

October 12, 2016

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

**Initial Structural Stability Assessment
Gypsum Disposal Area and Stilling Ponds 1 and 2
EPA Final CCR Rule
TVA Paradise Fossil Plant
Drakesboro, Kentucky**

1.0 PURPOSE

This letter documents AECOM's certification of the initial structural stability assessment for the TVA Paradise Fossil Plant's Gypsum Disposal Area and Stilling Ponds 1 and 2. Based on this assessment, the Gypsum Disposal Area and Stilling Ponds 1 and 2 are in compliance with the structural stability requirements in the Final CCR Rule at 40 CFR 257.73(d).

2.0 INITIAL STRUCTURAL STABILITY ASSESSMENT

As described in 40 CFR 257.73(d), documentation is required on how the Gypsum Disposal Area and Stilling Ponds 1 and 2 has been designed, constructed, operated, and maintained according to the structural stability requirements listed in the section. The combined capacity of all spillways must also be designed, constructed, operated, and maintained to adequately manage flow from the 1000-year storm event based upon a hazard potential classification of "significant."

3.0 SUMMARY OF FINDINGS

The attached report presents the initial structural stability assessment of the Gypsum Disposal Area and Stilling Ponds 1 and 2. The results show that the impoundment meets the structural stability requirements set forth in 40 CFR 257.73(d)(1)-(2).

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4.0 QUALIFIED PROFESSIONAL ENGINEER CERTIFICATION

I, Nicholas S Golden PE, being a Professional Engineer in good standing in the State of Kentucky, do hereby certify, to the best of my knowledge, information, and belief:

1. that the information contained in this certification is prepared in accordance with the accepted practice of engineering;
2. that the information contained herein is accurate as of the date of my signature below; and
3. that the initial structural stability assessment for the TVA Paradise Fossil Plant's Gypsum Disposal Area and Stilling Ponds 1 and 2 meet the requirements specified in 40 CFR 257.73(d)(1)-(2).

SIGNATURE 

DATE 10/12/16

ADDRESS: AECOM
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ATTACHMENTS: Initial Structural Stability Assessment (40 CFR §257.73(d)(1) for Coal Combustion Residuals (CCR)



COAL COMBUSTION PRODUCT DISPOSAL PROGRAM

**TENNESSEE VALLEY AUTHORITY – GYPSUM DISPOSAL AREA
TVA PARADISE FOSSIL PLANT
DRAKESBORO, KENTUCKY**

**INITIAL STRUCTURAL STABILITY ASSESSMENT
(40 CFR §257.73(d)(1))
FOR COAL COMBUSTION RESIDUALS (CCR)
EXISTING CCR SURFACE IMPOUNDMENTS**

Prepared for



Tennessee Valley Authority
1101 Market Street
Chattanooga, TN 37402-2801

October 12, 2016



Prepared by





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1.0 PROJECT BACKGROUND

On April 17, 2015 the “Disposal of Coal Combustion Residuals (CCR) from Electric Utilities” (EPA Final CCR Rule) was published in the Federal Register. AECOM has been contracted by the Tennessee Valley Authority (TVA) to analyze the Structural Stability of the Paradise Fossil Plant’s CCR surface impoundments (SI) and evaluate compliance with §257.73 of the EPA Final CCR Rule.

As required by §257.73 of the EPA Final CCR Rule, an initial structural integrity evaluation is required by October 17, 2016 and must include an initial structural stability assessment for each existing CCR surface impoundment that meets the conditions of paragraph (b) as follows:

1. Has a height of five feet or more and a storage volume of 20 acre-feet or more; or
2. Has a height of 20 feet or more.

The Gypsum Disposal Area and Stilling Ponds 1 and 2 meet the criteria. The location of the Gypsum Disposal Area and Stilling Ponds is shown in **Figure 1**.



Figure 1: Site Location Map

2.0 STRUCTURAL STABILITY ASSESSMENT

40 CFR 257.73(d)(1). *Periodic structural stability assessments. (1) The owner or operator of the CCR unit must conduct initial and periodic structural stability assessments and document whether the design, construction, operation, and maintenance of the CCR unit is consistent with recognized and generally accepted good engineering practices for the maximum volume of CCR and CCR wastewater which can be impounded therein. The assessment must, at a minimum, document whether the CCR unit has been designed, constructed, operated, and maintained with:*

- (i) *Stable foundations and abutments;*
- (ii) *Adequate slope protection to protect against surface erosion, wave action, and adverse effects of sudden drawdown;*

- (iii) Dikes mechanically compacted to a density sufficient to withstand the range of loading conditions in the CCR unit;*
- (iv) Vegetated slopes of dikes and surrounding areas, except for slopes which have an alternate form or forms of slope protection;*
- (v) A single spillway or a combination of spillways configured as specified in paragraph (d)(1)(v)(A) of this section. The combined capacity of all spillways must be designed, constructed, operated, and maintained to adequately manage flow during and following the peak discharge from the event specified in paragraph (d)(1)(v)(B) of this section.*
- (vi) Hydraulic structures underlying the base of the CCR unit or passing through the dike of the CCR unit that maintain structural integrity and are free of significant deterioration, deformation, distortion, bedding deficiencies, sedimentation, and debris which may negatively affect the operation of the hydraulic structure; and*
- (vii) For CCR units with downstream slopes which can be inundated by the pool of an adjacent water body, such as a river, stream or lake, downstream slopes that maintain structural stability during low pool of the adjacent water body or sudden drawdown of the adjacent water body.*

2.1 FOUNDATIONS AND ABUTMENTS - §257.73(d)(1)(i)

The geology of the area encompassing the Gypsum Disposal Area and Stilling Ponds includes alluvial deposits underlain by Pennsylvanian age bedrock formations. Geologic mapping indicates the site is primarily underlain by two geologic formations of Pennsylvanian age, the Carbondale and Shelburn Formations. Both formations generally consist of sandstone, which weathers to a dense sand. The Shelburn Formation underlies the Carbondale Formation. Underlying the Shelburn sandstone is a shale unit that is typically light-gray to black, and carbonaceous. Coal underlies the shale unit.

The site lies within an alluvial valley, which used to be the Jacob's Creek floodplain. The floodplain contained alluvial deposits consisting of gravel, sand, silt and clay. Previous mining operations existed in the vicinity of the impoundment resulting in thick deposits of mine spoils at the original surface of the Gypsum Disposal Area.

The foundation of the embankments and dikes consists of mine spoils. These materials are previously excavated overburden removed during the strip mining process and then replaced following removal of coal deposits. Accordingly, mine spoils tend to be heterogeneous. The majority of the mine spoils sampled consists of moist to wet, medium stiff to very stiff, lean clay (CL) with varying quantities of coal and rock fragments. The dike embankments were constructed using clayey mine spoils consisting of clayey sand (SC) or lean clay (CL) with varying quantities of gravel sized rock fragments.

In 2015, an Initial Annual (Intermediate) Inspection was performed for the Gypsum Disposal Area and Stilling Ponds 1 and 2 was completed. Based on the report, no evidence of actual or potential structural weakness of the inspected units was observed. No changes that may have affected the operational stability of the impounding structure were identified since the last inspection of the unit.

An assessment of seepage conditions of the foundation was performed by AECOM. Cone penetration testing (CPT) and hollow stem auger (HSA) boring exploration data was used in conjunction with historically available HSA data, laboratory testing data, and piezometer data to complete the geotechnical analyses including static slope stability and seepage. A review was made of available historical information, and a site visit was performed to obtain additional, site-specific information. Seepage modeling indicated a phreatic surface, which remains beneath the surface of the downstream slope during normal pool conditions, which is consistent with recent observations.

The phreatic surface used in the stability analysis was modeled using Seep/W software and known normal and flood pool elevations as boundary conditions. Initially, saturated permeability and anisotropy parameters from existing laboratory data and estimates from published correlations were modeled. Generally, hydraulic conductivities were initially determined from laboratory testing, while anisotropic ratios were determined based on published information from the United States Bureau of Reclamation. The values were then adjusted, when deemed appropriate, in order to calibrate the seepage models to the conditions as observed in historical piezometer data and field CPT dissipation data. The calibration process was completed at each cross section until parameters were determined which yielded a reasonable correlation to field readings.

The cross section locations were selected to be representative of the most critical cross sections, such as the maximum embankment height, the steepest embankment slopes, and the least resisting force at and beyond the downstream toe. The number and location of cross sections reflects engineering judgment to obtain appropriate geo-spatial coverage of the dike. The final calibrated model was conservatively constructed in order to present a phreatic surface slightly higher than the measured data to account for uncertainties. The modeled cross sections are shown in **Appendix B**.

The final seepage parameters are summarized in **Table 1** below.

Table 1: Summary of Seepage Parameters

Material	K_v (cm/s)	$^2K_h/K_v$
Raised Embankment	2.4×10^{-5}	4
Chimney and Finger Drain	0.001	0.5

Generally, the final adjusted values were within an order of magnitude of the laboratory test data. However, the permeability value of the drain was slightly lower than expected (10^{-3} cm/s) but still within a range typically associated with clean sand (10^{-1} to 10^{-3} cm/s).

As a part of the seepage analysis at each cross section, horizontal and vertical gradients could be determined at individual finite elements. A determination of high or critical, (vertical) exit gradients can also be performed following well established sources (including Terzaghi and Peck, USACE EM 1110-2-1901, and USBR Design Standard No. 13 Embankment Dams, Chapter 8, January, 2014). Determination of critical gradients for a soil is determined when evaluating effective stress conditions. In essence, the critical gradient occurs when the effective

stress is zero. Under this condition, a “quick” condition exists in cohesionless soils, and the foundation materials may “boil” or “heave.” The critical gradient (i_c) is most commonly expressed as the ratio of the buoyant unit weight of the soil (γ_b) to the unit weight of water (γ_w). The factor of safety (FS) with respect to piping is generally defined as the ratio of the critical gradient (i_c) to the predicted or measured exit gradient (i_e) determined using the SEEP/W model. However, as described in the USBR Design Standard No. 13 Embankment Dams, Chapter 8, January, 2014:

“It is important to recognize that the critical exit (vertical) gradient and the occurrence of boils and heaving of grains only occur in cohesionless soils. In most cohesive soils (plastic clays), with the exception of dispersive soils, inter-particle attractions create bonds between particles that make it less likely for these soils to lose strength due to seepage or for individual particles to be easily moved. Laboratory tests have shown that while sands can typically move or become quick under an upward gradient of around 1.0, clay particles may not move until threshold gradients reach values in the tens or even hundreds. Thus, any type of critical gradient in cohesive soils would be difficult to measure, would vary widely among such soils (due to such variables as percentage of clay fines, type of clay minerals, water content, and density), and should definitely not be calculated by the above equation.”

The embankment and foundation materials of the dikes are constructed with cohesive materials. The seepage analysis indicates gradients at the toe are predominantly horizontal, as is typical for seepage flow through an embankment or foundation. Again as stated by the in the USBR Design Standard No. 13 Embankment Dams, Chapter 8, January, 2014:

“Although formulae exist for computing factors of safety for conditions of critical exit (vertical) gradients, there is much more uncertainty when it comes to determining internal (horizontal) gradients that are capable of initiating internal erosion.”

It should also be noted that an internal chimney drain and graded filter have been constructed within the embankment, and that seepage exiting the embankment at the toe would be filtered in any case.

Therefore, while it is possible to measure vertical exit gradients and calculate critical gradients based on the available project information, performing a factor of safety calculation against piping is not appropriate for this project.

. At the downstream toe of an embankment, if the seepage pressures in a pervious layer are higher than the overburden pressure of the confining layer, uplift of the confining layer may occur. In simplest terms, the factor of safety against uplift can be calculated in total stresses (or forces) as the total downward pressure exerted by the weight of the confining layer divided by the upward water pressure at the base of the layer.

At the Stilling Pond 1 and 2 embankment dike, the subsurface conditions within the embankment and foundation are mine spoil consisting of a heterogeneous mixture of clay, sand,

silt, and gravel sized particles. Based on the subsurface conditions, no clearly defined pervious or confining layer is present. On this basis, and in consideration of the seepage analysis, uplift pressures would not develop at or beyond the toe of the Stilling Pond 1 or Stilling Pond 2 dike. The calculated factor of safety against heave for the Stilling Pond 1 and Stilling Pond 2 dike would exceed the recommended value of 1.5 for existing structures.

Seepage conditions have been analyzed in accordance with acceptable methodologies, and existing embankments and foundation materials are performing acceptably in regard to piping and heave potential in comparison to current criteria and based on existing analytical data. Further, no physical or visual evidence of piping, heave, or uplift has been observed in the field during multiple visits to the site between 2015 and 2016.

More information on the assessment of foundations and abutments can be found in the Initial Safety Factor Assessment prepared for CCR Certification by AECOM.

2.2 SLOPE PROTECTION - §257.73(d)(1)(ii)

The Gypsum Disposal Area and Stilling Ponds 1 and 2 are defined by a number of embankments. All three impoundments have both shared splitter dikes and their own perimeter dikes. The embankments vary in elevation, width, and slope. All of the dikes have gravel access roads topping the crests. Dike slopes are generally covered by grassy vegetation with riprap placed along shorelines, drainage ditches, and spillway outlets.

In 2015, an Initial Annual (Intermediate) Inspection was performed for the Gypsum Disposal Area and Stilling Ponds 1 and 2. Based on the report, the slopes are generally covered with either dense grass or riprap. No trees or large, bushy vegetation are present on the slopes. No evidence of burrowing animals was observed. No evidence of actual or potential structural weaknesses of the inspected units were observed.

Water travel over the dike slopes will not cause erosive effects based on the current slope protection and condition. Water will not overtop the dikes of the Stilling Ponds during a 1,000-year storm event. No additional slope protection is required based on anticipated erosive flows.

More information on the assessment of slope protection can be found in 2015 Initial Annual (Intermediate) Inspection and the attached **Photos**.

2.3 EMBANKMENT DIKE COMPACTION - §257.73(d)(1)(iii)

Construction documents dated from 1985 show that the Gypsum Disposal Area and Stilling Ponds 1 and 2 were developed by the construction of two dikes. The first dike (called Scrubber Dike in construction documents) defined the southern dike for the Gypsum Disposal Area and currently serves as the splitter dike between Stilling Ponds 1 and 2. The second dike built (called the deflector dike in construction documents) now serves as the north dike of Stilling Pond 1. The remaining boundaries of the Gypsum Disposal Area and Stilling Pond 1 and 2 were defined by existing road embankments and topography.

Original construction documents from 1985 indicate the dikes construction consisted of dewatering the area, clearing of vegetation, compaction of subgrade, and scarification of the foundation area. The compacted subgrade was to be done with a sheepsfoot roller followed by a flat wheeled roller until there it could support heavy equipment without rutting or heaving. The

construction of the dike included placement of earth fill (mine spoil) in layers of 6-inches compacted to 95 percent of maximum dry density per ASTM D698. Soil moisture content was to be within $\pm 3\%$ of the optimum moisture content. In place density testing using either the sand cone (ASTM D1556) or rubber balloon (ASTM D2167) test methods was made at a rate of at least one test per 1,000 cubic yards of fill placed, or a minimum of one per day. Rocks larger than 6 inches in diameter were removed from the fill. Mine spoils can be visually described as lean to fat clay with intermediate sand lenses, gray to dark gray, moist to wet, soft to very stiff and with heterogeneous mixture of coal, shale, sandstone and siltstone fragments.

Documentation for the construction of the western dike of Stilling Pond 1 (called the Clarification Pond in construction documents) was not found. It appears to have been constructed between 1985 and 1993.

Construction documents dated from 1993 show additional construction of the Gypsum Disposal Area. Construction included raising the southern dike, construction of the eastern and western perimeter dikes, and an internal divider dike. The construction documents from the improvements performed dated in 1993 reference the 1985 construction methods for placement and compaction of fill during dike construction. This includes the same details as listed above.

More information on the construction of the dikes can be found in the History of Construction Report prepared for CCR Certification by AECOM.

2.4 VEGETATED SLOPES - §257.73(d)(1)(iv)

The embankments forming the Gypsum Disposal Area and Stilling Ponds 1 and 2 are primarily covered with well-maintained grassy vegetation. The crest of each dike serves as an access road, consisting of gravel surface. Riprap is placed at relevant locations including shorelines, drainage ditches, and spillway outlets.

In 2015, an Initial Annual (Intermediate) Inspection was performed for the Gypsum Disposal Area. Based on the report, the slopes are generally covered with either dense grass or riprap. No trees or large, bushy vegetation are present on the slopes. No evidence of burrowing animals was observed. No evidence of actual or potential structural weakness of the inspected units was observed.

More information on the assessment of vegetated slopes can be found in the 2015 Initial Annual (Intermediate) Inspection and the **Photos**.

2.5 SPILLWAY CONDITION AND CAPACITY - §257.73(d)(1)(v)

Under existing conditions, the drainage area for the Gypsum Disposal Area and Stilling Ponds 1 and 2 is approximately 267 acres, containing areas north and east of the pond, and south of the plant.

Stilling Pond 1 receives stormwater drainage from the Gypsum Disposal Area and surrounding area. Water discharges from Stilling Pond 1 and outlets into Stilling Pond 2 through a new spillway structure that was constructed in 2016. The spillway consists of three 24" HDPE culvert pipes that share a concrete spillway inlet structure and concrete outlet/energy dissipater. The Stilling Pond 2 outlet structure consists of two 42" steel culvert pipes that discharge into an open

channel drainage ditch. These culverts were installed in 2016. The water discharging into the drainage ditch flows to the Peabody Ash Pond.

More information on existing spillway structure conditions can be found in the History of Construction Report prepared for CCR Certification by AECOM and the attached **Photos**.

AECOM performed a hydrologic and hydraulic (H&H) study of the existing Stilling Ponds. An H&H computer model was developed using HEC-HMS to examine the hydraulic behavior of the Gypsum Disposal Area and Stilling Ponds during the Inflow Design Flood (IDF). The required IDF used in the model calculations is based on each pond's hazard classification. Since Stilling Ponds 1 and 2 were classified as significant hazards, the required IDF is a 1,000 year flood.

All structure dimensions, and invert elevations are modeled using the best available information under current operating conditions of the PAF Plant. Existing topographic and survey information for the Gypsum Disposal Area was provided by TVA. Drainage areas, volumes, and other site geometry were determined using the AutoCAD Civil 3D software in conjunction with survey data provided by TVA.

The modeling results suggest the ponds would not overtop during a 1000-year design storm, and the freeboard for the Upper and Lower Stilling Ponds during this storm event is adequate.

More information on the assessment of spillway capacity can be found in the Initial Inflow Design Flood Control Plan prepared for CCR Certification by AECOM.

2.6 SPILLWAY STRUCTURAL INTEGRITY - §257.73(d)(1)(vi)

All concrete, backfill, skimmer devices, bracing, connections, pedestrian grating and railings, outlet headwalls, and erosion protection devices were installed in 2016.

The spillway and headwall were analyzed for structural stability and strength. The spillway was evaluated for two different limit states. The first limit state was calculated under normal operating conditions. The second limit state was calculated for loading under a 1,000 year flood event. The structural stability for both limit states was checked against factor of safety requirements regarding to floatation, sliding, moment equilibrium, and bearing capacity.

Since the spillway was designed and built in 2016, the original design calculations were used for the structural evaluation under normal operating conditions. The calculations for normal conditions are provided in Gypsum Disposal Area Stilling Pond 1, Spillway Basis of Design Calculations in **Appendix A1**.

Additional calculations were performed for loading under a 1,000 year flood event. Under such conditions, it was assumed that water would overtop the skimmers with the chambers being full. The calculations for the 1,000-year flood are provided in Gypsum Disposal Area Stilling Pond 1 Spillway, 1,000 - Year Flood Calculations in **Appendix A2**.

The existing structures satisfy the factor of safety requirements for both limit states under both conditions evaluated.

2.7 SUDDEN DRAWDOWN ASSESSMENT - §257.73(d)(1)(vii)

The Sudden Drawdown Assessment does not apply to the Gypsum Disposal Area and Stilling Ponds 1 and 2. The dike that separates Stilling Ponds 1 and 2 sits approximately 34 feet above the normal pool elevation of Stilling Pond 2. Likewise, the splitter dike is approximately 10 feet

above the normal pool elevation of Stilling Pond 1. The effects of a sudden drawdown would not affect either Stilling Ponds 1 or 2 due to the significant elevation difference between the two ponds. Additionally, the 100-year floodplain of the Green River is significantly lower than the elevation of Stilling Ponds 1 and 2.

3.0 CONCLUSION

Based on the initial structural stability assessment, the requirements of **Rule §257.73(d)(1)** for the Gypsum Disposal Area and Stilling Ponds 1 and 2 have been met.

4.0 REFERENCES

1. Environmental Protection Agency, "Final Rule: Disposal of Coal Combustion Residuals from Electric Utilities", Federal Register, April 17, 2015.
2. AECOM, Gypsum Disposal Area, History of Construction (40 CFR 257.73(c)) prepared for Coal Combustion Residuals (CCR) Existing Surface Impoundments, 2016.
3. AECOM, Gypsum Disposal Area, Initial Inflow Design Flood Control System Plan (40 CFR 257.82) prepared for Coal Combustion Residuals (CCR) Existing Surface Impoundments, 2016
4. AECOM, Gypsum Disposal Area, Initial Safety Factor Assessment (40 CFR 257.73(e)(1)) for Coal Combustion Residuals (CCR) Existing Surface Impoundments, 2016.
5. TVA Paradise Fossil Plant Wastewater Flow Schematic Rev 9-11
6. TriAD, Paradise Fossil Plant, Initial Annual (Intermediate) Inspection, 2016
7. USACE, "USACE EM 1110-2-1902 Slope Stability," October 31, 2003.
8. USBR Design Standard No. 13 Embankment Dams, Chapter 8, January, 2014
9. K. Terzaghi and R. B. Peck, Soil mechanics in engineering practice, New York: John Wiley & Sons, Inc., 1996.

PHOTOS



**GYPSUM DISPOSAL
AREA STILLING POND 2**

**GYPSUM DISPOSAL
AREA**

**GYPSUM DISPOSAL
AREA STILLING POND 1**

AECOM
TVA PARADISE FOSSIL PLANT PARADISE, KENTUCKY
SITE LOCATION MAP GYPSUM DISPOSAL AREA AND STILLING PONDS 1 & 2



Photo 1 –Gypsum Disposal Area southern dike, looking west



Photo 2 – Divider dike between Stilling Pond 1 and 2, looking southwest



Photo 3 – Divider dike between Stilling Pond 1 and 2, looking northeast



Photo 4 – Divider dike between Stilling Pond 1 and 2, looking east



Photo 5 – Divider dike between Stilling Pond 1 and 2, looking east



Photo 6 – Stilling Pond 2 south dike, looking southwest



Photo 7 – Stilling Pond 2 south dike, looking southwest



Photo 8 – Stilling Pond 2 south dike, looking northeast



Photo 9 – Stilling Pond 2 Outlet, two 42” steel culverts

APPENDIX A

HYDRAULIC STRUCTURES ASSESSMENT CALCULATION PACKAGE

APPENDIX A1:

GYPSUM DISPOSAL AREA STILLING POND 1 SPILLWAY BASIS OF DESIGN CALCULATIONS



**TENNESSEE VALLEY AUTHORITY
PARADISE FOSSIL PLANT
GYPSUM STACK SPILLWAY REPLACEMENT**

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SECTION 4 - HYDROLOGIC AND HYDRAULIC CALCULATIONS AND REPORT

SECTION 5 – HYDROCAD OUTPUT

SECTION 6 – HY8 OUTPUT

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SECTION 1
STRUCTURAL CALCULATIONS FOR SPILLWAY
INLET AND OUTLET

Job	<u>PAF Gypsum Stack Spillway</u>	Project No.	<u>60444361</u>	Sheet	<u>of</u>
Description	<u>Inlet Structure Calculations</u>	Computed by	<u>SAM</u>	Date	<u>4/26/16</u>
		Checked by	<u>LMP</u>	Date	<u>5/16/16</u>

I. PURPOSE

The purpose of this structural analysis is to evaluate the stability of the inlet structure and the outlet structure, and to design the reinforcing steel for both. The inlet structure is located at the upstream end of the spillway, at the northeast end of the Upper Stilling Pond. The outlet structure is located on the downstream side of the spillway, at the southwest end of the Lower Stilling Pond. Both structures were checked for overturning, bearing, and sliding. Steel reinforcing was designed to resist moments and shear forces applied to the structure, in accordance with ACI 318-11.

II. SITE AND PROJECT DESCRIPTION

The existing spillway at the Gypsum Stack Upper Stilling Pond is being replaced due to stability concerns. The Upper Stilling Pond receives process flows and stormwater runoff from the Gypsum Stack. The Lower Stilling Pond receives flow from the Upper Stilling Pond, and a small amount of additional stormwater runoff. The purpose of both ponds is to settle solids that are suspended in the process flows, and to manage stormwater. The existing structure is a riser-type spillway, approximately 23 feet in height. A 36-inch outlet pipe discharges into the Lower Stilling Pond.

The existing discharge pipe and a portion of the riser will be grouted and abandoned as a part of this project. The new spillway will consist of a concrete inlet weir structure which will carry flows from the Upper Stilling Pond to the Lower Stilling Pond via three 24-inch HDPE pipes. At the downstream end, there will be a concrete energy dissipation structure, which was designed in accordance with the Federal Highway Administration's Hydraulic Engineering Circular No. 14 – "Energy Dissipators". The structure is a United States Bureau of Reclamation (USBR) Type VI Impact Basin. A riprap outlet channel will convey flow from the lower structure to the Lower Stilling Pond.

III. METHODOLOGY

The Gypsum Stack Spillway Structures were designed using the Load Resistance and Factor Design Methodology. The compression strength of concrete is 4000 psi and the yield strength of reinforcing is 60,000 psi. All reinforcing shall be epoxy coated with a minimum clearance of 2" unless otherwise shown on the plans. The allowable bearing pressure for both structures is 7.3 KSF.

Surcharge loads from equipment on the structure will be negligible due to the nature of the configuration of the structure and were not considered for stability. High groundwater is not anticipated, and uplift on the structure is not anticipated.

Both structures were analyzed for global stability during and after construction with the following results:



Job	<u>PAF Gypsum Stack Spillway</u>	Project No.	<u>60444361</u>	Sheet	<u>of</u>
Description	<u>Inlet Structure Calculations</u>	Computed by	<u>SAM</u>	Date	<u>4/26/16</u>
		Checked by	<u>LMP</u>	Date	<u>5/16/16</u>

Required Factor of Safety for Floatation: 1.3

Inlet FS = 4.6
Outlet FS = 2.35

Required Factor of Safety for Sliding: 2.0

Inlet FS = 1.96 During Construction
Inlet FS = 2.24 After Construction
Outlet FS = 1.97 During Construction
Outlet FS = 2.53 After Construction

Required Factor of Safety for Bearing Pressure: 3.0

Inlet FS = 4.90 During Construction and increases after Construction
Outlet FS = 9.0 During Construction and Increases after Construction

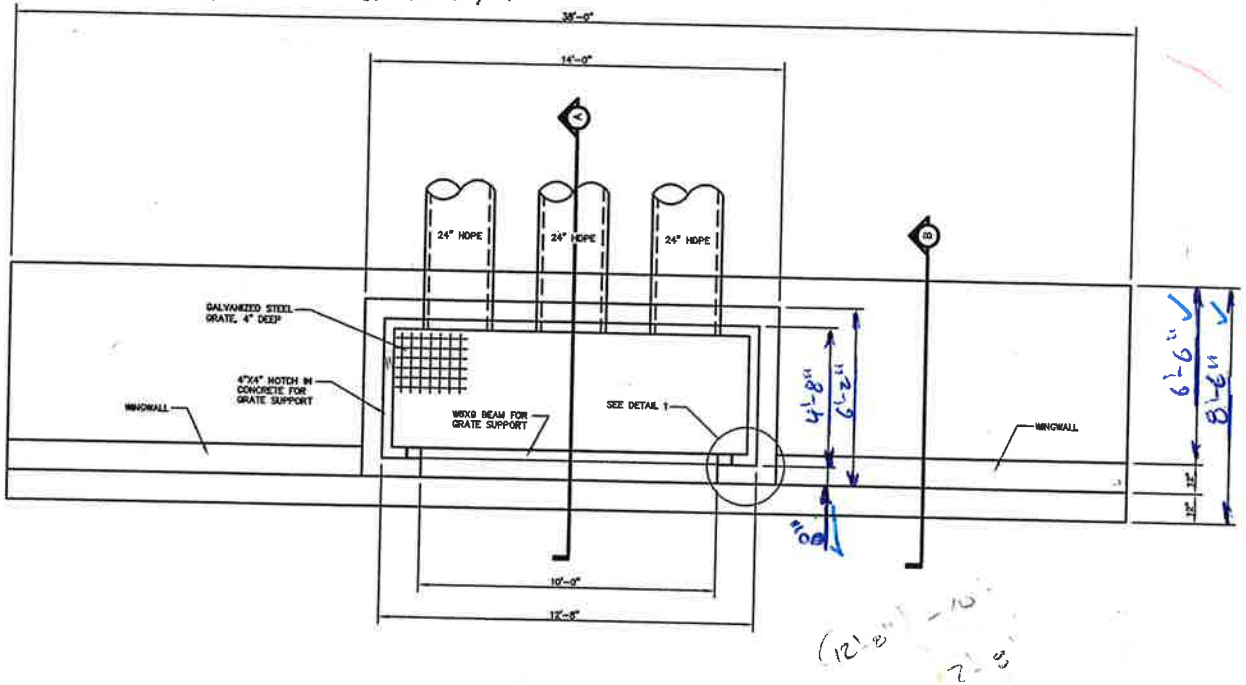
Neither structure will experience any uplift during or after construction.

The Dissipater structure will require porous backfill with drainage pipes directly behind the back and sidewalls to reduce hydrostatic pressure. The Dissipater Wall was designed assuming the velocity exiting the three 24" Dia. pipes was 25 ft./sec.

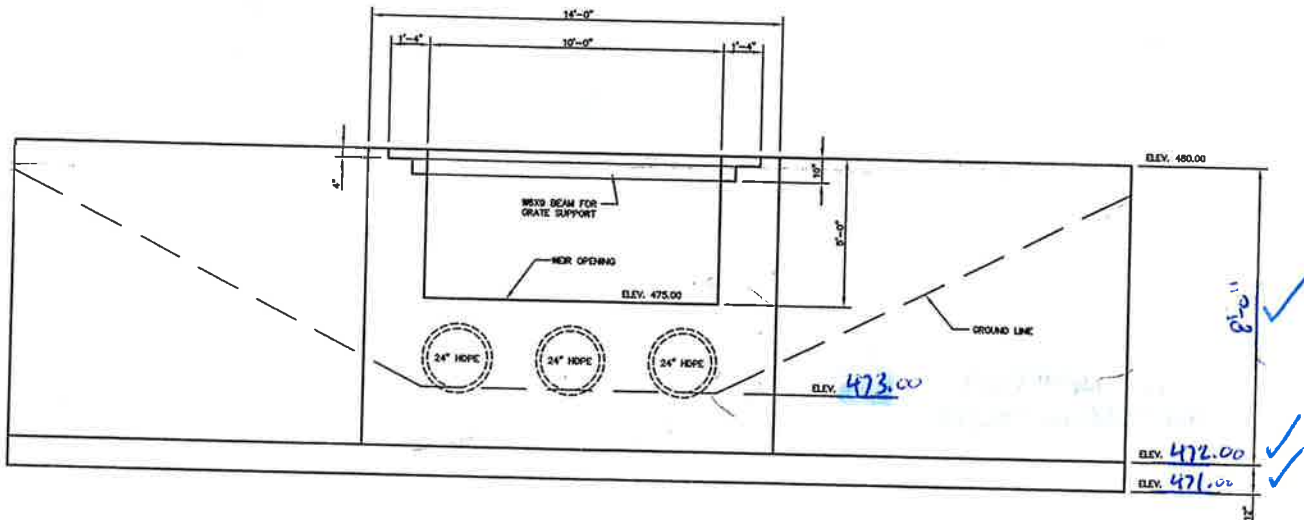
ATTACHMENT A

Detailed Inlet Structural Calculations

2. SIZE FOOTING & SHAPE KEY FOR GLOBAL STABILITY FOR SECTIONS A & B OF THE PREL. WARP STRUCTURE SHOWN BELOW;
 - THE DIMENSIONS SHOWN BELOW ARE PRELIMINARY. SEE SHT. 30 FOR FINAL DESIGN DIMENSIONS, FINAL DIM. FOR SECTION A & B SEE SHT. 19 & 20.



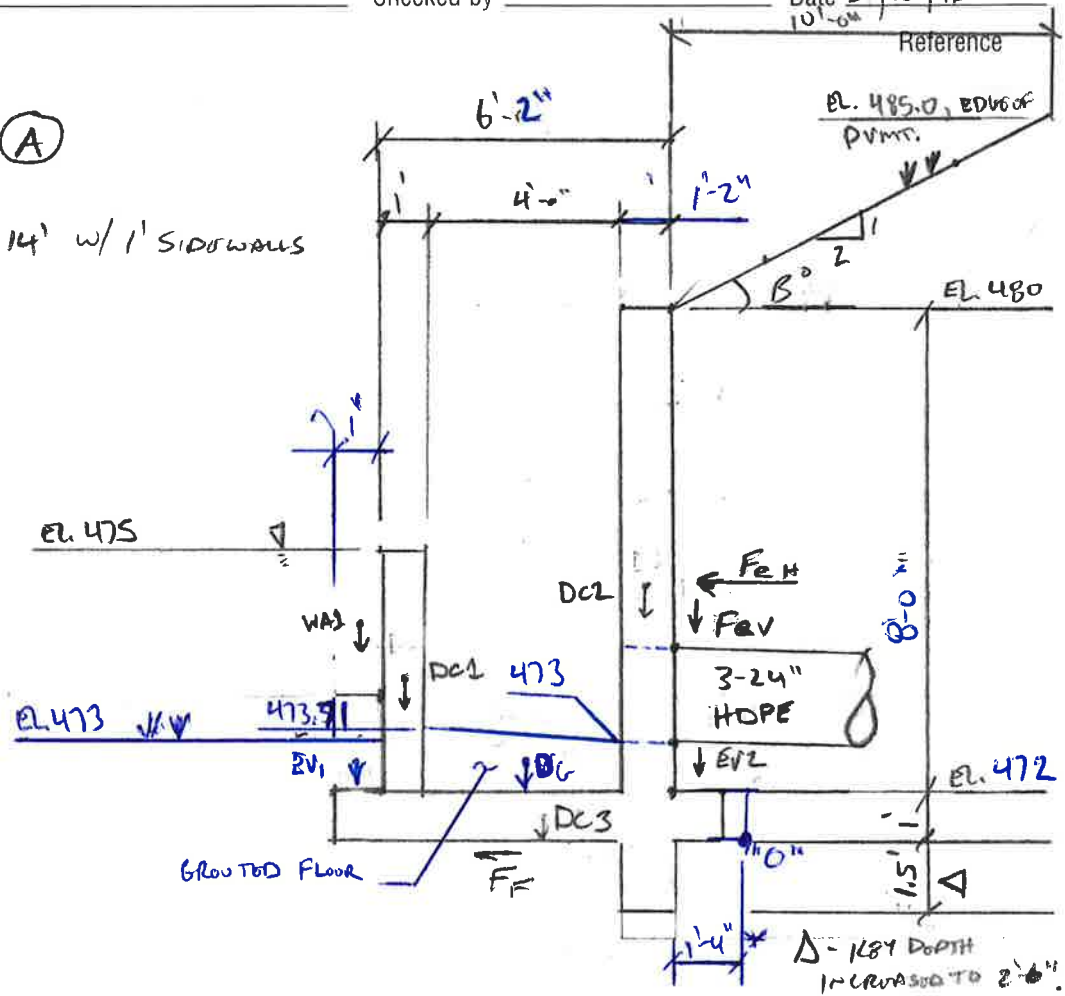
PLAN VIEW



FRONT ELEVATION

I. SECTION (A)

CHAMBER WIDTH = 14' w/ 1' SIDEWALLS



- CIL FLOTATION, SLIDING, MOMENT EQUILIBRIUM & BENDING

$$WA1 : 1'(3')(0.0624 \text{ K/FT}^2) = 0.19 \text{ K}_1$$

$$EV1 : 1'(1')(0.126 \text{ K/FT}^2) = 0.12 \text{ K}_1$$

$$EV2 : 1.33'(8')(0.126 \text{ K/FT}^2) = 1.28 \text{ K}_1 \quad \text{* EXTEND TO (3'-0") = 3'(8')(0.12 \text{ K/FT}^2) = 2.88 \text{ K}_1$$

$$DC1 : (1' \times 3') (0.15 \text{ K/FT}^2) = 0.45 \text{ K}_1$$

$$DC2 : (1.17' \times 8') (0.15 \text{ K/FT}^2) = 1.40 \text{ K}_1 \quad \text{** - SUB STR. ZA FOR REDUCTION IN WALL WEIGHT FROM PIPE CAVITIES}$$

$$DC3 : (1' \times 8.5') (0.15 \text{ K/FT}^2) = 1.28 \text{ K}_1 \quad \text{* EXTEND TO (3'-0") = (1' \times 10.2') (0.15 \text{ K/FT}^2) = 1.53 \text{ K}_1$$

$$DC4 : (\text{SIDE WALLS}) : 2(1' \times 4' \times 8') (0.15 \text{ K/FT}^2) / 14' = 0.69 \text{ K}_1$$

$$DG : (4' \times 1.35') (0.12 \text{ K/FT}^2) = 0.65 \text{ K}_1$$

$$\underline{6.06 \text{ K}_1}$$

$$\underline{7.91 \text{ K}_1}$$

Job GIPSON STACK CLOSURE
 Description INLET DESIGN CALCULATIONS

Project No. 60444361
 Computed by LMP
 Checked by SAM

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Reference

- SINCE RETAINING WALL HAS 3 - 24" ϕ HDPE PIPES EXTENDING THROUGH THE 10' WALL WIDTH, NEED TO DEDUCT THE OPENING IN WALL DUE TO THE PIPES.

$$\text{AREA OF } 2' \phi \text{ PIPE} = \frac{\pi (2')^2}{4} = 3.14 \text{ ft}^2$$

TAKE ^{1'} SECTION OF WALL W/ 2' PIPE \therefore DEDUCT $\frac{1}{2}$ AREA OF 2' ϕ PIPE:

$$A = 3.14 \text{ ft}^2, \text{ SO } \frac{1}{2} \text{ OF PIPE AREA} = \frac{3.14}{2} = 1.57 \text{ ft}^2$$

$$\begin{aligned} \text{OVER } 1' \text{ LENGTH OF WALL, } (1.17')(8') &= 9.36 \text{ ft}^2 - 1.57 \text{ ft}^2 \\ &= 7.79 \text{ ft}^2 \end{aligned}$$

$$\therefore 7.79 \text{ ft}^2 \times (.150 \text{ k/ft}^2) = \underline{1.17 \text{ k/ft}}$$

— OK —
 CALCS REVISED ON
 SHEET 5 TO REFLECT
 PIPE AREA DEDUCTION ✓

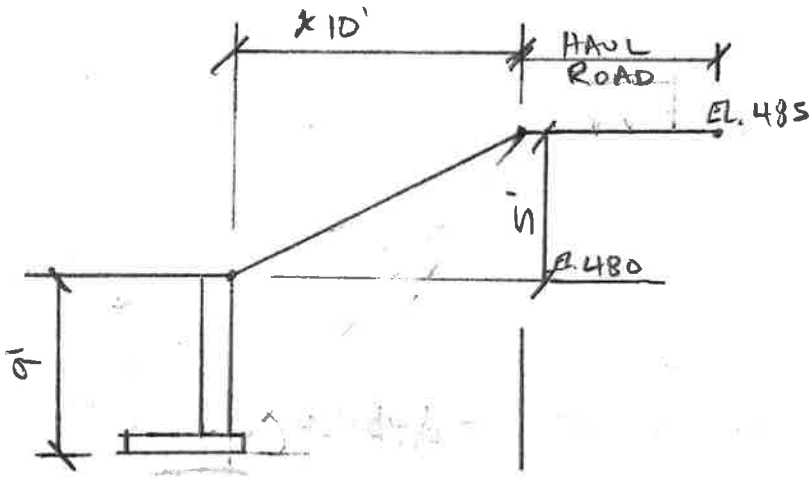
Job GYPSUM STAIR CLOSERS
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Reference

CHECK FOR EFFECTS OF LIVE LOAD SURCHARGE:

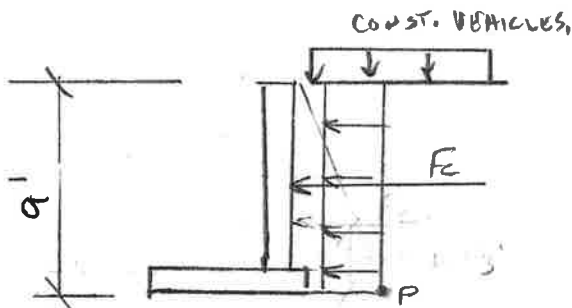


- AFTER CONSTRUCTION

- SEE SHEETS 4A & 4B FOR LIVE LOAD SURCHARGE CALC'S. OF A LOADED CAT 745 ARTICULATED TRUCK, TOTAL GROSS LOAD = 164 K

$F_{LS} = 0.36 \text{ K}$, $M_{LS} = 3.78 \text{ K'}$

- DURING CONSTRUCTION



$h_{eq} = 3.5'$ LRFD TABLE 3.11.6.4-2

$\phi = 33^\circ$

EQUIV EARTH PRESSURE = 40 #/FT^3

$P = 3.5' (0.04 \text{ K/FT}^2) = 0.14 \text{ KSF}$
 $F_e = 0.14 \text{ KSF} (9') = 1.26 \text{ K}$
 - NO HYDROSTATIC PRESSURE

Job Gypsum Stack Closure

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Description

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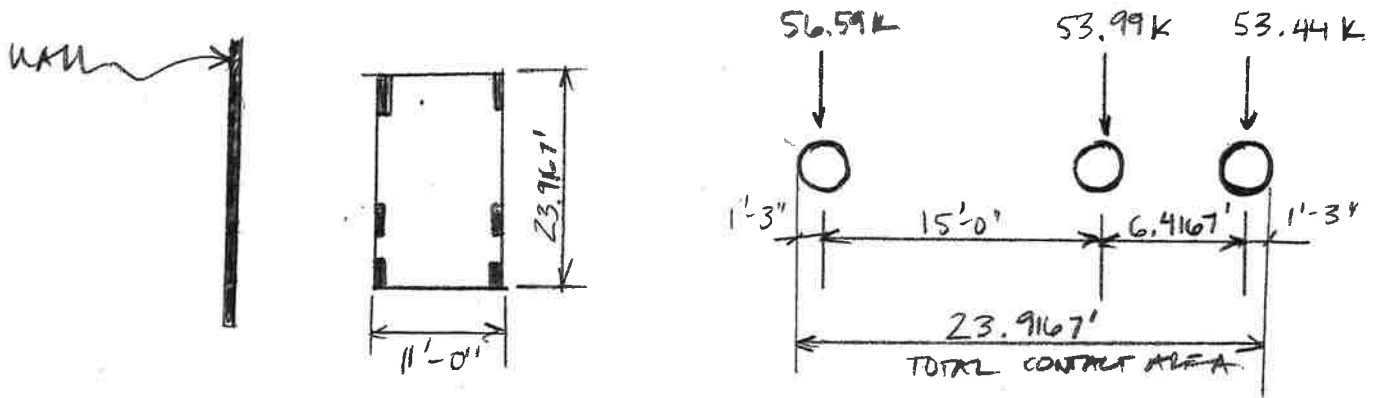
Date 4/27/16

Checked by LMP

Date 5/16/16

Reference

- SLIGHTLY REVISED STRIP LOAD CALLS FOR LOADED CAT 745 ARTICULATED TRUCK INSTEAD OF CAT 740 TRUCK:



$P = \text{TOTAL AXLE LOADS} = 56.59 + 53.99 + 53.44 = 164.02 \text{ K}$

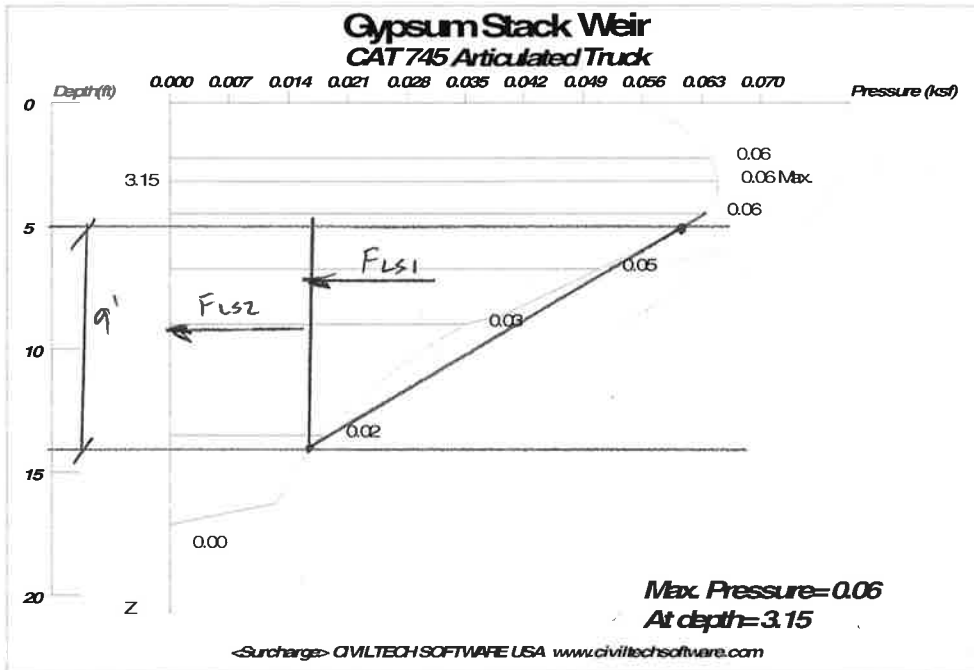
- DISTRIBUTE LOAD OVER TOTAL AREA:

$$\sigma = \frac{164.02 \text{ K}}{11' (23.9167')} = 0.623 \text{ kSF} \quad \text{SAY } \underline{625 \text{ PSF}}$$

STRIP LOAD OVER 11' WIDE STRIP

CALC BY: SAM 4/21/16
 CHECKED BY: LMP 5/16/16

46/29



Licensed to DFC URS Corp
 Date: 5/23/2016 File: UNTITLED

Wall Height, H= 9 Load Depth at Surface, D= -5
 Load Factor of Surcharge Loading = 1
 Rigid Wall Condition - No movement or deflection of the wall are allowed.
 Max. Pressure = 0.065 at depth = 3.15

X	Width	Length	Area Load
10.0	11.0	24.0	.62

$$F_{LS1} = \frac{1}{2} (0.04 \text{ ksf} \times 9') = 0.18 \text{ k}_1$$

$$F_{LS2} = \frac{(0.02 \text{ ksf} \times 9')}{0.36 \text{ k}_1} = 0.18 \text{ k}_1$$

$$M_{LS1} = 0.18 \text{ k}_1 \left(\frac{2}{3} \times 9' \right) = 1.08 \text{ k}_1$$

$$M_{LS2} = 0.18 \text{ k}_1 (4.5') = 0.81 \text{ k}_1$$

UNITS: LENGTH/DEPTH ft, Qpoint: kip, Qline: kip/ft, Qstrip/Qarea/PRESSURE: ksf

CK. FACTOR OF SAFETY FOR FLOATATION : F.S. = 1.3

UPLIFT : DEPTH OF WATER = 475.40 - 471 = 4.40'

$$F_b = (14.0' \times 6.17' \times 4.40' \times 0.0624 \text{ K/FT}^3) = 23.7 \text{ K} \uparrow$$

WIRE WEIGHT : (FROM P. 2)

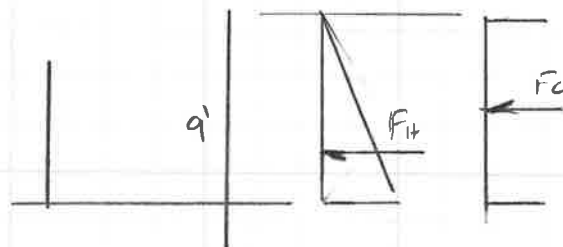
(Deduct 3 PIPES)

$$7.91 \text{ K} (14.0') - (1.17' \times 3 \times \pi \times 1')^2 (0.15 \text{ K/FT}^3) = 109.1 \text{ K} \downarrow$$

$$F.S. = 109.1 \text{ K} / 23.7 \text{ K} = 4.6 > 1.3 \therefore \text{OK}$$

CK. SLIDING : F.S. 2.0

① DURING CONSTRUCTION :



$$F_C = 1.26 \text{ K}_1, \quad F_H = \frac{1}{2} (0.04 \text{ K/FT}^3 \times q')^2 = 1.62 \text{ K}_1$$

$$F_P = \frac{1}{2} (2.45 \times 0.12 \text{ K/FT}^3 \times 2.5')^2 = 0.92 \text{ K}_1$$

$$F_F = 0.35 (6.06 \text{ K}_1 - \frac{1}{2} (\pi \times 1')^2 (1') \times 1.17' \times (0.15 \text{ K/FT}^3)) = 2.02 \text{ K}_1$$

$$F.S. \text{ SLIDING} = \frac{2.02 \text{ K}_1 + 0.92 \text{ K}_1}{1.62 \text{ K}_1 + 1.26 \text{ K}_1} = \frac{2.94 \text{ K}_1}{2.88 \text{ K}_1} = 1.02 < 2.0$$

UNB

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- INCREASE SHEAR KEY DEPTH FROM 1.5' TO 2.5'
- EXTEND FOOTER 12 INTS REAR FROM 1'-4" TO 3'-0"
- INCREASE PASSIVE PRESSURE HEIGHT FROM 2.5' TO 4.5'

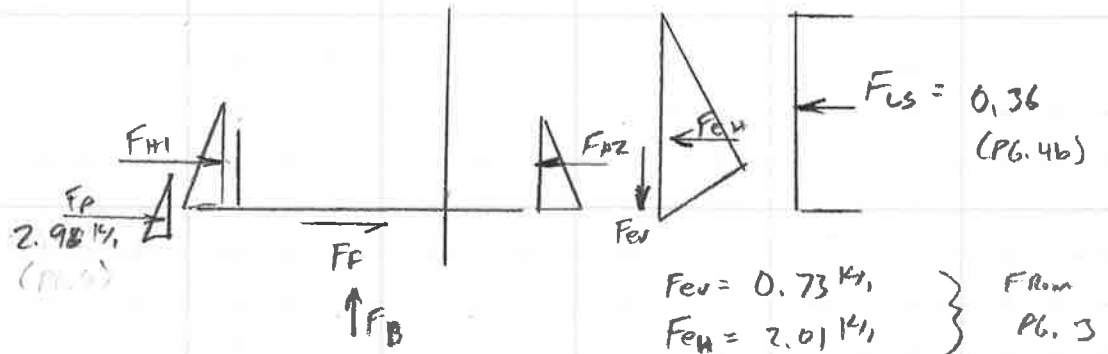
$$F_p = \frac{1}{2} (2.45) (0.12 \text{ K/FT}^3) (4.5')^2 = 2.98 \text{ K}_1$$

$$F_p = 0.35 \left(7.91 \text{ K}_1 - \frac{1}{2} (\pi) (1')^2 (1') (1.17') (0.15 \text{ K/FT}^3) \right) = 2.67 \text{ K}_1$$

$$F.S. \text{ SLIDING} = \frac{2.98 \text{ K}_1 + 2.67 \text{ K}_1}{1.26 \text{ K}_1 + 1.62 \text{ K}_1} = \frac{5.65 \text{ K}_1}{2.88 \text{ K}_1} = 1.96 \approx 2.0 \quad \therefore \text{OK}$$

② CHECK SLIDING AFTER CONSTRUCTION:

- ASSUME HYDROSTATIC PRESSURE TO ELV. 475.4



$$F_{H1} = F_{H2} \quad \therefore \text{NEGLECT}$$

$$F_B = 24.3 \text{ K}_1 / 14.33' = 1.70 \text{ K}_1$$

(ABOVE)

$$F_p = 0.35 (7.63 \text{ K}_1 + 0.73 \text{ K}_1 - 1.70 \text{ K}_1) = 2.33 \text{ K}_1$$

$$F.S. \text{ SLIDING} = \frac{2.98 \text{ K}_1 + 2.33 \text{ K}_1}{2.01 \text{ K}_1 + 0.36 \text{ K}_1} = \frac{5.31 \text{ K}_1}{2.37 \text{ K}_1} = 2.24 > 2.0 \quad \therefore \text{OK}$$

Job GYPSUM STACK CLOSURE

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 Computed by SAM

 Date 5/16/16

 Checked by LMP

 Date 5/19/16

Reference

- CHECK STABILITY & BEARING PRESSURE

① DURING CONSTRUCTION: (SEE SECTION A, PG. 2)
(NO WATER)

$$\Sigma V = \begin{matrix} E_{v1} & E_{v2} & D_{c1} & B_{c2} & D_{c3} \\ 0.12 \text{ K} & + 2.88 \text{ K} & + 0.45 \text{ K} & + 1.17 \text{ K} & + 1.53 \text{ K} \\ D_{c4} & D_6 & & & \\ + 0.69 \text{ K} & + 0.65 \text{ K} & & & = 7.49 \text{ K} \end{matrix}$$

$$\begin{aligned} \Sigma M_o &= \begin{matrix} E_{v1} & E_{v2} & D_{c1} & D_{c2} \\ 0.12 \text{ K} (9.67') & + 2.88 \text{ K} (1.5') & + 0.45 \text{ K} (8.67') & + 1.17 \text{ K} (3.59') \\ D_{c3} & D_{c4} & D_6 & \\ + 1.53 \text{ K} (10.17'/2) & + 0.69 \text{ K} (6.09') & + 0.65 \text{ K} (6.17') & + F_H + F_c \\ = 1.16 \text{ K} & + 4.32 \text{ K} & + 3.90 \text{ K} & + 5.03 \text{ K} & + 7.78 \text{ K} & + 4.2 \text{ K} & + 4.01 \text{ K} \\ + \frac{1}{2} (0.04 \text{ K/ft}^2) (9')^2 (9'/3) & + 1.26 \text{ K} (9'/2) & = 40.1 \text{ K} \end{matrix} \end{aligned}$$

$$\text{RESULTANT} = \frac{40.1 \text{ K}}{7.49 \text{ K}} = 5.35'$$

$$e = 10.17'/2 - 5.35' = -0.27'$$

$$L/6 = 10.17'/6 = 1.7' > 0.27' \quad \therefore \text{NO UPLIFT}$$

$$q = \frac{\Sigma V (1 \pm \frac{6e}{L})}{B L} = \frac{7.49 \text{ K} (1 \pm \frac{6(-0.27')}{10.17'})}{(1') (10.17')} = \begin{matrix} 0.85 \text{ KSF MAX} \\ 0.62 \text{ KSF MIN} \end{matrix}$$

BEARING CAPACITY FACTOR OF SAFETY = 3.0

ALLOWABLE BEARING PRESSURE = 7.3 KSF (SEE PG. 8)

$$F.S. = \frac{7.3 \text{ KSF}}{0.85 \text{ KSF}} = 8.6 > 3.0 \quad \therefore \text{OK}$$

F.S. ALLOWABLE BEARING PRESSURE AFTER CONSTRUCTION IS OK BY INSPECTION

Miller, Scott (Akron)

From: Douangvilay, Siphay
Sent: Wednesday, May 04, 2016 1:24 PM
To: Miller, Scott (Akron); Walker, Steve; Wall, Michael
Cc: Golden, Nick; Egan, Brian
Subject: RE: PAF Structure for the Gyp Stack Spillway

Scott,

We're calculating an ultimate bearing capacity of 5.3 ksf with the assumption that there is no embedment of the footing. With a minimum embedment of 2' (approximate frost depth for KY), we're calculating an ultimate bearing capacity of 7.3 ksf.

Thanks,
 Siphay

From: Miller, Scott (Akron)
Sent: Wednesday, May 04, 2016 11:05 AM
To: Douangvilay, Siphay; Walker, Steve; Wall, Michael
Cc: Golden, Nick; Egan, Brian
Subject: RE: PAF Structure for the Gyp Stack Spillway

Top of wall is El. 480.0
 Bottom of Footer is 468.5
 Width TBD, currently looking at 8'

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From: Douangvilay, Siphay
Sent: Wednesday, May 04, 2016 12:01 PM
To: Walker, Steve; Wall, Michael
Cc: Golden, Nick; Miller, Scott (Akron); Egan, Brian
Subject: RE: PAF Structure for the Gyp Stack Spillway

Please provide information regarding the new spillway's foundation (size, embedment, and bearing elevation).

Thanks,
 Siphay

CR SLIDING : F_{1S} = 2.0

① DURING CONSTRUCTION : (NO WATER)

$$F_F = 0.35(10.68 \text{ K}) = 3.74 \text{ K}, \quad F_P = 2.98 \text{ K}, \quad (\text{Pg. 6.})$$

$$F_H = 1.62 \text{ K}, \quad (\text{Pg. 5}) \quad F_C = 1.26 \text{ K}, \quad (\text{Pg. 4})$$

$$F_{1S} = \frac{3.74 \text{ K} + 2.98 \text{ K}}{1.62 \text{ K} + 1.26 \text{ K}} = \frac{6.72 \text{ K}}{2.88 \text{ K}} = 2.33 > 2.0 \quad \therefore \text{OK}$$

② AFTER CONSTRUCTION :

- ASSUMING NO BOUYANCY

- ASSUMING WATER PRESSURE EQUAL ON BOTH SIDES OF WALL.

- IGNORE F_{EL} (CONSERVATIVE)

$$F_F = 3.74 \text{ K}, \quad F_P = 2.98 \text{ K},$$

$$F_{EH} = 2.01 \text{ K}, \quad F_{LS} = 0.36 \text{ K},$$

$$F_{1S} = \frac{3.74 \text{ K} + 2.98 \text{ K}}{2.01 \text{ K} + 0.36 \text{ K}} = \frac{6.72 \text{ K}}{2.37 \text{ K}} = 2.84 > 2.0 \quad \therefore \text{OK}$$

CR STABILITY & BEARING PRESSURE:

① DURING CONSTRUCTION : (SEE SECTION B , PG. 9)
(NO WATER)

$$\Sigma V = 10.68 \text{ K},$$

$$\begin{aligned} \Sigma M_o &= \overset{(EV_1)}{0.12 \text{ K}} (9.67') + \overset{(EV_2)}{7.84 \text{ K}} (4.09') + \overset{(DC_1)}{1.2 \text{ K}} (8.67') \\ &+ \overset{(DC_2)}{1.52 \text{ K}} (5.08') + \overset{(FH)}{1.62 \text{ K}} (9\frac{1}{3}') + \overset{F_C}{1.26 \text{ K}} (9\frac{1}{2}') \\ &= 61.88 \text{ K}' \end{aligned}$$

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$$R_{\text{RESULTANT}} = \frac{61.88 \text{ K}_1}{10.68 \text{ K}_1} = 5.79'$$

$$e = 10.17'/2 - 5.79' = -0.71'$$

$$L/6 = 10.17'/6 = 1.70' > 0.71' \quad \therefore \text{OK NO UPLIFT.}$$

BEARING CAPACITY F.S. = 3.0

ALLOWABLE BEARING PRESSURE = 7.3 KSF (PG 8)

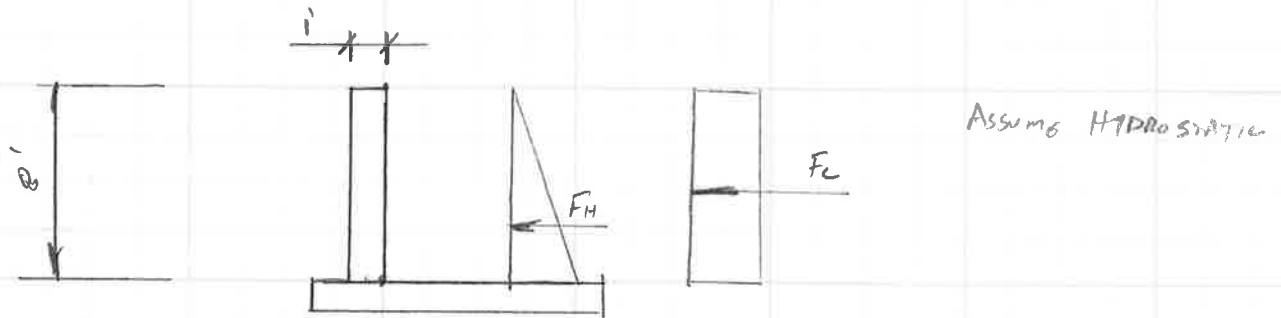
$$q = \frac{\gamma V \left(1 \pm \frac{6e}{L}\right)}{B L} = \frac{10.68 \text{ K}_1 \left(1 \pm \frac{6(-0.71')}{10.17'}\right)}{(1')(10.17')} = \begin{matrix} 1.49 \text{ KSF MAX} \\ 0.61 \text{ KSF MIN} \end{matrix}$$

$$F.S. = 7.3 \text{ KSF} / 1.49 \text{ KSF} = 4.90 > 3 \quad \therefore \text{OK}$$

F.S. ALLOWABLE BEARING PRESSURE AFTER CONSTRUCTION IS OK BY INSPECTOR.

DESIGN REINFORCING IN VERTICAL WALLS & FOOTERS (WINDWALLS & SIDEWALLS)

CALCULATE REINFORCING SECTION B WINDWALL:



MAXIMIZE MOMENTS USING STRENGTH I DESIGN: DURING CONSTRUCTION: (NO WATER)

$$F_H = 1.50 \left(\frac{1}{2}\right) (0.04 \text{ K/FT}^2) (8')^2 = 1.92 \text{ K}_1 \quad M_H = 1.92 \text{ K}_1 \left(\frac{8'}{3}\right) = 5.12 \text{ K}_1'$$

$$F_C = 1.75 (0.14 \text{ KSF} \times 8') = 1.96 \text{ K}_1 \quad M_C = 1.96 \text{ K}_1 \left(\frac{8'}{2}\right) = 7.84 \text{ K}_1'$$

$$\phi M_n = 5.12 \text{ K}_1' + 7.84 \text{ K}_1' = 12.96 \text{ K}_1'$$

$$d = 12" - 2" - 0.75"/2 = 9.625" \quad b = 12"$$

TAKS ϕ_{mn} = LESSOR OF THE FOLLOWING :

$$1.33 M_u = 1.33(12.96 \text{ kft}) = 17.3 \text{ kft} = 207.6 \text{ in kft}$$

OR

$$1.2 M_{cr} = 1.2 \gamma_3 [(\gamma_1 F_r) S_c] \quad F_r = 0.24 \sqrt{F'_c} = 0.48 \text{ ksi}$$

$$\gamma_1 = 1.6 \quad \gamma_3 = 0.67 \quad (\text{A615 STEEL})$$

$$S_c = \frac{I_g}{c} = \frac{(12")^4 / 12"}{6"} = 288 \text{ in}^3$$

$$1.2 M_{cr} = 1.2(0.67) [(1.6)(0.48 \text{ ksi})(288 \text{ in}^3)] = 178 \text{ in kft} \leftarrow \text{CONTROLS}$$

$$\phi_{mn} = \phi A_s F_y \left(d - \frac{A_s F_y}{2(0.85 F'_c)(b)} \right)$$

$$178 \text{ in kft} = 0.9 A_s (60 \text{ ksi}) \left(9.625" - \frac{A_s (60 \text{ ksi})}{2(0.85)(4 \text{ ksi})(12")} \right)$$

$$178 \text{ in kft} = 519.8 A_s - 39.7 A_s^2$$

$$A_s = 0.35 \text{ in}^2 \quad \underline{0.5\# \text{ S @ } 8"} = 0.31 \text{ in}^2 \quad (12"/8") = 0.47 \text{ in}^2$$

- 0.5\# 4 @ 8" VERTICAL - FRONT FACE

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$$340 \text{ K/ft} = 0.9 A_s (60 \text{ Ksi}) \left(9.625'' - \frac{A_s (60 \text{ Ksi})}{2(0.85)(4 \text{ Ksi})(12'')} \right)$$

$$340 \text{ K/ft} = 519.8 A_s - 39.7 A_s^2$$

$$A_s = 0.69 \text{ in}^2/\text{ft}$$

$$\therefore \text{use } \#6 @ 8'' = 0.66 \text{ in}^2/\text{ft} \approx 0.69 \text{ in}^2/\text{ft}$$

USE #4 @ 8" TOP

CHECK SHEAR!

$$V_u = (8.17' \times 1.44 \text{ K/ft}^2) = 11.76 \text{ K}$$

V_n = LESSER OF THE FOLLOWING TWO EQUATIONS!

$$\begin{aligned} \textcircled{1} \quad V_n &= 0.0316 \beta \sqrt{f_c} b d_v \\ &= 0.0316 (2) (2 \text{ Ksi}) (12'') (9.625'') \\ &= 14.6 \text{ K} \quad \leftarrow \text{controls} \end{aligned}$$

$$\begin{aligned} d_v &= 12'' - 2'' - 0.75''/2 = 9.625'' \\ b &= 12'' \\ \beta &= 2.0 \end{aligned}$$

$$\begin{aligned} \textcircled{2} \quad V_n &= 0.25 f_c b d_v \\ &= 0.25 (4 \text{ Ksi}) (12'') (9.625'') \\ V_n &= 115.5 \text{ K} \end{aligned}$$

$$\phi V_n = 0.9 (14.6 \text{ K}) = 13.14 \text{ K} > 11.76 \text{ K} \quad \therefore \text{OK}$$

Job Gypsum Spackle Closure

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 Computed by SAM

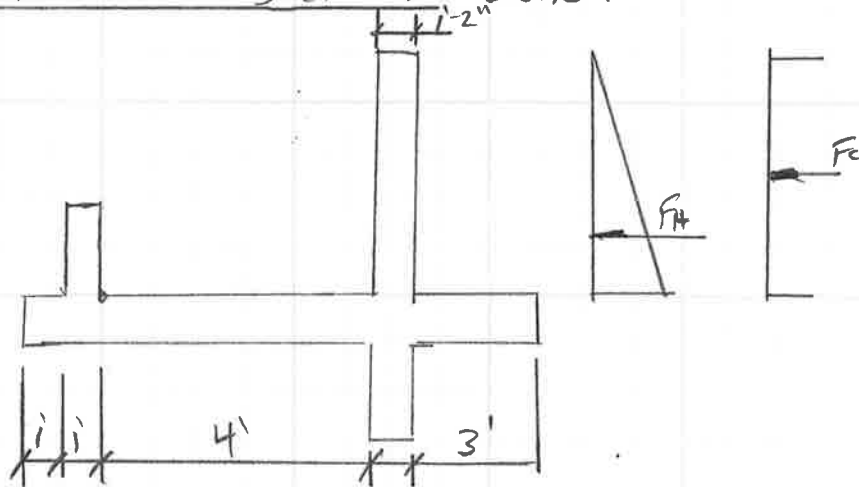
 Date 5/9/16

 Checked by LMP

 Date 5/19/16

Reference

CALCULATE REINFORCING SECTION A WEB



$$\phi M_n = 12.96 \text{ k-ft} \quad (\text{Pg. 11}) \quad d = 14'' - 2'' - 0.75''/2 = 11.625'' \quad b = 12''$$

TAKE $\phi M_n =$ LESSER OF THE FOLLOWING:

$$1.33 M_u = 1.33 (12.96 \text{ k-ft}) (12'') = 207 \text{ k-ft} \quad \leftarrow \text{CONTROLS}$$

$$1.2 M_{cr} = 1.2 (0.67) [(1.6)(0.48 \text{ ksi})(457 \text{ in}^3)] = 282 \text{ k-ft}$$

$$S_c = \frac{(14'')^3/12}{7''} = 457 \text{ in}^3$$

$$\phi M_n = \phi A_s F_y \left(d - \frac{A_s F_y}{2(0.85)(F_c)(b)} \right)$$

$$207 \text{ k-ft} = 0.9 A_s (60 \text{ ksi}) \left(11.625'' - \frac{A_s (60 \text{ ksi})}{2(0.85)(4 \text{ ksi})(12'')} \right)$$

$$207 \text{ k-ft} = 627.8 A_s - 39.7 A_s^2$$

$$A_s = 0.34 \text{ in}^2$$

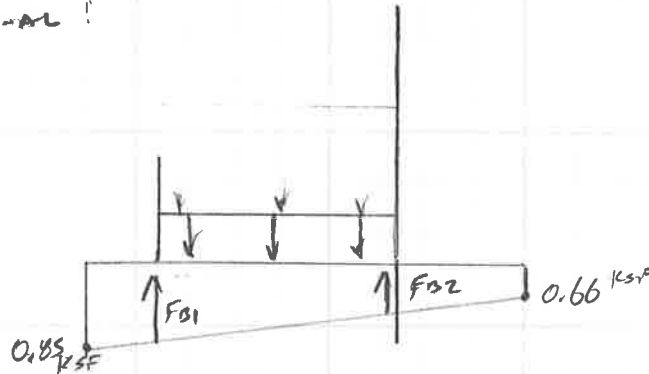
$$\therefore \text{USE \#5 @ 8''} = 0.47 \text{ in}^2 \quad (\text{BACK FACE})$$

$$\text{USE \#4 @ 8''} \quad (\text{FRONT FACE})$$

SECTION (A) FOOTER

TRANSVERSE: USE SAME STEEL AS SECTION (B) WINGWALL

LONGITUDINAL:



$$W_{\text{GRAV}} = (1.35' \text{ AVG}) (0.12 \text{ K/FT}^2) (0.9) = 0.15 \text{ KSF}$$

$$F_{b\text{MAX}} = 0.85 \text{ KSF} (1.75) = 1.49 \text{ KSF}$$

$$F_{b\text{MIN}} = 0.66 \text{ KSF} (1.75) = 1.16 \text{ KSF}$$

$$F_{b\text{MAX}} - W_G = 1.49 \text{ KSF} - 0.15 \text{ KSF} = 1.34 \text{ KSF}$$

$$F_{b\text{MIN}} - W_G = 1.16 \text{ KSF} - 0.15 \text{ KSF} = 1.01 \text{ KSF}$$

$$F_{b1} = 1.34 - 1.5' \left(\frac{1.34 - 1.01}{10.17'} \right) = 1.29 \text{ KSF}$$

AVG. = 1.21 KSF

$$F_{b2} = 1.34 - 6.59' \left(\frac{1.34 - 1.01}{10.17'} \right) = 1.13 \text{ KSF}$$

$$M_u = \frac{(1.21 \text{ KSF})(13')^2}{8} = 25.6 \text{ K'}, = 307 \text{ ''K'}, \leq \text{CONTROLS}$$

$$1.33 m_u = 1.33 (307 \text{ ''K'}) = 408 \text{ ''K'}$$

$$d = 12'' - 2'' - 1.5(0.75'') = 8.88''$$

$$1.2 m_{cr} = 178 \text{ ''K'} \quad (\text{PL12})$$

$$307 \text{ K}_1 = 0.9 A_s (60 \text{ Ksi}) \left(8.88 \text{ in} - \frac{A_s (60 \text{ Ksi})}{2(0.85)(4 \text{ Ksi})(12 \text{ in})} \right)$$

$$307 \text{ K}_1 = 479.5 A_s - 39.71 A_s^2$$

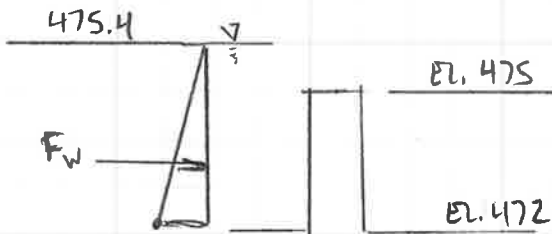
$$A_s = 0.68 \text{ in}^2$$

∴ use #6 @ 8" BOTTOM

use #4 @ 8" TOP

- SHEAR OK - (SEE PG. 14)

DESIGN REINFORCEMENT FOR VERTICAL WEIR WALL:



$$F_w = \frac{1}{2} (0.0624 \text{ K/FT}^2) (3.4')^2 = 0.36 \text{ K}_1$$

OR

$$P = \frac{C_D V^2}{1000}$$

Assume $V = 10 \text{ ft/s}$

$C_D = 1.4$

$$P = \frac{1.4 (10 \text{ FT/S})^2}{1000} = 0.14 \text{ KSF}$$

$$P = 3.4 (0.14 \text{ KSF}) = 0.48 \text{ K}_1 \leftarrow \text{controls}$$

$$M_u = 3.4 \left(\frac{1}{2} (0.48 \text{ K}_1) \right) = 0.82 \text{ K}_1 \text{ ft}$$

$$d = 12 \text{ in} - 2 \text{ in} - 0.5 \text{ in} = 9.75 \text{ in}$$

Miller, Scott (Akron)

From: Walker, Steve
Sent: Thursday, May 05, 2016 12:35 PM
To: Golden, Nick
Cc: Miller, Scott (Akron)
Subject: PAF gyp stack spillway structure

I ran some quick numbers. If we raise the invert 2', we'll have the following:

Base flow = 8.58 CFS
Weir elev. = 475.00
Upper Pond W.S. Elev. = 475.40
Outlet Pipe invert = 473.00
Depth of water within structure = 473.71
head diff. = $475.40 - 473.71 = 1.69'$ (approx. 20 inches)

What do you think? Is this OK?

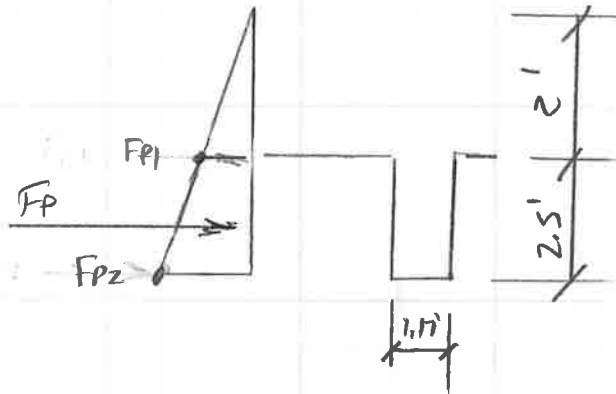
Stephen C. Walker, PE
Project Manager, GeoEnvironmental
D 1-330-800-2764 C 1-330-289-4233
steve.walker@aecom.com

AECOM
14 White Pond Drive, Akron, Ohio 44614
T 1-330-836-9111 F 1-330-836-9115
www.aecom.com

[Twitter](#) | [Facebook](#) | [LinkedIn](#) | [Google+](#)

M_u is minimal; use #4 @ 8" to match transverse spacing

DESIGN SHEAR KEY REINFORCEMENT:



$$d = 14'' - 2'' - \frac{0.625''}{2} = 11.69''$$

$$F_{p1} = 2.45 (0.12 \text{ k/ft}^2) (2') = 0.588 \text{ ksf}$$

$$F_{p2} = 2.45 (0.12 \text{ k/ft}^2) (4.5') = 1.32 \text{ ksf}$$

$$F_p = 0.588 \text{ ksf} (2.5') + \frac{1}{2} (2.5') (1.32 - 0.588) = 1.47 \text{ k} + 0.92 \text{ k} = 2.39 \text{ k}$$

$$M_u = 1.5 (2.39 \text{ k}) \left(\frac{2}{3} (2.5') \right) = 6 \text{ k-ft} = 72 \text{ k-in}$$

TAKING ϕM_n = LESSER OF THE FOLLOWING:

$$1.33 M_u = 1.33 (72 \text{ k-in}) = 95.8 \text{ k-in} \leftarrow \text{CONTROLS}$$

OR

$$1.2 M_{cr} = 282 \text{ k-in} \quad (\text{PG. 15})$$

$$95.8 \text{ k-in} = 0.9 A_s (60 \text{ ksi}) \left(11.69'' - \frac{A_s (60 \text{ ksi})}{2 (0.85 (4 \text{ ksi}) (12 \text{ in}))} \right)$$

$$95.8 \text{ k-in} = 631.3 A_s - 39.7 A_s^2$$

Job Gypsum STAIR CLOSURE

Project No. 60444361

Sheet 19 of 29

Description _____

Computed by SAM

Date 5/19/16

Checked by LMP

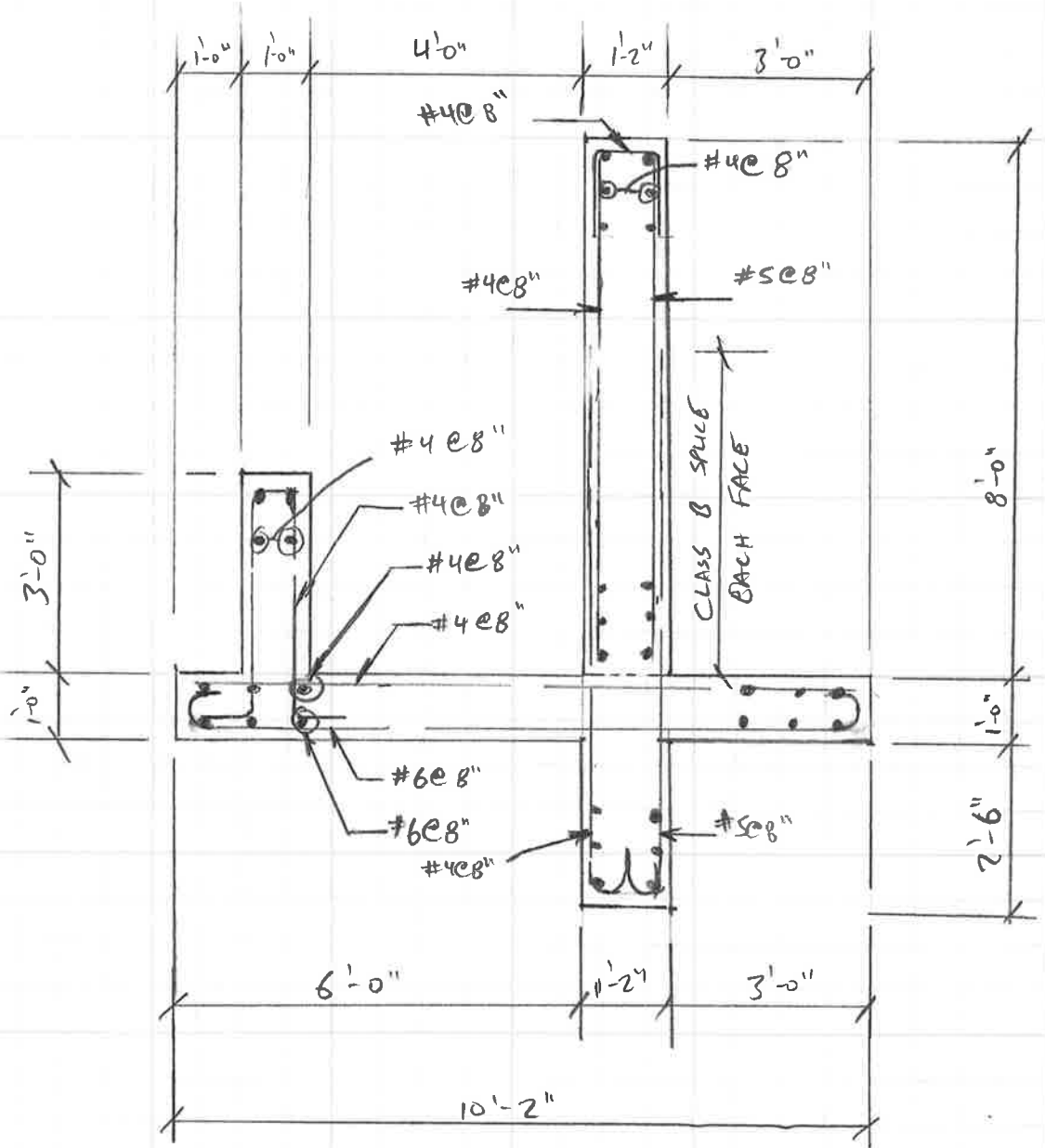
Date 5/19/16

Reference

$$A_s = 0.15 \text{ in}^2$$

$$u_s \#4 @ 8" = 0.3 \text{ in}^2$$

BOTH FACES



SECTION (A)

3/8" = 1'

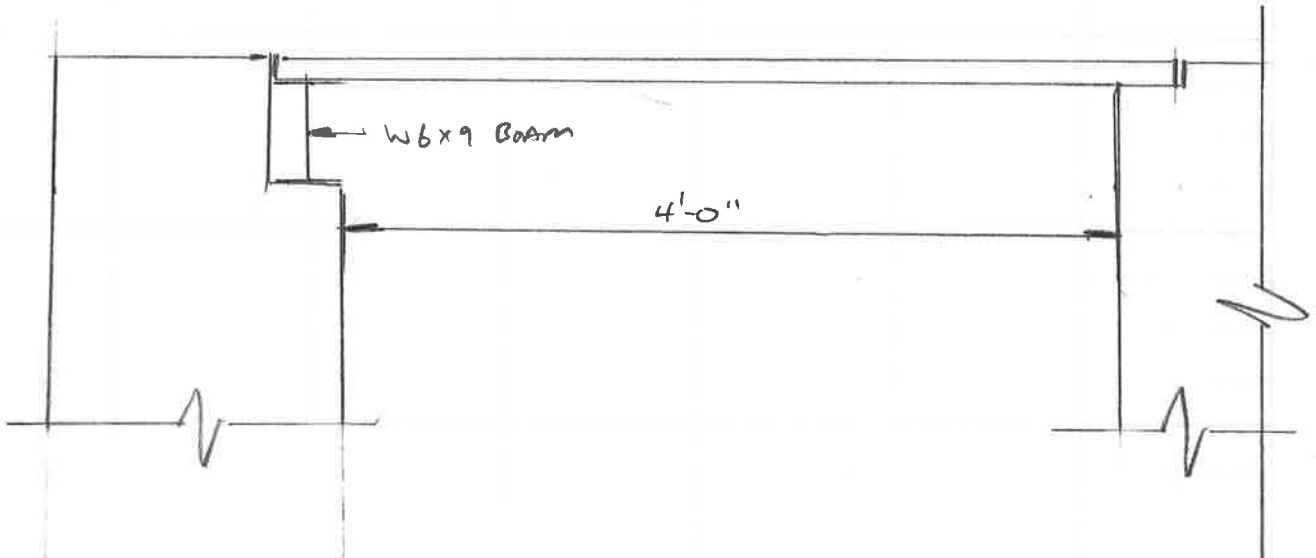
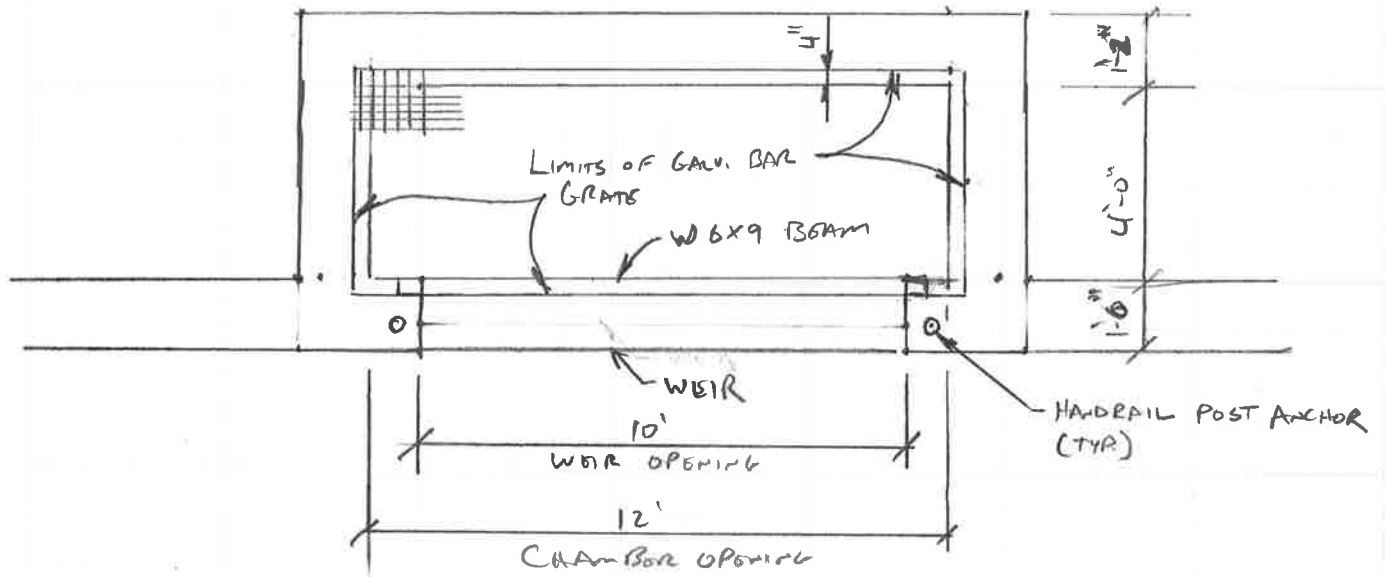
Job GYPsum STAIR CLOSURE
Description _____

Project No. 60444361
Computed by SAM
Checked by LMP

Page _____ of _____
Sheet 21 of 29
Date 5/3/16
Date 5/19/16

Reference

DESIGN STEEL I-BEAMS TO SUPPORT STEEL GRATING & POSTERIOR LOADS

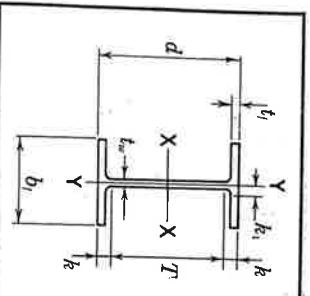


GW, GW-2, GAA & GBB Series Steel LOAD TABLE

Bearing Bar Size	SPAN (1-3/16" Center to Center Bar Spacings)														
	1'-0"	2'-0"	2'-6"	3'-0"	3'-6"	4'-0"	4'-6"	5'-0"	5'-6"	6'-0"	7'-0"	8'-0"			
3/4" x 1/8"	U	1421	355	227	158	116	89	70	<div style="border: 1px solid black; padding: 5px; display: inline-block;"> Load Table on www.mcnichols.com </div> Unit Stress 18,000 lbs per sq. inch U - Uniform Load- Pounds per Sq. Ft. D - Deflection in inches C - Concentrated Load-Pounds per Ft. width at mid span						
	D	.025	.099	.155	.224	.304	.398	.502							
	C	710	355	284	237	203	178	158							
D	.020	.079	.124	.179	.243	.319	.403								
3/4" x 3/16"	U	2131	533	341	237	174	133	105							
	D	.025	.099	.155	.224	.304	.397	.502							
	C	1066	533	426	355	304	266	237							
D	.020	.079	.124	.179	.243	.317	.403								
1" x 1/8"	U	2526	632	404	281	206	158	125					101	84	70
	D	.019	.075	.116	.168	.228	.298	.378					.465	.566	.668
	C	1263	632	505	421	361	316	281					253	230	211
D	.015	.060	.093	.134	.182	.238	.302	.373					.451	.537	
1" x 3/16"	U	3790	947	606	421	309	237	187	152	125	105				
	D	.019	.074	.116	.168	.228	.298	.377	.467	.562	.669				
	C	1895	947	758	632	541	474	421	379	345	316				
D	.015	.060	.093	.134	.182	.238	.302	.372	.451	.537					
1-1/4" x 1/8"	U	3947	987	631	439	322	247	195	158	130	110	81			
	D	.015	.060	.093	.134	.182	.239	.302	.373	.449	.538	.734			
	C	1973	987	789	658	564	493	439	395	359	329	282			
D	.012	.048	.074	.107	.146	.191	.242	.298	.361	.429	.584				
1-1/4" x 3/16"	U	5921	1480	947	658	483	370	292	237	196	164	121			
	D	.015	.060	.093	.134	.182	.238	.301	.373	.451	.535	.731			
	C	2960	1480	1184	987	846	740	658	592	538	493	423			
D	.012	.048	.074	.107	.146	.191	.241	.298	.360	.429	.584				
1-1/2" x 1/8"	U	5684	1421	910	632	464	355	281	227	188	158	116	89		
	D	.012	.050	.078	.112	.152	.198	.252	.310	.376	.447	.608	.796		
	C	2842	1421	1137	947	812	711	632	568	517	474	406	355		
D	.010	.040	.062	.089	.122	.159	.201	.248	.301	.358	.487	.635			
1-1/2" x 3/16"	U	8526	2132	1364	947	696	533	421	341	282	237	174	133		
	D	.012	.050	.078	.112	.152	.199	.251	.310	.376	.447	.608	.793		
	C	4263	2132	1705	1421	1218	1066	947	853	775	711	609	533		
D	.010	.040	.062	.089	.122	.159	.201	.248	.300	.358	.487	.636			
1-3/4" x 3/16"	U	11605	2901	1857	1289	947	725	573	464	384	322	237	181		
	D	.011	.043	.067	.096	.130	.170	.215	.266	.322	.383	.522	.680		
	C	5803	2901	2321	1934	1658	1451	1289	1161	1055	967	829	725		
D	.009	.034	.053	.077	.104	.136	.172	.213	.257	.306	.417	.545			
2" x 3/16"	U	15158	3790	2425	1684	1237	947	749	606	501	421	309	237		
	D	.009	.037	.058	.084	.114	.149	.189	.233	.282	.335	.456	.596		
	C	7579	3790	3032	2526	2165	1895	1684	1516	1378	1263	1083	947		
D	.007	.030	.047	.067	.091	.119	.151	.186	.225	.268	.365	.476			
2-1/4" x 3/16"	U	19184	4796	3070	2132	1566	1199	947	767	634	533	392	300		
	D	.008	.033	.052	.074	.101	.132	.168	.207	.250	.298	.406	.530		
	C	9592	4796	3837	3197	2741	2398	2132	1918	1744	1599	1370	1199		
D	.007	.026	.041	.060	.081	.106	.134	.166	.200	.238	.324	.424			
2-1/2" x 3/16"	U	23684	5921	3790	2632	1933	1480	1170	947	783	658	483	370		
	D	.007	.030	.047	.067	.091	.119	.151	.186	.225	.268	.365	.477		
	C	11842	5921	4737	3947	3383	2961	2632	2368	2153	1974	1692	1480		
D	.006	.024	.037	.054	.073	.095	.121	.149	.180	.215	.292	.381			

Spans in shaded area produce a deflection of 1/4" or less under a uniform load of 100 pounds per square foot. This deflection is recommended as the maximum to provide pedestrian comfort. It can be exceeded at the discretion of the engineer.

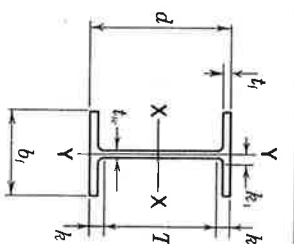
6/22



W SHAPES Dimensions

Designation	Area A In. ²	Depth d In.	Web		Flange		Distance			
			Thickness t _w In.	$\frac{t_w}{2}$ In.	Width b _f In.	Thickness t _f In.	T	K	K ₁	
W 8x 67	19.7	9	0.570	5/16	8.280	8 1/4	0.935	1 1/16	1 1/16	1 1/16
X 58	17.1	8 3/4	0.510	1/2	8.220	8 1/4	0.810	1 3/16	1 5/16	1 1/16
X 48	14.1	8 1/2	0.400	3/8	8.110	8 1/8	0.685	1 1/16	1 3/16	5/8
X 40	11.7	8 1/4	0.360	3/8	8.070	8 1/8	0.560	1 1/16	1 1/16	5/8
X 35	10.3	8 1/2	0.310	5/16	8.020	8	0.495	1 1/2	1	5/8
X 31	9.13	8	0.285	5/16	7.995	8	0.435	1 1/2	1	5/8
W 8x 28	8.25	8	0.285	5/16	6.535	6 1/2	0.465	7/16	6/16	15/16
X 24	7.08	7 7/8	0.245	1/4	6.495	6 1/2	0.400	3/8	6/16	9/16
W 8x 21	6.16	8 1/4	0.250	1/4	5.270	5 1/4	0.400	3/8	6 5/8	1/2
X 18	5.26	8 1/4	0.230	1/4	5.250	5 1/4	0.330	3/8	6 5/8	7/16
W 8 x 15	4.44	8 1/8	0.245	1/4	4.015	4	0.315	5/16	3/4	1/2
X 13	3.84	8	0.230	1/4	4.000	4	0.255	1/4	6 5/8	7/16
X 10	2.96	7 7/8	0.170	3/16	3.940	4	0.205	3/16	6 5/8	7/16
W 6x 25	7.34	6 3/8	0.320	5/16	6.080	6 1/8	0.455	7/16	4 3/4	7/16
X 20	5.87	6 1/4	0.260	1/4	6.020	6	0.385	3/8	4 3/4	7/16
X 15	4.43	6	0.230	1/4	5.990	6	0.260	1/4	4 3/4	3/8
W 6x 16	4.74	6 1/4	0.260	1/4	4.030	4	0.405	3/8	4 3/4	7/16
X 12	3.55	6	0.230	1/4	4.000	4	0.280	1/4	4 3/4	3/8
X 9	2.68	5 7/8	0.170	3/16	3.940	4	0.215	3/16	4 3/4	3/8
W 5x 19	5.54	5 1/8	0.270	1/4	5.030	5	0.430	7/16	3 1/2	7/16
X 16	4.68	5	0.240	1/4	5.000	5	0.360	3/8	3 1/2	7/16
W 4x 13	3.83	4 1/8	0.280	1/4	4.060	4	0.345	3/8	2 3/4	7/16

W SHAPES Properties



Non- Inal Wt. per Ft. Lb.	Compact Section Criteria		Elastic Properties						Plastic Modulus				
	$\frac{b_f}{2t_f}$	$\frac{h_c}{t_w}$	F _y Ksi	X ₁ Ksi	X ₂ × 10 ⁶ (1/Ksi) ²	I In. ⁴	S In. ³	r In.	I In. ⁴	S In. ³	r In.	Z _x In. ³	Z _y In. ³
67	4.4	11.1	—	6620	73.9	272	60.4	3.72	88.6	21.4	2.12	70.2	32.7
58	5.1	12.4	—	5820	122	228	52.0	3.65	75.1	18.3	2.10	59.8	27.9
48	5.9	15.8	—	4860	238	184	43.3	3.61	60.9	15.0	2.08	49.8	22.9
40	7.2	17.6	—	4080	474	146	35.5	3.53	49.1	12.2	2.04	39.8	18.5
35	8.1	20.4	—	3610	761	127	31.2	3.51	42.6	10.6	2.03	34.7	16.1
31	9.2	22.2	—	3230	1180	110	27.5	3.47	37.1	9.27	2.02	30.4	14.1
28	7.0	22.2	—	3480	931	98.0	24.3	3.45	21.7	6.63	1.62	27.2	10.1
24	8.1	25.8	—	3020	1610	82.8	20.9	3.42	18.3	5.63	1.61	23.2	8.5
21	6.6	27.5	—	2890	2090	75.3	18.2	3.49	9.77	3.71	1.26	20.4	5.6
18	8.0	29.9	—	2490	3890	61.9	15.2	3.43	7.97	3.04	1.23	17.0	4.6
15	6.4	28.1	—	2670	3440	48.0	11.8	3.29	3.41	1.70	0.876	13.6	2.6
13	7.8	29.9	—	2370	5780	39.6	9.91	3.21	2.73	1.37	0.843	11.4	2.1
10	9.6	40.5	39	1760	17900	30.8	7.81	3.22	2.09	1.06	0.841	8.87	1.6
25	6.7	15.5	—	4410	369	53.4	16.7	2.70	17.1	5.61	1.52	18.9	8.5
20	8.2	19.1	—	3550	846	41.4	13.4	2.66	13.3	4.41	1.50	14.9	6.7
15	11.5	21.6	—	2740	2470	29.1	9.72	2.56	9.32	3.11	1.46	10.8	4.7
16	5.0	19.1	—	4010	591	32.1	10.2	2.60	4.43	2.20	0.966	11.7	3.3
12	7.1	21.6	—	3100	1740	22.1	7.31	2.49	2.99	1.50	0.918	8.30	2.3
9	9.2	29.2	—	2380	4980	16.4	5.56	2.47	2.19	1.11	0.905	6.23	1.7
19	5.8	14.0	—	5140	192	26.2	10.2	2.17	9.13	3.63	1.28	11.6	5.5
16	6.9	15.8	—	4440	346	21.3	8.51	2.13	7.51	3.00	1.27	9.59	4.5
13	5.9	10.6	—	5560	154	11.3	5.46	1.72	3.86	1.90	1.00	6.28	2.9

D.L. : GRATING USE 20 #/FT² , BOAM USE 10 #/1,

L.L. : PEDESTRIAN USE 75 #/FT²

$$\text{UNIFORM LOAD / BOAM} = 1.25 (10 \#/1 + 20 \#/FT^2 (4.67' / 2)) + 1.75 (75 \#/FT^2 (4.67' / 2)) = 377.3 \#/1$$

$$M_u = \frac{(377.3 \#/1) (10.5')^2}{8} = 5,200 \# = 5.2 \text{ 'K}$$

$$F_b = \frac{M_u}{I} = \frac{5.2 \text{ 'K} (12 \text{ ' } \times 3 \text{ '})}{16.4 \text{ in}^4} = 11.4 \text{ KSI} < 36 \text{ KSI}$$

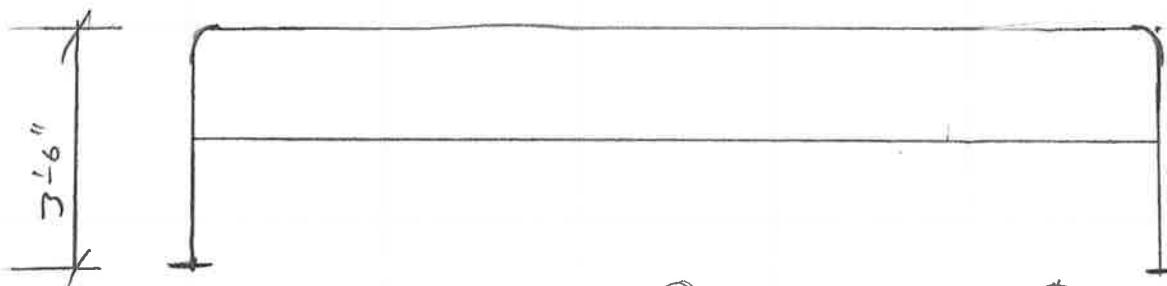
USE W 6 X 9 BOAMS , A36 STEEL GALVANIZED

DESIGN HANDRAIL : USE HOLLANDER MANUFACTURING CO. CATALOG FOR DESIGN SPEC. / EXAMPLE

- USE ALLOWABLE STRESS DESIGN

- ASSUME ASTM A53 TYPE , GRADE B $F_y = 35 \text{ KSI}$ $F_{all} = 25 \text{ KSI}$

- SEE PGS. 16A TO 16E (MANUFACTURE MATERIAL SPEC.'S & SAMPLE RAIL ANALYSIS)



- DESIGN FOR THE FOLLOWING :

① POINT LOAD = 200 #

② UNIFORM LOAD = 50 #/1, (ON ANY 1 RAIL)

Job GYPSUM STACK CLOSURE
Description _____

Project No. 60444361
Computed by SAM
Checked by LMP

Page _____ of _____
Sheet 24 of 29
Date 5/3/16
Date 5/19/16

Reference

DESIGN POST :

① - POINT LOAD

$$F_D = \frac{M}{S} \quad S = \frac{M}{F_D} = \frac{200\#(42'')/1000}{25\text{Ksi}}$$

$$S = 0.336 \text{ in}^3$$

② - UNIFORM LOAD

$$S = \frac{\frac{1}{2}(0.050\text{K/ft})(11')(42'')}{25\text{Ksi}}$$

$$S = 0.462 \text{ in}^3 \quad \text{- CONTROLS}$$

USE 2" , SCHEDULE 40 : $S = 0.561 \text{ in}^3$

DESIGN RAIL :

① - POINT LOAD

$$F_D = \frac{M}{S} \quad S = \frac{(0.200\text{K})(11')(12'')}{4(25\text{Ksi})}$$

$$S = 0.264 \text{ in}^3$$

② - UNIFORM LOAD (EQ. FROM PG. 165)

$$S = \frac{0.050\#/\text{ft}(11' \times 12'')^2}{96(25\text{Ksi})}$$

$$S = 0.363 \text{ in}^3 \quad \leftarrow \text{CONTROLS}$$

USE 1 1/2" SCHEDULE 80 : $S = 0.412 \text{ in}^3$

Table 1 Mechanical Properties of Pipe

Material	Minimum Tensile Strength (psi)	Minimum Yield Strength (psi)	Allowable Yield Strength* (psi)	Modulus of Elasticity (ksi)
Aluminum 6063-T6 Pipe ASTM429	30,000	25,000	18,000**	10,100
Aluminum 6061-T6 Pipe ASTM429	38,000	35,000	24,000***	10,100
Carbon Steel Structural Tubing ASTM A500 Grade B	58,000	42,000	25,500	
Carbon Steel Pipe ASTM A53 Type F Grade B	48,000	30,000	21,600	
Type E Grade B	60,000	35,000	25,000	
Hollaender Tubular Dowel 6061-T6	38,000	35,000	24,000	10,100

*The allowable yield strength of aluminum pipe in bending is defined by the Aluminum Association to be (1.17 x Minimum Yield Strength) / 1.65.

**Reduce to 8,000 within 1 inch of weld

***Reduce to 14,000 within 1 inch of weld

Table 2 Section Properties of Pipe and Reinforcing Dowel

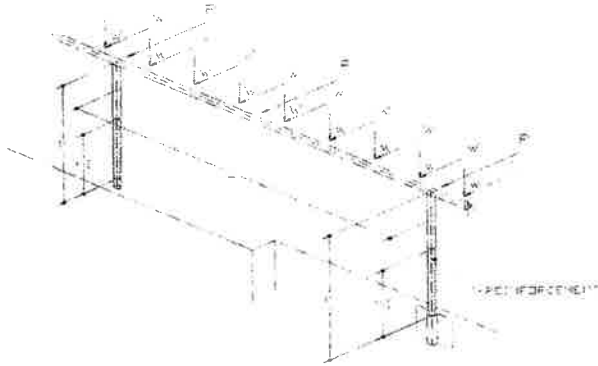
Nominal Pipe Size (ips)	OD (in.)	ID (in.)	Wall Thickness	Area (in. ²)	I (in. ⁴)	S (in. ³)
Schedule 10						
1 ½	1.900	1.682	0.109	0.613	0.247	0.260
2	2.375	2.157	0.109	0.776	0.499	0.420
Schedule 40						
1 ¼	1.660	1.380	0.140	0.669	0.195	0.235
1 ½	1.900	1.610	0.145	0.800	0.310	0.326
2	2.375	2.067	0.154	1.075	0.666	0.561
Schedule 80						
1 ¼	1.660	1.278	0.191	0.882	0.242	0.291
1 ½	1.900	1.500	0.200	1.068	0.391	0.412
2	2.375	1.939	0.218	1.477	0.868	0.731
Hollaender Tubular Dowel	1.600	1.250	0.175	0.783	0.201	0.252

← HANDRAIL POSTS

← HANDRAIL RAILING

Outside Diameter (OD), Inside Diameter (ID), Moment of Inertia (I), Section Modulus (S)

Railing System Dimensions and Loads



Symbols Used in Equations:

w = Uniform loading, (lb/ft).

L = Span between centerlines of posts or mounting brackets, (ft).

P = Concentrated load applied to the top rail, (lb).

h = Height of post from the top of the attachment to the point of load application, (in).

h₁ = Height of reinforcing insert inside post above the top of the attachment, (in).

f_b = Bending stress, (psi).

f_d = Allowable yield strength for design, (psi).

S = Section modulus, (in³).

S₁ = Combined section modulus of post with reinforcing insert, (in³).

Calculations for Structural Design

The calculations used here are applicable to free standing straight runs of guardrail with uniform post spacing. The loads applied to a length of guardrail are defined by building codes as either a concentrated load applied to the top rail at any point in any direction, or as a uniformly distributed load per linear foot of rail applied to the top rail either horizontally and/or vertically downward. These two types of loads are not specified to act concurrently. We will illustrate the design of a railing system using separate formulas to calculate the stresses in the posts and the rails respectively. Typically the stress in the post will be the limiting factor on post spacing, pipe size/schedule, and material.

Post Design

Loads that are applied horizontally at the top rail of a guardrail system produce the maximum bending moment on the posts. The post acts as a vertical cantilevered member in resisting the horizontal load applied to the rails or posts. The height of the rail used in the calculations is measured from the centerline of the top rail to the top of the attachment.

A concentrated load applied to the rail at a post, is distributed to the posts on either side of that post. In railing systems where posts and rail are of identical material and section, and where post spacing varies between 3 feet and 6 feet, the greatest proportion of a concentrated load carried by any one post can be estimated as follows:

End posts: 2-span rail – 85%; 3 or more spans – 82%

Intermediate posts: 2-span rail – 65%; 3 or more spans – 60%

In single span railing systems, each post shall be designed to carry the full concentrated load.

These are called the Load Proportion Factors, (P_f).

(A span is defined as the space between posts, 2-span=3 posts, 3-span=4 posts, etc.)

A uniform load is applied to the entire length of rail, and is specified as pounds per linear foot of rail. The load carried by a given post is determined by the load per foot multiplied by the post spacing, or span, in feet. An end post will carry half the load of an intermediate post.

The formulas for post design to calculate the bending stress in the post are as follows:

$$\text{Concentrated Load: } f_b = \frac{P \times P_f \times h}{S} \quad \text{Uniform Load: } f_b = \frac{w \times L \times h}{S}$$

For calculations based on the allowable yield strength of the pipe, the calculated bending stress must be less than or equal to the allowable yield strength of the post material.

Example 1: Concentrated loading condition using a Hollaender #52E-8 side mount flange, with an OSHA concentrated load of 200 pounds, for a 3-span guardrail.

Pipe: 1 1/2" schedule 40; $S = 0.326 \text{ in}^3$

Rail height: $h = 43 \text{ in.}$ (from the centerline of the top rail to the top of the #52E-8 flange)

Post spacing: 6 ft.

Based on the load distribution factors, the design load for an intermediate post is 60% of 200 lb, or 120 lb, and for an end post is 82% of 200 lb, or 164 lb.

$$\text{The bending stress in the intermediate post is: } f_b = \frac{200 \times .6 \times 43}{.326} = 15,828 \text{ psi}$$

$$\text{The bending stress in the end post is: } f_b = \frac{200 \times .82 \times 43}{.326} = 21,631 \text{ psi}$$

The 6063-T6 aluminum pipe, with an allowable design strength of 18,000 psi is acceptable for the intermediate post but not the end post. We can calculate the bending stress using a schedule 80 end post to see if this is acceptable:

Pipe: 1 1/2" schedule 80; $S = 0.412 \text{ in}^3$

$$\text{The bending stress for the schedule 80 end post is: } f_b = \frac{200 \times .82 \times 43}{.412} = 17,116 \text{ psi}$$

This bending stress is less than the allowable design strength for 6063-T6 aluminum pipe.

An easier way to do this would be to calculate for the required section modulus of the post if you had already chosen the type of pipe material you wanted to use by rearranging the formula such as this:

$$S = \frac{P \times P_f \times h}{f_d} \quad \text{where, } f_d = \text{the allowable design strength of the material.}$$

Example 2: Uniform loading condition using a Hollaender #45SBC-8 base flange with a 3 inch high barrel for the post mounting, and a uniform loading condition of 50 pounds per foot applied horizontally.

Pipe material: 6061-T6 aluminum alloy; $f_d = 24,000 \text{ psi}$

Rail height: 38 in. (from the centerline of the top rail to the top of the #45SBC-8 flange)

Post spacing: 6 ft.

There is no load distribution factor for the uniform loading condition. Each intermediate post must take the load per linear foot multiplied by the post spacing in feet.

$$\text{The required section modulus is: } S = \frac{50 \times 6 \times 38}{24,000} = 0.475 \text{ in}^3$$

This exceeds the section modulus for schedule 80 pipe that is 0.412 in^3 . We would either have to shorten the post spacing to 5.2 feet or reinforce the inside of the post with reinforcing dowel to increase the section

modulus at the top of the attachment. If this were side mounted rail with a 43 in. height, the post spacing would be reduced to 4.6 feet for a schedule 80 post.

We would choose to use schedule 40 posts that would be reinforced internally with Hollaender Tubular Dowel made to fit inside a schedule 40 post. The section modulus of schedule 40 pipe and the Hollaender

Tubular Dowel would be:
$$S = \frac{\pi(D^4 - d^4)}{32D} = \frac{\pi(1.90^4 - 1.25^4)}{32(1.9)} = 0.547in^3.$$

This is acceptable because it exceeds the required section modulus of 0.475 in³ for the #45SBC-8 base flange, and the required section modulus of 0.538 in³ for a 43 inch rail height using the #52E-8 side mount flange. This will also reduce the cost of the rail since there will be fewer posts by holding the 6 foot post spacing vs. reducing the post spacing to meet the load. Also, the Hollaender Tubular Dowel is 60% lighter than the standard solid aluminum reinforcing dowel that is normally specified, further reducing the cost of the rail. An added benefit of the Hollaender Tubular Dowel over the solid dowel is that a weep hole is not required to let water drain from the post.

The required height of the Hollaender Tubular Dowel inside the schedule 40 post is given by:

$$h_1 = h - \frac{f_d \times S}{w \times L} = 38 - \frac{24,000 \times 0.326}{50 \times 6} = 11.92in, \text{ say } 12 \text{ inches.}$$

This is the height of the dowel above the top of the #45SBC-8 base flange, which would make the total length of dowel for this flange to be 15 inches.

For the #52E-8 side mount flange the dowel still has to reach the same height inside the post but it is longer because of the depth of the flange. The reinforcing dowel would be 22 inches long because the flange is 5 inches deep and the top of the flange is 2 inches below the walking surface.

Rail Design

After we have designed the posts, we need to verify that the rail will take the loads specified by the applicable building code. These loads will be the same as specified for the post design, i.e. concentrated or uniform.

A concentrated load applied to the top rail at any point, in any direction creates the maximum bending moment in the rail when applied at the mid-span of the rail between posts. The distribution of loads over multiple spans of rail decreases the maximum bending moment in rails. A bending moment constant (k) is used in the formulas depending on the number of spans in the length of rail. The formula to calculate the bending stress in the rail for concentrated loading at mid-span is as follows:

For single span rail k = 4, for two or more spans k = 5;
$$f_b = \frac{P \times L}{S \times k}$$

Example 3: Concentrated loading condition for a two span length of rail, with an OSHA concentrated load of 200 pounds.

- Pipe: 1 1/2" schedule 40, 6063-T6 aluminum; S = 0.326 in³, f_d = 18,000 psi
- Post spacing: 72 in..
- Bending moment constant: k = 5

The bending stress in the rail is:
$$f_b = \frac{200 \times 72}{0.326 \times 5} = 8,834 \text{ psi}$$

The bending stress in the rail is less than the allowable yield strength of 6063-T6 aluminum pipe. If we increase the post spacing to the 8 foot maximum allowed by OSHA, and this was a single span rail, the bending stress in the rail would be 14,723 psi which is still less than the allowable yield strength of 6063-T6 aluminum pipe.

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However, even though OSHA allows for a maximum 8 ft. post spacing, all of the model building codes, BOCA, SBC, and UBC for guardrail, specify a uniform load of 50 lb/ft, and require that the loading conditions specified must not exceed the allowable design working stress of the material. Therefore the post spacing will be limited to the most stringent requirement which is the values determined from the post design calculations for a uniform load.

With a uniform load, the rail load is proportional to the rail span, which has been established by the post design calculation. As in the concentrated load formulas, a bending moment constant is used to allow for the distribution of loads over multiple spans. The formula to calculate the bending stress in the rail for uniform loading is as follows:

For one or two span rail $k = 96$, for three or more spans $k = 114$; $f_b = \frac{w \times L^2}{S \times k}$

Example 4: Uniform loading condition of 50 pounds per foot horizontally and 100 pounds per foot vertically downward. This combined load resolves into 111.8 pounds at 63 degrees from horizontal.

Pipe: 1 1/2" schedule 40, 6061-T6 aluminum; $S = 0.326 \text{ in}^3$, $f_d = 24,000 \text{ psi}$

Post spacing: 72 in.

Bending moment constant: $k = 114$

The bending stress in the rail is: $f_b = \frac{111.8 \times 72^2}{0.326 \times 114} = 15,594 \text{ psi}$

The bending stress in the rail is less than the allowable yield strength of 6061-T6 aluminum pipe, so the 6 foot post spacing is acceptable with 1 1/2" schedule 40 pipe for the rail.

References:

"Pipe Railing Systems Manual, Including Round Tube", third edition, Architectural Metal Products Division of The National Association of Architectural Metal Manufacturers, ANSI/NAAM AMP 521-95, December 19, 1995

"Metal Rail Manual", second edition, 1986, National Ornamental & Miscellaneous Metal Association

ATTACHMENT B

Detailed Outlet Structural Calculations

Job GYPSUM STACK CLOSURE

Project No. _____

 Sheet 1 of 17

 Description ENERGY DISSIPATER CALE'S.

 Computed by SAN

 Date 5/11/16

 Checked by LMP

 Date 5/24/16

Reference

- CALCULATE MOMENT EQUILIBRIUM, BEARING PRESSURES, FLOATATION & SLIDING FOR THE ENERGY DISSIPATOR @ GYPSUM STACK CLOSURE LOCATION.

- DETAILS OF STRUCTURE ON Pg. 2.

DEAD LOADS:

$$\text{FLOOR: } DC_1 = (1.9') \times (17.67') \times (13.5') \times (0.15 \text{ K/FT}^2) = 35.78 \text{ K}$$

$$\text{BACKWALL: } DC_2 = [(1.05') \times (9.17') \times (13.5') + 3(1.25)^2 \pi (1.05')] \times (0.15 \text{ K/FT}^2) = 16.36 \text{ K}$$

$$\text{SIDEWALLS: } DC_3 = [2(6.833' \times 9.17') + \left(\frac{9.17' + 5'}{2}\right) \times 9.17'] \times 2(1.05') \times (0.15 \text{ K/FT}^2) = 38.13 \text{ K}$$

$$\text{FRONT WALL: } DC_4 = [2(2' \times 0.67' \times 13.5') + 2(0.67' \times 5' \times 3')] \times (0.15 \text{ K/FT}^2) = 5.7 \text{ K}$$

$$\text{DISSIPATOR WALL: } DC_5 = [2(2' \times 0.67' \times 12') + 0.83' (51.54 \text{ FT}^2)] \times (0.15 \text{ K/FT}^2) = 8.8 \text{ K}$$

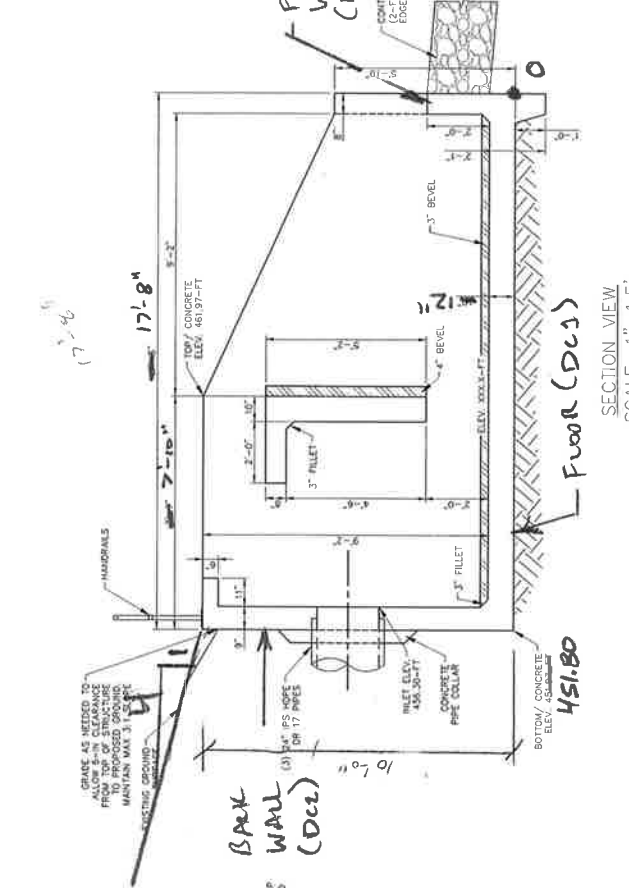
$$\text{TOTAL} = 105 \text{ K}$$

CHECK FACTOR OF SAFETY FOR FLOATATION: F.S. = 1.3

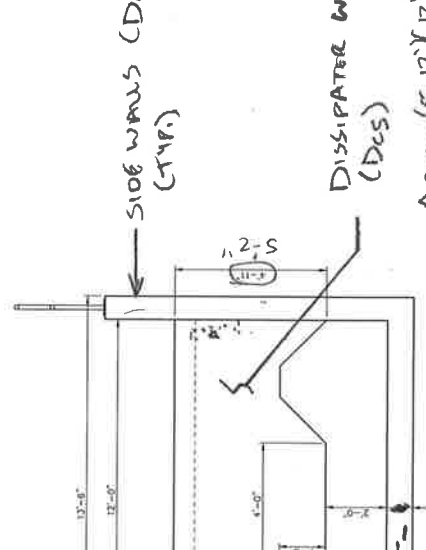
UPLIFT: DEPTH OF WATER = 2' + 1' = 3'

$$F_b = (3.0') \times (17.67') \times (13.5') \times (0.0624 \text{ K/FT}^2) = 44.66 \text{ K}$$

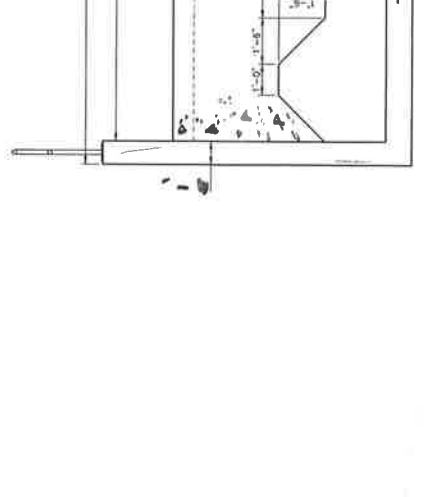
$$\text{F.S.} = \frac{105 \text{ K}}{44.66 \text{ K}} = 2.35 > 1.3 \quad \therefore \text{OK}$$



PLAN VIEW
SCALE: 1" = 1.5'



SECTION A-A
SCALE: 1" = 1.5'



SECTION VIEW
SCALE: 1" = 1.5'

DRAFT
ISSUED FOR APPROVAL
NOT FOR CONSTRUCTION

FOR SUPPORTING DESIGN CALCULATIONS SEE EXCEPT AS NOTED

SCALE: 1" = 1.5'

USBR TYPE VI ENERGY DISSIPATOR DETAILS
GYPSUM STACK CLOSURE
90% SUBMITTAL

PARADISE FOSSIL PLANT
TENNESSEE VALLEY AUTHORITY
MEMPHIS, TENNESSEE

DATE: 2013/07/24 | SHEET: 05 OF 05 | FIGURE 05

AREA = $(5.17 \times 12) - (4 \times 1.5) + 2(1.5)^2$
AREA = 51.54 FT²

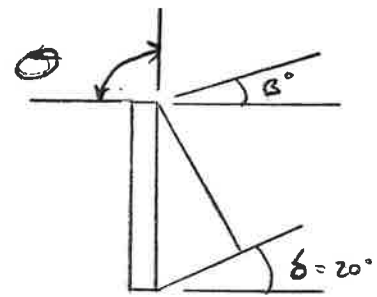
2/17

Job GYPSUM STACK CLOSURE
 Description ENERGY DISSIPATOR CALC'S

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Reference
 LRFD
 3.11.5.3

CALCULATE E_{H1} & E_{V2} FOR SLOPING BACKFILL:



$$\beta = \tan^{-1}\left(\frac{1}{4}\right) = 14.0^\circ$$

$$\delta = 20^\circ \quad \phi_F' = 30^\circ \quad \theta = 90^\circ$$

$$K_a = \frac{\sin^2(\theta + \phi_F')}{\pi [\sin^2\theta \sin(\theta - \delta)]}$$

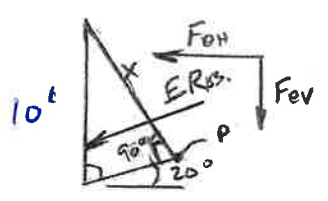
TABLE
 3.11.5.3-1

$$\pi = \left[1 + \sqrt{\frac{\sin(\phi_F' + \delta) \sin(\phi_F' - \beta)}{\sin(\theta - \delta) \sin(\theta + \beta)}} \right]^2$$

$$\pi = \left[1 + \sqrt{\frac{\sin(50^\circ) \sin(16^\circ)}{\sin(70^\circ) \sin(104^\circ)}} \right]^2 = 2.19$$

$$K_a = \frac{\sin^2(120^\circ)}{2.19 [(\sin^2 90^\circ) (\sin 70^\circ)]} = 0.36$$

Soil Pressure = $0.36 (0.120 \text{ k/ft}^2) = 0.044 \text{ k/ft}^2$



$$x = 10' (\sin 70^\circ) = 9.4'$$

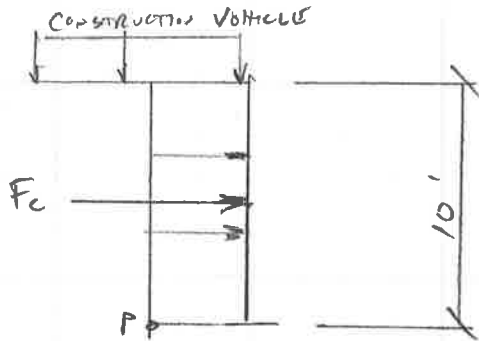
$$p = 9.4' (0.044 \text{ k/ft}^2) = 0.414 \text{ k/ft}^2$$

$$E_{Res.} = \frac{1}{2} (0.414 \text{ k/ft}^2) (9.4') = 1.95 \text{ k}$$

$$F_{EH} = 1.95 \text{ k}_1 (\cos 20^\circ) = 1.83 \text{ k}_1 \quad (13.5') = 24.7 \text{ k}$$

$$F_{EV} = 1.95 \text{ k}_1 (\sin 20^\circ) = 0.67 \text{ k}_1 \quad (13.5') = 9.0 \text{ k}$$

CONSTRUCTION LIVE LOAD SURCHARGE; (ASSUMES CONST. VEHICLE IS 8' IN LENGTH)



$$h_{eq} = 3.5'$$

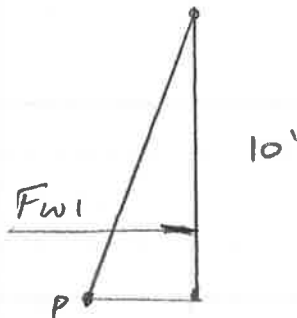
LRFD TAB,
3.11.6.4-2

$$\phi = 33^\circ, \text{EQUIV. EARTH PRESS.} = 40 \text{#/FT}^3$$

$$P = 3.5' (0.04 \text{ K/FT}^3) = 0.14 \text{ KSF}$$

$$F_c = (0.14 \text{ KSF} \times 10') \times (8') = 11.2 \text{ K}$$

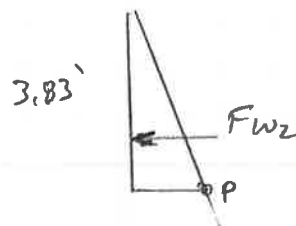
HYDROSTATIC PRESSURE; (ACTIVE SIDE)



$$P = 10' (0.0624 \text{ K/FT}^2) = 0.624 \text{ K/FT}^2$$

$$F_{w1} = \frac{1}{2} (0.624 \text{ K/FT}^2) \times (10') \times (13.5') = 42.1 \text{ K}$$

HYDROSTATIC PRESSURE; (PASSIVE SIDE)



$$P = 3.83' (0.0624 \text{ K/FT}^2) = 0.24 \text{ K/FT}^2$$

$$F_{w2} = \frac{1}{2} (0.24 \text{ K/FT}^2) \times (3.83') \times (17.67') = 8.6 \text{ K}$$

Job GYPSUM STACK CLOSURE

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 Description ENERGY DISSIPATOR CALC'S

 Computed by SAM

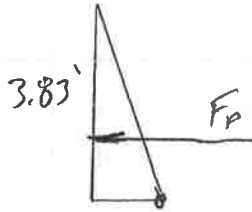
 Date 5/11/16

 Checked by LMP

 Date 5/24/16

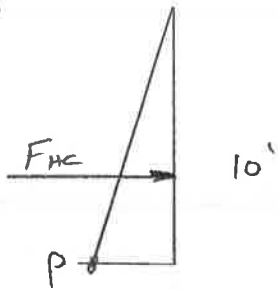
Reference

PASSIVE PRESSURE : (PASSIVE SIDE)



$$F_p = \frac{1}{2} (2.45 \times 0.12 \text{ k/ft}^2) (3.83')^2 (17.67') = 38.1 \text{ K}$$

SOIL PRESSURE DURING CONSTRUCTION :



$$P = 10' (0.04 \text{ k/ft}^2) = 0.4 \text{ k/ft}^2$$

$$F_{hc} = \frac{1}{2} (0.04 \text{ k/ft}^2) (10')^2 (13.5') = 27 \text{ K}$$

CHECK SLIDING : F.S. = 2.0

① CASE I - DURING CONSTRUCTION, NO HYDROSTATIC PRESSURE

PASSIVE

$$\begin{cases} F_p = 105.74 \text{ K} (0.35) = 37.01 \text{ K} \\ F_p = 42 \text{ K} \end{cases}$$

ACTIVE

$$\begin{cases} F_c = 11.2 \text{ K} \\ F_{hc} = 27 \text{ K} \end{cases}$$

$$F.S. = \frac{37 \text{ K} + 39.1 \text{ K}}{11.2 \text{ K} + 27 \text{ K}} = \frac{76.1}{38.2} = 1.99$$

(OK ONLY ACTS ON STRUCTURE FOR A FEW MONTHS)

Job Gypsum Stack Closure
 Description ENERGY DISSIPATER CALL'S.

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Reference

CK. SLIDING CONT:

(2) CASE II - AFTER CONSTRUCTION, HYDROSTATIC PRESSURE, NO LIVE LOAD SURCHARGE

PASSIVE

$$F_P = \left(\overset{Pg.1}{105.10} K + \overset{F_b}{44.66} K + \overset{F_{wv}}{9} K \right) (0.35) = 24.3 K$$

$$F_P = 38.1 K$$

$$F_{W2} = 8.62 K$$

ACTIVE

$$F_{W1} = 42.1 K \quad (Pg.4)$$

$$F_{E1} = 24.7 K$$

(UNDRAINED BACKWALL)

$$F.S. = \frac{24.3 K + 38.1 K + 8.6 K}{42.1 K + 24.7 K} = \frac{71.0 K}{66.8} = 1.06 < 2.0$$

∴ N.G.

(DRAINED BACKWALL)

$$F.S. = \frac{24.3 K + 38.1 K}{24.7 K} = 2.53 > 2.0 \quad \therefore \text{OK}$$

∴ NEED TO ADD 2'-0" POROUS BACKFILL WITH 6" DRAINPIPE SLOPES TO DRAIN BEHIND BACKWALL.

CHECK STABILITY & BEARING PRESSURE:

$$\Sigma V = 105 \text{ K} \quad \text{CPG. 1}$$

$$\Sigma M_0 = \overset{(D_{c1})}{35.78 \text{ K}} \left(17.67' / 2 \right) + \overset{D_{c2}}{16.36 \text{ K}} \left(17.04' \right) + \overset{D_{c3}}{(6.83' \times (1.05' \times 9.17') \times 0.15 \times 9.83' + 6.83' / 2)} \\ + \overset{D_{c3}}{(9.17' \times 5' \times 4.0' \times 9.17' / 2) \times 0.15} + \overset{D_{c4}}{5.7 \text{ K}} (6.33') + \overset{D_{c5}}{8.8 \text{ K}} (11') \quad \leftarrow \text{CONSERVATIVE}$$

$$\Sigma M_0 = \overset{(D_{c1})}{316.6 \text{ K}} + \overset{(D_{c2})}{278.8 \text{ K}} + \overset{(D_{c3})}{124.4 \text{ K}} + \overset{(D_{c3})}{31.5 \text{ K}} + \overset{(D_{c4})}{1.9 \text{ K}} + \overset{(D_{c5})}{96.8 \text{ K}}$$

$$\Sigma M_0 = 849.5 \text{ K}$$

CASE I DURING CONSTRUCTION

$$\Sigma M_0 = 849.5 \text{ K} - \overset{F_{H1}}{27 \text{ K}} \left(10' / 3 \right) - \overset{F_{H2}}{11.2 \text{ K}} \left(10' / 2 \right) = 703.5$$

$$\text{RESULTANT} = \frac{203.53 \text{ K}}{105 \text{ K}} = 6.7'$$

$$e = 17.67' / 2 - 6.3' = 2.5'$$

$$L/6 = 17.67' / 6 = 2.9' > 2.5' \quad \therefore \text{NO UPLIFT}$$

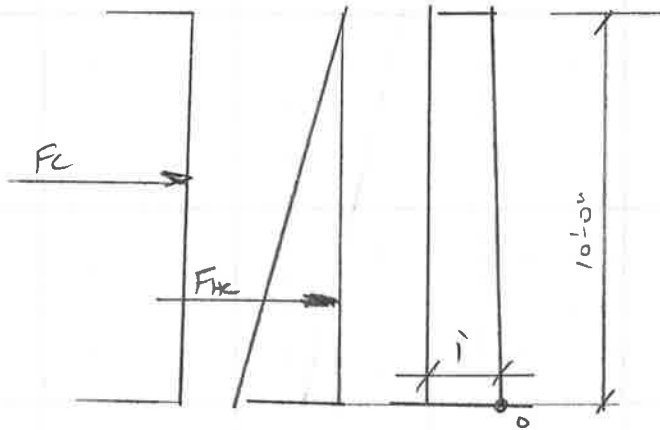
$$q = \frac{105 \text{ K} \left(1 \pm \frac{6(2.5')}{17.67'} \right)}{(13.5' \times 17.67')} = 0.81 \text{ KSF (MAX.)}, 0.07 \text{ KSF MIN.}$$

$$\text{ALLOWABLE BEARING PRESSURE} = 7.3 \text{ KSF}$$

$$F.S. = \frac{7.3 \text{ KSF}}{0.81 \text{ KSF}} = 9.0 > 3.0 \quad \therefore \text{OK}$$

BEARING CAPACITY AFTER CONSTRUCTION OK BY INSPECTION...

DESIGN ^{VERTICAL} REINFORCING IN VERTICAL WALLS: BACK FACE
 - ASSUME WALL THICKNESS = 1'-0" , TWO MATS OF REINFORCING



STRENGTH I DESIGN!

$$\sum M_o = 11.2K (1.75) (10 \frac{1}{2}) + 27K (1.50) (10 \frac{1}{3}) = 233 \text{ K} (12 \frac{1}{4}) / 13 = 215.1 \text{ K}$$

$$d = 12" - 2" - 0.75 \frac{1}{2} = 9.625" \quad b = 12"$$

TAKE ϕM_n AS LESSOR OF THE FOLLOWING:

$$1.33 M_o = 1.33 (215.1 \text{ K}) = 286 \text{ K}$$

OR

$$1.2 M_{cr} = 1.2 \gamma_3 [(\gamma_1 F_r) S_c] \quad F_r = 0.24 \sqrt{4Ksi} = 0.48Ksi$$

$$S_c = I_g / c = \frac{(12 \frac{1}{4})^4 / 12}{6"} = 288 \text{ in}^3$$

$$\gamma_1 = 1.6$$

$$\gamma_3 = 0.67 \text{ (A615 STEEL)}$$

$$= 1.2 (0.67) [(1.6)(0.48Ksi) 288 \text{ in}^3]$$

$$= 177.8 \text{ K}$$

$$\therefore \text{USE } \phi M_n = 215.1 \text{ K}$$

Job Gypsum Stack Closure

Project No. _____

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 Description EMBEDDING DISSIPATOR CALC'S.

 Computed by SAM

 Date 5/12/16

 Checked by LMP

 Date 5/24/16

Reference

$$\phi M_n = \phi A_s F_y \left(d - \frac{A_s F_y}{2(0.85)(F'_c)(b)} \right)$$

$$ZIS \text{ "K}_1 = 0.9 A_s (60 \text{ ksi}) \left(9.625" - \frac{A_s (60 \text{ ksi})}{2(0.85)(4 \text{ ksi})(12")} \right)$$

$$ZIS \text{ "K}_1 = 519.8 A_s - 39.7 A_s^2$$

$$A_s = 0.43 \text{ in}^2, \quad \therefore \text{use } \#5 @ 8" = 0.31 \text{ in}^2 \left(12 \frac{1}{8}" \right) = 0.47 \text{ in}^2$$

- use #5 @ 8" VERTICAL FRONT FACE - FOR SIMPLICITY

SIZE REINFORCING LONGITUDINAL, BACK FACE OF VERTICAL WALLS

$$L = \frac{4}{c} \text{ SIDEWALLS} = 13' \quad (F_c) \quad (F_{HL})$$

$$P = 1.75(0.14 \text{ KSF}) + 1.5(0.40 \text{ KSF}) = 0.845 \text{ KSF}$$

$$M = \frac{WL^2}{12} = \frac{(0.845 \text{ KSF})(13')^2}{12} = 11.9 \text{ "K}_1 = 142.8 \text{ "K}_1 \text{ (NEAR END WALLS)}$$

$$d = 12" - 2" - 0.625" - \frac{0.625"}{2} = 9.06" \quad b = 12"$$

TAKE ϕM_n AS LESSER OF THE FOLLOWING:

$$1.33 M_u = 1.33 (142.8 \text{ "K}_1) = 190 \text{ "K}_1$$

OR

$$1.2 M_{cr} = 177.8 \text{ "K}_1 \quad \leftarrow \text{CONTROLS}$$

$$\therefore \text{use } \phi M_n = 177.8 \text{ "K}_1$$

$$177.8 \text{ "K}_1 = 0.9 A_s (60 \text{ ksi}) \left(9.06' - \frac{A_s (60 \text{ ksi})}{2(0.85 \times 4 \text{ ksi}) (12")} \right)$$

$$177.8 \text{ "K}_1 = 489. A_s - 39.7 A_s^2$$

$$A_s = 0.375 \text{ in}^2 \quad \therefore \text{USE } \#5 @ 8" = 0.47 \text{ in}^2$$

- USE #5 @ 8" HORIZONTAL FRONT FACE - FOR SIMPLICITY

DESIGN DISSIPATOR REINFORCING STEEL:

- ASSUME ONE MAT OF REINFORCING
- ASSUME WALL THICKNESS = 10"

- CALCULATE PRESSURE ON DISSIPATOR WALL:

$$P = \frac{C_D V^2}{1000} \text{ (KSF)}$$

$$C_D = 1.4$$

LRFD

3.7.3.1

$$V = 25 \text{ FT/S (FROM DISSIPATOR CALC'S, PG. 11)}$$

$$P = \frac{1.4 (25^2)}{1000}$$

$$P = 0.875 \text{ KSF}$$

DESIGN HORIZONTAL STEEL:

$$Q_{Mn} = \frac{0.875 (13')^2}{12} = 12.3 \text{ "K}_1 = 147.9 \text{ "K}_1 \text{ (NEAR END WALLS)}$$

$$d = 10 \frac{1}{2} + 0.75" = 5.75" \quad b = 12"$$

TAKE Q_{Mn} AS LESSOR OF THE FOLLOWING:

$$1.33 M_u = 1.33 (147.9 \text{ "K}_1) = 197 \text{ "K}_1$$

OR

$$1.2 M_{cr} = 1.2 \gamma_3 [(\gamma_1 f_r) S_c] \quad f_r = 0.48 \text{ KSI}$$

SUMMARY

Energy Dissipator Dimensions (ft):

W_B	h_1	h_2	h_3	h_4	L	L_1	L_2
12	9.17	4.5	2	5	16	6.83	9.17
W_B	W_1	W_2	t_1	t_2	t_3	t_4	t_5
12	0.92	3	0.67	0.83	0.83	0.75	0.33

Parameter	Value	Units
Entrance Flow, Q	150.81	cfs
Entrance Velocity V_0	24.62	ft/s
Exit Velocity, V_2	16.54	ft/s

$$S_c = I_g/c = \frac{(10'')^4/12}{5''} = 166.7 \text{ in}^3$$

$$1.2 M_{er} = 1.2(0.67) [(1.6)(0.48 \text{ ksi})(166.7 \text{ in}^3)] = 102.9 \text{ ''k}$$

$$\therefore \text{use } M_n = 147.9 \text{ ''k}$$

$$147.9 \text{ ''k} = 0.9 A_s (60 \text{ ksi}) \left(5.75'' - \frac{A_s (60 \text{ ksi})}{2(0.98)(4 \text{ ksi})(12 \text{ ''})} \right)$$

$$147.9 \text{ ''k} = 310.5 A_s - 39.7 A_s^2$$

$$A_s = 0.51 \text{ in}^2$$

$$\therefore \text{use } \#6 @ 8'' = 0.44 \text{ in}^2 \left(\frac{12''}{8''} \right) = 0.66 \text{ in}^2$$

$\therefore \#6 @ 8''$ HORIZONTAL, $\#4 @ 8''$ VERTICAL

DESIGN REINFORCING IN FLOOR SLAB:

- ASSUME TWO MATS OF REINFORCING
- ASSUME FLOOR THICKNESS = 12''

- CALCULATE MAXIMUM PRESSURE ON BOTTOM OF FLOOR:

- USE STRENGTH 1, DESIGN

$$\Sigma V = 1.25 (105 \text{ ''k}) = 131.3 \text{ k}$$

$$\Sigma M_o = 849.5 \text{ ''k} (1.25) = 1061.9 \text{ ''k}$$

$$F_{HC} = 1.50 (27 \times 10/3) = 135 \text{ k}$$

$$F_c = 1.75 (11.2 \times 10/2) = 98 \text{ k}$$

$$\Sigma M_o = 1061.9 \text{ ''k} - 131.3 \text{ ''k} - 98 \text{ ''k} = 832.6 \text{ ''k}$$

Job GYPSON STAIR CLOSERS
 Description ENERGY DISSIPATOR CALC'S

Project No. _____
 Computed by SAW
 Checked by LMP

Page _____ of _____
 Sheet 13 of 17
 Date 5/12/16
 Date 5/24/16

Reference

$$ROBUSTNESS = \frac{832.6 \text{ K}}{131.3 \text{ K}} = 6.34''$$

$$e = \frac{17.67''}{2} - 6.34'' = 2.5''$$

$$L/6 = \frac{17.67''}{6} = 2.9 > 2.5 \quad \therefore \text{NO UPLIFT}$$

$$q = \frac{131.3 \text{ K} \left(1 \pm \frac{6(2.5'')}{17.67''} \right)}{(13.5' \times 17.67'')} = 1.02 \text{ KSF}, \quad 0.08 \text{ KSF} \approx 0 \text{ KSF}$$

M_u (From Beam Diagrams No. 2, Pg. 14)

$$W = \frac{1}{2} (1.02 \text{ KSF} \times 17.67'') = 9.01 \text{ K/}$$

$$M_{max} = \frac{2(9.03 \text{ K/} \times 17.67'')}{9 \sqrt{3}} = 248 \text{ K}'' \quad (12'') = 262 \text{ K}''$$

$\phi M_n =$ Lesser of the following:

$$1.33 m_u = 1.33 (262 \text{ K}'') = 348.5 \text{ K}''$$

OR

$$1.2 M_{cr} = 177.8 \text{ K}''$$

$$\therefore \text{USE } \phi M_n = 262 \text{ K}''$$

$$d = 12'' - 3'' - 0.625 \frac{1}{2} = 8.69''$$

$$262 \text{ K}'' = 0.9 A_s (60 \text{ KSI}) \left(8.69'' - \frac{A_s 60}{2(0.85 \times 4 \times 12)} \right)$$

$$262 = 469 A_s - 39.7 A_s^2$$

$$A_s = 0.59 \text{ in}^2$$

USE #6 @ 8'' =

$$0.66 \text{ in}^2$$

USE #4 @ 8''

TOP MAT LAT. & LONG.

Bottom MAT

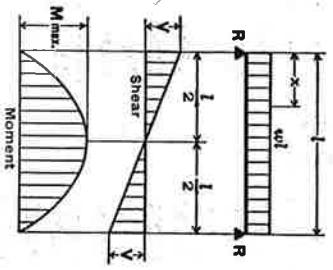
LAT. & LONG.

BEAM DIAGRAMS AND FORMULAS

For various static loading conditions

For meaning of symbols, see page 3-127

1. SIMPLE BEAM—UNIFORMLY DISTRIBUTED LOAD



Total Equiv. Uniform Load = wl

$R = V$ = $\frac{wl}{2}$

V_x = $w \left(\frac{l}{2} - x \right)$

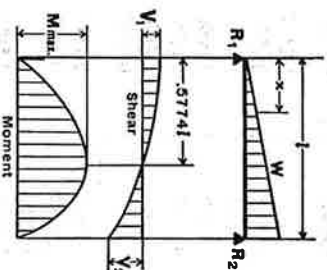
M max. (at center) = $\frac{wl^2}{8}$

M_x = $\frac{wx}{2} (l-x)$

Δ max. (at center) = $\frac{5wl^4}{384EI}$

Δ_x = $\frac{wx}{24EI} (l^3 - 2lx^2 + x^3)$

2. SIMPLE BEAM—LOAD INCREASING UNIFORMLY TO ONE END



Total Equiv. Uniform Load = $\frac{16W}{9\sqrt{3}} = 1.0264W$

$R_1 = V_1$ = $\frac{W}{3}$

$R_2 = V_2$ max. = $\frac{2W}{3}$

V_x = $\frac{W}{3} - \frac{Wx^2}{l^2}$

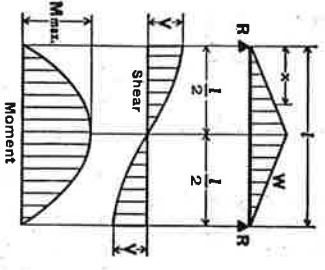
M max. (at $x = \frac{l}{\sqrt{3}} = .5774l$) = $\frac{2Wl}{9\sqrt{3}} = .1283 Wl$

M_x = $\frac{Wx}{3l^2} (l^2 - x^2)$

Δ max. (at $x = l\sqrt{1 - \sqrt{\frac{8}{15}}} = .5193l$) = $\frac{.01304}{EI} \frac{Wl^3}{3}$

Δ_x = $\frac{Wx}{180EI l^2} (3x^4 - 10l^2x^2 + 7l^3)$

3. SIMPLE BEAM—LOAD INCREASING UNIFORMLY TO CENTER



Total Equiv. Uniform Load = $\frac{4W}{3}$

$R = V$ = $\frac{W}{2}$

V_x (when $x < \frac{l}{2}$) = $\frac{W}{2l^2} (l^2 - 4x^2)$

M max. (at center) = $\frac{Wl}{6}$

M_x (when $x < \frac{l}{2}$) = $Wx \left(\frac{l}{2} - \frac{2x^2}{3l} \right)$

Δ max. (at center) = $\frac{Wl^3}{60EI}$

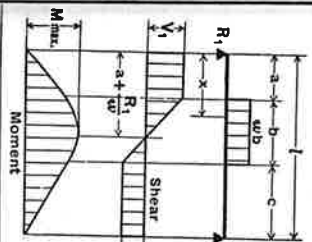
Δ_x (when $x < \frac{l}{2}$) = $\frac{Wx}{480EI l^2} (5l^2 - 4x^2)^2$

BEAM DIAGRAMS AND FORMULAS

For various static loading conditions

For meaning of symbols, see page 3-127

4. SIMPLE BEAM—UNIFORM LOAD PARTIALLY DISTRIBUTED



$R_1 = V_1$ (max. when $a < c$) = $\frac{wb}{2l} (2c + b)$

$R_2 = V_2$ (max. when $a > c$) = $\frac{wb}{2l} (2a + b)$

V_x (when $x > a$ and $< (a + b)$) = $R_1 - w(x - a)$

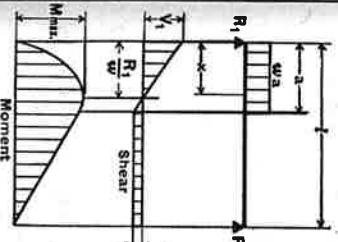
M max. (at $x = a + \frac{R_1}{w}$) = $R_1 \left(a + \frac{R_1}{2w} \right)$

(when $x < a$) = R_1x

M_x (when $x > a$ and $< (a + b)$) = $R_1x - \frac{w}{2} (x - a)^2$

M_x (when $x > (a + b)$) = $R_2(l - x)$

5. SIMPLE BEAM—UNIFORM LOAD PARTIALLY DISTRIBUTED AT ONE END



$R_1 = V_1$ max. = $\frac{wa}{2l} (2l - a)$

$R_2 = V_2$ = $\frac{wa^2}{2l}$

V_x (when $x < a$) = $R_1 - wx$

M max. (at $x = \frac{R_1}{w}$) = $\frac{R_1^2}{2w}$

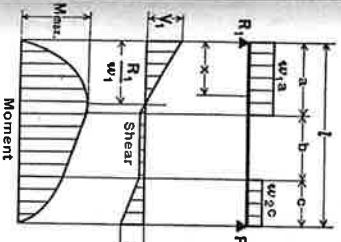
M_x (when $x < a$) = $R_1x - \frac{wx^2}{2}$

M_x (when $x > a$) = $R_2(l - x)$

Δ_x (when $x < a$) = $\frac{wx}{24EI} (a(2l-a)^2 - 2ax^2(2l-a) + lx^3)$

Δ_x (when $x > a$) = $\frac{wa^2(l-x)}{24EI} (4xl - 2x^2 - a^2)$

6. SIMPLE BEAM—UNIFORM LOAD PARTIALLY DISTRIBUTED AT EACH END



$R_1 = V_1$ = $\frac{wa(2l-a) + wzc^2}{2l}$

$R_2 = V_2$ = $\frac{wzc(2l-c) + wa^2a^2}{2l}$

V_x (when $x < a$) = $R_1 - wx$

V_x (when $x > a$ and $< (a + b)$) = $R_1 - wa$

V_x (when $x > (a + b)$) = $R_2 - wx(l - x)$

M max. (at $x = \frac{R_1}{w}$ when $R_1 < wa$) = $\frac{R_1^2}{2w}$

M max. (at $x = l - \frac{R_2}{w}$ when $R_2 < wzc$) = $\frac{R_2^2}{2w}$

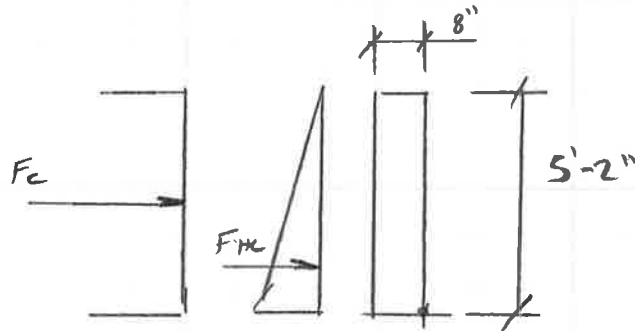
M_x (when $x < a$) = $R_1x - \frac{wx^2}{2}$

M_x (when $x > a$ and $< (a + b)$) = $R_1x - \frac{wa}{2} (2x - a)$

M_x (when $x > (a + b)$) = $R_2(l - x) - \frac{wx}{2} (l - x)^2$

Design Reinforcement in Front Wall:

- Assume 8" THICK
- Assume ONE MAT OF REINFORCEMENT



$$F_c = (0.14 \text{ ksf} \times 5.17') = 0.72 \text{ k/ft}$$

$$F_{mc} = \frac{1}{2} (0.04 \text{ k/ft}^2 \times 5.17')^2 = 0.53 \text{ k/ft}$$

$$M_o = 1.75 (0.72 \text{ k/ft} \times 5.17' \times \frac{1}{2}) + 1.5 (0.53 \text{ k/ft} \times 5.17' \times \frac{1}{3}) = 4.63 \text{ k-ft} = 55.5 \text{ in-k}$$

$$d = 8 \text{ in} / 2 + 0.625 \text{ in} = 4.625 \text{ in}, \quad b = 12 \text{ in}$$

Take ϕM_n AS LESSER OF THE FOLLOWING:

$$1.33 M_o = 1.33 (55.5 \text{ in-k}) = 73.8 \text{ in-k}$$

OR

$$1.2 M_{cr}$$

$$S_c = \frac{(8 \text{ in})^4 / 12}{4 \text{ in}} = 85.3 \text{ in}^3$$

$$1.2 (0.67) [1.6 (0.48 \text{ ksi}) (85.3 \text{ in}^3)] = 52.7 \text{ in-k} \leftarrow \text{Controls}$$

$$\therefore \text{USE } \phi M_n = 52.7 \text{ in-k}$$

$$52.7 \text{ in-k} = 0.9 A_s (60 \text{ ksi}) (4.625 \text{ in} - \frac{A_s (60 \text{ ksi})}{2 (0.85 (4 \text{ ksi}) (12 \text{ in}))})$$

$$52.7 = 249.8 A_s - 39.7 A_s^2$$

$$A_s = 0.22 \text{ in}^2, \quad \#5 @ 8 \text{ in} = 0.31 \text{ in}^2 \left(\frac{12 \text{ in}}{8 \text{ in}} \right) = 0.465 \text{ in}^2$$

USE LAT & EMB.

Job GYPSUM STALL CLOSURE

Project No. _____

Sheet 16 of 17

Description EMERGENCY DISSIPATION CALL'S

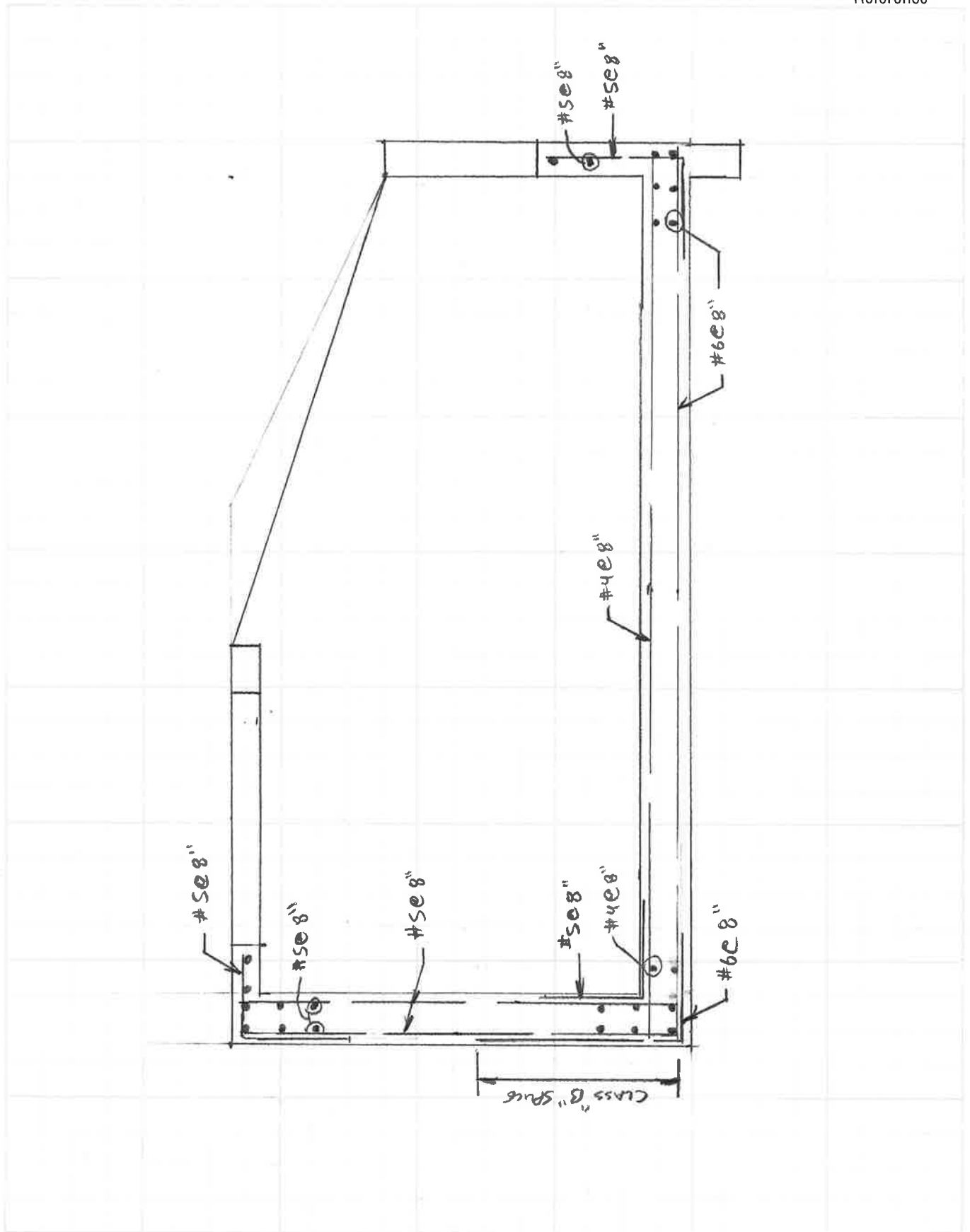
Computed by SAM

Date 5/12/16

Checked by LMP

Date 5/24/16

Reference

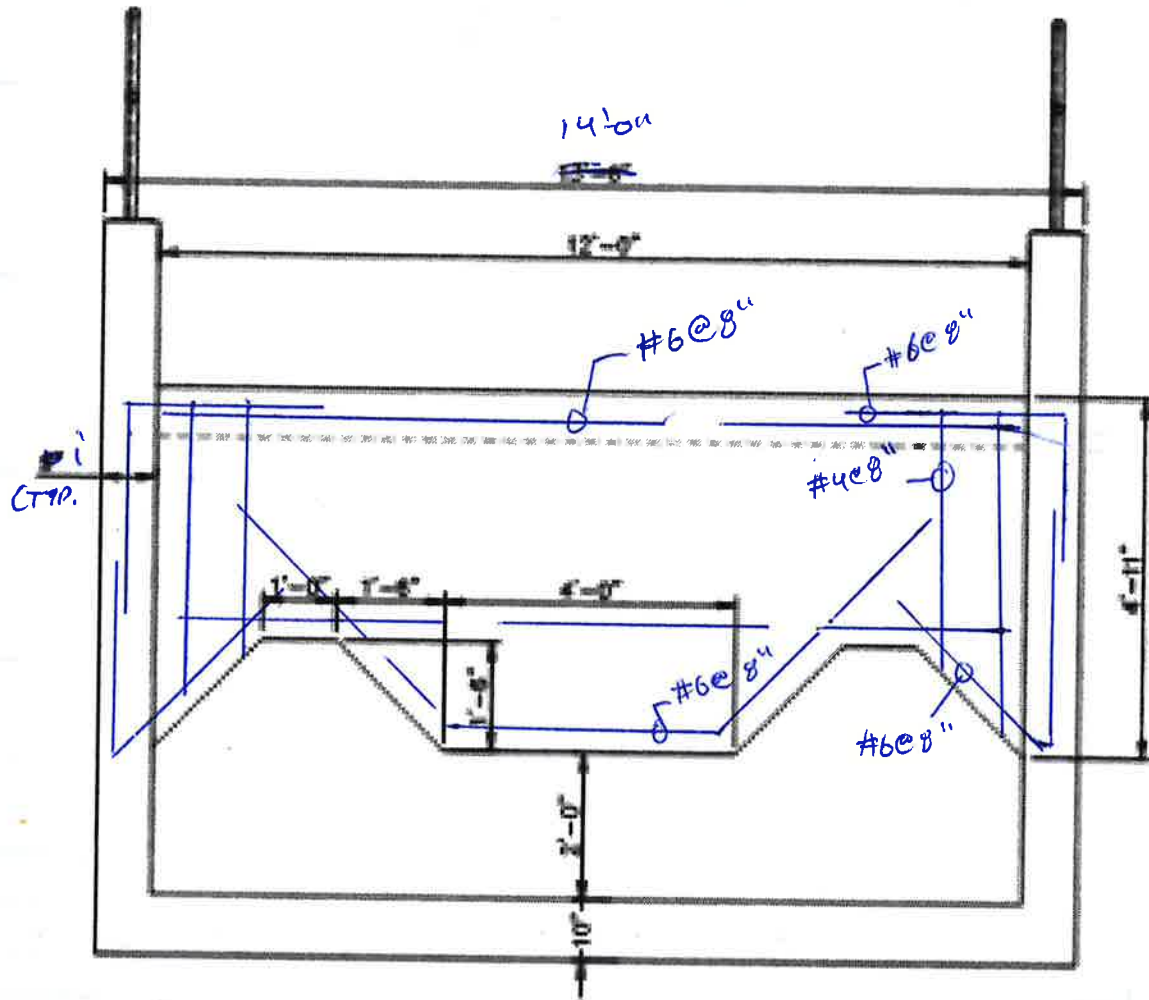


Job GYPSUM STACK CLOSURE

Project No. _____

Sheet 17 of 17Description EMBEDDED DISSIPATOR CALC'S.Computed by SAMDate 5/12/16Checked by LMPDate 5/24/16

Reference



SECTION 2

SKIMMER CALCULATIONS

Job	<u>PAF Gypsum Stack Spillway</u>	Project No.	<u>60444361</u>	Sheet	<u>1</u> of <u>16</u>
Description	<u>Steel Skimmer Calculations</u>	Computed by	<u>JD</u>	Date	<u>6/8/16</u>
		Checked by	<u>TL</u>	Date	<u>5/10/16</u>

I. PURPOSE

The purpose of the steel skimmer is to prevent small or large floating debris from entering the inlet structure. The design of the skimmer incorporates structural elements that were modeled using a finite element analysis program.

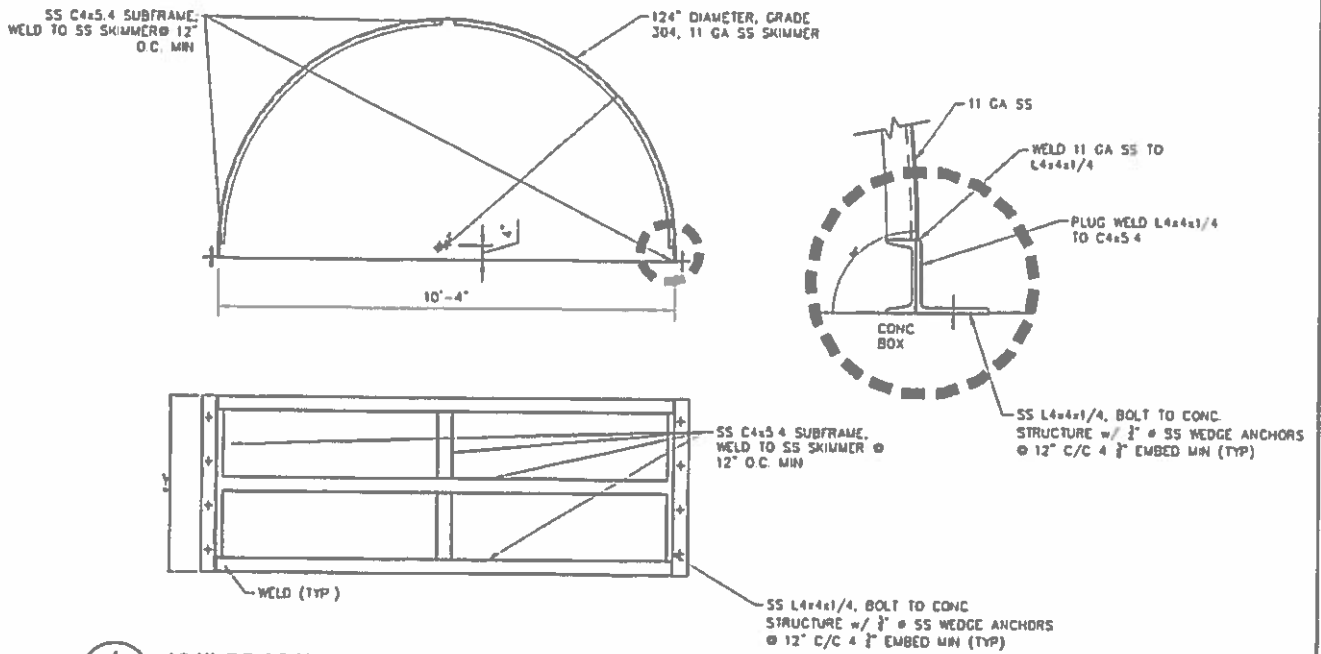
II. SITE AND PROJECT DESCRIPTION

The existing spillway at the Gypsum Stack Upper Stilling Pond is being replaced due to stability concerns. A new spillway will be constructed, which will make use of a steel skimmer that will be attached to the front of the inlet.

III. METHODOLOGY

The structural analysis and design for the skimmer inlet consisted of a finite element analysis (FEA) model of the 10'-4" diameter semi-circular skimmer shell and its steel membered sub-frame. This was done using a FEA software package titled Visual Analysis by IES. IES Visual Analysis is a general-purpose frame and finite element analysis tool with design capabilities. It was assumed that the skimmer shell would not have a differential hydrostatic load. The water level would be the same on the interior as it is on the exterior. The self-weight of the skimmer shell and the sub-frame members were the primary vertical loading for this analysis. A lateral load of 2000# was applied against the side of the skimmer to account for a possible impact load.

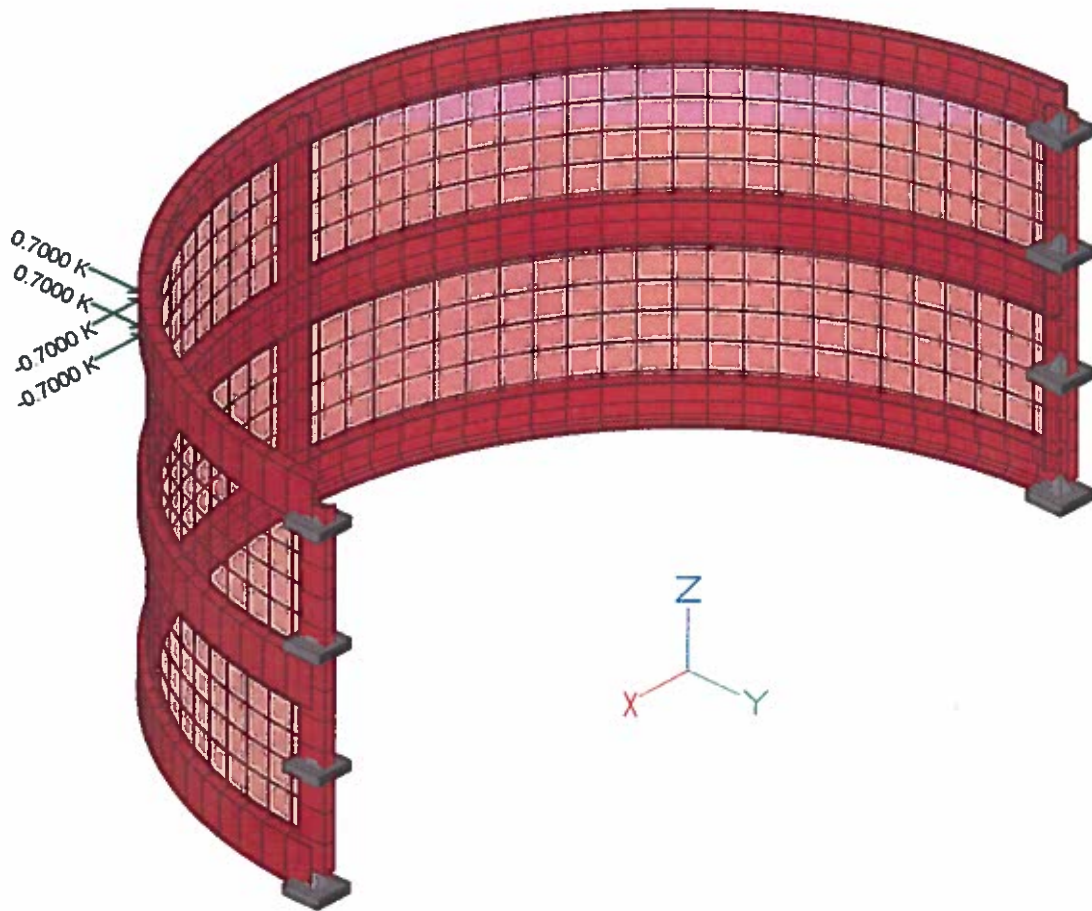
JOB TITLE TVA Paradise Fossil Plant
 JOB NO. 60444361 CALCULATION NO. 10'4" Skimmer
 ORIGINATOR J Dischinger DATE 6/8/2016
 REVIEWER T Lauth DATE 6/10/16
 SCALE _____ SHEET NO. _____ OF _____



1 124" GRADE 304 STAINLESS STEEL SKIMMER
 7/7 NTS

Skimmer designed for self weight & 2000lb impact load @ top bracing member @ a 45° angle

10'-4 Diameter Skimmer
AECOM - CLEVELAND, Jeremiah Dischinger
Jun 08, 2016; 04:20 PM
Load Case: F
IES VisualAnalysis 12.00.0006



Project: 10'-4 Diameter Skimmer

Jeremiah Dischinger, AECOM - CLEVELAND

June 13, 2016

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10'-4 Diameter Skimmer

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Company: AECOM - CLEVELAND Engineer: Jeremiah Dischinger

VisualAnalysis 12.00.0006 Report

Member Elements

Member	Section	Material	(1)Node	(2)Node	Length ft	Rz1	Rz2	One Way	Framing
BmX001-c1	C6x8.2	ASTM A36	N1413	N1432	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c2	C6x8.2	ASTM A36	N1419	N1438	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c3	C6x8.2	ASTM A36	N1394	N1413	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c4	C6x8.2	ASTM A36	N1400	N1419	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c5	C6x8.2	ASTM A36	N1375	N1394	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c6	C6x8.2	ASTM A36	N1381	N1400	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c7	C6x8.2	ASTM A36	N1356	N1375	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c8	C6x8.2	ASTM A36	N1362	N1381	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c9	C6x8.2	ASTM A36	N1337	N1356	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c10	C6x8.2	ASTM A36	N1343	N1362	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c11	C6x8.2	ASTM A36	N1318	N1337	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c12	C6x8.2	ASTM A36	N1324	N1343	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c13	C6x8.2	ASTM A36	N1299	N1318	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c14	C6x8.2	ASTM A36	N1305	N1324	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c15	C6x8.2	ASTM A36	N1280	N1299	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c16	C6x8.2	ASTM A36	N1286	N1305	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c17	C6x8.2	ASTM A36	N1261	N1280	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c18	C6x8.2	ASTM A36	N1267	N1286	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c19	C6x8.2	ASTM A36	N1242	N1261	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c20	C6x8.2	ASTM A36	N1248	N1267	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c21	C6x8.2	ASTM A36	N1432	N1451	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c22	C6x8.2	ASTM A36	N1438	N1457	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c23	C6x8.2	ASTM A36	N1451	N1470	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c24	C6x8.2	ASTM A36	N1457	N1476	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c25	C6x8.2	ASTM A36	N995	N1014	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c26	C6x8.2	ASTM A36	N1001	N1020	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c27	C6x8.2	ASTM A36	N1812	N013	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c28	C6x8.2	ASTM A36	N1818	N025	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c29	C6x8.2	ASTM A36	N1698	N1717	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c30	C6x8.2	ASTM A36	N1704	N1723	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c31	C6x8.2	ASTM A36	N1033	N1052	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c32	C6x8.2	ASTM A36	N1039	N1058	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c33	C6x8.2	ASTM A36	N1717	N1736	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c34	C6x8.2	ASTM A36	N1723	N1742	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c35	C6x8.2	ASTM A36	N1014	N1033	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c36	C6x8.2	ASTM A36	N1020	N1039	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c37	C6x8.2	ASTM A36	N976	N995	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c38	C6x8.2	ASTM A36	N982	N1001	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c39	C6x8.2	ASTM A36	N957	N976	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c40	C6x8.2	ASTM A36	N963	N982	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c41	C6x8.2	ASTM A36	N938	N957	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c42	C6x8.2	ASTM A36	N944	N963	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c43	C6x8.2	ASTM A36	N919	N938	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c44	C6x8.2	ASTM A36	N925	N944	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c45	C6x8.2	ASTM A36	N1489	N1508	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c46	C6x8.2	ASTM A36	N1495	N1514	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c47	C6x8.2	ASTM A36	N1470	N1489	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c48	C6x8.2	ASTM A36	N1476	N1495	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c49	C6x8.2	ASTM A36	N1071	N1090	0.338	Rigid	Rigid	Normal (2-way)	Beam

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BmX001-c50	C6x8.2	ASTM A36	N1077	N1096	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c51	C6x8.2	ASTM A36	N1565	N1584	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c52	C6x8.2	ASTM A36	N1571	N1590	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c53	C6x8.2	ASTM A36	N1147	N1166	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c54	C6x8.2	ASTM A36	N1153	N1172	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c55	C6x8.2	ASTM A36	N1166	N1185	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c56	C6x8.2	ASTM A36	N1172	N1191	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c57	C6x8.2	ASTM A36	N1204	N1223	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c58	C6x8.2	ASTM A36	N1210	N1229	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c59	C6x8.2	ASTM A36	N1793	N1812	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c60	C6x8.2	ASTM A36	N1799	N1818	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c61	C6x8.2	ASTM A36	N1774	N1793	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c62	C6x8.2	ASTM A36	N1780	N1799	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c63	C6x8.2	ASTM A36	N1755	N1774	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c64	C6x8.2	ASTM A36	N1761	N1780	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c65	C6x8.2	ASTM A36	N1052	N1071	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c66	C6x8.2	ASTM A36	N1058	N1077	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c67	C6x8.2	ASTM A36	N1090	N1109	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c68	C6x8.2	ASTM A36	N1096	N1115	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c69	C6x8.2	ASTM A36	N1736	N1755	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c70	C6x8.2	ASTM A36	N1742	N1761	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c71	C6x8.2	ASTM A36	N1546	N1565	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c72	C6x8.2	ASTM A36	N1552	N1571	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c73	C6x8.2	ASTM A36	N1584	N1603	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c74	C6x8.2	ASTM A36	N1590	N1609	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c75	C6x8.2	ASTM A36	N1109	N1128	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c76	C6x8.2	ASTM A36	N1115	N1134	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c77	C6x8.2	ASTM A36	N1223	N1242	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c78	C6x8.2	ASTM A36	N1229	N1248	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c79	C6x8.2	ASTM A36	N1603	N1622	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c80	C6x8.2	ASTM A36	N1609	N1628	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c81	C6x8.2	ASTM A36	N1128	N1147	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c82	C6x8.2	ASTM A36	N1134	N1153	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c83	C6x8.2	ASTM A36	N1185	N1204	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c84	C6x8.2	ASTM A36	N1191	N1210	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c85	C6x8.2	ASTM A36	N1660	N1679	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c86	C6x8.2	ASTM A36	N1666	N1685	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c87	C6x8.2	ASTM A36	N1641	N1660	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c88	C6x8.2	ASTM A36	N1647	N1666	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c89	C6x8.2	ASTM A36	N1622	N1641	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c90	C6x8.2	ASTM A36	N1628	N1647	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c91	C6x8.2	ASTM A36	N1527	N1546	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c92	C6x8.2	ASTM A36	N1533	N1552	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c93	C6x8.2	ASTM A36	N1508	N1527	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c94	C6x8.2	ASTM A36	N1514	N1533	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c95	C6x8.2	ASTM A36	N1679	N1698	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c96	C6x8.2	ASTM A36	N1685	N1704	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c19	C6x8.2	ASTM A36	N1237	N1256	0.338	Rigid	Rigid	Normal (2-way)	Beam
4									
BmX001-c19	C6x8.2	ASTM A36	N1256	N1275	0.338	Rigid	Rigid	Normal (2-way)	Beam
6									
BmX001-c19	C6x8.2	ASTM A36	N1275	N1294	0.338	Rigid	Rigid	Normal (2-way)	Beam
8									
BmX001-c20	C6x8.2	ASTM A36	N1294	N1313	0.338	Rigid	Rigid	Normal (2-way)	Beam
0									
BmX001-c20	C6x8.2	ASTM A36	N1313	N1332	0.338	Rigid	Rigid	Normal (2-way)	Beam
2									
BmX001-c20	C6x8.2	ASTM A36	N1332	N1351	0.338	Rigid	Rigid	Normal (2-way)	Beam
4									
BmX001-c20	C6x8.2	ASTM A36	N1351	N1370	0.338	Rigid	Rigid	Normal (2-way)	Beam
6									

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BmX001-c20 8	C6x8.2	ASTM A36	N1370	N1389	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c21 0	C6x8.2	ASTM A36	N1389	N1408	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c21 2	C6x8.2	ASTM A36	N1408	N1427	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c21 4	C6x8.2	ASTM A36	N1427	N1446	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c21 6	C6x8.2	ASTM A36	N1446	N1465	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c21 8	C6x8.2	ASTM A36	N1465	N1484	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c22 0	C6x8.2	ASTM A36	N1484	N1503	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c22 2	C6x8.2	ASTM A36	N914	N933	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c22 4	C6x8.2	ASTM A36	N933	N952	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c22 6	C6x8.2	ASTM A36	N952	N971	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c22 8	C6x8.2	ASTM A36	N971	N990	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c23 0	C6x8.2	ASTM A36	N990	N1009	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c23 2	C6x8.2	ASTM A36	N1009	N1028	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c23 4	C6x8.2	ASTM A36	N1712	N1731	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c23 6	C6x8.2	ASTM A36	N1028	N1047	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c23 8	C6x8.2	ASTM A36	N1693	N1712	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c24 0	C6x8.2	ASTM A36	N1807	N001	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c24 2	C6x8.2	ASTM A36	N1066	N1085	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c24 4	C6x8.2	ASTM A36	N1731	N1750	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c24 6	C6x8.2	ASTM A36	N1085	N1104	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c24 8	C6x8.2	ASTM A36	N1047	N1066	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c25 0	C6x8.2	ASTM A36	N1750	N1769	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c25 2	C6x8.2	ASTM A36	N1769	N1788	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c25 4	C6x8.2	ASTM A36	N1788	N1807	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c25 6	C6x8.2	ASTM A36	N1199	N1218	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c25 8	C6x8.2	ASTM A36	N1161	N1180	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c26 0	C6x8.2	ASTM A36	N1142	N1161	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c26 2	C6x8.2	ASTM A36	N1560	N1579	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c26 4	C6x8.2	ASTM A36	N1541	N1560	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c26 6	C6x8.2	ASTM A36	N1579	N1598	0.338	Rigid	Rigid	Normal (2-way)	Beam
BmX001-c26 8	C6x8.2	ASTM A36	N1104	N1123	0.338	Rigid	Rigid	Normal (2-way)	Beam

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BmX001-c27	C6x8.2	ASTM A36	N1218	N1237	0.338	Rigid	Rigid	Normal (2-way)	Beam
0									
BmX001-c27	C6x8.2	ASTM A36	N1598	N1617	0.338	Rigid	Rigid	Normal (2-way)	Beam
2									
BmX001-c27	C6x8.2	ASTM A36	N1123	N1142	0.338	Rigid	Rigid	Normal (2-way)	Beam
4									
BmX001-c27	C6x8.2	ASTM A36	N1180	N1199	0.338	Rigid	Rigid	Normal (2-way)	Beam
6									
BmX001-c27	C6x8.2	ASTM A36	N1503	N1522	0.338	Rigid	Rigid	Normal (2-way)	Beam
8									
BmX001-c28	C6x8.2	ASTM A36	N1522	N1541	0.338	Rigid	Rigid	Normal (2-way)	Beam
0									
BmX001-c28	C6x8.2	ASTM A36	N1617	N1636	0.338	Rigid	Rigid	Normal (2-way)	Beam
2									
BmX001-c28	C6x8.2	ASTM A36	N1636	N1655	0.338	Rigid	Rigid	Normal (2-way)	Beam
4									
BmX001-c28	C6x8.2	ASTM A36	N1655	N1674	0.338	Rigid	Rigid	Normal (2-way)	Beam
6									
BmX001-c28	C6x8.2	ASTM A36	N1674	N1693	0.338	Rigid	Rigid	Normal (2-way)	Beam
8									
COL007	C4x5.4	ASTM A36	N025	N023	0.333	Rigid	Rigid	Normal (2-way)	Column
COL008	C4x5.4	ASTM A36	N023	N021	0.333	Rigid	Rigid	Normal (2-way)	Column
COL009	C4x5.4	ASTM A36	N021	N019	0.333	Rigid	Rigid	Normal (2-way)	Column
COL010	C4x5.4	ASTM A36	N019	N017	0.333	Rigid	Rigid	Normal (2-way)	Column
COL011	C4x5.4	ASTM A36	N017	N015	0.333	Rigid	Rigid	Normal (2-way)	Column
COL012	C4x5.4	ASTM A36	N015	N013	0.333	Rigid	Rigid	Normal (2-way)	Column
COL013	C4x5.4	ASTM A36	N013	N011	0.333	Rigid	Rigid	Normal (2-way)	Column
COL014	C4x5.4	ASTM A36	N011	N009	0.333	Rigid	Rigid	Normal (2-way)	Column
COL015	C4x5.4	ASTM A36	N009	N007	0.333	Rigid	Rigid	Normal (2-way)	Column
COL016	C4x5.4	ASTM A36	N007	N005	0.333	Rigid	Rigid	Normal (2-way)	Column
COL017	C4x5.4	ASTM A36	N005	N002	0.333	Rigid	Rigid	Normal (2-way)	Column
COL018	C4x5.4	ASTM A36	N002	N001	0.333	Rigid	Rigid	Normal (2-way)	Column
COL031	C4x5.4	ASTM A36	N1381	N1380	0.333	Rigid	Rigid	Normal (2-way)	Column
COL032	C4x5.4	ASTM A36	N925	N924	0.333	Rigid	Rigid	Normal (2-way)	Column
COL033	C4x5.4	ASTM A36	N1380	N1379	0.333	Rigid	Rigid	Normal (2-way)	Column
COL034	C4x5.4	ASTM A36	N924	N923	0.333	Rigid	Rigid	Normal (2-way)	Column
COL035	C4x5.4	ASTM A36	N1379	N1378	0.333	Rigid	Rigid	Normal (2-way)	Column
COL036	C4x5.4	ASTM A36	N923	N922	0.333	Rigid	Rigid	Normal (2-way)	Column
COL037	C4x5.4	ASTM A36	N1378	N1377	0.333	Rigid	Rigid	Normal (2-way)	Column
COL038	C4x5.4	ASTM A36	N922	N921	0.333	Rigid	Rigid	Normal (2-way)	Column
COL039	C4x5.4	ASTM A36	N1377	N1376	0.333	Rigid	Rigid	Normal (2-way)	Column
COL040	C4x5.4	ASTM A36	N921	N920	0.333	Rigid	Rigid	Normal (2-way)	Column
COL041	C4x5.4	ASTM A36	N1376	N1375	0.333	Rigid	Rigid	Normal (2-way)	Column
COL042	C4x5.4	ASTM A36	N920	N919	0.333	Rigid	Rigid	Normal (2-way)	Column
COL043	C4x5.4	ASTM A36	N1375	N1374	0.333	Rigid	Rigid	Normal (2-way)	Column
COL044	C4x5.4	ASTM A36	N919	N918	0.333	Rigid	Rigid	Normal (2-way)	Column
COL045	C4x5.4	ASTM A36	N1374	N1373	0.333	Rigid	Rigid	Normal (2-way)	Column
COL046	C4x5.4	ASTM A36	N918	N917	0.333	Rigid	Rigid	Normal (2-way)	Column
COL047	C4x5.4	ASTM A36	N1373	N1372	0.333	Rigid	Rigid	Normal (2-way)	Column
COL048	C4x5.4	ASTM A36	N917	N916	0.333	Rigid	Rigid	Normal (2-way)	Column
COL049	C4x5.4	ASTM A36	N1372	N1371	0.333	Rigid	Rigid	Normal (2-way)	Column
COL050	C4x5.4	ASTM A36	N916	N915	0.333	Rigid	Rigid	Normal (2-way)	Column
COL051	C4x5.4	ASTM A36	N1371	N1369	0.333	Rigid	Rigid	Normal (2-way)	Column
COL052	C4x5.4	ASTM A36	N915	N913	0.333	Rigid	Rigid	Normal (2-way)	Column
COL053	C4x5.4	ASTM A36	N1369	N1370	0.333	Rigid	Rigid	Normal (2-way)	Column
COL054	C4x5.4	ASTM A36	N913	N914	0.333	Rigid	Rigid	Normal (2-way)	Column

Member Extreme Results

Member	Fx (lc)	Vy (lc)	Vz (lc)	Mx (lc)	My (lc)	Mz (lc)
	K	K	K	K-ft	K-ft	K-ft

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BmX001-c1	-0.229 (35)	-0.002 (1)	-0.000 (1)	-0.007 (35)	0.000 (34)	0.003 (34)
BmX001-c1	-0.000 (34)	0.005 (35)	0.300 (9)	-0.001 (34)	0.107 (35)	0.024 (35)
BmX001-c2	-0.645 (35)	-0.002 (1)	0.008 (34)	-0.006 (35)	-0.266 (35)	0.003 (34)
BmX001-c2	-0.041 (34)	0.007 (35)	0.337 (35)	-0.001 (34)	-0.032 (34)	0.029 (35)
BmX001-c3	-0.260 (9)	-0.001 (36)	-0.000 (36)	-0.005 (35)	-0.088 (9)	0.003 (34)
BmX001-c3	-0.000 (34)	0.027 (35)	0.276 (9)	-0.000 (34)	0.005 (9)	0.024 (35)
BmX001-c4	-0.617 (35)	-0.002 (36)	0.005 (34)	-0.005 (35)	-0.364 (35)	0.004 (34)
BmX001-c4	-0.043 (34)	0.012 (35)	0.292 (35)	-0.000 (34)	-0.034 (34)	0.028 (35)
BmX001-c5	-0.268 (35)	-0.001 (1)	-0.000 (36)	-0.004 (35)	-0.173 (9)	-0.007 (9)
BmX001-c5	-0.000 (34)	0.056 (35)	0.252 (9)	-0.000 (34)	0.000 (36)	0.016 (35)
BmX001-c6	-0.599 (35)	-0.002 (1)	0.002 (34)	-0.003 (35)	-0.448 (35)	0.004 (34)
BmX001-c6	-0.044 (34)	0.017 (35)	0.248 (35)	-0.000 (34)	-0.036 (34)	0.025 (35)
BmX001-c7	-0.248 (9)	-0.002 (36)	-0.000 (36)	-0.001 (9)	-0.248 (9)	0.003 (34)
BmX001-c7	0.000 (36)	0.033 (35)	0.222 (9)	0.000 (1)	0.000 (36)	0.036 (35)
BmX001-c8	-0.567 (35)	-0.001 (36)	-0.003 (36)	-0.001 (9)	-0.517 (35)	0.004 (34)
BmX001-c8	-0.044 (34)	0.015 (35)	0.207 (9)	0.000 (1)	-0.036 (34)	0.034 (35)
BmX001-c9	-0.258 (9)	-0.002 (1)	-0.000 (1)	0.000 (34)	-0.316 (9)	0.003 (34)
BmX001-c9	0.000 (36)	0.011 (35)	0.200 (9)	0.001 (35)	0.000 (36)	0.026 (35)
BmX001-c10	-0.573 (35)	-0.001 (1)	-0.008 (36)	0.000 (34)	-0.572 (35)	0.004 (34)
BmX001-c10	-0.043 (34)	0.006 (35)	0.171 (9)	0.001 (35)	-0.034 (34)	0.030 (35)
BmX001-c11	-0.259 (35)	-0.001 (36)	-0.000 (1)	0.001 (34)	-0.376 (9)	0.003 (34)
BmX001-c11	0.000 (36)	0.006 (35)	0.179 (9)	0.003 (35)	0.000 (36)	0.024 (35)
BmX001-c12	-0.568 (35)	-0.001 (1)	-0.013 (1)	0.001 (34)	-0.612 (35)	0.003 (34)
BmX001-c12	-0.041 (34)	0.003 (35)	0.134 (9)	0.003 (35)	-0.032 (34)	0.028 (35)
BmX001-c13	-0.254 (9)	-0.000 (36)	-0.000 (36)	0.001 (34)	-0.430 (35)	0.003 (34)
BmX001-c13	-0.000 (34)	0.008 (35)	0.158 (9)	0.005 (35)	0.000 (36)	0.022 (35)
BmX001-c14	-0.550 (35)	-0.000 (36)	-0.018 (36)	0.001 (34)	-0.639 (35)	0.003 (34)
BmX001-c14	-0.039 (34)	0.005 (35)	0.098 (9)	0.005 (35)	-0.028 (34)	0.027 (35)
BmX001-c15	-0.248 (35)	0.000 (34)	-0.000 (1)	0.001 (34)	-0.476 (9)	0.002 (34)
BmX001-c15	-0.000 (34)	0.011 (35)	0.138 (9)	0.006 (35)	-0.000 (34)	0.020 (35)
BmX001-c16	-0.522 (35)	0.000 (34)	-0.022 (1)	0.001 (34)	-0.653 (35)	0.003 (34)
BmX001-c16	-0.035 (34)	0.010 (35)	0.063 (9)	0.006 (35)	-0.023 (34)	0.026 (35)
BmX001-c17	-0.245 (9)	0.000 (34)	-0.000 (1)	0.001 (34)	-0.517 (35)	0.002 (34)
BmX001-c17	-0.000 (34)	0.012 (35)	0.119 (35)	0.007 (35)	-0.000 (34)	0.016 (35)
BmX001-c18	-0.486 (35)	0.001 (34)	-0.026 (1)	0.001 (34)	-0.654 (35)	0.002 (34)
BmX001-c18	-0.030 (34)	0.013 (35)	0.030 (9)	0.007 (35)	-0.018 (34)	0.022 (35)
BmX001-c19	-0.246 (35)	0.001 (34)	-0.000 (1)	0.001 (34)	-0.550 (35)	0.001 (34)
BmX001-c19	-0.000 (34)	0.012 (35)	0.099 (9)	0.008 (35)	-0.000 (34)	0.013 (35)
BmX001-c20	-0.444 (35)	0.001 (34)	-0.030 (35)	0.001 (34)	-0.655 (35)	0.001 (34)
BmX001-c20	-0.025 (34)	0.015 (35)	-0.001 (9)	0.008 (35)	-0.012 (34)	0.017 (35)
BmX001-c21	-0.167 (9)	-0.010 (35)	-0.000 (1)	-0.008 (35)	0.000 (34)	0.003 (34)
BmX001-c21	0.000 (1)	0.000 (1)	0.320 (9)	-0.001 (34)	0.215 (35)	0.023 (35)
BmX001-c22	-0.683 (35)	-0.003 (1)	0.011 (34)	-0.008 (35)	-0.152 (35)	0.003 (34)
BmX001-c22	-0.039 (34)	0.002 (35)	0.385 (35)	-0.001 (34)	0.025 (9)	0.029 (35)
BmX001-c23	-0.069 (35)	-0.015 (35)	-0.000 (36)	-0.010 (35)	0.000 (34)	0.002 (34)
BmX001-c23	0.000 (36)	-0.000 (34)	0.335 (9)	-0.001 (34)	0.329 (35)	0.019 (35)
BmX001-c24	-0.736 (35)	-0.005 (35)	0.013 (34)	-0.009 (35)	-0.047 (1)	0.003 (34)
BmX001-c24	-0.035 (34)	-0.000 (34)	0.436 (35)	-0.001 (34)	0.165 (9)	0.028 (35)
BmX001-c25	-0.218 (9)	-0.008 (35)	-0.189 (9)	-0.005 (35)	-0.369 (35)	-0.024 (35)
BmX001-c25	0.000 (1)	-0.000 (34)	0.000 (1)	-0.001 (34)	-0.000 (34)	-0.004 (34)
BmX001-c26	0.103 (34)	-0.005 (35)	-0.127 (9)	-0.005 (35)	-0.173 (9)	-0.030 (35)
BmX001-c26	0.313 (35)	-0.000 (34)	0.018 (1)	-0.001 (34)	0.078 (1)	-0.005 (34)
BmX001-c27	-0.302 (35)	-0.036 (1)	-0.195 (9)	-0.001 (9)	-0.001 (9)	-0.019 (1)
BmX001-c27	-0.000 (34)	0.040 (9)	0.000 (1)	0.003 (1)	0.065 (35)	0.032 (9)
BmX001-c28	-1.151 (9)	-0.027 (1)	-0.080 (36)	-0.001 (9)	-0.017 (9)	-0.016 (1)
BmX001-c28	0.238 (36)	0.002 (9)	0.051 (9)	0.003 (36)	0.025 (36)	0.024 (9)
BmX001-c29	0.000 (34)	-0.002 (36)	-0.296 (9)	0.000 (34)	0.000 (34)	-0.007 (36)
BmX001-c29	0.225 (35)	0.018 (35)	0.000 (1)	0.006 (35)	0.628 (35)	0.011 (9)
BmX001-c30	-1.240 (9)	-0.003 (1)	-0.469 (9)	0.000 (34)	0.047 (34)	-0.009 (1)
BmX001-c30	0.130 (1)	0.015 (9)	0.004 (1)	0.007 (35)	0.570 (35)	0.032 (9)
BmX001-c31	-0.258 (35)	-0.002 (35)	-0.149 (9)	-0.001 (35)	-0.477 (35)	-0.027 (35)

Project: 10'-4 Diameter Skimmer

Jeremiah Dischinger, AECOM - CLEVELAND

June 13, 2016

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BmX001-c31	-0.000 (34)	0.002 (1)	0.000 (36)	-0.000 (34)	-0.000 (34)	-0.004 (34)
BmX001-c32	0.068 (9)	-0.001 (9)	-0.146 (35)	-0.001 (35)	-0.267 (9)	-0.031 (35)
BmX001-c32	0.198 (35)	0.003 (1)	-0.002 (34)	-0.000 (34)	0.080 (1)	-0.005 (34)
BmX001-c33	0.000 (34)	-0.001 (36)	-0.304 (9)	0.001 (34)	0.000 (34)	-0.007 (1)
BmX001-c33	0.057 (9)	0.012 (35)	0.000 (36)	0.006 (35)	0.528 (9)	0.015 (9)
BmX001-c34	-1.208 (9)	-0.001 (36)	-0.385 (35)	0.001 (34)	0.047 (34)	-0.009 (1)
BmX001-c34	0.151 (36)	0.009 (35)	-0.004 (34)	0.006 (35)	0.413 (35)	0.035 (9)
BmX001-c35	-0.240 (35)	-0.005 (35)	-0.170 (9)	-0.003 (35)	-0.427 (35)	-0.026 (35)
BmX001-c35	-0.000 (34)	0.001 (1)	0.000 (36)	-0.001 (34)	-0.000 (34)	-0.004 (34)
BmX001-c36	0.090 (34)	-0.004 (35)	-0.136 (9)	-0.003 (35)	-0.219 (9)	-0.031 (35)
BmX001-c36	0.257 (35)	0.001 (36)	0.006 (36)	-0.001 (34)	0.080 (36)	-0.006 (34)
BmX001-c37	-0.188 (9)	-0.010 (35)	-0.207 (9)	-0.007 (35)	-0.305 (35)	-0.021 (35)
BmX001-c37	0.000 (1)	-0.000 (34)	0.000 (1)	-0.001 (34)	-0.000 (34)	-0.003 (34)
BmX001-c38	0.116 (34)	-0.007 (35)	-0.116 (9)	-0.007 (35)	-0.130 (9)	-0.028 (35)
BmX001-c38	0.369 (35)	-0.002 (34)	0.031 (36)	-0.001 (34)	0.072 (36)	-0.004 (34)
BmX001-c39	-0.147 (9)	-0.004 (35)	-0.222 (9)	-0.008 (35)	-0.235 (35)	-0.017 (35)
BmX001-c39	0.000 (1)	0.002 (1)	0.000 (1)	-0.001 (34)	0.000 (1)	-0.003 (34)
BmX001-c40	0.128 (34)	-0.007 (35)	-0.102 (9)	-0.008 (35)	-0.091 (9)	-0.026 (35)
BmX001-c40	0.423 (35)	-0.001 (34)	0.046 (36)	-0.001 (34)	0.062 (36)	-0.004 (34)
BmX001-c41	-0.095 (9)	0.007 (34)	-0.233 (9)	-0.009 (35)	-0.160 (9)	-0.023 (35)
BmX001-c41	0.000 (1)	0.028 (35)	0.000 (1)	-0.002 (34)	0.000 (1)	-0.002 (34)
BmX001-c42	0.138 (34)	-0.003 (9)	-0.086 (9)	-0.010 (35)	-0.056 (9)	-0.024 (35)
BmX001-c42	0.468 (35)	0.008 (1)	0.062 (36)	-0.002 (34)	0.047 (36)	-0.003 (34)
BmX001-c43	-0.043 (9)	0.020 (34)	-0.238 (9)	-0.011 (35)	-0.081 (35)	-0.047 (35)
BmX001-c43	0.000 (1)	0.078 (35)	0.000 (1)	-0.002 (34)	-0.000 (34)	-0.005 (34)
BmX001-c44	0.143 (34)	0.010 (9)	-0.067 (9)	-0.011 (35)	-0.027 (9)	-0.034 (35)
BmX001-c44	0.498 (35)	0.036 (35)	0.080 (1)	-0.002 (34)	0.025 (36)	-0.004 (34)
BmX001-c45	0.000 (34)	-0.021 (35)	-0.000 (36)	-0.011 (35)	0.000 (34)	-0.002 (9)
BmX001-c45	0.216 (35)	-0.001 (34)	0.333 (9)	-0.001 (34)	0.557 (35)	0.007 (35)
BmX001-c46	-0.889 (35)	-0.016 (35)	0.018 (34)	-0.012 (35)	-0.030 (1)	0.001 (34)
BmX001-c46	-0.025 (34)	-0.001 (34)	0.553 (35)	-0.001 (34)	0.499 (9)	0.023 (35)
BmX001-c47	0.000 (34)	-0.018 (35)	-0.000 (36)	-0.011 (35)	0.000 (34)	0.002 (34)
BmX001-c47	0.060 (35)	-0.000 (34)	0.340 (9)	-0.001 (34)	0.444 (35)	0.014 (35)
BmX001-c48	-0.805 (35)	-0.010 (35)	0.016 (34)	-0.011 (35)	-0.039 (36)	0.002 (34)
BmX001-c48	-0.030 (34)	-0.001 (34)	0.491 (35)	-0.001 (34)	0.322 (9)	0.026 (35)
BmX001-c49	-0.281 (35)	0.000 (34)	-0.104 (35)	0.000 (34)	-0.555 (35)	-0.026 (35)
BmX001-c49	-0.000 (34)	0.007 (35)	0.000 (36)	0.002 (35)	-0.000 (34)	-0.004 (34)
BmX001-c50	-0.014 (9)	0.001 (34)	-0.164 (35)	0.000 (34)	-0.365 (9)	-0.030 (35)
BmX001-c50	0.090 (36)	0.008 (35)	-0.012 (34)	0.002 (35)	0.075 (36)	-0.004 (34)
BmX001-c51	0.000 (34)	-0.022 (35)	0.000 (34)	-0.007 (35)	0.000 (34)	-0.037 (35)
BmX001-c51	0.834 (9)	-0.001 (34)	0.145 (35)	-0.001 (34)	0.876 (35)	-0.001 (34)
BmX001-c52	-1.218 (9)	-0.029 (35)	0.021 (34)	-0.008 (35)	0.009 (34)	-0.023 (35)
BmX001-c52	0.006 (36)	-0.001 (34)	0.870 (35)	-0.001 (34)	1.482 (35)	-0.001 (34)
BmX001-c53	-0.282 (35)	0.001 (34)	-0.008 (35)	0.001 (34)	-0.615 (35)	-0.013 (35)
BmX001-c53	-0.000 (34)	0.012 (35)	0.000 (36)	0.008 (35)	-0.000 (34)	-0.001 (34)
BmX001-c54	-0.193 (9)	0.001 (34)	-0.147 (35)	0.001 (34)	-0.538 (9)	-0.015 (35)
BmX001-c54	0.021 (36)	0.015 (35)	-0.021 (34)	0.008 (35)	0.038 (36)	-0.002 (34)
BmX001-c55	-0.275 (35)	0.001 (34)	0.000 (34)	0.001 (34)	-0.615 (35)	-0.009 (35)
BmX001-c55	-0.000 (34)	0.013 (35)	0.015 (9)	0.009 (35)	-0.000 (34)	-0.001 (34)
BmX001-c56	-0.238 (9)	0.001 (34)	-0.132 (35)	0.001 (34)	-0.571 (9)	-0.009 (35)
BmX001-c56	0.006 (36)	0.015 (35)	-0.021 (34)	0.009 (35)	0.027 (1)	-0.001 (34)
BmX001-c57	-0.258 (35)	0.001 (34)	-0.000 (36)	0.001 (34)	-0.597 (35)	-0.000 (35)
BmX001-c57	-0.000 (34)	0.013 (35)	0.059 (9)	0.009 (35)	-0.000 (34)	0.004 (35)
BmX001-c58	-0.345 (35)	0.001 (34)	-0.089 (35)	0.001 (34)	-0.624 (35)	0.000 (34)
BmX001-c58	-0.012 (34)	0.016 (35)	-0.021 (34)	0.009 (35)	0.003 (36)	0.007 (35)
BmX001-c59	-0.326 (35)	-0.015 (36)	-0.225 (9)	0.000 (9)	-0.000 (1)	-0.009 (36)
BmX001-c59	-0.000 (34)	0.013 (9)	0.000 (1)	0.003 (35)	0.141 (9)	0.020 (9)
BmX001-c60	-1.169 (9)	-0.018 (35)	-0.096 (35)	-0.000 (9)	-0.017 (9)	-0.008 (36)
BmX001-c60	0.230 (36)	-0.003 (34)	-0.034 (9)	0.003 (36)	0.047 (36)	0.027 (9)
BmX001-c61	-0.299 (35)	-0.002 (36)	-0.256 (9)	0.001 (34)	-0.000 (1)	-0.005 (1)
BmX001-c61	-0.000 (34)	0.001 (35)	0.000 (36)	0.004 (35)	0.228 (9)	0.016 (9)

Project: 10'-4 Diameter Skimmer

Jeremiah Dischinger, AECOM - CLEVELAND

June 13, 2016

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BmX001-c62	-1.177 (9)	-0.016 (9)	-0.167 (35)	0.001 (9)	-0.006 (9)	-0.007 (36)
BmX001-c62	0.214 (1)	0.004 (36)	-0.027 (34)	0.003 (35)	0.097 (35)	0.032 (9)
BmX001-c63	-0.216 (35)	0.000 (34)	-0.282 (9)	0.001 (34)	-0.000 (1)	-0.006 (36)
BmX001-c63	-0.000 (34)	0.004 (35)	0.000 (1)	0.005 (35)	0.324 (9)	0.017 (9)
BmX001-c64	-1.180 (9)	-0.010 (9)	-0.238 (35)	0.001 (34)	0.035 (9)	-0.008 (1)
BmX001-c64	0.194 (1)	0.005 (1)	-0.018 (34)	0.004 (35)	0.177 (35)	0.035 (9)
BmX001-c65	-0.272 (9)	-0.000 (36)	-0.127 (9)	0.000 (34)	-0.520 (35)	-0.027 (35)
BmX001-c65	-0.000 (34)	0.004 (35)	0.000 (36)	0.001 (35)	-0.000 (34)	-0.004 (34)
BmX001-c66	0.028 (9)	0.000 (34)	-0.157 (35)	0.000 (34)	-0.316 (9)	-0.031 (35)
BmX001-c66	0.138 (35)	0.005 (35)	-0.008 (34)	0.000 (35)	0.079 (36)	-0.005 (34)
BmX001-c67	-0.287 (35)	0.001 (34)	-0.080 (35)	0.001 (34)	-0.582 (35)	-0.024 (35)
BmX001-c67	-0.000 (34)	0.009 (35)	0.000 (36)	0.004 (35)	-0.000 (34)	-0.003 (34)
BmX001-c68	-0.058 (9)	0.001 (34)	-0.167 (35)	0.001 (34)	-0.412 (9)	-0.027 (35)
BmX001-c68	0.072 (36)	0.010 (35)	-0.015 (34)	0.004 (35)	0.068 (36)	-0.004 (34)
BmX001-c69	-0.093 (35)	0.000 (34)	-0.299 (9)	0.001 (34)	0.000 (34)	-0.007 (1)
BmX001-c69	-0.000 (34)	0.008 (35)	0.000 (36)	0.005 (35)	0.425 (9)	0.016 (9)
BmX001-c70	-1.188 (9)	-0.001 (9)	-0.310 (35)	0.001 (34)	0.043 (34)	-0.009 (1)
BmX001-c70	0.172 (36)	0.004 (1)	-0.011 (34)	0.005 (35)	0.282 (35)	0.035 (9)
BmX001-c71	0.000 (34)	-0.029 (35)	-0.000 (36)	-0.009 (35)	0.000 (34)	-0.030 (35)
BmX001-c71	0.717 (35)	-0.001 (34)	0.215 (9)	-0.001 (34)	0.827 (35)	-0.000 (34)
BmX001-c72	-1.158 (35)	-0.035 (35)	0.021 (34)	-0.010 (35)	0.002 (34)	-0.013 (35)
BmX001-c72	-0.004 (34)	-0.001 (34)	0.780 (35)	-0.001 (34)	1.188 (35)	-0.000 (34)
BmX001-c73	0.000 (34)	-0.009 (35)	0.000 (34)	-0.004 (35)	0.000 (34)	-0.040 (35)
BmX001-c73	0.900 (35)	-0.001 (34)	0.064 (35)	-0.001 (34)	0.897 (35)	-0.001 (34)
BmX001-c74	-1.216 (9)	-0.010 (35)	-0.060 (9)	-0.004 (35)	0.016 (34)	-0.027 (35)
BmX001-c74	0.021 (36)	-0.001 (34)	0.035 (1)	-0.001 (34)	1.482 (35)	-0.002 (34)
BmX001-c75	-0.288 (35)	0.001 (34)	-0.056 (9)	0.001 (34)	-0.601 (35)	-0.021 (35)
BmX001-c75	-0.000 (34)	0.010 (35)	0.000 (1)	0.006 (35)	-0.000 (34)	-0.003 (34)
BmX001-c76	-0.102 (9)	0.001 (34)	-0.165 (35)	0.001 (34)	-0.458 (9)	-0.024 (35)
BmX001-c76	0.054 (36)	0.012 (35)	-0.018 (34)	0.006 (35)	0.059 (36)	-0.003 (34)
BmX001-c77	-0.251 (9)	0.001 (34)	-0.000 (36)	0.001 (34)	-0.577 (35)	0.001 (34)
BmX001-c77	-0.000 (34)	0.013 (35)	0.079 (35)	0.009 (35)	-0.000 (34)	0.008 (35)
BmX001-c78	-0.397 (35)	0.001 (34)	-0.061 (35)	0.001 (34)	-0.644 (35)	0.001 (34)
BmX001-c78	-0.019 (34)	0.016 (35)	-0.019 (34)	0.009 (35)	-0.005 (34)	0.012 (35)
BmX001-c79	0.000 (34)	-0.004 (1)	-0.020 (9)	-0.002 (1)	0.000 (34)	-0.040 (35)
BmX001-c79	0.903 (9)	0.011 (9)	0.000 (36)	0.001 (9)	0.897 (35)	-0.002 (34)
BmX001-c80	-1.254 (9)	-0.005 (1)	0.020 (34)	-0.002 (36)	0.023 (34)	-0.027 (35)
BmX001-c80	0.037 (1)	0.015 (9)	0.067 (35)	0.001 (9)	1.496 (35)	-0.002 (34)
BmX001-c81	-0.286 (9)	0.001 (34)	-0.032 (9)	0.001 (34)	-0.612 (35)	-0.017 (35)
BmX001-c81	-0.000 (34)	0.012 (35)	0.000 (1)	0.007 (35)	-0.000 (34)	-0.002 (34)
BmX001-c82	-0.148 (9)	0.001 (34)	-0.158 (35)	0.001 (34)	-0.500 (9)	-0.019 (35)
BmX001-c82	0.037 (1)	0.014 (35)	-0.020 (34)	0.007 (35)	0.049 (36)	-0.002 (34)
BmX001-c83	-0.267 (9)	0.001 (34)	-0.000 (36)	0.001 (34)	-0.610 (35)	-0.005 (35)
BmX001-c83	-0.000 (34)	0.013 (35)	0.037 (35)	0.009 (35)	-0.000 (34)	-0.000 (34)
BmX001-c84	-0.290 (35)	0.001 (34)	-0.112 (35)	0.001 (34)	-0.596 (9)	-0.004 (35)
BmX001-c84	-0.004 (34)	0.016 (35)	-0.021 (34)	0.009 (35)	0.015 (1)	0.001 (9)
BmX001-c85	0.000 (34)	-0.003 (1)	-0.231 (9)	-0.001 (1)	0.000 (34)	-0.020 (35)
BmX001-c85	0.579 (35)	0.030 (9)	0.000 (1)	0.006 (9)	0.798 (35)	-0.003 (9)
BmX001-c86	-1.316 (9)	-0.004 (36)	-0.656 (9)	-0.001 (1)	0.041 (34)	-0.008 (1)
BmX001-c86	0.090 (36)	0.031 (9)	0.020 (36)	0.007 (9)	0.970 (35)	0.019 (9)
BmX001-c87	0.000 (34)	-0.004 (36)	-0.173 (35)	-0.001 (36)	0.000 (34)	-0.030 (35)
BmX001-c87	0.731 (9)	0.031 (9)	0.000 (36)	0.005 (9)	0.856 (35)	-0.003 (34)
BmX001-c88	-1.338 (9)	-0.004 (1)	-0.755 (9)	-0.001 (1)	0.036 (34)	-0.012 (35)
BmX001-c88	0.072 (36)	0.037 (9)	0.025 (1)	0.006 (9)	1.217 (35)	0.007 (9)
BmX001-c89	0.000 (34)	-0.004 (1)	-0.101 (9)	-0.001 (36)	0.000 (34)	-0.037 (35)
BmX001-c89	0.845 (35)	0.025 (9)	0.000 (1)	0.003 (9)	0.891 (9)	-0.003 (34)
BmX001-c90	-1.332 (9)	-0.004 (1)	-0.855 (9)	-0.001 (36)	0.030 (34)	-0.022 (35)
BmX001-c90	0.054 (1)	0.033 (9)	0.030 (36)	0.004 (9)	1.496 (35)	-0.003 (34)
BmX001-c91	0.000 (34)	-0.030 (35)	-0.000 (1)	-0.011 (35)	0.000 (34)	-0.019 (35)
BmX001-c91	0.562 (35)	-0.001 (34)	0.271 (9)	-0.001 (34)	0.754 (9)	0.001 (36)
BmX001-c92	-1.077 (35)	-0.030 (35)	0.021 (34)	-0.012 (35)	-0.009 (1)	-0.001 (9)

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BmX001-c92	-0.012 (34)	-0.001 (34)	0.697 (35)	-0.001 (34)	0.924 (35)	0.009 (35)
BmX001-c93	0.000 (34)	-0.026 (35)	-0.000 (1)	-0.011 (35)	0.000 (34)	-0.010 (9)
BmX001-c93	0.389 (9)	-0.001 (34)	0.311 (35)	-0.001 (34)	0.662 (35)	0.002 (1)
BmX001-c94	-0.983 (35)	-0.023 (35)	0.019 (34)	-0.012 (35)	-0.020 (36)	0.001 (34)
BmX001-c94	-0.019 (34)	-0.001 (34)	0.621 (35)	-0.001 (34)	0.698 (9)	0.017 (35)
BmX001-c95	0.000 (34)	-0.002 (1)	-0.272 (9)	-0.000 (36)	0.000 (34)	-0.010 (35)
BmX001-c95	0.404 (35)	0.024 (35)	0.000 (1)	0.006 (9)	0.720 (35)	0.005 (9)
BmX001-c96	-1.280 (9)	-0.003 (1)	-0.561 (9)	-0.000 (36)	0.045 (34)	-0.009 (1)
BmX001-c96	0.110 (1)	0.022 (9)	0.013 (36)	0.007 (9)	0.755 (35)	0.027 (9)
BmX001-c194	-0.223 (9)	0.001 (34)	0.018 (34)	0.001 (34)	-0.481 (9)	0.001 (34)
BmX001-c194	0.041 (36)	0.014 (35)	0.240 (35)	0.008 (35)	0.030 (36)	0.012 (35)
BmX001-c196	-0.174 (9)	0.001 (34)	0.016 (34)	0.001 (34)	-0.411 (9)	0.002 (34)
BmX001-c196	0.050 (1)	0.013 (35)	0.251 (35)	0.007 (35)	0.039 (1)	0.017 (35)
BmX001-c198	-0.121 (9)	0.000 (34)	0.013 (34)	0.001 (34)	-0.335 (9)	0.003 (34)
BmX001-c198	0.058 (1)	0.012 (35)	0.259 (35)	0.006 (35)	0.047 (36)	0.021 (35)
BmX001-c200	-0.063 (9)	-0.000 (36)	0.011 (34)	0.001 (34)	-0.255 (9)	0.003 (34)
BmX001-c200	0.064 (1)	0.011 (35)	0.262 (35)	0.005 (35)	0.053 (1)	0.025 (35)
BmX001-c202	-0.002 (9)	-0.001 (1)	0.008 (34)	0.001 (34)	-0.172 (9)	0.003 (34)
BmX001-c202	0.069 (1)	0.012 (35)	0.260 (35)	0.003 (35)	0.057 (36)	0.028 (35)
BmX001-c204	0.043 (34)	-0.001 (36)	0.005 (34)	0.000 (34)	-0.089 (9)	0.004 (34)
BmX001-c204	0.129 (35)	0.020 (35)	0.253 (35)	0.001 (35)	0.060 (1)	0.034 (35)
BmX001-c206	0.044 (34)	-0.001 (1)	0.002 (34)	-0.001 (9)	-0.006 (9)	0.004 (34)
BmX001-c206	0.182 (35)	0.037 (35)	0.242 (35)	0.000 (36)	0.136 (35)	0.046 (35)
BmX001-c208	0.044 (34)	-0.002 (36)	-0.003 (36)	-0.003 (35)	0.036 (34)	0.004 (34)
BmX001-c208	0.284 (35)	0.023 (35)	0.227 (9)	-0.000 (34)	0.213 (35)	0.028 (35)
BmX001-c210	0.043 (34)	-0.002 (36)	-0.008 (36)	-0.005 (35)	0.034 (34)	0.004 (34)
BmX001-c210	0.322 (35)	0.011 (35)	0.211 (9)	-0.000 (34)	0.282 (35)	0.031 (35)
BmX001-c212	0.041 (34)	-0.004 (35)	-0.013 (1)	-0.007 (35)	0.032 (34)	0.003 (34)
BmX001-c212	0.353 (35)	0.001 (1)	0.192 (9)	-0.001 (34)	0.342 (35)	0.030 (35)
BmX001-c214	0.039 (34)	-0.014 (35)	-0.018 (36)	-0.009 (35)	0.028 (34)	0.003 (34)
BmX001-c214	0.369 (35)	0.000 (1)	0.170 (9)	-0.001 (34)	0.394 (35)	0.028 (35)
BmX001-c216	0.035 (34)	-0.021 (35)	-0.022 (36)	-0.010 (35)	0.023 (34)	0.003 (34)
BmX001-c216	0.364 (35)	-0.000 (34)	0.148 (9)	-0.001 (34)	0.436 (35)	0.023 (35)
BmX001-c218	0.030 (34)	-0.027 (35)	-0.026 (1)	-0.011 (35)	0.018 (34)	0.002 (34)
BmX001-c218	0.336 (35)	-0.001 (34)	0.125 (9)	-0.001 (34)	0.470 (35)	0.016 (35)
BmX001-c220	0.025 (34)	-0.030 (35)	-0.030 (1)	-0.011 (35)	0.012 (34)	-0.005 (9)
BmX001-c220	0.288 (35)	-0.001 (34)	0.105 (9)	-0.001 (34)	0.496 (35)	0.007 (35)
BmX001-c222	-0.976 (35)	0.014 (34)	-0.536 (35)	-0.009 (35)	-0.176 (35)	-0.045 (35)
BmX001-c222	-0.143 (34)	0.075 (35)	-0.048 (34)	-0.002 (34)	0.005 (35)	-0.004 (34)
BmX001-c224	-0.979 (35)	0.003 (34)	-0.463 (35)	-0.008 (35)	-0.332 (35)	-0.022 (35)
BmX001-c224	-0.138 (34)	0.020 (35)	-0.037 (34)	-0.002 (34)	-0.015 (34)	-0.003 (34)
BmX001-c226	-0.959 (35)	-0.019 (35)	-0.390 (35)	-0.008 (35)	-0.464 (35)	-0.023 (35)
BmX001-c226	-0.128 (34)	-0.001 (34)	-0.027 (34)	-0.001 (34)	-0.028 (34)	-0.004 (34)
BmX001-c228	-0.919 (35)	-0.025 (35)	-0.320 (35)	-0.007 (35)	-0.572 (35)	-0.032 (35)
BmX001-c228	-0.116 (34)	-0.002 (34)	-0.018 (34)	-0.001 (34)	-0.037 (34)	-0.004 (34)
BmX001-c230	-0.868 (35)	-0.014 (35)	-0.255 (35)	-0.006 (35)	-0.658 (35)	-0.037 (35)
BmX001-c230	-0.103 (34)	-0.000 (34)	-0.011 (34)	-0.001 (34)	-0.043 (34)	-0.005 (34)
BmX001-c232	-0.813 (35)	-0.002 (35)	-0.194 (35)	-0.004 (35)	-0.724 (35)	-0.037 (35)
BmX001-c232	-0.090 (34)	0.001 (1)	-0.004 (34)	-0.001 (34)	-0.047 (34)	-0.006 (34)
BmX001-c234	-0.151 (36)	-0.001 (36)	-0.126 (9)	0.001 (34)	-0.080 (36)	-0.009 (1)
BmX001-c234	0.786 (9)	0.019 (35)	0.006 (36)	0.006 (35)	0.608 (9)	0.023 (9)
BmX001-c236	-0.758 (35)	0.000 (34)	-0.142 (9)	-0.001 (35)	-0.771 (35)	-0.037 (35)
BmX001-c236	-0.078 (34)	0.007 (35)	0.004 (36)	-0.000 (34)	-0.047 (34)	-0.005 (34)
BmX001-c238	-0.130 (1)	-0.003 (1)	-0.077 (35)	0.000 (34)	-0.080 (1)	-0.009 (1)
BmX001-c238	0.665 (9)	0.027 (9)	-0.002 (34)	0.006 (35)	0.632 (9)	0.016 (9)
BmX001-c240	-0.238 (1)	-0.027 (1)	-0.486 (9)	-0.000 (9)	-0.025 (36)	-0.016 (1)
BmX001-c240	1.056 (9)	0.068 (9)	0.080 (1)	0.003 (36)	0.165 (9)	0.056 (9)
BmX001-c242	-0.652 (35)	0.001 (34)	-0.055 (9)	0.000 (34)	-0.811 (35)	-0.032 (35)
BmX001-c242	-0.054 (34)	0.010 (35)	0.020 (36)	0.003 (35)	-0.041 (34)	-0.004 (34)
BmX001-c244	-0.172 (1)	0.000 (34)	-0.188 (9)	0.001 (34)	-0.078 (36)	-0.009 (1)
BmX001-c244	0.888 (9)	0.011 (35)	0.018 (36)	0.006 (35)	0.565 (9)	0.025 (9)

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BmX001-c246	-0.600 (35)	0.001 (34)	-0.016 (9)	0.001 (34)	-0.812 (35)	-0.029 (35)
BmX001-c246	-0.043 (34)	0.011 (35)	0.025 (1)	0.004 (35)	-0.036 (34)	-0.004 (34)
BmX001-c248	-0.705 (35)	0.000 (34)	-0.097 (9)	0.000 (34)	-0.799 (35)	-0.035 (35)
BmX001-c248	-0.066 (34)	0.009 (35)	0.013 (1)	0.001 (35)	-0.045 (34)	-0.005 (34)
BmX001-c250	-0.194 (1)	-0.000 (9)	-0.257 (9)	0.001 (34)	-0.072 (1)	-0.008 (36)
BmX001-c250	0.967 (9)	0.005 (36)	0.031 (1)	0.005 (35)	0.501 (9)	0.025 (9)
BmX001-c252	-0.214 (1)	0.001 (34)	-0.330 (9)	0.001 (34)	-0.062 (36)	-0.007 (36)
BmX001-c252	1.022 (9)	0.008 (35)	0.046 (36)	0.005 (35)	0.414 (9)	0.026 (9)
BmX001-c254	-0.230 (36)	-0.008 (1)	-0.408 (9)	0.001 (9)	-0.047 (1)	-0.008 (36)
BmX001-c254	1.052 (9)	0.026 (9)	0.062 (1)	0.004 (35)	0.303 (9)	0.035 (9)
BmX001-c256	-0.310 (9)	0.001 (34)	0.021 (34)	0.001 (34)	-0.606 (35)	-0.002 (9)
BmX001-c256	0.020 (1)	0.015 (35)	0.204 (35)	0.009 (35)	0.009 (36)	0.002 (35)
BmX001-c258	-0.395 (35)	0.001 (34)	0.021 (34)	0.001 (34)	-0.719 (35)	-0.012 (35)
BmX001-c258	-0.004 (34)	0.014 (35)	0.154 (35)	0.009 (35)	-0.009 (34)	-0.001 (34)
BmX001-c260	-0.446 (35)	0.001 (34)	0.021 (34)	0.001 (34)	-0.761 (35)	-0.017 (35)
BmX001-c260	-0.013 (34)	0.014 (35)	0.124 (35)	0.008 (35)	-0.016 (34)	-0.002 (34)
BmX001-c262	-0.006 (1)	-0.015 (35)	-0.036 (1)	-0.006 (35)	-0.027 (1)	-0.037 (35)
BmX001-c262	0.051 (9)	-0.001 (34)	0.063 (9)	-0.001 (34)	0.576 (9)	-0.001 (34)
BmX001-c264	0.004 (34)	-0.023 (35)	-0.035 (36)	-0.008 (35)	-0.015 (36)	-0.032 (35)
BmX001-c264	0.089 (35)	-0.001 (34)	0.068 (9)	-0.001 (34)	0.554 (9)	-0.000 (34)
BmX001-c266	-0.021 (36)	-0.006 (35)	-0.035 (1)	-0.004 (35)	-0.038 (1)	-0.039 (35)
BmX001-c266	0.051 (9)	-0.001 (9)	0.059 (9)	-0.001 (34)	0.596 (9)	-0.002 (34)
BmX001-c268	-0.549 (35)	0.001 (34)	0.018 (34)	0.001 (34)	-0.808 (35)	-0.026 (35)
BmX001-c268	-0.032 (34)	0.012 (35)	0.051 (35)	0.006 (35)	-0.030 (34)	-0.003 (34)
BmX001-c270	-0.268 (9)	0.001 (34)	0.019 (34)	0.001 (34)	-0.546 (9)	0.001 (34)
BmX001-c270	0.031 (36)	0.014 (35)	0.224 (35)	0.009 (35)	0.020 (36)	0.007 (35)
BmX001-c272	-0.037 (1)	-0.005 (36)	-0.033 (36)	-0.002 (1)	-0.049 (36)	-0.039 (35)
BmX001-c272	0.088 (9)	0.009 (9)	0.055 (9)	0.000 (9)	0.614 (9)	-0.002 (34)
BmX001-c274	-0.498 (35)	0.001 (34)	0.020 (34)	0.001 (34)	-0.791 (35)	-0.022 (35)
BmX001-c274	-0.022 (34)	0.013 (35)	0.089 (35)	0.007 (35)	-0.023 (34)	-0.002 (34)
BmX001-c276	-0.350 (9)	0.001 (34)	0.021 (34)	0.001 (34)	-0.667 (35)	-0.007 (35)
BmX001-c276	0.007 (1)	0.015 (35)	0.181 (35)	0.009 (35)	-0.002 (34)	-0.000 (34)
BmX001-c278	0.019 (34)	-0.031 (35)	-0.032 (36)	-0.011 (35)	0.005 (34)	-0.015 (9)
BmX001-c278	0.223 (35)	-0.001 (34)	0.088 (9)	-0.001 (34)	0.515 (35)	0.002 (1)
BmX001-c280	0.012 (34)	-0.029 (35)	-0.034 (1)	-0.010 (35)	-0.003 (1)	-0.024 (9)
BmX001-c280	0.153 (35)	-0.001 (34)	0.076 (9)	-0.001 (34)	0.531 (9)	0.001 (36)
BmX001-c282	-0.054 (1)	-0.004 (1)	-0.030 (36)	-0.001 (1)	-0.059 (36)	-0.037 (35)
BmX001-c282	0.162 (9)	0.019 (9)	0.046 (9)	0.002 (9)	0.630 (9)	-0.003 (34)
BmX001-c284	-0.072 (1)	-0.004 (1)	-0.025 (1)	-0.001 (36)	-0.068 (1)	-0.032 (35)
BmX001-c284	0.268 (9)	0.027 (9)	0.030 (9)	0.004 (9)	0.640 (9)	-0.004 (34)
BmX001-c286	-0.090 (36)	-0.004 (1)	-0.020 (1)	-0.001 (36)	-0.075 (1)	-0.023 (35)
BmX001-c286	0.395 (9)	0.031 (9)	0.006 (9)	0.005 (9)	0.642 (9)	-0.004 (34)
BmX001-c288	-0.110 (1)	-0.003 (1)	-0.041 (35)	-0.000 (1)	-0.079 (36)	-0.013 (35)
BmX001-c288	0.531 (9)	0.032 (9)	-0.008 (34)	0.006 (9)	0.642 (9)	0.006 (9)
COL007	0.009 (9)	-0.071 (9)	-0.019 (9)	-0.002 (35)	-0.007 (35)	-0.015 (1)
COL007	0.040 (35)	0.039 (36)	0.005 (1)	-0.000 (9)	0.001 (9)	0.019 (9)
COL008	-0.009 (9)	0.005 (34)	-0.015 (9)	-0.002 (36)	-0.011 (35)	-0.004 (35)
COL008	0.015 (1)	0.027 (35)	0.003 (1)	0.000 (9)	-0.001 (34)	0.005 (35)
COL009	-0.020 (35)	0.000 (34)	-0.013 (9)	-0.002 (36)	-0.014 (35)	-0.000 (1)
COL009	-0.005 (34)	0.044 (35)	0.002 (1)	0.000 (9)	-0.000 (34)	0.019 (35)
COL010	-0.036 (1)	-0.002 (36)	-0.011 (9)	-0.002 (36)	-0.018 (9)	-0.001 (36)
COL010	0.010 (9)	0.089 (9)	0.002 (1)	0.000 (9)	0.001 (1)	0.047 (9)
COL011	-0.093 (9)	-0.225 (9)	0.001 (34)	-0.002 (36)	-0.018 (9)	-0.026 (9)
COL011	0.050 (1)	0.011 (36)	0.090 (35)	0.001 (9)	0.013 (35)	0.049 (9)
COL012	-0.001 (9)	-0.203 (9)	0.001 (34)	-0.002 (36)	0.001 (34)	-0.091 (9)
COL012	0.026 (1)	0.023 (36)	0.092 (35)	0.001 (9)	0.044 (35)	0.009 (36)
COL013	-0.026 (1)	0.014 (34)	-0.095 (9)	-0.002 (1)	-0.002 (1)	-0.069 (35)
COL013	0.059 (9)	0.150 (35)	0.002 (1)	0.000 (9)	0.044 (9)	-0.001 (34)
COL014	-0.050 (1)	0.007 (34)	-0.093 (9)	-0.002 (1)	-0.019 (35)	-0.020 (35)
COL014	0.034 (9)	0.187 (35)	0.002 (1)	0.000 (9)	0.012 (9)	0.043 (35)
COL015	-0.069 (9)	-0.072 (35)	0.001 (34)	-0.002 (1)	-0.019 (35)	-0.000 (1)

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COL015	0.036 (1)	-0.001 (34)	0.016 (35)	0.000 (9)	0.000 (1)	0.042 (35)
COL016	-0.022 (9)	-0.036 (9)	0.001 (34)	-0.002 (36)	-0.014 (9)	-0.000 (1)
COL016	0.009 (1)	0.001 (1)	0.017 (35)	0.000 (9)	0.001 (36)	0.020 (9)
COL017	-0.015 (1)	-0.044 (9)	0.002 (34)	-0.002 (36)	-0.009 (9)	-0.005 (9)
COL017	0.029 (9)	0.009 (1)	0.016 (35)	0.000 (9)	0.002 (36)	0.009 (9)
COL018	-0.031 (1)	-0.153 (9)	0.003 (34)	-0.002 (35)	-0.004 (9)	-0.052 (9)
COL018	0.062 (9)	0.039 (1)	0.012 (35)	-0.000 (9)	0.003 (36)	0.015 (1)
COL031	-0.000 (1)	-0.030 (9)	-0.004 (35)	-0.000 (36)	-0.003 (35)	-0.000 (1)
COL031	0.002 (35)	-0.000 (34)	-0.000 (34)	0.001 (9)	-0.000 (34)	0.013 (9)
COL032	0.017 (34)	-0.075 (35)	0.003 (34)	0.001 (34)	-0.012 (35)	0.001 (34)
COL032	0.065 (35)	-0.024 (34)	0.031 (35)	0.006 (35)	0.000 (9)	0.032 (35)
COL033	-0.026 (35)	-0.008 (35)	0.000 (34)	-0.000 (36)	-0.002 (35)	-0.000 (1)
COL033	-0.001 (34)	-0.000 (34)	0.001 (35)	0.001 (9)	-0.000 (34)	0.004 (35)
COL034	0.008 (34)	-0.013 (35)	0.002 (34)	0.001 (34)	-0.002 (36)	-0.000 (1)
COL034	0.031 (35)	-0.004 (9)	0.028 (35)	0.006 (35)	0.008 (9)	0.009 (35)
COL035	-0.037 (35)	-0.001 (35)	0.000 (34)	-0.000 (36)	-0.002 (35)	-0.000 (1)
COL035	-0.001 (34)	0.000 (36)	0.002 (35)	0.001 (9)	-0.000 (34)	0.002 (35)
COL036	-0.020 (35)	-0.005 (35)	0.001 (34)	0.001 (34)	-0.001 (36)	-0.000 (36)
COL036	-0.005 (34)	-0.000 (34)	0.028 (35)	0.006 (35)	0.017 (9)	0.006 (35)
COL037	-0.041 (35)	-0.000 (36)	0.000 (34)	0.000 (34)	-0.001 (35)	-0.000 (36)
COL037	0.000 (1)	0.000 (9)	0.003 (35)	0.001 (35)	-0.000 (34)	0.003 (9)
COL038	-0.076 (35)	-0.023 (9)	0.001 (34)	0.001 (34)	-0.000 (1)	-0.003 (9)
COL038	-0.021 (34)	0.002 (1)	0.030 (35)	0.006 (35)	0.026 (35)	0.005 (9)
COL039	-0.038 (35)	-0.006 (9)	0.000 (34)	0.000 (34)	-0.001 (35)	-0.000 (1)
COL039	0.001 (36)	0.000 (1)	0.004 (35)	0.001 (35)	0.001 (35)	0.004 (9)
COL040	0.029 (34)	-0.021 (35)	-0.115 (9)	0.001 (34)	-0.013 (9)	-0.008 (35)
COL040	0.099 (35)	-0.007 (34)	0.002 (1)	0.005 (35)	0.026 (35)	0.001 (1)
COL041	-0.025 (9)	-0.032 (9)	0.000 (34)	0.000 (34)	0.000 (34)	-0.007 (9)
COL041	0.002 (1)	0.000 (36)	0.007 (35)	0.001 (35)	0.003 (35)	0.003 (9)
COL042	0.015 (34)	-0.048 (35)	-0.114 (9)	0.001 (34)	-0.051 (9)	-0.024 (35)
COL042	0.068 (35)	-0.014 (34)	0.002 (1)	0.005 (35)	0.002 (1)	-0.001 (34)
COL043	-0.041 (35)	-0.061 (35)	-0.004 (9)	-0.000 (36)	-0.000 (1)	-0.000 (1)
COL043	-0.000 (34)	-0.000 (34)	0.000 (1)	0.001 (9)	0.002 (9)	0.030 (35)
COL044	-0.045 (35)	-0.065 (35)	0.001 (34)	0.001 (34)	-0.061 (35)	-0.002 (9)
COL044	-0.015 (34)	-0.014 (34)	0.126 (35)	0.006 (35)	-0.001 (34)	0.022 (35)
COL045	-0.046 (35)	-0.024 (9)	-0.001 (9)	-0.000 (36)	-0.000 (9)	-0.000 (1)
COL045	0.001 (1)	-0.000 (36)	0.000 (1)	0.001 (9)	0.000 (9)	0.011 (9)
COL046	-0.123 (35)	-0.038 (35)	0.001 (34)	0.001 (34)	-0.019 (35)	-0.010 (35)
COL046	-0.029 (34)	-0.007 (34)	0.126 (35)	0.006 (35)	0.023 (9)	0.003 (35)
COL047	-0.040 (35)	-0.009 (9)	-0.000 (9)	-0.000 (36)	-0.000 (9)	-0.000 (1)
COL047	0.002 (1)	0.000 (1)	0.000 (1)	0.001 (9)	0.000 (1)	0.005 (9)
COL048	0.021 (34)	0.001 (34)	-0.016 (9)	0.001 (34)	-0.001 (1)	-0.007 (35)
COL048	0.083 (35)	0.039 (35)	0.002 (1)	0.006 (35)	0.023 (9)	0.006 (35)
COL049	-0.030 (9)	-0.009 (35)	0.000 (34)	0.000 (34)	-0.000 (9)	-0.000 (35)
COL049	0.003 (1)	-0.000 (34)	0.001 (35)	0.001 (35)	0.000 (35)	0.003 (35)
COL050	0.005 (34)	-0.001 (1)	-0.013 (9)	0.001 (34)	0.000 (34)	-0.000 (36)
COL050	0.017 (35)	0.009 (9)	0.002 (1)	0.006 (35)	0.018 (35)	0.008 (9)
COL051	-0.021 (9)	-0.024 (9)	0.000 (34)	0.000 (34)	0.000 (34)	-0.007 (9)
COL051	0.003 (1)	0.000 (1)	0.001 (35)	0.001 (35)	0.001 (35)	0.001 (9)
COL052	-0.035 (35)	-0.026 (35)	-0.011 (9)	0.001 (34)	0.001 (34)	-0.003 (1)
COL052	-0.008 (34)	-0.005 (34)	0.003 (1)	0.005 (35)	0.014 (35)	0.009 (35)
COL053	-0.018 (35)	-0.059 (9)	-0.001 (35)	0.000 (34)	0.000 (34)	-0.025 (9)
COL053	0.000 (36)	0.000 (36)	-0.000 (34)	0.001 (35)	0.001 (35)	0.000 (36)
COL054	-0.065 (35)	-0.136 (35)	-0.006 (9)	0.001 (34)	0.001 (34)	-0.041 (35)
COL054	-0.017 (34)	-0.024 (34)	0.005 (36)	0.005 (35)	0.011 (35)	0.006 (9)

(lc) = Load Case index, shown in 'Load Cases' or 'Result Cases' table.

Nodal Extreme Reactions

Node	FX	FY	FZ	MX	MY	MZ
------	----	----	----	----	----	----

Project: 10'-4 Diameter Skimmer

Jeremiah Dischinger, AECOM - CLEVELAND

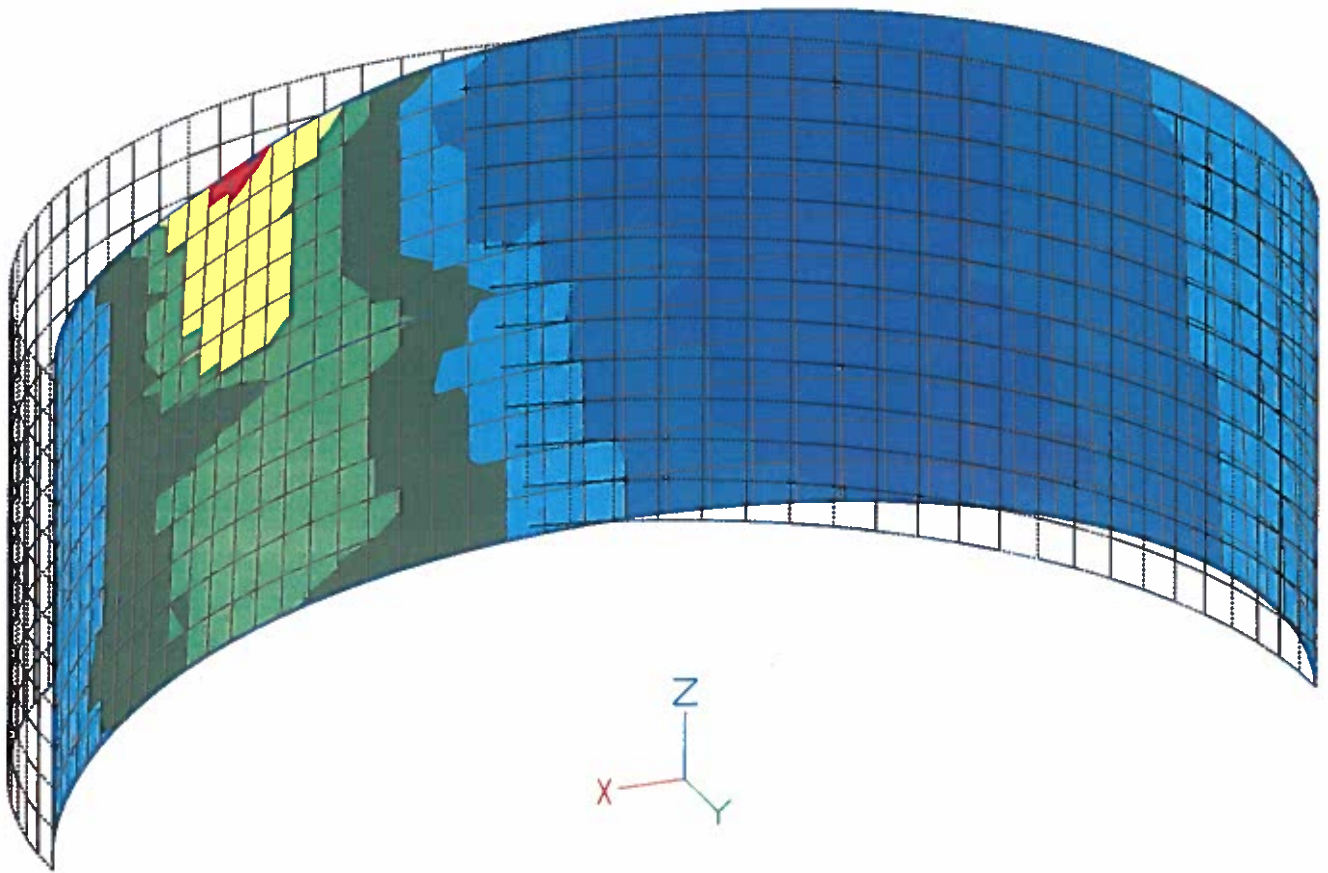
June 13, 2016

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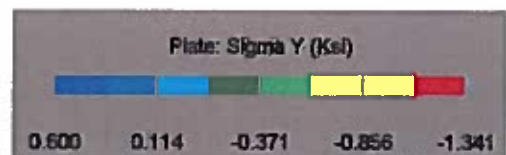
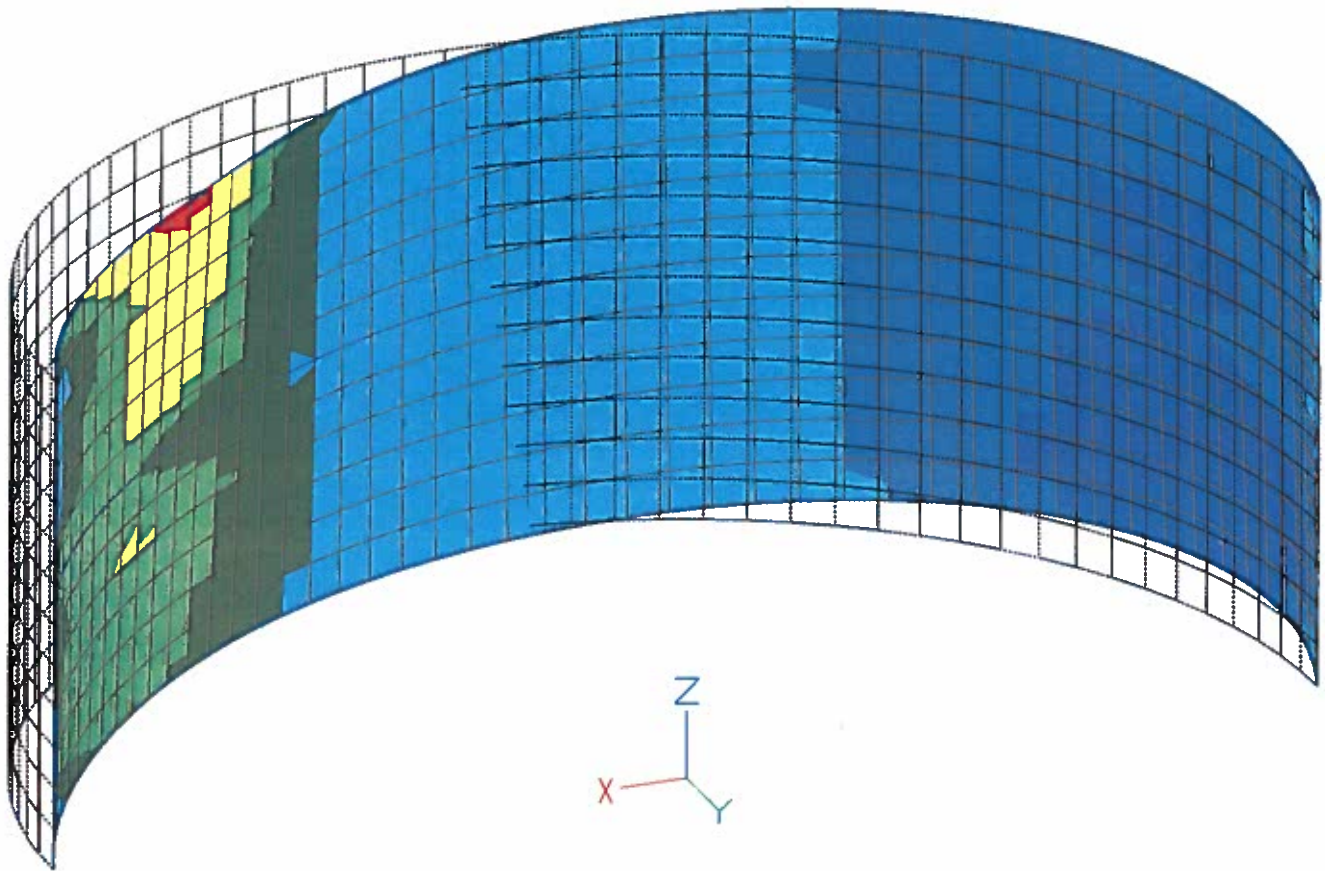
	K	K	K	K-ft	K-ft	K-ft
N001	-0.093 (36)	-0.304 (36)	-0.165 (9)	-NA-	-NA-	-NA-
N001	0.517 (9)	1.304 (9)	0.070 (1)	-NA-	-NA-	-NA-
N009	0.000 (34)	-0.321 (35)	-0.125 (9)	-NA-	-NA-	-NA-
N009	0.104 (35)	-0.007 (34)	0.125 (1)	-NA-	-NA-	-NA-
N017	-0.000 (1)	-0.382 (9)	-0.189 (9)	-NA-	-NA-	-NA-
N017	0.096 (9)	0.012 (36)	0.125 (1)	-NA-	-NA-	-NA-
N025	-0.111 (9)	-1.312 (9)	-0.000 (9)	-NA-	-NA-	-NA-
N025	0.093 (36)	0.304 (36)	0.070 (1)	-NA-	-NA-	-NA-
N914	0.056 (34)	-1.198 (35)	0.042 (34)	-NA-	-NA-	-NA-
N914	0.569 (35)	-0.182 (34)	0.176 (35)	-NA-	-NA-	-NA-
N917	-0.000 (1)	-0.103 (35)	0.075 (34)	-NA-	-NA-	-NA-
N917	0.142 (9)	-0.007 (34)	0.317 (35)	-NA-	-NA-	-NA-
N921	0.000 (34)	-0.044 (9)	0.075 (34)	-NA-	-NA-	-NA-
N921	0.145 (35)	0.012 (1)	0.247 (35)	-NA-	-NA-	-NA-
N925	-0.093 (1)	0.182 (34)	0.042 (34)	-NA-	-NA-	-NA-
N925	0.031 (9)	0.633 (35)	0.128 (35)	-NA-	-NA-	-NA-

(Ic) = Load Case index, shown in 'Load Cases' or 'Result Cases' table.

10'-4 Diameter Skimmer
AECOM - CLEVELAND, Jeremiah Dischinger
Jun 08, 2016; 04:27 PM
Result Case: F
Plate Sigma X, global stress
IES VisualAnalysis 12.00.0006



10'-4 Diameter Skimmer
AECOM - CLEVELAND, Jeremiah Dischinger
Jun 08, 2016; 04:26 PM
Result Case: F
Plate Sigma Y, global stress
IES VisualAnalysis 12.00.0006



SECTION 3
CONCRETE BULKHEAD CALCULATIONS



Job	<u>PAF Gypsum Stack Spillway</u>	Project No.	<u>60444361</u>	Sheet	<u>1</u> of <u>2</u>
Description	<u>Bulkhead Sizing Calculation</u>	Computed by	<u>BME</u>	Date	<u>3/22/16</u>
		Checked by	<u>SD</u>	Date	<u>5/18/16</u>

I. PURPOSE

The purpose of the bulkhead sizing calculation is to determine the size of concrete block required to withstand the pressure of the grout used for abandonment within the barrel of the existing 36-inch outlet and riser at the Upper Stilling Pone.

II. SITE AND PROJECT DESCRIPTION

The existing spillway at the Gypsum Stack Upper Stilling Pond is being replaced due to stability concerns. As a part of this project, the existing spillway will be grouted and abandoned after the new spillway is constructed. The existing discharge pipe and a portion of the riser will be grouted. The grout must be held in place within the existing spillway until it sets. The concrete bulkhead will serve this purpose.

III. METHODOLOGY

The weight of the grout was determined, and the pressure due to the anticipated grout height within the riser was calculated. The maximum resisting force equals the weight of the concrete block multiplied by the coefficient of friction between the concrete and the proposed stone bedding under the block. Resisting forces due to friction within the pipe barrel were ignored.

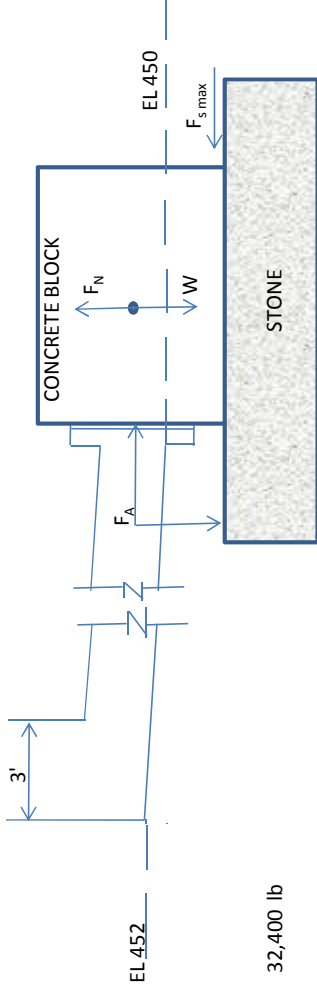
Weight of grout was assumed to be 138 pounds per cubic foot.

Weight of concrete was assumed to be 150 pounds per cubic foot.

Calculated factor of safety = 1.99

Spillway Abandonment - Concrete Block Sizing Calculation

F_N normal force
 F_A applied force
 μ_s coefficient of friction
 $f_{s,max}$ resisting force
 W Weight



$$F_N = W = \text{Concrete Block} = \frac{150 \text{ lbs}}{\text{ft}^3} \times 216 \text{ ft}^3 = 32,400 \text{ lb}$$

$$F_A = \text{Weight of Grout} = \frac{110.2 \text{ lbs}}{\text{ft}^3} \times 70.69 \text{ ft}^3 = 7,790 \text{ lb}$$

Coefficient of Friction

$$\mu_s = 0.6$$

$$f_{s,max} =$$

-Coefficient of friction for concrete to stone

$$F.O.S = f_{s,max} / F_A$$

$$F.O.S = 2.50$$

Volume of a Cylinder

$$V = \pi r^2 h = 70.69 \text{ ft}^3$$

$$\pi = 3.141592654$$

$$r^2 = 1.5 \text{ ft}$$

$$h = 10 \text{ ft}$$

Size of Concrete Block

5'x5'x5' Concrete Block	125 ft ³
6'x6'x6' Concrete Block	216 ft ³
7'x7'x7' Concrete Block	343 ft ³
8'x8'x8' Concrete Block	512 ft ³

-5' riser pipe + 3' spillway pipe + 2' chng in elev.; only add the vertical height of the grout

**APPENDIX A2:
GYPSUM DISPOSAL AREA STILLING POND 1 SPILLWAY
1,000-YEAR FLOOD CALCULATIONS**

Job TVA PAFProject No. 6044361Sheet of Description Paradise Gypsum Stack SpillwayComputed by TPNDate 8/25/16Replacement EvaluationChecked by SAMDate 9/29/16

Reference

Structure Geometry

See AECOM Gypsum Stack Spillway Replacement

Issued for construction drawings dated 6/27/16

Material Properties (Per Design Drawings)

Concrete strength \rightarrow 4 ksiRebar Yield Stress \rightarrow 60 ksi

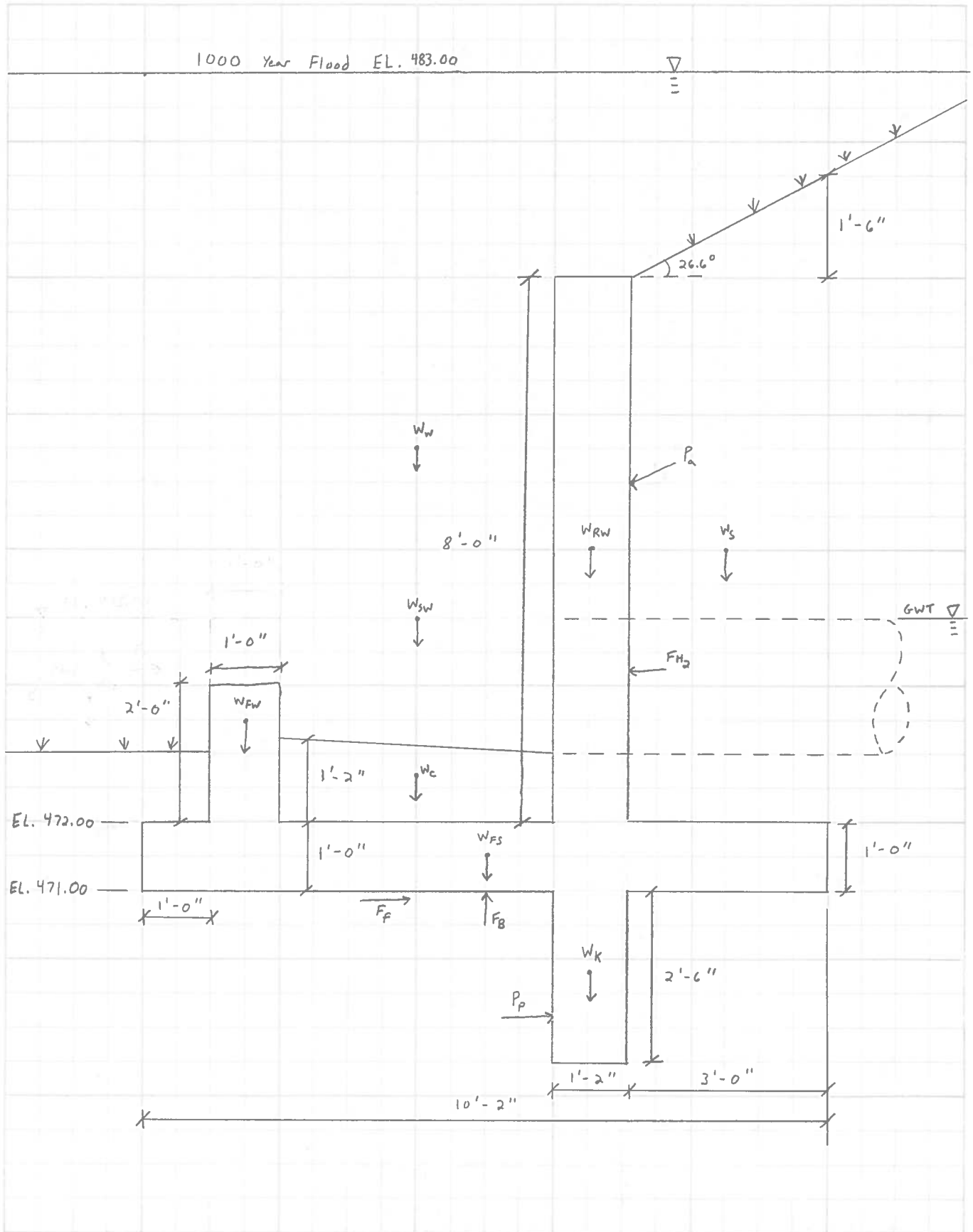
Soil properties per Geotechnical Exploration and Analysis Gypsum Stack Stilling Pond performed by AECOM dated 2/23/16, and original design calculations performed by AECOM dated 6/16.

Soil bearing capacity = 7,300 psf

Active earth pressure coefficient $k_a = .50$ Passive earth pressure coefficient $k_p = 2.45$ Soil unit weight $\gamma = 120$ pcf

Job TVA PAFProject No. 60444361Sheet of Description Paradise Gypsum Stack SpillwayComputed by TPNDate 8/25/16Replacement EvaluationChecked by SAMDate 9/29/16

Reference



Job TVA PAF

 Project No. 60444361

 Sheet of

 Description Paradise Gypsum stack Spillway

 Computed by TPN

 Date 8/25/16

Replacement Evaluation

 Checked by SAM

 Date 9/29/16

Reference

Spillway - 1000 yr Flood

1000 yr flood el. = 483.00

For 1000 yr flood, water will overtop skimmers and chambers will be full.

Evaluate structure without wing walls

Consider floatation, sliding, moment equilibrium, and bearing capacity

$$W_{FW} = (2')(1')(10')(0.150 \text{ kip/ft}^3) = 3.000 \text{ kip}$$

$$W_{FS} = (1')(10.167')(14')(0.150 \text{ kip/ft}^3) = 21.351 \text{ kip}$$

$$W_{RW} = (8')(1.167')(12')(0.150 \text{ kip/ft}^3) = 16.805 \text{ kip}$$

$$\text{Subtract pipe openings} \rightarrow (3)(\pi)(1')^2(1.167')(0.150 \text{ kip/ft}^3) = 1.649 \text{ kip}$$

$$\rightarrow 15.156 \text{ kip}$$

$$W_{SW} = 2(8')(1')(7.167')(0.150 \text{ kip/ft}^3) = 17.201 \text{ kip}$$

$$W_K = (2.5')(1.167')(14')(0.150 \text{ kip/ft}^3) = 6.127 \text{ kip}$$

$$W_C = (1')(4')(12')(0.150 \text{ kip/ft}^3) + \frac{1}{2}(0.167')(4')(12')(0.150 \text{ kip/ft}^3) = 7.801 \text{ kip}$$

$$W_S = (8')(3')(14')(0.120 \text{ kip/ft}^3) + \frac{1}{2}(1.5')(3')(14')(0.120 \text{ kip/ft}^3) = 44.100 \text{ kip}$$

$$W_W = (11')(1')(14')(0.0624 \text{ k/ft}^3) + (8')(1')(10')(0.0624 \text{ k/ft}^3) + (10')(4')(10')(0.0624 \text{ k/ft}^3) + (3')(1.167')(12')(0.0624 \text{ k/ft}^3) + 2(3')(1')(7.167')(0.0624 \text{ k/ft}^2) = 44.866 \text{ kip}$$

 $F_H =$ Equal and opposite hydrostatic pressure

$$F_B = (12')(10.167')(14')(0.0624 \text{ kip/ft}^3) = 106.583 \text{ kip}$$

$$P_a = \frac{1}{2} k_a \gamma H^2 = \frac{1}{2} (.50)(0.120 \text{ kip/ft}^3)(9')^2 = 2.43 \text{ kip/ft}$$

$$P_v = 2.43 \text{ kip/ft} \sin(26.6^\circ) = 1.088 \text{ kip/ft} \times 14 \text{ ft} = 15.232 \text{ kip}$$

$$P_H = 2.43 \text{ kip/ft} \cos(26.6^\circ) = 2.173 \text{ kip/ft} \times 14 \text{ ft} = 30.419 \text{ kip}$$

$$P_p = \frac{1}{2} k_p \gamma H^2 = \left(\frac{1}{2}\right)(2.45)(0.120 \text{ kip/ft}^3)(4.5')^2 = 2.977 \text{ kip/ft} \times 14 \text{ ft} = 41.675 \text{ kip}$$

Job TVA PAF

 Project No. 60444361

 Sheet of

 Description Paradise Gypsum Stack Spillway

 Computed by TPN

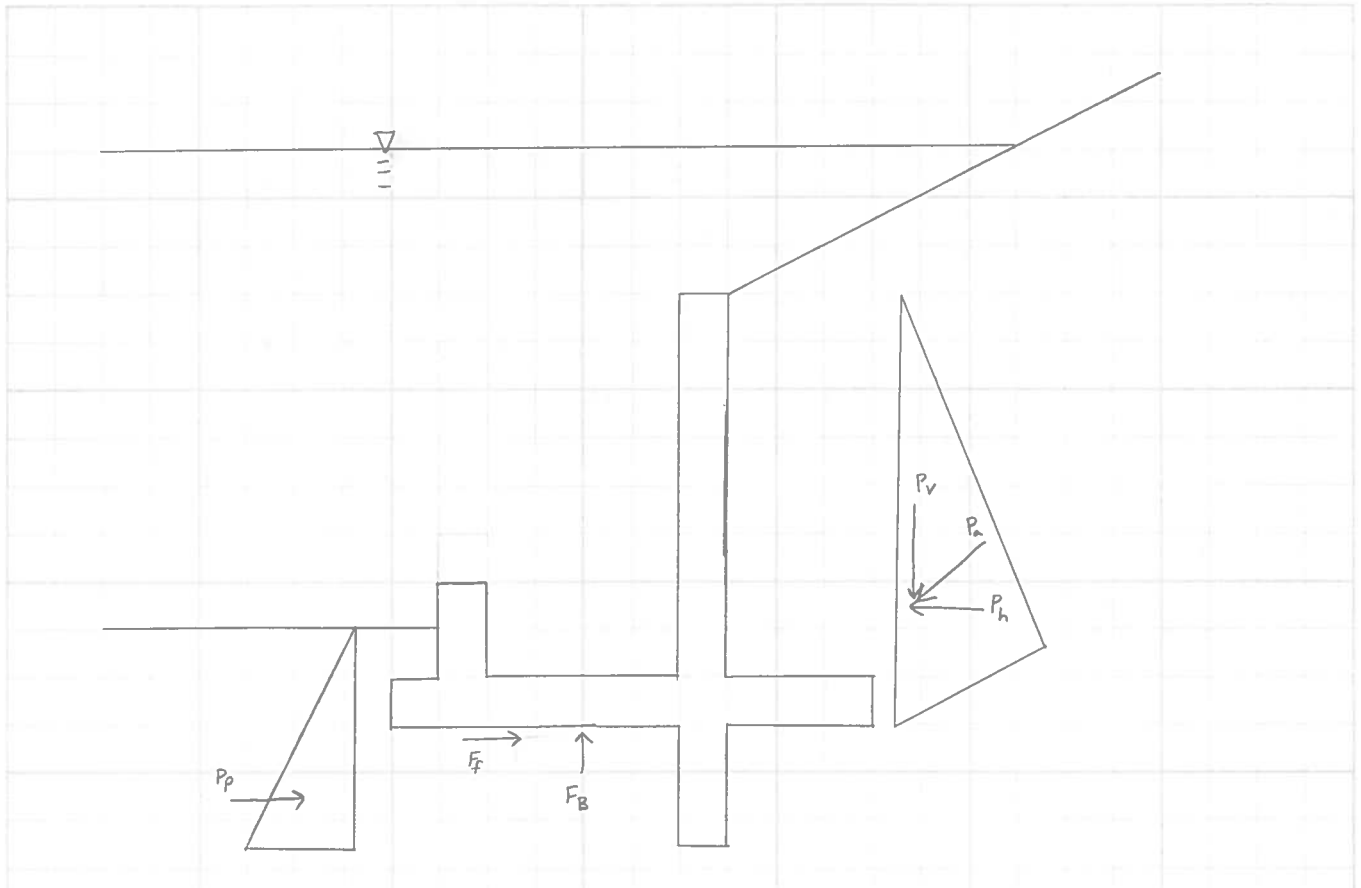
 Date 8/25/16

 Replacement Evaluation

 Checked by SAW

 Date 9/29/16

Reference



Note: Conservatively applying buoyant force because structure is buried as shown here. Top is class 1/11 riprap and will not scour. Entire structure is submerged, therefore hydrostatic forces are equal.

Net downward to create friction on bottom of floor slab

$$W_w + W_{fw} + W_{sw} + W_c + W_{fs} + W_{rw} + W_s + P_v - F_B$$

$$44.866 \text{ kip} + 3.000 \text{ kip} + 17.201 \text{ kip} + 7.801 \text{ kip} + 21.351 \text{ kip} + 15.156 \text{ kip} + 44.100 \text{ kip} + 15.232 \text{ kip} - 106.583 \text{ kip} = 62.124 \text{ kip}$$

$$F_f = 62.124 \text{ kip} (0.35) = 21.743 \text{ kip}$$

1000 yr flood is an "Unusual Load Combination" (UNLC)

Per TVA - CCR Rule Template 257.73(d) 2.1.5

min allowable floatation stability factor of safety for UNLC = 1.2

Job TVA PAF

 Project No. 6044361

 Sheet of

 Description Paradise Gypsum Stack Spillway

 Computed by TPN

 Date 8/25/16

 Replacement Evaluation

 Checked by SAM

 Date 9/29/16

Reference

$$FS_f = \frac{W_s + W_c + S}{U - W_g} = \frac{168.707 \text{ kip}}{106.583 \text{ kip}} = 1.583 > 1.2 \checkmark$$

Per TVA-CCR Rule Template 257.73(d) 2.1.5

min allowable sliding stability factor of safety for UNLC = 1.5

$$FS = \frac{F_f + P_p}{P_h} = \frac{21.743 \text{ kip} + 41.675 \text{ kip}}{30.419 \text{ kip}} = 2.085 > 1.5 \checkmark$$

Per TVA-CCR Rule Template 257.73(d) 2.1.5

moment equilibrium stability requirement for UNLC is 75% of base in compression

sum moments about right corner, ignoring shear key

$$44.866 \text{ kip} (6.583') + 3.000 \text{ kip} (8.667') + 21.351 \text{ kip} (5.083') + 15.156 \text{ kip} (3.583') + \\ 17.201 \text{ kip} (6.083') + 7.801 \text{ kip} (6.167') + 44.100 \text{ kip} (1.5') + 15.232 \text{ kip} (3.000') + \\ 30.419 \text{ kip} (3.000') - 106.583 \text{ kip} (5.167') = 289.316 \text{ kip}\cdot\text{ft}$$

Resultant located at $289.316 \text{ kip}\cdot\text{ft} / 62.124 \text{ kip} = 4.657'$ from right corner

$e = 0.427'$ right of center

$e < \frac{L}{6} = 1.695' \therefore$ Base is 100% in compression \checkmark

Per TVA-CCR Rule Template 257.73(d) 2.1.5

min allowable bearing capacity factor of safety for UNLC = 2.6

$$q = \frac{P(1 \pm \frac{6e}{L})}{BL} = \frac{62.124 \text{ kip} (1 \pm \frac{6(0.427')}{10.167'})}{(14,000')(10.167')} = .546 \text{ ksf} / .326 \text{ ksf}$$

$$FS = \frac{7.3 \text{ ksf}}{.546 \text{ ksf}} = 13.370 > 2.6 \checkmark$$

Job TVA PAF

 Project No. 6044361

 Sheet of

 Description Paradise Gypsum Stack Spillway

 Computed by TPN

 Date 8/25/16

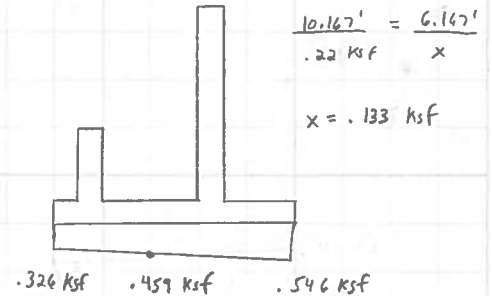
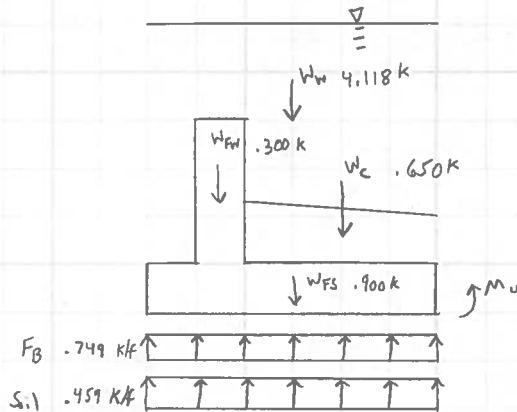
Replacement Evaluation

 Checked by SAM

 Date 9/29/16

Reference

Floor slab is twice as long in longitudinal direction than the transverse direction. \therefore One way slab bending in transverse direction. Check transverse rebar.



$$M_u = -1.2 (4.118 \text{ k}) (3') - 0.9 (.300 \text{ k}) (4.5') - 0.9 (.650 \text{ k}) (2') - 0.9 (.900 \text{ k}) (3') + 1.2 (.749 \text{ k/ft}) (6') (3') + 1.6 (.459 \text{ k/ft}) (6') (3') = 9.758 \text{ kip}\cdot\text{ft} = 117.096 \text{ kip}\cdot\text{in}$$

#6 bars at 8"

$$\phi M_n = \left(\phi A_s f_y / d - \frac{A_s f_y}{2 (.85) f_c' b} \right) = .9 (.66 \text{ in}^2) (60 \text{ ksi}) \left(8.625'' - \frac{(.66 \text{ in}^2) (60 \text{ ksi})}{2 (.85) (4 \text{ ksi}) (12'')} \right)$$

$$A_s = .44 \text{ in}^2 \left(\frac{12''}{8''} \right) = .66 \text{ in}^2$$

$$\phi M_n = 290.099 \text{ kip}\cdot\text{in} > 117.096 \text{ kip}\cdot\text{in} \checkmark$$

$$1.2 M_{cr} = \frac{f_r I_g}{y_t}$$

$$f_r = 7.5 \sqrt{f_c'} = 474.342 \text{ psi} \rightarrow .474 \text{ ksi}$$

$$I_g = \frac{bh^3}{12} = \frac{12 (12)^3}{12} = 1728 \text{ in}^4$$

$$1.2 M_{cr} = \left(\frac{.474 \text{ ksi} (1728 \text{ in}^4)}{6''} \right) (1.2) = 163.81 \text{ kip}\cdot\text{in} \checkmark$$

$$1.33 M_n = 1.33 (117.096 \text{ kip}\cdot\text{in}) = 155.738 \text{ kip}\cdot\text{in} \rightarrow \text{controls}$$

$$\phi M_n = 290.099 \text{ kip}\cdot\text{in} > 1.33 M_n = 155.738 \text{ kip}\cdot\text{in} \checkmark$$

Job TVA PAF

 Project No. 60444361

 Sheet of

 Description Paradise Gypsum Stack Spillway

 Computed by TPN

 Date 8/25/16
Replacement Evaluation

 Checked by Spm

 Date 9/29/16

Reference

Check rear wall

Hydrostatic is equal and opposite on side wall, therefore only soil load

$$P = 30.419 \text{ k} / 14' = 2.173 \text{ k/ft}$$

$$M_n = 2.173 \text{ k/ft} (3') = 6.518 \text{ k}\cdot\text{ft/ft}$$

$$M_u = 1.6 (6.518 \text{ k}\cdot\text{ft/ft}) (12 \text{ in/ft}) = 125.152 \text{ k}\cdot\text{in/ft}$$

5 bars at 8"

$$\phi M_n = \phi A_s F_y \left(d - \frac{A_s F_y}{2(0.85) f_c' b} \right) = .9 (.465 \text{ in}^2) (60 \text{ ksi}) \left(11.063'' - \frac{(.465 \text{ in}^2) (60 \text{ ksi})}{2(.85) (4 \text{ ksi}) (12 \text{ in})} \right)$$

$$A_s = .31 \text{ in}^2 \left(\frac{13''}{8''} \right) = .465 \text{ in}^2$$

$$\phi M_n = 269.207 \text{ kip}\cdot\text{in/ft}$$

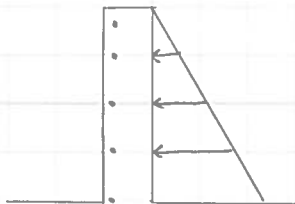
$$1.2 M_{cr} = \frac{f_r I_g}{y_t}; \quad f_r = 7.5 \sqrt{f_c'} = 474.342 \text{ psi} \rightarrow .474 \text{ ksi}$$

$$I_g = \frac{b h^3}{12} = \frac{14'' (12'')^3}{12} = 2016 \text{ in}^4$$

$$1.2 M_{cr} = \frac{1.2 (.474 \text{ ksi}) (2016 \text{ in}^4)}{7''} = 163.814 \text{ kip}\cdot\text{in/ft} \leftarrow \text{controls}$$

$$1.33 M_n = 1.33 (125.152 \text{ kip}\cdot\text{in/ft}) = 166.452 \text{ kip}\cdot\text{in/ft}$$

$$\phi M_n = 269.207 \text{ kip}\cdot\text{in/ft} > 1.2 M_{cr} = 163.814 \text{ kip}\cdot\text{in/ft} \checkmark$$



$$0.5 (120 \text{ k/ft}^2) (8') = .480 \text{ k/ft}^2$$

$$M_u = \frac{1.6 (0.480 \text{ k/ft}^2) (13')^2}{8} = 16.224 \text{ kip}\cdot\text{ft/ft} = 194.688 \text{ kip}\cdot\text{in/ft}$$

5 bars at 8"

$$\phi M_n = .9 (.465 \text{ in}^2) (60 \text{ ksi}) \left(11.688'' - \frac{(.465 \text{ in}^2) (60 \text{ ksi})}{2(.85) (4 \text{ ksi}) (12'')} \right) = 284.900 \text{ kip}\cdot\text{in/ft}$$

$$\phi M_n = 284.900 \text{ kip}\cdot\text{in/ft} > 1.2 M_{cr} = 163.814 \text{ kip}\cdot\text{in/ft} \checkmark$$

Job TVA PAF

 Project No. 60444361

 Sheet of

 Description Paradise Gypsum Stack Spilling

 Computed by TPN

 Date 8/25/16
Replacement Evaluation

 Checked by SAM

 Date 9/29/16

Reference

Check side wall

Hydrostatic is equal and opposite on side wall, therefore only soil load

$$M_u = 1.6 (2.43 \text{ kip/ft})(1')(3') = 11.664 \text{ kip}\cdot\text{ft} = 139.968 \text{ kip}\cdot\text{in}$$

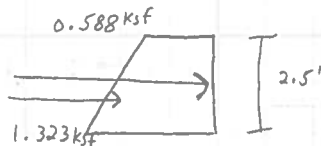
#5 bars at 8"

$$\phi M_n = \phi A_s f_y \left(d - \frac{A_s f_y}{2(0.85)f_c' b} \right) = 0.9 (.465 \text{ in}^2) (60 \text{ ksi}) \left(9.688'' - \frac{(.465 \text{ in}^2)(60 \text{ ksi})}{2(0.85)(4 \text{ ksi})(12'')} \right)$$

$$\phi M_n = 234.680 \text{ kip}\cdot\text{in} \checkmark ; 1.33 (139.968 \text{ kip}\cdot\text{in}) = 186.157 \text{ kip}\cdot\text{in}$$

$$1.2 M_{cr} = \frac{f_r I_g}{y_t} = 163.81 \text{ kip}\cdot\text{in} \leftarrow \text{controls} < 234.680 \text{ kip}\cdot\text{in} \checkmark$$

Check Shear Key



$$M_1 = 0.588 \text{ ksf} (2.5') (1.25') = 1.84 \text{ k}\cdot\text{ft/ft}$$

$$M_2 = \frac{1}{2} (1.323 \text{ ksf} - 0.588 \text{ ksf}) (2.5') \left(\frac{2}{3}\right) (2.5') = 1.53 \text{ k}\cdot\text{ft/ft}$$

$$M_u = 1.6 (3.37 \text{ k}\cdot\text{ft/ft}) = 5.39 \text{ k}\cdot\text{ft/ft} = 64.68 \text{ k}\cdot\text{in/ft}$$

#5 bars at 8"

$$\phi M_n = \phi A_s f_y \left(d - \frac{A_s f_y}{2(0.85)f_c' b} \right) = 0.9 (.465 \text{ in}^2) (60 \text{ ksi}) \left(11.688'' - \frac{(.465 \text{ in}^2)(60 \text{ ksi})}{2(0.85)(4 \text{ ksi})(12'')} \right)$$

$$\phi M_n = 284.900 \text{ kip}\cdot\text{in/ft}$$

$$1.2 M_{cr} = 1.2 \frac{(.474 \text{ ksi})(2744 \text{ in}^4)}{7''} = 222.970 \text{ kip}\cdot\text{in/ft}$$

$$1.33 M_u = 1.33 (64.68 \text{ k}\cdot\text{in/ft}) = 86.024 \text{ kip}\cdot\text{in/ft} \leftarrow \text{controls}$$

$$\phi M_n = 284.900 \text{ kip}\cdot\text{in/ft} > 1.33 M_u = 86.024 \text{ kip}\cdot\text{in/ft} \checkmark$$

Job TVA PAFProject No. 60444361Sheet of Description Paradise Gypsum Stack SpillwayComputed by TPNDate 8/25/16Replacement EvaluationChecked by S. AgamDate 9/29/16

Reference

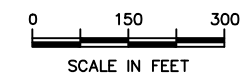
Headwall - 1000 yr flood

During the 1000 year flood, the outlet structure would be partially submerged, but any buoyant force would be counteracted by water above the footing. In addition, the structure has an open front, and any additional hydrostatic pressure would be counteracted by the earth behind the wall. Therefore, 1000 yr flood (UNLC) conditions are not necessary.

APPENDIX B

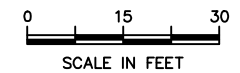
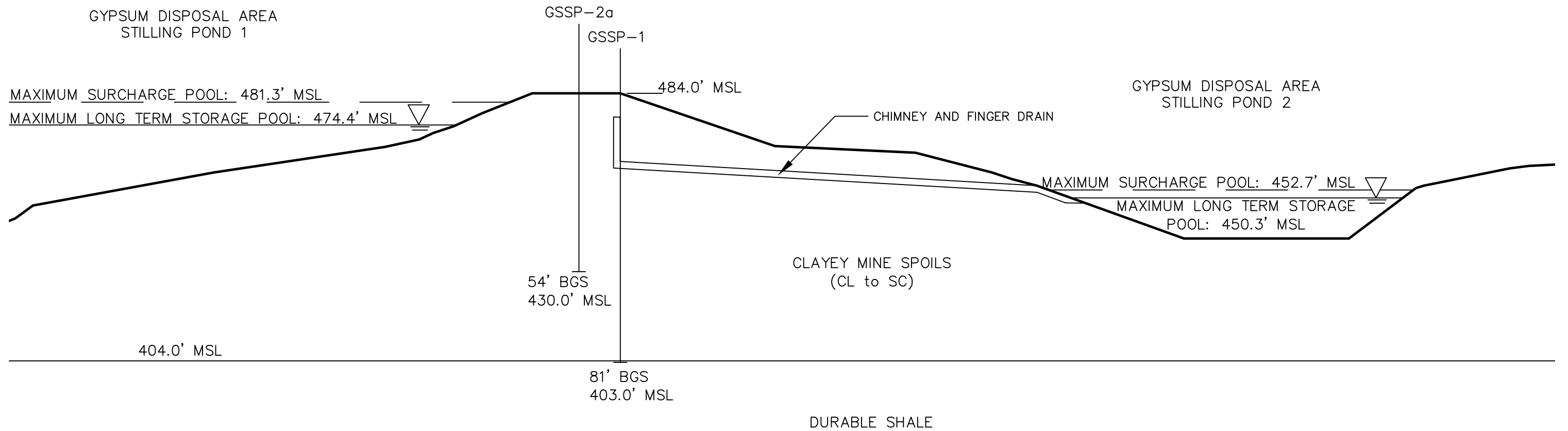
GEOTECHNICAL EXPLORATION AND ANALYSIS CROSS SECTIONS AND BORING LOCATION

S:\TVA\CCP\PAF\Gypsum Stack Stilling Ponds\Gypsum Stack Stilling Pond\2016-06-08\GSSP_topography.dwg User:DouangvilayS Oct 11, 2016 - 11:05am



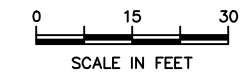
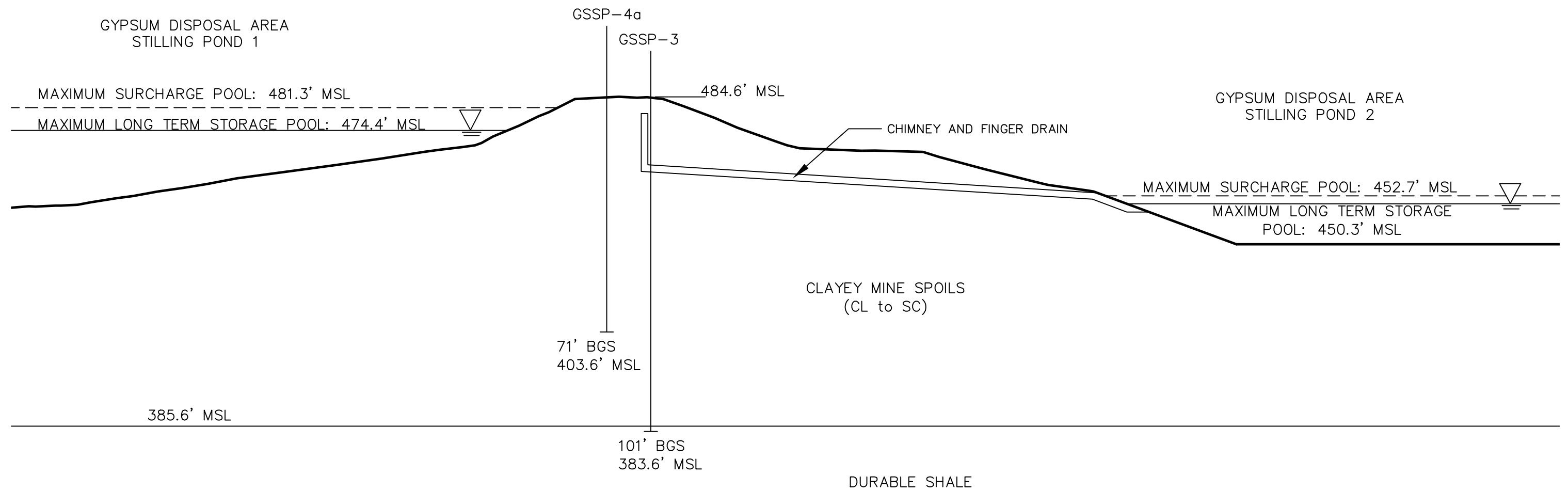
AECOM				
PARADISE FOSSIL PLANT TENNESSEE VALLEY AUTHORITY				
GYPSUM DISPOSAL AREA STILLING PONDS 1 AND 2 PLAN VIEW				
DRAWN BY: NC	CHECKED BY: MW	PROJECT No: 60439833	DATE: 09/16/16	EXHIBIT 1

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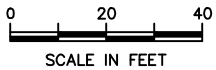
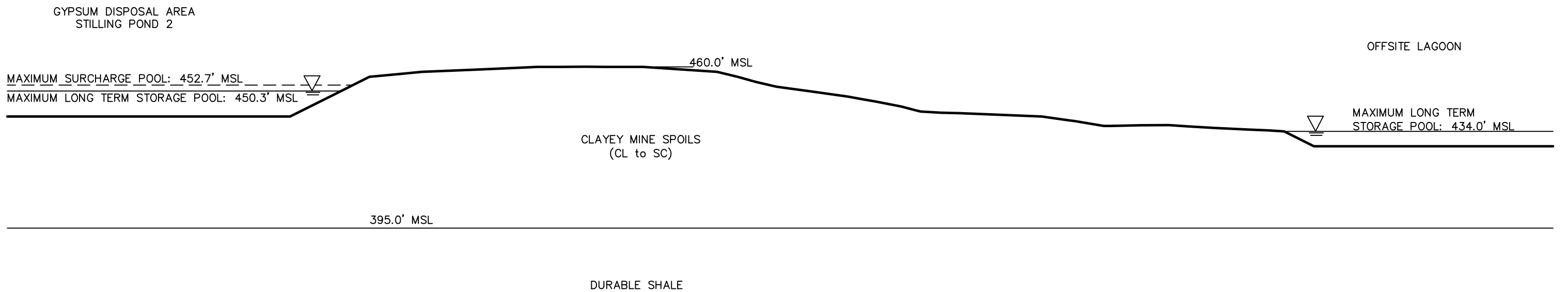
AECOM				
PARADISE FOSSIL PLANT TENNESSEE VALLEY AUTHORITY				
GYPSUM DISPOSAL AREA STILLING PONDS 1 AND 2 CROSS SECTION A-A'				
DRAWN BY: NC	CHECKED BY: MW	PROJECT No: 60439833	DATE: 09/16/16	EXHIBIT 2

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AECOM				
PARADISE FOSSIL PLANT TENNESSEE VALLEY AUTHORITY				
GYPSUM DISPOSAL AREA STILLING PONDS 1 AND 2 CROSS SECTION B-B'				
DRAWN BY: NC	CHECKED BY: MW	PROJECT No: 60439833	DATE: 09/16/16	EXHIBIT 3

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AECOM				
PARADISE FOSSIL PLANT TENNESSEE VALLEY AUTHORITY				
GYPSUM DISPOSAL AREA STILLING PONDS 1 AND 2 CROSS SECTION C-C'				
DRAWN BY: NC	CHECKED BY: MW	PROJECT No: 60439833	DATE: 09/16/16	EXHIBIT 4