Research Report
KTC-07-06/SPR246-02-5F

KENTUCKY TRANSPORTATION CENTER

SEISMIC EVALUATION AND RANKINGS OF EMBANKMENTS FOR BRIDGES ON AND OVER THE PARKWAYS IN WESTERN KENTUCKY

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SEISMIC EVALUATION AND RANKING OF EMBANKMENTS FOR BRIDGES ON AND OVER THE PARKWAYS IN WESTERN KENTUCKY

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16. Abstract

This study represents one of the *Seismic Evaluation of Bridges on and over the Parkways in Western Kentucky* investigative series. The effort is focused on the seismic vulnerability of bridge embankments against slope instability and liquefaction potential. An evaluation and rating procedure is presented to assist in identifying and prioritizing bridge embankments that are susceptible to failure due to projected seismic events.

To expedite the process, the algorithm titled *Seismic Assessment System for Bridges* (SASB) was programmed. Three hundred and eight-nine (389) bridge embankments (parallel bridges included) along the five western Kentucky parkways – Audubon, Pennyrile, Purchase, Western Kentucky, and William Natcher – were evaluated for projected 50-year and 250-year seismic events in this process.

30% of the bridge embankments are rated as '*critical*' for projected 50-year event earthquakes, and 36% for projected 250-year event earthquakes. Based on this preliminary investigation, it is recommended that a more detailed analysis be carried out for bridge embankments rated as '*critical*'.

17. Key Words Embankment; Seismic Evaluation; Parkways in Western Kentucky	**18. Distribution Statement** Unlimited with approval of Kentucky Transportation Cabinet

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EXECUTIVE SUMMARY

BACKGROUND AND OBJECTIVE

The majority of the three-hundred and eighty-nine (389) bridges, with few exceptions, along the western Kentucky Parkways – Audubon, Pennyrile, Purchase, Western Kentucky, and William Natcher Parkway – were designed and constructed during a period where a less stringent seismic design specification was required, as compared to today's standard (i.e. newer seismic design guidelines, updated time-history data, better understanding on soil-structure interaction, etc). Therefore, it is the aim of this preliminary study to investigate the vulnerability of bridge embankments against slope stability failure and liquefaction potential.

TASKS

To accomplish this objective, several tasks are identified: (1) compiling an inventory of bridges along the five parkways, (2) conducting field inspection of bridges, and subsequently (3) performing analytical investigation of bridge embankments to assess their vulnerability against slope stability and liquefaction potential failures.

Tasks (1) and (2) had been carried out and completed in July 2002. A resulting bridge inventory was compiled and details can be found in a separate report (Report number: KTC-07-03/SPR 246-02-2F). Investigation and results of Task (3) are presented in this report.

BRIDGE EMBANKMENT RANKING

In Task (3), methodologies to evaluate the slope stability (Chapter 2) and liquefaction potential (Chapter 3) are derived. Subsequently, a rating system which is a combination of both methodologies is developed to identify and prioritize bridge embankments in accordance with their seismic vulnerability. To expedite the evaluation and rating process, the algorithm titled *Seismic Assessment System for Bridges* (SASB) is programmed.

Based on this preliminary investigation, 30% of bridge embankments are rated as 'critical' – embankments that are identified as having unstable slope and risk of liquefaction – for projected 50-year event earthquakes, and 36% for projected 250-year event earthquakes. The 'critical' bridge embankments along the five parkways in the respective county are listed in Tables E.1 (50-year) and E.2 (250-year), respectively. For these bridge embankments, it is recommended that a more detailed and sophisticated analysis be carried out.

Table E.1: Ranking of *Critical* Bridge Embankments along Western Kentucky Parkways for a 50-Year Event Earthquake.

County	BIN[1,2]	PGA[3]	Slope Stability C/D ratio[4]	Liquefaction Potential[5]	Embankment Ranking[6]
Butler	16- 9007-B00061	0.09g	0.14	Low	A1
Caldwell	17-9001-B00033 & 17-9001-B00033 P	0.09g	0.62	Low	A1
Christian	24-9004-B00099	0.09g	0.77	Low	A1
Daviess	30 9005 B00059 & 30 9005 B00059 P	0.15g	0.18	High	A1
	30-9005-B00058 & 30-9005-B00058 P	0.15g	0.12	Moderate	A2
	30-9007-B00082 & 30-9007-B00082 P	0.15g	0.41	Moderate	A3
	30-9005-B00060	0.15g	0.24	Low	A4
	30-9007-B00081 & 30-9007-B00081 P	0.15g	0.29	Low	A5
	30-9007-B00089 & 30-9007-B00089 P	0.15g	0.30	Low	A6
	30-9005-B00063	0.15g	0.31	Low	A7
	30-9007-B00085 & 30-9007-B00085 P	0.15g	0.32	Low	A8
	30-9005-B00061	0.15g	0.34	Low	A9
	30-9007-B00083	0.15g	0.49	Low	A10
Fulton	38-9003-B00055 & 38-9003-B00055 P	0.30g	0.17	High	A1
	38-0307-B00015	0.30g	0.18	High	A2
	38-9003-B00053 & 38-9003-B00053 P	0.30g	0.21	High	A3
	38-0051-B00012 & 38-0051-B00012 P	0.30g	0.24	Moderate	A4
	38-9003-B00054 & 38-9003-B00054 P	0.30g	0.29	Moderate	A5
Graves	42-9003-B00170 & 42-9003-B00170 P	0.15g	0.39	Moderate	A1
	42-0058-B00096	0.15g	0.10	Low	A2
	42-9003-B00154 & 42-9003-B00154 P	0.15g	0.10	Low	A3
	42-9003-B00175	0.15g	0.16	Low	A4

[1] As defined in the Kentucky Transportation Cabinet (KyTC) Bridge Inventory
[2] The letter 'P' stands for parallel bridges
[3] PGA is the peak ground acceleration defined in Street et. al. (1996)
[4] Slope stability C/D ratio computation is presented in Chapter 2
[5] Liquefaction potential determination is presented in Chapter 3
[6] Only bridges with rank classification of A (Critical) are listed herein. A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county

Table E.1 (Cont'): Ranking of *Critical* Bridge Embankments along Western Kentucky Parkways for a 50-Year Event Earthquake.

County	BIN[1,2]	PGA[3]	Slope Stability C/D ratio[4]	Liquefaction Potential[5]	Embankment Ranking[6]
Graves	42 9003 B00162 & 42 9003 B00162 P	0.15	0.19	Low	A5
	42 9003 B00177 & 42 9003 B00177 P	0.15	0.2	Low	A6
	42 9003 B00176 & 42 9003 B00176 P	0.15	0.22	Low	A7
	42 9003 B00155 & 42 9003 B00155 P	0.15	0.24	Low	A8
	42 9003 B00169	0.15	0.26	Low	A9
	42 9003 B00172	0.15	0.26	Low	A10
	42 9003 B00160	0.15	0.3	Low	A11
	42 9003 B00156 & 42 9003 B00156 P	0.15	0.31	Low	A12
	42 9003 B00165 & 42 9003 B00165 P	0.15	0.35	Low	A13
	42 0944 B00180	0.15	0.4	Low	A14
	42 1748 B00128	0.15	0.42	Low	A15
	42 9003 B00167 & 42 9003 B00167 P	0.15	0.43	Low	A16
	42 0121 B00111	0.15	0.52	Low	A17
	42 0301 B00028	0.15	0.52	Low	A18
	42 9003 B00161	0.15	0.55	Low	A19
Grayson	No bridges listed as 'critical'				
Hardin	47 31W B00108	0.09	0.72	Low	A1
Henderson	51 9005 B00072	0.15	0.14	Low	A1
	51 9004 B00069	0.15	0.39	Low	A2
	51 9004 B00062 & 51 9004 B00062 P	0.15	0.51	Low	A3
	51 9004 B00111	0.15	0.6	Low	A4
	51 9004 B00065	0.15	0.61	Low	A5

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Table E.1 (Cont'): Ranking of *Critical* Bridge Embankments along Western Kentucky Parkways for a 50-Year Event Earthquake.

County	BIN[1,2]	PGA[3]	Slope Stability C/D ratio[4]	Liquefaction Potential[5]	Embankment Ranking[6]
Hickman	53 0094 B00050	0.3	0.24	High	A1
	53 9003 B00068	0.3	0.3	Low	A2
Hopkins	54 9004 B00015	0.09	0.35	Low	A1
	54 9001 B00137 & 54 9001 B00137 P	0.09	0.45	Low	A2
	54 9001 B00143 & 54 9001 B00143 P	0.09	0.47	Low	A3
	54 9001 B00144 & 54 9001 B00144 P	0.09	0.47	Low	A4
	54 9001 B00136 & 54 9001 B00136 P	0.09	0.54	Low	A5
	54 9004 B00095 & 54 9004 B00095 P	0.09	0.56	Low	A6
	54 9001 B00145 & 54 9001 B00145 P	0.09	0.57	Low	A7
	54 9004 B00014 & 54 9004 B00014 P	0.09	0.7	Low	A8
	54 9001 B00140 & 54 9001 B00140 P	0.09	0.77	Low	A9
	54 9001 B00146 & 54 9001 B00146 P	0.09	0.81	Low	A10
Lyon	No bridges listed as 'critical'				
Marshall	79 0795 B00012	0.15	0.17	Low	A1
	79 9003 B00064 & 79 9003 B00064 P	0.15	0.23	Low	A2
	79 9003 B00074 & 79 9003 B00074 P	0.15	0.3	Low	A3
	79 0408 B00103	0.15	0.31	Low	A4
	79 1422 B00050	0.15	0.33	Low	A5
	79 9003 B00066	0.15	0.37	Low	A6
	79 9003 B00076 & 79 9003 B00076 P	0.15	0.44	Low	A7
	79 0348 B00102	0.15	0.51	Low	A8
	79 9003 B00068	0.15	0.66	Low	A9

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6 Only bridges with rank classification of A (Critical) are listed herein. A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county

Table E.1 (Cont'): Ranking of *Critical* Bridge Embankments along Western Kentucky Parkways for a 50-Year Event Earthquake.

County	BIN[1,2]	PGA[3]	Slope Stability C/D ratio[4]	Liquefaction Potential[5]	Embankment Ranking[6]
Muhlenberg	89 9001 B00096 & 89 9001 B00096 P	0.09	0.34	Low	A1
	89 9001 B00094 & 89 9001 B00094 P	0.09	0.37	Low	A2
	89 9001 B00093 & 89 9001 B00093 P	0.09	0.41	Low	A3
	89 9001 B00109 & 89 9001 B00109 P	0.09	0.42	Low	A4
Ohio	92 9007 B00063 & 92 9007 B00063 P	0.09	0.28	Low	A1
	92 9007 B00075 & 92 9007 B00075 P	0.09	0.32	Low	A2
	92 9001 B00134 & 92 9001 B00134 P	0.09	0.42	Low	A3
	92 9001 B00133 & 92 9001 B00133 P	0.09	0.62	Low	A4
Warren	No bridges listed as 'critical'				
Webster	117 9004 B00074 & 117 9004 B00074 P	0.09	0.79	Low	A1

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5 Liquefaction potential determination is presented in Chapter 3
6 Only bridges with rank classification of A (Critical) are listed herein. A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county

Table E.2: Ranking of *Critical* Bridge Embankments along Western Kentucky Parkways for a 250-Year Event Earthquake.

County	BIN[1,2]	PGA[3]	Slope Stability C/D ratio[4]	Liquefaction Potential[5]	Embankment Ranking[6]
Butler	16 9007 B00061	0.09	0.14	Low	A1
Caldwell	17 9001 B00033 & 17 9001 B00033 P	0.09	0.62	Low	A1
Christian	24 9004 B00099	0.09	0.77	Low	A1
Daviess	30 9005 B00058 & 30 9005 B00058 P	0.15	0.12	High	A1
	30 9005 B00059 & 30 9005 B00059 P	0.15	0.18	High	A2
	30 9005 B00060	0.15	0.24	Moderate	A3
	30 9007 B00081 & 30 9007 B00081 P	0.15	0.29	Moderate	A4
	30 9007 B00082 & 30 9007 B00082 P	0.15	0.41	Moderate	A5
	30 9007 B00089 & 30 9007 B00089 P	0.15	0.3	Low	A6
	30 9005 B00063	0.15	0.31	Low	A7
	30 9007 B00085 & 30 9007 B00085 P	0.15	0.32	Low	A8
	30 9005 B00061	0.15	0.34	Low	A9
	30 9007 B00083	0.15	0.49	Low	A10
	30 9007 B00094 & 30 9007 B00094 P	0.15	0.58	Low	A11
	30 9007 B00088 & 30 9007 B00088 P	0.15	0.69	Low	A12
	30 9007 B00092	0.15	0.87	Low	A13
Fulton	38 9003 B00055 & 38 9003 B00055 P	0.4	0.17	High	A1
	38 0307 B00015	0.4	0.18	High	A2
	38 9003 B00053 & 38 9003 B00053 P	0.4	0.21	High	A3
	38 0051 B00012	0.4	0.24	High	A4
	38 9003 B00054 & 38 9003 B00054 P	0.4	0.29	High	A5
Graves	42 9003 B00177 & 42 9003 B00177 P	0.19	0.2	High	A1

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5 Liquefaction potential determination is presented in Chapter 3
6 Only bridges with rank classification of A (Critical) are listed herein. A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county

Table E.2 (Cont'): Ranking of *Critical* Bridge Embankments along Western Kentucky Parkways for a 250-Year Event Earthquake.

County	BIN[1,2]	PGA[3]	Slope Stability C/D ratio[4]	Liquefaction Potential[5]	Embankment Ranking[6]
Graves	42 9003 B00176 & 42 9003 B00176 P	0.19	0.22	High	A2
	42 9003 B00170 & 42 9003 B00170 P	0.19	0.39	Moderate	A3
	42 1748 B00128	0.19	0.42	Moderate	A4
	42 0058 B00096	0.19	0.1	Low	A5
	42 9003 B00154 & 42 9003 B00154 P	0.19	0.1	Low	A6
	42 9003 B00175	0.19	0.16	Low	A7
	42 9003 B00162 & 42 9003 B00162 P	0.19	0.19	Low	A8
	42 9003 B00155 & 42 9003 B00155 P	0.19	0.24	Low	A9
	42 9003 B00169	0.19	0.26	Low	A10
	42 9003 B00172	0.19	0.26	Low	A11
	42 9003 B00160	0.19	0.3	Low	A12
	42 9003 B00156 & 42 9003 B00156 P	0.19	0.31	Low	A13
	42 9003 B00165 & 42 9003 B00165 P	0.19	0.35	Low	A14
	42 0944 B00180	0.19	0.4	Low	A15
	42 9003 B00167 & 42 9003 B00167 P	0.19	0.43	Low	A16
	42 0121 B00111	0.19	0.52	Low	A17
	42 0301 B00028	0.19	0.52	Low	A18
	42 9003 B00161	0.19	0.55	Low	A19
	42 9003 B00166 & 42 9003 B00166 P	0.19	0.58	Low	A20
	42 0339 B00143	0.19	0.72	Low	A21
	42 9003 B00159 & 42 9003 B00159 P	0.19	0.82	Low	A22
	42 9003 B00157 & 42 9003 B00157 P	0.19	0.84	Low	A23

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Table E.2 (Cont'): Ranking of *Critical* Bridge Embankments along Western Kentucky Parkways for a 250-Year Event Earthquake.

County	BIN[1,2]	PGA[3]	Slope Stability C/D ratio[4]	Liquefaction Potential[5]	Embankment Ranking[6]
Grayson	No bridges listed as 'critical'				
Hardin	47 31W B00108	0.09	0.72	Low	A1
Henderson	51 0425 B00137 & 51 0425 B00137 P	0.15	18	Low	A1
	51 9005 B00072	0.15	54.1	Low	A2
	51 9004 B00069	0.15	28.6	Low	A3
	51 9004 B00062 & 51 9004 B00062 P	0.15	26	Low	A4
	51 9004 B00111	0.15	27.3	Low	A5
	51 9004 B00065	0.15	18	Low	A6
	51 9004 B00064	0.15	15	Low	A7
	51 9004 B00073 & 51 9004 B00073 P	0.15	27	Low	A8
	51 9005 B00074	0.15	26.1	Low	A9
	51 9005 B00075	0.15	20.89	Low	A10
Hickman	53 0094 B00050	0.4	0.24	High	A1
	53 9003 B00068	0.4	0.3	Moderate	A2
	53 1529 B00056	0.4	0.52	Moderate	A3
Hopkins	54 9004 B00015	0.09	0.35	Low	**A1**
	54 9001 B00137 & 54 9001 B00137 P	0.09	0.45	Low	A2
	54 9001 B00143 & 54 9001 B00143 P	0.09	0.47	Low	A3
	54 9001 B00144 & 54 9001 B00144 P	0.09	0.47	Low	A4
	54 9001 B00136 & 54 9001 B00136 P	0.09	0.54	Low	A5
	54 9004 B00095 & 54 9004 B00095 P	0.09	0.56	Low	A6
	54 9001 B00145 & 54 9001 B00145 P	0.09	0.57	Low	A7

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Table E.2 (Cont'): Ranking of *Critical* Bridge Embankments along Western Kentucky Parkways for a 250-Year Event Earthquake.

County	BIN[1,2]	PGA[3]	Slope Stability C/D ratio[4]	Liquefaction Potential[5]	Embankment Ranking[6]
Hopkins	54 9004 B00014 & 54 9004 B00014 P	0.09	0.7	Low	A8
	54 9001 B00140 & 54 9001 B00140 P	0.09	0.77	Low	A9
	54 9001 B00146 & 54 9001 B00146 P	0.09	0.81	Low	A10
Lyon	No bridges listed as 'critical'				
Marshall	79 9003 B00076 & 79 9003 B00076 P	0.15	0.44	Moderate	A1
	79 0795 B00012	0.15	0.17	Low	A2
	79 9003 B00064 & 79 9003 B00064 P	0.15	0.23	Low	A3
	79 9003 B00074 & 79 9003 B00074 P	0.15	0.3	Low	A4
	79 0408 B00103	0.15	0.31	Low	A5
	79 1422 B00050	0.15	0.33	Low	A6
	79 9003 B00066	0.15	0.37	Low	A7
	79 0348 B00102	0.15	0.51	Low	A8
	79 9003 B00068	0.15	0.66	Low	A9
	79 9003 B00073	0.15	0.69	Low	A10
	79 641 B00126	0.15	0.77	Low	A11
Muhlenberg	89 9001 B00096 & 89 9001 B00096 P	0.09	0.34	Low	A1
	89 9001 B00094 & 89 9001 B00094 P	0.09	0.37	Low	A2
	89 9001 B00093 & 89 9001 B00093 P	0.09	0.41	Low	A3
	89 9001 B00109 & 89 9001 B00109 P	0.09	0.42	Low	A4
Ohio	92 9007 B00063 & 92 9007 B00063 P	0.09	0.28	Low	A1
	92 9007 B00075 & 92 9007 B00075 P	0.09	0.32	Low	A2
	92 9001 B00134 & 92 9001 B00134 P	0.09	0.42	Low	A3

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Table E.2 (Cont'): Ranking of *Critical* Bridge Embankments along Western Kentucky Parkways for a 250-Year Event Earthquake.

County	BIN[1,2]	PGA[3]	Slope Stability C/D ratio[4]	Liquefaction Potential[5]	Embankment Ranking[6]
Ohio	92 9001 B00133 & 92 9001 B00133 P	0.09	0.62	Low	A4
Warren	114 0884 B00050	0.09	0.83	Low	A1
Webster	117 9004 B00074 & 117 9004 B00074 P	0.09	0.79	Low	A1

[1] As defined in the Kentucky Transportation Cabinet (KyTC) Bridge Inventory
[2] The letter 'P' stands for parallel bridges
[3] PGA is the peak ground acceleration defined in Street et. al. (1996)
[4] Slope stability C/D ratio computation is presented in Chapter 2
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[6] Only bridges with rank classification of A (Critical) are listed herein. A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county

NOTE: This report is the fifth (5th) in a series of six (6) reports for SPR 206: "*Seismic Evaluation of Bridges on/over Parkways in Western Kentucky*". The six (6) reports are:

Report Number:	Report Title:
(1) KTC-07-02/SPR246-02-1F	Seismic Evaluation of Bridges on and over the Parkways in Western Kentucky – Summary Report
(2) KTC-07-03/SPR246-02-2F	Site Investigation of Bridges on and over the Parkways in Western Kentucky
(3) KTC-07-04/SPR246-02-3F	Preliminary Seismic Evaluation and Ranking of Bridges on and over the Parkways in Western Kentucky
(4) KTC-07-05/SPR246-02-4F	Detailed Seismic Evaluation of Bridges on and over the Parkways in Western Kentucky
(5) KTC-07-06/SPR246-02-5F*	Seismic Evaluation and Ranking of Embankments for Bridges on and over the Parkways in Western Kentucky
(6) KTC-07-07/SPR246-02-6F	Seismic-Hazard Maps and Time Histories for the Commonwealth of Kentucky

* Denotes current report

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1 INTRODUCTION

1.1 Background

Western Kentucky lies just east of the New Madrid Seismic Zone (NMSZ). The zone to date remains one of the most hazardous seismic zones in central United States. Historical evidence indicated that the largest reported earthquakes along this fault occurred in the winter of 1811 and 1812, registering a magnitude of 7.5 (i.e. earthquakes having magnitude of 7.0 to 7.9 can cause major damage over an area of beyond 100 kilometer according to the Richter scale) or greater on the Richter scale. Accordingly, reverberations from these earthquakes were felt throughout the entire eastern region of the United States. If an earthquake of similar intensity were to occur today, an even more damaging outcome is anticipated, which could have severe social, economical impact, etc., in that region (i.e. Western Kentucky).

The Kentucky Transportation Cabinet (KTC) of the Commonwealth of Kentucky has commissioned several studies intended to evaluate structural integrity of bridges in the vicinity of NMSZ in Western Kentucky in recent years. As a continuing effort, this study (KTC-06-xx/SPR246-02-5F) evaluates the seismic stability of bridge embankments for bridges located on and/or over the five parkways in Western Kentucky.

1.2 Objective and Scope

This report (SPR246-02-5F) is one in a series of six reports (see Table 1.1) aiming at evaluating the seismic stability of bridge embankments of bridges – in terms of soil stability and liquefaction potential of a bridge embankment during a predicted earthquake event. Bridge embankments that will be considered in this investigation are the bridges located on and/or over the five parkways in Western Kentucky. The five parkways shown in Fig. 1.1 are the Audubon, Pennyryle, Purchase, Western Kentucky, and William Natcher Parkways. The scope of the evaluation is the 389 bridges located along these parkways in Western Kentucky; where the majority were designed and constructed in an era when seismic design requirements were less stringent as compared to today's standard.

1.3 Research Tasks and Outcome

To conduct the seismic stability (i.e. soil stability and liquefaction potential) of the approach embankments of the bridges of the five parkways, pertinent information required were collected and the following tasks were conducted to obtain the information:

1. Compiling a bridge inventory. This specific task involved the collection of pertinent information such as location, geometry, construction type, soil types and layers, etc., of the bridges based on the available bridge plans.
2. Conducting site investigation. The research team carried out on-site investigations of the bridges to confirm information gathered from the previous task, and also to examine the current state of the bridges.
3. Carrying out analytical computation to assess the risk of the approach embankments of the bridges. Computer algorithms evaluating the slope stability (Chapter 2) and

liquefaction potential (Chapter 3) were written in Microsoft Assess 2003. Details of the methodologies for slope stability and liquefaction potential assessment are discussed in subsequent chapters. The bridge embankment ranking based on the potential for slope stability and liquefaction is presented in Chapter 4.

Tasks 1 and 2 are compiled in Report Number KTC-07-03/SPR246-02-2F. Information obtained from these tasks were then use in Task 3 to carry out seismic embankment evaluation. The significance of this study is to provide state and local agencies the ability to easily identify and prioritize bridges that are in need of repair or to undertake other appropriate actions.

Table 1.1: Seismic evaluation of bridges along parkways in Western Kentucky

NOTE: This report is the fifth (5th) in a series of six (6) reports for SPR 206: "*Seismic Evaluation of Bridges on/over Parkways in Western Kentucky*". The six (6) reports are:	
Report Number:	Report Title:
(1) KTC-06-xx/SPR246-02-1F	Seismic Evaluation of Bridges and Embankments in Western Kentucky – Summary Report
(2) KTC-06-xx/SPR246-02-2F	Site Investigation of Bridges on/over Parkways in Western Kentucky
(3) KTC-06-xx/SPR246-02-3F	Preliminary Seismic Evaluation and Ranking of Bridges and Embankments in Western Kentucky
(4) KTC-06-xx/SPR246-02-4F	Detailed Seismic Evaluation of Bridges on/over Parkways in Western Kentucky
(5) KTC-06-xx/SPR246-02-5F*	Seismic Evaluation of Bridge Embankment on/over Parkways in Western Kentucky
(6) KTC-06-xx/SPR246-02-6F	LRFD Seismic Maps

* Denotes current report

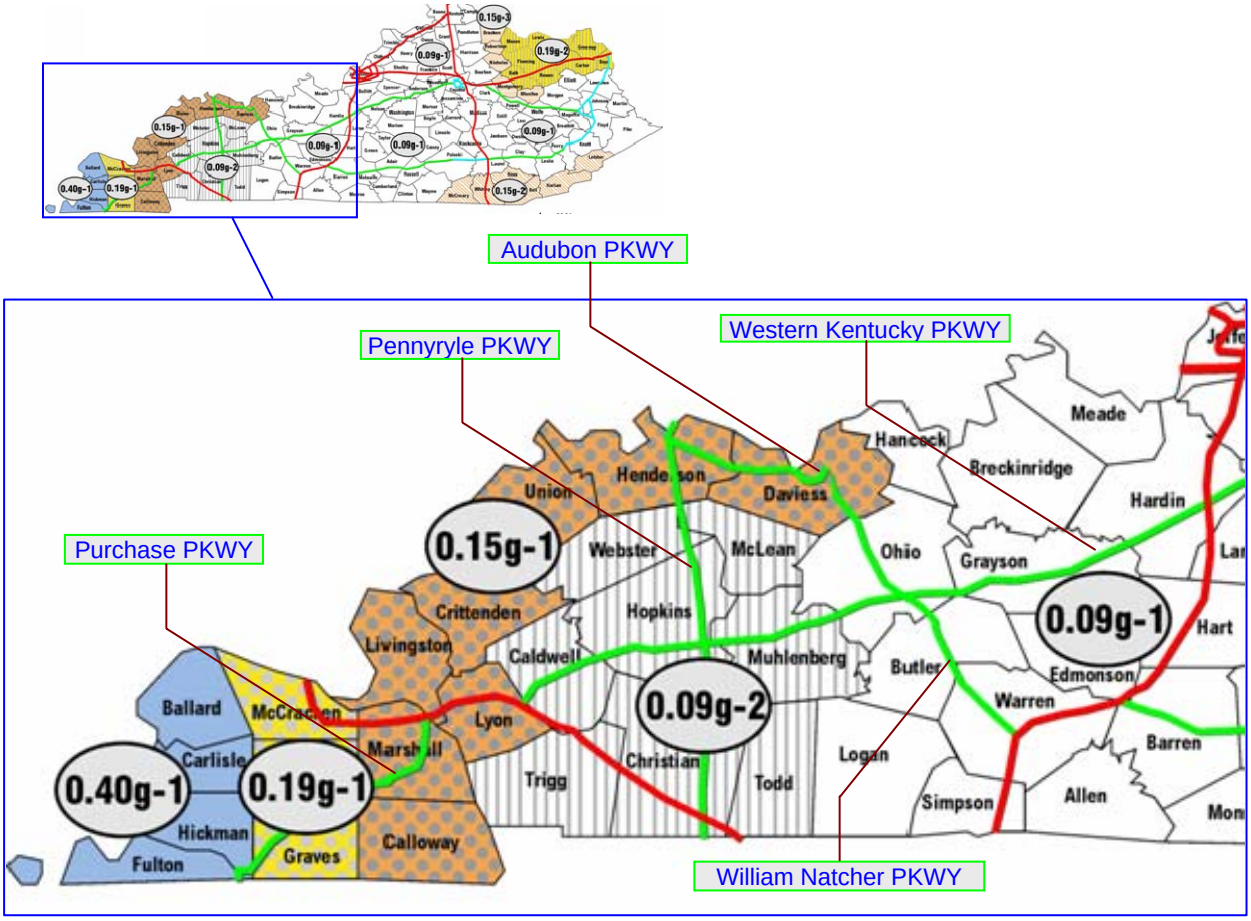

Fig. 1.1 The five parkways in western Kentucky in which seismic assessment was conducted on the bridge embankments.

2 SEISMIC SLOPE STABILITY ASSESSMENT

2.1 Introduction

This chapter presents the methodologies for predicting the seismic slope stability of a bridge embankment. Before the physical and mechanical behavior of slope stability mechanisms are discussed any further, the following assumptions are made in regard to the embankment and foundation conditions:

1. The embankment is constructed of a single material. It is recognized that the embankment fill may generally be of varying depth and distribution of multiple materials. Since the aim of this study is to perform a relatively simple 2-D preliminary evaluation of slope stability problems, this assumption thus reduces the complexity of the analytical formulation (i.e. constant material property).
2. The embankment top and base are level, and that the base of the embankment corresponds to the elevation of the toe of the embankment. This assumption determines the height of an embankment, and the overall embankment geometry can thus be defined by this height and the slope (i.e. the inclination is the ratio of the vertical to the horizontal distance). Embankment geometry (i.e. top and base) of bridges along these parkways will first be obtained from the original bridge plans, followed by subsequent verification through site investigation.
3. The foundation soils have a uniform undrained shear strength (S_u); usually different from the embankment soils. Foundation stratigraphy and geometry are likely more variable than that of the embankment; since the foundation is usually natural soil rather than controlled fill as in the case of embankment. The contact between softer foundation soils and a harder bedrock surface or stiff soils, for instance, may also be irregular. Therefore, detailed definition of these conditions typically requires a detailed subsurface exploration. Since the current investigation is intended to provide relative ranking of the embankments, not to predict the actual expected performance, such a complex task is neither necessary nor warranted at this preliminary stage.

2.2 Limit Equilibrium Slope Stability

The seismic slope stability of the bridge embankment is assessed using a two dimensional (2-D) limit equilibrium method in which the inertia force due to earthquake shaking is represented by a constant horizontal force in a pseudo-static state (i.e. the constant horizontal force is equal to the weight, W, of the potential sliding mass multiplied by a seismic acceleration coefficient, K_h) as shown in Figs. 2.3 to 2.7.

In this study, the seismic pseudo-static force in the vertical direction is ignored since it has minimal impact on the factor of safety (FS) calculated based on the driving and resisting forces of the various failure modes to be discussed later in this chapter. It is apparent that the driving force to cause slope instability or mass movement is a function of the seismic acceleration coefficient, K_h. The selection of K_h is subject to judgement, and its value is mostly empirical. For example, K_h used in US practice varies between 0.10 and 0.15. In other instances, values between 0.15 and 0.25 have been used in Japan in its Earth Dam Specification. A K_h

value of two-third (2/3) of the predicted peak ground acceleration (PGA) has been used by Sutterer (2000). Since Sutterer (2000) conducted his investigation in the Commonwealth of Kentucky, the same proposition (i.e. 2/3 time the PGA) will be applied to the slope stability investigation herein.

The PGA will likely vary from county to county due to attenuation of the motion as it travels from the source to the county seat of each county and the county's location in relation to the NMSZ. For the bridges along the five respective parkways, the PGA of each county is taken from a report titled *Source Zone, Recurrence Rates, and Time Histories for Earthquakes affecting Kentucky* (Street et. al. 1996). In this investigation, the 50-year and the 250-year time history events will be considered. The peak ground acceleration contour maps of these two time events are presented in Figs. 2.1 and 2.2, respectively.

It should be noted that, in addition to ignoring the vertical seismic pseudo-static force, the buoyant effect on the weight of submerged soil is also neglected to simplify the derivation. The simplification is consistent with the one applied by Sutterer et. al. (2000). As in any earthquake event, seismic forces and corresponding responses occur almost in an instance. Therefore, the event would take place with little or minimal dissipation of excess pore water pressure and, thus constitutes an undrained condition. Therefore, undrained shear strength (S_u) can and will be used in current investigation.

In this investigation, the *FS* will be determined (and lowest) from one of the following probable slope failure models: (1) wedge failure mode, (2) toe circle slope failure mode, and (3) base failure mode. The mechanism of each failure mode is as follows.

2.2.1 Wedge Failure Mode

A wedge failure mode is depicted in Fig. 2.3 where is a certain plane of rupture of an embankment. A factor of safety (*FS*), as a result of the driving wedge and resisting friction at the rupture plan, can be expressed as

$$FS = \frac{2\left(1+a^2\right)}{(a-b)(1+a\cdot K_h)}\frac{S}{\gamma\cdot h}\text{, when } a \le b+w \tag{2.1.a}$$

$$FS = \frac{2\left(1+a^2\right)(a+b)(w+2\cdot b)}{(1+a\cdot K_h)\left\{(a-b)(2\cdot b+w)^2+2(a-w+b)\cdot\left[a\cdot w+b(a-b)\right]\right\}}\text{, when } a > b+w \tag{2.1.b}$$

Where

- γ = unit density of soil (force per cubic length)
- S = undrained shear strength of the embankment fill (force per unit area)
- a = potential sliding surface inclination
- b = embankment slope
- h = height of the potential sliding wedge
- w = dimensionless parameter for embankment width = ratio of width of embankment (top) to height of the potential sliding wedge (h)

Most of the parameters are also defined in Fig. 2.3.

Equations 2.1.a and 2.1.b can be rearranged for FS = 1, giving the critical K_{hf} causing failure:

$$K_{hf} = \frac{1}{a}\left\{\frac{2\left(1+a^2\right)}{(a-b)}\frac{S}{\gamma \cdot h} - 1\right\}, \text{ when } a \le b + w \tag{2.1.c}$$

$$K_{hf} = \frac{1}{a}\left\{\frac{2\left(1+a^2\right)(a+b)(w+2b)}{(a-b)(2b+w)^2 + 2(a-b-w)\cdot\left[a\cdot w + b\cdot(a-b)\right]}\frac{S}{\gamma \cdot h} - 1\right\}, \text{ when } a > b + w \tag{2.1.d}$$

2.2.2 Circular Slope Failure Mode

The circular slope failure mode may likely occur for embankments with homogeneous pure cohesive soil. This type of slope failure can be of one of the cases shown in Figs. 2.4, 2.5, and 2.6. The factor of safety (FS) for these cases can be expressed in an integrated equation as

$$FS = \frac{S}{\gamma \cdot h}\frac{12\theta_o \cdot r_o^2}{C_1 + K_h \cdot C_2} \tag{2.2.a}$$

Where h, S, and γ have the same definitions as described previously.

$$C_1 = 3\sqrt{r_o^2 - x_o^2} - b\cdot(3x_o + b) - 1 \tag{2.2.b}$$

$$C_2 = \left\{x_o^2 + 4\sqrt{r_o^2 - x_o^2} - x_o\sqrt{x_o^2 + 2\sqrt{r_o^2 - x_o^2} - 1} - 2\right\}\left(\sqrt{x_o^2 + 2\sqrt{r_o^2 - x_o^2} - 1} - x_o\right)$$
$$- b\left(3\sqrt{r_o^2 - x_o^2} - 2\right) \tag{2.2.c}$$

$$\theta_o = arcsin\left(\frac{\sqrt{2x_o^2 + 2\sqrt{r_o^2 - x_o^2} - 2x_o\sqrt{x_o^2 + 2\sqrt{r_o^2 - x_o^2} - 1}}}{2r_o}\right) \tag{2.2.d}$$

It is apparent that Eq. 2.2.is a function of variables x_o, r_o, and h, and the minimum FS is obtained when h is equal to the overall height of the embankment H (i.e. the circular surface extending upward from the toe of the embankment represents the most probable rupture surface). Therefore, to obtain the minimum FS, only values x_o and r_o should be optimized. It should be noted that the slope failure depicted in Fig. 2.5 represents a special case with x_o = 0, and the slope failure depicted in Fig. 2.6 applies for a special case of $x_o = -x_o$.

Rearranging Eq. 2.2.a for FS = 1 gives the critical horizontal acceleration coefficient K_{hf} causing failure as

$$K_{hf} = \frac{12\theta_o \cdot r_o^2 \cdot \frac{S}{\gamma \cdot h} - C_1}{C_2} \tag{2.2.e}$$

2.2.3 Base Failure Mode

Base failure mode is depicted in Fig. 2.7, where it is likely to take place when there is softer natural soil stratum present beneath the embankment. To simplify the mathematical computation, generally, a circular rupture surface similar to that of the circular slope failure mode is assumed. It is also further assumed that the embankment fill and the foundation (i.e. natural) soil have the same unit density (γ).

In this case, the height of the embankment fill is also the height of the embankment (h = H). The foundation (natural) soil depth is $d \cdot h$, and rupture arc surface radius is defined in Fig. 2.7. r_o, x_o, and d are dimensionless parameters, and the θ_o, θ_1 represent the angles of arc segments in potential failure arc surface.

The factor of safety (FS) is therefore described by the following equations

$$FS = \frac{12(\theta_o \cdot \lambda + \theta_1) \cdot r_o^2}{(D_1 + K_h D_2)} \cdot \frac{S}{\gamma \cdot h} \tag{2.3.a}$$

Where

$$\lambda = \frac{S_o}{S} \tag{2.3.b}$$

$$\begin{aligned} D_1 = {} & b(3x_o - b) + 3\left\{d(2r_o - d) - x_o^2\right\} \\ & + \left\{\sqrt{d(1+d)(2r_o - d)(2r_o - d - 1)} + d^2 - 2r_o d - 2d + 2r_o - 1\right\} \\ & + \sqrt{2}\left\{r_o(1+2d) - d(1+d) - \sqrt{d(1+d)(2r_o - d)(2r_o - d - 1)}\right\}^{3/2} sin(\theta_o + \theta_1) \end{aligned} \tag{2.3.c}$$

$$\begin{aligned} D_2 = {} & 4[d(2r_o - d)]^{3/2} + b(3r_o - 3d - 1) + 3\left[\sqrt{d(2r_o - d)} - x_o\right](2r_o - 2d - 1) \\ & + \left[\sqrt{(1+d)(2r_o - d - 1)} - \sqrt{d(2r_o - d)}\right](3r_o - 3d - 2) \\ & + \sqrt{2}\left[r_o(1+2d) - d(1+d) - \sqrt{d(1+d)(2r_o - d)(2r_o - d - 1)}\right]^{3/2} cos(\theta_o + \theta_1) \end{aligned} \tag{2.3.d}$$

$$\theta_o = arccos\frac{r_o - d}{r_o} \tag{2.3.e}$$

$$\theta_1 = arcsin\frac{\sqrt{2r_o(1+2d) - 2d(1+d) - 2\sqrt{d(1+d)(2r_o - d)(2r_o - d - 1)}}}{2r_o} \tag{2.3.f}$$

Most of the parameters are defined in Fig. 2.7. S_o is the undrained shear strength of the subsurface foundation soil, and S is the undrained shear strength in the embankment. The factor of safety (FS) is a function of two variables r_o and x_o. Therefore, optimization is required to find the values for r_o and x_o for the minimum FS.

Rearranging Eq. 2.3.a for FS = 1, the critical horizontal acceleration coefficient K_{hf} causing failure can be obtained as

$$K_{hf} = \frac{12(\lambda \cdot \theta_o + \theta_1) \cdot r_o^2 \cdot \frac{S}{\gamma \cdot h} - D_1}{D_2} \tag{2.3.g}$$

2.3 Slope Displacement Estimate

It should be noted that the K_h (i.e. 2/3 of the peak ground acceleration) in Section 2.2 accounts for embankments in which the seismic acceleration never exceeds the acceleration causing failure, resulting in little to no movement. Since the selected K_h represents one or several brief loads during the seismic event, it is therefore of interest to know for those slopes with a factor of safety less than one as to how far the mass actually moved while the ground motion was taking place.

The effects of earthquakes on embankment stability in terms of the deformations they produced were first proposed by Newmark (1965). In the prediction of slope displacement, Newmark (1965) used a sliding block analogy which assumes a slope can be simulated as a wedge resting on an inclined plane. The method, used for over 30 years, has since been refined by various reseachers. In this study, the equation by Dodds (1997), modified from Ambraseys and Menu (1988), will be used to make slope displacement estimate

$$log_{10}(u) = \alpha + \beta_1 \, log_{10}\left(1 - \frac{A_y}{A_{max}}\right) + \beta_2 \, log_{10}\left(\frac{A_y}{A_{max}}\right) \tag{2.4}$$

The parameters α, β_1, and β_2 vary with earthquake magnitude ($M_{b,Lg}$). The following linear relations can be used to calculate these parameters for magnitude of 4.5 to 7.5 on both bedrock and soil sites in western Kentucky, which were recommended by Sutterer et. al. (2000):

$$\begin{aligned} \alpha_{bedrock} &= 0.735 \cdot M_{b,Lg} - 4.41 \\ (\beta_1)_{bedrock} &= 0.35 \cdot M_{b,Lg} + 1.94 \\ (\beta_2)_{bedrock} &= -0.15 \cdot M_{b,Lg} + 0.21 \end{aligned} \tag{2.5}$$

$$\begin{aligned} \alpha_{soil} &= 1.025 \cdot M_{b,Lg} - 6.292 \\ (\beta_1)_{soil} &= -0.174 \cdot M_{b,Lg} + 3.58 \\ (\beta_2)_{soil} &= -0.056 \cdot M_{b,Lg} - 0.794 \end{aligned} \tag{2.6}$$

u is Eq. 2.4 is the estimate embankment or slope displacement in centimeter. A_y is defined as the yield acceleration, which is equal to the critical horizontal coefficient (K_{hf}) multiplied by the gravity (g). A_{max} is the estimated peak ground acceleration expected for an event of a specific return period. When the ratio of A_y/A_{max} is less than one, some displacement would be expected to occur (i.e. when ground acceleration exceeds the yield acceleration).

2.4 Seismic Slope Stability Assessment

Newmark (1965) prescribed that displacement of 0 to 10 cm are unlikely to correspond to serious landslide. On the other hand, when calculated displacement exceeds 100 cm a damaging landslide is highly probable. Displacements in the range of 10 to 100 cm may likely be sufficient to cause serious ground cracking or loss of strength to contribute in continuing or post-earthquake failure.

Newmark's analysis constituted a highly idealized and simplistic failure mechanism; therefore, judgment is required to determine whether the displacement criteria set forth can be accommodated safely. Considering the specific conditions in western Kentucky, both the factor of safety (*FS*) and the predicted embankment displacement (*u*) will be used to assess the embankment stability of the bridges along the five parkways as summarized in Table 2.1 (see also flow chart in Fig. 2.8).

Table 2.1: Slope stability criteria

Classification	General description
Class I	$FS > 1.0$ (stable slope condition)
Class II	$FS \leq 1.0$, and $u \leq 10$ cm (critical but not unstable)
Class III	$FS \leq 1.0$, and $u > 10$ cm (unstable, detailed sub-surface exploration and evaluation recommended)

Over 300 bridges on the five parkways were evaluated for slope stability (Section 2.2), and subsequent displacement evaluation (Section 2.3, when *FS* is less than one) – constituting a complete slope stability assessment in this study.

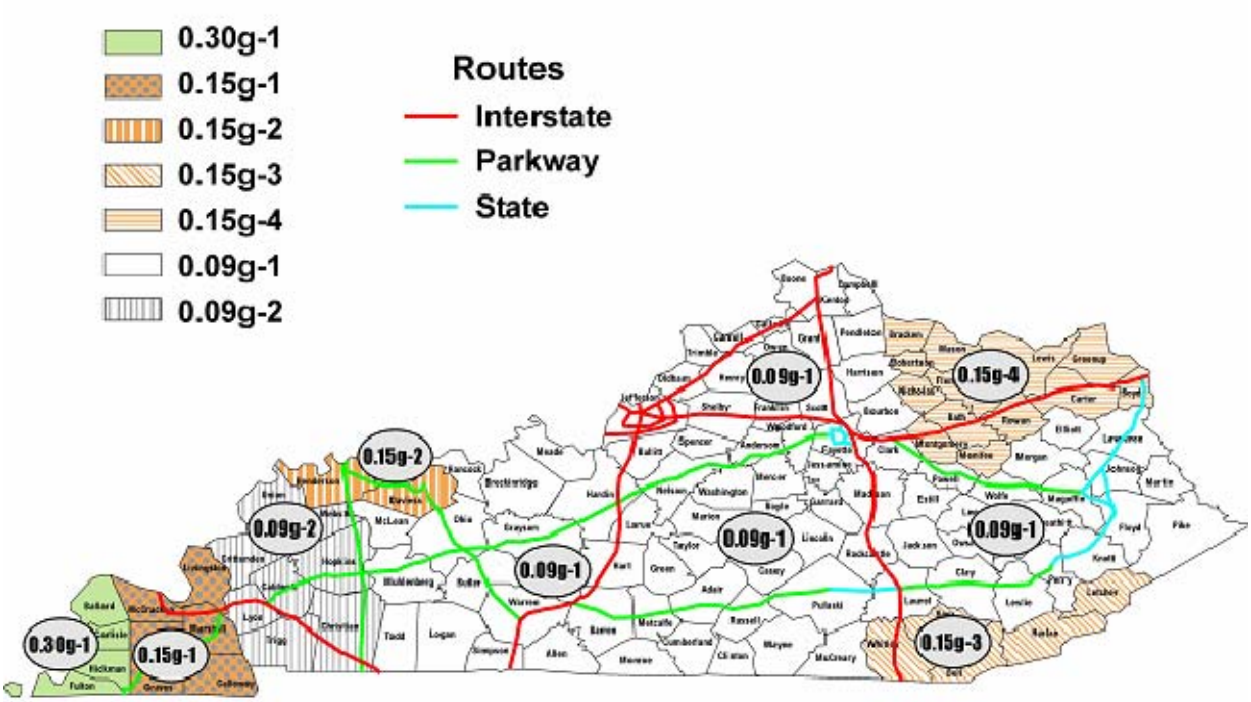

Fig. 2.1 – Time History-Response Spectra for a 50-year event in Kentucky
(Identification Map for 90 Percent Probability of Not Being Exceeded in 50 Years)

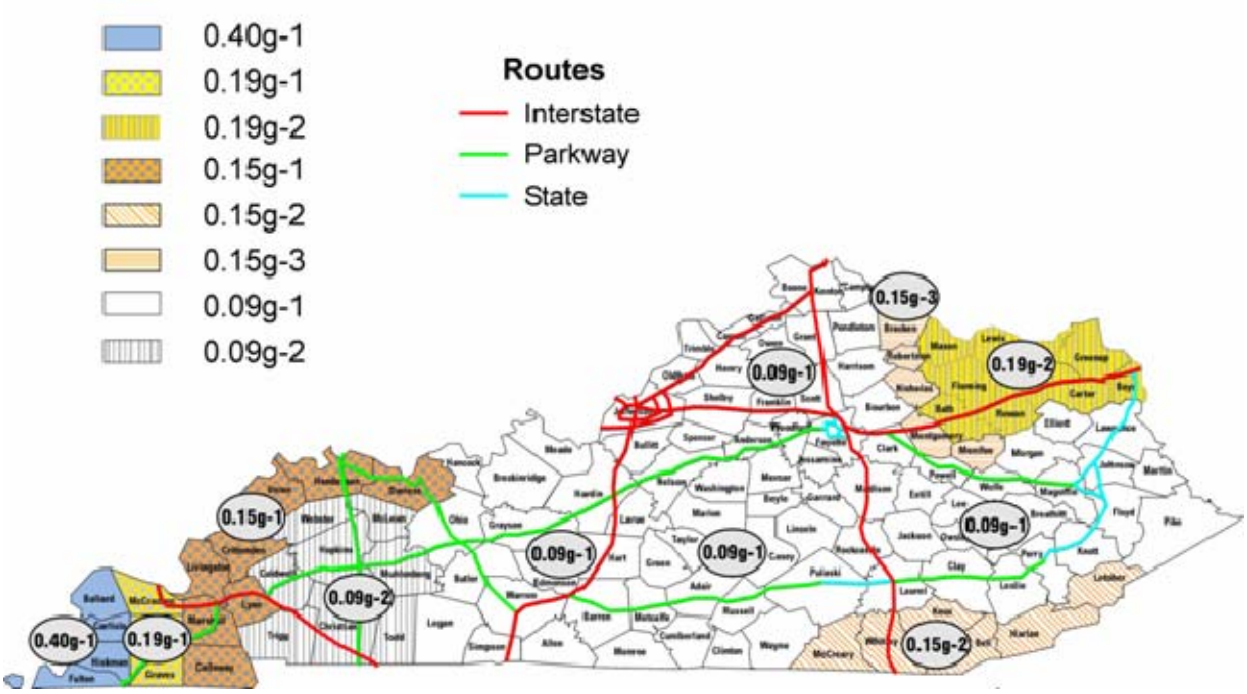

Fig. 2.2 – Time History-Response Spectra for a 250-year event in Kentucky
(Identification Map for 90 Percent Probability of Not Being Exceeded in 250 Years)

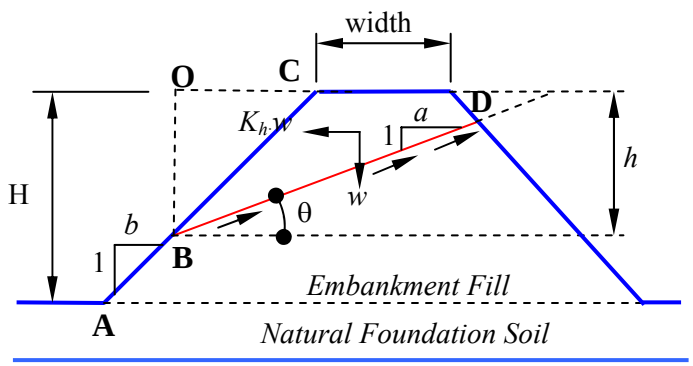

Fig. 2.3 – Wedge failure mode of an embankment

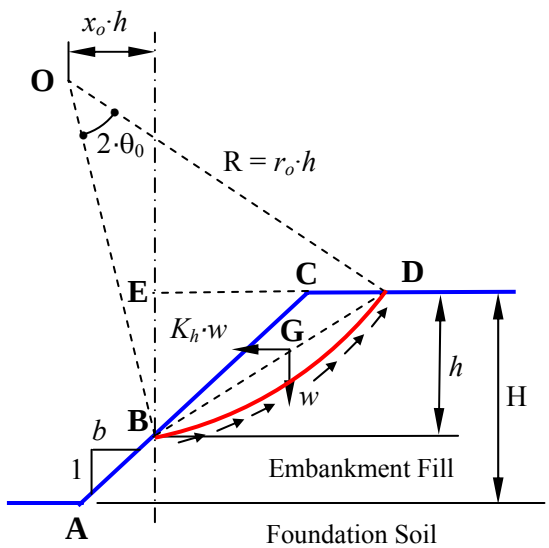

Fig. 2.4 – Circular slope failure mode: case I

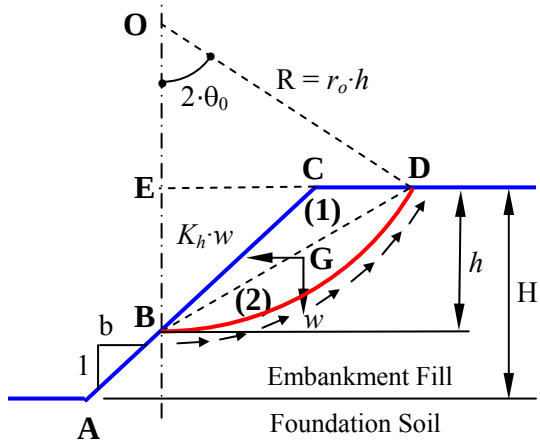

Fig. 2.5 – Circular slope failure mode: case II

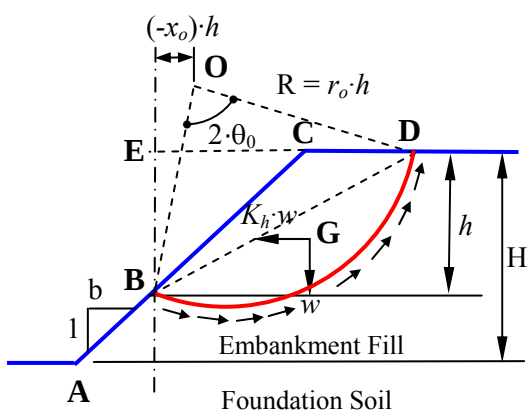

Fig. 2.6 – Circular slope failure mode: case III

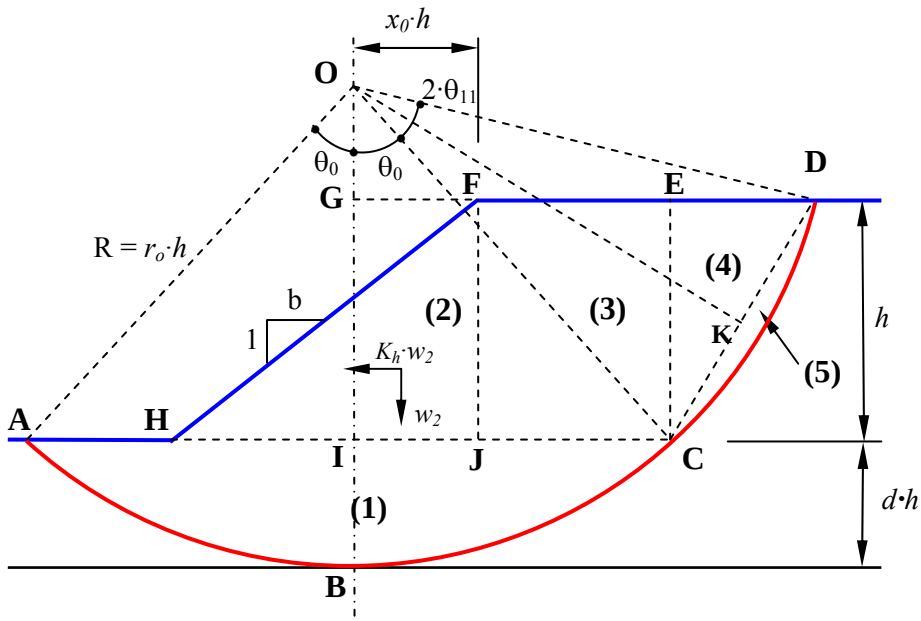

Fig. 2.7 – Base Failure mode of an embankment

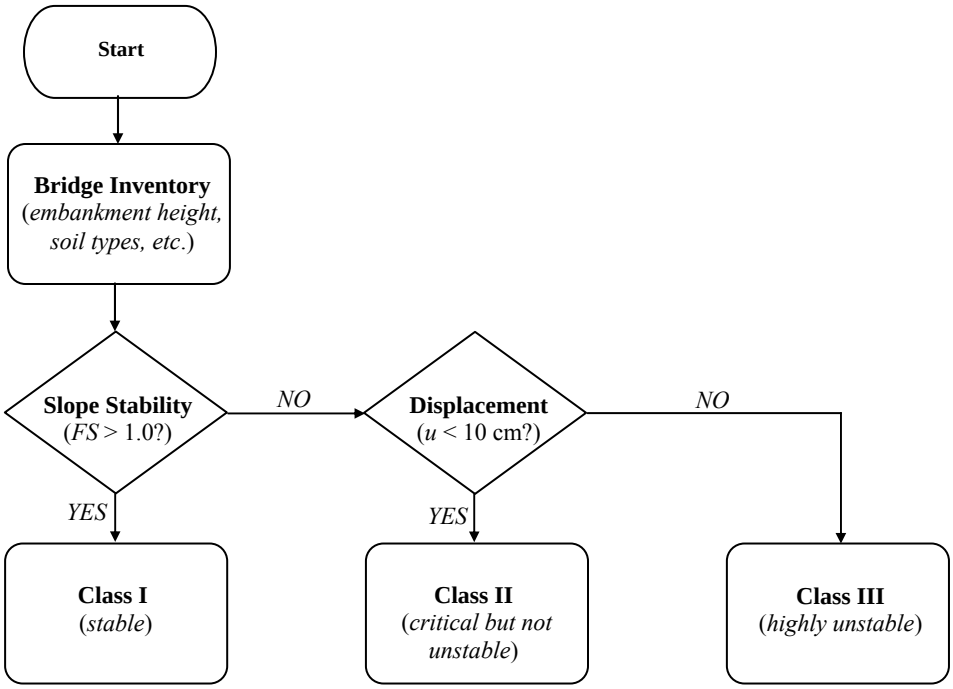

Fig. 2.8 – Slope stability assessment process

3 LIQUEFACTION POTENTIAL ASSESSMENT

3.1 Introduction

Liquefaction is defined as the transformation of a granular material from a solid to a liquefied state as a consequence of increased pore-water pressure and reduced effective stress (Marcuson 1978). Increased pore-water pressure is induced by the tendency of granular materials to compact when subjected to cyclic shear deformations. The change of state occurs most readily in loose to moderately dense granular soils with poor drainage, such as silty sands or sands and gravels capped by or containing seams of impermeable sediment. As liquefaction occurs, the soil stratum softens, allowing large cyclic deformations to occur. In loose materials, the softening is also accompanied by a loss of shear strength that may lead to large shear deformations or even flow failure under moderate to high shear stresses, such as beneath a foundation or sloping ground. In moderately dense to dense materials, liquefaction leads to transient softening and increased cyclic shear strains, but a tendency to dilate during shear inhibits major strength loss and large ground deformations. A condition of cyclic mobility or cyclic liquefaction may develop following liquefaction of moderately dense granular materials. Beneath gently sloping to flat ground, liquefaction may lead to ground oscillation or lateral spread as a consequence of either flow deformation or cyclic mobility. Loose soils also compact during liquefaction and reconsolidation, leading to ground settlement. Sand boils may also erupt as excess pore water pressures dissipate.

3.2 Methodology for Liquefaction Potential

Many procedures have been developed over the last forty years to evaluate the liquefaction potential. Of these procedures, the most popular one is provided by Seed and Idriss (1971). This method, known also as the simplified procedure, has been modified and refined since its first inception, through Seed (1979), Seed and Idriss (1982), and Seed et. al. (1985). In 1985, the National Research Council sponsored a workshop in which 36 experts and observers thoroughly reviewed the state-of-knowledge for assessing liquefaction hazard. The resulting report (NRC 1985) from the workshop has since become the standard and reference for liquefaction hazard assessment for quite sometime. Most recently, Youd et. al. (2001) conducted a workshop in which 20 experts updated and incorporated new procedures and findings.

The method from that workshop (Youd et. al. 2001) will be used to conduct the liquefaction potential assessment for the bridge embankments along the five parkways. The assessment methodology involving the determination of factor of safety [seismic demand (Section 3.2.1.1) and capacity (Section 3.2.1.2)] of liquefaction and liquefaction potential index (LPI) will be discussed as follows.

3.2.1 Factor of Safety (*FS*) against Liquefaction

3.2.1.1 Seismic Demand of Soil for Liquefaction Potential

The seismic demand on a soil layer, expressed in terms of CSR (Cyclic Stress Ratio), can be computed as follows (Seed and Idriss 1971):

$$CSR = \frac{(\tau_h)_{avg}}{\sigma_o'} \cong 0.65 \frac{a_{max}}{g} \cdot \frac{\sigma_o}{\sigma_o'} \cdot r_d \tag{3.1}$$

Where

$(\tau_h)_{avg}$ = the average cyclic shear stress during the time history of interest
$a_{\max}$ = peak horizontal acceleration at the ground surface generated by the earthquake
g = acceleration of gravity
σ_0 = total vertical overburden stress
σ_0' = effective vertical over burden stresses
r_d = stress reduction coefficient

The r_d coefficient accounts for flexibility of the soil profile. It depends upon the soil profile, and the variability range for different soil profile increase with depth. The following equation presented in Youd et al. (2001) will be used to determine the value of r_d

$$r_d = \frac{(1.000 - 0.4113z^{0.5} + 0.04052z + 0.001753z^{1.5})}{(1.000 - 0.4177z^{0.5} + 0.05729z - 0.006205z^{1.5} + 0.001210z^2)} \tag{3.2}$$

z is the depth of beneath ground surface in meters. A water table at a depth of 10 ft beneath the ground surface was assumed in the analysis to represent a probable scenario for all bridges without detailed subsurface exploration.

3.2.1.2 Seismic Capacity or Resistance of Soil for Liquefaction Potential

The capacity of the soil to resist liquefaction, expressed in terms of CRR (Cyclic Resistance Ratio), can be obtained commonly through a variety of field tests that includes the standard penetration test (SPT), the cone penetration test (CPT), shear-wave velocity measurements (*Vs*), and the Becker penetration test (BPT). By far, the soil data in majority of the bridge plans of the five parkways was determined using the SPT (*N*-value) method. Therefore, the seismic capacity or resistance of soil in this study will be determined based on this method.

The relation between the SPT test value and the cyclic resistance ratio (CRR) (or cyclic stress ratio, CSR) which is the seismic capacity of a given soil is depicted in Fig. 3.1. In the figure, $(N_1)_{60}$ is the SPT blow count normalized to an overburden pressure of approximately 100 kPa (1 ton/sq ft) and a hammer energy ratio or hammer efficiency of 60%. The graph shows sites where liquefaction effects were or were not observed following past earthquakes with magnitudes of approximately 7.5. The CRR curves with fines contents of greater than or equal to 5%, 15%, and 35%, on the graph were conservatively positioned to separate regions with the effect of liquefaction from regions with little to no liquefaction. Curves were developed for granular soils with the fines contents of 5% or less, 15%, and 35% as shown on the plot.

The *CRR* curve shown in Fig. 3.1 for fines content of greater than or equal to 5% at an earthquake magnitude of 7.5 (indicated by a sub-script 7.5) is approximated by the following equation (Youd et. al. 2001):

$$CRR_{7.5} = \frac{1}{34-(N_1)_{60}} + \frac{(N_1)_{60}}{135} + \frac{50}{[10\cdot(N_1)_{60}+45]^2} - \frac{1}{200} \tag{3.3}$$

It is generally agreed that for $(N_1)_{60} \geq 30$, clean granular soils are too dense to liquefy, and therefore, are classified as non-liquefiable. It is evident that the *CRR* value changes with the increase or decrease of fines content (Fig. 3.1), among other grain characteristics. To account for different percentage of fines content, the following correction of $(N_1)_{60}$ shall be made $(N_1)_{60cs}$ (Youd et. al. 2001):

$$(N_1)_{60cs} = \alpha + \beta(N_1)_{60} \tag{3.4}$$

Where α and β can be determined from the following relationships (Youd et. al. 2001):

For fines content, $FC \leq 5\%$,

$$\alpha = 0 \tag{3.5.a}$$

$$\beta = 1.0 \tag{3.6.a}$$

For fines content, $5\% < FC < 35\%$,

$$\alpha = exp\left[1.76 - \left(\frac{190}{FC^2}\right)\right] \tag{3.5.b}$$

$$\beta = \left[0.99 + \left(\frac{FC^{1.5}}{1000}\right)\right] \tag{3.6.b}$$

For fines content, $FC \geq 35\%$,

$$\alpha = 5.0 \tag{3.5.c}$$

$$\beta = 1.2 \tag{3.6.c}$$

In addition to fines content and grain characteristics, other factors that may affect the SPT count are included in the following equation (Youd et. al. 2001):

$$(N_1)_{60} = N_m C_N C_E C_B C_R C_S \tag{3.7}$$

Where

N_m = measured standard penetration resistance
C_N = factor to normalize N_m to a common reference effective overburden stress
C_E = correction for hammer energy ratio (ER)
C_B = correction factor for borehole diameter
C_R = correction factor for rod length
C_S = correction factor for samplers with or without liners

These correction factors are tabulated in Table 3.1.

Table 3.1: Corrections to SPT (Youd et. al. 2001)

Factor	Equipment variable	Term	Correction
Overburden pressure	–	C_N	$2.2/(1.2 + \sigma'_{vo}/P_a)$
Overburden pressure	–	C_N	$C_N \leq 1.7$
Energy ratio	Donut hammer	C_E	0.5-1.0
Energy ratio	Safety hammer	C_E	0.7-1.2
Energy ratio	Automatic-trip Donut-type hammer	C_E	0.8-1.3
Borehole diameter	65-115 mm	C_B	1.0
Borehole diameter	150 mm	C_B	1.05
Borehole diameter	200 mm	C_B	1.15
Rod length	< 3 m	C_R	0.75
Rod length	3-4 m	C_R	0.8
Rod length	4-6 m	C_R	0.85
Rod length	6-10 m	C_R	0.95
Rod length	10-30 m	C_R	1.0
Sampling method	Standard sampler	C_S	1.0
Sampling method	Sampler without liners	C_S	1.1-1.3

The C_N factor shown in Table 3.1 is used to normalize the measured standard penetration resistance (N_m) to an effective overburden pressure, σ'_{vo}, with atmospheric pressure, P_a, equals to 100 KPa or 1 tsf or 1 atm. The C_N factor is verified and recommended for use for an effective overburden pressure of less than and equal to 200 KPa or 2 tsf (Youd et. al. 2001)

3.2.1.3 Factor of Safety (*FS*) Determination

The factor of safety (*FS*) for liquefaction potential can therefore be calculated, once the demand (*CRS*, Section 3.2.1.1) and the resistance ($CRR_{7.5}$, Section 3.2.1.2) of a given soil are determined, as follows

$$FS = \frac{CRR_{7.5}}{CSR} \tag{3.8.a}$$

It should be noted that Eq. 3.8.a applies only to earthquakes with a magnitude of 7.5. For different magnitude of earthquakes, a magnitude scaling factor (*MSF*) shall be introduced (Seed and Idriss 1982)

$$FS = \frac{CRR_{7.5}}{CSR} \cdot MSF \tag{3.8.b}$$

Where *MSF* is defined as

$$MSF = \frac{10^{2.24}}{M_w^{2.56}}, \text{ and } M_w \text{ is earthquake magnitude} \tag{3.9}$$

The simplified procedure of determining the factor of safety was derived largely based on historical data set which mainly for cases with level to gently sloping sites (i.e. low static shear stress) and validated for cases with depths less than about 15 m (i.e. low overburden pressure). Therefore, for embankments or sites with high overburden pressure and/or high static shear stress, correction factors high overburden pressure, K_σ, and high static shear stress, K_α, can be accounted for by

$$FS = \frac{CRR_{7.5}}{CSR} \cdot MSF \cdot K_\sigma \cdot K_\alpha \tag{3.8.c}$$

Since most of the bridge embankments of the parkways are gently sloped, the correction factor for static shear stress, K_α, will be equal to unity (1.0). The high overburden pressure correction factor, K_σ, will be determined using Eq. 3.10

$$K_\sigma = (\sigma'_{vo}/P_a)^{(f-1)} \tag{3.10}$$

Eq. 3.10 is derived by Hynes and Olsen (1999). The σ'_{vo} and P_a are as defined previously. f is an exponent that is a function of site conditions, including relative density, stress history, aging, and over consolidation ratio (Youd et. al. 2001). It is generally agreed that f can take the following values

Relative densities between 40 – 60%:

$$f = 0.7 - 0.8 \tag{3.11.a}$$

Relative densities between 60 – 80%:

$$f = 0.6 - 0.7 \tag{3.11.b}$$

The method (Eqs. 3.8.a, b, or c) provides a relatively quick assessment of liquefaction potential of a given soil or embankment. In general, when FS is equal or greater than 1.0, the site is in no danger of liquefaction. When FS is less than 1.0, the risk of an embankment facing liquefaction is undoubtedly greater. In such cases, the risk is then classified using the subsequent methodology.

3.2.2 Liquefaction Potential Index (LPI)

For FS less than 1.0, the evaluation of liquefaction failure of a given soil or embankment can be determined using the liquefaction potential index (LPI) introduced by Iwasaki et. al. (1982a and b). The method combines depth (z), cumulative thickness of liquefiable intervals, and factor of safety (FS) of liquefiable intervals into a single parameter or index known as LPI:

$$\text{LPI} = \int_0^{20} F(z) \cdot w(z)\,dz \tag{3.12}$$

Where

$$F(z) = 1 - FS \qquad \text{for } FS < 0 \tag{3.13}$$

$$w(z) = 10 - 0.5z \tag{3.14}$$

z is the depth in meter and limiting the liquefiable overall soil depth to 20 m. $w(z)$ is calculated for the critical soil layer across the profile. A summary of how liquefaction potential is classified for embankment, when *FS* is less than 1.0, is presented in Table 3.2 (also see flow chart in Fig. 3.2).

Table 3.2: Liquefaction potential assessment of an embankment

Liquefaction potential Index*	**Classification**
$0 < LPI < 5$	Low
$5 \leq LPI < 15$	Moderate
$15 \leq LPI$	High

* when *FS* (Section 3.2.1) < 1.0. Embankments with $FS \geq 1.0$ are non-liquefiable.

A liquefaction potential assessment was performed on all bridge embankments.

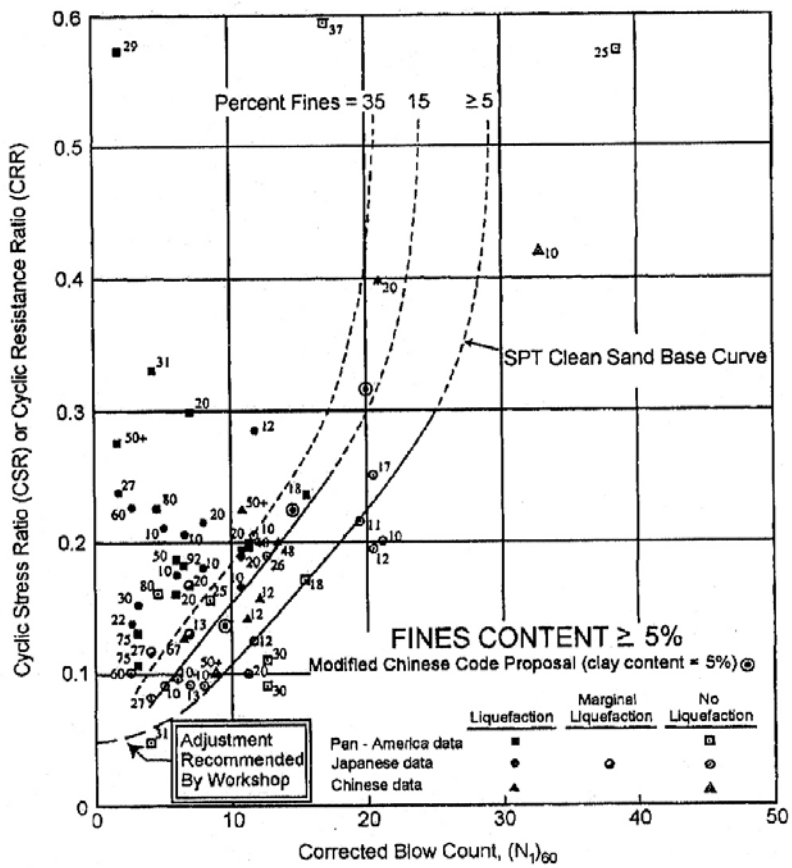

Fig. 3.1 – SPT clean-sand base curve for magnitude of 7.5 earthquakes with data from liquefaction case histories (Youd et. al. 2001).

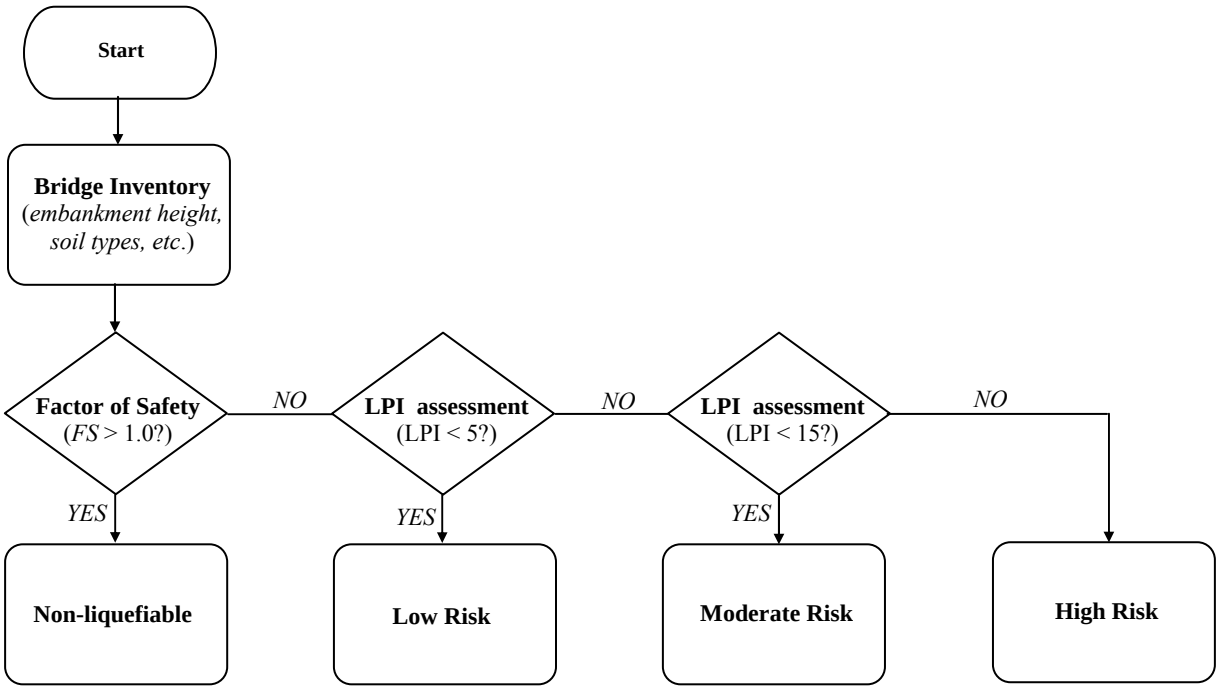

Fig. 3.2 – Liquefaction potential assessment process

4 SEISMIC EMBANKMENT RANKING

4.1 Seismic Embankment Ranking Procedure

Having discussed the slope stability (Chapter 2) and liquefaction potential (Chapter 3) assessment procedures, the individual bridge embankment for the five parkway bridges in western Kentucky shall be ranked in the following manner (Table 4.1).

Table 4.1: Embankment ranking category

Category	Descriptions
C	Slope stability class **I** (stable), **low** liquefaction potential or **non-liquefiable**, and/or combination
B	Slope stability class **II** (critical), **moderate** liquefaction potential, and/or combination
A	Slope stability class **III** (unstable), **high** liquefaction potential, and/or combination

All of the bridge embankments of the five parkways will be ranked in accordance to the procedures and classifications established before. To assist government officials (i.e. city, county, state, etc) in identifying the potential seismic vulnerability in bridge embankment, these methodologies will be applied to the individual counties where the five parkways lie. Additionally, the bridge embankments in each of the counties will also be ranked starting from the one with the highest seismic risk. For instance, all bridge embankments classified as having category A in a county will be ordered numerically such as A1, A2, and so forth, with bridge A1 being the most susceptible to seismic hazard, A2 being the second most susceptible in that county, and so forth.

4.2 Seismic Assessment System for Bridges (SASB)

The ranking assessment of embankment is coded into program using Microsoft Access 2003, and named seismic assessment system for bridges (SASB). SASB performs and ranks an embankment in accordance to the procedures discussed in previous chapters. The use of the SASB program and its requirement are presented in Appendix A.

Summary of the embankment ranking for bridges along the parkways in western Kentucky for 50-year event earthquakes are presented in Tables 4.2 to 4.18, and 250-year event earthquakes in Tables 4.19 to 4.35.

Table 4.2: Seismic Embankment Ranking of Bridges in Butler County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
16 9007 B00061	0.09	45.79	0.14	>>45.0	Class III	0	Low	**Class A**	**A1**
16 9007 B00057	0.09	22.6	1.23		Class I	0	Low	**Class C**	**C1**
16 9007 B00057 P									**C1**
16 9007 B00062	0.09	20	1.27		Class I	0	Low	**Class C**	**C2**
16 9007 B00059	0.09	24.7	1.3		Class I	0	Low	**Class C**	**C3**
16 9007 B00059 P									**C3**
16 9007 B00060	0.09	26.19	1.32		Class I	0	Low	**Class C**	**C4**
16 9007 B00060 P									**C4**
16 9007 B00063	0.09	7	2.02		Class I	0	Low	**Class C**	**C5**
16 9001 B00034	0.09	23.29	2.03		Class I	0	Low	**Class C**	**C6**
16 0231 B00054	0.09	22	2.15		Class I	0	Low	**Class C**	**C7**
16 0403 B00053	0.09	17.5	2.7		Class I	0	Low	**Class C**	**C8**
16 9007 B00055 C	0.09	Culvert			Culvert				**C9**
16 9007 B00056 C	0.09	Culvert			Culvert				**C9**
16 9007 B00058 C	0.09	Culvert			Culvert				**C9**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (u) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.3: Seismic Embankment Ranking of Bridges in Caldwell County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
17 9001 B00033	0.09	22	0.62	>>45.0	Class III	0	Low	**Class A**	**A1**
17 9001 B00033 P									**A1**
17 9001 B00029	0.09	33.59	1.02		Class I	0	Low	**Class C**	**C1**
17 9001 B00029 P									**C1**
17 0293 B00007	0.09	15	1.51		Class I	0	Low	**Class C**	**C2**
17 0091 B00037	0.09	13.12	1.96		Class I	0	Low	**Class C**	**C3**
17 2619 B00048	0.09	12.67	2.66		Class I	0	Low	**Class C**	**C4**
17 2613 B00061	0.09	4	5.06		Class I	0	Low	**Class C**	**C5**
17 9001 B00060	0.09	6	5.35		Class I	0	Low	**Class C**	**C6**
17 9001 B00028 C		Culvert							**C7**
17 9001 B00030 C		Culvert							**C7**
17 9001 B00031 C		Culvert							**C7**
17 9001 B00032 C		Culvert							**C7**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.4: Seismic Embankment Ranking of Bridges in Christian County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
24 9004 B00099	0.09	25.29	0.77	>>45.0	Class III	0	Low	**Class A**	**A1**
24 9004 B00098	0.09	22.79	1.09		Class I	0	Low	**Class C**	**C1**
24 9004 B00102	0.09	32.89	1.09		Class I	0	Low	**Class C**	**C2**
24 9004 B00102 P									**C2**
24 9004 B00096	0.09	20	1.16		Class I	0	Low	**Class C**	**C3**
24 9004 B00095	0.09	24.6	1.43		Class I	0	Low	**Class C**	**C4**
24 9004 B00117	0.09	10	1.57		Class I	0	Low	**Class C**	**C5**
24 9004 B00105	0.09	12.79	1.64		Class I	0	Low	**Class C**	**C6**
24 9004 B00105 P									**C6**
24 9004 B00118	0.09	16.6	1.92		Class I	0	Low	**Class C**	**C7**
24 9004 B00118 P									**C7**
24 9004 B00093	0.09	20.2	2.03		Class I	0	Low	**Class C**	**C8**
24 9004 B00093 P									**C8**
24 9004 B00104	0.09	20.59	2.11		Class I	0	Low	**Class C**	**C9**
24 9004 B00104 P									**C9**
24 9004 B00101	0.09	21	2.25		Class I	0	Low	**Class C**	**C10**
24 9004 B00100	0.09	9	3.02		Class I	0	Low	**Class C**	**C11**
24 9004 B00097	0.09	14.7	3.22		Class I	0	Low	**Class C**	**C12**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.4 (Cont'): Seismic Embankment Ranking of Bridges in Christian County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
24 9004 B00094	0.09	10	3.84		Class I	0	Low	**Class C**	**C13**
24 9004 B00116	0.09	2	10		Class I	0	Low	**Class C**	**C14**
24 9004 B00092 C	0.09	Culvert			Culvert				**C15**
24 9004 B00103 C	0.09	Culvert			Culvert				**C15**
24 9004 B00106 C	0.09	Culvert			Culvert				**C15**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.5: Seismic Embankment Ranking of Bridges in Daviess County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
30 9005 B00059	0.15	20	0.18	>>85	Class III	16.16	High	**Class A**	**A1**
30 9005 B00059 P									**A1**
30 9005 B00058	0.15	25.79	0.12	>>85	Class III	5.72	Moderate	**Class A**	**A2**
30 9005 B00058 P		Parallel Bridge	0.12						**A2**
30 9007 B00082	0.15	14.29	0.41	>>85	Class III	5.98	Moderate	**Class A**	**A3**
30 9007 B00082 P									**A3**
30 9005 B00060	0.15	27.95	0.24	>>85	Class III	3.6	Low	**Class A**	**A4**
30 9007 B00081	0.15	12.29	0.29	>>85	Class III	4.03	Low	**Class A**	**A5**
30 9007 B00081 P									**A5**
30 9007 B00089	0.15	12	0.3	>>85	Class III	0.43	Low	**Class A**	**A6**
30 9007 B00089 P									**A6**
30 9005 B00063	0.15	24.03	0.31	>>85	Class III	0	Low	**Class A**	**A7**
30 9007 B00085	0.15	28.7	0.32	>>85	Class III	0	Low	**Class A**	**A8**
30 9007 B00085 P									**A8**
30 9005 B00061	0.15	31.09	0.34	>>85	Class III	0	Low	**Class A**	**A9**
30 9007 B00083	0.15	25.5	0.49	>>85	Class III	0	Low	**Class A**	**A10**
30 9007 B00094	0.15	12.69	0.58	9.6	Class II	0.01	Low	**Class B**	**B1**
30 9007 B00094 P									**B1**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.5 (Cont'): Seismic Embankment Ranking of Bridges in Daviess County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
30 9007 B00088	0.15	11.69	0.69	8.1	Class II	0	Low	**Class B**	**B2**
30 9007 B00088 P									**B2**
30 9007 B00090	0.15	12	0.86	1.1	Class II	0	Low	**Class B**	**B3**
30 9007 B00090 P									**B3**
30 9007 B00092	0.15	25.69	0.87	1.6	Class II	0	Low	**Class B**	**B4**
30 9007 B00093	0.15	20.5	1.24		Class I	0	Low	**Class C**	**C1**
30 9007 B00091	0.15	10	3.8		Class I	0	Low	**Class C**	**C2**
30 9007 B00084	0.15	3.7	5.01		Class I	0	Low	**Class C**	**C3**
30 9007 B00086	0.15	4.299	8.4		Class I	0	Low	**Class C**	**C4**
30 9005 B00062 C		Culvert			Culvert				**C5**
30 9007 B00087 C		Culvert							**C5**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.6: Seismic Embankment Ranking of Bridges in Fulton County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
38 9003 B00055	0.3	29.69	0.17	>>200	Class III	19.82	High	**Class A**	**A1**
38 9003 B00055 P									**A1**
38 0307 B00015	0.3	27	0.18	>>200	Class III	29.81	High	**Class A**	**A2**
38 9003 B00053	0.3	14.5	0.21	>>200	Class III	22.96	High	**Class A**	**A3**
38 9003 B00053 P									**A3**
38 0051 B00012	0.3	21.3	0.24	>>200	Class III	5.04	Moderate	**Class A**	**A4**
38 9003 B00054	0.3	20	0.29	>>200	Class III	5.83	Moderate	**Class A**	**A5**
38 9003 B00054 P									**A5**
38 9003 B00056 C		Culvert							**C1**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.7: Seismic Embankment Ranking of Bridges in Graves County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
42 9003 B00170	0.15	14	0.39	>>85	Class III	5.43	Moderate	**Class A**	**A1**
42 9003 B00170 P									**A1**
42 0058 B00096	0.15	24.79	0.1	>>85	Class III	0	Low	**Class A**	**A2**
42 9003 B00154	0.15	26.39	0.1	>>85	Class III	0	Low	**Class A**	**A3**
42 9003 B00154 P									**A3**
42 9003 B00175	0.15	18.08	0.16	>>85	Class III	0	Low	**Class A**	**A4**
42 9003 B00162	0.15	11.89	0.19	>>85	Class III	0	Low	**Class A**	**A5**
42 9003 B00162 P									**A5**
42 9003 B00177	0.15	8.799	0.2	>>85	Class III	0	Low	**Class A**	**A6**
42 9003 B00177 P									**A6**
42 9003 B00176	0.15	11.5	0.22	>>85	Class III	0.73	Low	**Class A**	**A7**
42 9003 B00176 P									**A7**
42 9003 B00155	0.15	21.69	0.24	>>85	Class III	0	Low	**Class A**	**A8**
42 9003 B00155 P									**A8**
42 9003 B00169	0.15	28.2	0.26	>>85	Class III	0	Low	**Class A**	**A9**
42 9003 B00172	0.15	18.6	0.26	>>85	Class III	0	Low	**Class A**	**A10**
42 9003 B00160	0.15	11.6	0.3	>>85	Class III	0	Low	**Class A**	**A11**
42 9003 B00156	0.15	33.1	0.31	>>85	Class III	0	Low	**Class A**	**A12**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.7 (Cont'): Seismic Embankment Ranking of Bridges in Graves County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
42 9003 B00156 P			0.31						**A12**
42 9003 B00165	0.15	7.799	0.35	>>85	Class III	0	Low	**Class A**	**A13**
42 9003 B00165 P									**A13**
42 0944 B00180	0.15	24.4	0.4	N/A	Class III	0	Low	**Class A**	**A14**
42 1748 B00128	0.15	20.69	0.42	N/A	Class III	0	Low	**Class A**	**A15**
42 9003 B00167	0.15	9.3	0.43	>>85	Class III	0	Low	**Class A**	**A16**
42 9003 B00167 P									**A16**
42 0121 B00111	0.15	21.79	0.52	>>85	Class III	0	Low	**Class A**	**A17**
42 0301 B00028	0.15	20	0.52	>>85	Class III	0	Low	**Class A**	**A18**
42 9003 B00161	0.15	13.7	0.55	27.1	Class III	0	Low	**Class A**	**A19**
42 9003 B00166	0.15	4.5	0.58	8.1	Class II	0	Low	**Class B**	**B1**
42 9003 B00166 P									**B1**
42 0339 B00143	0.15	23.6	0.72	3.3	Class II	0	Low	**Class B**	**B2**
42 9003 B00159	0.15	9.5	0.82	1.2	Class II	0	Low	**Class B**	**B3**
42 9003 B00159 P									**B3**
42 9003 B00157	0.15	10.3	0.84	0.9	Class II	0	Low	**Class B**	**B4**
42 9003 B00157 P									**B4**
42 0080 B00106	0.15	18.5	0.92	0.5	Class II	0	Low	**Class B**	**B5**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.7 (Cont'): Seismic Embankment Ranking of Bridges in Graves County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
42 9003 B00163	0.15	10.19	1.02		Class I	-0.77	Low	**Class C**	**C1**
42 9003 B00163 P									**C1**
42 9003 B00164	0.15	12.2	1.05		Class I	0	Low	**Class C**	**C2**
42 0131 B00009	0.15	17.5	1.14		Class I	0	Low	**Class C**	**C3**
42 9003 B00158	0.15	10.7	1.27		Class I	0	Low	**Class C**	**C4**
42 9003 B00158 P									**C4**
42 9003 B00153	0.15	21.2	1.8		Class I	0	Low	**Class C**	**C5**
42 9003 B00168	0.15	14	2.08		Class I	0	Low	**Class C**	**C6**
42 9003 B00168 P									**C6**
42 9003 B00173	0.15	2.26	8.21		Class I	0	Low	**Class C**	**C7**
42 9003 B00173 P									**C7**
42 9003 B00171	0.15	0.5	10		Class I	0	Low	**Class C**	**C8**
42 9003 B00174 C	0.15	Culvert			Culvert				**C9**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.8: Seismic Embankment Ranking of Bridges in Grayson County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
43 0224 B00003	0.09	16.3	1.66		Class I	0	Low	**Class C**	**C1**
43 9001 B00069	0.09	17.66	1.69		Class I	0	Low	**Class C**	**C2**
43 0259 B00009	0.09	15	1.73		Class I	0	Low	**Class C**	**C3**
43 0185 B00019	0.09	26.2	1.81		Class I	0	Low	**Class C**	**C4**
43 0079 B00023	0.09	16.69	1.91		Class I	0	Low	**Class C**	**C5**
43 9001 B00070	0.09	20.69	1.98		Class I	0	Low	**Class C**	**C6**
43 9001 B00027	0.09	23.29	2.03		Class I	0	Low	**Class C**	**C7**
43 9001 B00027 P									**C7**
43 9001 B00060	0.09	16.35	2.11		Class I	0	Low	**Class C**	**C8**
43 9001 B00078	0.09	10.5	3		Class I	0	Low	**Class C**	**C9**
43 0088 B00006	0.09	10.79	3.14		Class I	0	Low	**Class C**	**C10**
43 9001 B00073	0.09	10.2	3.46		Class I	0	Low	**Class C**	**C11**
43 9001 B00026	0.09	9.5	3.47		Class I	0	Low	**Class C**	**C12**
43 9001 B00026 P									**C12**
43 9001 B00082	0.09	4	6.08		Class I	0	Low	**Class C**	**C13**
43 9001 B00076	0.09	1	8.16		Class I	0	Low	**Class C**	**C14**
43 9001 B00028 C		Culvert							**C15**
43 9001 B00029 C		Culvert							**C15**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.8 (Cont'): Seismic Embankment Ranking of Bridges in Grayson County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
43 9001 B00030 C		Culvert							**C15**
43 9001 B00031 C		Culvert							**C15**
43 9001 B00032 C	0.09	Culvert			Culvert				**C15**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.9: Seismic Embankment Ranking of Bridges in Hardin County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
47 31W B00108	0.09	45.1	0.72	>>45.0	Class III	0	Low	**Class A**	**A1**
47 9001 B00093	0.09	32.5	1.09		Class I	0	Low	**Class C**	**C1**
47 9001 B00093 P									**C1**
47 31W B00153	0.09	27.09	1.13		Class I	0	Low	**Class C**	**C2**
47 9001 B00092	0.09	31.5	1.17		Class I	0	Low	**Class C**	**C3**
47 9001 B00092 P									**C3**
47 9001 B00127	0.09	34.09	1.26		Class I	0	Low	**Class C**	**C4**
47 9001 B00127 P									**C4**
47 9001 B00085	0.09	23.45	1.69		Class I	0	Low	**Class C**	**C5**
47 1136 B00053	0.09	17.99	1.84		Class I	0	Low	**Class C**	**C6**
47 9001 B00094	0.09	13.1	2.28		Class I	0	Low	**Class C**	**C7**
47 9001 B00094 P									**C7**
47 9001 B00045	0.09	19.2	2.29		Class I	0	Low	**Class C**	**C8**
47 9001 B00090	0.09	16	2.34		Class I	0	Low	**Class C**	**C9**
47 0084 B00043	0.09	16.76	2.4		Class I	0	Low	**Class C**	**C10**
47 9001 B00056	0.09	10	3.91		Class I	0	Low	**Class C**	**C11**
47 9001 B00095 C		Culvert							**C12**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates s.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.10: Seismic Embankment Ranking of Bridges in Henderson County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
51 9005 B00072	0.15	54.1	0.14	>>85	Class III	0	Low	**Class A**	**A1**
51 9004 B00069	0.15	28.6	0.39	>>85	Class III	0	Low	**Class A**	**A2**
51 9004 B00062	0.15	26	0.51	>>85	Class III	0	Low	**Class A**	**A3**
51 9004 B00062 P									**A3**
51 9004 B00111	0.15	27.3	0.6	>>85	Class III	0	Low	**Class A**	**A4**
51 9004 B00065	0.15	18	0.61	>>85	Class III	0	Low	**Class A**	**A5**
51 9004 B00064	0.15	15	0.76	4.5	Class II	0	Low	**Class B**	**B1**
51 0425 B00137	0.15	18	0.77	2	Class II	0	Low	**Class B**	**B2**
51 0425 B00137 P									**B2**
51 9004 B00073	0.15	27	0.8	1.4	Class II	0	Low	**Class B**	**B3**
51 9004 B00073 P									**B3**
51 9005 B00074	0.15	26.1	0.81	>>85	Class II	0	Low	**Class B**	**B4**
51 9005 B00075	0.15	20.89	0.82	4.3	Class II	0	Low	**Class B**	**B5**
51 9005 B00073	0.15	25.5	0.92	1.4	Class II	0	Low	**Class B**	**B6**
51 9005 B00073 P									**B6**
51 9005 B00077	0.15	8.4	0.96	0.3	Class II	0	Low	**Class B**	**B7**
51 9005 B00077 P									**B7**
51 9004 B00112	0.15	19.5	1.08		Class I	0	Low	**Class C**	**C1**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.10 (Cont'): Seismic Embankment Ranking of Bridges in Henderson County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
51 9005 B00076	0.15	21.1	1.09		Class I	0	Low	**Class C**	**C2**
51 9004 B00066	0.15	25	1.31		Class I	0	Low	**Class C**	**C3**
51 9004 B00067	0.15	19.69	1.45		Class I	0	Low	**Class C**	**C4**
51 9005 B00080	0.15	27.89	1.51		Class I	0	Low	**Class C**	**C5**
51 9005 B00078	0.15	24	1.75		Class I	0	Low	**Class C**	**C6**
51 9004 B00068	0.15	6.5	2.36		Class I	0	Low	**Class C**	**C7**
51 9004 B00068 P									**C7**
51 9004 B00063	0.15	1	5.58		Class I	0	Low	**Class C**	**C8**
51 9005 B00079	0.15	5.899	7.13		Class I	0	Low	**Class C**	**C9**
51 9004 B00061 C		Culvert							**C10**
51 9005 B00070 C		Culvert							**C10**
51 9005 B00071 C		Culvert							**C10**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.11: Seismic Embankment Ranking of Bridges in Hickman County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
53 0094 B00050	0.3	12.9	0.24	>>200	Class III	20.4	High	**Class A**	**A1**
53 9003 B00068	0.3	27.39	0.3	>>200	Class III	0	Low	**Class A**	**A2**
53 1529 B00056	0.3	13	0.52	8	Class II	0	Low	**Class B**	**B1**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.12: Seismic Embankment Ranking of Bridges in Hopkins County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
54 9004 B00015	0.09	37	0.35	>>45.0	Class III	0	Low	**Class A**	**A1**
54 9001 B00137	0.09	18.3	0.45	>>45.0	Class III	0	Low	**Class A**	**A2**
54 9001 B00137 P									**A2**
54 9001 B00143	0.09	34.3	0.47	>>45.0	Class III	0	Low	**Class A**	**A3**
54 9001 B00143 P									**A3**
54 9001 B00144	0.09	41	0.47	>>45.0	Class III	0	Low	**Class A**	**A4**
54 9001 B00144 P									**A4**
54 9001 B00136	0.09	19.69	0.54	>>45.0	Class III	0	Low	**Class A**	**A5**
54 9001 B00136 P									**A5**
54 9004 B00095	0.09	32	0.56	>>45.0	Class III	0	Low	**Class A**	**A6**
54 9004 B00095 P									**A6**
54 9001 B00145	0.09	32.41	0.57	>>45.0	Class III	0	Low	**Class A**	**A7**
54 9001 B00145 P									**A7**
54 9004 B00014	0.09	11.39	0.7	>>45.0	Class III	0	Low	**Class A**	**A8**
54 9004 B00014 P									**A8**
54 9001 B00140	0.09	31.29	0.77	>>45.0	Class III	0	Low	**Class A**	**A9**
54 9001 B00140 P									**A9**
54 9001 B00146	0.09	14.2	0.81	24.6	Class III	0	Low	**Class A**	**A10**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.12 (Cont'): Seismic Embankment Ranking of Bridges in Hopkins County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
54 9001 B00146 P									**A10**
54 9004 B00211	0.09	10.2	0.96	0.3	Class II	0	Low	**Class B**	**B1**
54 9004 B00019	0.09	13.89	1		Class I	0	Low	**Class C**	**C1**
54 9004 B00096	0.09	33.7	1.01		Class I	0	Low	**Class C**	**C2**
54 9004 B00096 P									**C2**
54 9004 B00012	0.09	27.19	1.02		Class I	0	Low	**Class C**	**C3**
54 9004 B00012 P									**C3**
54 9004 B00021	0.09	21.9	1.02		Class I	0	Low	**Class C**	**C4**
54 9004 B00021 P									**C4**
54 9004 B00018	0.09	26.39	1.07		Class I	0	Low	**Class C**	**C5**
54 9004 B00101	0.09	40.29	1.07		Class I	0	Low	**Class C**	**C6**
54 9004 B00101 P									**C6**
54 9004 B00099	0.09	30.72	1.13		Class I	0	Low	**Class C**	**C7**
54 9004 B00099 P									**C7**
54 9001 B00138	0.09	14.17	1.15		Class I	0	Low	**Class C**	**C8**
54 9001 B00138 P									**C8**
54 9004 B00011	0.09	13.92	1.17		Class I	0	Low	**Class C**	**C9**
54 0454 B00117	0.09	31.39	1.2		Class I	0	Low	**Class C**	**C10**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.12 (Cont'): Seismic Embankment Ranking of Bridges in Hopkins County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
54 9001 B00139	0.09	35.9	1.25		Class I	0	Low	**Class C**	**C11**
54 9001 B00139 P									**C11**
54 0062 B00048	0.09	28.5	1.31		Class I	0	Low	**Class C**	**C12**
54 9004 B00020	0.09	10.4	1.39		Class I	0	Low	**Class C**	**C13**
54 9004 B00020 P									**C13**
54 9004 B00097	0.09	19.39	1.42		Class I	0	Low	**Class C**	**C14**
54 9004 B00097 P									**C14**
54 9004 B00100	0.09	19	1.74		Class I	0	Low	**Class C**	**C15**
54 9004 B00100 P									**C15**
54 0813 B00131	0.09	13.4	1.83		Class I	0	Low	**Class C**	**C16**
54 0109 B00070	0.09	13.28	1.86		Class I	0	Low	**Class C**	**C17**
54 9004 B00016	0.09	15	2.03		Class I	0	Low	**Class C**	**C18**
54 9004 B00106	0.09	10.09	2.43		Class I	0	Low	**Class C**	**C19**
54 9004 B00106 P									**C19**
54 9004 B00013	0.09	9	4.65		Class I	0	Low	**Class C**	**C20**
54 9004 B00098	0.09	4	9.06		Class I	0	Low	**Class C**	**C21**
54 9004 B00098 P									**C21**
54 9001 B00141 C	0.09	Culvert			Culvert				**C22**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
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4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.12 (Cont'): Seismic Embankment Ranking of Bridges in Hopkins County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
54 9004 B00010 C	0.09	Culvert			Culvert				**C22**
54 9004 B00017 C	0.09	Culvert			Culvert				**C22**
54 9004 B00104 C	0.09	Culvert			Culvert				**C22**
54 9004 B00105 C		Culvert							**C22**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.13: Seismic Embankment Ranking of Bridges in Lyon County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
72 9001 B00030	0.09	35.29	1.34		Class I	0	Low	**Class C**	**C1**
72 9001 B00030 P									**C1**
72 9001 B00029	0.09	22.54	2.1		Class I	0	Low	**Class C**	**C2**
72 0093 B00050	0.09	14.59	2.61		Class I	0	Low	**Class C**	**C3**
72 9001 B00052	0.09	10	4.73		Class I	0	Low	**Class C**	**C4**
72 9001 B00052 P									**C4**
72 9001 B00049	0.09	6.299	7.14		Class I	0	Low	**Class C**	**C5**
72 9001 B00049 P									**C5**
72 9001 B00051 C		Culvert			Culvert				**C6**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.14: Seismic Embankment Ranking of Bridges in Marshall County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
79 0795 B00012	0.15	26.19	0.17	>>85	Class III	0	Low	**Class A**	**A1**
79 9003 B00064	0.15	13.39	0.23	>>85	Class III	0	Low	**Class A**	**A2**
79 9003 B00064 P									**A2**
79 9003 B00074	0.15	33.138	0.3	>>85	Class III	0	Low	**Class A**	**A3**
79 9003 B00074 P									**A3**
79 0408 B00103	0.15	11.27	0.31	>>85	Class III	0	Low	**Class A**	**A4**
79 1422 B00050	0.15	27.39	0.33	>>85	Class III	0	Low	**Class A**	**A5**
79 9003 B00066	0.15	28.6	0.37	>>85	Class III	0	Low	**Class A**	**A6**
79 9003 B00076	0.15	12.59	0.44	>>85	Class III	3.65	Low	**Class A**	**A7**
79 9003 B00076 P									**A7**
79 0348 B00102	0.15	24	0.51	>>85	Class III	0	Low	**Class A**	**A8**
79 9003 B00068	0.15	21.7	0.66	16.9	Class III	0	Low	**Class A**	**A9**
79 9003 B00073	0.15	10.64	0.69	4	Class II	0	Low	**Class B**	**B1**
79 641 B00126	0.15	23	0.77	2	Class II	0	Low	**Class B**	**B2**
79 0068 B00001	0.15	12.5	0.81	1.2	Class II	0	Low	**Class B**	**B3**
79 0068 B00001 P									**B3**
79 9003 B00075	0.15	11.88	0.89	0.6	Class II	0	Low	**Class B**	**B4**
79 9003 B00075 P									**B4**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.14 (Cont'): Seismic Embankment Ranking of Bridges in Marshall County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
79 0024 B00114	0.15	31	0.91	1.3	Class II	0	Low	**Class B**	**B5**
79 0024 B00114 P									**B5**
79 9003 B00071	0.15	15.1	1.96		Class I	0	Low	**Class C**	**C1**
79 9003 B00065 C		Culvert							**C2**
79 9003 B00067 C		Culvert							**C2**
79 9003 B00069 C		Culvert							**C2**
79 9003 B00070 C		Culvert							**C2**
79 9003 B00072 C		Culvert							**C2**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.15: Seismic Embankment Ranking of Bridges in Muhlenberg County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
89 9001 B00096	0.09	37	0.34	>>45.0	Class III	0	Low	**Class A**	**A1**
89 9001 B00096 P									**A1**
89 9001 B00094	0.09	35	0.37	>>45.0	Class III	0	Low	**Class A**	**A2**
89 9001 B00094 P									**A2**
89 9001 B00093	0.09	54	0.41	>>45.0	Class III	0	Low	**Class A**	**A3**
89 9001 B00093 P									**A3**
89 9001 B00109	0.09	26	0.42	>>45.0	Class III	0	Low	**Class A**	**A4**
89 9001 B00109 P									**A4**
89 9001 B00090	0.09	16.79	1		Class I	0	Low	**Class C**	**C1**
89 9001 B00090 P									**C1**
89 9001 B00092	0.09	26.5	1.02		Class I	0	Low	**Class C**	**C2**
89 9001 B00092 P									**C2**
89 2692 B00085	0.09	21.79	1.07		Class I	0	Low	**Class C**	**C3**
89 9001 B00089	0.09	30.8	1.21		Class I	0	Low	**Class C**	**C4**
89 9001 B00089 P									**C4**
89 9001 B00091	0.09	24.89	1.37		Class I	0	Low	**Class C**	**C5**
89 9001 B00091 P									**C5**
89 0431 B00132	0.09	10.09	1.65		Class I	0	Low	**Class C**	**C6**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.15 (Cont'): Seismic Embankment Ranking of Bridges in Muhlenberg County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
89 0431 B00132 P									**C6**
89 2695 B00058	0.09	7.7	4.49		Class I	0	Low	**Class C**	**C7**
89 2697 B00131	0.09	3.099	5.21		Class I	0	Low	**Class C**	**C8**
89 2694 B00059	0.09	4.9	6.41		Class I	0	Low	**Class C**	**C9**
89 9001 B00115 C		Culvert							**C10**
89 9001 B00130	0.09		0				Lack of Plans		**N/A**
89 9001 B00905	0.09		0				Lack of Plans		**N/A**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.16: Seismic Embankment Ranking of Bridges in Ohio County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
92 9007 B00063	0.09	18.39	0.28	>>45.0	Class III	0	Low	**Class A**	**A1**
92 9007 B00063 P									**A1**
92 9007 B00075	0.09	32.2	0.32	>>45.0	Class III	0	Low	**Class A**	**A2**
92 9007 B00075 P									**A2**
92 9001 B00134	0.09	19.5	0.42	>>45.0	Class III	0	Low	**Class A**	**A3**
92 9001 B00134 P									**A3**
92 9001 B00133	0.09	27	0.62	>>45.0	Class III	0	Low	**Class A**	**A4**
92 9001 B00133 P									**A4**
92 9007 B00069	0.09	26.8	0.95	1	Class II	0	Low	**Class B**	**B1**
92 1245 B00112	0.09	27.2	1.03		Class I	0	Low	**Class C**	**C1**
92 9007 B00076	0.09	14.19	1.04		Class I	0	Low	**Class C**	**C2**
92 9007 B00076 P									**C2**
92 0505 B00093	0.09	28.39	1.06		Class I	0	Low	**Class C**	**C3**
92 9007 B00060	0.09	28	1.09		Class I	0	Low	**Class C**	**C4**
92 9007 B00060 P									**C4**
92 9007 B00062	0.09	37	1.23		Class I	0	Low	**Class C**	**C5**
92 9007 B00071	0.09	30	1.29		Class I	0	Low	**Class C**	**C6**
92 9007 B00061	0.09	36	1.31		Class I		Low	**Class C**	**C7**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.16 (Cont'): Seismic Embankment Ranking of Bridges in Ohio County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
92 2712 B00136	0.09	24.1	1.53		Class I	0	Low	**Class C**	**C8**
92 9007 B00072	0.09	25	1.89		Class I	0	Low	**Class C**	**C9**
92 9007 B00072 P									**C9**
92 9001 B00130	0.09	21	2.25		Class I	0	Low	**Class C**	**C10**
92 9001 B00130 P									**C10**
92 1245 B00108	0.09	7	2.63		Class I	0	Low	**Class C**	**C11**
92 9007 B00065	0.09	11.09	2.96		Class I	0	Low	**Class C**	**C12**
92 9007 B00074	0.09	10	4.23		Class I	0	Low	**Class C**	**C13**
92 9007 B00067	0.09	4	4.3		Class I	0	Low	**Class C**	**C14**
92 9007 B00067 P									**C14**
92 9007 B00070	0.09	3	5.83		Class I	0	Low	**Class C**	**C15**
92 9001 B00132	0.09	4.5	9.07		Class I	0	Low	**Class C**	**C16**
92 9001 B00132 P									**C16**
92 9007 B00064	0.09	2.599	10		Class I	0	Low	**Class C**	**C17**
92 9001 B00131 C		Culvert							**C18**
92 9007 B00066 C	0.09	Culvert			Culvert				**C18**
92 9007 B00068 C	0.09	Culvert			Culvert				**C18**
92 9007 B00073 C	0.09	Culvert			Culvert				**C18**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.17: Seismic Embankment Ranking of Bridges in Warren County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
114 0884 B00050	0.09	21.5	0.83	8.1	Class II	0	Low	**Class B**	**B1**
114 9007 B00057	0.09	23.23	1.06		Class I	0	Low	**Class C**	**C1**
114 9007 B00049	0.09	18.79	1.07		Class I	0	Low	**Class C**	**C2**
114 9007 B00049 P									**C2**
114 0231 B00055	0.09	30.366	1.12		Class I	0	Low	**Class C**	**C3**
114 9007 B00052	0.09	30.4	1.18		Class I	0	Low	**Class C**	**C4**
114 9007 B00052 P									**C4**
114 9007 B00054	0.09	15.88	1.22		Class I	0	Low	**Class C**	**C5**
114 9007 B00054 P									**C5**
114 9007 B00051	0.09	29.59	1.39		Class I	0	Low	**Class C**	**C6**
114 9007 B00051 P									**C6**
114 9007 B00053	0.09	25.34	1.39		Class I	0	Low	**Class C**	**C7**
114 9007 B00053 P									**C7**
114 9007 B00059	0.09	4.163	1.63		Class I	0	Low	**Class C**	**C8**
114 0626 B00056	0.09	5.213	2.88		Class I	0	Low	**Class C**	**C9**
114 9007 B00060	0.09	8.134	2.9		Class I	0	Low	**Class C**	**C10**
114 9007 B00058	0.09	8.758	3.61		Class I	0	Low	**Class C**	**C11**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (u) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.18: Seismic Embankment Ranking of Bridges in Webster County on/over Western Kentucky Parkways for 50-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
117 9004 B00074	0.09	37.75	0.79	14.3	Class III	0	Low	**Class A**	**A1**
117 9004 B00074 P		Parallel Bridge	0.79						**A1**
117 9004 B00073	0.09	21	0.96	0.7	Class II	0	Low	**Class B**	**B1**
117 9004 B00068	0.09	26.36	1.01		Class I	0	Low	**Class C**	**C1**
117 9004 B00072	0.09	20.6	1.14		Class I	0	Low	**Class C**	**C2**
117 9004 B00072 P		Parallel Bridge	1.14						**C2**
117 9004 B00071	0.09	34.159	1.38		Class I	0	Low	**Class C**	**C3**
117 9004 B00071 P		Parallel Bridge	1.38						**C3**
117 9004 B00069	0.09	24.6	1.45		Class I	0	Low	**Class C**	**C4**
117 9004 B00069 P		Parallel Bridge	1.45						**C4**
117 9004 B00070	0.09	13.59	2.14		Class I	0	Low	**Class C**	**C5**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.19: Seismic Embankment Ranking of Bridges in Butler County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
16 9007 B00061	0.09	45.79	0.14	>>340	Class III	0	Low	**Class A**	**A1**
16 9007 B00057	0.09	22.6	1.23		Class I	0	Low	**Class C**	**C1**
16 9007 B00057 P									**C1**
16 9007 B00062	0.09	20	1.27		Class I	0	Low	**Class C**	**C2**
16 9007 B00059	0.09	24.7	1.3		Class I	0	Low	**Class C**	**C3**
16 9007 B00059 P									**C3**
16 9007 B00060	0.09	26.19	1.32		Class I	0	Low	**Class C**	**C4**
16 9007 B00060 P									**C4**
16 9007 B00063	0.09	7	2.02		Class I	0	Low	**Class C**	**C5**
16 9001 B00034	0.09	23.29	2.03		Class I	0	Low	**Class C**	**C6**
16 0231 B00054	0.09	22	2.15		Class I	0	Low	**Class C**	**C7**
16 0403 B00053	0.09	17.5	2.7		Class I	0	Low	**Class C**	**C8**
16 9007 B00055 C	0.09	Culvert			Culvert				**C9**
16 9007 B00056 C	0.09	Culvert			Culvert				**C9**
16 9007 B00058 C	0.09	Culvert			Culvert				**C9**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.20: Seismic Embankment Ranking of Bridges in Caldwell County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
17 9001 B00033	0.09	22	0.62	>>340	Class III	0	Low	**Class A**	**A1**
17 9001 B00033 P									**A1**
17 9001 B00029	0.09	33.59	1.02		Class I	0	Low	**Class C**	**C1**
17 9001 B00029 P									**C1**
17 0293 B00007	0.09	15	1.51		Class I	0	Low	**Class C**	**C2**
17 0091 B00037	0.09	13.12	1.96		Class I	0	Low	**Class C**	**C3**
17 2619 B00048	0.09	12.67	2.66		Class I	0	Low	**Class C**	**C4**
17 2613 B00061	0.09	4	5.06		Class I	0	Low	**Class C**	**C5**
17 9001 B00060	0.09	6	5.35		Class I	0	Low	**Class C**	**C6**
17 9001 B00028 C		Culvert							**C7**
17 9001 B00030 C		Culvert							**C7**
17 9001 B00031 C		Culvert							**C7**
17 9001 B00032 C		Culvert							**C7**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (u) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.21: Seismic Embankment Ranking of Bridges in Christian County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
24 9004 B00099	0.09	25.29	0.77	>>340	Class III	0	Low	**Class A**	**A1**
24 9004 B00098	0.09	22.79	1.09		Class I	0	Low	**Class C**	**C1**
24 9004 B00102	0.09	32.89	1.09		Class I	0	Low	**Class C**	**C2**
24 9004 B00102 P									**C2**
24 9004 B00096	0.09	20	1.16		Class I	0	Low	**Class C**	**C3**
24 9004 B00095	0.09	24.6	1.43		Class I	0	Low	**Class C**	**C4**
24 9004 B00117	0.09	10	1.57		Class I	0	Low	**Class C**	**C5**
24 9004 B00105	0.09	12.79	1.64		Class I	0	Low	**Class C**	**C6**
24 9004 B00105 P									**C6**
24 9004 B00118	0.09	16.6	1.92		Class I	0	Low	**Class C**	**C7**
24 9004 B00118 P									**C7**
24 9004 B00093	0.09	20.2	2.03		Class I	0	Low	**Class C**	**C8**
24 9004 B00093 P									**C8**
24 9004 B00104	0.09	20.59	2.11		Class I	0	Low	**Class C**	**C9**
24 9004 B00104 P									**C9**
24 9004 B00101	0.09	21	2.25		Class I	0	Low	**Class C**	**C10**
24 9004 B00100	0.09	9	3.02		Class I	0	Low	**Class C**	**C11**
24 9004 B00097	0.09	14.7	3.22		Class I	0	Low	**Class C**	**C12**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.21 (Cont'): Seismic Embankment Ranking of Bridges in Christian County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
24 9004 B00094	0.09	10	3.84		Class I	0	Low	**Class C**	**C13**
24 9004 B00116	0.09	2	10		Class I	0	Low	**Class C**	**C14**
24 9004 B00092 C	0.09	Culvert			Culvert				**C15**
24 9004 B00103 C	0.09	Culvert			Culvert				**C15**
24 9004 B00106 C	0.09	Culvert			Culvert				**C15**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.22: Seismic Embankment Ranking of Bridges in Daviess County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
30 9005 B00058	0.15	25.79	0.12	>>660	Class III	21.15	High	**Class A**	**A1**
30 9005 B00058 P									**A1**
30 9005 B00059	0.15	20	0.18	>>660	Class III	30.8	High	**Class A**	**A2**
30 9005 B00059 P									**A2**
30 9005 B00060	0.15	27.95	0.24	>>660	Class III	13.43	Moderate	**Class A**	**A3**
30 9007 B00081	0.15	12.29	0.29	>>660	Class III	7.76	Moderate	**Class A**	**A4**
30 9007 B00081 P									**A4**
30 9007 B00082	0.15	14.29	0.41	>>660	Class III	10.43	Moderate	**Class A**	**A5**
30 9007 B00082 P									**A5**
30 9007 B00089	0.15	12	0.3	>>660	Class III	2.81	Low	**Class A**	**A6**
30 9007 B00089 P									**A6**
30 9005 B00063	0.15	24.03	0.31	>>660	Class III	0	Low	**Class A**	**A7**
30 9007 B00085	0.15	28.7	0.32	>>660	Class III	2.55	Low	**Class A**	**A8**
30 9007 B00085 P									**A8**
30 9005 B00061	0.15	31.09	0.34	>>660	Class III	0	Low	**Class A**	**A9**
30 9007 B00083	0.15	25.5	0.49	>>660	Class III	0	Low	**Class A**	**A10**
30 9007 B00094	0.15	12.69	0.58	70.3	Class III	0.08	Low	**Class A**	**A11**
30 9007 B00094 P									**A11**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.22 (Cont'): Seismic Embankment Ranking of Bridges in Daviess County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
30 9007 B00088	0.15	11.69	0.69	59.2	Class III	0	Low	**Class A**	**A12**
30 9007 B00088 P									**A12**
30 9007 B00092	0.15	25.69	0.87	12.1	Class III	0	Low	**Class A**	**A13**
30 9007 B00090	0.15	12	0.86	8.5	Class II	0	Low	**Class B**	**B1**
30 9007 B00090 P									**B1**
30 9007 B00093	0.15	20.5	1.24		Class I	0	Low	**Class C**	**C1**
30 9007 B00091	0.15	10	3.8		Class I	0	Low	**Class C**	**C2**
30 9007 B00084	0.15	3.7	5.01		Class I	0	Low	**Class C**	**C3**
30 9007 B00086	0.15	4.299	8.4		Class I	0	Low	**Class C**	**C4**
30 9005 B00062 C		Culvert			Culvert				**C5**
30 9007 B00087 C		Culvert							**C5**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.23: Seismic Embankment Ranking of Bridges in Fulton County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
38 9003 B00055	0.4	29.69	0.17	>>2250	Class III	26.8	High	**Class A**	**A1**
38 9003 B00055 P									**A1**
38 0307 B00015	0.4	27	0.18	>>2250	Class III	41.88	High	**Class A**	**A2**
38 9003 B00053	0.4	14.5	0.21	>>2250	Class III	37.03	High	**Class A**	**A3**
38 9003 B00053 P									**A3**
38 0051 B00012	0.4	21.3	0.24	>>2250	Class III	21.9	High	**Class A**	**A4**
38 9003 B00054	0.4	20	0.29	>>2250	Class III	14.44	Moderate	**Class A**	**A5**
38 9003 B00054 P									**A5**
38 9003 B00056 C		Culvert							**C1**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.24: Seismic Embankment Ranking of Bridges in Graves County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
42 9003 B00177	0.19	8.799	0.2	>>890	Class III	25.91	High	**Class A**	**A1**
42 9003 B00177 P									**A1**
42 9003 B00176	0.19	11.5	0.22	>>890	Class III	33.91	High	**Class A**	**A2**
42 9003 B00176 P									**A2**
42 9003 B00170	0.19	14	0.39	>>890	Class III	12.73	Moderate	**Class A**	**A3**
42 9003 B00170 P									**A3**
42 1748 B00128	0.19	20.69	0.42	N/A	Class III	7.9	Moderate	**Class A**	**A4**
42 0058 B00096	0.19	24.79	0.1	>>890	Class III	1.67	Low	**Class A**	**A5**
42 9003 B00154	0.19	26.39	0.1	>>890	Class III	0	Low	**Class A**	**A6**
42 9003 B00154 P									**A6**
42 9003 B00175	0.19	18.08	0.16	>>890	Class III	0	Low	**Class A**	**A7**
42 9003 B00162	0.19	11.89	0.19	>>890	Class III	4.93	Low	**Class A**	**A8**
42 9003 B00162 P									**A8**
42 9003 B00155	0.19	21.69	0.24	>>890	Class III	0	Low	**Class A**	**A9**
42 9003 B00155 P									**A9**
42 9003 B00169	0.19	28.2	0.26	>>890	Class III	3.76	Low	**Class A**	**A10**
42 9003 B00172	0.19	18.6	0.26	>>890	Class III	0	Low	**Class A**	**A11**
42 9003 B00160	0.19	11.6	0.3	>>890	Class III	3.63	Low	**Class A**	**A12**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.24 (Cont'): Seismic Embankment Ranking of Bridges in Graves County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
42 9003 B00156	0.19	33.1	0.31	>>890	Class III	0	Low	**Class A**	**A13**
42 9003 B00156 P									**A13**
42 9003 B00165	0.19	7.799	0.35	>>890	Class III	0	Low	**Class A**	**A14**
42 9003 B00165 P									**A14**
42 0944 B00180	0.19	24.4	0.4	N/A	Class III	0	Low	**Class A**	**A15**
42 9003 B00167	0.19	9.3	0.43	>>890	Class III	0	Low	**Class A**	**A16**
42 9003 B00167 P									**A16**
42 0121 B00111	0.19	21.79	0.52	>>890	Class III	0	Low	**Class A**	**A17**
42 0301 B00028	0.19	20	0.52	>>890	Class III	0	Low	**Class A**	**A18**
42 9003 B00161	0.19	13.7	0.55	281.1	Class III	0	Low	**Class A**	**A19**
42 9003 B00166	0.19	4.5	0.58	87.5	Class III	0	Low	**Class A**	**A20**
42 9003 B00166 P									**A20**
42 0339 B00143	0.19	23.6	0.72	38.6	Class III	0	Low	**Class A**	**A21**
42 9003 B00159	0.19	9.5	0.82	16.4	Class III	0	Low	**Class A**	**A22**
42 9003 B00159 P									**A22**
42 9003 B00157	0.19	10.3	0.84	13.8	Class III	0	Low	**Class A**	**A23**
42 9003 B00157 P									**A23**
42 9003 B00173	0.19	2.26	8.21		Class I	5.21	Moderate	**Class B**	**B1**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.24 (Cont'): Seismic Embankment Ranking of Bridges in Graves County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
42 9003 B00173 P									**B1**
42 0080 B00106	0.19	18.5	0.92	8.7	Class II	0	Low	**Class B**	**B2**
42 9003 B00163	0.19	10.19	1.02		Class I	-14.7	Low	**Class C**	**C1**
42 9003 B00163 P									**C1**
42 9003 B00164	0.19	12.2	1.05		Class I	0	Low	**Class C**	**C2**
42 0131 B00009	0.19	17.5	1.14		Class I	0	Low	**Class C**	**C3**
42 9003 B00158	0.19	10.7	1.27		Class I	0	Low	**Class C**	**C4**
42 9003 B00158 P									**C4**
42 9003 B00153	0.19	21.2	1.8		Class I	0	Low	**Class C**	**C5**
42 9003 B00168	0.19	14	2.08		Class I	2.43	Low	**Class C**	**C6**
42 9003 B00168 P									**C6**
42 9003 B00171	0.19	0.5	10		Class I	0.61	Low	**Class C**	**C7**
42 9003 B00174 C	0.19	Culvert			Culvert				**C8**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.25: Seismic Embankment Ranking of Bridges in Grayson County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
43 0224 B00003	0.09	16.3	1.66		Class I	0	Low	**Class C**	**C1**
43 9001 B00069	0.09	17.66	1.69		Class I	0	Low	**Class C**	**C2**
43 0259 B00009	0.09	15	1.73		Class I	0	Low	**Class C**	**C3**
43 0185 B00019	0.09	26.2	1.81		Class I	0	Low	**Class C**	**C4**
43 0079 B00023	0.09	16.69	1.91		Class I	0	Low	**Class C**	**C5**
43 9001 B00070	0.09	20.69	1.98		Class I	0	Low	**Class C**	**C6**
43 9001 B00027	0.09	23.29	2.03		Class I	0	Low	**Class C**	**C7**
43 9001 B00027 P									**C7**
43 9001 B00060	0.09	16.35	2.11		Class I	0	Low	**Class C**	**C8**
43 9001 B00078	0.09	10.5	3		Class I	0	Low	**Class C**	**C9**
43 0088 B00006	0.09	10.79	3.14		Class I	0	Low	**Class C**	**C10**
43 9001 B00073	0.09	10.2	3.46		Class I	0	Low	**Class C**	**C11**
43 9001 B00026	0.09	9.5	3.47		Class I	0	Low	**Class C**	**C12**
43 9001 B00026 P									**C12**
43 9001 B00082	0.09	4	6.08		Class I	0	Low	**Class C**	**C13**
43 9001 B00076	0.09	1	8.16		Class I	0	Low	**Class C**	**C14**
43 9001 B00028 C		Culvert							**C15**
43 9001 B00029 C		Culvert							**C15**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.25 (Cont'): Seismic Embankment Ranking of Bridges in Grayson County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
43 9001 B00030 C		Culvert							**C15**
43 9001 B00031 C		Culvert							**C15**
43 9001 B00032 C		Culvert			Culvert				**C15**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.26: Seismic Embankment Ranking of Bridges in Hardin County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
47 31W B00108	0.09	45.1	0.72	>>340	Class III	0	Low	**Class A**	**A1**
47 9001 B00093	0.09	32.5	1.09		Class I	0	Low	**Class C**	**C1**
47 9001 B00093 P									**C1**
47 31W B00153	0.09	27.09	1.13		Class I	0	Low	**Class C**	**C2**
47 9001 B00092	0.09	31.5	1.17		Class I	0	Low	**Class C**	**C3**
47 9001 B00092 P									**C3**
47 9001 B00127	0.09	34.09	1.26		Class I	0	Low	**Class C**	**C4**
47 9001 B00127 P		Parallel Bridge	1.26						**C4**
47 9001 B00085	0.09	23.45	1.69		Class I	0	Low	**Class C**	**C5**
47 1136 B00053	0.09	17.99	1.84		Class I	0	Low	**Class C**	**C6**
47 9001 B00094	0.09	13.1	2.28		Class I	0	Low	**Class C**	**C7**
47 9001 B00094 P									**C7**
47 9001 B00045	0.09	19.2	2.29		Class I	0	Low	**Class C**	**C8**
47 9001 B00090	0.09	16	2.34		Class I	0	Low	**Class C**	**C9**
47 0084 B00043	0.09	16.76	2.4		Class I	0	Low	**Class C**	**C10**
47 9001 B00056	0.09	10	3.91		Class I	0	Low	**Class C**	**C11**
47 9001 B00095 C		Culvert							**C12**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.27: Seismic Embankment Ranking of Bridges in Henderson County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
51 0425 B00137	0.15	18	0.77	14.7	Class III	0	Low	**Class A**	**A1**
51 0425 B00137 P									**A1**
51 9005 B00072	0.15	54.1	0.14	>>660	Class III	0.13	Low	**Class A**	**A2**
51 9004 B00069	0.15	28.6	0.39	>>660	Class III	0	Low	**Class A**	**A3**
51 9004 B00062	0.4	26	0.51	>>2250	Class III	0	Low	**Class A**	**A4**
51 9004 B00062 P									**A4**
51 9004 B00111	0.15	27.3	0.6	>>660	Class III	0	Low	**Class A**	**A5**
51 9004 B00065	0.15	18	0.61	>>660	Class III	0	Low	**Class A**	**A6**
51 9004 B00064	0.15	15	0.76	32.8	Class III	0	Low	**Class A**	**A7**
51 9004 B00073	0.15	27	0.8	10.7	Class III	0	Low	**Class A**	**A8**
51 9004 B00073 P									**A8**
51 9005 B00074	0.15	26.1	0.81	>>660	Class III	0	Low	**Class A**	**A9**
51 9005 B00075	0.15	20.89	0.82	31.5	Class III	0	Low	**Class A**	**A10**
51 9005 B00073	0.15	25.5	0.92	10.7	Class II	0	Low	**Class B**	**B1**
51 9005 B00073 P									**B1**
51 9005 B00077	0.15	8.4	0.96	2.4	Class II	0	Low	**Class B**	**B2**
51 9005 B00077 P									**B2**
51 9004 B00112	0.15	19.5	1.08		Class I	0	Low	**Class C**	**C1**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.27 (Cont'): Seismic Embankment Ranking of Bridges in Henderson County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
51 9005 B00076	0.15	21.1	1.09		Class I	0	Low	**Class C**	**C2**
51 9004 B00066	0.15	25	1.31		Class I	0	Low	**Class C**	
51 9004 B00067	0.15	19.69	1.45		Class I	0	Low	**Class C**	**C3**
51 9005 B00080	0.15	27.89	1.51		Class I	0	Low	**Class C**	**C4**
51 9005 B00078	0.15	24	1.75		Class I	0	Low	**Class C**	**C5**
51 9004 B00068	0.15	6.5	2.36		Class I	0	Low	**Class C**	**C6**
51 9004 B00068 P									**C6**
51 9004 B00063	0.4	1	5.58		Class I	0	Low	**Class C**	**C7**
51 9005 B00079	0.15	5.899	7.13		Class I	0	Low	**Class C**	**C8**
51 9004 B00061 C		Culvert							**C9**
51 9005 B00070 C		Culvert							**C9**
51 9005 B00071 C		Culvert							**C9**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.28: Seismic Embankment Ranking of Bridges in Hickman County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
53 0094 B00050	0.4	12.9	0.24	>>2250	Class III	35.65	High	**Class A**	**A1**
53 9003 B00068	0.4	27.39	0.3	>>2250	Class III	10.7	Moderate	**Class A**	**A2**
53 1529 B00056	0.4	13	0.52	93.7	Class III	5.94	Moderate	**Class A**	**A3**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.29: Seismic Embankment Ranking of Bridges in Hopkins County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
54 9004 B00015	0.09	37	0.35	>>340	Class III	0	Low	**Class A**	**A1**
54 9001 B00137	0.09	18.3	0.45	>>340	Class III	0	Low	**Class A**	**A2**
54 9001 B00137 P									**A2**
54 9001 B00143	0.09	34.3	0.47	>>340	Class III	0	Low	**Class A**	**A3**
54 9001 B00143 P									**A3**
54 9001 B00144	0.09	41	0.47	>>340	Class III	0	Low	**Class A**	**A4**
54 9001 B00144 P									**A4**
54 9001 B00136	0.09	19.69	0.54	>>340	Class III	0	Low	**Class A**	**A5**
54 9001 B00136 P									**A5**
54 9004 B00095	0.09	32	0.56	>>340	Class III	0	Low	**Class A**	**A6**
54 9004 B00095 P									**A6**
54 9001 B00145	0.09	32.41	0.57	>>340	Class III	0	Low	**Class A**	**A7**
54 9001 B00145 P									**A7**
54 9004 B00014	0.09	11.39	0.7	>>340	Class III	0	Low	**Class A**	**A8**
54 9004 B00014 P									**A8**
54 9001 B00140	0.09	31.29	0.77	>>340	Class III	0	Low	**Class A**	**A9**
54 9001 B00140 P									**A9**
54 9001 B00146	0.09	14.2	0.81	183.5	Class III	0	Low	**Class A**	**A10**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.29 (Cont'): Seismic Embankment Ranking of Bridges in Hopkins County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
54 9001 B00146 P									**A10**
54 9004 B00211	0.09	10.2	0.96	2.6	Class II	0	Low	**Class B**	**B1**
54 9004 B00019	0.09	13.89	1		Class I	0	Low	**Class C**	**C1**
54 9004 B00096	0.09	33.7	1.01		Class I	0	Low	**Class C**	**C2**
54 9004 B00096 P									**C2**
54 9004 B00012	0.09	27.19	1.02		Class I	0	Low	**Class C**	**C3**
54 9004 B00012 P									**C3**
54 9004 B00021	0.09	21.9	1.02		Class I	0	Low	**Class C**	**C4**
54 9004 B00021 P									**C4**
54 9004 B00018	0.09	26.39	1.07		Class I	0	Low	**Class C**	**C5**
54 9004 B00101	0.09	40.29	1.07		Class I	0	Low	**Class C**	**C6**
54 9004 B00101 P									**C6**
54 9004 B00099	0.09	30.72	1.13		Class I	0	Low	**Class C**	**C7**
54 9004 B00099 P									**C7**
54 9001 B00138	0.09	14.17	1.15		Class I	0	Low	**Class C**	**C8**
54 9001 B00138 P									**C8**
54 9004 B00011	0.09	13.92	1.17		Class I	0	Low	**Class C**	**C9**
54 0454 B00117	0.09	31.39	1.2		Class I	0	Low	**Class C**	**C10**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.29 (Cont'): Seismic Embankment Ranking of Bridges in Hopkins County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
54 9001 B00139	0.09	35.9	1.25		Class I	0	Low	**Class C**	**C11**
54 9001 B00139 P									**C11**
54 0062 B00048	0.09	28.5	1.31		Class I	0	Low	**Class C**	**C12**
54 9004 B00020	0.09	10.4	1.39		Class I	0	Low	**Class C**	**C13**
54 9004 B00020 P									**C13**
54 9004 B00097	0.09	19.39	1.42		Class I	0	Low	**Class C**	**C14**
54 9004 B00097 P									**C14**
54 9004 B00100	0.09	19	1.74		Class I	0	Low	**Class C**	**C15**
54 9004 B00100 P									**C15**
54 0813 B00131	0.09	13.4	1.83		Class I	0	Low	**Class C**	**C16**
54 0109 B00070	0.09	13.28	1.86		Class I	0	Low	**Class C**	**C17**
54 9004 B00016	0.09	15	2.03		Class I	0	Low	**Class C**	**C18**
54 9004 B00106	0.09	10.09	2.43		Class I	0	Low	**Class C**	**C19**
54 9004 B00106 P									**C19**
54 9004 B00013	0.09	9	4.65		Class I	0	Low	**Class C**	**C20**
54 9004 B00098	0.09	4	9.06		Class I	0	Low	**Class C**	**C21**
54 9004 B00098 P									**C21**
54 9001 B00141 C	0.09	Culvert			Culvert				**C22**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.29 (Cont'): Seismic Embankment Ranking of Bridges in Hopkins County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
54 9004 B00010 C	0.09	Culvert			Culvert				**C22**
54 9004 B00017 C	0.09	Culvert			Culvert				**C22**
54 9004 B00104 C		Culvert							**C22**
54 9004 B00105 C		Culvert							**C22**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.30: Seismic Embankment Ranking of Bridges in Lyon County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
72 9001 B00030	0.15	35.29	1.19		Class I	0	Low	**Class C**	**C1**
72 9001 B00030 P									**C1**
72 9001 B00029	0.15	22.54	1.86		Class I	0	Low	**Class C**	**C2**
72 0093 B00050	0.15	14.59	2.61		Class I	0	Low	**Class C**	**C2**
72 9001 B00052	0.15	10	4.21		Class I	0	Low	**Class C**	**C3**
72 9001 B00052 P									**C3**
72 9001 B00049	0.15	6.299	6.68		Class I	0	Low	**Class C**	**C4**
72 9001 B00049 P									**C4**
72 9001 B00051 C		Culvert			Culvert				**C5**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.31: Seismic Embankment Ranking of Bridges in Marshall County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
79 9003 B00076	0.15	12.59	0.44	>>660	Class III	8.34	Moderate	**Class A**	**A1**
79 9003 B00076 P									**A1**
79 0795 B00012	0.15	26.19	0.17	>>660	Class III	0	Low	**Class A**	**A2**
79 9003 B00064	0.15	13.39	0.23	>>660	Class III	0	Low	**Class A**	**A3**
79 9003 B00064 P									**A3**
79 9003 B00074	0.15	33.138	0.3	>>660	Class III	0	Low	**Class A**	**A4**
79 9003 B00074 P									**A4**
79 0408 B00103	0.15	11.27	0.31	>>660	Class III	0	Low	**Class A**	**A5**
79 1422 B00050	0.15	27.39	0.33	>>660	Class III	0	Low	**Class A**	**A6**
79 9003 B00066	0.15	28.6	0.37	>>660	Class III	0	Low	**Class A**	**A7**
79 0348 B00102	0.15	24	0.51	>>660	Class III	0	Low	**Class A**	**A9**
79 9003 B00068	0.15	21.7	0.66	125.5	Class III	0	Low	**Class A**	**A10**
79 9003 B00073	0.15	10.64	0.69	29.2	Class III	0	Low	**Class A**	**A10**
79 641 B00126	0.15	23	0.77	14.7	Class III	0	Low	**Class A**	**A11**
79 0068 B00001	0.15	12.5	0.81	8.9	Class II	0	Low	**Class B**	**B1**
79 0068 B00001 P									**B1**
79 9003 B00075	0.15	11.88	0.89	4.6	Class II	0	Low	**Class B**	**B2**
79 9003 B00075 P									**B2**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.31 (Cont'): Seismic Embankment Ranking of Bridges in Marshall County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
79 0024 B00114	0.15	31	0.91	9.4	Class II	0	Low	**Class B**	**B3**
79 0024 B00114 P									**B3**
79 9003 B00071	0.15	15.1	1.96		Class I	0	Low	**Class C**	**C1**
79 9003 B00065 C		Culvert							**C2**
79 9003 B00067 C		Culvert							**C2**
79 9003 B00069 C		Culvert							**C2**
79 9003 B00070 C		Culvert							**C2**
79 9003 B00072 C		Culvert							**C2**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.32: Seismic Embankment Ranking of Bridges in Muhlenberg County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
89 9001 B00096	0.09	37	0.34	>>340	Class III	0	Low	**Class A**	**A1**
89 9001 B00096 P									**A1**
89 9001 B00094	0.09	35	0.37	>>340	Class III	0	Low	**Class A**	**A2**
89 9001 B00094 P									**A2**
89 9001 B00093	0.09	54	0.41	>>340	Class III	0	Low	**Class A**	**A3**
89 9001 B00093 P									**A3**
89 9001 B00109	0.09	26	0.42	>>340	Class III	0	Low	**Class A**	**A4**
89 9001 B00109 P									**A4**
89 9001 B00090	0.09	16.79	1		Class I	0	Low	**Class C**	**C1**
89 9001 B00090 P									**C1**
89 9001 B00092	0.09	26.5	1.02		Class I	0	Low	**Class C**	**C2**
89 9001 B00092 P									**C2**
89 2692 B00085	0.09	21.79	1.07		Class I	0	Low	**Class C**	**C3**
89 9001 B00089	0.09	30.8	1.21		Class I	0	Low	**Class C**	**C4**
89 9001 B00089 P									**C4**
89 9001 B00091	0.09	24.89	1.37		Class I	0	Low	**Class C**	**C5**
89 9001 B00091 P									**C5**
89 0431 B00132	0.09	10.09	1.65		Class I	0	Low	**Class C**	**C6**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.32 (Cont'): Seismic Embankment Ranking of Bridges in Muhlenberg County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
89 0431 B00132 P									**C6**
89 2695 B00058	0.09	7.7	4.49		Class I	0	Low	**Class C**	**C7**
89 2697 B00131	0.09	3.099	5.21		Class I	0	Low	**Class C**	**C8**
89 2694 B00059	0.09	4.9	6.41		Class I	0	Low	**Class C**	**C9**
89 9001 B00115 C		Culvert							**C10**
89 9001 B00130	0.09				Lack of Plans				**N/A**
89 9001 B00905	0.09				Lack of Plans				**N/A**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.33: Seismic Embankment Ranking of Bridges in Ohio County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
92 9007 B00063	0.09	18.39	0.28	>>340	Class III	0	Low	**Class A**	**A1**
92 9007 B00063 P									**A1**
92 9007 B00075	0.09	32.2	0.32	>>340	Class III	0	Low	**Class A**	**A2**
92 9007 B00075 P									**A2**
92 9001 B00134	0.09	19.5	0.42	>>340	Class III	0	Low	**Class A**	**A3**
92 9001 B00134 P									**A3**
92 9001 B00133	0.09	27	0.62	>>340	Class III	0	Low	**Class A**	**A4**
92 9001 B00133 P									**A4**
92 9007 B00069	0.09	26.8	0.95	7.1	Class II	0	Low	**Class B**	**B1**
92 1245 B00112	0.09	27.2	1.03		Class I	0	Low	**Class C**	**C1**
92 9007 B00076	0.09	14.19	1.04		Class I	0	Low	**Class C**	**C2**
92 9007 B00076 P									**C2**
92 0505 B00093	0.09	28.39	1.06		Class I	0	Low	**Class C**	**C3**
92 9007 B00060	0.09	28	1.09		Class I	0	Low	**Class C**	**C4**
92 9007 B00060 P									**C4**
92 9007 B00062	0.09	37	1.23		Class I	0	Low	**Class C**	**C5**
92 9007 B00071	0.09	30	1.29		Class I	0	Low	**Class C**	**C6**
92 9007 B00061	0.09	36	1.31		Class I		Low	**Class C**	**C7**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.33 (Cont'): Seismic Embankment Ranking of Bridges in Ohio County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
92 2712 B00136	0.09	24.1	1.53		Class I	0	Low	**Class C**	**C8**
92 9007 B00072	0.09	25	1.89		Class I	0	Low	**Class C**	**C9**
92 9007 B00072 P									**C9**
92 9001 B00130	0.09	21	2.25		Class I	0	Low	**Class C**	**C10**
92 9001 B00130 P									**C10**
92 1245 B00108	0.09	7	2.63		Class I	0	Low	**Class C**	**C11**
92 9007 B00065	0.09	11.09	2.96		Class I	0	Low	**Class C**	**C12**
92 9007 B00074	0.09	10	4.23		Class I	0	Low	**Class C**	**C13**
92 9007 B00067	0.09	4	4.3		Class I	0	Low	**Class C**	**C14**
92 9007 B00067 P									**C14**
92 9007 B00070	0.09	3	5.83		Class I	0	Low	**Class C**	**C15**
92 9001 B00132	0.09	4.5	9.07		Class I	0	Low	**Class C**	**C16**
92 9001 B00132 P									**C16**
92 9007 B00064	0.09	2.599	10		Class I	0	Low	**Class C**	**C17**
92 9001 B00131 C		Culvert							**C18**
92 9007 B00066 C	0.09	Culvert			Culvert				**C18**
92 9007 B00068 C	0.09	Culvert			Culvert				**C18**
92 9007 B00073 C	0.09	Culvert			Culvert				**C18**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.34: Seismic Embankment Ranking of Bridges in Warren County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
114 0884 B00050	0.09	21.5	0.83	61.3	Class III	0	Low	**Class A**	**A1**
114 9007 B00057	0.09	23.23	1.06		Class I	0	Low	**Class C**	**C1**
114 9007 B00049	0.09	18.79	1.07		Class I	0	Low	**Class C**	**C2**
114 9007 B00049 P									**C2**
114 0231 B00055	0.09	30.366	1.12		Class I	0	Low	**Class C**	**C3**
114 9007 B00052	0.09	30.4	1.18		Class I	0	Low	**Class C**	**C4**
114 9007 B00052 P									**C4**
114 9007 B00054	0.09	15.88	1.22		Class I	0	Low	**Class C**	**C5**
114 9007 B00054 P									**C5**
114 9007 B00051	0.09	29.59	1.39		Class I	0	Low	**Class C**	**C6**
114 9007 B00051 P									**C6**
114 9007 B00053	0.09	25.34	1.39		Class I	0	Low	**Class C**	**C7**
114 9007 B00053 P									**C7**
114 9007 B00059	0.09	4.163	1.63		Class I	0	Low	**Class C**	**C8**
114 0626 B00056	0.09	5.213	2.88		Class I	0	Low	**Class C**	**C9**
114 9007 B00060	0.09	8.134	2.9		Class I	0	Low	**Class C**	**C10**
114 9007 B00058	0.09	8.758	3.61		Class I	0	Low	**Class C**	**C11**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

Table 4.35: Seismic Embankment Ranking of Bridges in Webster County on/over Western Kentucky Parkways for 250-year event earthquakes

BIN[1, 2, 3]	PGA[4]	Height[5] (ft)	Slope Stability Assessment			Liquefaction Potential Evaluation		Seismic Embankment Category[11]	Seismic Embankment Ranking[12]
			FS[6]	*u*[7] (cm)	Class[8]	*LPI*[9]	Class[10]		
117 9004 B00074	0.09	37.75	0.79	105.6	Class III	0	Low	**Class A**	**A1**
117 9004 B00074 P									**A1**
117 9004 B00073	0.09	21	0.96	5.4	Class II	0	Low	**Class B**	**B1**
117 9004 B00068	0.09	26.36	1.01		Class I	0	Low	**Class C**	**C1**
117 9004 B00072	0.09	20.6	1.14		Class I	0	Low	**Class C**	**C2**
117 9004 B00072 P									**C2**
117 9004 B00071	0.09	34.159	1.38		Class I	0	Low	**Class C**	**C3**
117 9004 B00071 P									**C3**
117 9004 B00069	0.09	24.6	1.45		Class I	0	Low	**Class C**	**C4**
117 9004 B00069 P									**C4**
117 9004 B00070	0.09	13.59	2.14		Class I	0	Low	**Class C**	**C5**

1 Bridge identification number (BIN) as defined in the bridge inventory of the Kentucky Transportation Cabinet.
2 The letter P indicates parallel bridges.
3 The letter C indicates culverts. No further evaluation was necessary or performed on this type of structures.
4 Peak ground acceleration (PGA) is defined in Street *et. al.* (1996) for the state of Kentucky.
5 Embankment height is defined as the difference between the top embankment elevation and the ground elevation.
6 The calculation of factor of safety (*FS*) of a slope is presented in Chapter 2.
7 The displacement calculation is presented in Chapter 2. Displacement (*u*) is calculated when $FS < 1.0$. Displacements preceded by '>>' generally exceed three times the upper displacement limit for the peak ground acceleration present.
8 Class I = Stable; Class II = Critical ($FS < 1.0$ and $u < 10$ cm); and Class III = Unstable ($FS < 1.0$ and $u > 10$ cm)
9 The calculation of liquefaction potential index (*LPI*) is presented in Chapter 3.
10 No = Non-liquefiable ($FS > 1.0$ and $LPI = 0.0$); Low ($LPI < 5$); Moderate ($5 \leq LPI < 15$); and High ($LPI \geq 15$)
11 The category of embankment behavior is defined in Table 4.1.
12 A bridge with a ranking of A1 is more susceptible to damage than a bridge with a ranking of A2 in that particular county. The same applies for categories B and C.

5 SUMMARY AND CONCLUSION

Procedures to evaluate the slope stability (Chapter 2) and liquefaction potential (Chapter 3) of a given bridge embankment were presented in this study. The procedures were subsequently used to form the basis of seismic bridge embankment ranking (Chapter 4). The resulting ranking classifications are as presented in Table 4.1 with bridge embankments in category A representing the ones that are the most susceptible to seismic hazard, and bridge embankments in category C representing the ones that are the least susceptible to seismic hazard, whereas category B is for bridge embankments that are in moderate risk.

To automate the computation and ranking process, the procedures and definitions of bridge embankment classifications were coded in Microsoft Access 2003, in a program named Seismic Assessment System for Bridges (SASB).

There are a total of 389 bridges [107 parallel bridges (107 x 2 = 214 bridges), 40 culvert bridges, and 135 independent bridges] along the parkways in western Kentucky. In this process, 240 sets of calculations were performed, which included only the independent and parallel bridges (e.g. only one set of calculation was required per each parallel bridge). The 40 culvert bridges were excluded in the evaluation. It should be noted that calculations for two of the parallel bridges located in Muhlenberg County were also not performed due to the lack of bridge plans and site data. Since the two bridges are located in a region with a seismic performance category (SPC) of B [i.e. sites having acceleration coefficient of less than 0.19g in accordance with the *Seismic Retrofitting Manual for Highway Bridges* (Buckle and Friedland 1995)], therefore, seismic risk for these bridges were presumably not as high.

The ranking of bridge embankments in the county they reside was evaluated accordingly. The results are summarized in Tables 4.2-4.35, respectively. A breakdown of bridge embankments in accordance with their category is summarized in Tables 5.1 and 5.2. Comparing the 50- and 250-year event earthquakes, almost the same number and percentage of bridges remain in category C. An increase of 6% of bridges in category A was noted when 250-year event earthquakes, compared to 50-year event earthquakes, were considered. It is recommended that a more detailed and sophisticated analysis be performed on bridge embankments rated as category A, 30% and 36% for 50- and 250-year event earthquakes, respectively.

Table 5.1: Overall embankment ranking of parkway bridges in western Kentucky

For 50-year event earthquakes*		
Category	**Number of bridges**	**Percentage (%)**
A	73	30
B	25	10
C	142	60
	Total	100

For 250-year event earthquakes*		
Category	**Number of bridges**	**Percentage (%)**
A	88	36
B	11	5
C	141	59
	Total	100

* For the state of Kentucky, these earthquake events are defined in *Source Zone, Recurrence Rates, and Time Histories for Earthquakes affecting Kentucky* (Street et. al. 1996)

Table 5.2: Ranking of embankments in the individual counties for 50- and 250-year event earthquakes

For 50-year event earthquakes[1]

County[2]	SPC[3]	PGA[1]	Embankment category[4]				Percentage breakdown (%)[4]			
			A	B	C	Total[5]	A	B	C	Total
Fulton	D	0.30g	5	0	0	**5**	100	0	0	**100**
Hickman	D	0.30g	2	1	0	**3**	67	33	0	**100**
Graves	C	0.15g	19	5	8	**32**	59	16	25	**100**
Marshall	C	0.15g	9	5	1	**15**	60	33	7	**100**
Henderson	C	0.15g	5	6	9	**20**	25	30	45	**100**
Daviess	C	0.15g	10	4	4	**18**	56	22	22	**100**
Lyon	B	0.09g	0	0	5	**5**	0	0	100	**100**
Caldwell	B	0.09g	1	0	6	**7**	14	0	86	**100**
Muhlenberg[6]	B	0.09g	4	0	9	**13**	31	0	69	**100**
Grayson	B	0.09g	0	0	14	**14**	0	0	100	**100**
Hardin	B	0.09g	1	0	11	**12**	8	0	92	**100**
Christian	B	0.09g	1	0	14	**15**	7	0	93	**100**
Hopkins	B	0.09g	10	1	21	**32**	31	3	66	**100**
Webster	B	0.09g	1	1	5	**7**	14	14	71	**100**
Warren	B	0.09g	0	1	11	**12**	0	8	92	**100**
Butler	B	0.09g	1	0	8	**9**	11	0	89	**100**
Ohio	B	0.09g	4	1	16	**21**	19	5	76	**100**
		Summary	73	25	142	**240**				

For 250-year event earthquakes[1]

County[2]	SPC[3]	PGA[1]	Embankment category[4]				Percentage breakdown (%)[4]			
			A	B	C	Total[5]	A	B	C	Total
Fulton	D	0.30g	5	0	0	**5**	100	0	0	**100**
Hickman	D	0.30g	3	0	0	**3**	100	0	0	**100**
Graves	C	0.15g	23	2	7	**32**	72	6	22	**100**
Marshall	C	0.15g	11	3	1	**15**	73	20	7	**100**
Henderson	C	0.15g	9	2	9	**20**	45	10	45	**100**
Daviess	C	0.15g	13	1	4	**18**	72	6	22	**100**
Lyon	C	0.15g	0	0	5	**5**	0	0	100	**100**
Caldwell	B	0.09g	1	0	6	**7**	14	0	86	**100**
Muhlenberg[6]	B	0.09g	4	0	9	**13**	31	0	69	**100**
Grayson	B	0.09g	0	0	14	**14**	0	0	100	**100**
Hardin	B	0.09g	1	0	11	**12**	8	0	92	**100**
Christian	B	0.09g	1	0	14	**15**	7	0	93	**100**
Hopkins	B	0.09g	10	1	21	**32**	31	3	66	**100**
Webster	B	0.09g	1	1	5	**7**	14	14	71	**100**
Warren	B	0.09g	1	0	11	**12**	8	0	92	**100**
Butler	B	0.09g	1	0	8	**9**	11	0	89	**100**
Ohio	B	0.09g	4	1	16	**21**	19	5	76	**100**
		Summary	88	11	141	**240**				

1 Based on *Source Zone, Recurrence Rates, and Time Histories for Earthquakes affecting Kentucky* (Street et. al. 1996)
2 Only counties with bridges along the parkways were listed and evaluated
3 Defined in *Seismic Retrofitting Manual for Highway Bridges* (Buckle and Friedland 1995)
4 Embankment categories A, B, or C are as defined in Table 4.1, Page 23
5 Summation of number of bridges evaluated in categories A, B, and C
6 Two (2) parallel bridges in this county were not evaluated due to the lack of plans

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APPENDIX A

Seismic Assessment System for Bridges (SASB)

APPENDIX A

This section briefly describes the working of the Seismic Assessment System for Bridges (SASB). SASB is intended for preliminary seismic assessment of bridge embankment. In general, the seismic evaluation of a given bridge embankment is based upon two factors: (1) slope stability and (2) liquefaction potential, as described in Chapters 2 and 3, respectively. This program, which was written in Microsoft Access 2003, allows user to evaluate new bridge embankment or to evaluate existing bridges along the five western Kentucky parkways. A database containing general bridges' information of the five western Kentucky parkways has been created.

The followings are the step-by-step instructions of SASB:

Step 1: Double-click on **SASB_KTC_05** to activate the program. A welcome page as depicted in Fig. A1 is shown. Click on **Continue** to proceed.

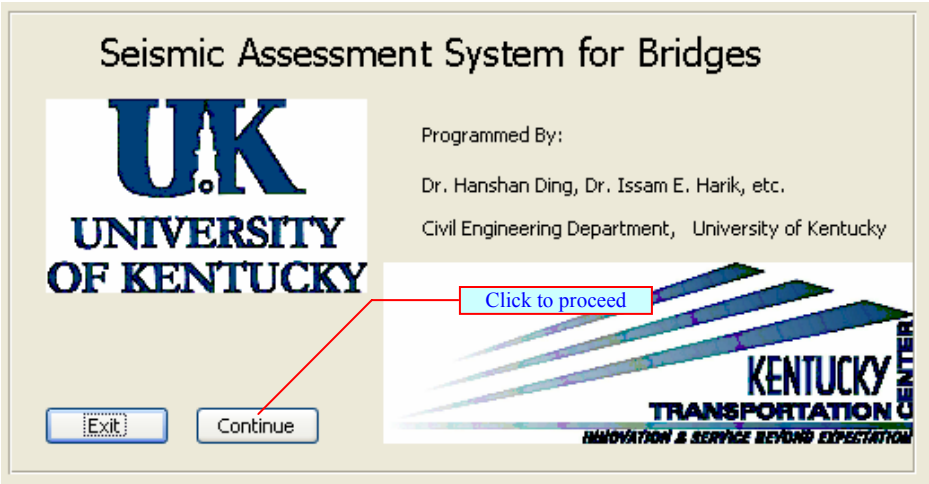

Fig. A1. Welcome page of the Seismic Assessment System for Bridges (SASB) program.

Step 2: Users are subsequently presented with two basic options (Fig. A2): (a) input new bridge data for seismic embankment evaluation, or (b) review or modify existing bridge in the database.

Step 2.a: Two additional options are presented to obtain the seismic evaluation results of an existing bridge along the five western Kentucky parkways (Figs. A3 and A4). There are 384 bridges along the five western Kentucky parkways, and they are all included in the database. To locate a specific bridge, users have the option of selecting the desired bridge's identification number (BIN). The users also have the option of sorting and narrowing down the bridge selection by specifying a county or a parkway.

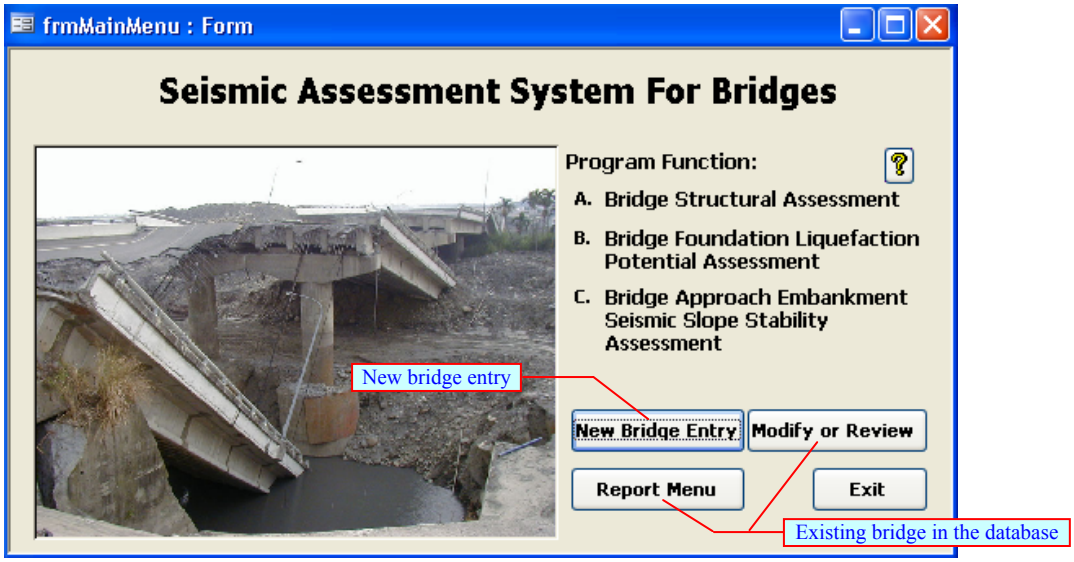

Fig. A2. Bridge information page.

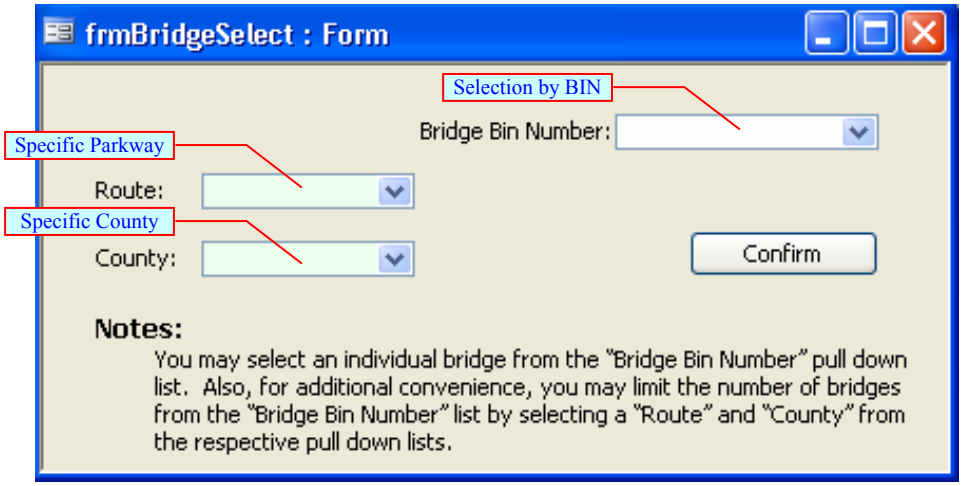

Fig. A3. Selecting a bridge in the existing database.

NOTE: Fig. A3 presents bridge data or result in a manner that follows the evaluation processes or steps described in Chapter 2 (slope stability) and Chapter 3 (liquefaction potential). Fig. A4 provides the users a direct summary results based on the default values of a bridge in the database (i.e. in general, information of the bridges along the parkways is obtained directly from the bridge plans). The main difference between the two is that Fig. A3 gives users the flexibility to alter the default values of certain parameters (i.e. height, slope, soil profile, etc); accounting for possible changes in site physical condition. In light of such possibility, values based on the updated information may be used in lieu of the default values.

Step 2.b: SASB allows users to define new bridge for seismic evaluation as shown in Fig. A5. Users will subsequently be prompted by the program to input the bridge's embankment details or properties (Figs. A6, A7, A8, and A9).

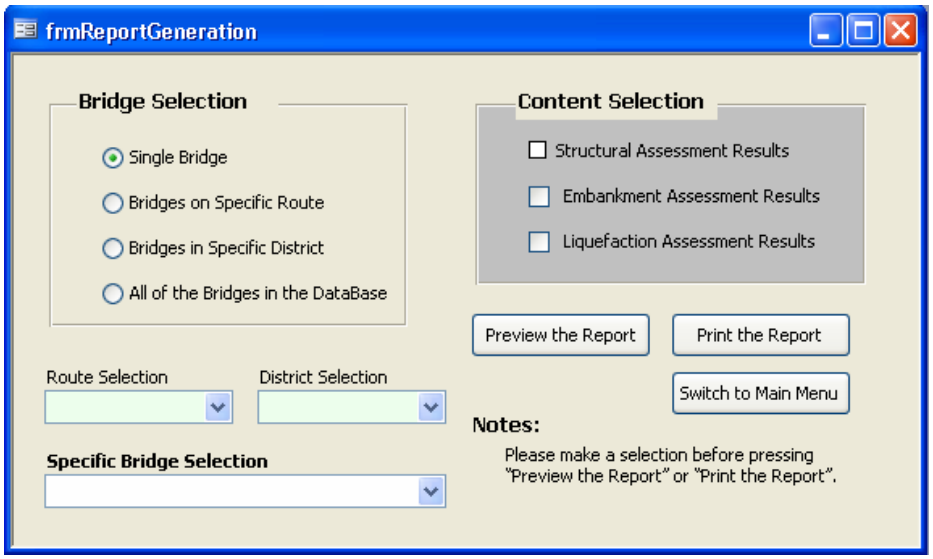

Fig. A4. Seismic evaluation based on default values of a given bridge in the database.

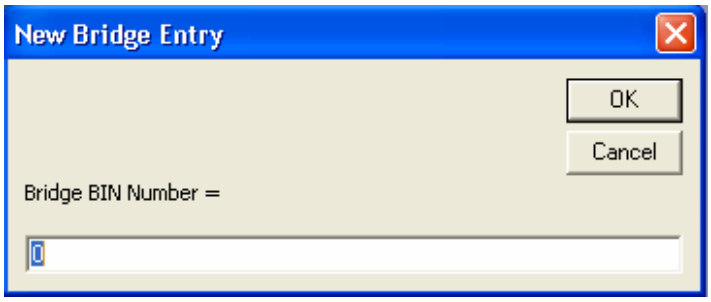

Fig. A5. Generating a new bridge entry.

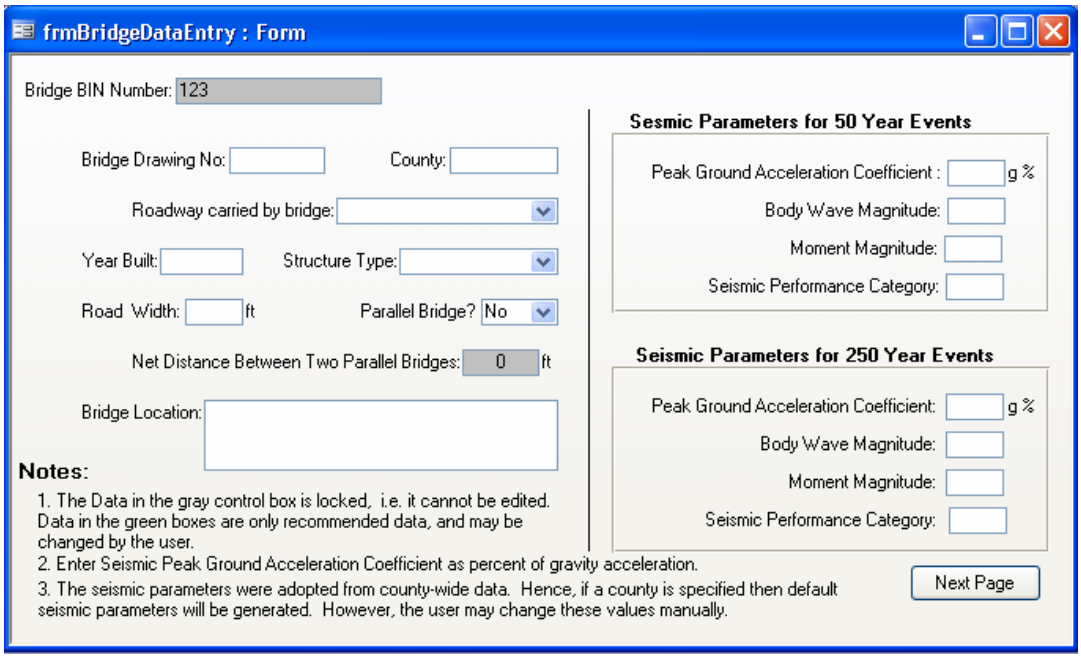

Fig. A6. Creating input for a new bridge (Step I).

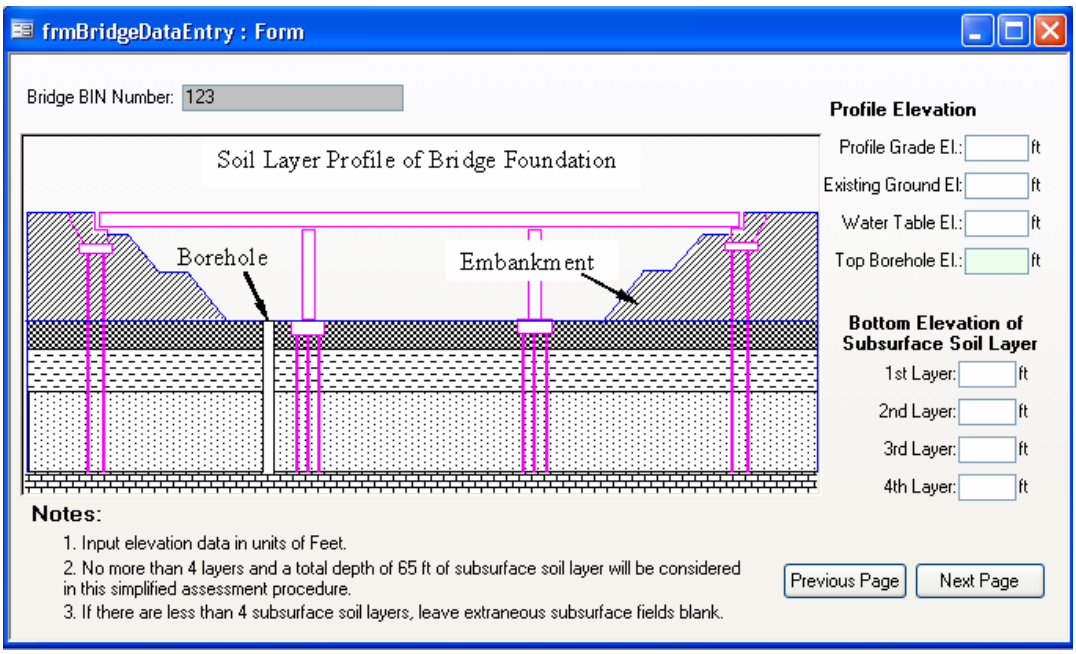

Fig. A7. Creating input for a new bridge (Step II).

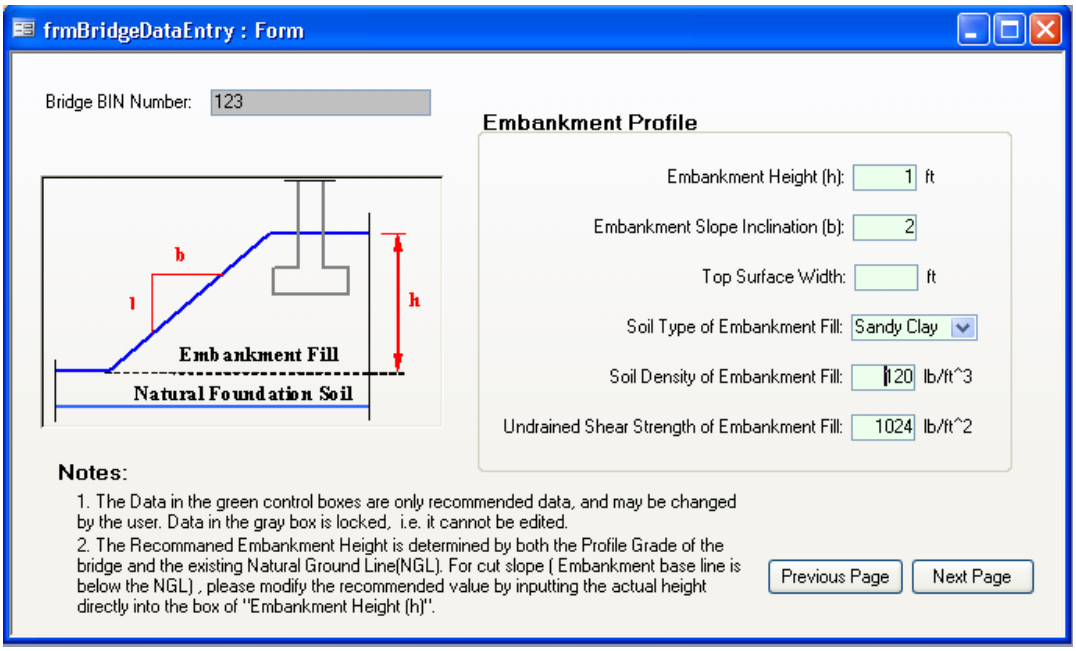

Fig. A8. Creating input for a new bridge (Step III).

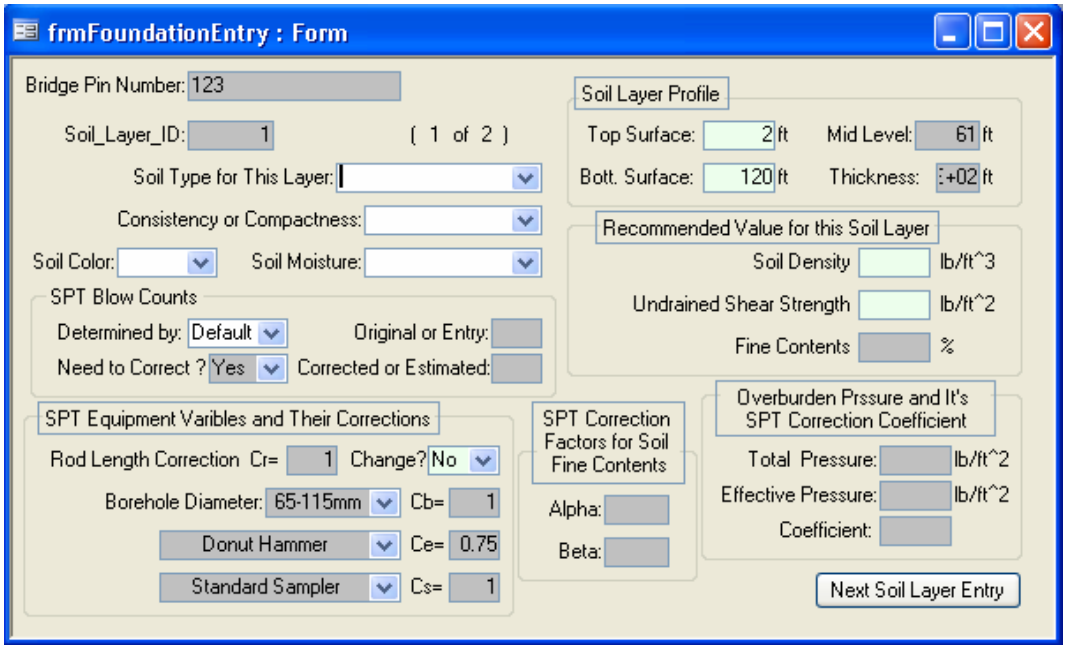

Fig. A9. Creating input for a new bridge (Step IV).

Step 3: Based on given information [either for an existing bridge (Step 2.a) or a new bridge (Step 2.b), SASB will perform slope stability analyses (see Chapter 2) and liquefaction analysis (see Chapter 3). The outcomes of these processes are depicted in Fig. A10 and Fig. A11, respectively.

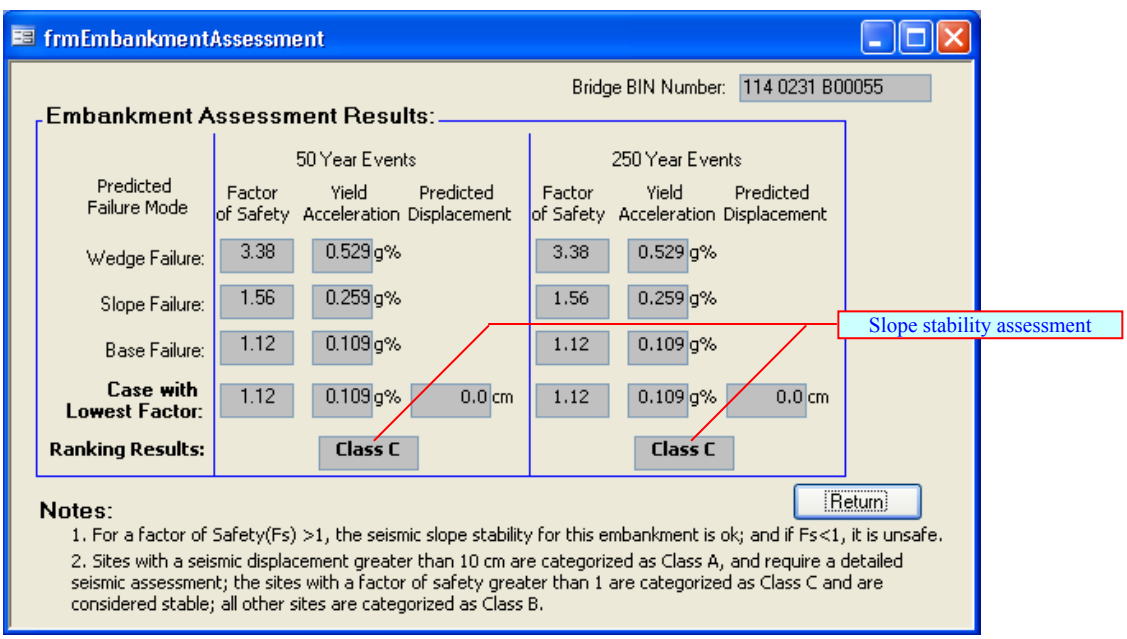

Fig. A10. Slope stability assessment.

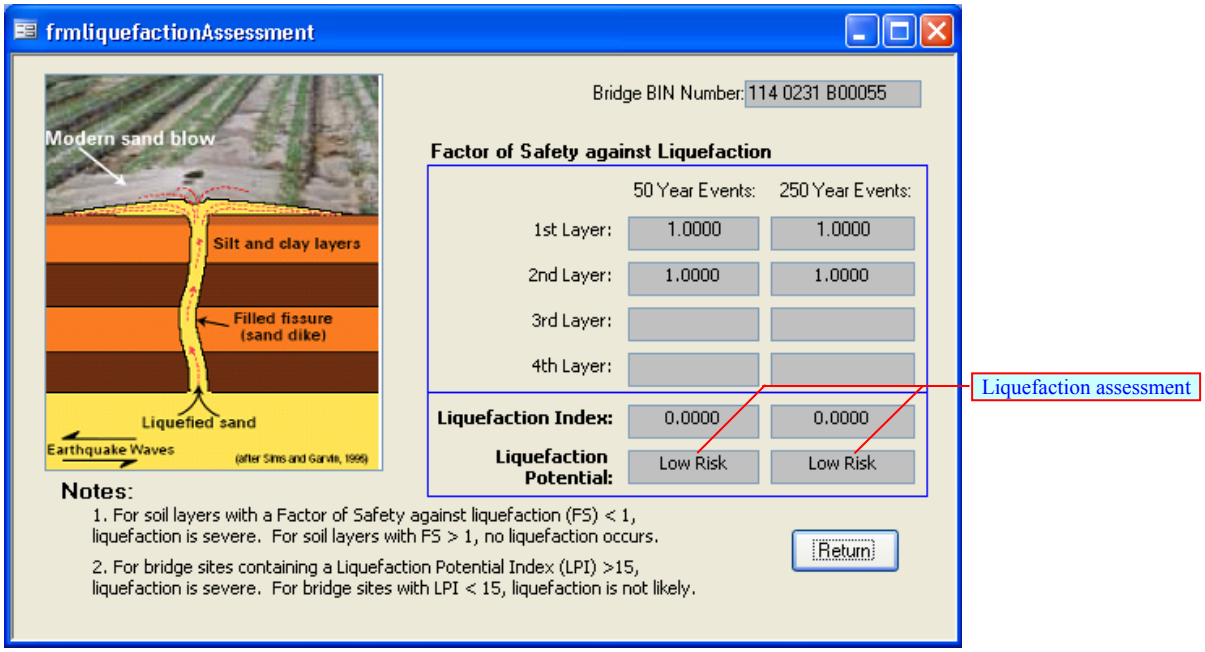

Fig. A11. Liquefaction assessment.

Step 4: Finally, users of SASB have the option of viewing or printing the report of a specific bridge as seen in Fig. A12, by clicking **Report Menu**. A sample report of a specific bridge is presented in Fig. A13.

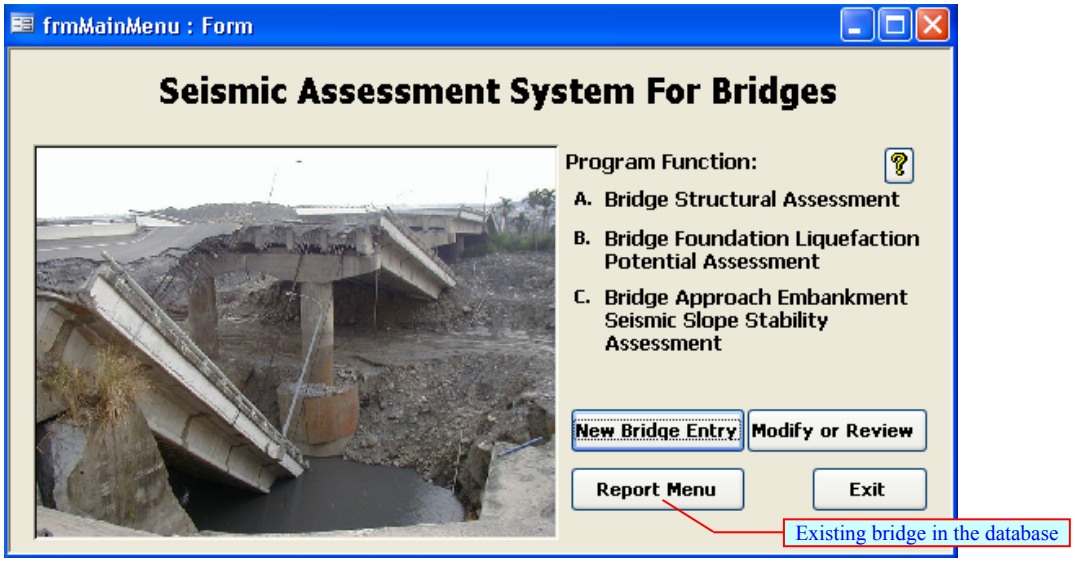

Fig. A12. Obtaining output of a seismic evaluation.

Assessment Results for Specific Bridge

Bridge Bin Number:	1140231 B00055	*Structure Type:*	Concrete Bridge
County:	Warren	*Year Built:*	1970
Route:	Natcher Parkway	*Location:*	OVER GREEN RV PW NTRCH

Seismic Parameters:

Seismic Magnitude for 50 year event:	6.4
Seismic Peak Ground Acceleration for 50 year event:	0.09 %g
Seismic Magnitude for 250 year event:	7.7
Seismic Peak Ground Acceleration for 250 year event:	0.09 %g

Bridge Profile:

Bridge Profile Grade Elevation:	509.5 ft
Existing Ground Elevation:	479.1 ft
Water Table Elevation:	472 ft
Embank Slope Inclination:	1 : 2
Type of Embankment Soil:	Sandy Clay
Soil Density of Embankment:	120 lb/ft^3
Height of Embankment:	30.4 ft

Ranking Results:

	For 50 Year Event	*For 250 Year Event*
Factor of Safety for Slope Stability:	1.12	1.12
Embankment Rank Results:	Class C	Class C
Liquefaction Potential Index:	0.00	0.00
Liquefaction Ranking Results:	Low Risk	Low Risk

Fig. A13. Sample output of SASB.

NOTE: SASB contains other types of output files. Users are encouraged to exploit the different output options.

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