Research Report
KTC-06-22/SPR-206-00-3F

KENTUCKY TRANSPORTATION CENTER

PRELIMINARY SEISMIC EVALUATION AND RANKING OF BRIDGES ALONG I-24 IN WESTERN KENTUCKY

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KTC-06-22/SPR206-00-3F

PRELIMINARY SEISMIC EVALUATION AND RANKING OF BRIDGES ALONG I-24 IN WESTERN KENTUCKY

by

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Kentucky Transportation Center
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in cooperation with

Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
U.S. Department of Transportation

September 2006

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
KTC-06-22/SPR206-00-3F		

4. Title and Subtitle	5. Report Date
PRELIMINARY SEISMIC EVALUATION AND RANKING OF BRIDGES ALONG I-24 IN WESTERN KENTUCKY	September 2006
	6. Performing Organization Code
7. Author(s): Wael Zatar, Issam Harik, Peng Yuan, and Ching Chiaw Choo	**8. Performing Organization Report No.** KTC-06-22/SPR206-00-3F
9. Performing Organization Name and Address Kentucky Transportation Center College of Engineering University of Kentucky Lexington, Kentucky 40506-0281	**10. Work Unit No. (TRAIS)**
	11. Contract or Grant No. SPR206
12. Sponsoring Agency Name and Address Kentucky Transportation Cabinet State Office Building Frankfort, Kentucky 40622	**13. Type of Report and Period Covered** Final
	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the Kentucky Transportation Cabinet and the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract

This study represents one of the Seismic Evaluation of I-24 Bridges investigative series. The focus is on preliminary seismic evaluation and ranking of bridges according to their seismic vulnerability. Bridges along I-24 are considered in this investigation. The ranking will assist in identifying and prioritizing bridges for secondary evaluation, retrofit measure, or other course of action. The rating system described herein is based on a methodology provided by the FHWA Retrofitting Manual for highway bridges.

One hundred and twenty seven (127) highway bridges were evaluated and rated in this process for projected 50-year and 250-year seismic events. The Tennessee River Bridge and the Cumberland River Bridge, also on I-24, are evaluated and presented in separate reports. Furthermore, culverts are excluded from the investigation.

Based on this preliminary investigation, bridges along I-24 have ranking from 0 to 38, based on a scale of 0 (lowest) to 100 (highest), for the 50-year event, and 0 to 48 for the 250-year event. A priority list is presented in this report for bridges that require further seismic evaluation.

17. Key Words	18. Distribution Statement
Seismic Evaluation, Bridges, Parkways in Western Kentucky, Seismic Rating System, Structural Vulnerability, Seismic and Geotechnical Hazards	Unlimited with approval of Kentucky Transportation Cabinet

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	53	

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EXECUTIVE SUMMARY

BACKGROUND

In May 1995, the Federal Highway Administration (FHWA) published a revised Seismic Retrofitting Manual for Highway Bridges (known hereafter as the Retrofitting Manual) to serve as a guide for seismic evaluation and retrofit design of current bridges in order to reduce serious damage due to an anticipated earthquake. The main draw of the retrofitting manual is that it provides a procedure for screening and/or ranking of bridges in seismically active regions. Such screening and/or ranking procedure allows bridge owners to identify and prioritize bridges according to their seismic vulnerability, and take a subsequent action.

OBJECTIVE AND TASKS

With the guidance provided in this manual, a screening and/or ranking process was carried out for bridges along I-24 in western Kentucky to identify the seismically vulnerable bridges. To achieve this objective, the following tasks were carried out:

1. Compile an inventory of bridges on and over I-24
2. Conduct field inspection of bridges on and over I-24
3. Develop a database of bridges on and over I-24
4. Carry out a preliminary seismic evaluation and ranking of bridges on and over I-24

Tasks 1 and 2 have been completed and the results are presented in a separate research report titled *Site Investigation of Bridges on/over I-24 in Western Kentucky* (KTC-05-xx/SPR206-00-2F) of this series.

SUMMARY AND CONCLUSIONS

A step-by-step procedure for the preliminary seismic evaluation and ranking of I-24 bridges is presented in this report. In general, the evaluation process takes into consideration the following aspects in deriving the bridge ranking: (a) structural vulnerability; (b) seismic and geotechnical hazards; and (c) bridge importance. The ranking process utilized the seismic input developed by Street et. al. (1996) specifically for the state of Kentucky, in lieu of the commonly used ASSHTO seismic maps.

One hundred and twenty seven (127) bridges, located in McCracken, Livingston, Marshall, Lyon, Caldwell, Trigg, and Christian Counties, on and over I-24 were rated using the aforementioned methodology for earthquake events of 50 years and 250 years (i.e. a seismic event that has 90% probability of not being exceeded in 50 and 250 years), respectively. Bridges that are excluded in this report are the Tennessee River Bridge and the Cumberland River Bridge (which are evaluated separately in the 5th and 6th report of this series) and culverts. Based on this preliminary investigation, bridges on and over I-24 have ranking from 0 to 38, based on a scale of 0 (lowest) to 100 (highest), for the 50-year seismic event, and 0 to 48 for 250-year seismic event. The bridges with the highest ranking are presented in Table E.1.

RECOMMENDATION

Bridges with relatively high ranking are located in counties closer to the New Madrid Seismic Zone (NMSZ). These counties are the McCracken, Livingston, and Marshall Counties. Based on this preliminary study, it is the recommendation of this study that some of the high ranking bridges be given the first priority for secondary and/or detailed evaluation. The detailed seismic evaluation of selected bridges is presented in the 4th report of this series.

Table E.1: Bridges with Relatively High Ranking

County	BIN[1,2]	Year Built	Rank[3] (50-yr)	Rank[3] (250-yr)
McCracken	73-0024-B00107 & 73-0024-B00107P	1967	29	36
McCracken	73-0024-B00115 & 73-0024-B00115P	1971	29	36
McCracken	73-0024-B00114 & 73-0024-B00114P	1963	28	36
McCracken	73-0024-B00120 & 73-0024-B00120P	1975	14	18
McCracken	73-0024-B00113	1974	38	48
McCracken	73-0024-B00113	1974	38	48
McCracken	73-0024-B00112 & 73-0024-B00112P	1969	11	14
McCracken	73-0994-B00121	1971	19	24
Lyon	73-0024-B00041 & 73-0024-B00041P	1971	14	23

[1] As defined in the Kentucky Transportation Cabinet (KyTC) Bridge Inventory
[2] The letter 'P' stands for parallel bridges
[3] Based on a scale of 0 (lowest) to 100 (highest)

NOTE: This report is the third (3rd) in a series of seven reports for Project SRP 206: "Seismic Evaluation of I-24 Bridges". The seven reports are:	
Report Number:	**Report Title:**
(1) KTC-06-20/SPR206-00-1F	Seismic Evaluation of I-24 Bridges and Embankments in Western Kentucky – Summary Report
(2) KTC-06-21/SPR206-00-2F	Site Investigation of Bridges along I-24 in Western Kentucky
(3) KTC-06-22/SPR206-00-3F*	Preliminary Seismic Evaluation and Ranking of Bridges along I-24 in Western Kentucky
(4) KTC-06-23/SPR206-00-4F	Detailed Seismic Evaluation of Bridges along I-24 in Western Kentucky
(5) KTC-06-24/SPR206-00-5F	Seismic Evaluation of the Tennessee River Bridges on I-24 in Western Kentucky
(6) KTC-06-25/SPR206-00-6F	Seismic Evaluation of the Cumberland River Bridges on I-24 in Western Kentucky
(7) KTC-06-26/SPR206-00-7F	Seismic Evaluation and Ranking of Bridge Embankments along I-24 in Western Kentucky

* Denotes current report

ACKNOWLEDGEMENTS

The Federal Highway Administration and the Kentucky Transportation Cabinet (KyTC) provided the financial support for this project. The authors would like to acknowledge the cooperation, suggestions, and advices of Chris Hill, V.J. Gupta, and David Ritchie. Many thanks are extended to the following undergraduate and graduate students in the Department of Civil Engineering who devoted many hours to this project: Robert Goodpaster, Joshua Johnson, Josh Webb and Scott Pabian.

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1. INTRODUCTION

1.1 Background

The New Madrid and Wabash Valley Seismic Zones (Fig. 1.1) can cause considerable vibrations in Western Kentucky if a sizable earthquake were to occur in that region. The New Madrid Seismic Zone (NMSZ) is potentially one of the most destructive fault zones in the United States. In 1811-1812, four of the most severe earthquakes in the American history occurred in the New Madrid Seismic Zone. The instrumental observations indicate that the New Madrid Seismic Zone is still the most hazardous zone in the east of the Rocky Mountains (Johnston 1985; and Johnston and Nava 1985).

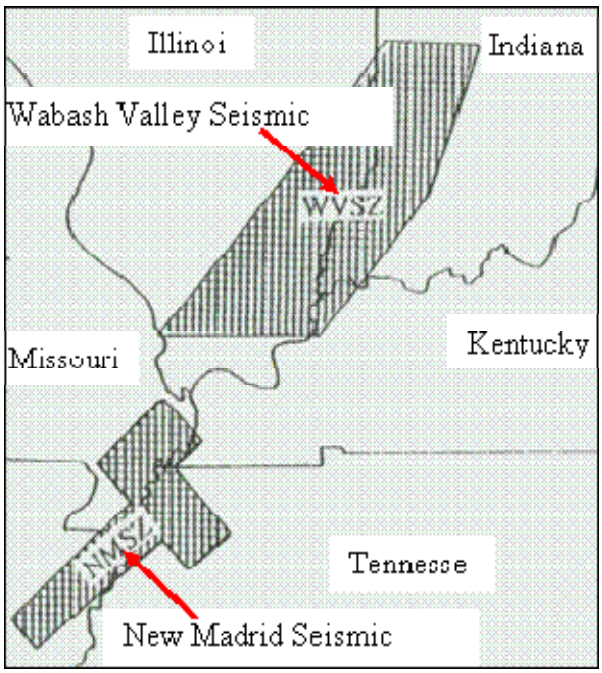


Fig. 1.1 – Seismic zones affecting Kentucky.

Interstate 24 (I-24) is located in close proximity to the NMSZ is depicted in Fig. 1.2. The Federal Highway Administration has designated I-24 as a high-priority route and an emergency route for the city of Memphis, Tennessee. Due to its close proximity to the NMSZ, Memphis is at a high risk of structural damage for its bridges and buildings, which were built before the use of seismic building codes. It is for these reasons that emergency personnel and equipment from surrounding states must utilize clear and safe routes in the event that a major earthquake strikes.

Fig. 1.2 – I-24 crossing McCracken, Marshall, Livingston, Lyon, Trigg, Caldwell, and Christian Counties in Western Kentucky (Courtesy of Kentucky Transportation Cabinet).

The Kentucky Transportation Cabinet (KyTC), as a result, has commissioned and is currently sponsoring numerous projects in an effort to investigate the structural integrity of bridges; especially those located in close proximity of these seismic zones (i.e. the New Madrid Seismic Zone to the west and the Wabash Valley Seismic Zone to the North-west of Kentucky). These efforts include field inspections, seismic evaluations, bridge prioritization, and retrofitting recommendations. One of the past projects in 1988 was to identify critical links along highways in the state of Kentucky. The study identified I-24 to be a critical link, and therefore was designated as a priority route. The significance of such identification is that bridges on this priority route are then labeled as "Essential" and must therefore remain open in the event of an earthquake. There are 127 bridges along I-24 in the seven counties in Western Kentucky. Fig. 1.3 shows the distribution of bridges in the seven counties. 70 of these bridges were designed using the pre-1971 design standards and were subsequently not built to withstand major seismic events.

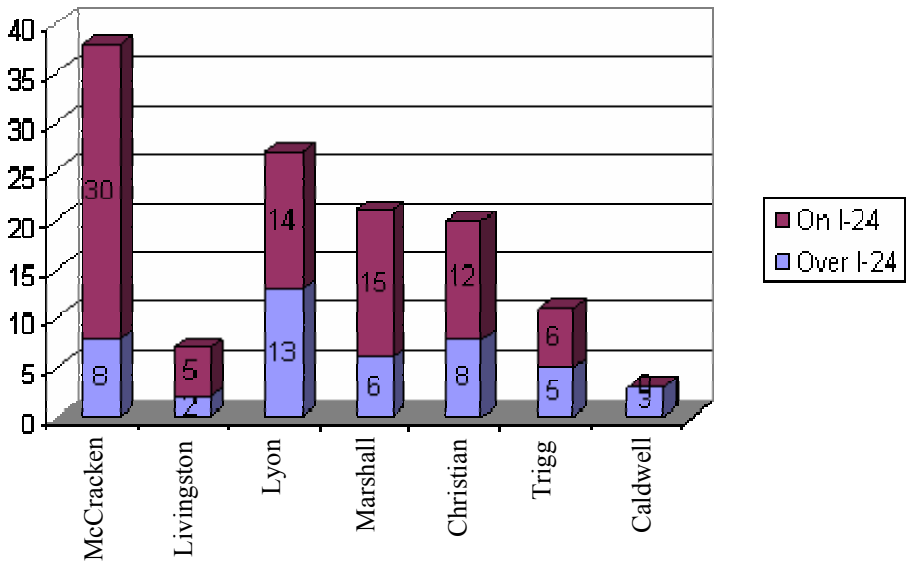


Fig. 1.3 – Distribution of bridges along I-24 among counties.

1.2 Objective and Tasks

The primary objective of the study is to provide ranking of these 127 bridges for the projected 50-year and 250-year seismic events. Such ranking is important because it assists in identifying and prioritizing seismically vulnerable bridges.

In this report, a step-by-step procedure for a preliminary seismic evaluation and ranking of these bridges is presented in Chapter 2, and the results are presented in subsequent chapters. The step-by-step procedure is based on the methodology provided in the retrofitting manual (Buckle and Friedland, 1995).

2. SEISMIC RATING SYSTEM

2.1 General

In this study, a preliminary screening process – known also as the "Seismic Rating System of Bridges" is used to: (1) identify the bridges that are seismically vulnerable; and (2) to subsequently prioritize bridges that are in greater need of further action (i.e. detailed seismic evaluation).

The information provided herein is obtained from the Seismic Retrofitting Manual for Highway Bridges (Buckle and Friedland, 1995) that is published by the Federal Highway Administration (Report No. FHWA-RD-94-052). The Seismic Rating System will be explained with the aid of Fig 2.1.

2.2 Acceleration (*A*) and Importance coefficients (*I*)

A bridge attached to the earth during an earthquake, will move back and forth rather irregularly. Commonly, this movement can be described as time histories of displacements, velocity, and accelerations. Most building codes prescribe how much horizontal force has to be considered during to a design earthquake. Since this force is generally related to the ground acceleration, the ground acceleration has to be considered. The peak ground acceleration (*PGA*) is the maximum acceleration experienced by the building structure during the course of the earthquake motion.

Peak ground acceleration contour maps (Fig. 2.2), defining the seismic zones and response spectra, are given on a county-basis for the seismic design of new bridges and the seismic evaluation of existing bridges in Kentucky. Peak ground accelerations (*PGA*) are listed in Table 2.1 for counties in Western Kentucky. The peak ground acceleration is a function of the acceleration coefficient (*A*) and the gravitational acceleration constant ($g = 9.81 m/sec^2$ or 386 in/sec^2).

The acceleration coefficient (*A*) adopted in this report is different from the American Association of State Highway and Transportation Officials (AASHTO) specifications because local peak-particle accelerations, time histories and response spectra for Kentucky have already been procured by the Kentucky Transportation Center (KTC). This information is obtained from a time history response spectra identification map for the 50-year event and the 250-year event derived by Street et. al. (1996).

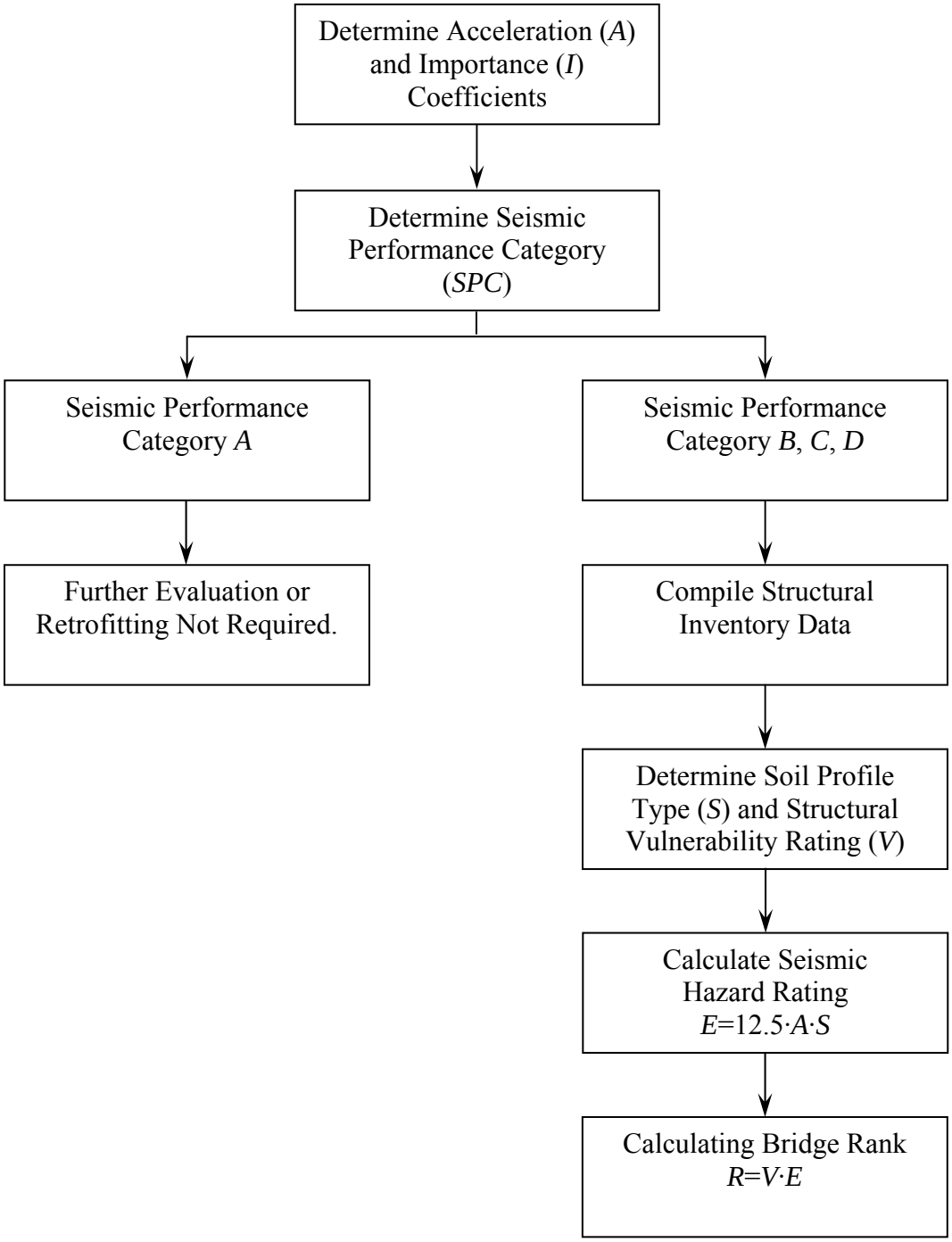
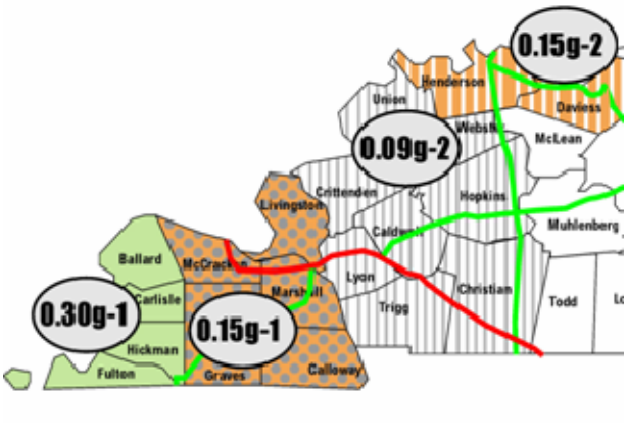
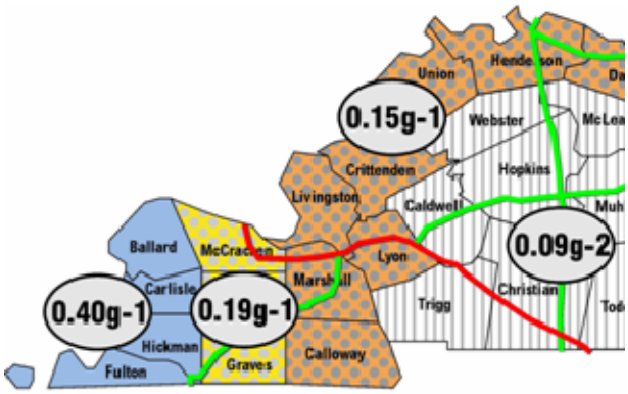


Fig. 2.1 – Seismic Ranking System.

(Seismic Retrofitting manual, Buckle and Friedland 1995, Figure 6)



(a) Seismic map for the 50-year seismic event



(b) Seismic map for the 250-year seismic event

Fig. 2.2 – Seismic maps for bridges along I-24 (Street et al. 1996).

Table 2.1: Peak ground acceleration (*PGA*) and seismic performance category (*SPC*)

County	Seismic Events			
	50-Years[1]		250-Years[1]	
	PGA	***SPC***	***PGA***	***SPC***
Christian	0.09g	*B*	0.09g	*B*
Trigg	0.09g	*B*	0.09g	*B*
Caldwell	0.09g	*B*	0.09g	*B*
Lyon	0.09g	*B*	0.15g	*C*
Marshall	0.15g	*C*	0.15g	*C*
McCracken	0.15g	*C*	0.15g	*C*
Livingston	0.15g	*C*	0.15g	*C*

[1] 90% probability of not being exceeded in the specified years

Two categories used to describe the Importance coefficient (*I*), as documented in the Seismic Retrofitting Manual (Buckle and Friedland, 1995). The two categories are known as *essential* and *standard*. Bridges classified as "*Essential*" are bridges that must remain functional and operational after an earthquake event. All other bridges are categorized as *standard*. The importance of all the bridges along I-24 in Western Kentucky can be classified as "*Essential*".

2.3 Seismic Performance Category (*SPC*)

Based upon the considerations for seismic hazard and importance, four Seismic Performance Categories (*SPC*) *A*, *B*, *C*, and *D* are defined by the Retrofitting Manual, as shown in Table 2.2. This classification system is different from the classification system used in the AASHTO Specifications for new design. Since all the bridges along I-24 are classified as "Essential" bridges, the *SPC* of these bridges can be exclusively determined by the seismic hazard (acceleration coefficient).

Table 2.2: Classification of Seismic Performance Category (*SPC*)

(Seismic Retrofitting Manual, Table 1)

Acceleration Coefficient	Importance Classification	
	Essential	*Standard*
$A \leq 0.09$	*B*	*A*
$0.09 < A \leq 0.19$	*C*	*B*
$0.19 < A \leq 0.29$	*C*	*C*
$0.29 < A$	*D*	*C*

The Seismic Performance Category (*SPC*) of the bridges along I-24 are also listed in Table 2.1. The seismic evaluation procedures with regard to the *SPC* vary from one category to the other. For example, bridges in *SPC B* only need to be screened, evaluated, and strengthened based on the vulnerability of their bearings, expansion joints and support widths. In the seismic performance categories *C* and *D*, however, items including screening, evaluation and retrofitting shall include all major components subjected to failure during a strong earthquake. The effects of soil failure, such as liquefaction, are also considered for bridges in Seismic Performance Categories *C* and *D*.

2.4 Structural Inventory Data

In order to obtain the critical information regarding each bridge, a comprehensive inventory of the bridges was compiled by review of the "as-built" plans, construction and

maintenance records, and conducting on-site inspections. The on-site inspection form that is shown in Fig. 2.3 is used to collect the necessary data. In this inventory all the necessary data was organized and processed by a database entitled Seismic Inventory of Bridges, which was programmed using Microsoft Access 2000 (Appendix A). Data pertinent to one hundred and twenty-seven (127) bridges was collected and implemented as a seismic evaluation information system.

2.5 Soil Profile Type and Soil Coefficient (*S*)

Table 2.3 shows how the different soil profile type and site coefficient (*S*) are determined. In locations where the soils properties are not known in sufficient detail to determine the soil profile type with confidence, or where the profile does not fit any of the above four types, the site coefficient shall be based on engineering judgment.

Table 2.3: Soil Profile Type and Site Coefficient (*S*)

(Seismic Retrofitting Manual, Buckle and Friedland 1995, Table 3)

Soil Type	Soil Profile	Site Coefficient
I	Rock or stiff soils Soil depth less than 60 m (200 ft)	1.0
II	Stiff cohesive or deep cohesionless soil Soil depth exceeds 60 m (200 ft)	1.2
III	Soft to medium stiff clays and sands Soil depth exceeds 9 m (30 ft)	1.5
IV	Soft clays or silts Soil depth exceeds 12 m (40 ft)	2.0

2.6 Structural Vulnerability Rating (*V*)

Although the performance of a bridge is based on the interaction of all of its components, it has been observed during past earthquakes that certain bridge components of four general types are more vulnerable to damage than others. These are (a) connections, bearings, and seats; (b) columns and foundations; (c) abutments; and (d) foundations. Of these components, the bearings are generally the least expensive to retrofit. For that reason, the Seismic Retrofitting Manual proposes a separate vulnerability-rating factor (V_1) for the connections, bearings, and seat details.

GENERAL	Crossing				Bridge Number	
	Year Built		County		Detour Length (Miles)	
	Latitude		Longitude		If *yes*. Please list them (Structure or load).	
	Have modifications been made since the bridge was constructed? *No.*					
	Does the bridge cross a body of water?			*Yes* *No*		
	Has the bridge been seismically retrofitted?			*Yes* *No*		
	Is it a rigid box culvert?			*Yes* *No*		
SUPERSTRUCTURE	Is the superstructure integral with the abutments?			*Yes* *No*	**COMMENTS:**	
	Does the superstructure contain box girders?			*Yes* *No*		
	Is there lateral movement under traffic loading?			*Yes* *No*		
	Is the bridge likely to collapse in an earthquake after toppling failure of the bearings?			*Yes* *No*		
	Would gross movement of superstructure cause instability?			*Yes* *No*		
	Is the bridge skewed?			*Yes* *No*		
	Is there any unusual gap or offset at an expansion joint?			*Yes* *No*		
BEARINGS	Type	*Rocker* *Roller* *Elastometric Pad* *Sliding* *Multi-rotation*			Condition	
	If there are pedestals, are the bearings likely to overturn in an earthquake?					*Yes* *No*
	Does the bridge with less than 3 girders have exterior girder supported on the seat edge?					*Yes* *No*
	Are the bearing seats, under the abutment end-diaphragm, continuous?					*Yes* *No*
	Are there any girders supported on individual pedestals or columns?					*Yes* *No*
	What is the longitudinal support length measured in a direction perpendicular to the support?					13 in
SUBSTRUCTURE	Is the abutment a cantilever earth-retaining abutment?					*Yes* *No*
	Are the reinforced concrete columns monolithic with the superstructure?					*Yes* *No*
	Is there horizontal or vertical movement or tilting of the abutments, columns or piers?					*Yes* *No*
	Is there unusual or extensive erosion of soil at or near any of the substructure units?					*Yes* *No*
	Do you think abutment-slope failures are possible in an earthquake?					*Yes* *No*
OTHER						

Fig. 2.3 – Typical site investigation form for bridges along I-24 in Western Kentucky.

The other three components are combined under another rating factor (V_2). The overall rating for the bridge (V) is then given by the larger of these two factors. A flow chart summarizing the process to calculate Vulnerability Rating (V) is shown in Fig. 2.4.

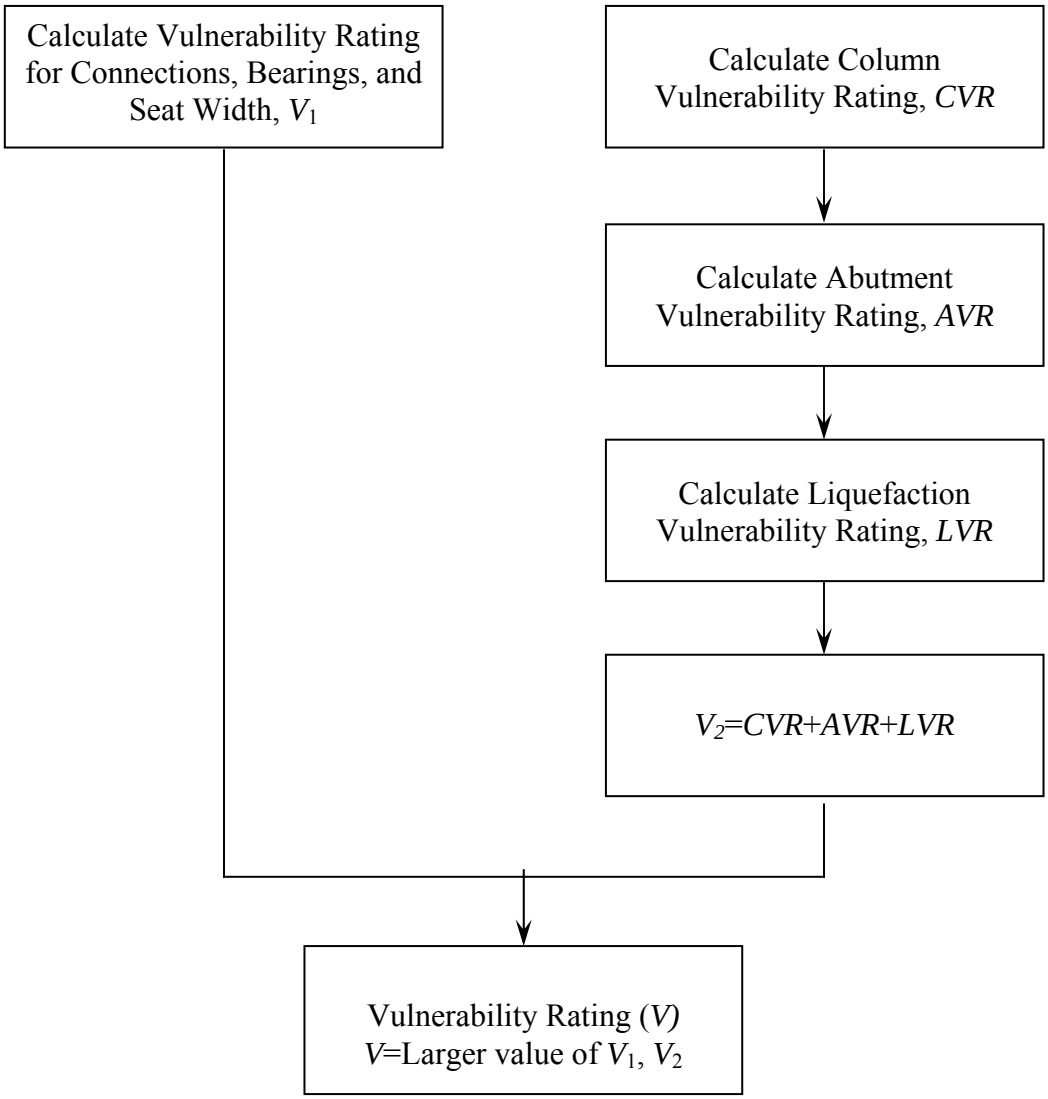


Fig. 2.4 – Flow Chart for Calculation of Bridge Vulnerability Rating (*V*)

2.6.1 Vulnerability Rating for Connections, Bearings, and Seat Widths (V_1)

According to the Seismic Retrofitting Manual (Buckle and Friedland, 1995), a step-by-step method is suggested for determining the vulnerability rating for connections, bearings, and seat widths (V_1). Fig. 2.5 shows a flow chart that details the process for determining (V_1).

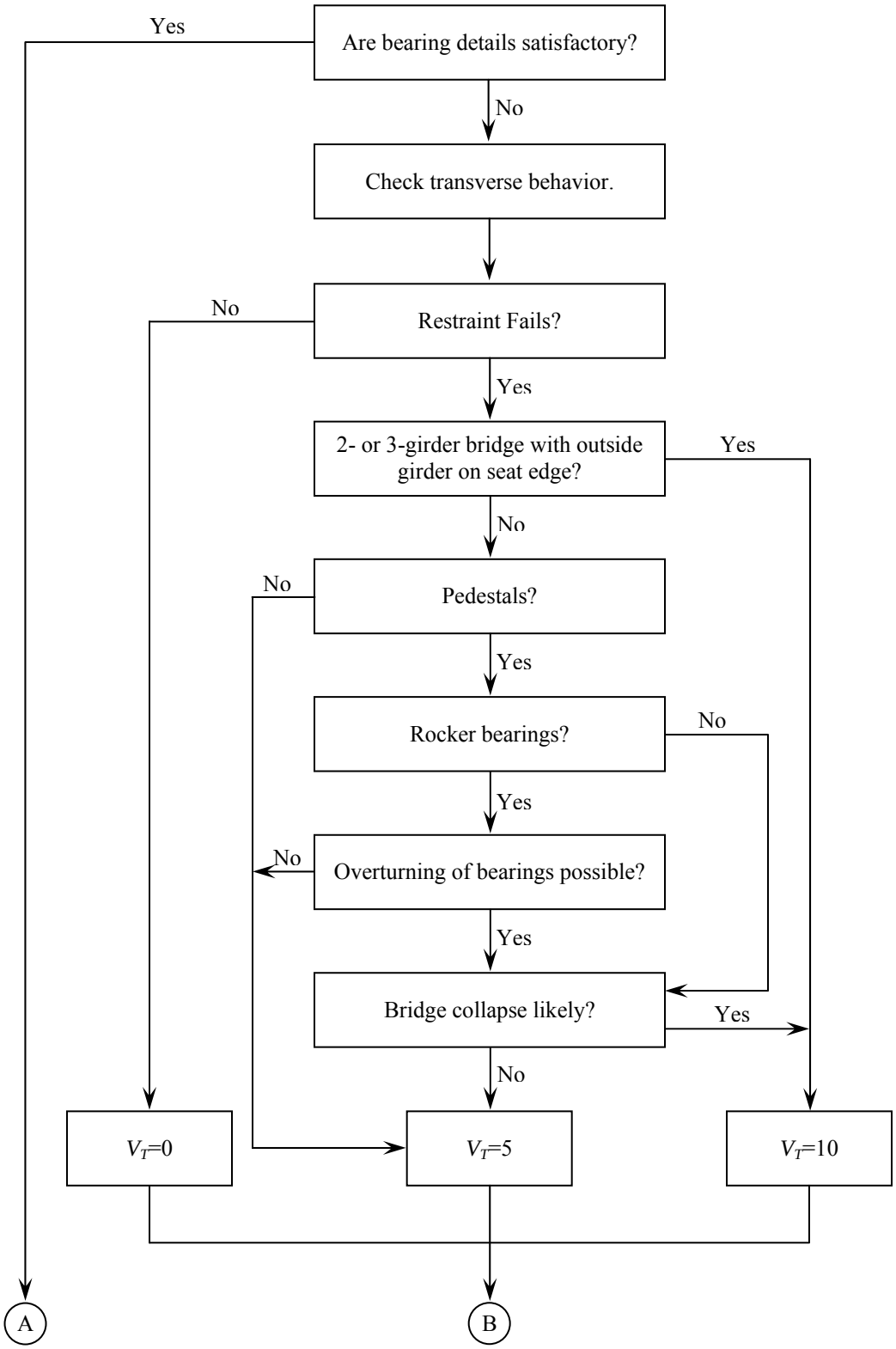


Fig. 2.5 – Flow Chart for Calculation of Vulnerability Rating for Connections, Bearings, and Seat Widths (V_1)

(Seismic Retrofitting Manual, Figure 9b)

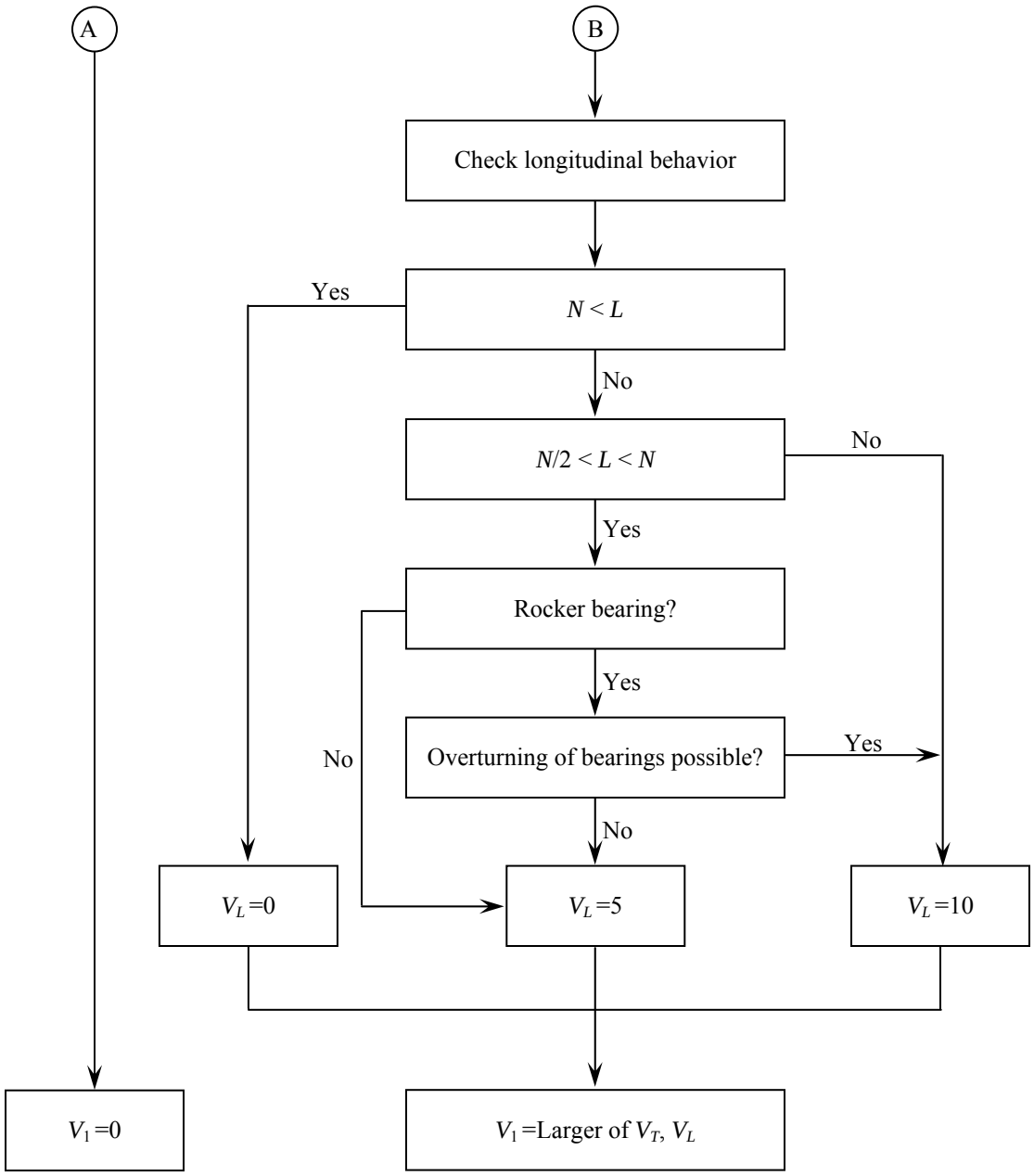


Fig. 2.5 (Cont') – Flow Chart for Calculation of Vulnerability Rating for Connections, Bearings, and Seat Widths (V_1)
(Seismic Retrofitting Manual, Buckle and Friedland, Figure 9b)

2.6.2 Vulnerability Rating for Columns, Abutments, and Liquefaction Potential (V_2)

The vulnerability rating for the other components in the bridges that are susceptible to failure, V_2, is calculated from the individual component ratings as follows:

$$V_2 = CVR + AVR + LVR \leq 10$$

Where, CVR = column vulnerability rating
AVR = abutment vulnerability rating
LVR = liquefaction vulnerability rating

Suggested methods for calculating of each of these component ratings are given in Figs. 2.6 through 2.8.

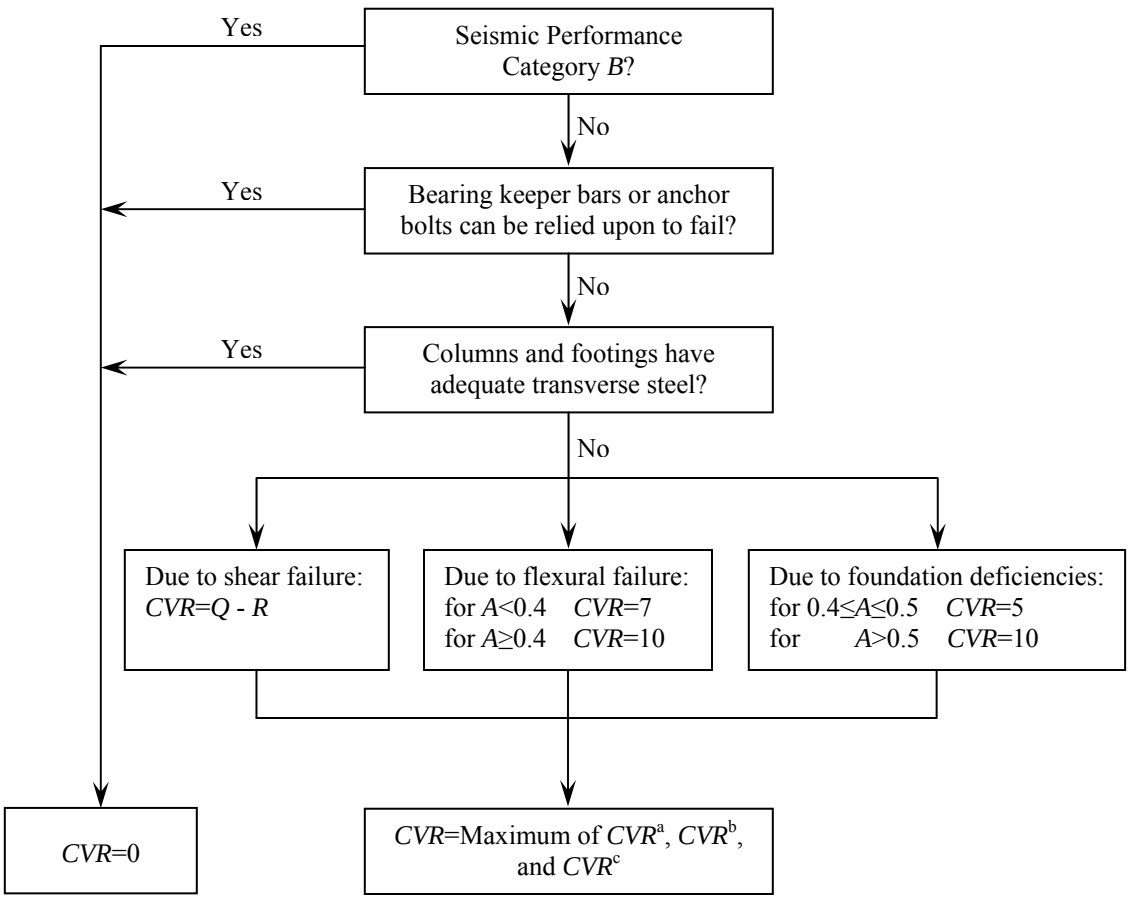


Fig. 2.6 – Flow Chart for Calculation of Column Vulnerability Rating (*CVR*)

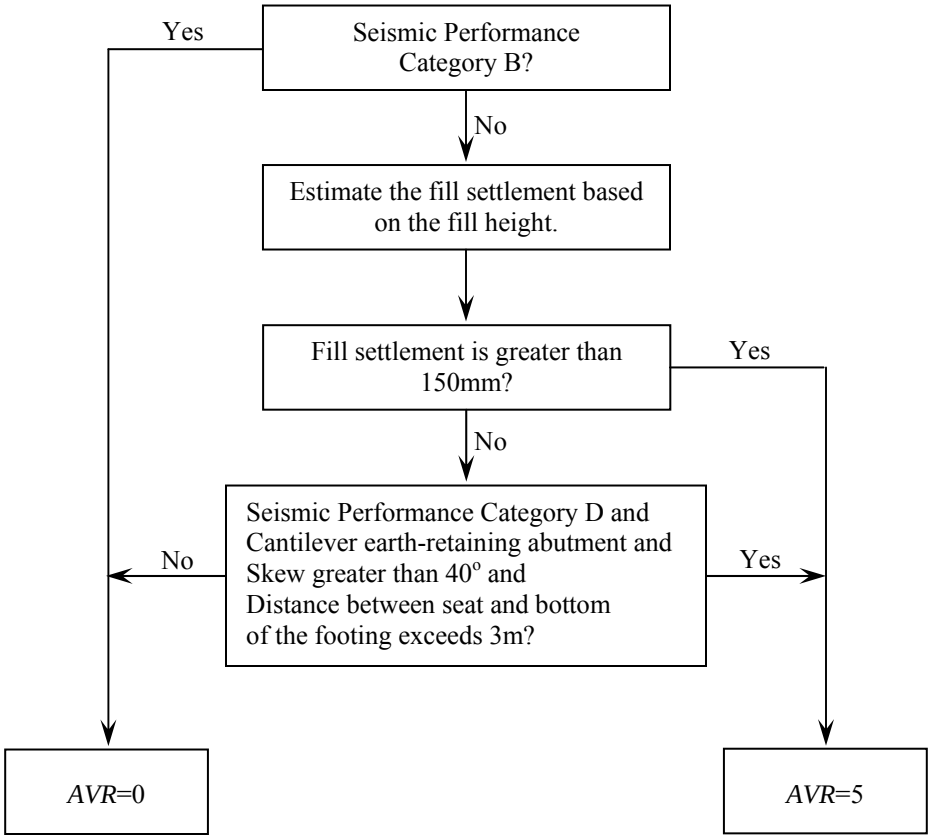


Fig. 2.7 – Flow Chart for Calculation of Abutment Vulnerability Rating (*AVR*)

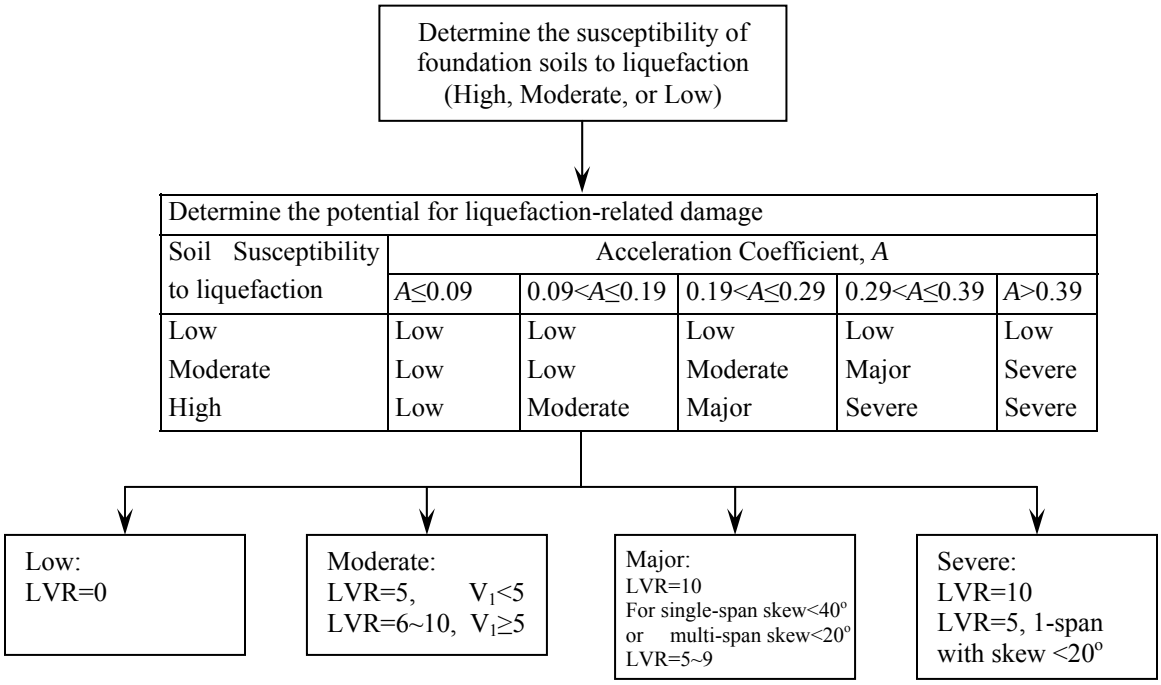


Fig. 2.8 - Flow Chart for Calculation of Liquefaction Vulnerability Rating (*LVR*)

2.7 Seismic Hazard Rating (*E*) and Bridge Rank (*R*)

As a measure of the seismic hazard, the peak ground acceleration (*PGA*) in rock or competent soil is used. The hazard is modified by the soil profile coefficient *S*, varying from 1.0 for rock to 2.0 for soft clays and sands, to allow for soil amplification effects. The seismic hazard rating (*E*) is calculated using the following equation:

$E = 12.5 \cdot A \cdot S \leq 10$ (Seismic Retrofitting Manual, Buckle and Friedland, 1995 Eq. 2-4)

The bridge rank (*R*) is calculated based on a structural vulnerability rating (*V*) and a seismic hazard rating (*E*). Each rating (*V* and/or *E*) falls in the range of 0 to 10 and the rank (*R*) is found by multiplying these two ratings.

$R = V \cdot E$ (Seismic Retrofitting Manual, Eq. 2-2)

Since *V* and *E*, each, range from 0 to 10, the minimum and maximum values for *R* shall range from 0 and 100. In general, the higher the bridge rank (*R)*, the greater the need for detailed seismic evaluation and potential for retrofitting needs.

3. INVENTORY OF BRIDGES ALONG I-24 IN WESTERN KENTUCKY

3.1 Introduction

As mentioned previously, the preliminary seismic bridge evaluation and ranking requires adequate knowledge of the bridge components, location, and site condition. In this study, a comprehensive inventory of I-24 bridges was compiled by reviewing the 'as-built' plans, construction and maintenance records, and site inspections, where applicable. The following briefly summarizes the general characteristics of the bridges along I-24 in Western Kentucky.

3.2 Characteristics of Bridges along I-24 in Western Kentucky

The bridges along I-24 in Western Kentucky are characterized based on the associated construction type, length, number of spans, maximum span length, skew angle, bearing, etc. Over 50% of bridges are between 100 and 200 feet in length and 75% are between 100 and 300 feet in length. Thirty percent of the bridges are not skewed while 15% have a skew angle greater than 40 degrees.

Most bridges over I-24 in Western Kentucky were built in the same period, and are quite similar not only in their construction/material types but also in layouts. There are two main types of the bridges over I-24 in Western Kentucky. Forty of these bridges are designated as Type A that includes all 2-span continuous composite steel girder bridges. Three bridges are designated as Type B that includes all 2-span reinforced concrete box girder bridges. Other than these two types, there are two 1-span steel bridges and one 4-span continuous composite steel girder bridge. The maximum span lengths of the bridges range from 92 feet to 118 feet. Except for the bridge with the four main spans with a total length of 338 feet, all the 2-span bridges have a total length between 228 feet and 260 feet. Given such uniformity of the bridges over I-24 in Western Kentucky, makes analyzing a "typical" bridge, using qualitative analysis and quantitative analysis, a reasonable solution.

Despite the uniformity of the bridges over I-24 in Western Kentucky, bridges on I-24 vary in their structural characteristics. The bridges on I-24 include 38 pairs of parallel bridges (Westbound and Eastbound) and five reinforced concrete culverts.

Bearings are an important aspect in the evaluation process. They also include restraints provided at the locations of the shear keys and the restrainer bars. There are basically three types of bearings used in bridges along I-24 in Western Kentucky: (1) rocker bearings, used in 50% of

the bridges; (2) roller bearings, used in 40% of the bridges; and (3) elastomeric bearings, used in 10% of the bridges. A complete statistical data of the different aspects of bridges along I-24 in Western Kentucky is presented in the figures shown in Appendix B.

4. RANKING OF I-24 BRIDGES

This chapter presents the preliminary seismic evaluation and ranking of bridges along I-24 in Western Kentucky that is carried out using the methodology presented in Chapter 2 and the statistical data of the bridges, provided in Chapter 3. The preliminary seismic evaluation and ranking process that is based on structural vulnerability and seismic hazard as discussed, ranks the bridge on a scale from zero to 100, where zero stands for the lowest risk and 100 stands for the highest risk. All is all, 127 bridges along I-24 in Western Kentucky were evaluated for the 50-years and the 250-years. The rating of these bridges is presented in Table 4.1 for both the 50-year and the 250-year seismic events.

Table 4.1: Preliminary Seismic Ranking of Bridges along I-24 in Western Kentucky

County	BIN[1,2]	Year Built	Seismic Events			
			50-Year		250-Year	
			PGA[3]	Ranking[4]	PGA[3]	Ranking[4]
Livingston	70-0024-B00061	1974	0.15g	0	0.15g	0
	70-0024-B00062 & 70-0024-B00062 P	1977	0.15g	0	0.15g	0
	70-0024-B00063 & 70-0024-B00063 P	1977	0.15g	38	0.15g	38
	70-0453-B00064 & 70-0453-B00064 P	1976	0.15g	14	0.15g	14
Lyon	72-0024-B00035 & 72-0024-B00035 P	1697	0.09g	0	0.15g	0
	72-0024-B00036 & 72-0024-B00036 P	1969	0.09g	7	0.15g	11
	72-0024-B00037 & 72-0024-B00037 P	1976	0.09g	7	0.15g	11
	72-0024-B00039 & 72-0024-B00039 P	1976	0.09g	0	0.15g	0
	72-0024-B00041 & 72-0024-B00041 P	1971	0.09g	14	0.15g	23
	72-0024-B00044 & 72-0024-B00044 P	1967	0.09g	11	0.15g	19
	72-0024-B00048 & 72-0024-B00048 P	1967	0.09g	7	0.15g	11
	72-5123-B00046 & 72-5123-B00046 P	1967	0.09g	0	0.15g	0
	72-9001-B00049 & 72-9001-B00049 P	1976	0.09g	0	0.15g	0
	72-0093-B00042	1976	0.09g	0	0.15g	0

[1] As defined in the Kentucky Transportation Cabinet (KyTC) Bridge Inventory
[2] The letter 'P' stands for parallel bridge
[3] The peak ground acceleration (PGA) is as defined in Street et. al. (1996)
[4] The ranking methodology and procedure system is described in Chapter 2. A scale from zero (lowest risk) to 100 (highest risk) is employed.

Table 4.1 (Cont'): Preliminary Seismic Ranking of Bridges along I-24 in Western Kentucky

County	BIN[1,2]	Year Built	Seismic Events			
			50-Year		250-Year	
			PGA[3]	Ranking[4]	PGA[3]	Ranking[4]
Lyon	72-0293-B00043	1976	0.09g	11	0.15g	19
	72-0295-B00038	1976	0.09g	7	0.15g	11
	72-0810-B00033	1976	0.09g	11	0.15g	19
	72-0903-B00047	1967	0.09g	11	0.15g	19
	72-5039-B00040	1976	0.09g	8	0.15g	14
	72-5118-B00045	1967	0.09g	0	0.15g	0
	72-5225-B00032	1977	0.09g	8	0.15g	14
	72-5229-B00034	1976	0.09g	11	0.15g	19
Caldwell	17-0139-B00065	1970	0.09g	11	0.09g	11
	17-0276-B00066 & 17-0276-B00066 P	1971	0.09g	0	0.09g	0
Marshall	79-0024-B00111	1967	0.15g	11	0.15g	11
	79-0024-B00109	1970	0.15g	19	0.15g	19
	79-0095-B00112	1967	0.15g	19	0.15g	19
	79-1042-B00081 & 79-1042-B00081 P	1966	0.15g	19	0.15g	19
	79-1610-B00092	1967	0.15g	19	0.15g	19
	79-0024-B00116 & 79-0024-B00116 P	1970	0.15g	11	0.15g	11
	79-0024-B00117 & 79-0024-B00117 P	1972	0.15g	19	0.15g	19
	79-0024-B00118 & 79-0024-B00118 P	1969	0.15g	38	0.15g	38
	79-0024-B00136	1973	0.15g	0	0.15g	0
	79-0024-B00082 & 79-0024-B00082 P	1964	0.15g	0	0.15g	0

[1] As defined in the Kentucky Transportation Cabinet (KyTC) Bridge Inventory
[2] The letter 'P' stands for parallel bridge
[3] The peak ground acceleration (PGA) is as defined in Street et. al. (1996)
[4] The ranking methodology and procedure system is described in Chapter 2. A scale from zero (lowest risk) to 100 (highest risk) is employed.

Table 4.1 (Cont'): Preliminary Seismic Ranking of Bridges along I-24 in Western Kentucky

County	BIN[1,2]	Year Built	Seismic Events			
			50-Year		250-Year	
			PGA[3]	Ranking[4]	PGA[3]	Ranking[4]
Marshall	79-0024-B00113 & 79-0024-B00113 P	1967	0.15g	11	0.15g	11
	79-0024-B00114 & 79-0024-B00114 P	1974	0.15g	11	0.15g	11
	79-0024-B00115 & 79-0024-B00115 P	1969	0.15g	0	0.15g	0
Trigg	111-0024-B00027 & 111-0024-B00027 P	1969	0.09g	0	0.09g	0
	111-0024-B00044 & 111-0024-B00044 P	1969	0.09g	0	0.09g	0
	111-0024-B00048 & 111-0024-B00048 P	1970	0.09g	0	0.09g	0
	111-0024-B00043	1968	0.09g	11	0.09g	11
	111-0024-B00045	1979	0.09g	11	0.09g	11
	111-0024-B00050	1967	0.09g	0	0.09g	0
	111-6049-B00047	1969	0.09g	11	0.09g	11
	111-6051-B00049	1969	0.09g	0	0.09g	0
McCracken	73-0024-B00115 & 73-0024-B00115 P	1971	0.15g	29	0.19g	36
	73-0024-B00116 & 73-0024-B00116 P	1975	0.15g	14	0.19g	18
	73-0024-B00118 & 73-0024-B00118 P	1975	0.15g	14	0.19g	18
	73-0024-B00119 & 73-0024-B00119 P	1971	0.15g	14	0.19g	18
	73-0024-B00120 & 73-0024-B00120 P	1975	0.15g	14	0.19g	18
	73-0068-B00060 & 73-0068-B00060 P	1968	0.15g	14	0.19g	29
	73-0024-B00117	1972	0.15g	0	0.19g	0
	73-0062-B00121	1971	0.15g	14	0.19g	18
	73-0024-B00113	1974	0.15g	14	0.19g	48
	73-0131-B00009	1968	0.15g	14	0.19g	19

[1] As defined in the Kentucky Transportation Cabinet (KyTC) Bridge Inventory
[2] The letter 'P' stands for parallel bridge
[3] The peak ground acceleration (PGA) is as defined in Street et. al. (1996)
[4] The ranking methodology and procedure system is described in Chapter 2. A scale from zero (lowest risk) to 100 (highest risk) is employed.

Table 4.1 (Cont'): Preliminary Seismic Ranking of Bridges along I-24 in Western Kentucky

County	BIN[1,2]	Year Built	Seismic Events			
			50-Year		250-Year	
			PGA[3]	Ranking[4]	PGA[3]	Ranking[4]
McCracken	73-0787-B00064	1966	0.15g	14	0.19g	18
	73-0994-B00122	1971	0.15g	19	0.19g	24
	73-3075-B00065	1966	0.15g	38	0.19g	48
	73-0024-B00101 & 73-0024-B00101 P	1968	0.15g	14	0.19g	18
	73-0024-B00102 & 73-0024-B00102 P	1969	0.15g	23	0.19g	29
	73-0024-B00103 & 73-0024-B00103 P	1969	0.15g	11	0.19g	14
	73-0024-B00104 & 73-0024-B00104 P	1968	0.15g	14	0.19g	18
	73-0024-B00105 & 73-0024-B00105 P	1969	0.15g	11	0.19g	14
	73-0024-B00107 & 73-0024-B00107 P	1967	0.15g	29	0.19g	36
	73-0024-B00111 & 73-0024-B00111 P	1971	0.15g	0	0.19g	0
	73-0024-B00112 & 73-0024-B00112 P	1971	0.15g	11	0.19g	14
	73-0024-B00114 & 73-0024-B00114 P	1963	0.15g	28	0.19g	36
Christian	24-0024-B00090 & 24-0024-B00090 P	1976	0.09g	8	0.09g	8
	24-0024-B00122 & 24-0024-B00122 P	1968	0.09g	0	0.09g	0
	24-0024-B00125 & 24-0024-B00125 P	1972	0.09g	11	0.09g	11
	24-0024-B00129 & 24-0024-B00129 P	1969	0.09g	8	0.09g	8
	24-0695-B00124	1969	0.09g	0	0.09g	0
	24-0024-B00130 & 24-0024-B00130 P	1968	0.09g	0	0.09g	0
	24-0024-B00132 & 24-0024-B00132 P	1971	0.09g	8	0.09g	8
	24-0024-B00128	1969	0.09g	8	0.09g	8
	24-0024-B00133	1971	0.09g	8	0.09g	8

[1] As defined in the Kentucky Transportation Cabinet (KyTC) Bridge Inventory
[2] The letter 'P' stands for parallel bridge
[3] The peak ground acceleration (PGA) is as defined in Street et. al. (1996)
[4] The ranking methodology and procedure system is described in Chapter 2. A scale from zero (lowest risk) to 100 (highest risk) is employed.

Table 4.1 (Cont'): Preliminary Seismic Ranking of Bridges along I-24 in Western Kentucky

County	BIN[1,2]	Year Built	Seismic Events			
			50-Year		250-Year	
			PGA[3]	Ranking[4]	PGA[3]	Ranking[4]
Christian	24-0024-B00134	1971	0.09g	8	0.09g	8
	24-0107-B00127	1967	0.09g	8	0.09g	8
	24-0115-B00131	1970	0.09g	8	0.09g	8
	24-0164-B00123	1968	0.09g	11	0.09g	11
	24-0272-B00121	1968	0.09g	11	0.09g	11

[1] As defined in the Kentucky Transportation Cabinet (KyTC) Bridge Inventory
[2] The letter 'P' stands for parallel bridge
[3] The peak ground acceleration (PGA) is as defined in Street et. al. (1996)
[4] The ranking methodology and procedure system is described in Chapter 2. A scale from zero (lowest risk) to 100 (highest risk) is employed.

5. SUMMARY AND CONCLUSIONS

The New Madrid Seismic Zone (NMSZ) is a seismically active zone. Interstate 24 (I-24) in Western Kentucky is close to the NMSZ, and is designated a high priority route that must remain open following a seismic event. As a part of the *Seismic Evaluation of I-24 Bridges* investigative series, the primary focus of this particular study is to perform a preliminary seismic evaluation and ranking of the bridges along I-24 in Western Kentucky. The ranking system shall assist in identifying and prioritizing bridges, based on their seismic vulnerability, for further detailed evaluations, retrofit measures, and/or other course of action. The ranking system in this study is based on a methodology developed by the Federal Highway Administration (Buckle and Friedland, 1995). The methodology takes into consideration the structural vulnerability, seismic and geotechnical hazards, and bridge importance, into consideration. Details of the methodology are presented in Chapter 2 of this report.

An inventory that includes information pertinent to the bridges along I-24 in Western Kentucky is compiled for the preliminary evaluation. The information listed in the inventory include: structural type, length, number of spans, maximum span length, skew angle, construction type, bearing, etc. The statistical data of the information is presented in Appendix B.

One hundred and twenty seven (127) bridges along I-24 in Western Kentucky were evaluated and ranked for the projected 50-year and 250-year seismic events. These seismic events have 90% probability of not being exceeded in the specified number of years. The Tennessee River Bridges and the Cumberland River Bridges along I-24 however are not included in the 127 bridges count and are evaluated separately in the 5th and 6th report of this series. Culverts are also not considered in this study. Bridges along I-24 in Western Kentucky have ranking of 0 to 38, based on a scale from zero (lowest risk) to 100 (highest risk), for the 50-year event, and 0 to 48 for the 250-year event. The bridges with the highest ranking are presented in Table 5.1. As expected, bridges that have high potential of seismic vulnerability are mainly located in counties that are in close proximity to the NMSZ.

Based on this preliminary investigation, it is the recommendation of this part of the study to consider that the bridges with relatively high ranking be given the first priority for detailed evaluations. The detailed seismic evaluations of selected bridges, in Table 5.1 are presented in the 4th report of this series.

Table 5.1: Bridges Requiring Detailed Evaluation

Priority	County	BIN[1,2]	Year Built	Rank[3] (50-year)	Rank[3] (250-year)
First	McCracken	73-0024-B00107 & 73-0024-B00107P	1967	29	36
	McCracken	73-0024-B00115 & 73-0024-B00115P	1971	29	36
	McCracken	73-0024-B00114 & 73-0024-B00114P	1963	28	36
	McCracken	73-0024-B00120 & 73-0024-B00120P	1975	14	18
	McCracken	73-0024-B00113	1974	38	48
	McCracken	73-0024-B00113	1974	38	48
Second	McCracken	73-0024-B00112 & 73-0024-B00112P	1969	11	14
	McCracken	73-0994-B00121	1971	19	24
	Lyon	73-0024-B00041 & 73-0024-B00041P	1971	14	23

[1] As defined in the Kentucky Transportation Cabinet (KyTC) Bridge Inventory
[2] The letter 'P' stands for parallel bridge
[3] The ranking methodology and procedure system is described in Chapter 2. A scale from zero (lowest risk) to 100 (highest risk) is employed.

REFERENCES

Buckle, I. G., and Friedland, I. M., (1995), "Seismic Retrofitting Manual for Highway Bridges," Federal Highway Administration, US Department of Transportation. Publication No. FHWA-RD-94-052.

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Johnston, A.C. and Nava, S.J., (1985), "Recurrence Rates and Probability Estimates for the New Madrid Seismic Zone", Journal of Geophysical Research, Vol. 90, No. B8, 6737-6753.

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APPENDIX A

SEISMIC INVENTORY OF BRIDGES ALONG I-24

Fig. A.1 – Seismic Inventory of Bridges along I-24 in Western Kentucky.

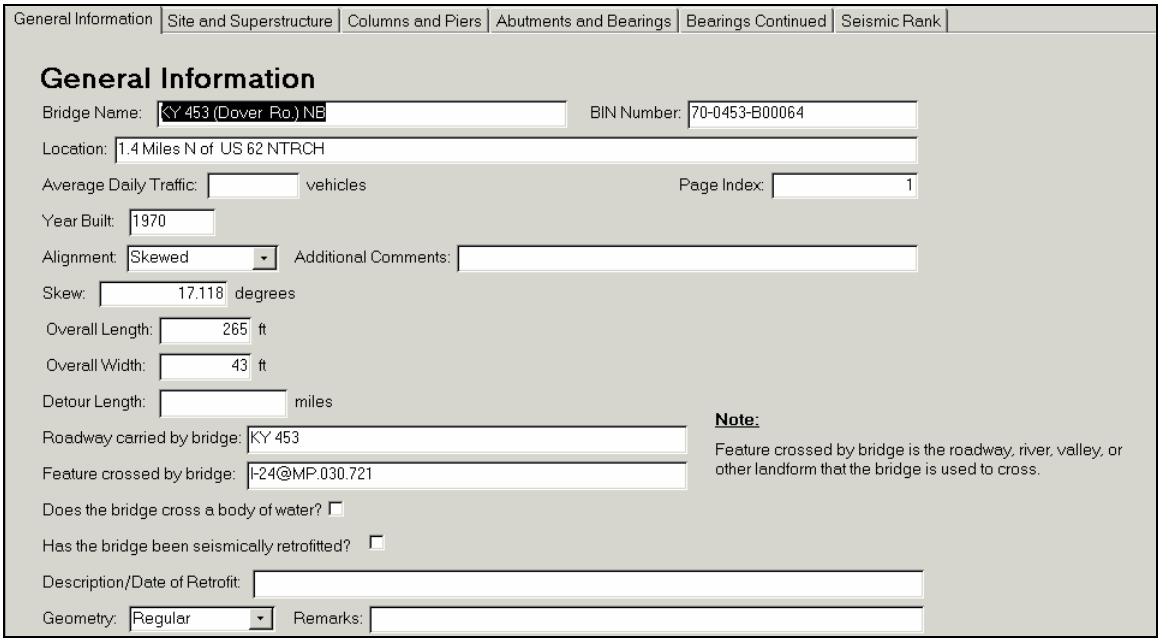

Fig. A.2 – Seismic Inventory of Bridges along I-24 in Western Kentucky.

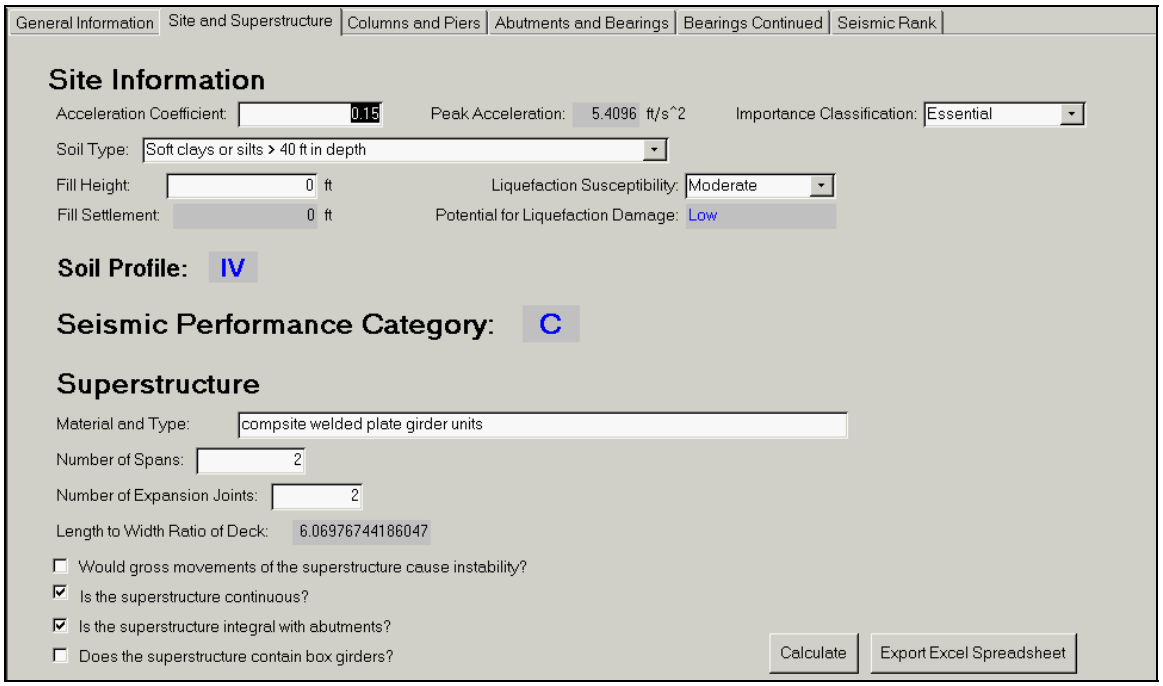

Fig. A.3 - Seismic Inventory of Bridges along I-24 in Western Kentucky.

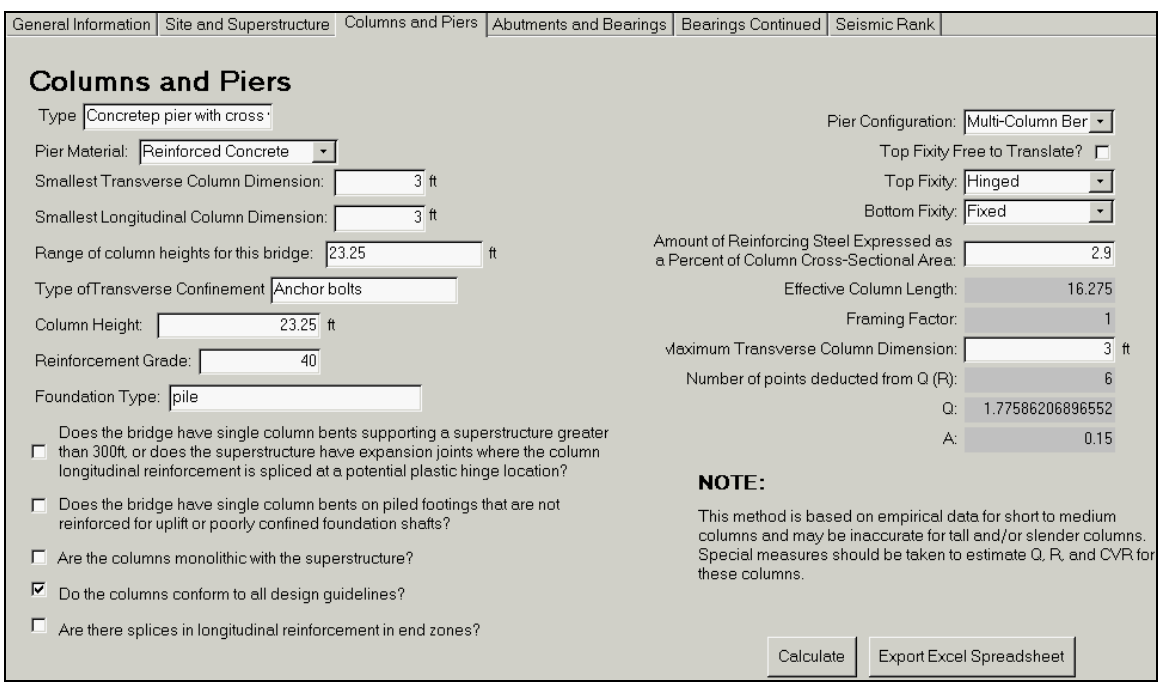

Fig. A.4 – Seismic Inventory of Bridges along I-24 in Western Kentucky

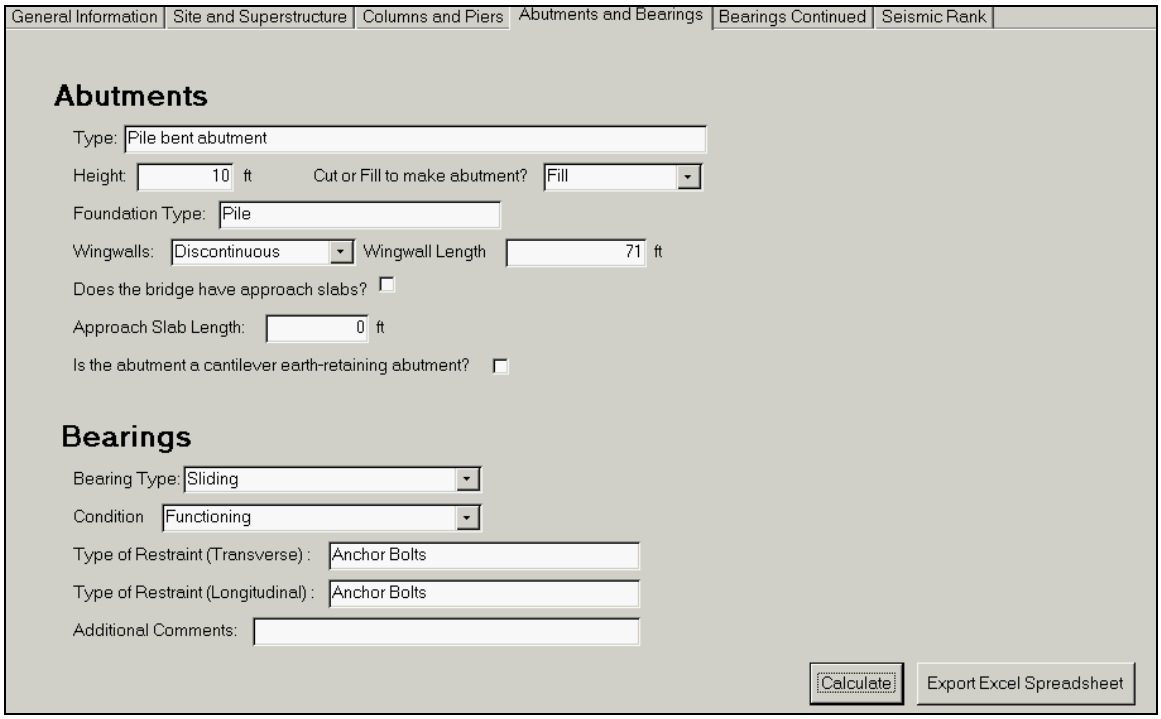

Fig. A.5 – Seismic Inventory of Bridges along I-24 in Western Kentucky.

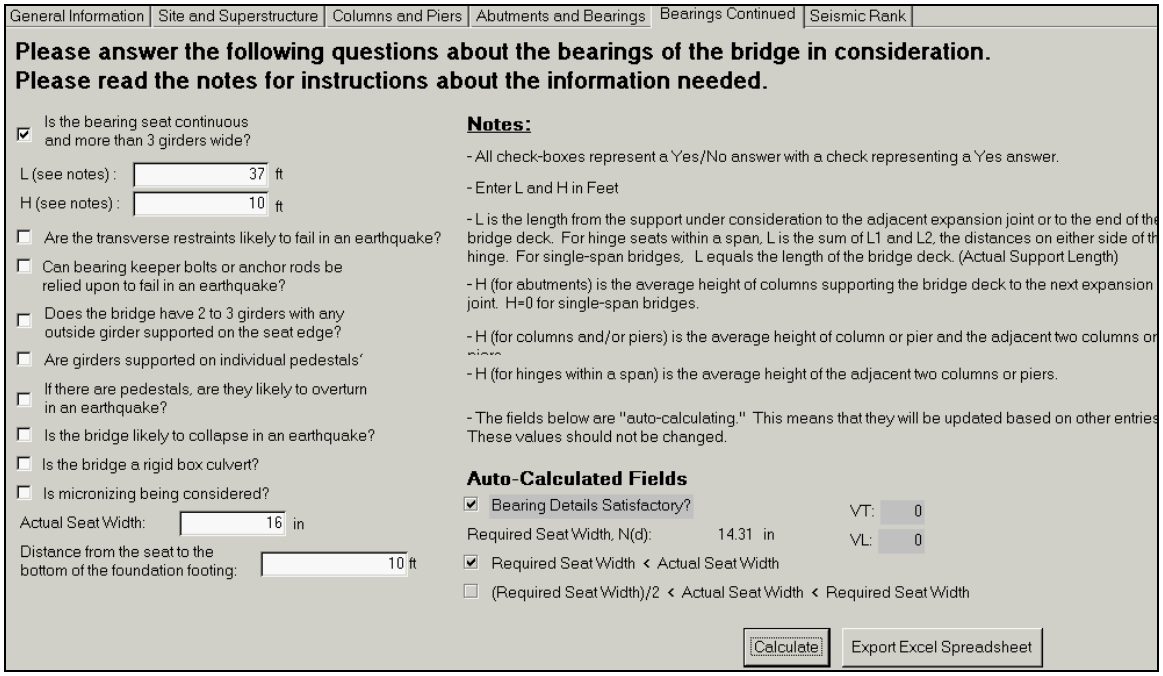

Fig. A.6 – Seismic Inventory of Bridges along I-24 in Western Kentucky.

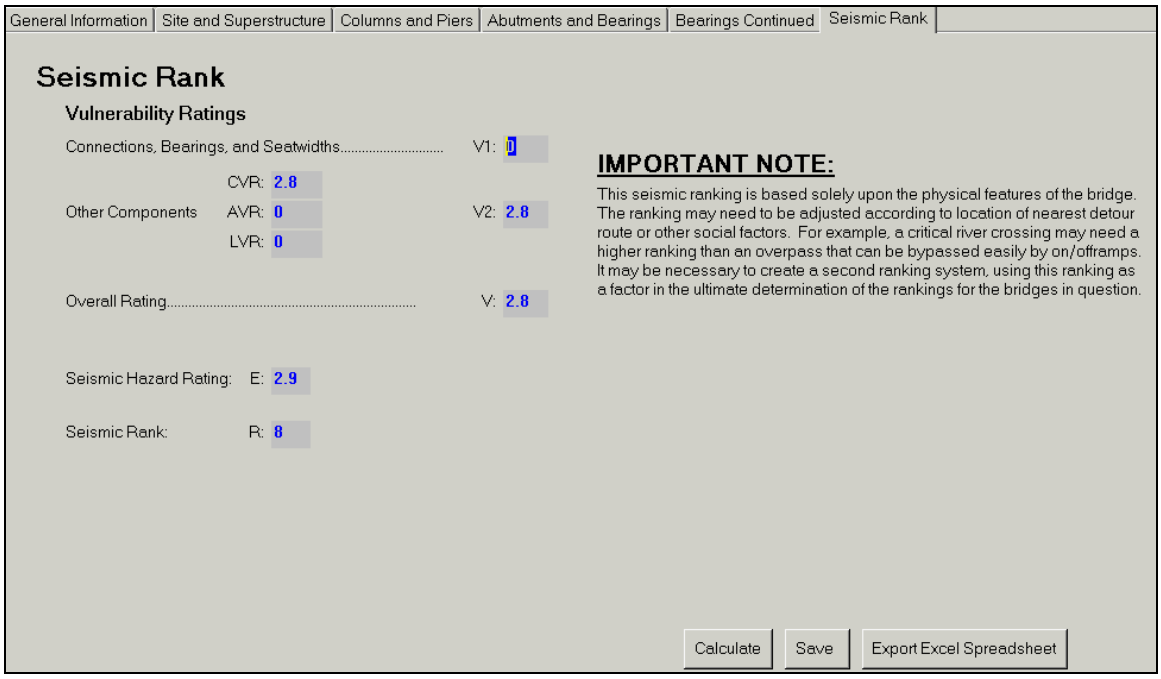

Fig. A.7 – Seismic Inventory of Bridges along I-24 in Western Kentucky.

APPENDIX B

INVENTORY OF BRIDGES ALONG I-24 IN WESTERN KENTCUKY

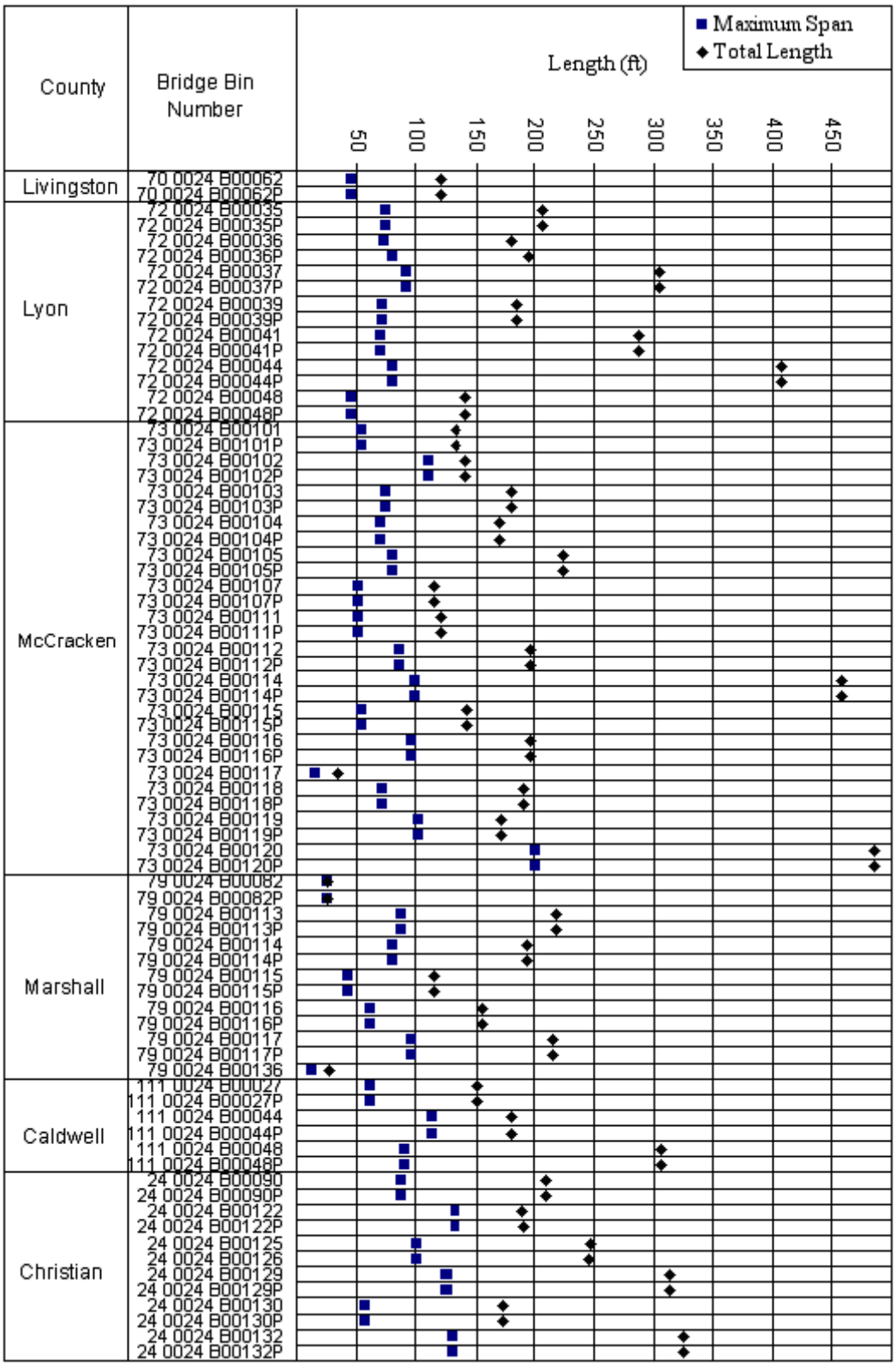

Fig. B.1 – Total Length and Maximum Span Length of Bridges on I-24 in Western Kentucky

County	Bridge Bin Number	Bearing Type							
				Sliding		Rocker			Elastomeric
Livingston	70 0024 B00061								
	70 0024 B00062P					◆			
	70 0024 B00062					◆			
Lyon	72 0024 B00035					◆			
	72 0024 B00035P					◆			
	72 0024 B00036					◆			
	72 0024 B00036P					◆			
	72 0024 B00037					◆			
	72 0024 B00037P					◆			
	72 0024 B00039								◆
	72 0024 B00039P								◆
	72 0024 B00041					◆			
	72 0024 B00041P					◆			
	72 0024 B00044			◆					
	72 0024 B00044P			◆					
	72 0024 B00048								◆
	72 0024 B00048P								◆
McCracken	73 0024 B00101			◆					
	73 0024 B00101P			◆					
	73 0024 B00102					◆			
	73 0024 B00102P					◆			
	73 0024 B00103			◆					
	73 0024 B00103P			◆					
	73 0024 B00104			◆					
	73 0024 B00104P			◆					
	73 0024 B00105					◆			
	73 0024 B00105P					◆			
	73 0024 B00107			◆					
	73 0024 B00107P			◆					
	73 0024 B00111								◆
	73 0024 B00111P								◆
	73 0024 B00112					◆			
	73 0024 B00112P					◆			
	73 0024 B00114					◆			
	73 0024 B00114P					◆			
	73 0024 B00115			◆					
	73 0024 B00115P			◆					
	73 0024 B00116			◆					
	73 0024 B00116P			◆					
	73 0024 B00117			◆					
	73 0024 B00118					◆			
	73 0024 B00118P					◆			
	73 0024 B00119					◆			
	73 0024 B00119P					◆			
	73 0024 B00120					◆			
	73 0024 B00120P					◆			
Marshall	79 0024 B00082								
	79 0024 B00082P								
	79 0024 B00113					◆			
	79 0024 B00113P					◆			
	79 0024 B00114								◆
	79 0024 B00114P								◆
	79 0024 B00115			◆					
	79 0024 B00115P			◆					
	79 0024 B00116					◆			
	79 0024 B00116P					◆			
	79 0024 B00117					◆			
	79 0024 B00117P					◆			
	79 0024 B00136								
Trigg	111 0024 B00027					◆			
	11 0024 B00027P					◆			
	111 0024 B00044					◆			
	11 0024 B00044P					◆			
	111 0024 B00048			◆					
	11 0024 B00048P			◆					
Christian	24 0024 B00090					◆			
	24 0024 B00090P					◆			
	24 0024 B00122					◆			
	24 0024 B00122P					◆			
	24 0024 B00125					◆			
	24 0024 B00126					◆			
	24 0024 B00129					◆			
	24 0024 B00129P					◆			
	24 0024 B00130			◆					
	24 0024 B00130P			◆					
	24 0024 B00132					◆			
	24 0024 B00132P					◆			

Fig. B.2 – Bearing Type of Bridges on I-24 in Western Kentucky.

County	Bridge Bin Number	Bridge Type: Steel		Precast Concrete		Culvert	
Livingston	70 0024 B00061						◆
	70 0024 B00062	◆					
	70 0024 B00062P	◆					
Lyon	72 0024 B00035	◆					
	72 0024 B00035P	◆					
	72 0024 B00036	◆					
	72 0024 B00036P	◆					
	72 0024 B00037	◆					
	72 0024 B00037P	◆					
	72 0024 B00039			◆			
	72 0024 B00039P			◆			
	72 0024 B00041	◆					
	72 0024 B00041P	◆					
	72 0024 B00044	◆					
	72 0024 B00044P	◆					
	72 0024 B00048			◆			
	72 0024 B00048P			◆			
McCracker	73 0024 B00101	◆					
	73 0024 B00101P	◆					
	73 0024 B00102	◆					
	73 0024 B00102P	◆					
	73 0024 B00103	◆					
	73 0024 B00103P	◆					
	73 0024 B00104	◆					
	73 0024 B00104P	◆					
	73 0024 B00105	◆					
	73 0024 B00105P	◆					
	73 0024 B00107			◆			
	73 0024 B00107P			◆			
	73 0024 B00111			◆			
	73 0024 B00111P			◆			
	73 0024 B00112			◆			
	73 0024 B00112P			◆			
	73 0024 B00114	◆					
	73 0024 B00114P	◆					
	73 0024 B00115	◆					
	73 0024 B00115P	◆					
	73 0024 B00116	◆					
	73 0024 B00116P	◆					
	73 0024 B00117						◆
	73 0024 B00118	◆					
	73 0024 B00118P	◆					
	73 0024 B00119			◆			
	73 0024 B00119P			◆			
	73 0024 B00120	◆					
	73 0024 B00120P	◆					
Marshal	79 0024 B00082						◆
	79 0024 B00082P						◆
	79 0024 B00113	◆					
	79 0024 B00113P	◆					
	79 0024 B00114			◆			
	79 0024 B00114P			◆			
	79 0024 B00115	◆					
	79 0024 B00115P	◆					
	79 0024 B00116	◆					
	79 0024 B00116P	◆					
	79 0024 B00117	◆					
	79 0024 B00117P	◆					
	79 0024 B00136						◆
Trigg	111 0024 B00027	◆					
	111 0024 B00027P	◆					
	111 0024 B00044	◆					
	111 0024 B00044P	◆					
	111 0024 B00048	◆					
	111 0024 B00048P	◆					
Christian	24 0024 B00090	◆					
	24 0024 B00090P	◆					
	24 0024 B00122	◆					
	24 0024 B00122P	◆					
	24 0024 B00125	◆					
	24 0024 B00126	◆					
	24 0024 B00129	◆					
	24 0024 B00129P	◆					
	24 0024 B00130			◆			
	24 0024 B00130P			◆			
	24 0024 B00132	◆					
	24 0024 B00132P	◆					

Fig. B.3 – Bridge Type of Bridges on I-24 in Western Kentucky.

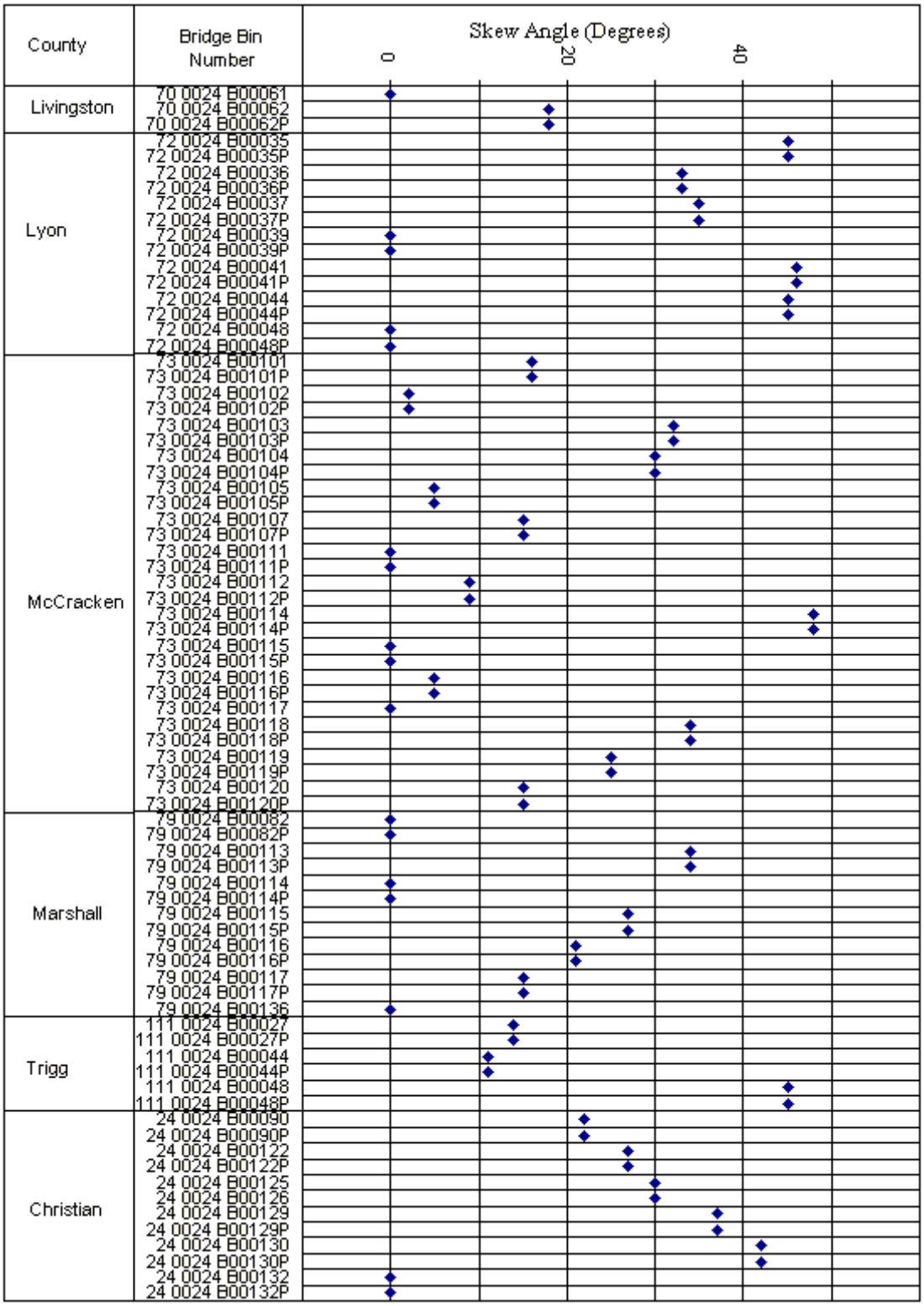

Fig. B.4 – Skew Angle of Bridges on I-24 in Western Kentucky.

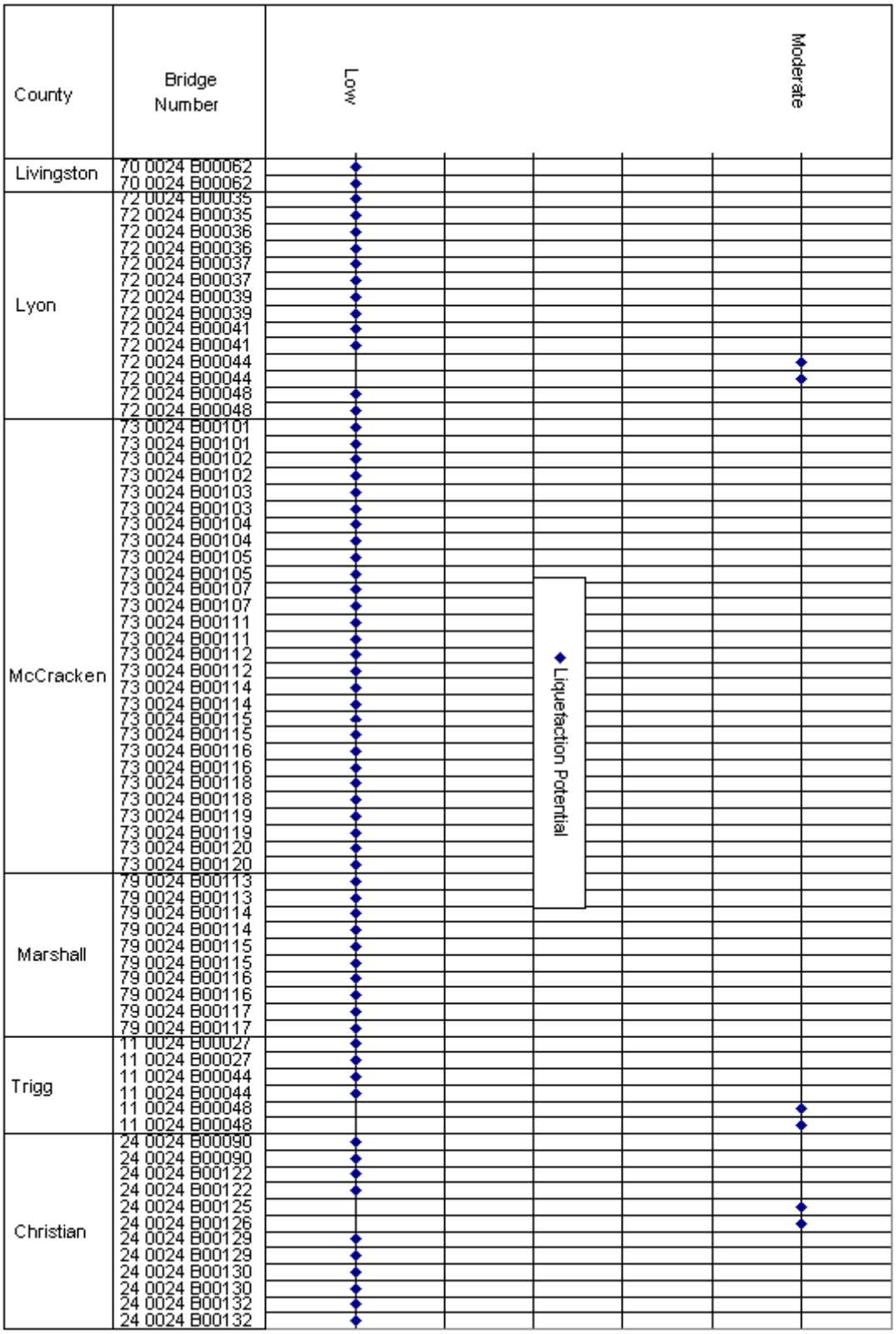

Fig. B.5 – Liquefaction Potential of Bridges on I-24 in Western Kentucky.

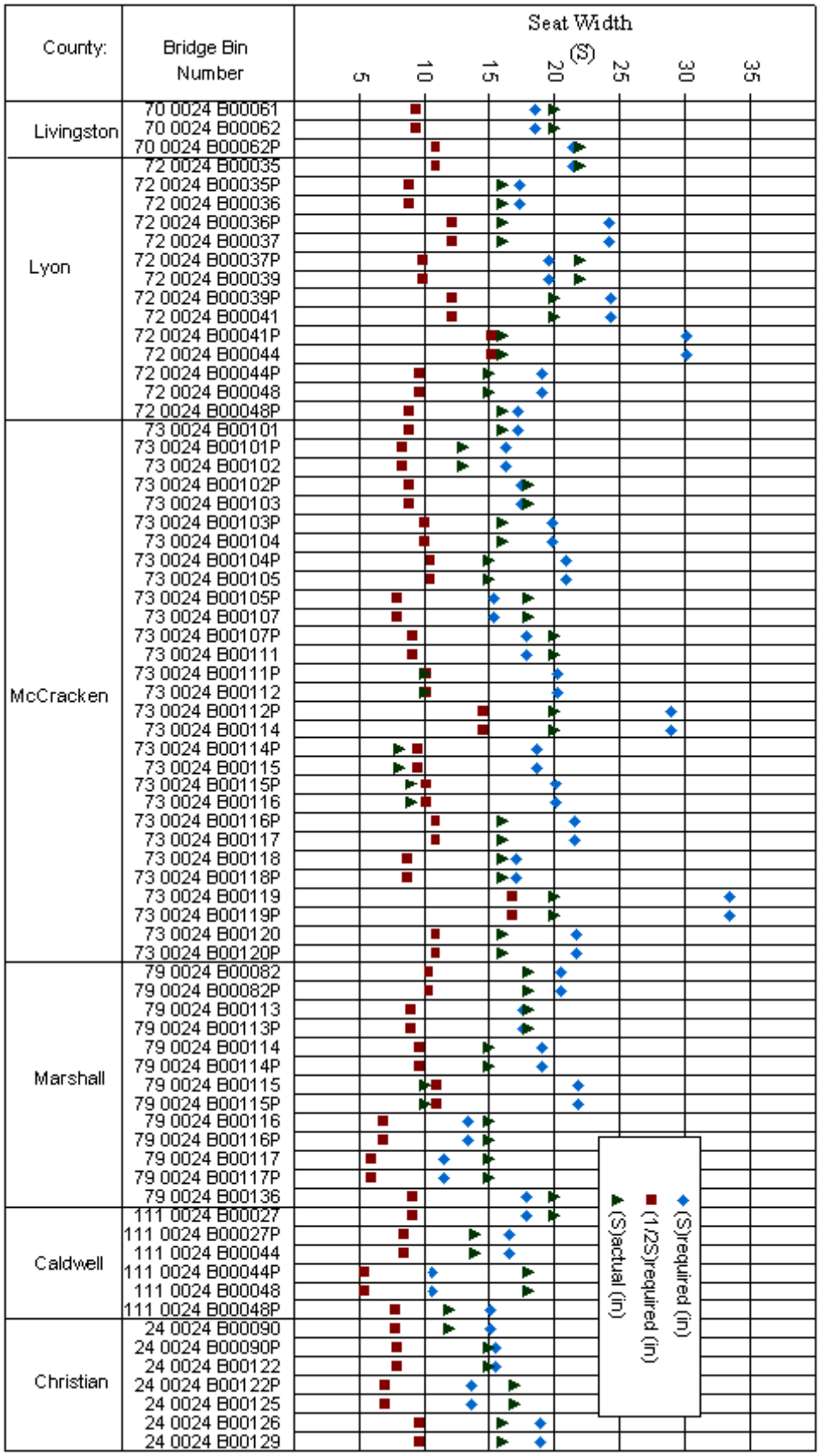

Fig. B.6 – Seat Width of Bridges on I-24 in Western Kentucky.

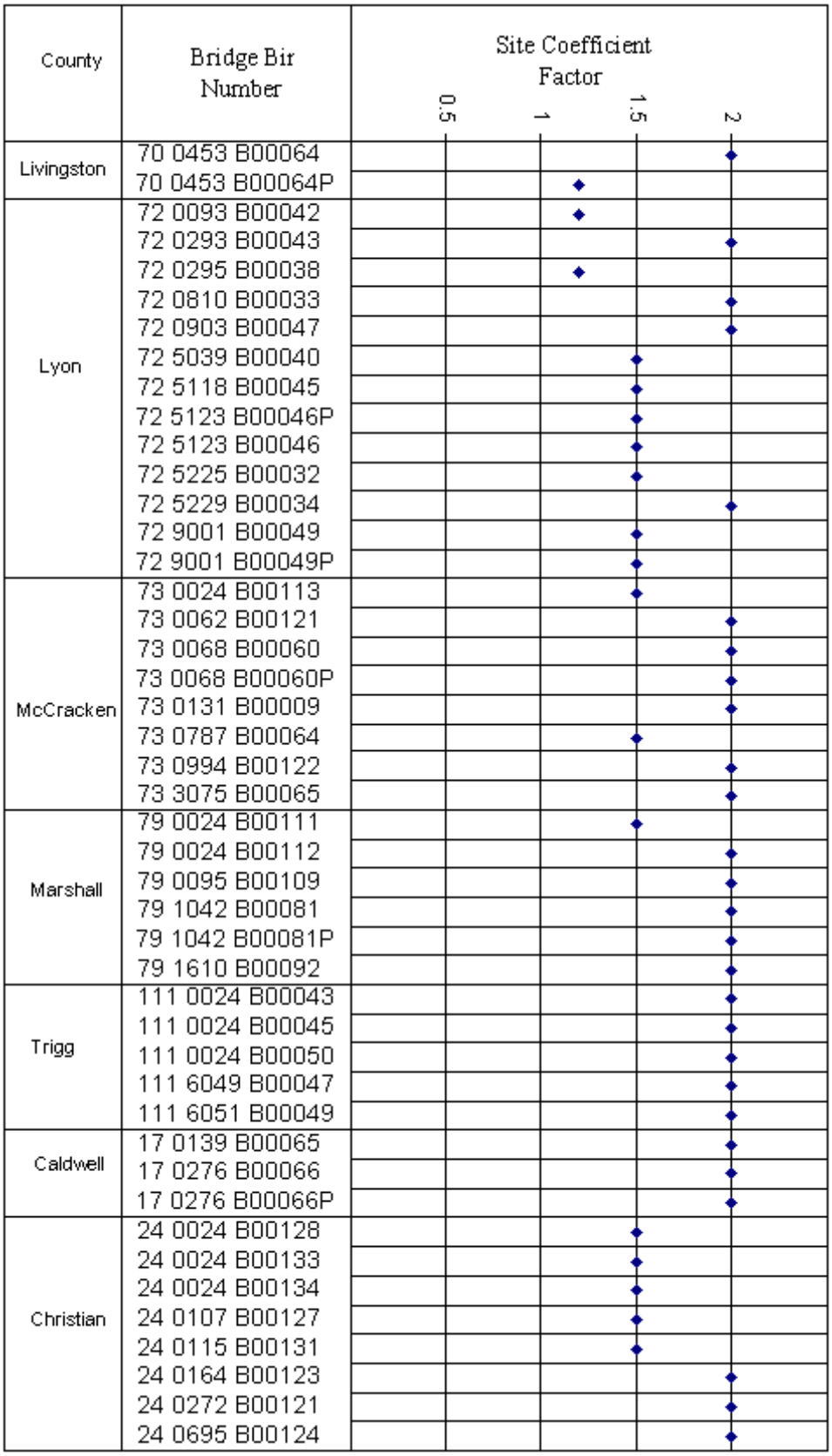

Fig. B.7 – Site Coefficient of Bridge Sites on I-24 in Western Kentucky.

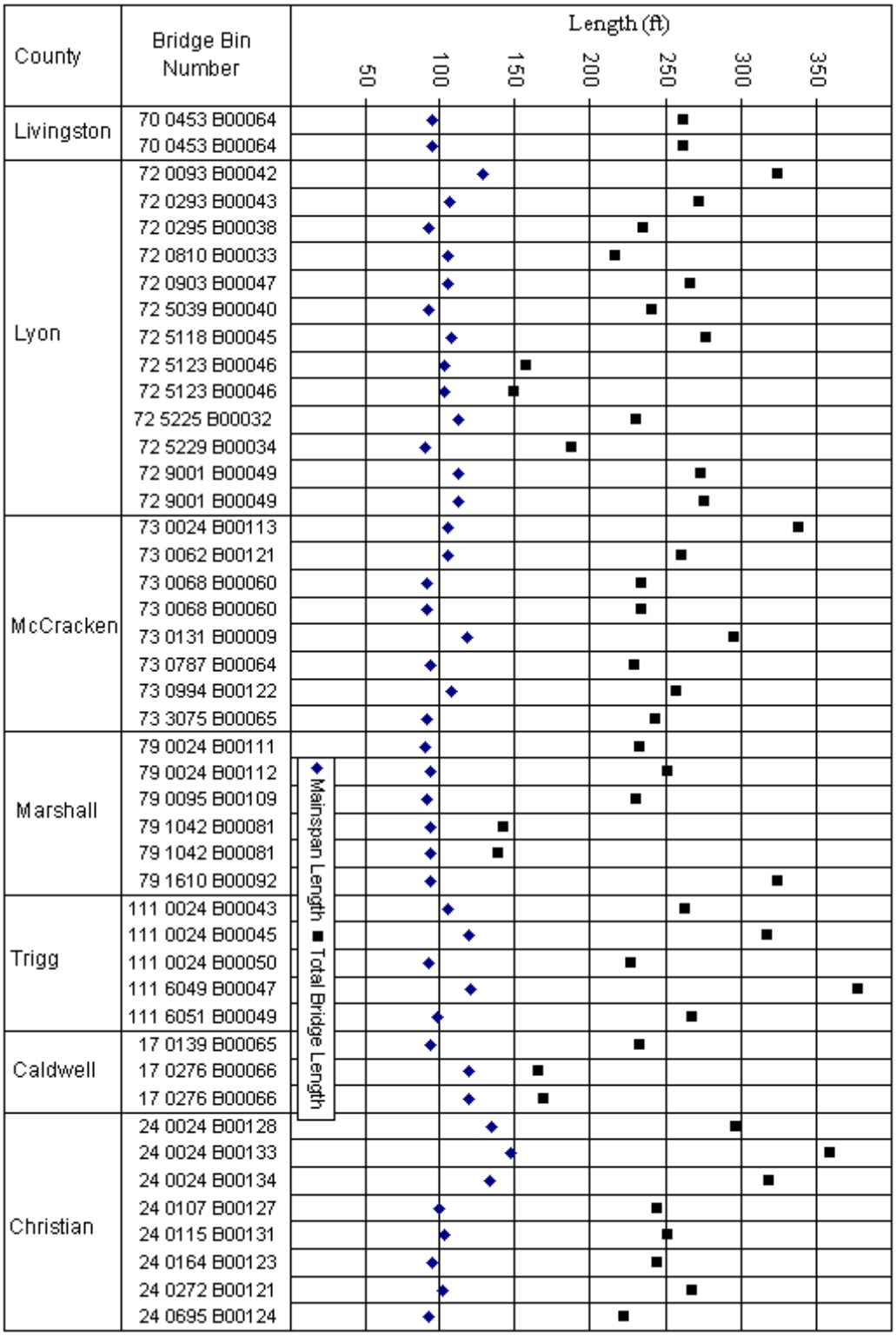

Fig. B.8 – Total Length and Maximum Span Length of Bridges over the I-24 in Western Kentucky.

County	Bridge Number	Bearing Type			Sliding	Rocker	Elastomeric
Livingston	70 0453 B00064					◆	
	70 0453 B00064P					◆	
Lyon	72 0093 B00042				◆		
	72 0293 B00043				◆		
	72 0295 B00038				◆		
	72 0810 B00033					◆	
	72 0903 B00047					◆	
	72 5039 B00040					◆	
	72 5118 B00045					◆	
	72 5123 B00046					◆	
	72 5123 B00046P					◆	
	72 5225 B00032					◆	
	72 5229 B00034					◆	
	72 9001 B00049				◆		
	72 9001 B00049P				◆		
McCracken	73 0024 B00113						◆
	73 0062 B00121					◆	
	73 0068 B00060				◆		
	73 0068 B00060P				◆		
	73 0131 B00009				◆		
	73 0787 B00064				◆		
	73 0994 B00122					◆	
	73 3075 B00065				◆		
Marshall	79 0024 B00111					◆	
	79 0024 B00112					◆	
	79 0095 B00109					◆	
	79 1042 B00081				◆		
	79 1042 B00081P				◆		
	79 1610 B00092				◆		
Trigg	111 0024 B00043					◆	
	111 0024 B00045					◆	
	111 0024 B00050				◆		
	111 6049 B00047					◆	
	111 6051 B00049				◆		
Caldwell	17 0139 B00065					◆	
	17 0276 B00066				◆		
	17 0276 B00066P				◆		
Christian	24 0024 B00128					◆	
	24 0024 B00133					◆	
	24 0024 B00134					◆	
	24 0107 B00127					◆	
	24 0115 B00131					◆	
	24 0164 B00123					◆	
	24 0272 B00121					◆	
	24 0695 B00124					◆	

Fig. B.9 – Bearing Type of Bridges over the I-24 in Western Kentucky.

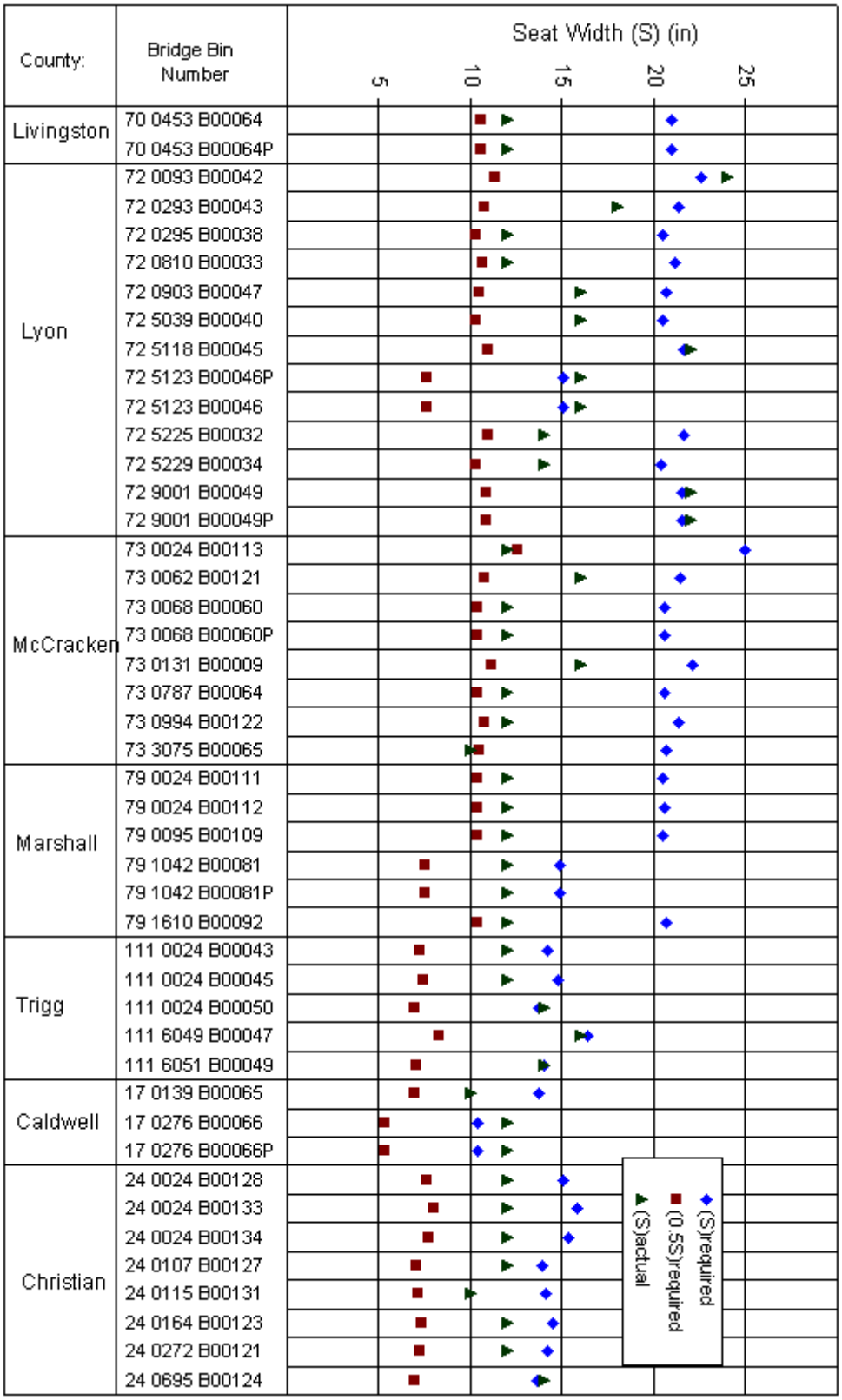

Fig. B.10 – Seat Width of Bridges over the I-24 in Western Kentucky.

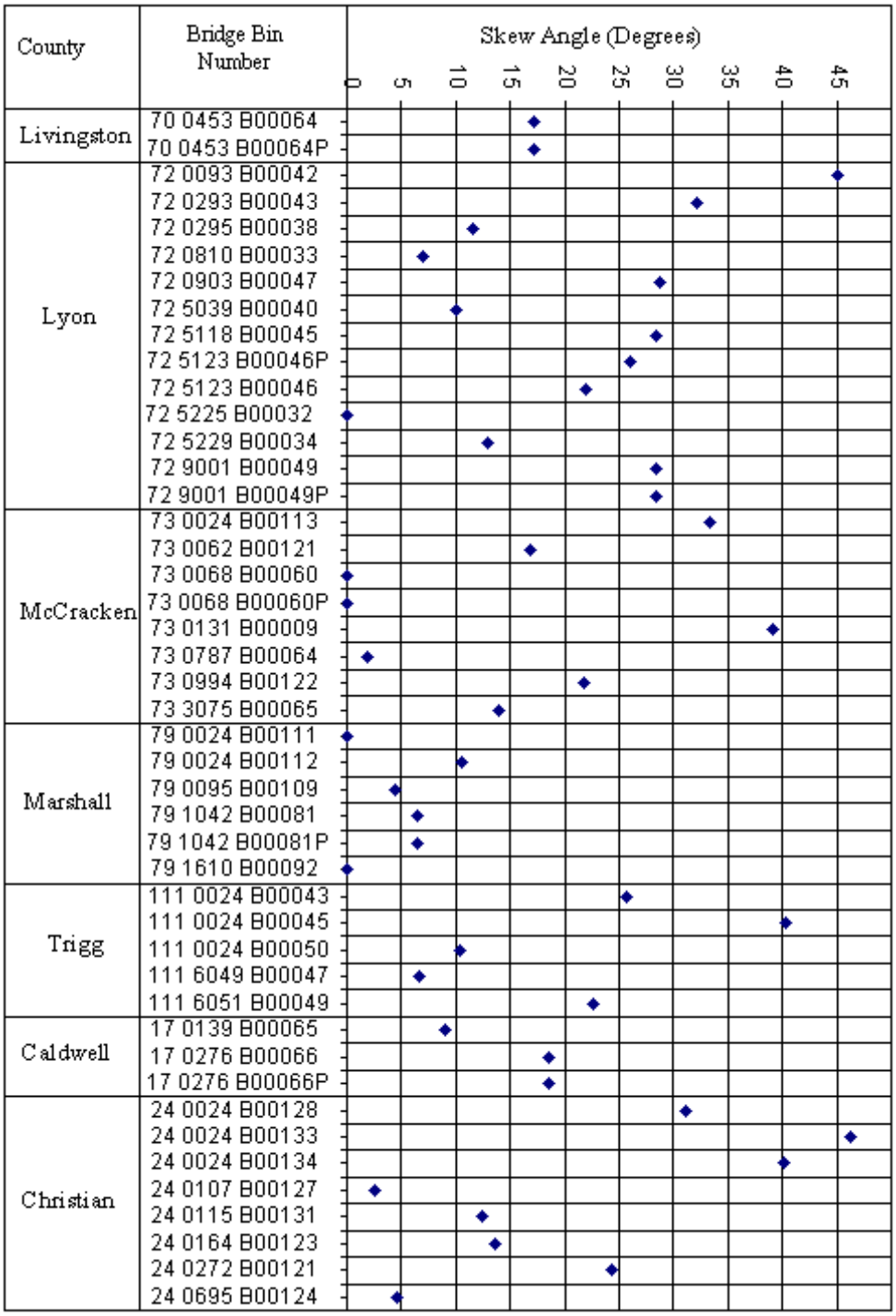

Fig. B.11 – Skew Angle of Bridges over the I-24 in Western Kentucky.

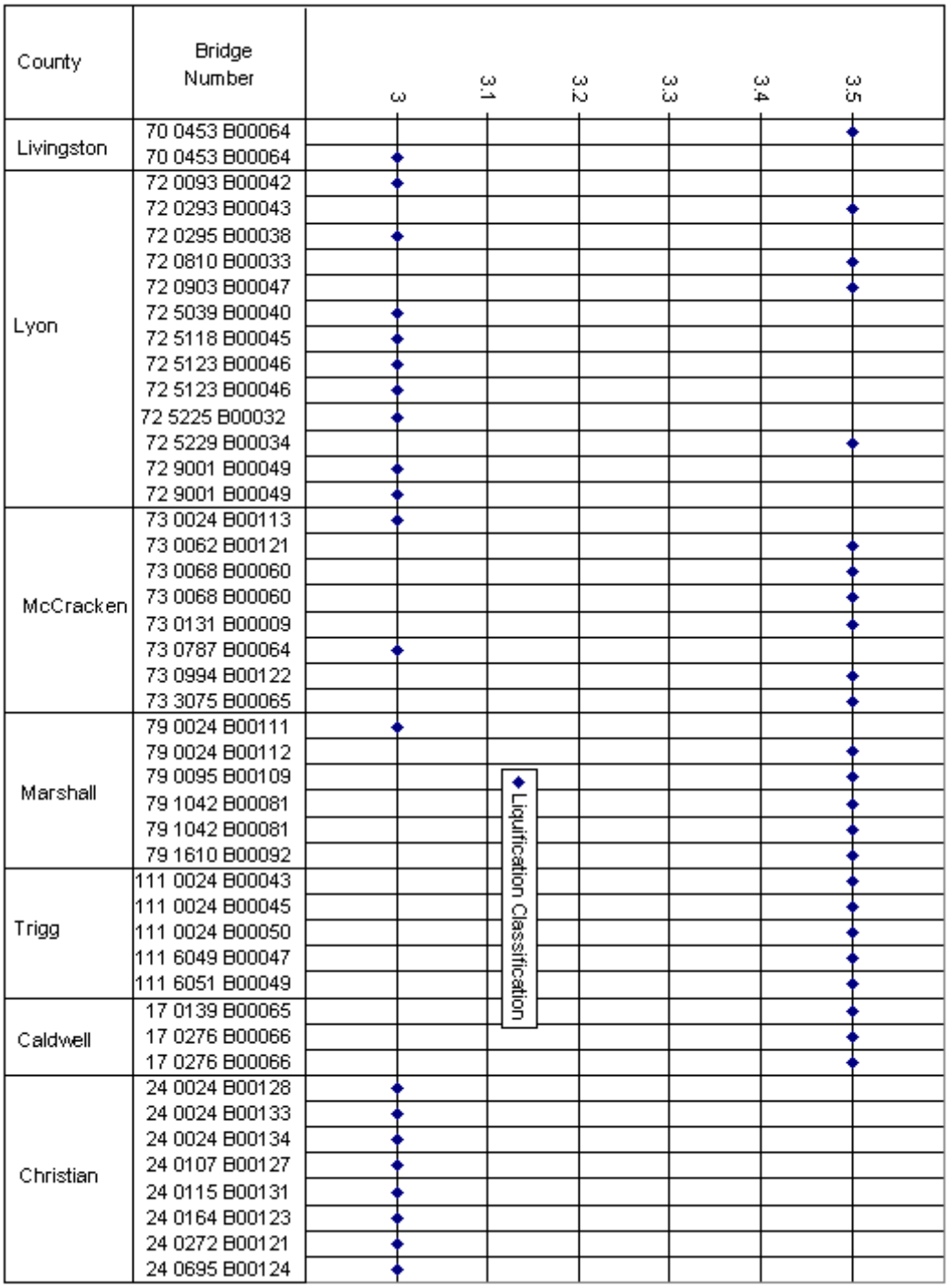

Fig. B.12 – Liquefaction Potential of Bridges over the I-24 in Western Kentucky.

County	Bridge Bin Number	Site Soil Coefficient				
		1.2	1.4	1.6	1.8	2
Livingston	70 0453 B00064					◆
	70 0453 B00064P	◆				
Lyon	72 0093 B00042	◆				
	72 0293 B00043					◆
	72 0295 B00038	◆				
	72 0810 B00033					◆
	72 0903 B00047					◆
	72 5039 B00040		◆			
	72 5118 B00045		◆			
	72 5123 B00046		◆			
	72 5123 B00046P		◆			
	72 5225 B00032		◆			
	72 5229 B00034					◆
	72 9001 B00049		◆			
	72 9001 B00049P		◆			
McCracken	73 0024 B00113		◆			
	73 0062 B00121					◆
	73 0068 B00060					◆
	73 0068 B00060P					◆
	73 0131 B00009					◆
	73 0787 B00064		◆			
	73 0994 B00122					◆
	73 3075 B00065					◆
Marshall	79 0024 B00111		◆			
	79 0024 B00112					◆
	79 0095 B00109					◆
	79 1042 B00081					◆
	79 1042 B00081P					◆
	79 1610 B00092					◆
Trigg	111 0024 B00043					◆
	111 0024 B00045					◆
	111 0024 B00050					◆
	111 6049 B00047					◆
	111 6051 B00049					◆
Caldwel	17 0139 B00065					◆
	17 0276 B00066					◆
	17 0276 B00066P					◆
Christian	24 0024 B00128		◆			
	24 0024 B00133		◆			
	24 0024 B00134		◆			
	24 0107 B00127		◆			
	24 0115 B00131		◆			
	24 0164 B00123					◆
	24 0272 B00121					◆
	24 0695 B00124					◆

Fig. B.13 – Site Coefficient of Bridges over the I-24 in Western Kentucky.

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