



AECOM
564 White Pond Drive
Akron, OH 44320-1100
www.aecom.com

330-836-9111 tel
330-836-9115 fax

October 15, 2018

Tennessee Valley Authority
1101 Market Street
Chattanooga, Tennessee 37402

**Engineer's Certification of Seismic Impact Zone Demonstration
Slag Ponds 2A and 2B, and Slag Stilling Pond 2C
EPA Final CCR Rule
TVA Paradise Fossil Plant
Drakesboro, Kentucky**

1.0 PURPOSE

The purpose of this document is to certify that the Seismic Impact Zone Demonstration for the TVA Paradise Fossil Plant Slag Ponds 2A and 2B, and Slag Stilling Pond 2C are in compliance with the Seismic Impact Zone Location Restriction specified in the EPA Final CCR Rule at 40 CFR §257.63. Presented below are the project background, summary of findings, limitations and certification.

2.0 BACKGROUND

As required by 40 CFR §257.63 of the EPA Final CCR Rule, by October 17, 2018, the owner or operator of an existing surface impoundment must demonstrate either that the unit is not located in a seismic impact zone or that the unit's structural components are designed to resist the maximum horizontal acceleration in lithified earth material for the site.

3.0 SUMMARY OF FINDINGS

In support of the above demonstration, AECOM has determined that Slag Pond 2A and 2B and Slag Stilling Pond 2C at the Paradise Fossil Plant (PAF) in Drakesboro, Kentucky are located within a Seismic Impact Zone, (defined as an area with a Maximum Horizontal Acceleration of 0.1g). A report detailing the demonstration procedure of the Seismic Impact Zone Demonstration is attached to this document.

In accordance with 40 CFR §257.63 the results of the engineering assessment performed on the surface impoundment have determined that the unit meets the appropriate factors of safety and is structurally sound. These factors of safety indicate the surface impoundments' structural components have been designed to resist the maximum horizontal acceleration in lithified earth material.

Rest of Page Left Blank Intentionally



AECOM 330-836-9111 tel
564 White Pond Drive 330-836-9115 fax
Akron, OH 44320-1100
www.aecom.com

4.0 CERTIFICATION

I, Nicholas Golden, being a Professional Engineer in good standing in the State of Kentucky, do hereby certify, to the best of my knowledge, information, and belief that the information contained in this certification has been prepared in accordance with generally accepted engineering practices; that the information contained herein is accurate as of the date of my signature below; and that Slag Ponds 2A and 2B and Slag Stilling Pond 2C meet the requirements of 40 CFR § 257.63(a).

SIGNATURE

DATE

10/15/18

ADDRESS:

AECOM
564 White Pond Drive,
Akron, Ohio 44320

TELEPHONE: (330)-836-9111

ATTACHMENTS: Engineer's Certification of Seismic Impact Zone Demonstration (40 CFR §257.63) for Coal Combustion Residuals (CCR) Existing Surface Impoundments – Slag Ponds 2A and 2B and Slag Stilling Pond 2C



COAL COMBUSTION PRODUCT DISPOSAL PROGRAM

TENNESSEE VALLEY AUTHORITY – PARADISE FOSSIL PLANT
SLAG PONDS 2A AND 2B, AND SLAG STILLING POND 2C
DRAKESBORO, KENTUCKY

ENGINEER'S CERTIFICATION OF SEISMIC IMPACT ZONE DEMONSTRATION (40 CCR §257.63) FOR COAL COMBUSTION RESIDUALS (CCR) EXISTING SURFACE IMPOUNDMENTS

Prepared for



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

October 12, 2018 – Rev 0

Prepared by





TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
1.1	Objective.....	1
1.2	Rule Requirements	1
1.3	Site Description.....	1
2.0	DEMONSTRATION	3
2.1	Site Stratigraphy and Geologic Setting.....	3
2.2	Seismic Events	3
2.3	Structural Analysis	3
	2.3.1 Spillway Structural Integrity	3
	2.3.2 Seismic Factor of Safety.....	4
3.0	CONCLUSIONS	5
4.0	REFERENCES.....	6

FIGURES

Figure 1: TVA PAF Site Location

Figure 2: Site Overview

Figure 3: Slag Ponds 2A and 2B and Slag Stilling Pond 2C Critical Cross-Sections

TABLES

Table 1: Slag Ponds Seismic Safety Factors for Critical Cross Sections



1.0 INTRODUCTION

1.1 OBJECTIVE

The purpose of this demonstration is to evaluate compliance with 40 CFR §257.63 of the Environmental Protection Agency Final Coal Combustion Residual Rule (EPA Final CCR Rule). This Seismic Impact Zone Demonstration is based on existing documentation such as construction drawings, record drawings, and any other pertinent data and/or investigations to support historic conditions and operations at Slag Ponds 2A and 2B and Slag Stilling Pond 2C at the Tennessee Valley Authority (TVA) Paradise Fossil Plant (PAF).

1.2 RULE REQUIREMENTS

40 CFR §257.63(a) *New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located in seismic impact zones unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that all structural components including liners, leachate collection and removal systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site.*

40 CFR §257.63(b) *The owner or operator of the CCR unit must obtain a certification from a qualified professional engineer stating that the demonstration meets the requirements of paragraph (a) of this section.*

40 CFR §257.63(c) *The owner or operator of the CCR unit must complete the demonstration required by paragraph (a) of this section by the date specified in either (c)(1) or (2) of this section*

40 CFR §257.63(c)(1) *For an existing surface impoundment, the owner or operator must complete the demonstration on later than October 17, 2018.*

1.3 SITE DESCRIPTION

PAF is located in Drakesboro, Kentucky along the west bank of the Green River and State Route 176. The plant sits inside the eastern border of Muhlenberg County as depicted below in **Figure 1**. Slag Ponds 2A and 2B and Slag Stilling Pond 2C are located in the northeast corner of PAF. The slag ponds are located directly east of the coal storage yard, west of the Green River, south of Red Water Pond 2, and north of the plant.

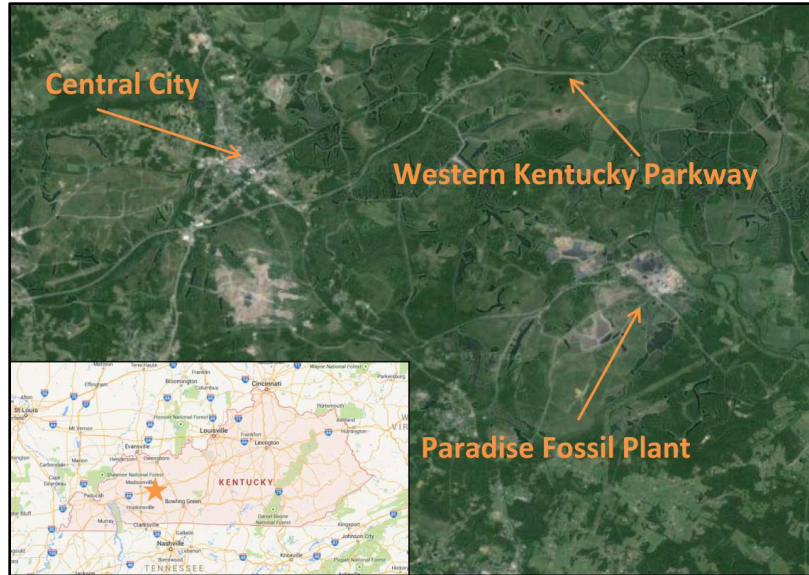


Figure 1. TVA PAF Site Location

Slag Ponds 2A and 2B and Slag Stilling Pond 2C serve as an ash pond management facility for the storage and settling of boiler slag. Influent to this impoundment consists of sluiced boiler slag, which flows into the southeastern portion of Slag Pond 2A via a series of ash inlets. Slag Ponds 2A and 2B also receive other process water streams from the plant and discharge from other ponds in the area such as the Red Water Ponds and Coal Yard Runoff Ponds. Water flows from Slag Pond 2A to Slag Pond 2B to Slag Stilling Pond 2C. Slag Stilling Pond 2C discharges to the Green River via Kentucky Pollutant Discharge Elimination System (KYPDES) permit no. KY0004201 at Outfall 002. **Figure 2** provides a current aerial of the site.



Figure 2. Site Overview



2.0 DEMONSTRATION

2.1 SITE STRATIGRAPHY AND GEOLOGIC SETTING

PAF lies within the Shawnee Hills section of the Interior Low Plateau Physiographic Province in Northwestern Kentucky and Carbondale Formation (TVA, Paradise CCR Management Operations Environmental Assessment).

The region is underlain by coal rich Pennsylvanian age bedrock formations. Strip mining operations have significantly altered the topography and geology within the vicinity of the plant and, as such, portions of the site are likely underlain by mine spoils. Geologic mapping indicates the plant and surrounding areas are underlain by the Sturgis and Carbondale Formations in general order of descending geology. The Sturgis Formation is described as consisting of interlayered medium- to coarse-grained micaceous sandstone, silty and clayey shale, coal, and underclay. The Carbondale Formation generally consists of cyclic sequences of fine-grained sandstone, sandy shale, coal, and silty underclay. Although not depicted on the geologic mapping, alluvial deposits are likely present along the banks of the Green River. The geologic mapping indicates this alluvium generally consists of gravel, sand, silt, and clay and may be as much as 90 feet thick.

2.2 SEISMIC EVENTS

The US Geological Survey (USGS) information and geologic studies carried out by TVA indicate that PAF and the surrounding area may be subject to minor seismic events. Seismic events affecting the central portion of western Kentucky, thus the plant, primarily emanate from two zones of earthquake activity – the New Madrid Seismic Zone of the central Mississippi Valley and the Wabash Valley Seismic Zone located along the border between Illinois and southwestern Indiana. Although the majority of the events emanating from these zones are too small to be felt at the surface, the Wabash Valley Seismic Zone has produced three earthquakes within the last 20 years with magnitudes of 5 or greater and the New Madrid Seismic Zone produced a series of four earthquakes between December 1811 and early February 1812 each exhibiting estimated magnitudes on the order of 7.0 to 8.0 (Stantec 2009).

2.3 STRUCTURAL ANALYSIS

2.3.1 SPILLWAY STRUCTURAL INTEGRITY

Water discharges from the Slag Pond Complex into the Green River through the east perimeter dike by way of three spillways located in Slag Stilling Pond 2C. The spillways contain 48" concrete vertical risers, each topped with an anti-vortex plate. The respective lengths of the spillway concrete vertical risers are 201 feet, 182 feet and 192 feet. The spillway foundation consists of a reinforced concrete pad measuring 6.5 feet x 6.5 feet x 1.5 feet. Topping each pad is a hollow reinforced concrete junction box having 1 foot thick walls measuring 6 feet x 6 feet x 4 feet. The junction box is encased in large diameter stone to approximately 1 foot below the riser elevation.

An analysis of the existing spillway structure was performed using the design earthquake for 2% exceedance in 50 years. The existing spillway is designed to resist the loading caused by the design seismic event. Therefore, the spillway structure at Slag Stilling Pond 2C meet the requirement of 40 CFR §257.63(a).

2.3.2 SEISMIC FACTOR OF SAFETY

AECOM performed a static safety evaluation for Slag Ponds 2A and 2B. Static and seismic slope stability of the system was evaluated. Slope stability analyses were performed for normal pool, flood pool, temporary loading, pseudo-static, and post-earthquake conditions at six cross sections. The design earthquake event that was simulated for the pseudo-static analysis has a probability of exceedance of 2% in 50 years, corresponding to a return period of approximately 2,475 years per the EPA Final CCR Rule requirements. For this analysis a peak ground acceleration value of 0.192 g was determined based on USGS mapping (PSH Degradation NEHRP BC Rock). This peak ground acceleration value exceeds the required seismic impact zone requirement set by the Final EPA CCR Rule of 0.1g.

AECOM performed a geotechnical evaluation for Slag Ponds 2A and 2B. Static and seismic slope stability of the system was evaluated. Slope stability analyses were performed for normal pool, flood pool, temporary loading, pseudo-static, and post-earthquake conditions at six cross sections, **Figure 3**.

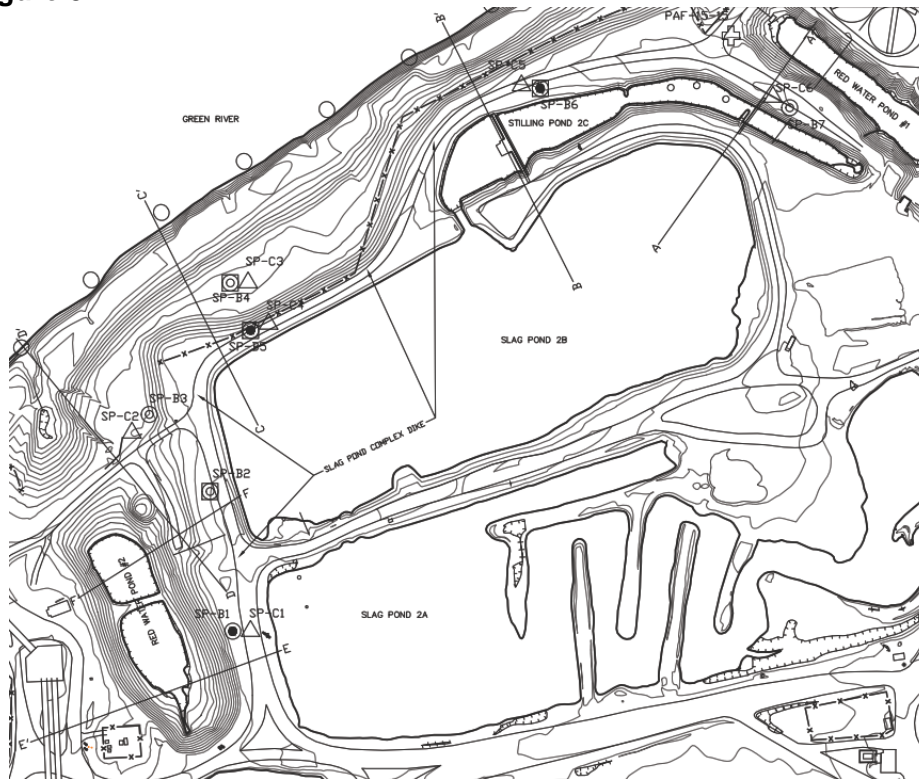


Figure 3. Slag Ponds 2A and 2B and Slag Stilling Pond 2C Critical Cross-Sections



The results pertinent to the seismic factor of safety and liquefaction analysis are summarized below in **Table 1**. The evaluation was performed in accordance with section 40 CFR §257.73(e) of the CCR Rule.

Table 1. Slag Ponds Seismic Safety Factors for Critical Cross Sections		
Critical Cross Section	EPA Criteria	Calculated FOS
A-A'	Seismic Factor of Safety (Pseudo-static stability)	1.53
	Liquefaction Factor of Safety (Post-earthquake stability)	1.89
B-B'	Seismic Factor of Safety (Pseudo-static stability)	1.27
	Liquefaction Factor of Safety (Post-earthquake stability)	1.67
C-C'	Seismic Factor of Safety (Pseudo-static stability)	1.19
	Liquefaction Factor of Safety (Post-earthquake stability)	1.98
D-D'	Seismic Factor of Safety (Pseudo-static stability)	1.29
	Liquefaction Factor of Safety (Post-earthquake stability)	1.42
E-E'	Seismic Factor of Safety (Pseudo-static stability)	1.21
	Liquefaction Factor of Safety (Post-earthquake stability)	1.42
F-F'	Seismic Factor of Safety (Pseudo-static stability)	1.59
	Liquefaction Factor of Safety (Post-earthquake stability)	2.94

These results meet or exceed the minimum required seismic factor of safety of 1.00 and liquefaction factor of safety of 1.20.

3.0 CONCLUSIONS

In accordance with 40 CFR §257.63, Slag Ponds 2A and 2B exceed the minimum Factors of Safety for seismic stability of the dikes. The existing surface water control systems have adequate stability to resist the maximum horizontal acceleration in lithified earth material for the site. Therefore, the site meets the requirements of 40 CFR §257.63.



4.0 REFERENCES

- 257-73(c) History of Construction at Paradise Fossil Plant Slag Ponds 2A and 2B, AECOM, 2016.
- 257-73(d) Structural Stability Assessment at Paradise Fossil Plant Slag Ponds 2A and 2B, AECOM, 2016
- 257-73(e) Safety Factor Assessment at Paradise Fossil Plant Slag Ponds 2A and 2B, AECOM, 2016.
- Geotechnical Exploration and Analysis at Paradise Fossil Plant, AECOM, 2016.
- Paradise CCR Management Operations Environmental Assessment, Tennessee Valley Authority, 2017.

ATTACHMENTS
Structural Analysis of Existing Spillways

JOB TITLE Paradise Coal Combustion Residuals
PROJECT/JOB NO. Slag Pond inlet CALCULATION NO. _____
COMPUTED BY 9th DATE 6/20/2018
VERIFIED BY _____ DATE _____
~~SCALE~~ 1/2500 yr Seismic Analysis SHEET NO. 1 OF 3

Summary of Results and analysis method

Results

Previous analysis indicated the existing structure would not meet stability requirements for a 1/2500 year extreme event Earthquake

The structure was modified as shown on sheets 2 & 2a for this analysis.

If modified in accordance with those sheets the structure meets requirements

SCALE _____ SHEET NO. 2 OF 3
Summary of Results of Analysis Method - c

The inlet structure was analyzed for stability for an earthquake with a probability of occurrence of 2% in 50 years. This corresponds to an earthquake with an annual recurrence interval of 1/2475 years. This is considered an extreme event.

The analysis was performed using the seismic Co-efficient method in general accordance with the procedure outlined in the USACE manual EM-1110-2100.

Peak acceleration was determined using the USGS Unified Hazard Design tool which yield a peak acceleration of 0.174. This was reduced to 2/3 of the effective Peak in accordance with section 4.7b of the above referenced manual.

Hydrodynamic effects were included using the Westergaard method in accord with section 4.7 b

USACE Manual EM 1110-2400 provided guidance for the design of "tower" structures. Because only 4' of this structure is above ground analysis as a "tower" is generally not warranted. Nevertheless to account for simultaneous orthogonal earthquake effects sliding forces & moments were increased by a factor of 1.3 in accordance with EM 1110-2400 section 4.6-3e

The factor of safety for sliding is taken as 1.3 in accordance with EM 1110-2100 Table 4.2 as required for the seismic coefficient method.

The allowable bearing pressure was taken as

$$\frac{q_{ult}}{2} \times 150\% = \frac{4}{2} \times 1.5 = 3 \text{ KSF} \text{ w/ } FS = \underline{\underline{1.33}}$$

Structure modification included in the analysis

1. Footing increased from 6.5x6.5 to 8.5x8.5
2. Upper Pipe Sections are secured w/ #4 reinforcing bars to the concrete base.

Reconsider the slag pond inlet per EM-1110-2-2100

(1) Assume 1/2500 year return interval for eq

Per EM-1110-2-2100 $K_R = 0.67$ (peak) = $0.67(0.174)$
 $= \underline{0.117}$ (seismic co-efficient)

(2) Consider the mass added affect using the Westergaard method

$$P_e = \frac{7}{12} K_f h^3 \omega^2 \times \text{structure width}$$

where $K_f = \text{the seismic coeffic} = a/g = 0.184$

$$P_e = \frac{7}{12} (0.117) (5)^3 (0.0624) \times 6' \underline{3.19^k} \checkmark$$

height of application $0.4(h) = 0.4(5) = 2'$ above the ground

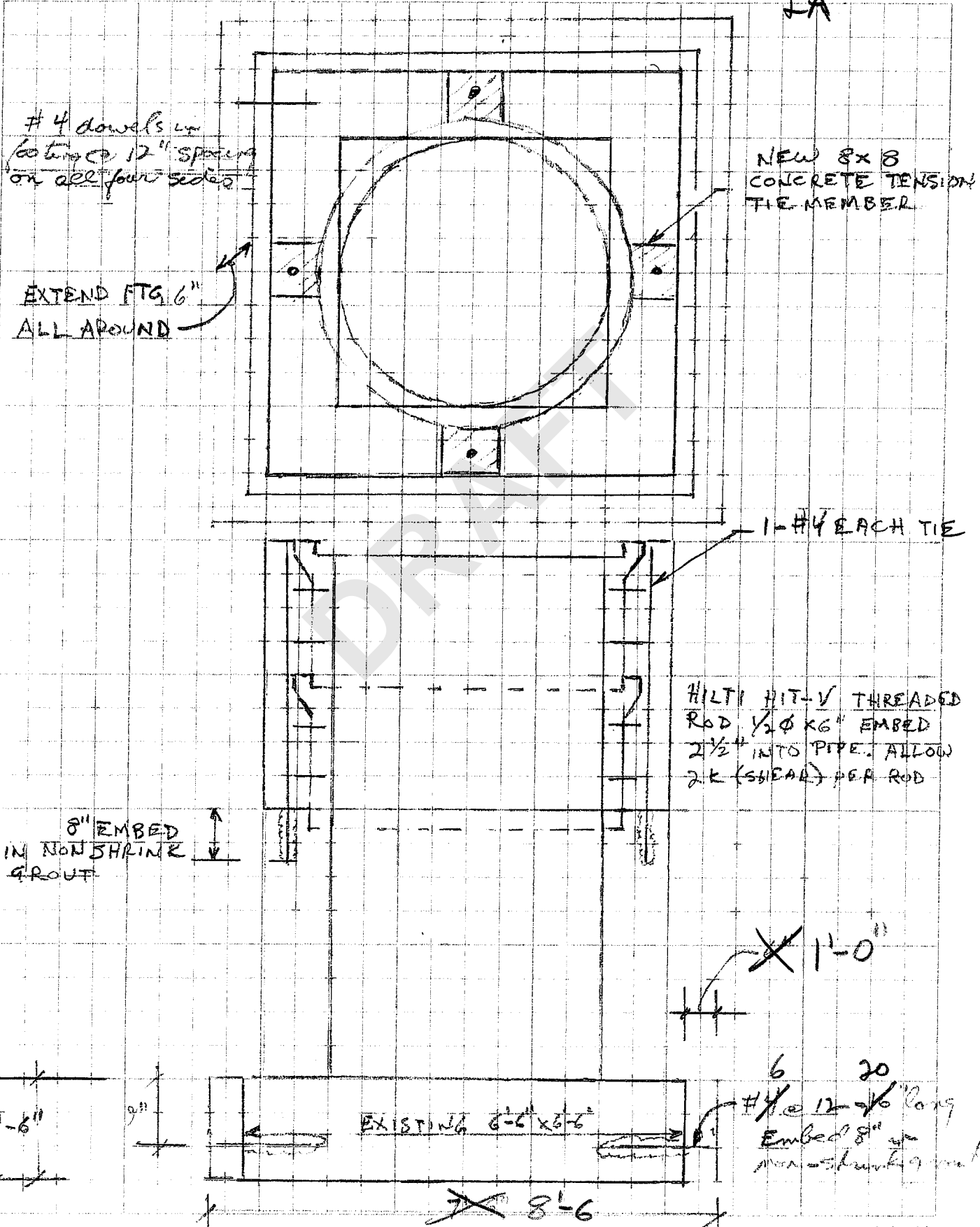
then apply at a $(403)^{404}$
 $\text{so } 403 = 396.5 = \underline{\underline{6.5'}}$ above bottom of ftg
7.5'

(3) For EQ use use ΣV neglecting uplift

$$E_q = (16.25 + 12.00 + \overset{47.4?}{2.73} + 2 + 14.5) 0.117 = 5.55^k \rightarrow$$

Provide FSS Sliding > 1.3
 FSO Resultant within the base
 Bearing Pressure 150% of usual
 usual $2/150 = 1.33$
 $q_{max} = q_{ult} / 1.33 = 3 \text{ KSF}$

2A



Determine the height \bar{h} of the center of mass of the inlet structure above the base of the footing

$$\bar{h} = \frac{\overset{\text{Skimmer}}{2^k (9.5')} + \overset{\text{Resero}}{2.73^k (7.5')} + \overset{\text{Box}}{12^k (3.5')} + \overset{\text{Base}}{16.25^k (0.25)} + \overset{\text{Earth}}{14.5 (2.75)}}{2 + 2.73 + 12 + 16.25 + 14.5}$$

$$\bar{h} = \frac{133.54}{47.48} = 2.81'$$

DRAFT

	HORZ	VERT	ARM	M ₀	M _p
W ₁		✓ 16.25 ↓	4.25		69.06
W ₂		✓ 12.00 ↓	4.25		51.0
W ₃		✓ 2.73 ↓	4.25		11.60
W ₄		✓ 2.00 ↓	4.25		8.50
EV		✓ 14.50 ↓	4.25		61.6
UF		20.05 ↑	4.25	85.25	
EQ	5.55		2.81	19.605	
			7.5	23.93	
mass added	3.19		6.5	20.73 ↓	
	8.74 ←	27.43		121.5	201.78
				124.6	
				F ₅₀ = 1.66 > 1 ok	
				$F_{55} = \frac{0.55(27.43)}{8.74} = 1.72 > 1.3 \text{ (ok)}$	
				$\bar{h} = \frac{201.78 - 124.6}{27.43} = 2.93$	
				$e = \frac{8.5 - 2.93}{2} = 1.32$	
				$q_{max} = \frac{2(27.43)}{3(8.5 - 1.44)(8.5)} = 0.77 < 3 \text{ ok}$	
				$q_{min} = \frac{27.43}{8.5^2} + \frac{27.43(1.32)}{102.35} = 0.37 + 0.35$	
				$S_x = \frac{(8.5)(8.5^2)}{6} = 102.35$	
				$q_{max} = \frac{0.77}{0.77} \quad q_{min} = 0.02 \quad q_{max} < 3 \text{ KSF (ok)}$	

To account for co-incident occurrences of orthogonal earthquake forces assume

$$E = E_x + 0.3 E_y \quad \text{because of symmetry}$$

$$E = 1.3 E_x \quad \text{applied to Shears \& Moments} \quad \text{See EM 110-2400}$$

$$\text{then } FSS = \frac{0.55 (27.43)}{(1.3)(8.74)} = 1.32 > 1.1 \text{ OK}$$

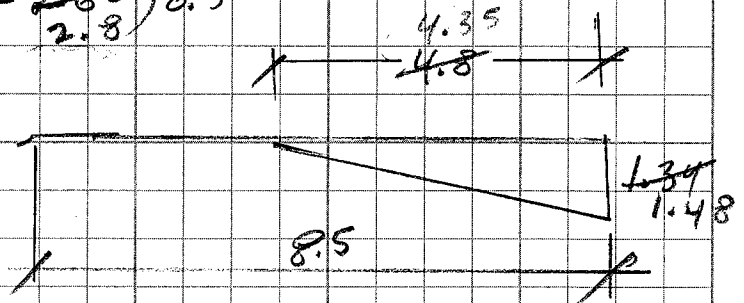
$$\checkmark M_o = 1.3 (121.5) = 157.95 \quad FSO = \frac{201.78}{157.95} = 1.3 > 1 \text{ OK}$$

ie resultant is within the base

$$\bar{N} = \frac{M_{net}}{P} = \frac{201.78 - 157.95}{27.43} = 1.60 \text{ 1.45}$$

$$e = 8.5/2 - 1.6 = 2.65 \text{ 2.8}$$

$$g = \frac{2 (27.43)}{3 \left(\frac{8.5}{2} - 2.65 \right) 8.5} = 1.34 < 3 \text{ (OK)}$$



check overturning of the Top (Pipe) Sections

$$Eq_1 = 2(0.117)(1.3) = 0.304 \quad \text{arm} = 4'$$

$$Eq_2 = 2.73(0.117)(1.3) = 0.41 \quad \text{arm} = 2'$$

$$\text{Mass added} = 3.19 \quad \text{arm} = 2'$$

$$\Sigma M_o = 0.304(4) + 0.41(2) + 3.19(2) = 8.42 \text{ K-FT}^*$$

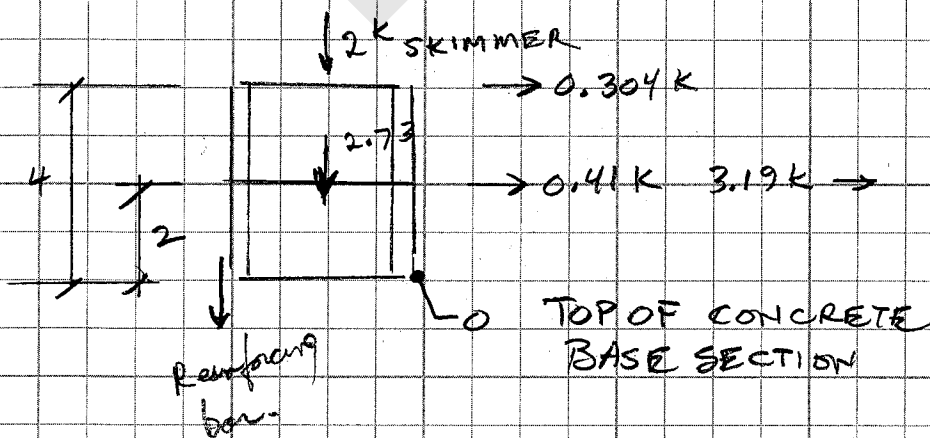
$$\Sigma M_R = \frac{(2 + 2.73)(4.67)}{2} = 11.04 > 8.42 \text{ OK}$$

also add 1 #4 $A = 0.31$

$$P = 0.31(24) = 7.4 \text{ K}$$

$$\text{Then } M_R = 11.04 + 7.4(2.33) = 28.4 >> 8.42$$

OK



* Previous 1/1000 2 mode 7.23

Previous 1/1000 Finite Element 10.63

1/6

Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g. the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

Input

Edition

Dynamic: Continuous U.S. 2014 (v4.1.1)

Spectral Period

Peak ground acceleration

Latitude

Decimal degrees

37.2684

Time Horizon

Return period in years

2475

Longitude

Decimal degrees, negative values for western longitudes

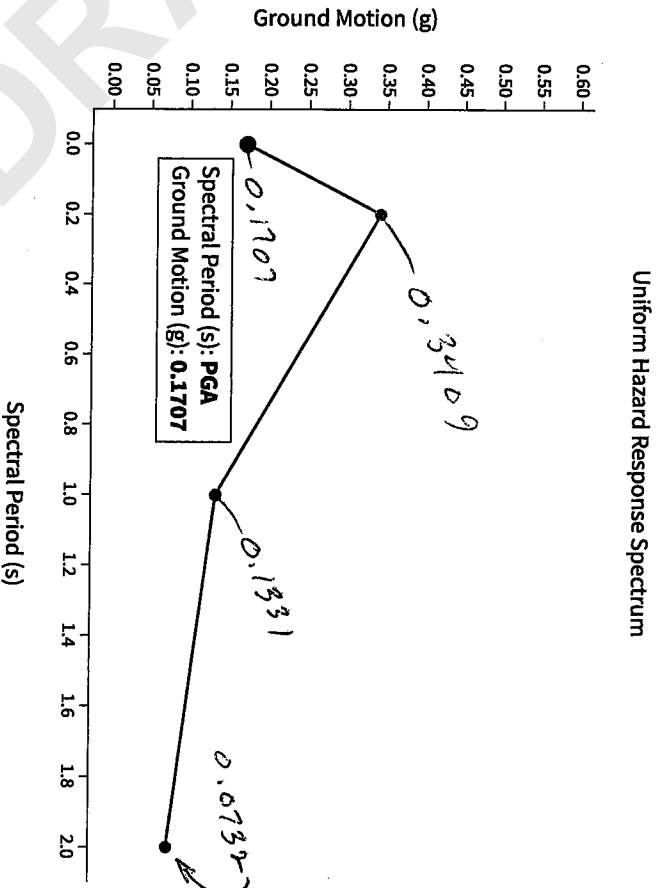
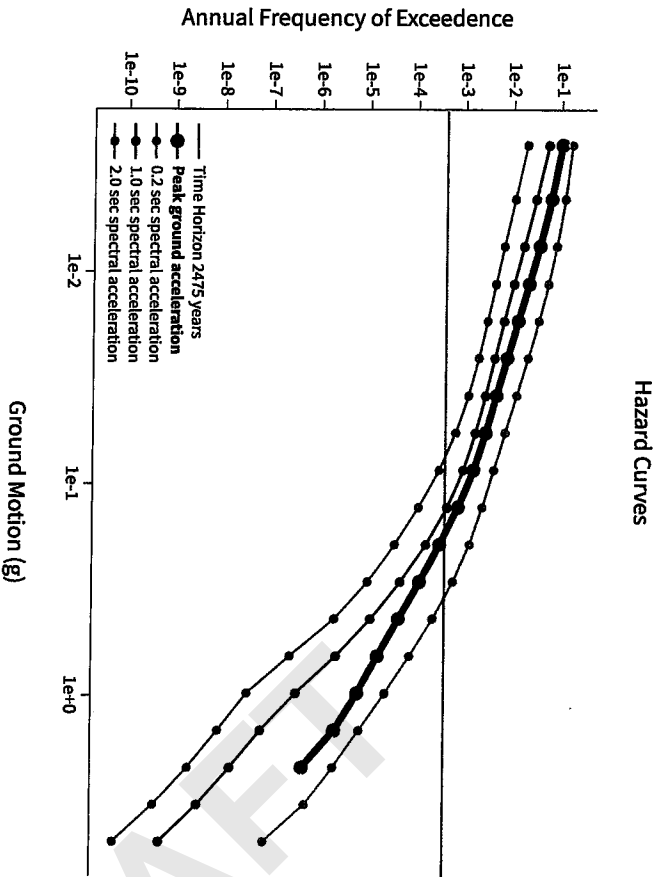
-86.98389

Site Class

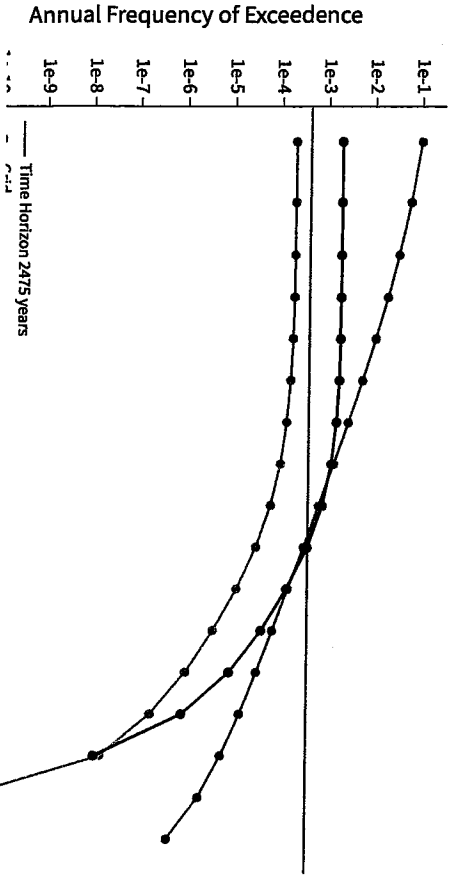
760 m/s (B/C boundary)

Hazard Curve

2/6

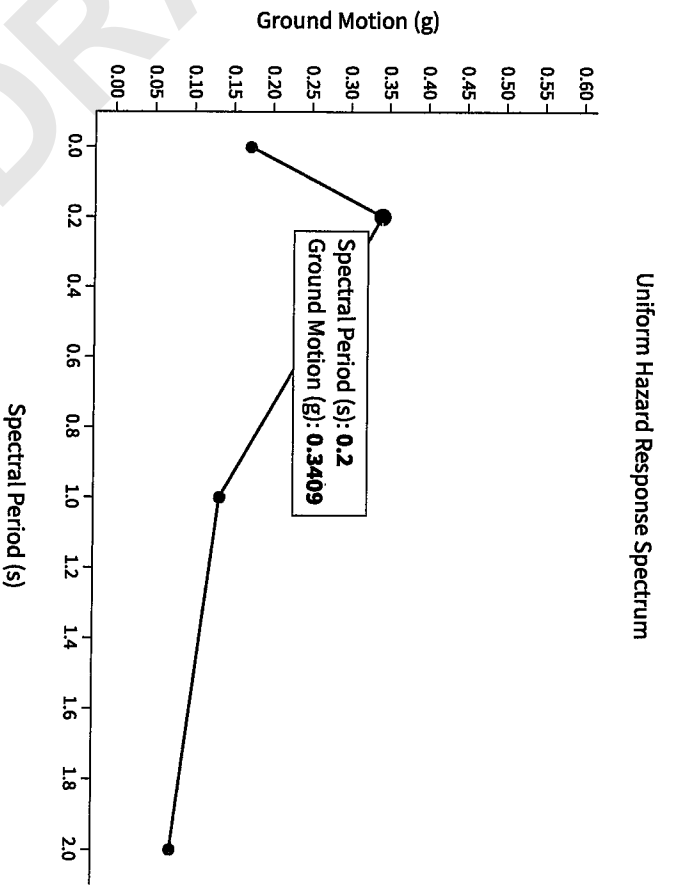
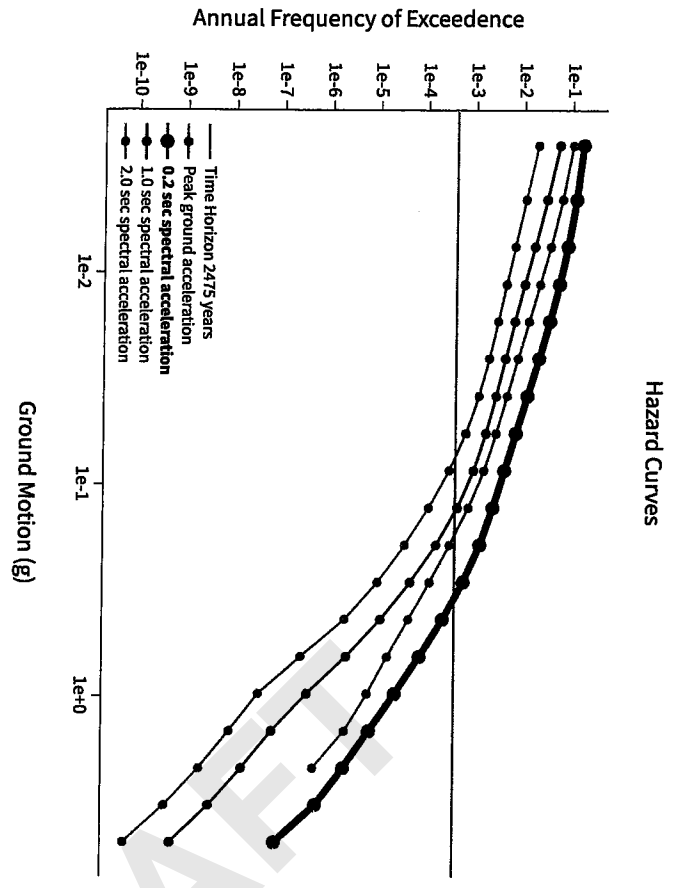


Component Curves for Peak ground acceleration

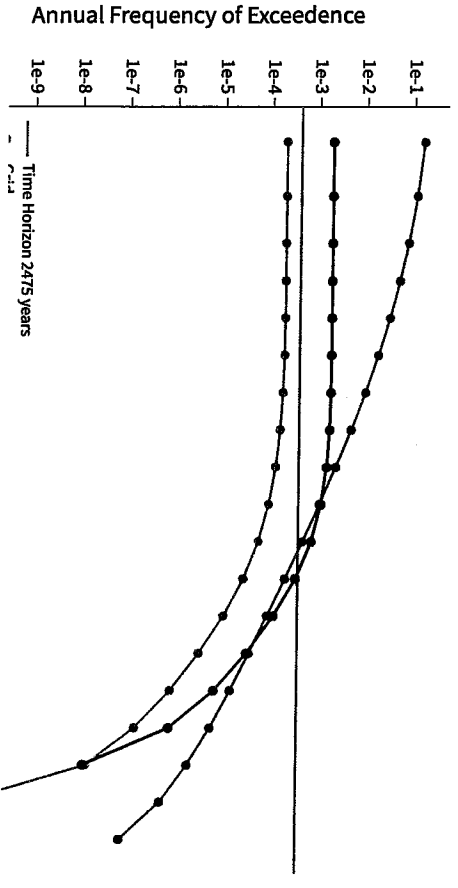


Hazard Curve

3/c

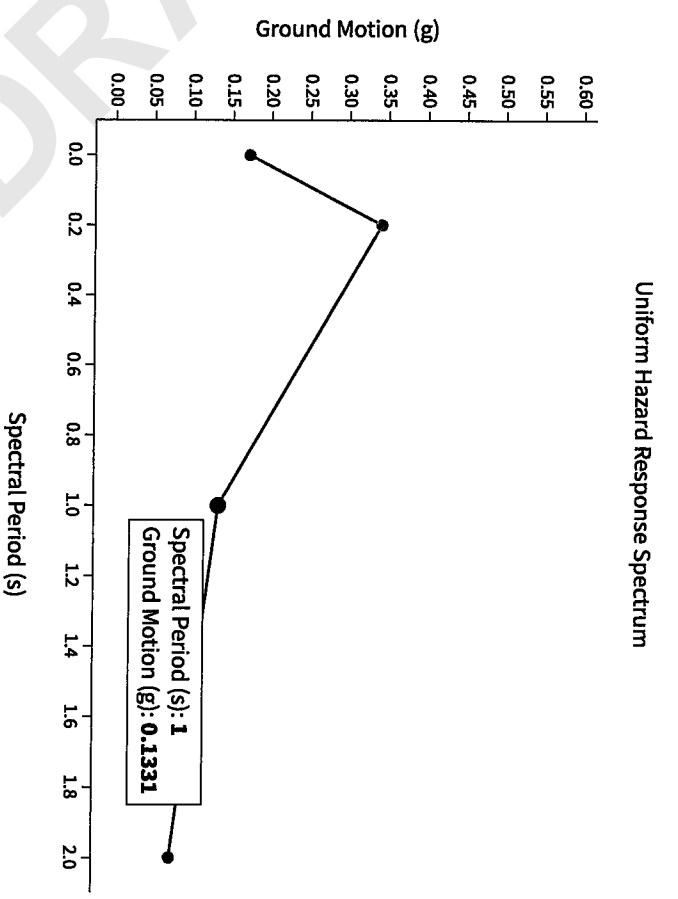
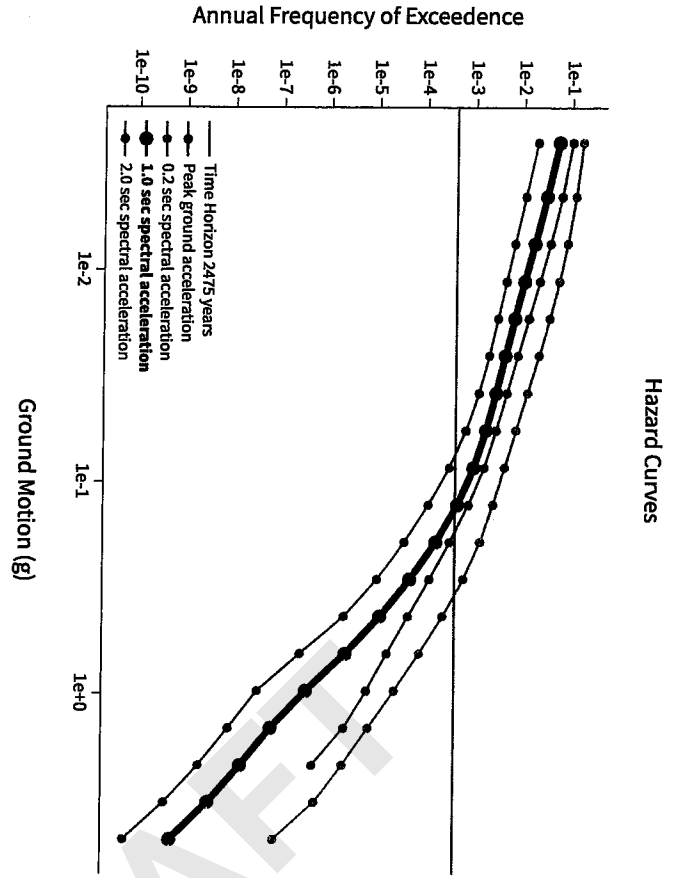


Component Curves for 0.2 sec spectral acceleration

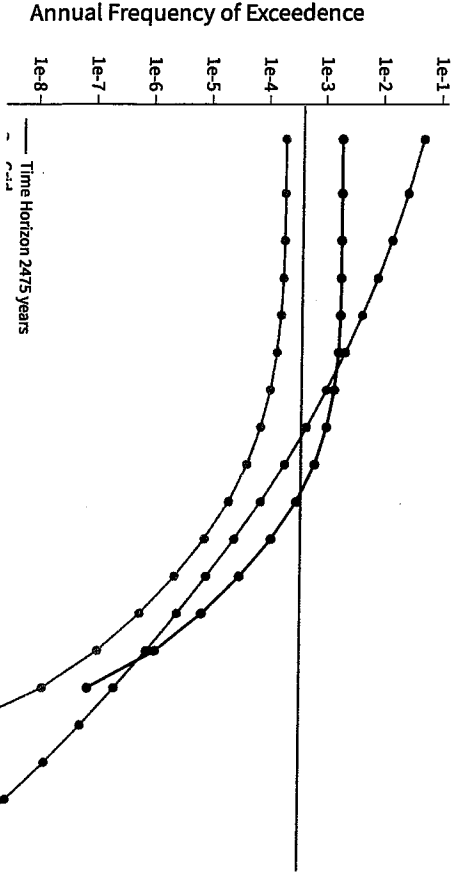


Hazard Curve

4/6



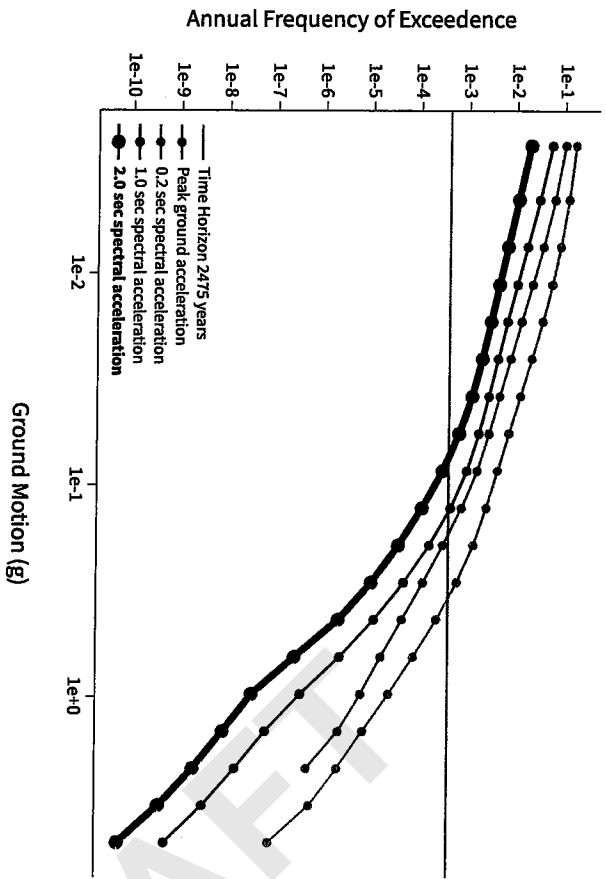
Component Curves for 1.0 sec spectral acceleration



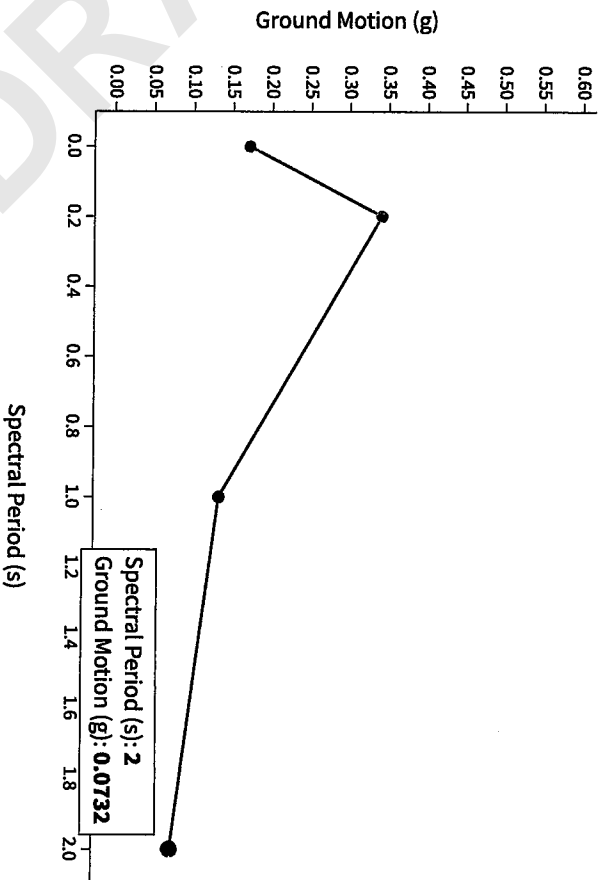
5/6

Hazard Curve

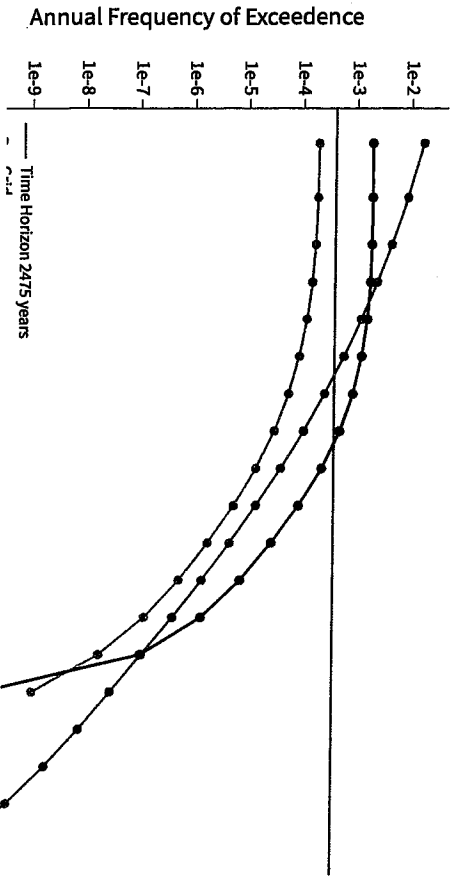
Hazard Curves



Uniform Hazard Response Spectrum



Component Curves for 2.0 sec spectral acceleration



**US Seismic Hazard
2% in 50 years PGA**

Hazard (%g)

0-2

3-4

4-8

8-10

10-14

14-20

20-30

30-40

40-50

> 50

Peaks

State or other

Trans form

Divergent

Others

Counties

Pardiss

200

EVANSVILLE

100

100

2014 Kentucky Hazard

6/1

