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MEMORANDUM

TO:	Rhonald Hasenyager, P.G., R.G.
FROM:	Kipkoech Chepkoit, Ph.D., P.E.
DATE:	07/16/2019
SUBJECT:	18E0022A – Seismic Evaluation of Emery Pond

1 Introduction

The area currently occupied by Emery pond will be closed by removal of CCR and retrofitted to meet current Federal and State of Illinois regulations. The retrofitted pond will be designed to meet the liner criteria for new CCR surface impoundments of 40 CFR 257.72 and the structural integrity criteria of 40 CFR 257.74. The retrofit will require installation of a composite liner system meeting the federal requirements of 40 CFR 257.71. The retrofitted pond will be permitted and operated as a water treatment device under 35 IAC Section 309 Subpart B and also as a CCR surface impoundment under 40 CFR 257.

This memo presents seismic evaluation to document compliance with pertinent sections of 40 CFR 257 as stated above. The seismic impact zone is based on information obtained from geotechnical exploration performed in May 2019 and other existing reports.

2 Site Seismicity

Marion power plant is located in an area of relatively high seismic activities. A record number of confirmed earthquakes of relatively high intensity have been recorded within 100 miles of the site. The figure below shows a map of all the fault zones within 100 mile radius of the project site.

The New Madrid fault zone, which is the primary region of seismic activity for the mid-continental region, is located approximately 80 miles southwest of Marion power plant. The fault zone in this area is characterized by high angle normal faults forming a complex horst and graben system. The strongest recorded earthquakes resulting from this fault zone occurred in December 1811 through February 1812, with three principal earthquakes of estimated Intensity XI on the Modified Mercalli Scale.

Another possible source of seismic activity is the St. Genevieve fault zone, which extends northwest/southeast from southwestern Illinois towards St. Genevieve County, Missouri. Several seismic events of body wave magnitude (m_b) 4.5 to 5.8 have been recorded near this fault zone.

The Wabash Valley Fault System is a tectonic region located in the Midwest of the United States, centered on the valley of the lower Wabash River, along southern Illinois and southwestern Indiana. This fault system is approximately 85 miles northeast of Marion power plant. The fault system consists of vertically oriented faults deeply buried under layer of sediment. This zone has been proven to have had earthquake for the last 20,000 years, with geologic evidence that they may have been as strong as 7.0–7.5 or greater on the Richter magnitude scale.

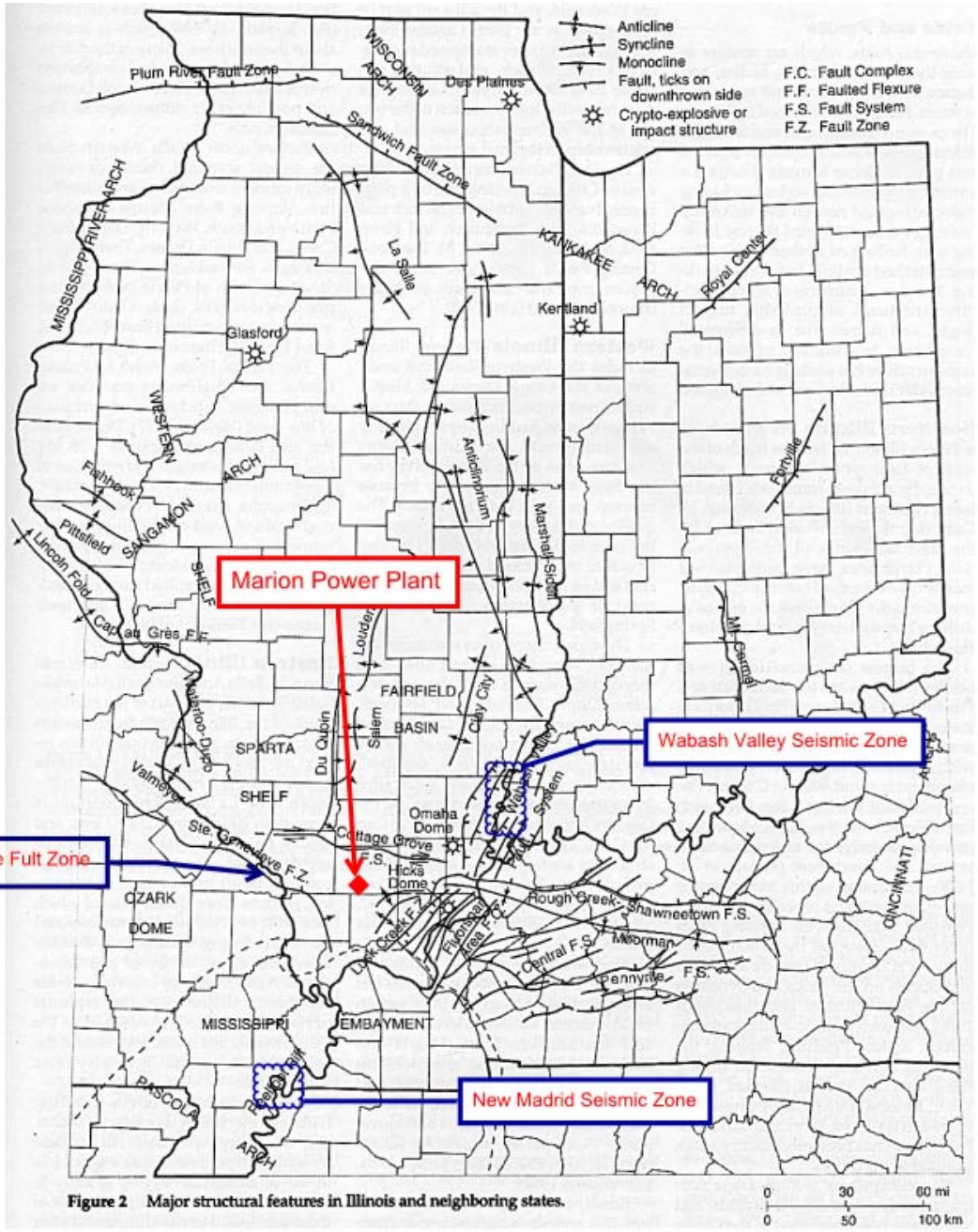


Figure 2 Major structural features in Illinois and neighboring states.

3 Evaluation Approach

The approach of evaluation is per MSHA Engineering Manual (Chapter 7) and existing literature. In brief the steps of approach are:

- Develop subsurface profile based on soil boring logs
- Characterize the subsurface material as “sand-like” or “clay-like” from field and laboratory testing
- Obtain earthquake ground parameters (USGS Earthquake Hazard Tools)
- Evaluate if the design earthquake will trigger a strength loss in sand-like or clay-like materials
- Evaluate seismic stability using the appropriate post-earthquake strength parameters
- Evaluate permanent deformations

4 Summary Design Soil Parameters

Table below presents summary of design soil parameters are based on visual description of the soils, field test results, lab test results and engineer's experience and knowledge of the site geology.

Material	Moist Unit Weight (pcf)	Undrained		Drained		Material Characterization
		Cohesion (ksf)	Friction Angle (°)	Cohesion (ksf)	Friction Angle (°)	
Ash Fill[1]	83	1.066	---	---	30	Clay-like
Compacted Fill	120	1.0	---	0.05	30	Clay-like
Structural Fill	120	---	30	---	30	Sand-like
Clay/Clayey Silt[2]	120	0.875	26.5	0.085	35	Clay-like
Sandstone	130	5.0	---	5.00	---	NA
[1]Soil parameters based on triaxial UU test [2]Soil parameters based on triaxial CU test						

In addition the predominant soil material across the site, clay and/or clayey-silt had the following soil index parameters:

- Average fine content greater than 80%.
- Plasticity index varying from 10 to 15
- Liquidity index between -0.364 and 0.253

Given the subsurface material encountered, it is concluded the site is not prone to liquefaction.

5 Earthquake Design Parameters

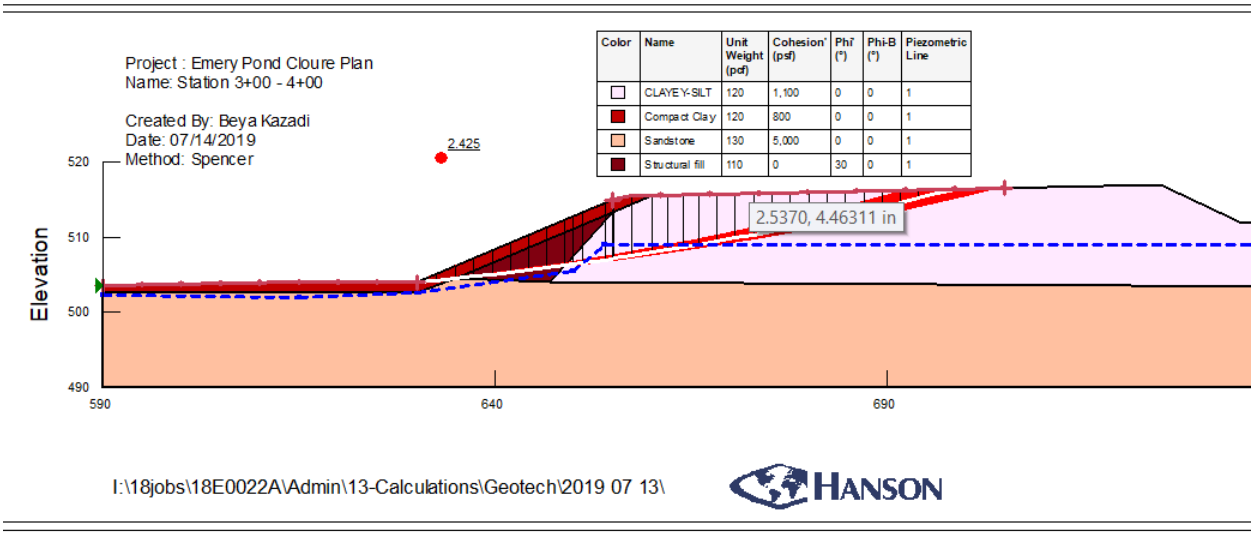
Seismic zones, which represent areas of the United States with the greatest seismic risk, are mapped by the U.S. Geological Survey (USGS) and readily available for the U.S. http:/earthquake.usgs.gov/hazards/apps/) and commonly used to determine the maximum horizontal acceleration (MHA) in lithified earth material to evaluate if a site is located in a seismic impact zone.

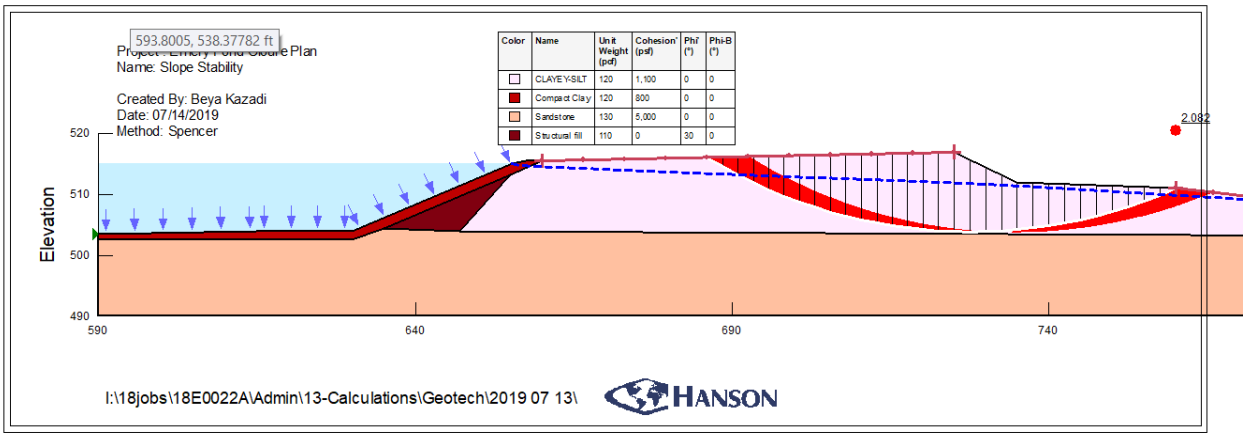
Using the site latitudes and longitudes in the USGS (2014) seismic hazard map tool, a Peak Ground Acceleration (PGA) of 0.507g is calculated at the B-C boundary (firm rock) in the USGS maps for 2475 years return period (98% or greater probability that the acceleration will not be exceeded in 50 years). This PGA is due to earthquake magnitude of 7.5. The USGS-generated MHA indicates that the site is within a seismic impact zone (>0.1 g). Therefore, the Emery Pond site should be considered to be in a seismic impact zone for this evaluation. PGA based on IBC 2015 was determined to be 0.584g from the USGS website. This takes into account Site Class D and maximum considered earthquake (MCE).

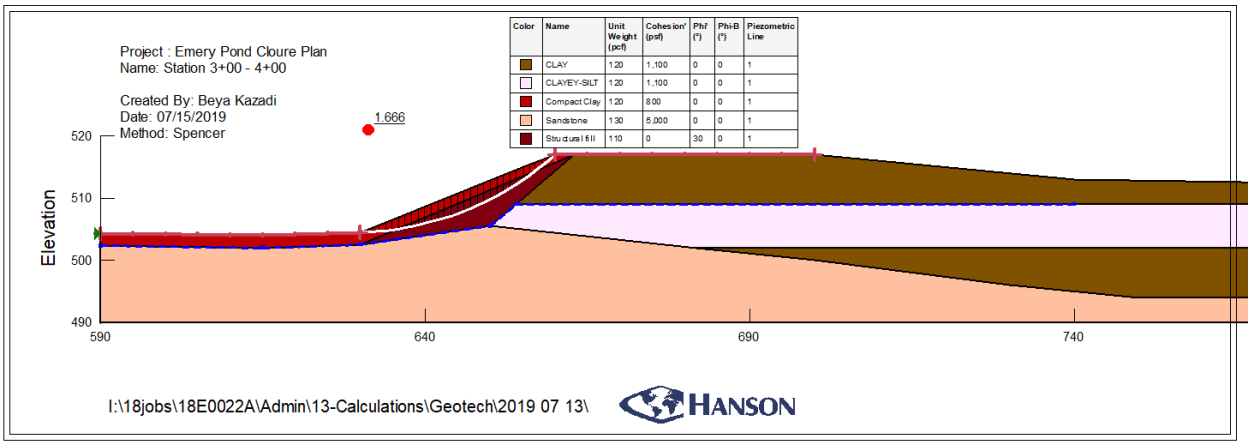
6 Slope Stability Results and Conclusion

Post-earthquake slope stability analyses was performed with 80% peak undrained strength in Ash Fill, Compacted Clay, and Clay/Clayey-Silt. The strength parameters of the other layers remain the same based on SPT blow count assessment. Upstream and downstream slopes were analyzed. Upstream/impound slopes stability was analyzed assuming empty pond (critical condition) and downstream slope stability was analyzed assuming the pond is filled to El. 515. The upstream/impound slope results indicate factor of safety from 1.44 to 2.43. The downstream slope results indicate factor of safety from 1.23 to 2.08. These values exceed the required minimum seismic factor of safety of 1.2.

Given above post-earthquake factors of safety, deformations are considered acceptably small.






Project : Emery Pond Cloure Plan
Name: Station 3+00 - 4+00
Created By: Beya Kazadi
Date: 07/15/2019
Method: Spencer
1.666
Color | Name | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) | Piezometric Line
CLAY | 120 | 1,100 | 0 | 0 | 1
CLAYEY-SILT | 120 | 1,100 | 0 | 0 | 1
Compact Clay | 120 | 800 | 0 | 0 | 1
Sandstone | 130 | 5,000 | 0 | 0 | 1
Structural fill | 110 | 0 | 30 | 0 | 1
Elevation
520
510
500
490
590
640
690
740
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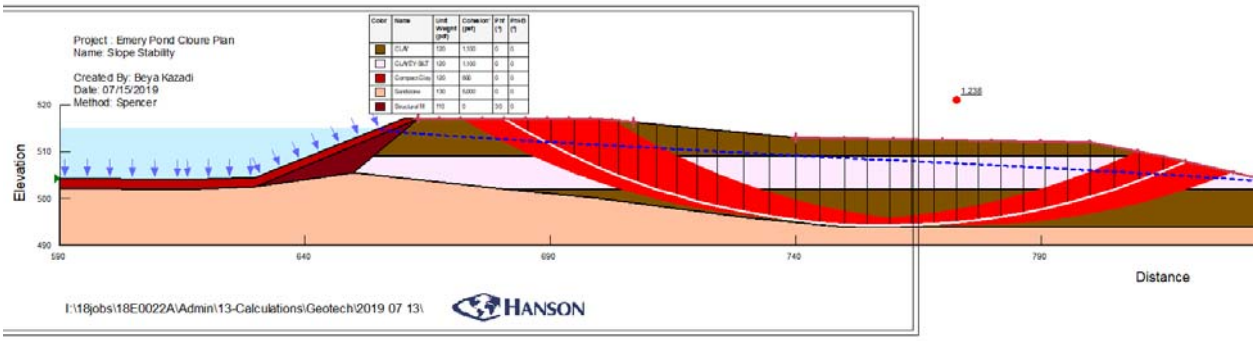
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Name: Slope Stability
Created By: Beya Kazadi
Date: 07/15/2019
Method: Spencer
1.238
Elevation
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590
640
690
740
790
Distance
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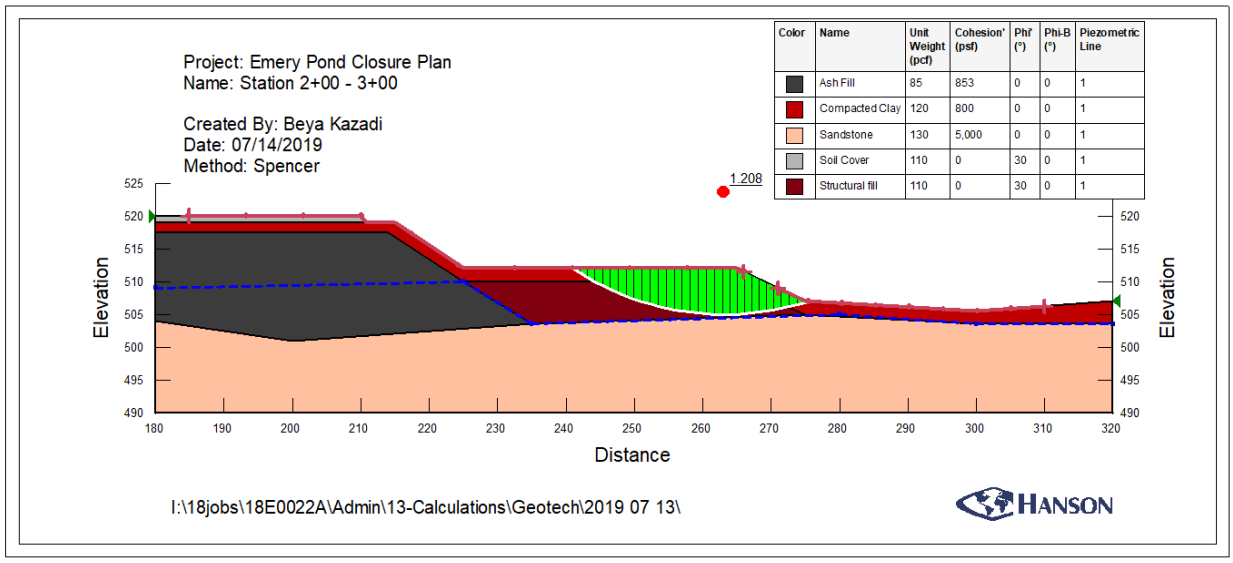
Project: Emery Pond Closure Plan
Name: Station 2+00 - 3+00
Created By: Beya Kazadi
Date: 07/14/2019
Method: Spencer
1.208
Color | Name | Unit Weight (pcf) | Cohesion' (psf) | Phi' (°) | Phi-B (°) | Piezometric Line
Ash Fill | 85 | 853 | 0 | 0 | 1
Compacted Clay | 120 | 800 | 0 | 0 | 1
Sandstone | 130 | 5,000 | 0 | 0 | 1
Soil Cover | 110 | 0 | 30 | 0 | 1
Structural fill | 110 | 0 | 30 | 0 | 1
Elevation
525
520
515
510
505
500
495
490
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
Distance
I:\18jobs\18E0022A\Admin\13-Calculations\Geotech\2019 07 13\
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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: Conterminous U.S. 2014

Spectral Period

Peak ground acceleration

Latitude

Decimal degrees

37.618512

Time Horizon

Return period in years

2475

Longitude

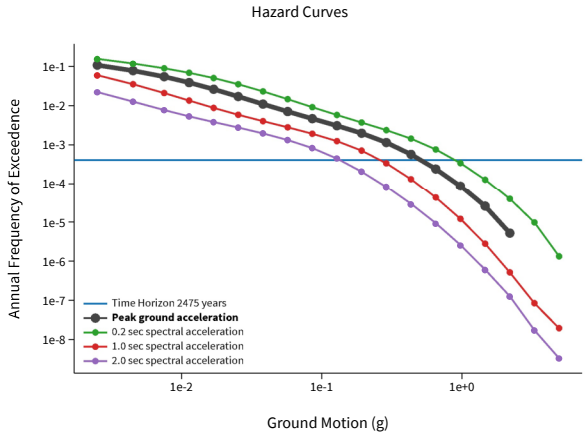
Decimal degrees, negative values for western long…

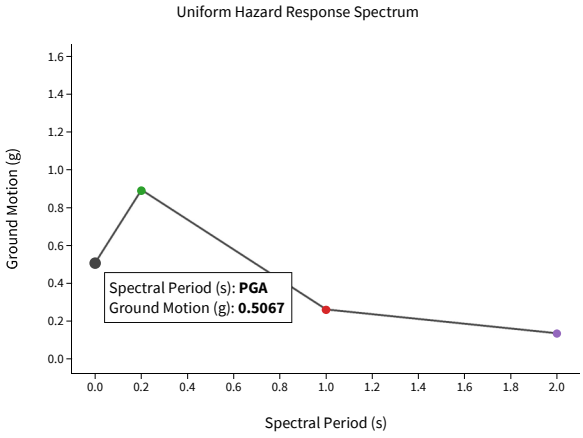
-88.953743

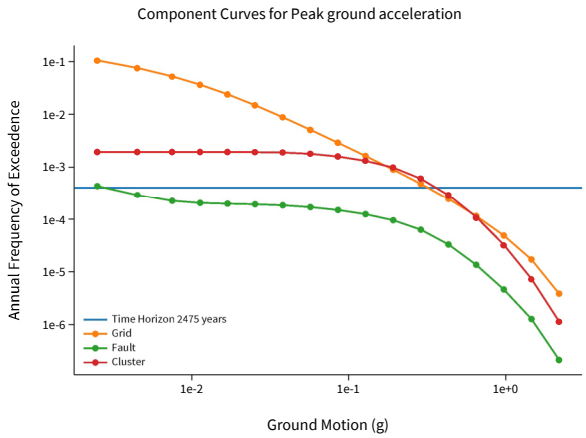
Site Class

760 m/s (B/C boundary)

Hazard Curve





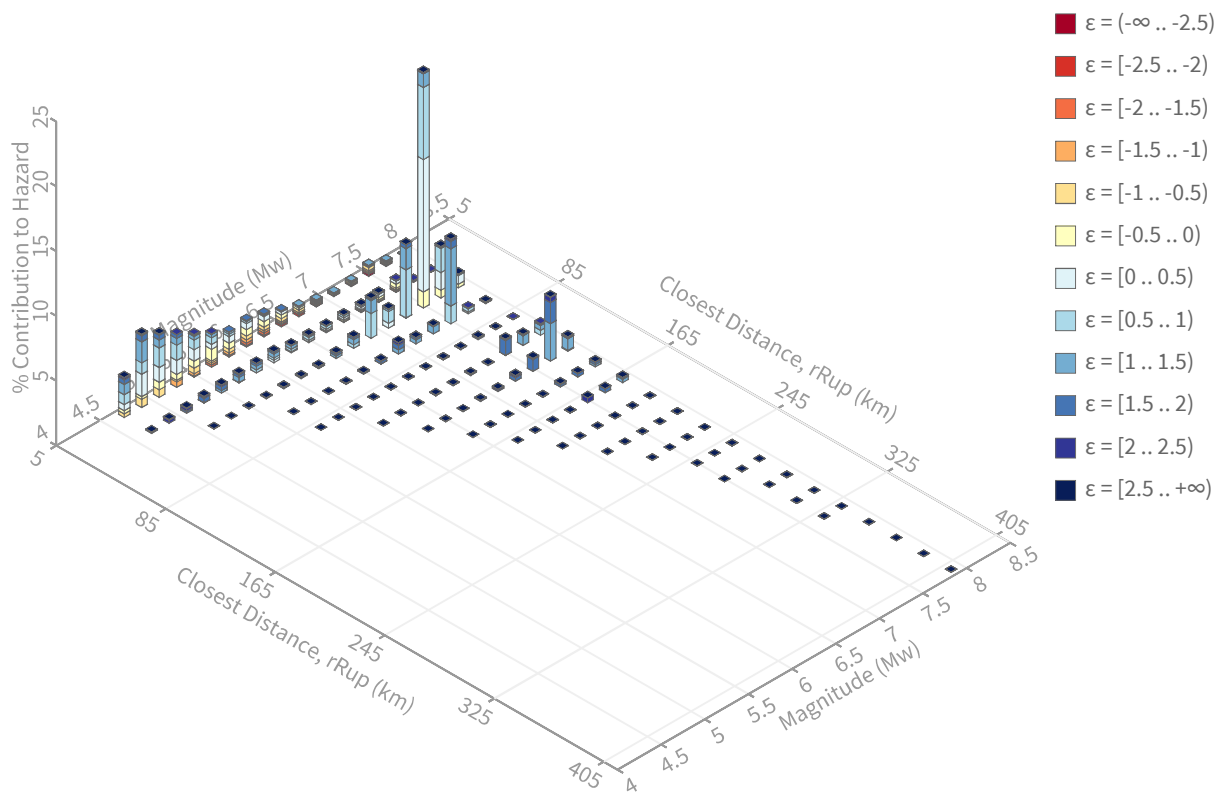


View Raw Data

Deaggregation

Component

Total



Summary statistics for, Deaggregation: Total

Deaggregation targets

Return period: 2475 yrs
Exceedance rate: 0.0004040404 yr^{-1}
PGA ground motion: 0.50670301 g

Recovered targets

Return period: 2482.7409 yrs
Exceedance rate: 0.00040278066 yr^{-1}

Totals

Binned: 100 %
Residual: 0 %
Trace: 0.56 %

Mean (for all sources)

r: 46.75 km
m: 6.73
ε_0: 0.65 σ

Mode (largest r-m bin)

r: 44.26 km
m: 7.52
ε_0: 0.4 σ
Contribution: 18.17 %

Mode (largest ε_0 bin)

Deaggregation Contributors

Source Set ↳ Source	Type	r	m	ε_0	lon	lat	az	%
SSCn New Madrid	Cluster							31.10
NMFS RLME 4		53.11	7.45	0.54	89.020°W	37.270°N	188.60	7.83
NMFS RLME 1		101.48	7.58	1.36	89.288°W	36.995°N	203.19	5.49
NMFS RLME 7		51.59	7.44	0.52	89.020°W	37.270°N	188.60	5.11
NMFS RLME 3		53.10	7.45	0.54	89.020°W	37.270°N	188.60	3.35
NMFS RLME 5		101.24	7.56	1.37	89.288°W	36.995°N	203.19	3.34
NMFS RLME 2		101.49	7.58	1.36	89.288°W	36.995°N	203.19	2.35
NMFS RLME 8		51.58	7.44	0.52	89.020°W	37.270°N	188.60	2.19
NMFS RLME 6		101.25	7.56	1.37	89.288°W	36.995°N	203.19	1.43
SSCn Fixed Smoothing Zone 6 (opt)	Grid							15.45
PointSourceFinite: -88.954, 37.731		12.75	5.51	0.46	88.954°W	37.731°N	0.00	4.29
PointSourceFinite: -88.954, 37.686		8.75	5.33	0.12	88.954°W	37.686°N	0.00	3.62
PointSourceFinite: -88.954, 37.641		5.56	5.23	-0.30	88.954°W	37.641°N	0.00	3.13
PointSourceFinite: -88.954, 37.776		16.82	5.73	0.66	88.954°W	37.776°N	0.00	1.51
PointSourceFinite: -88.954, 37.821		20.83	5.95	0.76	88.954°W	37.821°N	0.00	1.26
USGS Fixed Smoothing Zone 1 (opt)	Grid							14.62
PointSourceFinite: -88.954, 37.731		12.81	5.49	0.49	88.954°W	37.731°N	0.00	4.23
PointSourceFinite: -88.954, 37.686		8.77	5.31	0.13	88.954°W	37.686°N	0.00	3.59
PointSourceFinite: -88.954, 37.641		5.56	5.22	-0.29	88.954°W	37.641°N	0.00	3.11
PointSourceFinite: -88.954, 37.821		21.05	5.90	0.84	88.954°W	37.821°N	0.00	1.29
PointSourceFinite: -88.954, 37.776		16.94	5.69	0.71	88.954°W	37.776°N	0.00	1.07
USGS New Madrid 500-year	Cluster							9.61
NMSZ: Center Model		68.90	7.49	0.98	89.070°W	37.165°N	191.55	7.04
NMSZ: Mid-West Model		65.59	7.48	0.92	89.193°W	37.218°N	205.45	1.09
USGS New Madrid 750-year	Cluster							6.41
NMSZ: Center Model		68.90	7.49	0.98	89.070°W	37.165°N	191.55	4.69
USGS New Madrid 500-year	Fault							5.72
New Madrid central		52.43	7.62	0.61	89.070°W	37.165°N	191.55	4.23
SSCn Adaptive Smoothing Zone 6 (opt)	Grid							3.65
USGS Adaptive Smoothing Zone 1 (opt)	Grid							3.30
Commerce Lineament	Grid							3.15
USGS Fixed Smoothing Zone 2 (opt)	Grid							1.75
Wabash Valley	Grid							1.42
SSCn Fixed Smoothing Zone 8 (opt)	Grid							1.13

OSHPD

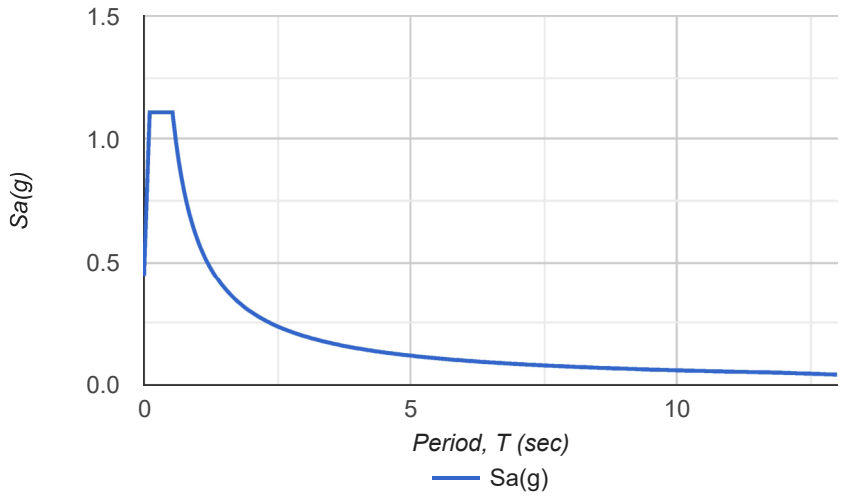
Latitude, Longitude: 37.618512, -88.953743

Date	7/16/2019, 5:48:54 PM
Design Code Reference Document	IBC-2015
Risk Category	III
Site Class	D - Stiff Soil

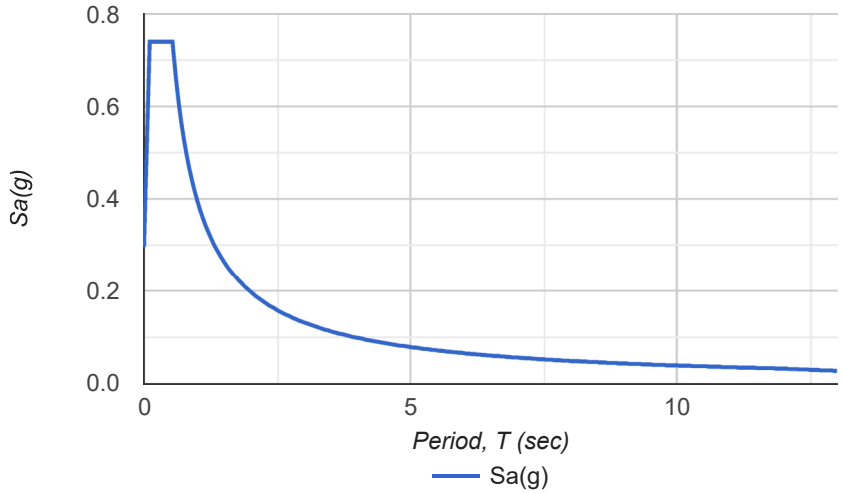
Type	Value	Description
S_S	1.013	MCE_R ground motion. (for 0.2 second period)
S_1	0.349	MCE_R ground motion. (for 1.0s period)
S_{MS}	1.109	Site-modified spectral acceleration value
S_{M1}	0.594	Site-modified spectral acceleration value
S_{DS}	0.74	Numeric seismic design value at 0.2 second SA
S_{D1}	0.396	Numeric seismic design value at 1.0 second SA

Type	Value	Description
SDC	D	Seismic design category
F_a	1.095	Site amplification factor at 0.2 second
F_v	1.703	Site amplification factor at 1.0 second
PGA	0.584	MCE_G peak ground acceleration
F_{PGA}	1	Site amplification factor at PGA
PGA_M	0.584	Site modified peak ground acceleration
T_L	12	Long-period transition period in seconds
SsRT	1.013	Probabilistic risk-targeted ground motion. (0.2 second)
SsUH	1.222	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration
SsD	1.5	Factored deterministic acceleration value. (0.2 second)
S1RT	0.349	Probabilistic risk-targeted ground motion. (1.0 second)
S1UH	0.43	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration.
S1D	0.6	Factored deterministic acceleration value. (1.0 second)
PGAd	0.6	Factored deterministic acceleration value. (Peak Ground Acceleration)
C_{RS}	0.829	Mapped value of the risk coefficient at short periods
C_{R1}	0.811	Mapped value of the risk coefficient at a period of 1 s

MCER Response Spectrum



Design Response Spectrum



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OSHPD

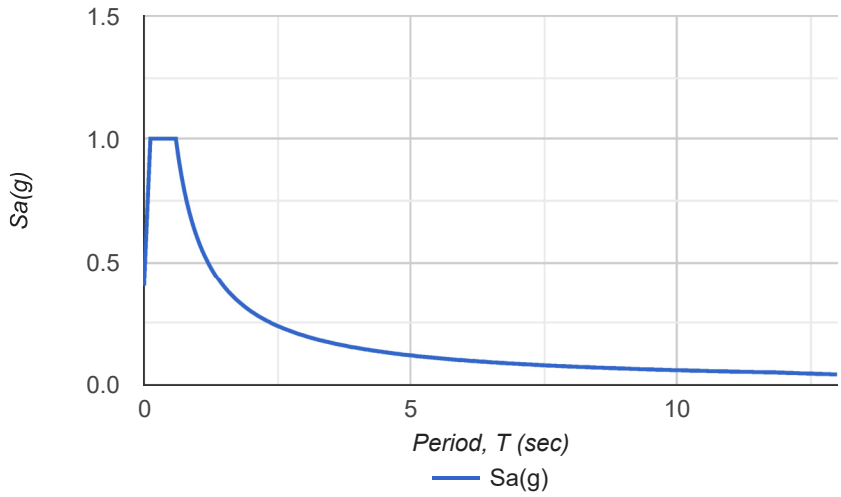
Latitude, Longitude: 37.618512, -88.953743

Date	7/16/2019, 5:50:14 PM
Design Code Reference Document	NEHRP-2015
Risk Category	II
Site Class	D - Stiff Soil

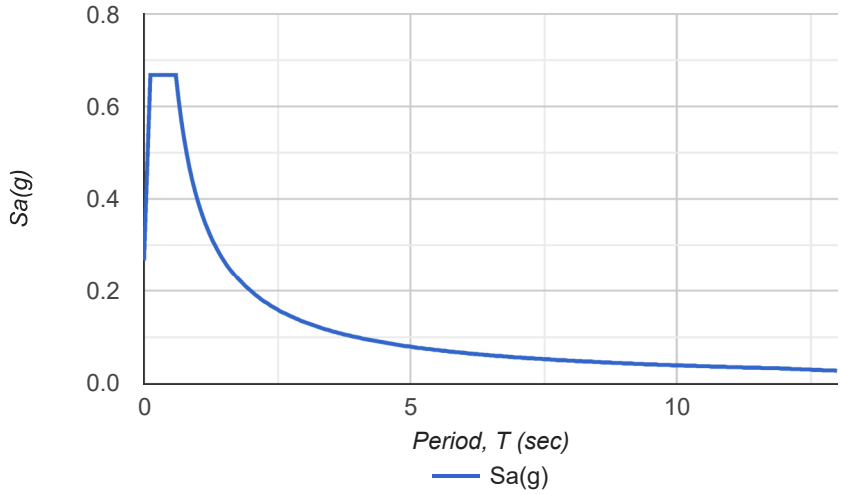
Type	Value	Description
S_S	0.869	MCE_R ground motion. (for 0.2 second period)
S_1	0.299	MCE_R ground motion. (for 1.0s period)
S_{MS}	1.002	Site-modified spectral acceleration value
S_{M1}	0.599 -See Section 11.4.7	Site-modified spectral acceleration value
S_{DS}	0.668	Numeric seismic design value at 0.2 second SA
S_{D1}	0.399 -See Section 11.4.7	Numeric seismic design value at 1.0 second SA

Type	Value	Description
SDC	D -See Section 11.4.7	Seismic design category
F_a	1.152	Site amplification factor at 0.2 second
F_v	2.002 -See Section 11.4.7	Site amplification factor at 1.0 second
PGA	0.516	MCE_G peak ground acceleration
F_{PGA}	1.1	Site amplification factor at PGA
PGA_M	0.567	Site modified peak ground acceleration
T_L	12	Long-period transition period in seconds
SsRT	0.869	Probabilistic risk-targeted ground motion. (0.2 second)
SsUH	0.996	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration
SsD	2.905	Factored deterministic acceleration value. (0.2 second)
S1RT	0.299	Probabilistic risk-targeted ground motion. (1.0 second)
S1UH	0.344	Factored uniform-hazard (2% probability of exceedance in 50 years) spectral acceleration.
S1D	0.92	Factored deterministic acceleration value. (1.0 second)
PGAd	1.539	Factored deterministic acceleration value. (Peak Ground Acceleration)
C_{RS}	0.873	Mapped value of the risk coefficient at short periods
C_{R1}	0.868	Mapped value of the risk coefficient at a period of 1 s

MCER Response Spectrum



Design Response Spectrum



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