.2    -1602.4     1548.2      305.0    1583.0
 800.0     505.4     2517.8     553.9    -1685.7     1646.8      326.6    1695.3
 799.0     505.4     2632.3     566.2    -1778.6     1746.7      348.3    1807.5
 798.0     505.4     2746.7     578.5    -1871.4     1846.7      369.9    1919.7
 797.0     505.4     2852.8     590.8    -1955.9     1946.6      391.5    2032.0
 796.0     505.4     2951.9     603.1    -2033.3     2046.5      413.2    2144.2
 795.0     505.4     3058.7     621.0    -2118.5     2140.9      434.8    2256.5
 794.0     505.4     3172.0     639.4    -2210.1     2234.7      456.4    2368.7




 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
 DATE: 21-MARCH-2011                                         TIME: 15:22:04

                        ****************************
                        *   SUMMARY OF RESULTS FOR   *
                        *   CANTILEVER WALL DESIGN   *
                        ****************************

    I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'ANOKA SIDE - ALLUVIAL SANDS
     'FAILURE TOWARD DOWNSTREAM

   II.--SUMMARY

       RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

       LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

   WALL BOTTOM ELEV. (FT)      :      810.32
        PENETRATION (FT)       :       14.68

   MAX. BEND. MOMENT (LB-FT)   :   6.1870E+03
        AT ELEVATION (FT)      :      819.11

   MAX. SCALED DEFL. (LB-IN^3):   1.2771E+09
        AT ELEVATION (FT)      :      832.00

           NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
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                   ELLASTICITY IN PSI TIMES PILE MOMENT
                   OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                   IN INCHES.




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                       BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                        TIME: 15:22:04

                    ****************************
                    * COMPLETE OF RESULTS FOR  *
                    *  CANTILEVER WALL DESIGN  *
                    ****************************

    I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'ANOKA SIDE - ALLUVIAL SANDS
    'FAILURE TOWARD DOWNSTREAM

   II.--RESULTS

                  BENDING                        SCALED          NET
   ELEVATION      MOMENT           SHEAR       DEFLECTION      PRESSURE
     (FT)         (LB-FT)          (LB)        (LB-IN^3)        (PSF)
    832.00      0.0000E+00            0.       1.2771E+09         0.00
    831.00      8.7311E-11            0.       1.1799E+09         0.00
    830.10     -3.3967E-10            0.       1.0923E+09         0.00
    830.00      1.0400E-02            0.       1.0826E+09         6.24
    829.00      1.3842E+01           38.       9.8530E+08        68.64
    828.00      9.6314E+01          138.       8.8805E+08       131.04
    827.00      3.0983E+02          300.       7.9100E+08       193.44
    826.00      7.1678E+02          524.       6.9450E+08       255.84
    825.00      1.3796E+03          812.       5.9928E+08       318.24
    824.00      2.3217E+03         1044.       5.0649E+08       147.39
    823.14      3.2592E+03         1108.       4.2961E+08         0.00
    823.00      3.4113E+03         1106.       4.1772E+08       -23.46
    822.00      4.4824E+03         1013.       3.3486E+08      -163.92
    821.00      5.3894E+03          778.       2.5971E+08      -305.97
    820.00      5.9954E+03          416.       1.9383E+08      -417.63
    819.00      6.1839E+03          -58.       1.3825E+08      -529.29
    818.00      5.9364E+03         -363.       9.3293E+07       -80.90
    817.00      5.5237E+03         -472.       5.8572E+07      -137.92
    816.06      4.9775E+03         -727.       3.4549E+07      -401.18
    816.00      4.9361E+03         -749.       3.3372E+07      -390.86
    815.00      4.0226E+03        -1048.       1.6651E+07      -206.78
    814.00      2.9024E+03        -1162.       6.8519E+06       -22.69
    813.00      1.7594E+03        -1093.       2.0643E+06       161.39
    812.00      7.7779E+02         -840.       3.4015E+05       345.48
    811.00      1.4169E+02         -402.       9.7988E+03       529.56
    810.32      0.0000E+00            0.       0.0000E+00       654.55

          NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                 ELLASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.

  III.--WATER AND SOIL PRESSURES

                         <-------------SOIL PRESSURES-------------->
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                 WATER      <----LEFTSIDE----->     <---RIGHTSIDE---->
ELEVATION      PRESSURE     PASSIVE      ACTIVE     ACTIVE     PASSIVE
   (FT)          (PSF)       (PSF)        (PSF)      (PSF)       (PSF)
  832.00           0.          0.           0.         0.          0.
  831.00           0.          0.           0.         0.          0.
  830.10           0.          0.           0.         0.          0.
  830.00           6.          0.           0.         0.          0.
  829.00          69.          0.           0.         0.          0.
  828.00         131.          0.           0.         0.          0.
  827.00         193.          0.           0.         0.          0.
  826.00         256.          0.           0.         0.          0.
  825.00         318.          0.           0.         0.          0.
  824.00         381.        234.          45.         1.          1.
  823.14         434.        436.          84.         1.          1.
  823.00         443.        468.          90.         1.          1.
  822.00         505.        671.         129.         2.          2.
  821.00         505.        814.         157.         2.          2.
  820.00         505.        926.         178.         3.          3.
  819.00         505.       1038.         200.         3.          4.
  818.00         505.        590.         222.         4.          4.
  817.00         505.        648.         243.         5.          5.
  816.06         505.        912.         264.         5.          5.
  816.00         505.        927.         265.         5.          6.
  815.00         505.       1017.         287.         9.         37.
  814.00         505.       1108.         308.        24.        124.
  813.00         505.       1196.         330.        45.        236.
  812.00         505.       1291.         351.        67.        348.
  811.00         505.       1390.         373.        89.        461.
  810.32         505.       1485.         395.       110.        573.
  809.00         505.       1585.         416.       132.        685.
```

Stanley Consultants INC.
Computed by: L. Karels
Checked by: J. Jacks
Approved by:
Filename: SheetPile_Wall_Case4_830.xmcd

Comp Date: 03/21/2011
Print Date: 3/25/2011
Print Time: 2:05 PM

Page No. ______.
Project No. 23082
Coon Rapids Dam
Upstream Cofferdam
Preliminary Design
Sheet 1 of 2

Coon Rapids Dam Cofferdam Sheet Pile Wall - CASE 4 - Usual Case

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

✓ ☑ ✓ ☑

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam for the proposed Coon Rapids Dam structural improvements. On Hennepin side (existing stilling basin side), glacial till is shallow.. Potential failure occuring from upstream to downstream during usual headwater case (El. 830.1).

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 6.21 \times 10^3 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 1.24\,10^9 lbf \cdot in^3$

Wall Bottom Elevation: 811.16 ft

Required Penetration: 13.84 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \quad I_{PZ} := 184.20 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 2.468 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y \quad f_b = 25 \cdot ksi \quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_27} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_27} = 0.232 \cdot in$ < 4 in. OK.

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $I_{PZ} := 84.38 in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 4.117 \cdot ksi$

Allowable Stress: $f_b := 0.5 F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_22} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_22} = 0.507 \cdot in$ < 4 in. OK

Conclusion

A PZ 22 (or equivalent) is adequate.

```
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'FAILURE TOWARD DOWNSTREAM
CONTROL  CANTILEVER  DESIGN  1.00  1.50
WALL   832
SURFACE RIGHTSIDE   2    0    827
                  100    827
SURFACE LEFTSIDE   4    0    825
                  10    825
                  16    822
                  100    822
SOIL RIGHTSIDE  STRENGTHS   2
   63    63    1    0    0    0    815   0
   135    135    37    0    0    0
SOIL LEFTSIDE  STRENGTHS   2
   120    120    27    0    0    0    815   0
   135    135    37    0    0    0
WATER ELEVATIONS   62.4    830.1    822
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                        BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                             TIME: 15:24:48

                           ****************
                           *  INPUT DATA  *
                           ****************

      I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'FAILURE TOWARD DOWNSTREAM

     II.--CONTROL
        CANTILEVER WALL DESIGN
        FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
        FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50

    III.--WALL DATA
        ELEVATION AT TOP OF WALL    = 832.00 FT.

     IV.--SURFACE POINT DATA

         IV.A.--RIGHTSIDE
            DIST. FROM      ELEVATION
            WALL (FT)         (FT)
                 0.00        827.00
               100.00        827.00

         IV.B.--LEFTSIDE
            DIST. FROM      ELEVATION
            WALL (FT)         (FT)
                 0.00        825.00
                10.00        825.00
                16.00        822.00
               100.00        822.00

      V.--SOIL LAYER DATA

         V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                   ANGLE OF           ANGLE OF                            <-SAFETY->
   SAT.    MOIST   INTERNAL   COH-      WALL      ADH-    <--BOTTOM-->   <-FACTOR->
  WGHT.    WGHT.   FRICTION   ESION   FRICTION    ESION   ELEV.   SLOPE   ACT. PASS.
  (PCF)    (PCF)    (DEG)     (PSF)    (DEG)      (PSF)   (FT)   (FT/FT)
  63.00    63.00     1.00      0.00     0.00       0.00  815.00    0.00    DEF  DEF
 135.00   135.00    37.00      0.00     0.00       0.00                    DEF  DEF

         V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                   ANGLE OF           ANGLE OF                            <-SAFETY->
   SAT.    MOIST   INTERNAL   COH-      WALL      ADH-    <--BOTTOM-->   <-FACTOR->
  WGHT.    WGHT.   FRICTION   ESION   FRICTION    ESION   ELEV.   SLOPE   ACT. PASS.
  (PCF)    (PCF)    (DEG)     (PSF)    (DEG)      (PSF)   (FT)   (FT/FT)
 120.00   120.00    27.00      0.00     0.00       0.00  815.00    0.00    DEF  DEF
 135.00   135.00    37.00      0.00     0.00       0.00                    DEF  DEF

    VI.--WATER DATA
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```
          UNIT WEIGHT          = 62.40 (PCF)
          RIGHTSIDE ELEVATION = 830.10 (FT)
          LEFTSIDE ELEVATION  = 822.00 (FT)
          NO SEEPAGE

      VII.--VERTICAL SURCHARGE LOADS
          NONE

     VIII.--HORIZONTAL LOADS
          NONE




 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
 DATE: 21-MARCH-2011                                          TIME: 15:24:51

                             **************************
                             *   SOIL PRESSURES FOR   *
                             * CANTILEVER WALL DESIGN *
                             **************************

     I.--HEADING
      'COON RAPIDS DAM
      'UPSTREAM COFFERDAM ANALYSIS
      'HENNEPIN SIDE - GLACIAL TILL
      'FAILURE TOWARD DOWNSTREAM

    II.--SOIL PRESSURES

         RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

         LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                          <------NET------>
           NET      <---LEFTSIDE--->     (SOIL + WATER)     <--RIGHTSIDE--->
 ELEV.    WATER    PASSIVE   ACTIVE     ACTIVE   PASSIVE    ACTIVE   PASSIVE
 (FT)     (PSF)     (PSF)    (PSF)      (PSF)     (PSF)     (PSF)     (PSF)
 832.0     0.0       0.0      0.0        0.0       0.0       0.0       0.0
 831.0     0.0       0.0      0.0        0.0       0.0       0.0       0.0
 830.1     0.0       0.0      0.0        0.0       0.0       0.0       0.0
 830.0     6.2       0.0      0.0        6.2       6.2       0.0       0.0
 829.0    68.6       0.0      0.0       68.6      68.6       0.0       0.0
 828.0   131.0       0.0      0.0      131.0     131.0       0.0       0.0
 827.0   193.4       0.0      0.0      193.4     193.4       0.0       0.0
 826.0   255.8       0.0      0.0      256.4     256.5       0.6       0.6
 825.0   318.2       0.0      0.0      319.4     319.5       1.2       1.2
 824.0   380.6     233.8     45.1      148.5     337.4       1.7       1.8
 823.1   434.9     437.1     84.2        0.0     353.0       2.2       2.4
 823.0   443.0     467.7     90.1      -22.3     355.4       2.3       2.5
 822.0   505.4     671.1    129.3     -162.8     379.2       2.9       3.1
 821.0   505.4     813.7    156.8     -304.8     352.3       3.5       3.7
 820.0   505.4     926.0    178.4     -416.5     331.3       4.1       4.3
 819.0   505.4    1038.2    200.0     -528.1     310.3       4.6       4.9
 818.0   505.4     590.4    221.7      -79.7     289.3       5.2       5.5
 817.0   505.4     648.0    243.3     -136.8     268.3       5.8       6.1
```

```
  816.0     505.4      927.5     264.9     -415.7     247.3       6.4        6.8
  815.0     505.4     1332.9     234.9     -818.9     331.3       8.6       60.8
  814.0     505.4     1750.6     202.9    -1225.5     512.5      19.7      209.9
  813.0     505.4     1875.8     222.3    -1332.5     684.0      37.9      400.8
  812.0     505.4     2026.2     242.0    -1464.8     855.2      55.9      591.7
  811.0     505.4     2173.9     260.0    -1594.5    1028.1      74.0      782.7
  810.0     505.4     2295.2     277.9    -1697.7    1201.1      92.0      973.6
  809.0     505.4     2404.1     295.9    -1788.7    1374.1     110.0     1164.5
  808.0     505.4     2539.3     313.8    -1905.8    1547.1     128.1     1355.5
  807.0     505.4     2694.0     331.9    -2042.5    1720.0     146.1     1546.4
  806.0     505.4     2866.4     350.7    -2196.8    1892.1     164.2     1737.3
  805.0     505.4     3063.3     365.8    -2375.7    2067.9     182.2     1928.3
  804.0     505.4     3235.9     375.7    -2530.2    2248.9     200.3     2119.2
  803.0     505.4     3404.2     387.7    -2680.5    2427.9     218.3     2310.1
  802.0     505.4     3595.4     405.2    -2853.6    2601.3     236.3     2501.1
  801.0     505.4     3789.2     420.1    -3029.4    2777.3     254.4     2692.0
  800.0     505.4     3983.0     429.9    -3205.1    2958.5     272.4     2882.9
  799.0     505.4     4165.4     439.6    -3369.5    3139.7     290.5     3073.9
  798.0     505.4     4336.4     449.3    -3522.5    3320.9     308.5     3264.8
  797.0     505.4     4517.8     463.8    -3685.9    3497.4     326.5     3455.7
  796.0     505.4     4709.7     481.5    -3859.6    3670.7     344.6     3646.7
  795.0     505.4     4901.5     494.7    -4033.4    3848.4     362.6     3837.6
  794.0     505.4     5093.3     505.0    -4207.2    4029.0     380.7     4028.5
```

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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                           TIME: 15:24:51

                         ***************************
                         *   SUMMARY OF RESULTS FOR   *
                         *   CANTILEVER WALL DESIGN   *
                         ***************************

  I.--HEADING
   'COON RAPIDS DAM
   'UPSTREAM COFFERDAM ANALYSIS
   'HENNEPIN SIDE - GLACIAL TILL
   'FAILURE TOWARD DOWNSTREAM

 II.--SUMMARY

     RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

     LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

 WALL BOTTOM ELEV. (FT)      :       811.16
      PENETRATION (FT)       :        13.84

 MAX. BEND. MOMENT (LB-FT)   :   6.2148E+03
      AT ELEVATION (FT)      :       819.09

 MAX. SCALED DEFL. (LB-IN^3):   1.2390E+09
      AT ELEVATION (FT)      :       832.00
```

```
       NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
              ELLASTICITY IN PSI TIMES PILE MOMENT
              OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
              IN INCHES.




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 21-MARCH-2011                                           TIME: 15:24:51

                         *****************************
                         * COMPLETE OF RESULTS FOR   *
                         *  CANTILEVER WALL DESIGN   *
                         *****************************

     I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'FAILURE TOWARD DOWNSTREAM

    II.--RESULTS

                    BENDING                        SCALED         NET
    ELEVATION       MOMENT          SHEAR        DEFLECTION     PRESSURE
      (FT)          (LB-FT)          (LB)        (LB-IN^3)        (PSF)
     832.00       0.0000E+00          0.         1.2390E+09        0.00
     831.00       3.4925E-10          0.         1.1436E+09        0.00
     830.10      -5.6986E-11          0.         1.0577E+09        0.00
     830.00       1.0400E-02          0.         1.0482E+09        6.24
     829.00       1.3842E+01         38.         9.5276E+08       68.64
     828.00       9.6314E+01        138.         8.5737E+08      131.04
     827.00       3.0983E+02        300.         7.6217E+08      193.44
     826.00       7.1687E+02        525.         6.6753E+08      256.42
     825.00       1.3803E+03        813.         5.7416E+08      319.40
     824.00       2.3242E+03       1047.         4.8323E+08      148.55
     823.13       3.2717E+03       1111.         4.0738E+08        0.00
     823.00       3.4167E+03       1110.         3.9633E+08      -22.30
     822.00       4.4919E+03       1017.         3.1533E+08     -162.76
     821.00       5.4041E+03        783.         2.4207E+08     -304.81
     820.00       6.0165E+03        423.         1.7811E+08     -416.47
     819.00       6.2125E+03        -49.         1.2448E+08     -528.13
     818.00       5.9736E+03       -353.         8.1518E+07      -79.75
     817.00       5.5708E+03       -462.         4.8860E+07     -136.77
     816.00       4.9943E+03       -738.         2.5807E+07     -415.65
     815.60       4.6611E+03       -937.         1.9054E+07     -577.15
     815.00       4.0086E+03      -1219.         1.1322E+07     -364.00
     814.00       2.6670E+03      -1405.         3.7123E+06       -8.45
     813.00       1.3170E+03      -1236.         7.0971E+05      347.10
     812.00       3.1409E+02       -711.         3.2922E+04      702.65
     811.16       0.0000E+00          0.         0.0000E+00      999.60

       NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
              ELLASTICITY IN PSI TIMES PILE MOMENT
              OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
              IN INCHES.

   III.--WATER AND SOIL PRESSURES

                         <-------------SOIL PRESSURES-------------->
```

```
                              Case_4_830.out
                   WATER      <----LEFTSIDE----->      <---RIGHTSIDE---->
  ELEVATION      PRESSURE     PASSIVE      ACTIVE      ACTIVE    PASSIVE
     (FT)          (PSF)       (PSF)        (PSF)       (PSF)      (PSF)
    832.00           0.           0.           0.         0.         0.
    831.00           0.           0.           0.         0.         0.
    830.10           0.           0.           0.         0.         0.
    830.00           6.           0.           0.         0.         0.
    829.00          69.           0.           0.         0.         0.
    828.00         131.           0.           0.         0.         0.
    827.00         193.           0.           0.         0.         0.
    826.00         256.           0.           0.         0.         0.
    825.00         318.           0.           0.         1.         1.
    824.00         381.         234.          45.         1.         1.
    823.13         435.         437.          84.         2.         2.
    823.00         443.         468.          90.         2.         2.
    822.00         505.         671.         129.         2.         2.
    821.00         505.         814.         157.         3.         3.
    820.00         505.         926.         178.         3.         4.
    819.00         505.        1038.         200.         4.         4.
    818.00         505.         590.         222.         5.         5.
    817.00         505.         648.         243.         5.         6.
    816.00         505.         927.         265.         6.         6.
    815.60         505.        1090.         253.         6.         7.
    815.00         505.        1333.         235.         7.        28.
    814.00         505.        1751.         203.         9.        61.
    813.00         505.        1876.         222.        20.       210.
    812.00         505.        2026.         242.        38.       401.
    811.16         505.        2174.         260.        56.       592.
    810.00         505.        2295.         278.        74.       783.
                                                         92.       974.
```

Sheet Pile Cofferdam Structural Analysis

Partial Earthen Upstream Cofferdam

Unusual Headwater Elevation (832)

Coon Rapids Dam Cofferdam Sheet Pile Wall - Partial Earthen Embankment - Unusual Case - Alluvium Present to 795 - 5 ft of Stickup

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

✓ ☑ ✓ ☑

$k := 1000 \cdot lbf$ $kpf := \frac{k}{ft}$ $ksf := \frac{k}{ft^2}$ $ksi := \frac{k}{in^2}$ $kcf := \frac{k}{ft^3}$ $ppf := \frac{lbf}{ft}$ $psf := \frac{lbf}{ft^2}$ $psi := \frac{lbf}{in^2}$ $pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf$ $\gamma_{water} := 62.4 \cdot pcf$ $\gamma_{conc} := 150 \cdot pcf$ $f_c := 4 \cdot ksi$ $f_y := 60 \cdot ksi$ $F_y := 50 \cdot ksi$ $E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min}$ $cps := \frac{2 \cdot \pi \cdot rad}{sec}$ $MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam with an earhen embankment to elevation 827 and sheet pile to elevation 832 (5 ft of stickup) and Unusual headwater to elevation 832. Alluvium present tc elevation 795 (point at which original solution no longer works).

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 5.96 \times 10^3 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 9.29\ 10^8 lbf \cdot in^3$

Wall Bottom Elevation: 814.48 ft

Required Penetration: 12.52 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2in^3$ $I_{PZ} := 184.20in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 2.368 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_27} := \dfrac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_27} = 0.174 \cdot in$ < 4 in. OK.

Using a PZ 22

$S_{PZ} := 18.1 in^3$ $I_{PZ} := 84.38 in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \dfrac{M}{S_{PZ}}$ $\sigma_b = 3.951 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_22} := \dfrac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_22} = 0.38 \cdot in$ < 4 in. OK

Conclusion

A PZ 22 (or equivalent) is adequate.

```
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'FAILURE TOWARD DOWNSTREAM
CONTROL  CANTILEVER  DESIGN  1.00  1.25
WALL   832
SURFACE RIGHTSIDE    4     0     827
                  5     827
                  41     815
                  100     815
SURFACE LEFTSIDE    4     0     827
                  5     827
                  41     815
                  100     815
SOIL RIGHTSIDE  STRENGTHS    2
   120     120     27     0     0     0     815     0
   125     125     32     0     0     0
SOIL LEFTSIDE  STRENGTHS    2
   120     120     27     0     0     0     815     0
   125     125     32     0     0     0
WATER ELEVATIONS    62.4     832     815
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                          TIME: 12:50:10

                            ****************
                            *  INPUT DATA  *
                            ****************

      I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'FAILURE TOWARD DOWNSTREAM

    II.--CONTROL
       CANTILEVER WALL DESIGN
       FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
       FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.25

   III.--WALL DATA
       ELEVATION AT TOP OF WALL     = 832.00 FT.

    IV.--SURFACE POINT DATA

        IV.A.--RIGHTSIDE
           DIST. FROM     ELEVATION
           WALL (FT)        (FT)
              0.00         827.00
              5.00         827.00
             41.00         815.00
            100.00         815.00

        IV.B.--LEFTSIDE
           DIST. FROM     ELEVATION
           WALL (FT)        (FT)
              0.00         827.00
              5.00         827.00
             41.00         815.00
            100.00         815.00

    V.--SOIL LAYER DATA

      V.A.--RIGHTSIDE
         LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
         LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                   ANGLE OF            ANGLE OF                           <-SAFETY->
  SAT.    MOIST    INTERNAL   COH-      WALL      ADH-    <--BOTTOM-->    <-FACTOR->
 WGHT.    WGHT.    FRICTION   ESION   FRICTION    ESION   ELEV.   SLOPE   ACT. PASS.
 (PCF)    (PCF)     (DEG)     (PSF)    (DEG)      (PSF)   (FT)   (FT/FT)
120.00   120.00     27.00     0.00      0.00      0.00   815.00    0.00    DEF   DEF
125.00   125.00     32.00     0.00      0.00      0.00                     DEF   DEF

      V.B.--LEFTSIDE
         LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
         LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                   ANGLE OF            ANGLE OF                           <-SAFETY->
  SAT.    MOIST    INTERNAL   COH-      WALL      ADH-    <--BOTTOM-->    <-FACTOR->
 WGHT.    WGHT.    FRICTION   ESION   FRICTION    ESION   ELEV.   SLOPE   ACT. PASS.
 (PCF)    (PCF)     (DEG)     (PSF)    (DEG)      (PSF)   (FT)   (FT/FT)
120.00   120.00     27.00     0.00      0.00      0.00   815.00    0.00    DEF   DEF
125.00   125.00     32.00     0.00      0.00      0.00                     DEF   DEF
```

```
    VI.--WATER DATA
         UNIT WEIGHT          = 62.40 (PCF)
         RIGHTSIDE ELEVATION = 832.00 (FT)
         LEFTSIDE ELEVATION  = 815.00 (FT)
         NO SEEPAGE

   VII.--VERTICAL SURCHARGE LOADS
         NONE

  VIII.--HORIZONTAL LOADS
         NONE




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                           BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                             TIME: 12:50:13

                           **************************
                           *    SOIL PRESSURES FOR   *
                           * CANTILEVER WALL DESIGN *
                           **************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD DOWNSTREAM

  II.--SOIL PRESSURES

       RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

       LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                         <------NET------>
          NET     <---LEFTSIDE--->        (SOIL + WATER)      <--RIGHTSIDE--->
ELEV.    WATER    PASSIVE   ACTIVE       ACTIVE   PASSIVE     ACTIVE   PASSIVE
(FT)     (PSF)     (PSF)    (PSF)        (PSF)     (PSF)      (PSF)     (PSF)
832.0      0.0       0.0      0.0          0.0       0.0        0.0       0.0
831.0     62.4       0.0      0.0         62.4      62.4        0.0       0.0
830.0    124.8       0.0      0.0        124.8     124.8        0.0       0.0
829.0    187.2       0.0      0.0        187.2     187.2        0.0       0.0
828.0    249.6       0.0      0.0        249.6     249.6        0.0       0.0
827.0    312.0       0.0      0.0        312.0     312.0        0.0       0.0
826.0    374.4     265.6     45.1        130.4     456.9       21.6     127.5
825.3    419.2     456.4     77.4          0.0     560.8       37.2     219.0
825.0    436.8     531.3     90.1        -51.2     601.7       43.3     255.0
824.0    499.2     759.0    135.2       -195.0     728.4       64.9     364.3
823.0    561.6     890.8    180.2       -242.7     809.0       86.5     427.6
822.0    624.0     993.9    225.3       -261.7     875.8      108.1     477.1
821.0    686.4    1130.3    270.3       -314.2     958.6      129.8     542.6
820.0    748.8    1273.3    315.4       -373.1    1044.6      151.4     611.2
819.0    811.2    1417.2    359.6       -433.4    1131.9      172.6     680.3
818.0    873.6    1561.6    400.2       -496.0    1223.0      192.1     749.6
```

```
 817.0    936.0     1708.1    438.8     -561.4    1317.0     210.6     819.9
 816.0    998.4     1854.5    478.6     -626.3    1410.0     229.7     890.1
 815.0   1060.8     2475.4    463.2    -1189.8    1818.0     224.8    1220.4
 814.0   1060.8     2912.2    433.8    -1633.2    2141.3     218.2    1514.4
 813.0   1060.8     2745.3    446.7    -1450.1    2162.4     234.4    1548.3
 812.0   1060.8     2309.8    462.4     -997.2    2219.2     251.8    1620.8
 811.0   1060.8     1954.1    477.6     -624.2    2282.6     269.1    1699.4
 810.0   1060.8     2099.9    490.3     -753.9    2352.4     285.2    1781.9
 809.0   1060.8     2210.3    503.1     -848.2    2418.7     301.3    1860.9
 808.0   1060.8     2329.3    515.8     -951.2    2479.4     317.3    1934.4
 807.0   1060.8     2430.9    528.5    -1036.7    2540.6     333.4    2008.3
 806.0   1060.8     2543.0    541.2    -1132.7    2614.8     349.5    2095.2
 805.0   1060.8     2666.1    554.6    -1239.6    2724.9     365.8    2218.7
 804.0   1060.8     2748.0    570.8    -1304.9    2827.8     382.4    2337.7
 803.0   1060.8     2918.0    586.9    -1458.2    2946.4     399.0    2472.5
 802.0   1060.8     3006.0    601.1    -1529.4    3055.5     415.7    2595.9
 801.0   1060.8     3136.0    615.4    -1642.7    3171.4     432.4    2726.0
 800.0   1060.8     3282.5    629.6    -1772.5    3302.2     449.1    2870.9
 799.0   1060.8     3367.3    643.8    -1840.7    3405.7     465.8    2988.8
 798.0   1060.8     3521.3    658.0    -1977.8    3554.5     482.7    3151.7
 797.0   1060.8     3673.5    672.3    -2112.9    3676.6     499.8    3288.1
 796.0   1060.8     3759.6    686.5    -2182.0    3779.0     516.8    3404.7




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                            TIME: 12:50:13

                    ******************************
                    *   SUMMARY OF RESULTS FOR   *
                    *   CANTILEVER WALL DESIGN   *
                    ******************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD DOWNSTREAM

  II.--SUMMARY

     RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

     LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

  WALL BOTTOM ELEV. (FT)      :       814.48
       PENETRATION (FT)       :        12.52

  MAX. BEND. MOMENT (LB-FT)   :   5.9656E+03
       AT ELEVATION (FT)      :       820.52

  MAX. SCALED DEFL. (LB-IN^3):   9.2875E+08
       AT ELEVATION (FT)      :       832.00

         NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
```

```
ELLASTICITY IN PSI TIMES PILE MOMENT
OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
IN INCHES.




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                        BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                         TIME: 12:50:13

                    *****************************
                    * COMPLETE OF RESULTS FOR   *
                    *   CANTILEVER WALL DESIGN  *
                    *****************************

   I.--HEADING
   'COON RAPIDS DAM
   'UPSTREAM COFFERDAM ANALYSIS
   'HENNEPIN SIDE - GLACIAL TILL
   'FAILURE TOWARD DOWNSTREAM

  II.--RESULTS

                 BENDING                             SCALED
 ELEVATION       MOMENT            SHEAR           DEFLECTION       NET
   (FT)          (LB-FT)            (LB)           (LB-IN^3)      PRESSURE
                                                                   (PSF)
   832.00      0.0000E+00             0.           9.2875E+08        0.00
   831.00      1.0400E+01            31.           8.4220E+08       62.40
   830.00      8.3200E+01           125.           7.5568E+08      124.80
   829.00      2.8080E+02           281.           6.6932E+08      187.20
   828.00      6.6560E+02           499.           5.8347E+08      249.60
   827.00      1.3000E+03           780.           4.9880E+08      312.00
   826.00      2.2057E+03          1001.           4.1643E+08      130.39
   825.28      2.9469E+03          1048.           3.5955E+08        0.00
   825.00      3.2418E+03          1041.           3.3788E+08      -51.23
   824.00      4.2331E+03           918.           2.6493E+08     -194.95
   823.00      5.0453E+03           699.           1.9927E+08     -242.67
   822.00      5.6197E+03           447.           1.4229E+08     -261.74
   821.00      5.9267E+03           159.           9.4979E+07     -314.17
   820.00      5.9185E+03          -185.           5.7869E+07     -373.08
   819.00      5.5370E+03          -588.           3.0932E+07     -433.45
   818.00      4.7217E+03         -1053.           1.3500E+07     -495.95
   817.00      3.4099E+03         -1582.           4.1557E+06     -561.40
   816.85      3.1590E+03         -1669.           3.3006E+06     -571.43
   816.00      1.6524E+03         -1765.           6.3018E+05      343.86
   815.00      2.3953E+02          -880.           9.5716E+03     1426.28
   814.48      0.0000E+00             0.           0.0000E+00     1984.86

           NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                  ELLASTICITY IN PSI TIMES PILE MOMENT
                  OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                  IN INCHES.

 III.--WATER AND SOIL PRESSURES

                             <-------------SOIL PRESSURES-------------->
                  WATER      <----LEFTSIDE----->      <---RIGHTSIDE---->
 ELEVATION      PRESSURE     PASSIVE      ACTIVE      ACTIVE     PASSIVE
   (FT)           (PSF)       (PSF)       (PSF)       (PSF)       (PSF)
  832.00            0.          0.          0.          0.          0.
  831.00           62.          0.          0.          0.          0.
```

```
  830.00          125.         0.         0.         0.         0.
  829.00          187.         0.         0.         0.         0.
  828.00          250.         0.         0.         0.         0.
  827.00          312.         0.         0.         0.         0.
  826.00          374.       266.        45.        22.       128.
  825.28          419.       456.        77.        37.       219.
  825.00          437.       531.        90.        43.       255.
  824.00          499.       759.       135.        65.       364.
  823.00          562.       891.       180.        87.       428.
  822.00          624.       994.       225.       108.       477.
  821.00          686.      1130.       270.       130.       543.
  820.00          749.      1273.       315.       151.       611.
  819.00          811.      1417.       360.       173.       680.
  818.00          874.      1562.       400.       192.       750.
  817.00          936.      1708.       439.       211.       820.
  816.85          946.      1731.       445.       214.       831.
  816.00          998.      1854.       479.       230.       890.
  815.00         1061.      2475.       463.       225.      1220.
  814.48         1061.      2912.       434.       218.      1514.
  813.00         1061.      2745.       447.       234.      1548.
```

Coon Rapids Dam Cofferdam Sheet Pile Wall - Partial Earthen Embankment - Unusual Case - Shallow Glacial Till - 5 ft of Stickup

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

✓ ☑ ✓ ☑

$k := 1000\cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110\cdot pcf \quad \gamma_{water} := 62.4\cdot pcf \quad \gamma_{conc} := 150\cdot pcf \quad f_c := 4\cdot ksi \quad f_y := 60\cdot ksi \quad F_y := 50\cdot ksi \quad E := 29000\cdot ksi$

$rpm := \frac{2\cdot\pi\cdot rad}{min} \quad cps := \frac{2\cdot\pi\cdot rad}{sec} \quad MPa := 10^6\cdot\frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam with an earhen embankment to elevation 827 and sheet pile to elevation 832 (5 ft of stickup) and Unusual headwater to elevation 832. Dense glacial till assumed at elevation 815. Check for adequate embedment assuming maximum driving penetration of 5 ft.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 5.96\times 10^3 lbf\cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 9.26\,10^8 lbf\cdot in^3$

Wall Bottom Elevation: 814.61 ft

Approximately elevation 815 - OK.

Required Penetration: 12.39 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2in^3 \quad I_{PZ} := 184.20in^4 \quad E = 29000\cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 2.368\cdot ksi$

Allowable Stress: $f_b := 0.5F_y \quad f_b = 25\cdot ksi \quad f_b > \sigma_b$ OK.

Stanley Consultants INC.
Computed by: L. Karels
Checked by: J. Jacks
Approved by:
Filename: SheetPile_Wall_Partial_Embank_832_5ft_Till.xmcd

Comp Date: 03/21/2011
Print Date: 3/25/2011
Print Time: 2:04 PM

Page No. ______
Project No. 23082
Coon Rapids Dam
Upstream Cofferdam
Preliminary Design
Sheet 2 of 2

Deflection: $\delta_{PZ\_27} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_27} = 0.173 \cdot in$ < 4 in. OK.

Using a PZ 22

$S_{PZ} := 18.1in^3$ $I_{PZ} := 84.38in^4$ $E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}}$ $\sigma_b = 3.951 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y$ $f_b = 25 \cdot ksi$ $f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_22} := \frac{\delta_{max}}{E \cdot I_{PZ}}$ $\delta_{PZ\_22} = 0.378 \cdot in$ < 4 in. OK

Conclusion

A PZ 22 (or equivalent) is adequate.

```
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'FAILURE TOWARD DOWNSTREAM
CONTROL  CANTILEVER  DESIGN  1.00  1.25
WALL   832
SURFACE RIGHTSIDE    4     0     827
                   5     827
                   41     815
                   100     815
SURFACE LEFTSIDE   4     0     827
                   5     827
                   41     815
                   100     815
SOIL RIGHTSIDE   STRENGTHS    2
   120     120     27     0     0     0     815    0
   135     135     37     0     0     0
SOIL LEFTSIDE   STRENGTHS    2
   120     120     27     0     0     0     815    0
   135     135     37     0     0     0
WATER ELEVATIONS    62.4     832     815
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                        BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                          TIME: 12:52:46

                          ****************
                          *  INPUT DATA  *
                          ****************

       I.--HEADING
      'COON RAPIDS DAM
      'UPSTREAM COFFERDAM ANALYSIS
      'HENNEPIN SIDE - GLACIAL TILL
      'FAILURE TOWARD DOWNSTREAM

      II.--CONTROL
         CANTILEVER WALL DESIGN
         FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
         FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.25

     III.--WALL DATA
         ELEVATION AT TOP OF WALL     = 832.00 FT.

      IV.--SURFACE POINT DATA

          IV.A.--RIGHTSIDE
             DIST. FROM      ELEVATION
             WALL (FT)         (FT)
                 0.00         827.00
                 5.00         827.00
                41.00         815.00
               100.00         815.00

          IV.B.--LEFTSIDE
             DIST. FROM      ELEVATION
             WALL (FT)         (FT)
                 0.00         827.00
                 5.00         827.00
                41.00         815.00
               100.00         815.00

      V.--SOIL LAYER DATA

        V.A.--RIGHTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                    ANGLE OF          ANGLE OF                            <-SAFETY->
   SAT.    MOIST   INTERNAL   COH-      WALL     ADH-     <--BOTTOM-->    <-FACTOR->
  WGHT.    WGHT.   FRICTION   ESION   FRICTION   ESION    ELEV.   SLOPE   ACT. PASS.
  (PCF)    (PCF)     (DEG)    (PSF)     (DEG)    (PSF)    (FT)   (FT/FT)
 120.00   120.00     27.00     0.00      0.00     0.00   815.00    0.00    DEF  DEF
 135.00   135.00     37.00     0.00      0.00     0.00                     DEF  DEF

        V.B.--LEFTSIDE
            LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
            LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                    ANGLE OF          ANGLE OF                            <-SAFETY->
   SAT.    MOIST   INTERNAL   COH-      WALL     ADH-     <--BOTTOM-->    <-FACTOR->
  WGHT.    WGHT.   FRICTION   ESION   FRICTION   ESION    ELEV.   SLOPE   ACT. PASS.
  (PCF)    (PCF)     (DEG)    (PSF)     (DEG)    (PSF)    (FT)   (FT/FT)
 120.00   120.00     27.00     0.00      0.00     0.00   815.00    0.00    DEF  DEF
 135.00   135.00     37.00     0.00      0.00     0.00                     DEF  DEF
```

```
      VI.--WATER DATA
           UNIT WEIGHT          = 62.40 (PCF)
           RIGHTSIDE ELEVATION = 832.00 (FT)
           LEFTSIDE ELEVATION  = 815.00 (FT)
           NO SEEPAGE

     VII.--VERTICAL SURCHARGE LOADS
           NONE

    VIII.--HORIZONTAL LOADS
           NONE




 PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                            BY CLASSICAL METHODS
 DATE: 23-MARCH-2011                                         TIME: 12:52:51

                            **************************
                            *   SOIL PRESSURES FOR   *
                            * CANTILEVER WALL DESIGN *
                            **************************

     I.--HEADING
       'COON RAPIDS DAM
       'UPSTREAM COFFERDAM ANALYSIS
       'HENNEPIN SIDE - GLACIAL TILL
       'FAILURE TOWARD DOWNSTREAM

    II.--SOIL PRESSURES

          RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

          LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                          <------NET------>
          NET    <---LEFTSIDE--->         (SOIL + WATER)      <--RIGHTSIDE--->
 ELEV.   WATER   PASSIVE   ACTIVE        ACTIVE   PASSIVE      ACTIVE   PASSIVE
 (FT)    (PSF)    (PSF)    (PSF)          (PSF)    (PSF)        (PSF)    (PSF)
 832.0     0.0      0.0      0.0            0.0      0.0          0.0      0.0
 831.0    62.4      0.0      0.0           62.4     62.4          0.0      0.0
 830.0   124.8      0.0      0.0          124.8    124.8          0.0      0.0
 829.0   187.2      0.0      0.0          187.2    187.2          0.0      0.0
 828.0   249.6      0.0      0.0          249.6    249.6          0.0      0.0
 827.0   312.0      0.0      0.0          312.0    312.0          0.0      0.0
 826.0   374.4    265.6     45.1          130.4    456.9         21.6    127.5
 825.3   419.2    456.4     77.4            0.0    560.8         37.2    219.0
 825.0   436.8    531.3     90.1          -51.2    601.7         43.3    255.0
 824.0   499.2    759.0    135.2         -195.0    728.4         64.9    364.3
 823.0   561.6    890.8    180.2         -242.7    809.0         86.5    427.6
 822.0   624.0    993.9    225.3         -261.7    875.8        108.1    477.1
 821.0   686.4   1130.3    270.3         -314.2    958.6        129.8    542.6
 820.0   748.8   1273.3    315.4         -373.1   1044.6        151.4    611.2
 819.0   811.2   1417.2    359.6         -433.4   1131.9        172.6    680.3
 818.0   873.6   1561.6    400.2         -496.0   1223.0        192.1    749.6
```

```
 817.0    936.0      1708.1     438.8    -561.4     1317.0      210.6      819.9
 816.0    998.4      1854.5     478.6    -626.3     1410.0      229.7      890.1
 815.0   1060.8      2944.2     419.3   -1679.8     2091.3      203.6     1449.8
 814.0   1060.8      3820.2     347.2   -2583.4     2686.4      176.0     1972.8
 813.0   1060.8      3652.7     363.6   -2398.6     2723.4      193.3     2026.2
 812.0   1060.8      3594.3     378.5   -2323.6     2824.9      209.8     2142.6
 811.0   1060.8      3531.3     390.1   -2245.8     2936.3      224.8     2265.6
 810.0   1060.8      3024.6     403.7   -1723.4     3045.7      240.5     2388.6
 809.0   1060.8      2780.6     419.9   -1462.2     3152.6      257.6     2511.7
 808.0   1060.8      2961.8     434.4   -1627.0     3261.1      274.0     2634.7
 807.0   1060.8      3095.4     446.5   -1745.4     3372.0      289.2     2757.7
 806.0   1060.8      3277.6     458.6   -1912.4     3482.9      304.4     2880.7
 805.0   1060.8      3408.8     470.8   -2028.5     3589.3      319.6     2999.2
 804.0   1060.8      3616.2     483.7   -2220.3     3703.8      335.1     3126.7
 803.0   1060.8      3749.0     497.7   -2337.0     3824.9      351.2     3261.8
 802.0   1060.8      3959.3     512.0   -2531.0     3997.5      367.4     3448.7
 801.0   1060.8      4120.6     526.3   -2676.1     4182.5      383.7     3648.0
 800.0   1060.8      4245.6     542.7   -2784.9     4333.8      399.9     3815.8
 799.0   1060.8      4502.3     559.4   -3025.4     4533.7      416.1     4032.3
 798.0   1060.8      4662.9     574.0   -3169.8     4728.0      432.3     4241.2
 797.0   1060.8      4788.1     588.4   -3278.8     4880.4      448.5     4408.0
 796.0   1060.8      5025.6     602.7   -3500.0     5071.3      464.8     4613.2
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                              TIME: 12:52:52

                         ******************************
                         *   SUMMARY OF RESULTS FOR   *
                         *   CANTILEVER WALL DESIGN   *
                         ******************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD DOWNSTREAM

  II.--SUMMARY

      RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

      LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

  WALL BOTTOM ELEV. (FT)      :        814.61
        PENETRATION (FT)      :         12.39

  MAX. BEND. MONENT (LB-FT)   :    5.9656E+03
        AT ELEVATION (FT)     :        820.52

  MAX. SCALED DEFL. (LB-IN^3):    9.2559E+08
        AT ELEVATION (FT)     :        832.00

           NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
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                 ELLASTICITY IN PSI TIMES PILE MOMENT
                 OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                 IN INCHES.



PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                        TIME: 12:52:52

                    ******************************
                    * COMPLETE OF RESULTS FOR    *
                    *  CANTILEVER WALL DESIGN    *
                    ******************************

     I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'FAILURE TOWARD DOWNSTREAM

    II.--RESULTS

                     BENDING                          SCALED          NET
    ELEVATION        MOMENT          SHEAR          DEFLECTION      PRESSURE
       (FT)          (LB-FT)          (LB)          (LB-IN^3)         (PSF)
      832.00       0.0000E+00          0.          9.2559E+08          0.00
      831.00       1.0400E+01         31.          8.3923E+08         62.40
      830.00       8.3200E+01        125.          7.5290E+08        124.80
      829.00       2.8080E+02        281.          6.6673E+08        187.20
      828.00       6.6560E+02        499.          5.8107E+08        249.60
      827.00       1.3000E+03        780.          4.9660E+08        312.00
      826.00       2.2057E+03       1001.          4.1441E+08        130.39
      825.28       2.9469E+03       1048.          3.5767E+08          0.00
      825.00       3.2418E+03       1041.          3.3605E+08        -51.23
      824.00       4.2331E+03        918.          2.6329E+08       -194.95
      823.00       5.0453E+03        699.          1.9782E+08       -242.67
      822.00       5.6197E+03        447.          1.4103E+08       -261.74
      821.00       5.9267E+03        159.          9.3917E+07       -314.17
      820.00       5.9185E+03       -185.          5.6997E+07       -373.08
      819.00       5.5370E+03       -588.          3.0250E+07       -433.45
      818.00       4.7217E+03      -1053.          1.3009E+07       -495.95
      817.00       3.4099E+03      -1582.          3.8558E+06       -561.40
      816.66       2.8316E+03      -1779.          2.1918E+06       -583.76
      816.00       1.6066E+03      -1856.          5.1645E+05        348.12
      815.00       1.6159E+02       -797.          3.5768E+03       1769.40
      814.61       0.0000E+00          0.          0.0000E+00       2323.13

            NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                   ELLASTICITY IN PSI TIMES PILE MOMENT
                   OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                   IN INCHES.

   III.--WATER AND SOIL PRESSURES

                              <-------------SOIL PRESSURES-------------->
                  WATER       <----LEFTSIDE----->    <---RIGHTSIDE---->
  ELEVATION     PRESSURE      PASSIVE     ACTIVE      ACTIVE     PASSIVE
     (FT)         (PSF)        (PSF)       (PSF)       (PSF)      (PSF)
    832.00           0.          0.          0.          0.         0.
    831.00          62.          0.          0.          0.         0.
```

```
  830.00         125.          0.          0.          0.          0.
  829.00         187.          0.          0.          0.          0.
  828.00         250.          0.          0.          0.          0.
  827.00         312.          0.          0.          0.          0.
  826.00         374.        266.         45.         22.        128.
  825.28         419.        456.         77.         37.        219.
  825.00         437.        531.         90.         43.        255.
  824.00         499.        759.        135.         65.        364.
  823.00         562.        891.        180.         87.        428.
  822.00         624.        994.        225.        108.        477.
  821.00         686.       1130.        270.        130.        543.
  820.00         749.       1273.        315.        151.        611.
  819.00         811.       1417.        360.        173.        680.
  818.00         874.       1562.        400.        192.        750.
  817.00         936.       1708.        439.        211.        820.
  816.66         957.       1758.        453.        217.        844.
  816.00         998.       1854.        479.        230.        890.
  815.00        1061.       2944.        419.        204.       1450.
  814.61        1061.       3820.        347.        176.       1973.
  813.00        1061.       3653.        364.        193.       2026.
```

Coon Rapids Dam Cofferdam Sheet Pile Wall - Partial Earthen Embankment - Unusual Case - Alluvium Present to 795 - 7 ft Stickup Check

Reference:\\Mnp-fs1\apps\technical_programs\Structural\ST084 ACI 318-2005 Mathcad Electronic Book.mcd

Units:

✓ ☑ ✓ ☑

$k := 1000 \cdot lbf \quad kpf := \frac{k}{ft} \quad ksf := \frac{k}{ft^2} \quad ksi := \frac{k}{in^2} \quad kcf := \frac{k}{ft^3} \quad ppf := \frac{lbf}{ft} \quad psf := \frac{lbf}{ft^2} \quad psi := \frac{lbf}{in^2} \quad pcf := \frac{lbf}{ft^3}$

$\gamma_{soil} := 110 \cdot pcf \quad \gamma_{water} := 62.4 \cdot pcf \quad \gamma_{conc} := 150 \cdot pcf \quad f_c := 4 \cdot ksi \quad f_y := 60 \cdot ksi \quad F_y := 50 \cdot ksi \quad E := 29000 \cdot ksi$

$rpm := \frac{2 \cdot \pi \cdot rad}{min} \quad cps := \frac{2 \cdot \pi \cdot rad}{sec} \quad MPa := 10^6 \cdot \frac{newton}{m^2}$

Description

Determine the structural stability of the upstream sheetpile cofferdam with an earhen embankment to elevation 825 and sheet pile to elevation 832 (7 ft of stickup) and Unusual headwater to elevation 832. Alluvium present tc elevation 795 (point at which original solution no longer works). Check of 7 ft stickup.

References

PZ/PS Hot Rolled Steel Sheet Piling Table - Skyline Steel

Design

PZ 27 sheet pile with earthen berm constructed between upstream cofferdam and concrete dam.

CWALSHT Results: Q-Case

Maximum Bending Moment: $M := 1.94 \times 10^4 lbf \cdot ft$

Maximum Scaled Deflection: $\delta_{max} := 6.02\ 10^9 lbf \cdot in^3$

Wall Bottom Elevation: 806.54 ft

Not enough embedment - Need Less Stickup

Required Penetration: 18.46 ft

Section Design

Using a PZ 27

$S_{PZ} := 30.2 in^3 \quad I_{PZ} := 184.20 in^4 \quad E = 29000 \cdot ksi$

Bending Stress: $\sigma_b := \frac{M}{S_{PZ}} \quad \sigma_b = 7.709 \cdot ksi$

Allowable Stress: $f_b := 0.5F_y \quad f_b = 25 \cdot ksi \quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_27} := \frac{\delta_{max}}{E \cdot I_{PZ}} \quad \delta_{PZ\_27} = 1.127 \cdot in$ < 4 in. OK.

Using a PZ 22

$S_{PZ} := 18.1\text{in}^3$ $\quad I_{PZ} := 84.38\text{in}^4$ $\quad E = 29000\cdot\text{ksi}$

Bending Stress: $\sigma_b := \dfrac{M}{S_{PZ}}$ $\quad \sigma_b = 12.862\cdot\text{ksi}$

Allowable Stress: $f_b := 0.5F_y$ $\quad f_b = 25\cdot\text{ksi}$ $\quad f_b > \sigma_b$ OK.

Deflection: $\delta_{PZ\_22} := \dfrac{\delta_{max}}{E\cdot I_{PZ}}$ $\quad \delta_{PZ\_22} = 2.46\cdot\text{in}$ $\quad < 4$ in. OK

Conclusion

A PZ 22 (or equivalent) is adequate.

```
'COON RAPIDS DAM
'UPSTREAM COFFERDAM ANALYSIS
'HENNEPIN SIDE - GLACIAL TILL
'FAILURE TOWARD DOWNSTREAM
CONTROL  CANTILEVER  DESIGN  1.00  1.25
WALL   832
SURFACE RIGHTSIDE    4     0     825
                   5     825
                   35     815
                   100     815
SURFACE LEFTSIDE    4     0     825
                   5     825
                   35     815
                   100     815
SOIL RIGHTSIDE   STRENGTHS    2
   120     120     27     0     0     0     815     0
   125     125     32     0     0     0
SOIL LEFTSIDE   STRENGTHS    2
   120     120     27     0     0     0     815     0
   125     125     32     0     0     0
WATER ELEVATIONS    62.4     832     815
FINISHED
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                          TIME: 11:29:00

                          ****************
                          *  INPUT DATA  *
                          ****************

    I.--HEADING
   'COON RAPIDS DAM
   'UPSTREAM COFFERDAM ANALYSIS
   'HENNEPIN SIDE - GLACIAL TILL
   'FAILURE TOWARD DOWNSTREAM

   II.--CONTROL
      CANTILEVER WALL DESIGN
      FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
      FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.25

  III.--WALL DATA
      ELEVATION AT TOP OF WALL    = 832.00 FT.

   IV.--SURFACE POINT DATA

      IV.A.--RIGHTSIDE
         DIST. FROM     ELEVATION
         WALL (FT)        (FT)
              0.00       825.00
              5.00       825.00
             35.00       815.00
            100.00       815.00

      IV.B.--LEFTSIDE
         DIST. FROM     ELEVATION
         WALL (FT)        (FT)
              0.00       825.00
              5.00       825.00
             35.00       815.00
            100.00       815.00

    V.--SOIL LAYER DATA

     V.A.--RIGHTSIDE
         LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
         LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                ANGLE OF         ANGLE OF                           <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-    WALL     ADH-    <--BOTTOM-->   <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION    ELEV.  SLOPE  ACT.  PASS.
 (PCF)   (PCF)   (DEG)    (PSF)   (DEG)    (PSF)    (FT)  (FT/FT)
120.00  120.00   27.00     0.00    0.00     0.00   815.00   0.00   DEF   DEF
125.00  125.00   32.00     0.00    0.00     0.00                   DEF   DEF

     V.B.--LEFTSIDE
         LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURE  = DEFAULT
         LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURE = DEFAULT

                ANGLE OF         ANGLE OF                           <-SAFETY->
  SAT.   MOIST  INTERNAL  COH-    WALL     ADH-    <--BOTTOM-->   <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION  FRICTION  ESION    ELEV.  SLOPE  ACT.  PASS.
 (PCF)   (PCF)   (DEG)    (PSF)   (DEG)    (PSF)    (FT)  (FT/FT)
120.00  120.00   27.00     0.00    0.00     0.00   815.00   0.00   DEF   DEF
125.00  125.00   32.00     0.00    0.00     0.00                   DEF   DEF
```

```
     VI.--WATER DATA
        UNIT WEIGHT          = 62.40 (PCF)
        RIGHTSIDE ELEVATION = 832.00 (FT)
        LEFTSIDE ELEVATION  = 815.00 (FT)
        NO SEEPAGE

    VII.--VERTICAL SURCHARGE LOADS
        NONE

   VIII.--HORIZONTAL LOADS
        NONE
```

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                           TIME: 11:29:01

                          **************************
                          *   SOIL PRESSURES FOR   *
                          * CANTILEVER WALL DESIGN *
                          **************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD DOWNSTREAM

  II.--SOIL PRESSURES

       RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

       LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

                                            <------NET------>
         NET     <---LEFTSIDE--->        (SOIL + WATER)      <--RIGHTSIDE--->
ELEV.   WATER    PASSIVE    ACTIVE       ACTIVE   PASSIVE     ACTIVE   PASSIVE
(FT)    (PSF)     (PSF)     (PSF)        (PSF)     (PSF)      (PSF)     (PSF)
832.0     0.0       0.0       0.0          0.0       0.0        0.0       0.0
831.0    62.4       0.0       0.0         62.4      62.4        0.0       0.0
830.0   124.8       0.0       0.0        124.8     124.8        0.0       0.0
829.0   187.2       0.0       0.0        187.2     187.2        0.0       0.0
828.0   249.6       0.0       0.0        249.6     249.6        0.0       0.0
827.0   312.0       0.0       0.0        312.0     312.0        0.0       0.0
826.0   374.4       0.0       0.0        374.4     374.4        0.0       0.0
825.0   436.8       0.0       0.0        436.8     436.8        0.0       0.0
824.0   499.2     265.6      45.1        255.2     581.7        0.0       0.0
823.0   561.6     531.3      90.1         73.6     726.5       21.6     127.5
822.5   593.5     647.9     113.2          0.0     791.3       43.3     255.0
822.0   624.0     759.0     135.2        -70.2     853.2       54.3     311.0
821.0   686.4     890.8     180.2       -117.9     933.8       64.9     364.3
820.0   748.8     993.9     225.3       -136.9    1000.6       86.5     427.6
819.0   811.2    1130.3     270.3       -189.4    1083.4      108.1     477.1
818.0   873.6    1273.3     315.4       -248.3    1169.4      129.8     542.6
```

```
 817.0    936.0     1417.2     359.6    -308.6    1256.7     172.6     680.3
 816.0    998.4     1561.6     400.2    -371.2    1347.8     192.1     749.6
 815.0   1060.8     2080.3     392.5    -828.6    1696.0     190.9    1027.7
 814.0   1060.8     2442.0     373.0   -1192.1    1975.5     189.0    1287.7
 813.0   1060.8     2305.8     386.3   -1039.6    2014.5     205.4    1340.0
 812.0   1060.8     1833.6     399.7    -551.1    2077.7     221.7    1416.5
 811.0   1060.8     1652.5     415.1    -352.6    2144.7     239.1    1499.0
 810.0   1060.8     1875.8     429.8    -558.9    2211.8     256.1    1580.8
 809.0   1060.8     1965.1     442.5    -632.1    2273.6     272.2    1655.3
 808.0   1060.8     2094.6     455.2    -745.5    2333.0     288.3    1727.4
 807.0   1060.8     2203.2     467.9    -838.1    2427.9     304.3    1835.1
 806.0   1060.8     2320.0     480.6    -938.8    2523.2     320.4    1943.1
 805.0   1060.8     2446.2     493.9   -1048.7    2640.2     336.7    2073.4
 804.0   1060.8     2557.8     509.9   -1143.7    2753.1     353.3    2202.1
 803.0   1060.8     2688.0     526.0   -1257.2    2871.4     370.0    2336.6
 802.0   1060.8     2811.6     540.2   -1364.1    2991.3     386.7    2470.8
 801.0   1060.8     2913.3     554.5   -1449.1    3104.3     403.4    2597.9
 800.0   1060.8     3084.6     568.7   -1603.7    3247.4     420.1    2755.2
 799.0   1060.8     3189.3     582.9   -1691.7    3360.4     436.8    2882.5
 798.0   1060.8     3310.2     597.1   -1795.9    3495.5     453.4    3031.9
 797.0   1060.8     3489.1     611.3   -1958.1    3640.2     470.1    3190.7
 796.0   1060.8     3592.9     625.6   -2045.0    3752.6     487.1    3317.4
 795.0   1060.8     3707.9     639.8   -2143.0    3881.8     504.1    3460.8
 794.0   1060.8     3893.3     654.0   -2311.5    4040.6     520.9    3633.9
```

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PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                          TIME: 11:29:02

                       ****************************
                       *   SUMMARY OF RESULTS FOR  *
                       *   CANTILEVER WALL DESIGN  *
                       ****************************

   I.--HEADING
    'COON RAPIDS DAM
    'UPSTREAM COFFERDAM ANALYSIS
    'HENNEPIN SIDE - GLACIAL TILL
    'FAILURE TOWARD DOWNSTREAM

  II.--SUMMARY

      RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

      LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

  WALL BOTTOM ELEV. (FT)      :      806.54
       PENETRATION (FT)       :       18.46

  MAX. BEND. MOMENT (LB-FT)   :  1.9368E+04
       AT ELEVATION (FT)      :      814.75

  MAX. SCALED DEFL. (LB-IN^3):  6.0217E+09
       AT ELEVATION (FT)      :      832.00
```

```
                    NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                           ELLASTICITY IN PSI TIMES PILE MOMENT
                           OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
                           IN INCHES.




PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHOREDOR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 23-MARCH-2011                                          TIME: 11:29:02

                         *****************************
                         * COMPLETE OF RESULTS FOR   *
                         *  CANTILEVER WALL DESIGN   *
                         *****************************

     I.--HEADING
     'COON RAPIDS DAM
     'UPSTREAM COFFERDAM ANALYSIS
     'HENNEPIN SIDE - GLACIAL TILL
     'FAILURE TOWARD DOWNSTREAM

    II.--RESULTS

                  BENDING                            SCALED
    ELEVATION     MOMENT          SHEAR            DEFLECTION        NET
      (FT)        (LB-FT)         (LB)             (LB-IN^3)       PRESSURE
                                                                    (PSF)
     832.00     0.0000E+00          0.            6.0217E+09         0.00
     831.00     1.0400E+01         31.            5.6357E+09        62.40
     830.00     8.3200E+01        125.            5.2497E+09       124.80
     829.00     2.8080E+02        281.            4.8639E+09       187.20
     828.00     6.6560E+02        499.            4.4787E+09       249.60
     827.00     1.3000E+03        780.            4.0946E+09       312.00
     826.00     2.2464E+03       1123.            3.7128E+09       374.40
     825.00     3.5672E+03       1529.            3.3349E+09       436.80
     824.00     5.2841E+03       1875.            2.9633E+09       255.19
     823.00     7.2562E+03       2039.            2.6008E+09        73.57
     822.49     8.3065E+03       2058.            2.4199E+09         0.00
     822.00     9.3083E+03       2041.            2.2509E+09       -70.15
     821.00     1.1306E+04       1947.            1.9170E+09      -117.87
     820.00     1.3191E+04       1819.            1.6027E+09      -136.94
     819.00     1.4933E+04       1656.            1.3111E+09      -189.37
     818.00     1.6485E+04       1437.            1.0453E+09      -248.28
     817.00     1.7788E+04       1159.            8.0800E+08      -308.65
     816.00     1.8782E+04        819.            6.0137E+08      -371.15
     815.00     1.9340E+04        219.            4.2713E+08      -828.65
     814.00     1.9084E+04       -791.            2.8619E+08     -1192.14
     813.00     1.7722E+04      -1907.            1.7807E+08     -1039.61
     812.00     1.5377E+04      -2702.            1.0042E+08      -551.07
     811.00     1.2432E+04      -3154.            4.9264E+07      -352.62
     810.16     9.6458E+03      -3522.            2.3135E+07      -525.41
     810.00     9.0678E+03      -3596.            1.9532E+07      -391.00
     809.00     5.4139E+03      -3573.            5.4190E+06       436.99
     808.00     2.1970E+03      -2722.            7.2399E+05      1264.98
     807.00     2.4510E+02      -1043.            7.5342E+03      2092.96
     806.54     0.0000E+00          0.            0.0000E+00      2471.51

                NOTE:  DIVIDE SCALED DEFLECTION MODULUS OF
                       ELLASTICITY IN PSI TIMES PILE MOMENT
                       OF INERTIA IN IN^4 TO OBTAIN DEFLECTION
```

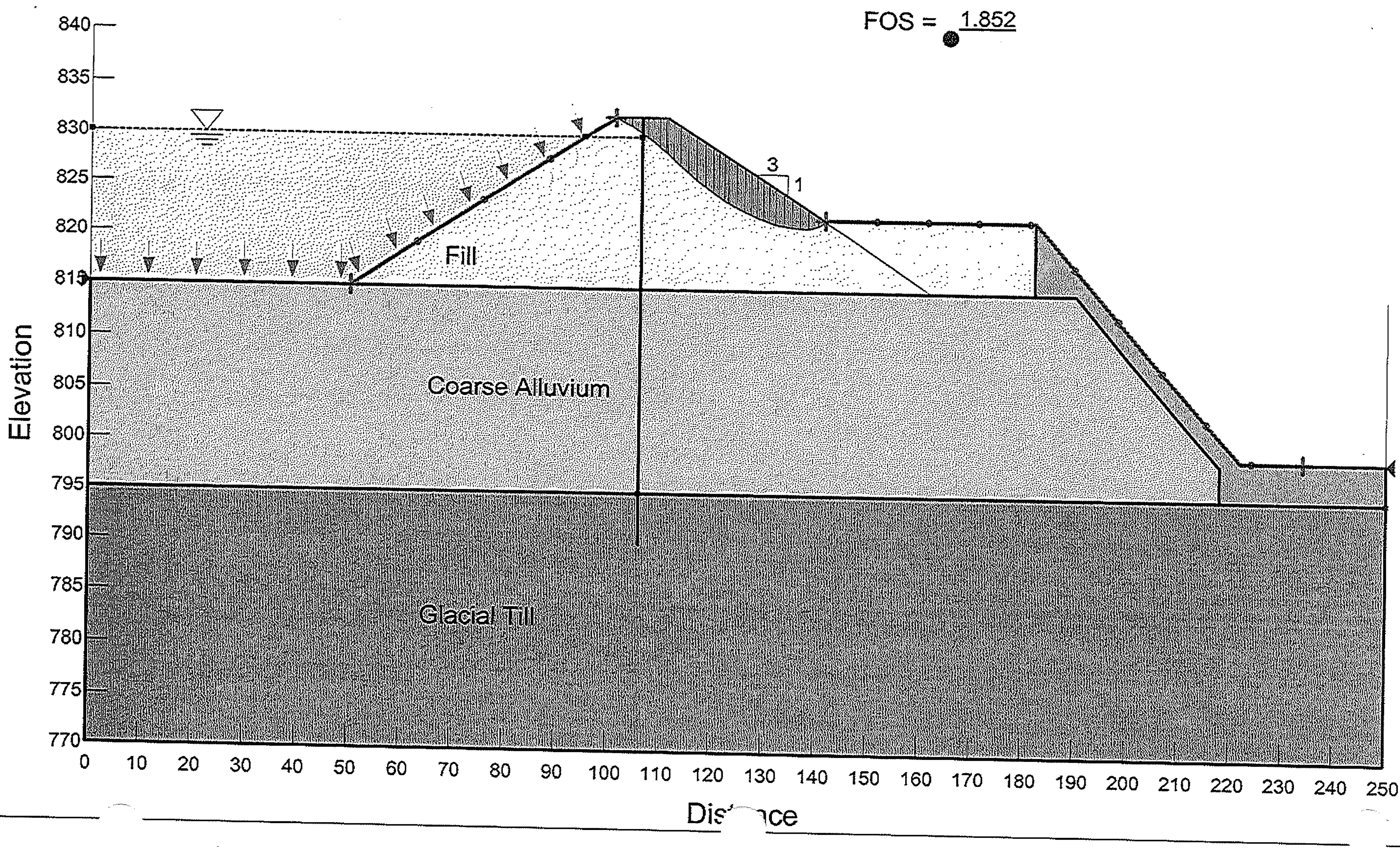
```
          IN INCHES.

  III.--WATER AND SOIL PRESSURES

                              <-------------SOIL PRESSURES-------------->
                   WATER      <----LEFTSIDE----->      <---RIGHTSIDE---->
 ELEVATION       PRESSURE     PASSIVE       ACTIVE       ACTIVE     PASSIVE
   (FT)            (PSF)       (PSF)         (PSF)        (PSF)      (PSF)
   832.00             0.            0.           0.           0.          0.
   831.00            62.            0.           0.           0.          0.
   830.00           125.            0.           0.           0.          0.
   829.00           187.            0.           0.           0.          0.
   828.00           250.            0.           0.           0.          0.
   827.00           312.            0.           0.           0.          0.
   826.00           374.            0.           0.           0.          0.
   825.00           437.            0.           0.           0.          0.
   824.00           499.          266.          45.          22.        128.
   823.00           562.          531.          90.          43.        255.
   822.49           594.          648.         113.          54.        311.
   822.00           624.          759.         135.          65.        364.
   821.00           686.          891.         180.          87.        428.
   820.00           749.          994.         225.         108.        477.
   819.00           811.         1130.         270.         130.        543.
   818.00           874.         1273.         315.         151.        611.
   817.00           936.         1417.         360.         173.        680.
   816.00           998.         1562.         400.         192.        750.
   815.00          1061.         2080.         392.         191.       1028.
   814.00          1061.         2442.         373.         189.       1288.
   813.00          1061.         2306.         386.         205.       1340.
   812.00          1061.         1834.         400.         222.       1417.
   811.00          1061.         1652.         415.         239.       1499.
   810.16          1061.         1840.         427.         253.       1568.
   810.00          1061.         1876.         430.         256.       1581.
   809.00          1061.         1965.         442.         272.       1655.
   808.00          1061.         2095.         455.         288.       1727.
   807.00          1061.         2203.         468.         304.       1835.
   806.54          1061.         2320.         481.         320.       1943.
   805.00          1061.         2446.         494.         337.       2073.
```

Slope Stability Analysis

Full Earthen Cofferdam

Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Headwater to Elevation 830.1 - Usual High Pool Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Karels
Checked By: J. Jacks
File Name: Full_Earthen_830.gsz
Date: 3/22/2011



Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Headwater to Elevation 830.1 - Usual High Pool Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Karels
Checked By: J. Jacks
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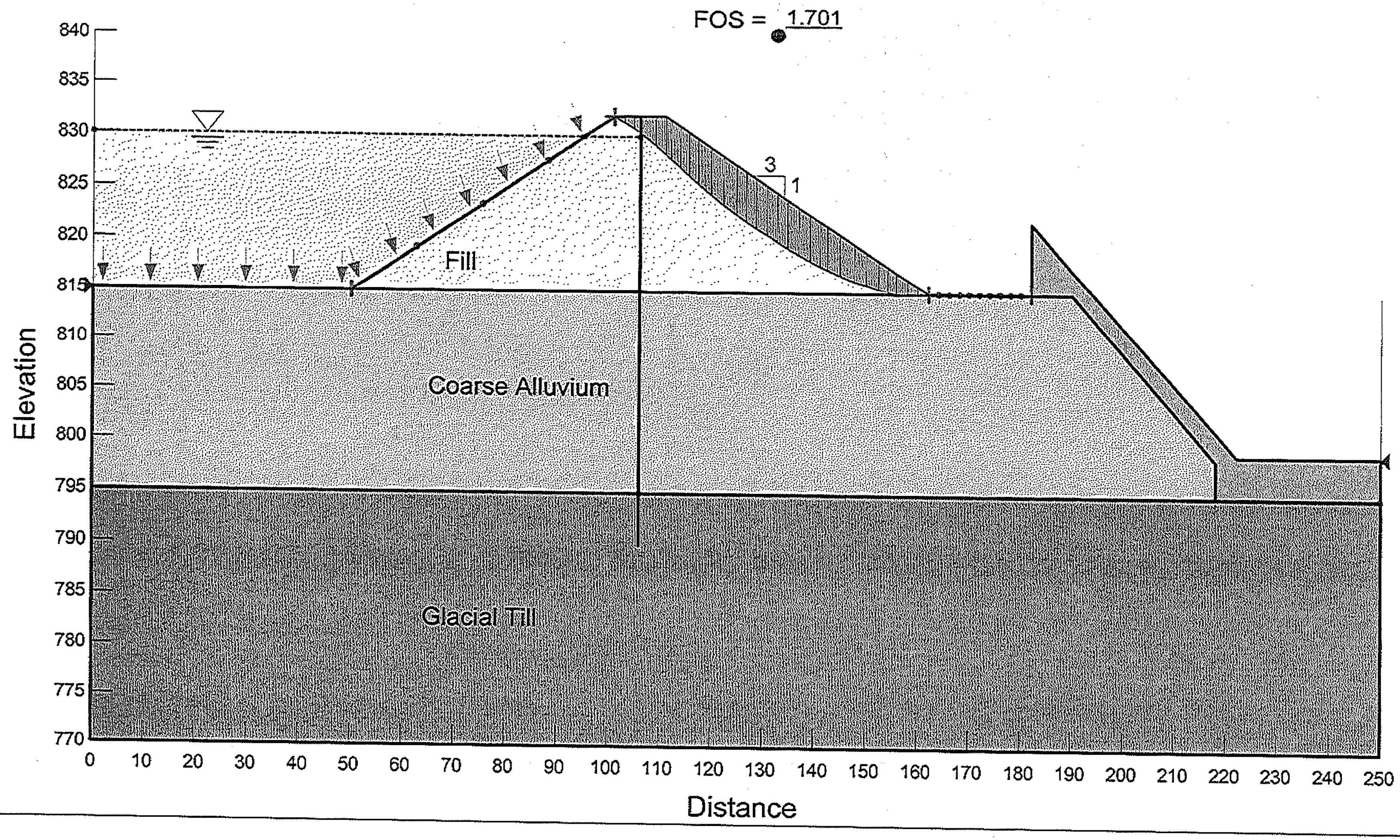
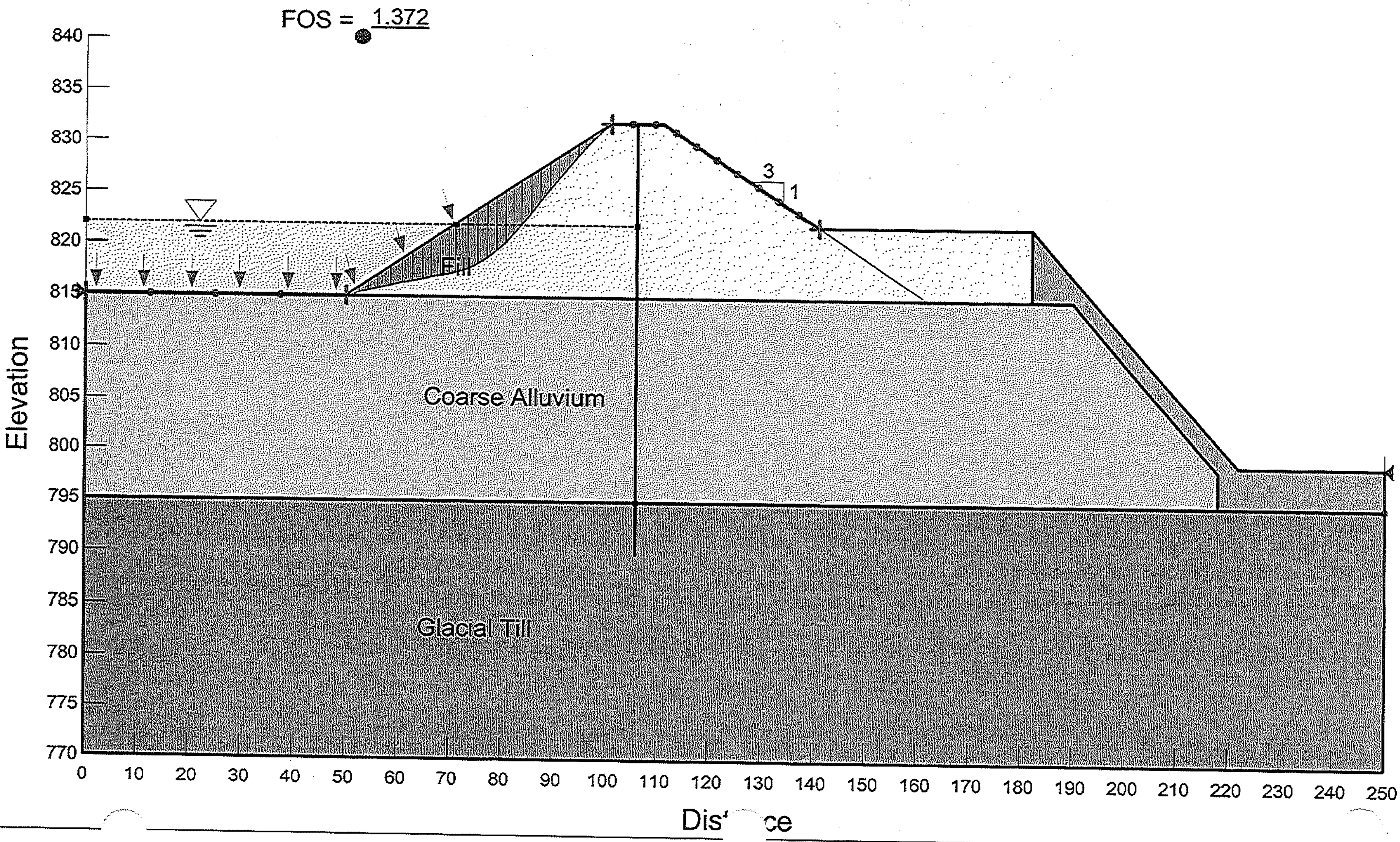


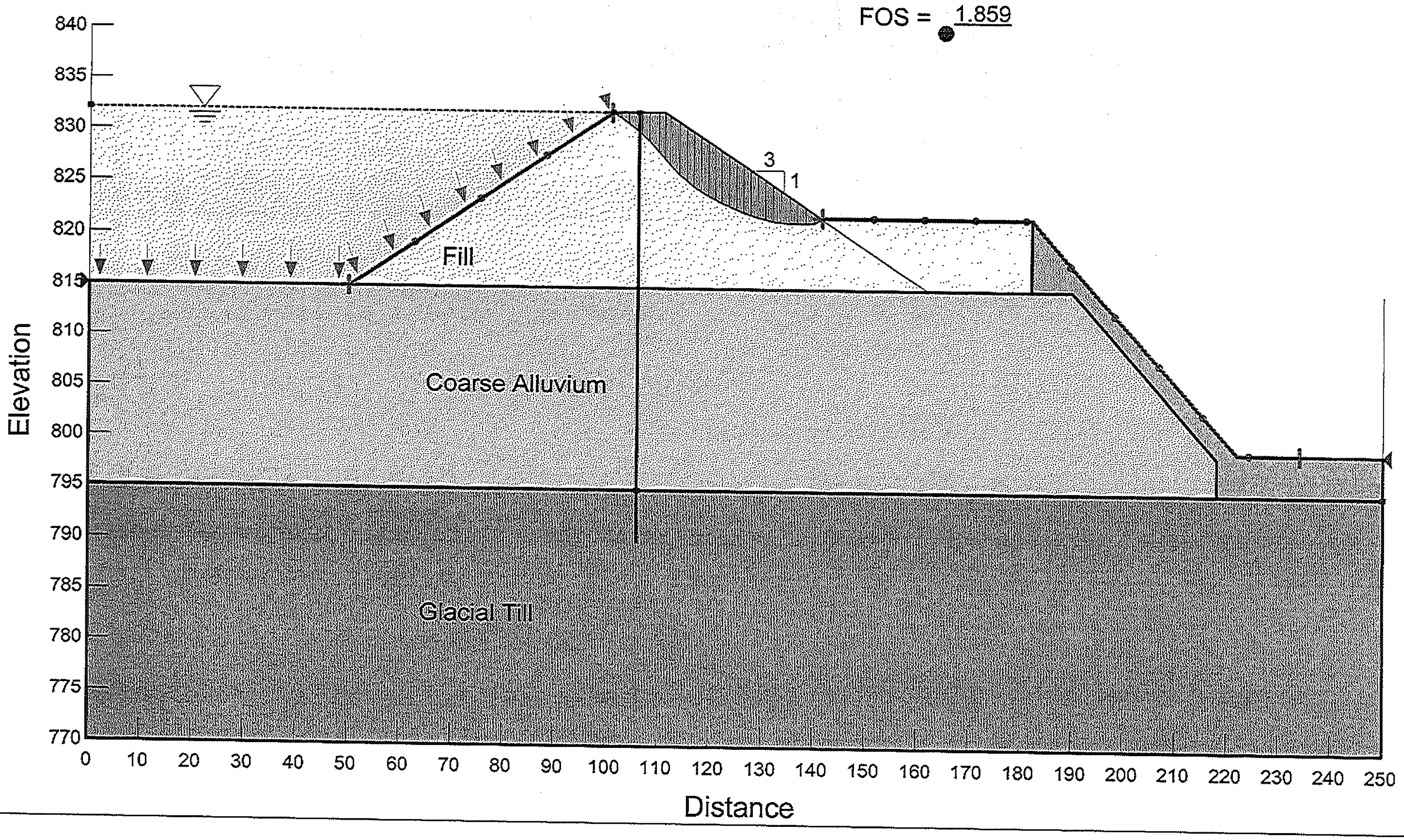
Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Headwater to Elevation 822 - Drained "S" Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Karels
Checked By: J. Jacks
File Name: Full_Earthen_830_Drained.gsz
Date: 3/22/2011



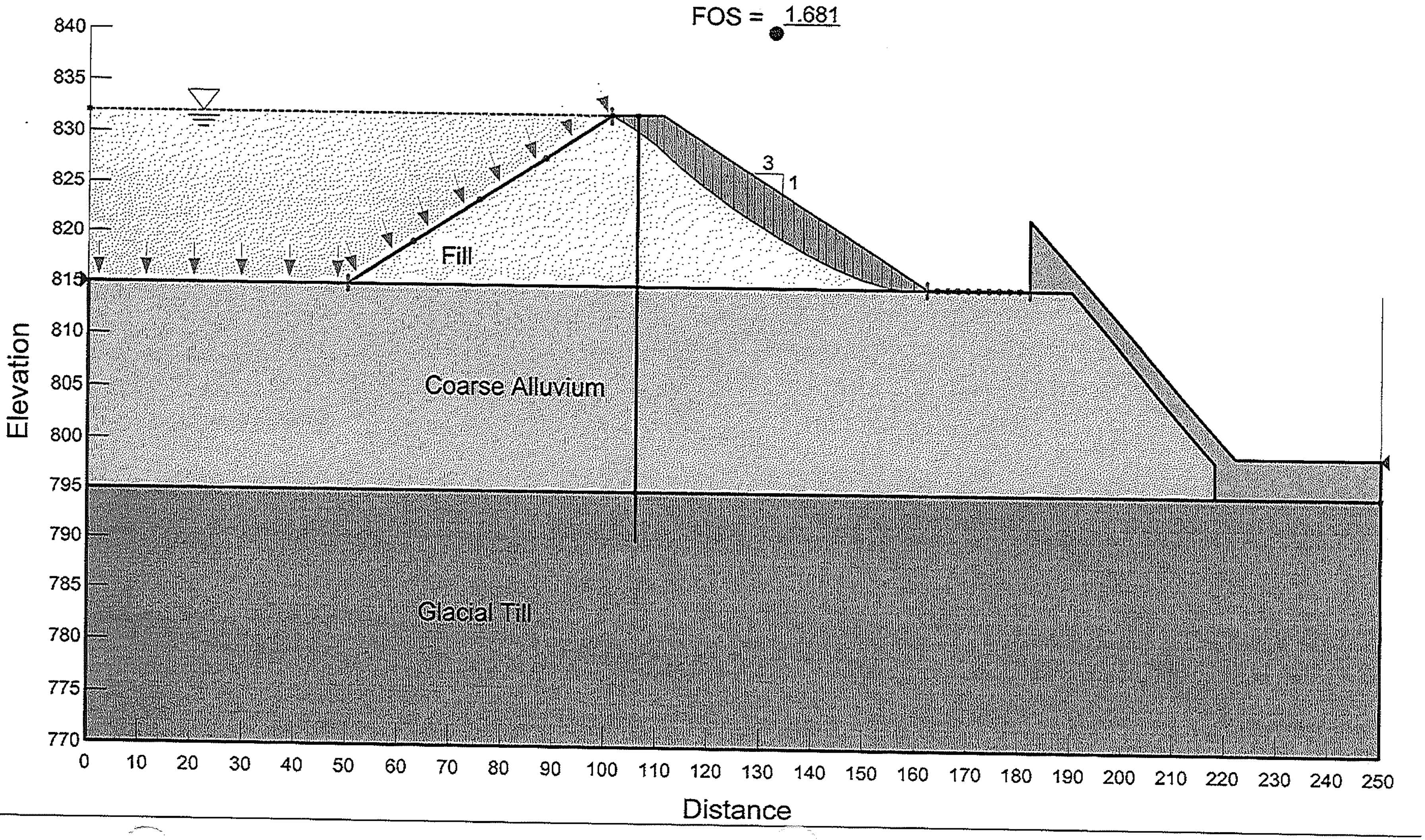
Coon Rap.. Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Tailwater to Elevation 832 - Unusual High Pool Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Kareis
Checked By: J. Jacks
File Name: Full_Earthen_832.gsz
Date: 3/22/2011



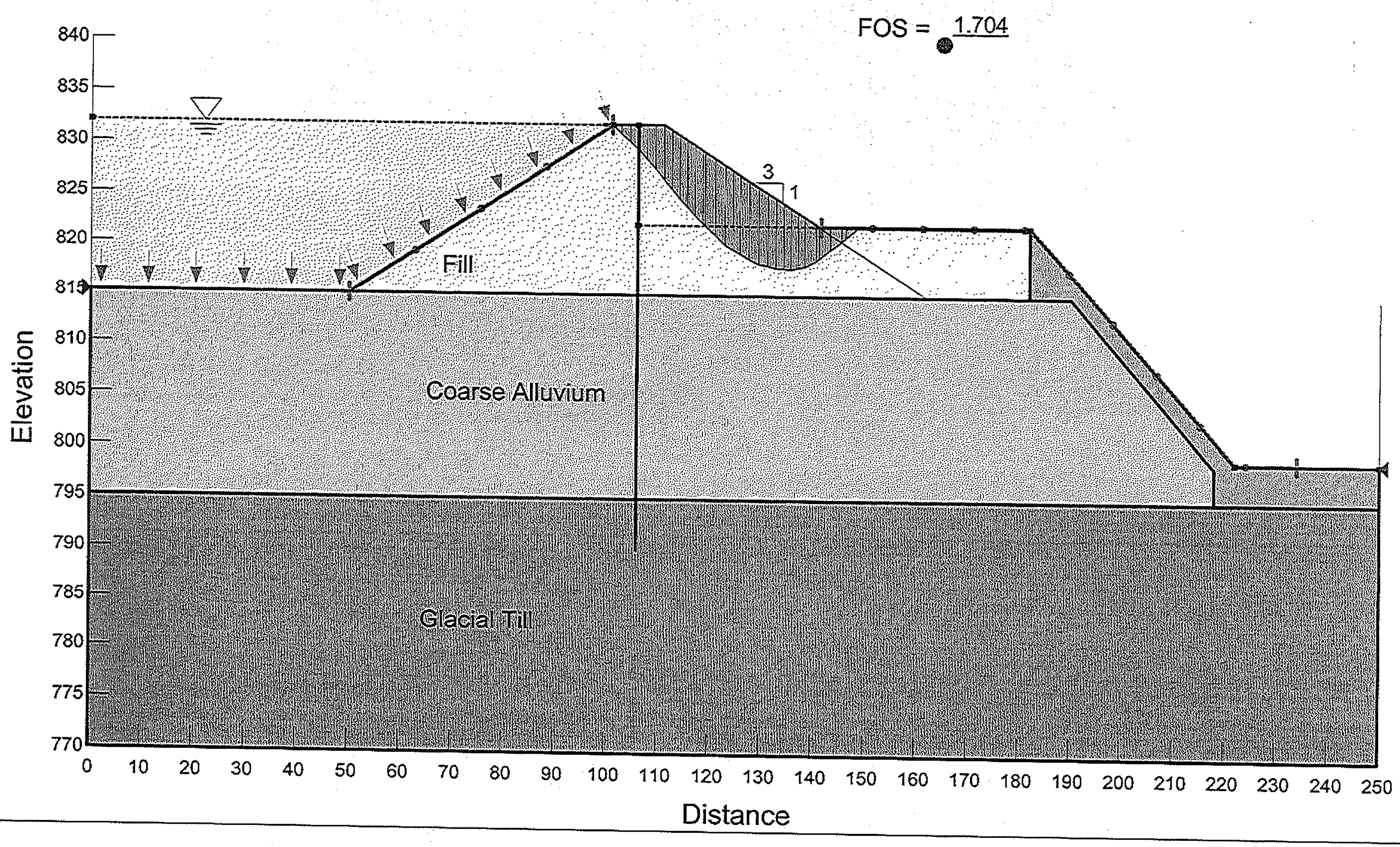
Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Tailwater to Elevation 832 - Unusual High Pool Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Karels
Checked By: J. Jacks
File Name: Full_Earthen_832_Construction.gsz
Date: 3/22/2011



Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Tailwater to Elevation 832 - Unusual High Pool Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Karels
Checked By: J. Jacks
File Name: Full_Earthen_832_Seepage.gs:
Date: 3/22/2011



Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Tailwater to Elevation 832 - Unusual High Pool Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Karels
Checked By: J. Jacks
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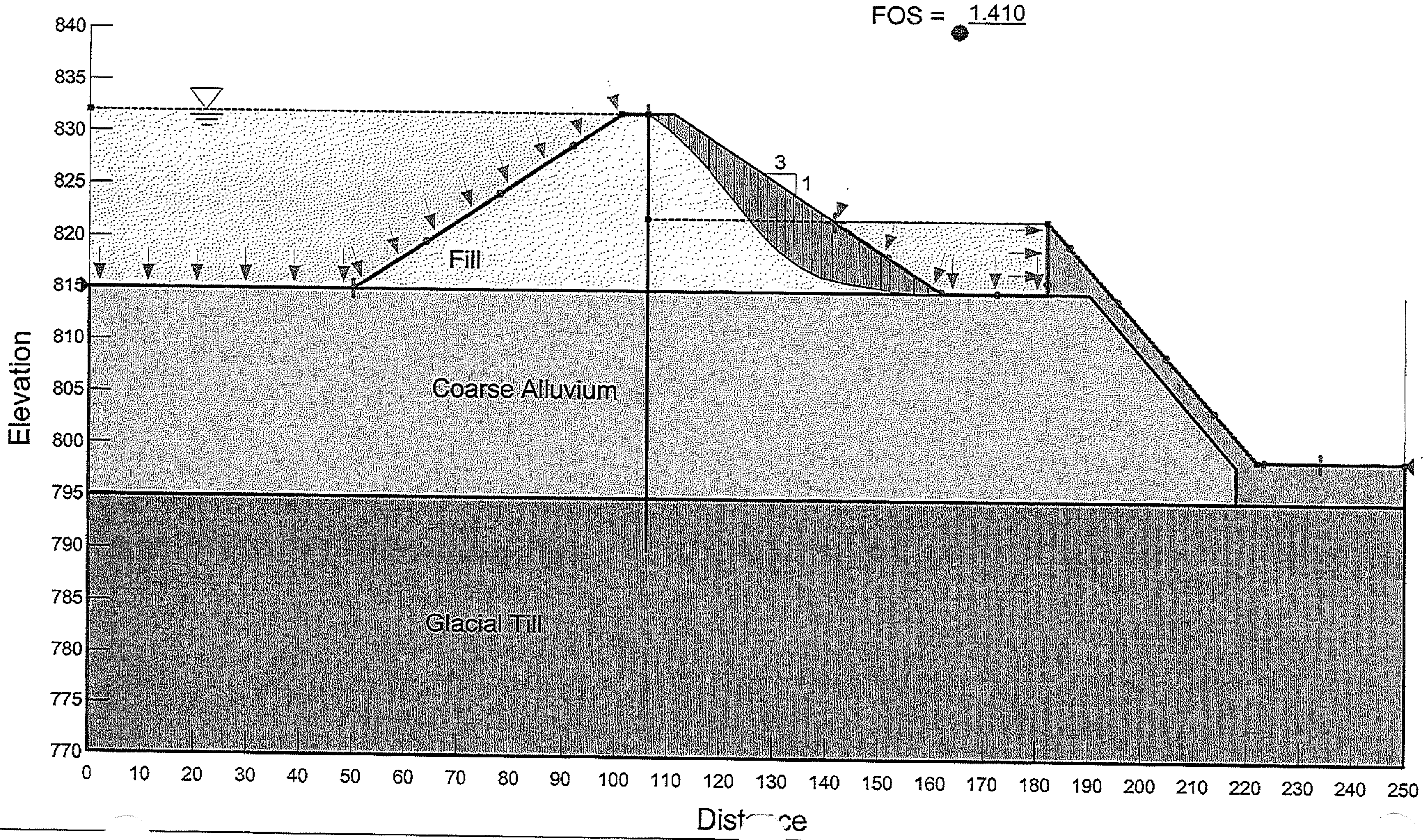
Date: 3/22/2011

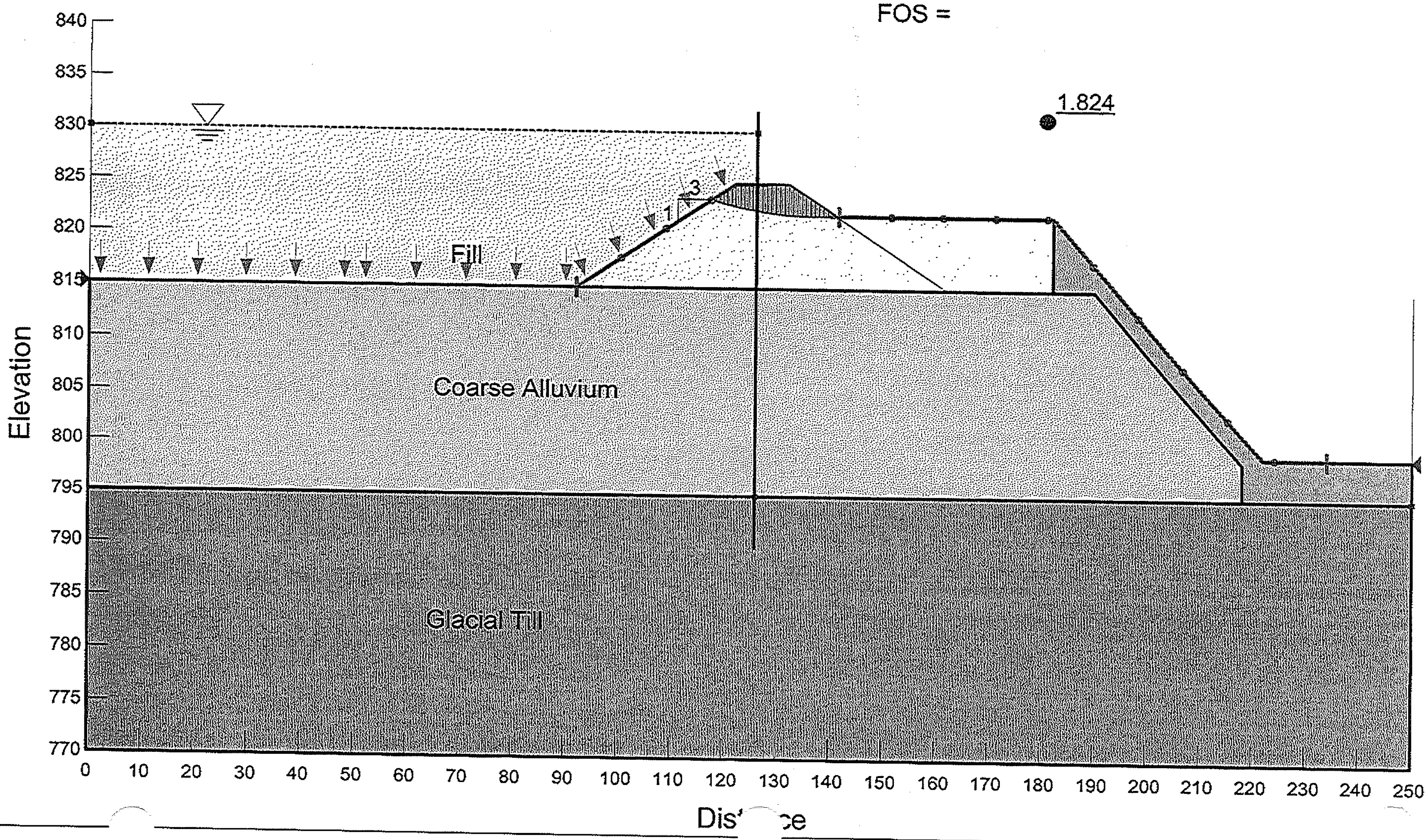


Slope Stability Analysis

Partial Earthen Cofferdam

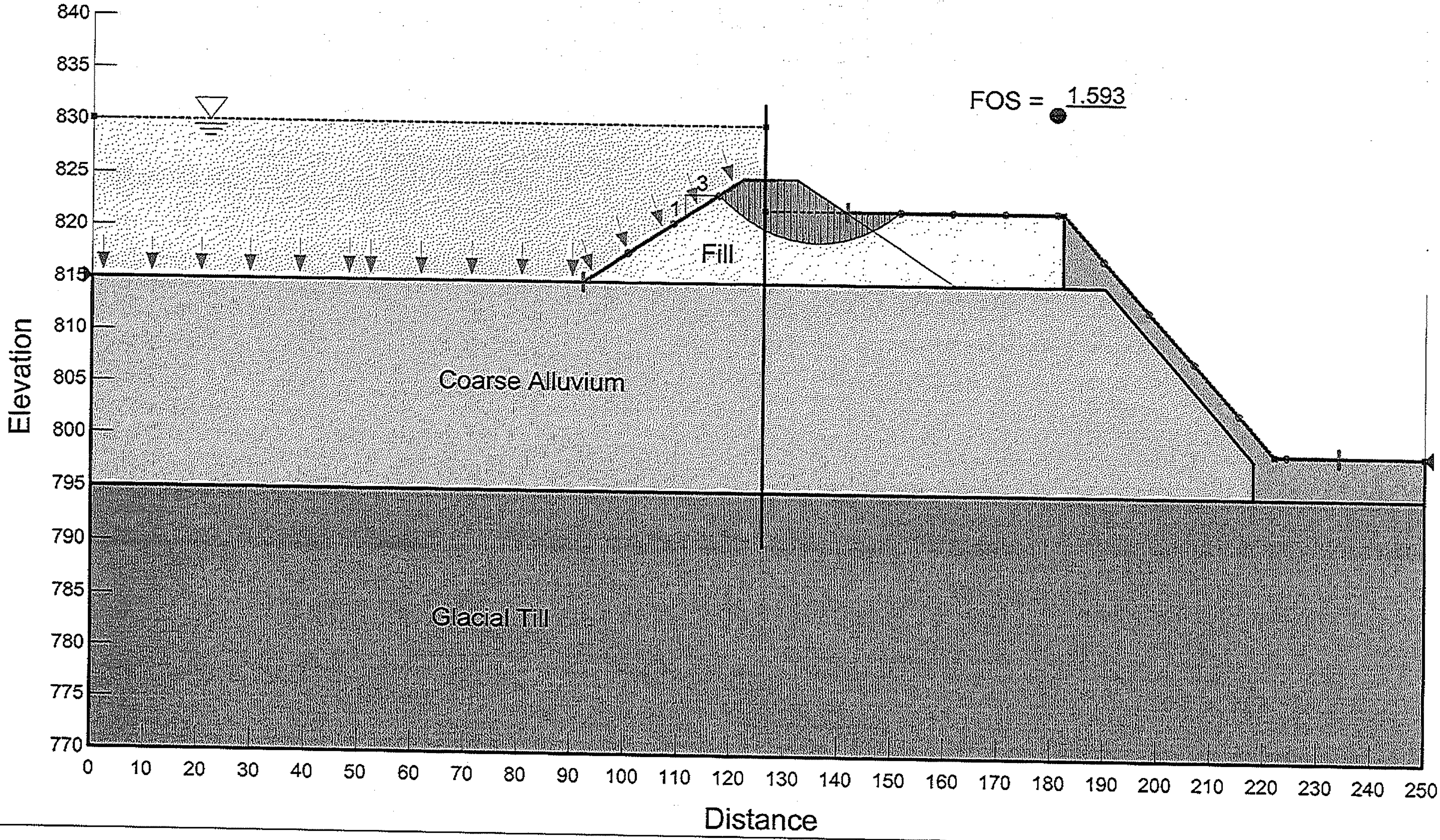
Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Headwater to Elevation 830.1 - Usual High Pool Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Karels
Checked By: J. Jacks
File Name: Partial_Earthen_830.gsz
Date: 3/22/2011



Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Headwater to Elevation 830.1 - Usual High Pool Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Karels
Checked By: J. Jacks
File Name: Partial_Earthen_830_Seepage.gsz
Date: 3/22/2011



Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
Upstream Earthen Cofferdam Slope Stability
Headwater to Elevation 832 - Unusual High Pool Case
Hennepin Side - Shallow Glacial Till

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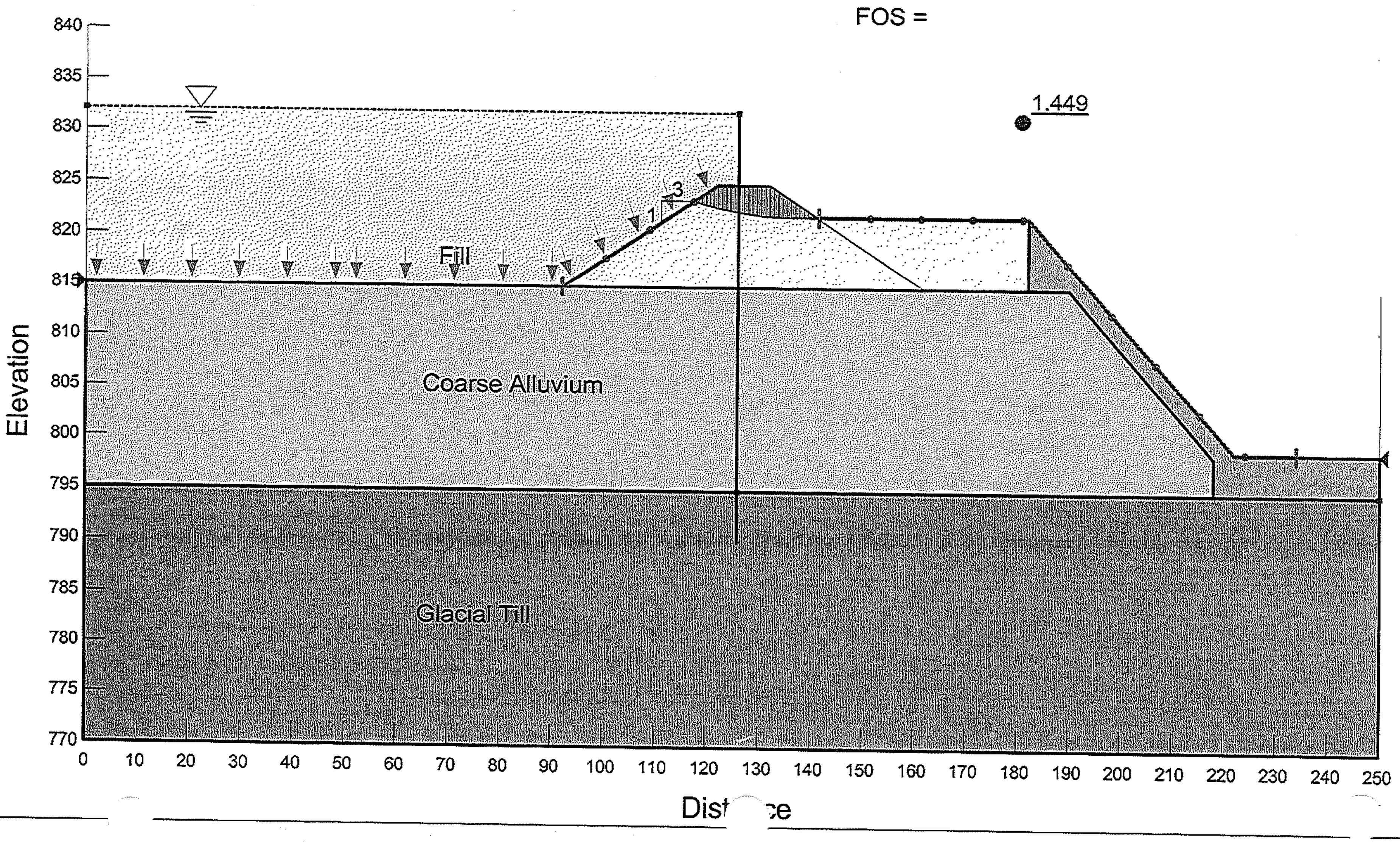

Coon Rapids Dam
Fish Barrier and Dam Improvement Preliminary Analysis
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Headwater to Elevation 832 - Unusual High Pool Case
Hennepin Side - Shallow Glacial Till

Computed By: L. Karels
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File Name: Partial_Earthen_832_Seepage.gsz
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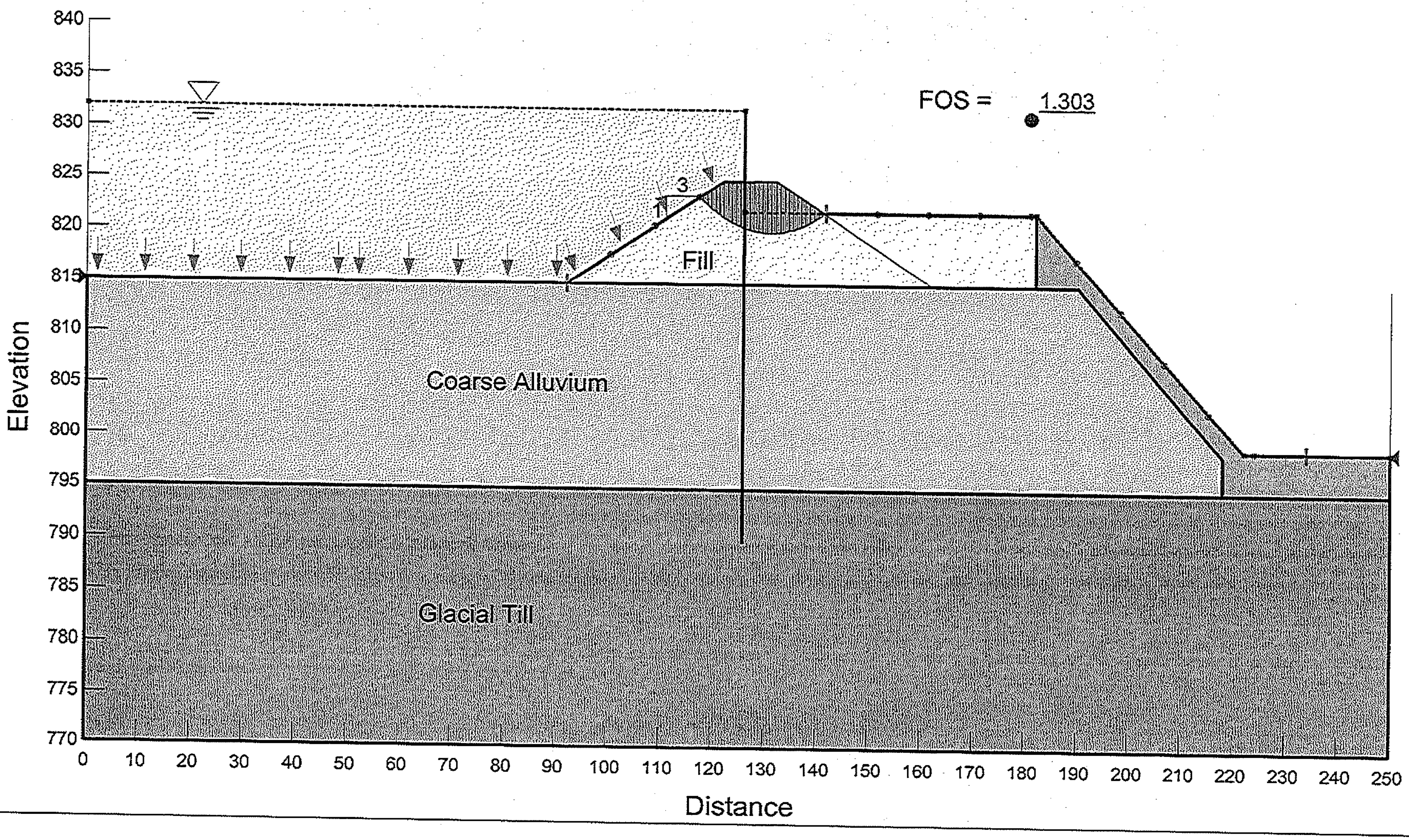


Bearing Capacity Analysis

Full Earthen Cofferdam

Stanley Consultants INC.

Project No. 23082 Page No.

Subject Upstream Earthen Cofferdam Bearing Capacity

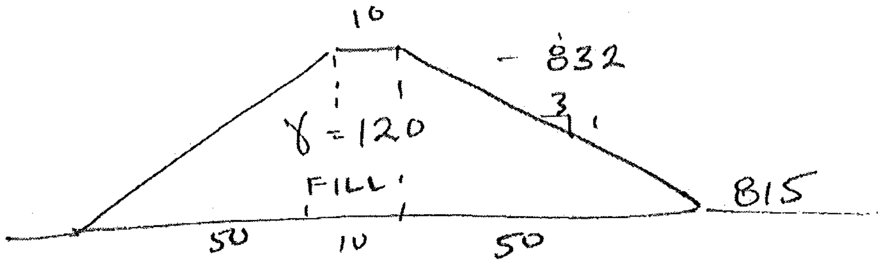
Computed by Date 3/21/11

Checked by JRS Date 3-24-11

Approved by Date

Sheet No. of

BEARING CAPACITY COMPUTATION



$\phi = 32°$ COARSE

$\gamma = 125$ ALLUVIUM

$$A = 10(832-815) + (832-815)50 = 1020\ ft^2$$

$$W = 1020\ ft^2\ (120\ psf) = 122,400\ lb/ft = 122.4^{k}/ft$$

$$122.4^{k}/110\ ft = 1.11\ ^{k}/ft^2 = 1112\ psf$$

$$q_u = \cancel{cN_c}^{\,0} + \cancel{qN_q}^{\,0} + \tfrac{1}{2}\gamma B N_\gamma \quad (strip)$$

$$= \tfrac{1}{2}\gamma B N_\gamma \quad where\ N_\gamma = 10(+/-)$$

$$= \tfrac{1}{2}(\underset{-62.5}{125\ psf})(110\ ft)(10) = 34^{k}$$

$$=$$

$$q_a = q_u/6 = 34^{k}/6 = \boxed{5.7\ ksf > 1.1\ ksf\ ✓\ ok}$$

Cellular Cofferdam Computations

Stanley Consultants INC.

Computed By: LDK　Date: 3/17/2011　Job No. 23082 - Coon Rapids Dam
Checked By: JRJ　Date: 3/18/2011　Subject Design of Upstream Cellular Cofferdam Structure
Approved By: ______　Date: ______　Sheet No. 1 of 3

Diagrams and Variables, Sliding Stability:

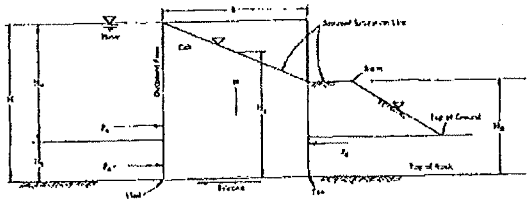


Fig 69

Driving Forces:

Full water pressure, $P_W = \gamma_W H^2/2$, per foot of wall
Active earth pressure, $P_a = \gamma' K_a H_s^2/2$, per foot of wall

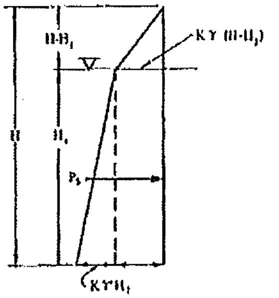
where K_a = active earth pressure coefficient
γ' = submerged unit weight of soil on the outboard side of the cofferdam
γ_W = unit weight of water = 62.4 pounds per cubic foot
H and H_s = height of cofferdam and soil, respectively
H_B = height from toe of cofferdam to top of berm

Resisting Forces:

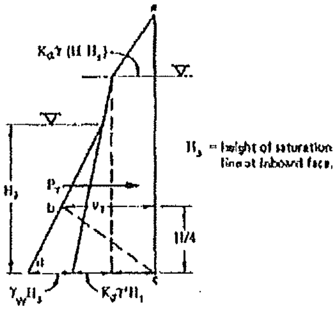
Friction force along bottom of the cell, $W \tan\delta'$;

$$W \tan\delta' = B[\gamma(H-H_1) + \gamma' H_1] \tan\delta'$$

where W = effective weight of cell fill
B = equivalent width of cofferdam
γ = unit weight of cell fill above saturation line
H = total height of cofferdam
H_1 = average height of saturation line
γ' = submerged unit weight of cell fill
$\tan\delta'$ = coefficient of friction of cell fill on rock, for smooth rock ~ 0.5
δ' = ϕ angle of the soil for other types



Vertical Plane On Centerline of Cofferdam
(a)



Inboard Sheeting
(b)

Notes:

System:

Top El	832	830.1 + 2 ft freeboard
Base El	815	
D	22	
B	17.27	*(0.785*D for 90 deg T)*
Wet Water	832	*High Water Case*
Dry Water	820	*(Unusual)*
Wet Soil	815	
Dry Soil	820	

Soil:

Unit Weight	125	
Friction Ang.	27	*Fill*
Friction Ang.	32	*Foundation*

Water:

Unit Weight	62.5	
Ka	0.38	<u>Radians(45-phi/2)</u> 0.55
Kp	2.66	<u>Radians(45+phi/2)</u> 1.02
γ'	62.5	
H	17	
H_s	5	
H_b	5	
H_1	12.6825	*Assume 2H:1V Sat Line*
H_3	5.486667	
$\tan(\delta')$	0.51	= tan(36)
W	23.00958 k	
Friction	11.7	=W*tan(δ')
$P_{w(drive)}$	9.03 k	
Pa	0.293379 k	
$P_{w(resist)}$	0.78125	
P_p	2.08	

$FOS_{Sliding}$ = 1.56　> 1.25 OK

Overturning about Toe:

Notes:

Driving Moment: 51.18

Resist Moment: 203.46

FOS_{Over} = 3.98　> 1.5 OK

Slipping between Sheeting and Cell Fill:

Notes:

FS = Resisting Moment due to Friction on Outboard Piling / Driving Moment due to Water and Soil Pressures

FS_{Slip} = 10.53　> 1.5 OK

Stanley Consultants INC

Computed By:	LDK	**Date:**	3/17/2011	**Job No.**	23082 - Coon Rapids Dam
Checked By:	JRJ	**Date:**	3/18/2011	**Subject**	Design of Upstream Cellular Cofferdam Structure
Approved By:		**Date:**		**Sheet No.**	2 of 3

Shear Failure on Centerline of Cell (Vertical Shear): *Notes:*

Q= 3M / 2B *where M = net overturning moment about the base*

M= 46.90 k-ft/ft

Q= 4.07 k/ft

$K = \cos(\phi)^2 / (2 - \cos(\phi)^2)$
= 0.66

Ps= ((1/2)*K*unit weight*(H-H1)^2 + K*unitweight*(H-H1)*H1 + (1/2)*K*unitweighteff*H1^2)/1000
= 8.58

S= Ps*tan(phi)
= 4.37

f= steel on steel coef of friction = 0.3

From Figure:
Pt= (1/2)(Ka)(Unitweight)(H-H1)^2 + (Ka)(Unitweight)(H-H1)(H1) + (1/2)(ka)(Unitweighteff)(H1)^2 + (1/2)(Unitweightwater)(H3)^2 - (1/2)(H/4)[(Unitweightwater)(H3)+(Ka)(Unitweighteff)(H1)+(Ka)(Unitweight)(H-H1)]

Pt= 4.04
St= S+f*Pt
= 5.59

FOS = St / Q

FOS = 1.37 > 1.25 OK

Horizontal Shear (Cummings' Methods): *Notes:*

Mr= (a*c^2*(unitweight_weighted)/2 + c^3*(unitweight_weighted)/3)/1000

Unitweight_weighted =
78 pcf

Note: *Weighted unit weight computed based on percentages of cofferdam above A-T line that are saturated and unsaturated.*

c= B*tan(phi)
= 8.80

a= H-c
= 8.20

Mr= 42.48

Ml= Pt*f*B
= 20.95303464

$$FOS = \frac{Mr + Ml + Pp*Hb/3}{(1/3)*(PwHw + PaHs)}$$

FOS = 1.29 > 1.25 OK

Stanley Consultants INC.

Computed By: JRJ
Checked By: LDK
Approved By:

Date: 3/17/2011
Date: 3/18/2011
Date:

Job No. 23082 - Coon Rapids Dam
Subject Design of Upstream Cellular Cofferdam Structure
Sheet No. 3 of 3

Interlock Tension:

Notes:

$t = \sigma_t * R/12$ *lbs per linear inch*

σ_t in lbs/ft, R in ft

R= radius= 10

$\sigma_t = (K_a(\gamma)(H-H_1) + K_a(\gamma')*(H_1-H/4) + \gamma_w*(H_3-H/4))$, use K rather than K_a

= 779.43 lbs/ft

$t =$ 649.53 lbs/in

$t_{max} =$ 3000 lbs/in for PSA23

Bearing Capacity:

Notes:

$$FOS = \frac{(1/2)*(\gamma')*B*N_g}{(6*M)/B^2 + (\gamma)*H}$$

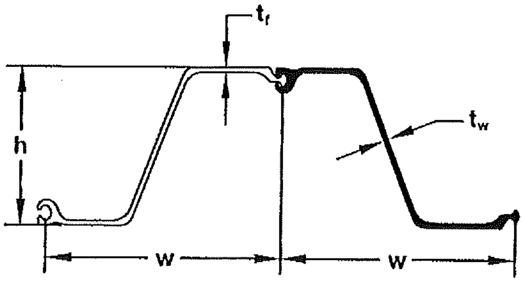
$N_g =$ 25 *for phi equals 32 degrees*

FOS = 4.40

Structural Data Sheets

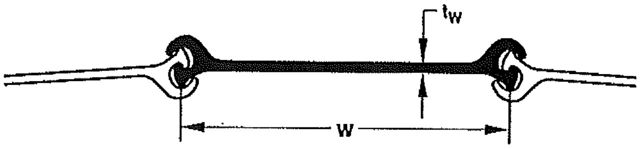
PZ/PS

PZ/PS Hot Rolled Steel Sheet Piling



PZ

SECTION	Width (w) in (mm)	Height (h) in (mm)	THICKNESS Flange (t_f) in (mm)	Wall (t_w) in (mm)	Cross Sectional Area in²/ft (cm²/m)	WEIGHT Pile lb/ft (kg/m)	Wall lb/ft² (kg/m²)	SECTION MODULUS Elastic in³/ft (cm³/m)	Plastic in³/ft (cm³/m)	Moment of Inertia in⁴/ft (cm⁴/m)	COATING AREA Both Sides ft²/ft of single (m²/m)	Wall Surface ft²/ft² of wall (m²/m²)
PZ 22	22.0 559	9.0 229	0.375 9.50	0.375 9.50	6.47 136.9	40.3 60.0	22.0 107.4	18.1 973	21.79 1171.1	84.38 11500	4.48 1.37	1.22 1.22
PZ 27	18.0 457	12.0 305	0.375 9.50	0.375 9.50	7.94 168.1	40.5 60.3	27.0 131.8	30.2 1620	36.49 1961.9	184.20 25200	4.48 1.37	1.49 1.49
PZ 35	22.6 575	14.9 378	0.600 15.21	0.500 12.67	10.29 217.8	66.0 98.2	35.0 170.9	48.5 2608	57.17 3073.5	361.22 49200	5.37 1.64	1.42 1.42
PZ 40	19.7 500	16.1 409	0.600 15.21	0.500 12.67	11.77 249.1	65.6 97.6	40.0 195.3	60.7 3263	71.92 3866.7	490.85 67000	5.37 1.64	1.64 1.64



PS

SECTION	Width (w) in (mm)	Web (t_w) in (mm)	Maximum Interlock Strength k/in (kN/m)	Minimum Cell Diameter* ft (m)	Cross Sectional Area in²/ft (cm²/m)	WEIGHT Pile lb/ft (kg/m)	Wall lb/ft² (kg/m²)	Elastic Section Modulus in³/sheet (cm³/sheet)	Moment of Inertia in⁴/sheet (cm⁴/sheet)	COATING AREA Both Sides ft²/ft of single (m²/m)	Wall Surface ft²/ft² of wall (m²/m²)
PS 27.5	19.69 500	0.4 10.2	24 [illegible]	30 9.14	8.09 171.2	45.1 67.1	27.5 134.3	3.3 54	5.3 221	3.65 1.11	1.11 1.11
PS 31	19.69 500	0.5 12.7	24 [illegible]	30 9.14	9.12 193.0	50.9 75.7	31.0 151.4	3.3 54	5.3 221	3.65 1.11	1.11 1.11

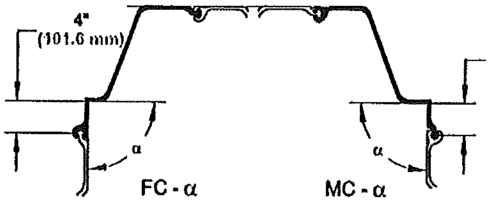
- Minimum cell diameter cannot be guaranteed for piles over 65 feet [illegible] in length
- Minimum cell diameter cannot be guaranteed if piles are spliced
- 58 Piles are needed to make a 30 foot diameter cell

PZ/PS

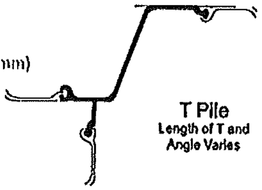
PZ/PS Hot Rolled Steel Sheet Piling

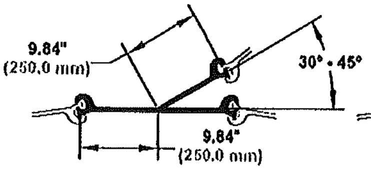
Available Steel Grades							
PZ's			PS's				
ASTM	YIELD STRENGTH		ASTM	YIELD STRENGTH		INTERLOCK STRENGTH	
	(ksi)	(MPa)		(ksi)	(MPa)	(k/in)	(kN/m)
A 328	39	270	A 328	39	270	16	2800
A 572 Grade 50	50	345	A 572 Grade 50	50	345	20	3500
A 572 Grade 60	60	415	A 572 Grade 60	60	415	24	4200
A 572 Grade 65	65	450	A 572 Grade 65	65	450	24	4200
A 588	50	345	A 588	50	345	20	3500
A 690	50	345	A 690	50	345	20	3500

Corner and Junction Piles

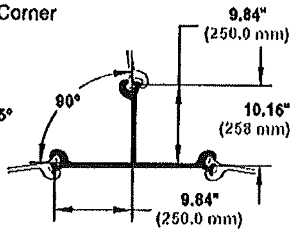


Female or Male Corner

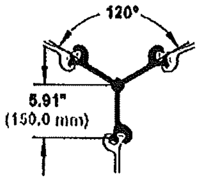




30° Y Pile



90° T Pile



120° Y Pile

Delivery Conditions & Tolerances

	ASTM A 6	
Mass	± 2.5%	
Length	+ 5 inches	– 0 inches

Maximum Rolled Lengths*

PZ	85 feet for singles, 70 feet for pairs	(25.9 m, 21.3 m)
PS	65 feet	(19.8 m)

* Longer lengths may be possible upon request.