PB91-125427

NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH

State University of New York at Buffalo

EVALUATION OF LIQUEFACTION POTENTIAL IN MEMPHIS AND SHELBY COUNTY

by

T. S. Chang, P. S. Tang, C. S. Lee and H. Hwang

Center for Earthquake Research and Information
Memphis State University
Memphis, Tennessee 38152

Technical Report NCEER-90-0018

August 10, 1990

This research was conducted at Memphis State University and was partially supported by the National Science Foundation under Grant No. ECE 86-07591.

EVALUATION OF LIQUEFACTION POTENTIAL IN MEMPHIS AND SHELBY COUNTY

by

T.S. Chang[1], P.S. Tang[2], C.S. Lee[3] and H. Hwang[4]

August 10, 1990

Technical Report NCEER-90-0018

NCEER Project Numbers 88-3016 and 89-3009

NSF Master Contract Number ECE 86-07591

1 Assistant Research Professor, Center for Earthquake Research and Information, Memphis State University
2 Graduate Research Assistant, Center for Earthquake Research and Information, Memphis State University
3 Research Associate, Center for Earthquake Research and Information, Memphis State University
4 Associate Research Professor, Center for Earthquake Research and Information, Memphis State University

NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH
State University of New York at Buffalo
Red Jacket Quadrangle, Buffalo, NY 14261

PREFACE

The National Center for Earthquake Engineering Research (NCEER) is devoted to the expansion and dissemination of knowledge about earthquakes, the improvement of earthquake-resistant design, and the implementation of seismic hazard mitigation procedures to minimize loss of lives and property. The emphasis is on structures and lifelines that are found in zones of moderate to high seismicity throughout the United States.

NCEER's research is being carried out in an integrated and coordinated manner following a structured program. The current research program comprises four main areas:

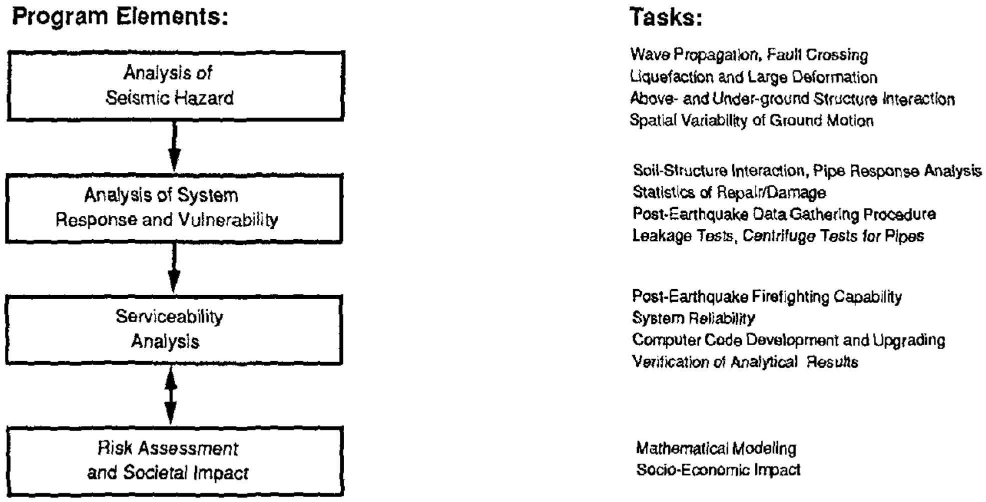
- Existing and New Structures
- Secondary and Protective Systems
- Lifeline Systems
- Disaster Research and Planning

This technical report pertains to Program 3, Lifeline Systems, and more specifically to water delivery systems.

The safe and serviceable operation of lifeline systems such as gas, electricity, oil, water, communication and transportation networks, immediately after a severe earthquake, is of crucial importance to the welfare of the general public, and to the mitigation of seismic hazards upon society at large. The long-term goals of the lifeline study are to evaluate the seismic performance of lifeline systems in general, and to recommend measures for mitigating the societal risk arising from their failures.

From this point of view, Center researchers are concentrating on the study of specific existing lifeline systems, such as water delivery and crude oil transmission systems. The water delivery system study consists of two parts. The first studies the seismic performance of water delivery systems on the west coast, while the second addresses itself to the seismic performance of the water delivery system in Memphis, Tennessee. For both systems, post-earthquake fire fighting capabilities will be considered as a measure of seismic performance.

The components of the water delivery system study are shown in the accompanying figure.



This report summarizes the methodology and results of an evaluation procedure for soil liquefaction potential in Memphis and Shelby County, Tennessee. Twenty-two representative sites were selected where appropriate geotechnical data had been collected, and a parametric study was performed by computer simulation of 53 earthquake acceleration-time records covering peak bedrock accelerations of 0.08 to 0.35 g. The dominant frequencies and durations of shaking were chosen to be consistent with earthquakes of 6.5 and 7.5 M_w in the New Madrid seismic zone. Stress and pore pressure response at the representative sites were analyzed with the computer programs MASH and APOLLO. Liquefaction susceptibility at each site was determined by means of liquefaction index criteria which account for soil type, drainage conditions, Standard Penetration Test values, and peak bedrock accelerations. Liquefaction potential maps for Memphis and Shelby County are developed for 6.5 and 7.5 M_w earthquakes in the New Madrid seismic zone on the basis of the liquefaction index. The potential for structural damage because of soil liquefaction is discussed.

ABSTRACT

This report presents the evaluation of liquefaction potential in Memphis and Shelby County. The study is based on the actual subsurface conditions by using available geotechnical and geological information collected and compiled by the Center for Earthquake Research and Information (CERI). From the various subsurface conditions of the target liquefiable soil layers (sand, silt, etc.), 22 representative sites are selected for parametric study. These sites are then subjected to 53 earthquake acceleration time histories with peak bedrock accelerations ranging from 0.08g to 0.35g resulting from large New Madrid earthquakes. The stress and pore pressure analyses of the selected sites are carried out using the MASH and APOLLO computer programs. The results from the analysis are used to establish liquefaction index criteria, which express the liquefaction susceptibility of a soil layer as a function of soil types, drainage conditions, N values, and peak bedrock accelerations. The liquefaction index criteria are then used to establish the liquefaction potential maps for Memphis and Shelby County resulting from moment magnitude 7.5 and 6.5 earthquakes in the NMSZ. These maps indicate areas of most likely, moderate, and unlikely liquefaction potential in Memphis and Shelby County.

The potential of structural damage due to liquefaction in the study area is also addressed. In addition, a map showing areas with high risk of landslide or lateral earth movement is also included. The liquefaction potential maps developed in this study are useful for seismic hazard assessment, land use planning, and earthquake preparedness and emergency response planning for Memphis and Shelby County.

ACKNOWLEDGMENT

The authors express their appreciation to the National Center for Earthquake Engineering Research (NCEER), SUNY, Buffalo, and the National Science Foundation (NSF) for the financial support that initiated the earthquake engineering study in the Memphis and Shelby County area (NCEER contract number 88-3016 and 89-3009 under NSF master contract number ECE 86-07591).

Special thanks are also given to all the organizations in both the public and private sector in the Memphis area for their generosity in providing invaluable geotechnical data for this study. The authors would also like to express their gratitude to Mr. Yongqian Lin for compiling data and preparing maps used in this study. The assistance of Ms. Tanya George in preparing figures and Ms. Valinda Stokes in typing this manuscript is also much appreciated.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION 1
INTRODUCTION

The New Madrid seismic zone (NMSZ) is regarded by seismologists and earthquake engineers as the most hazardous seismic zone in the eastern United States. Within this seismic zone, three large earthquakes (of estimated Magnitude M_S = 8.0+) and numerous aftershocks occurred in the winter of 1811-1812. Memphis and Shelby County, located less than 100 miles southward to the southern segment of the NMSZ, are the most important and densely populated areas exposed to significant seismic hazards (figure 1-1). The liquefaction potential study focuses on Memphis and Shelby County which is situated in the transition zone between the Gulf Coastal Upland and the Mississippi Alluvial Plain in the northern Mississippi embayment [1] as shown in figure 1-1.

Knowledge accumulated from past post earthquake studies by engineers and seismologists has demonstrated that the transient-type loss of foundation's bearing capacity due to liquefaction of the supporting granular soils near the ground surface is one of the major causes attributed to the failure of many structures during an earthquake [2-6]. Regional liquefaction evaluation is thus the key element in seismic hazard assessments for areas where earthquakes pose a threat to the safety of lives and property.

Liquefaction potential evaluation criteria involving in situ density of soils in terms of Standard Penetration Test Blow Count (SPT N-value) and the estimated shear stress in soils induced by earthquake shaking were established by Seed et al. based on the post earthquake field investigations of both liquefied and nonliquefied sites [2,3,7,8]. These criteria are widely used in practice to evaluate the liquefaction potential of sites with granular soil layers. This method may be simple, direct, and adequate to some extent. However, the criteria established according to the local subsurface conditions and

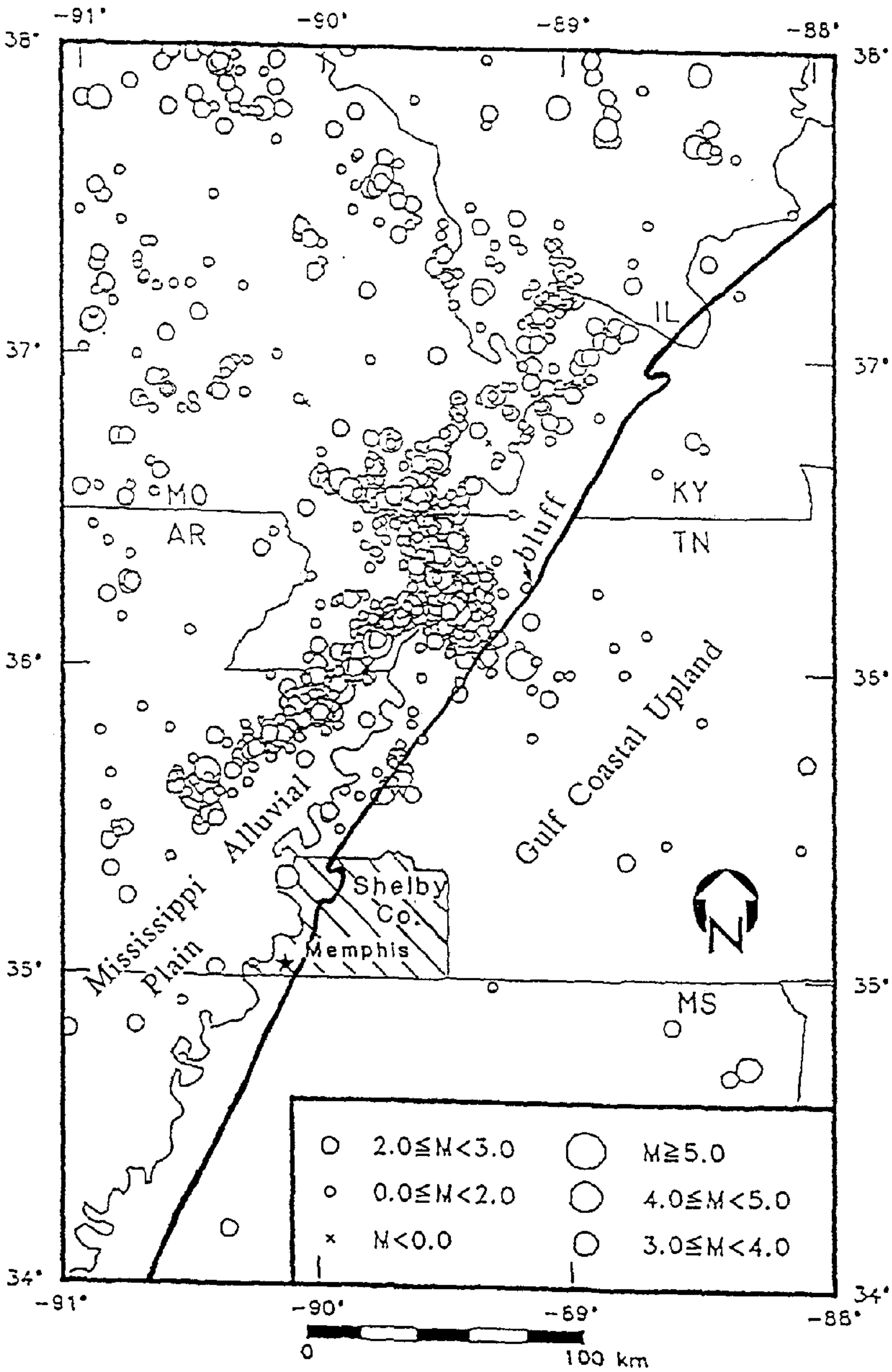


FIGURE 1-1 Seismicity in the New Madrid Seismic Zone: 1974-1990

seismicity are more desirable and reliable for liquefaction evaluation of a specific region. Thus, the latter approach is used in this study to evaluate the liquefaction potential in Memphis and Shelby County.

Local subsurface conditions and seismicity of the study area as reported in previous studies at the Center for Earthquake Research and Information (CERI), Memphis State University, are used in this study [1,9]. The liquefaction potential study in the Memphis and Shelby County area is divided into three main stages:

1. a parametric liquefaction potential study based on the selected representative sites,

2. development of general index criteria for overall liquefaction potential evaluation, and

3. application of the established general criteria to develop liquefaction potential maps of the study area.

SECTION 2

PARAMETRIC LIQUEFACTION POTENTIAL STUDY

Liquefaction phenomenon of soil deposits can be described as the reduction of shear strength due to pore pressure buildup in the soil skeleton. The shear strength of soils τ can be expressed as

$$\tau = c + \sigma' \tan \phi \tag{2.1}$$

and

$$\sigma' = \sigma - u \tag{2.2}$$

where τ = shear strength
c = cohesion
σ' = effective stress
σ = total stress
u = pore pressure
ϕ = angle of internal friction

For granular soils, the cohesion c is nominal and thus the shear strength of granular soils depends mainly on the angle of internal friction ϕ and the effective stress σ' acting on the soil skeleton. Liquefaction phenomenon for granular soils can be defined as the condition where the shear strength is reduced to zero. This occurs when the pore pressure buildup u under cyclic loadings equals the total stress σ, thereby reducing the effective stress σ' to zero. Under such a condition, the granular soils virtually lose all shear strength, resulting in quick-condition type failure. Seed and Idriss [2,10] first investigated and demonstrated pore pressure buildup in sand subjected to cyclic loadings. After a number of applied stress cycles, the pore pressure increases progressively until eventually soil failure occurs. This phenomenon can be described by the pore pressure ratio r_u which is the ratio of the pore pressure u built up over the effective overburden pressure σ_0' exerted onto the soils. Mathematically, the pore pressure ratio r_u is expressed as:

$$r_u = \frac{u}{\sigma_0'} \qquad (2.3)$$

When the pore pressure ratio is equal to 1, the soil is said to liquefy. In this study liquefaction potential is evaluated based on the above discussed pore pressure ratio r_u. The parametric liquefaction study using the selected representative soil profiles consists of two main parts:

1. Site response analysis using MASH program [11] to study the shear stress induced in the target soil layers at the selected representative sites as the earthquake waves propagate upward through the soil profile from the underlying bedrock to the ground surface.

2. Pore pressure analysis of soil layers using APOLLO program [12] to study the pore pressure buildup as shear stress is induced by earthquake excitations.

The parameters, which strongly affect the liquefaction potential of soils as listed below, are examined in this study on the basis of actual subsurface conditions in the study area:

1. Soil characteristics: soil types (SP, SM, GP, SC ,GC, CL, ML) and in situ density (N-value and relative density).

2. Site conditions: depth, thickness, and pore water drainage condition of liquefiable layers.

3. Earthquake characteristics: peak bedrock acceleration, dominant frequency, and duration of the scenario earthquake.

Granular soils susceptible to liquefaction are analyzed in this study according to their engineering properties. In practice, the in situ density N-values of soils is the best indicator of the strength and liquefaction resistance. The soils may be subjected to three boundary (drainage) conditions with regard to pore water dissipation:

1. one-way drainage: pore water is only allowed to dissipate from either the top or bottom of the soil layer.

2. two-way drainage: pore water is allowed to dissipate both from the top and bottom of the soil layer.

3. undrained: pore water dissipates at a very slow rate.

The boundary conditions of a soil layer is strongly governed by the permeability k of its adjacent soil layers. A boundary soil with a low permeability (like clayey silt with $k < 7.0 \times 10^{-6}$ cm/sec) prevents or retards the dissipation of pore water from the soil. On the other hand, a boundary soil with a high permeability (like gravel with $k > 2.0$ cm/sec) allows pore water to dissipate easily. For example, a granular soil with a layer of gravel on top and silty clay on the bottom is said to drain in one-way, i.e., pore water dissipates only from the top layer (gravel with high permeability).

The acceleration, duration, and frequency contents of earthquakes are the dominant factors affecting the induced shear stress and number of stress cycles of the soil profile. The peak magnitude and number of cycles of the induced shear stress strongly control the pore pressure buildup in the soil layer.

2.1 Representative Soil Profile

Figure 2-1 shows 22 representative sites selected for the parametric study. The subsurface conditions of the 22 sites are taken from Ng et al. [1]. These sites are selected to cover possible site conditions with regard to depth, in situ density, soil type, and drainage condition of

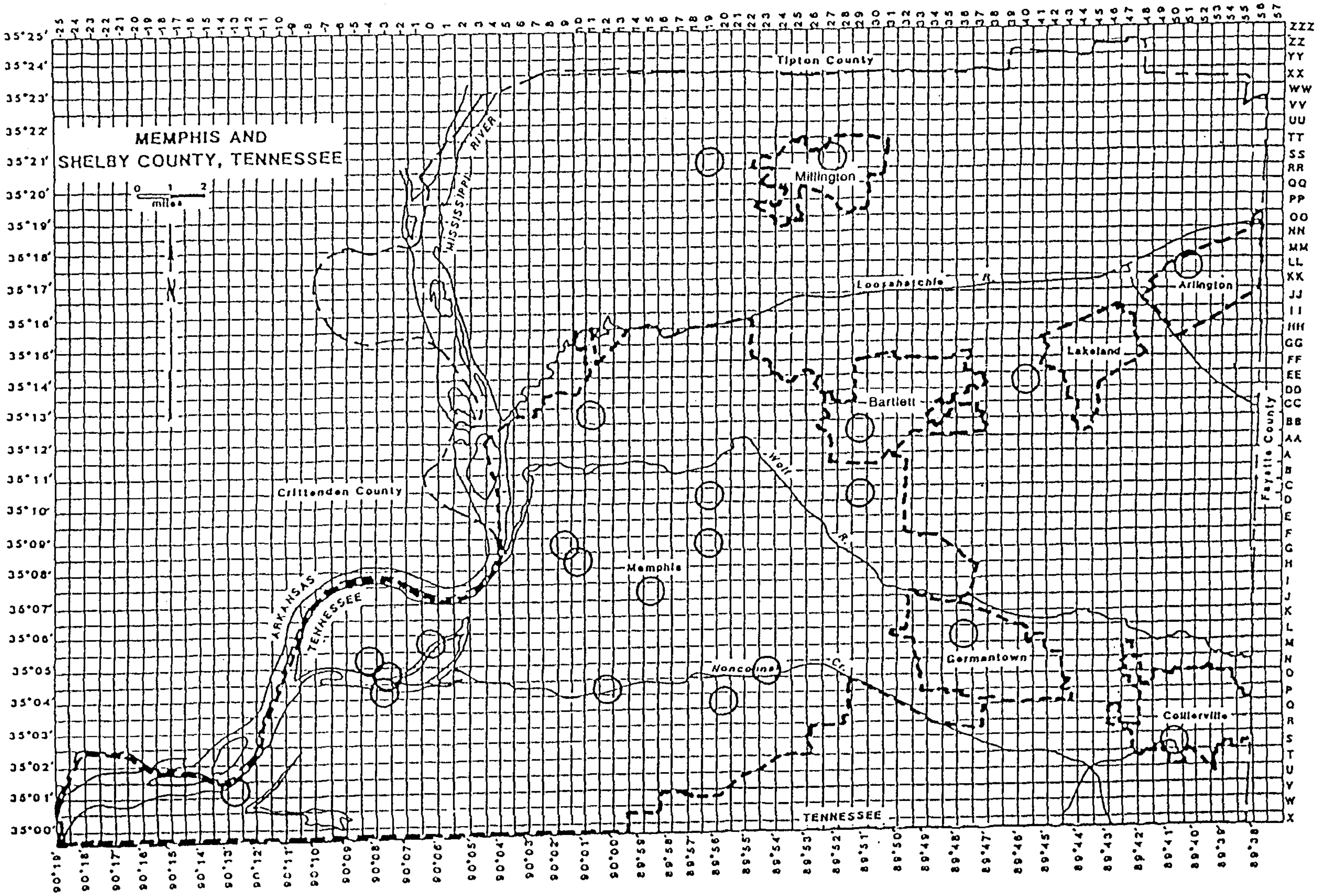


FIGURE 2-1 Selected Sites for Liquefaction Potential Study

liquefaction-susceptible soil layers in the study area. The summary of soil conditions of the profiles used is presented in table 2-I.

2.2 Engineering Properties of Soils

The soils encountered in the study area include clay (CL), clayey silt or silty clay (ML/CL), sand (SP), clayey sand (SC), silty sand (SM), gravel (GP), and silt to sandy silt (ML). The static properties of soils used in the study are discussed in detail in previous reports by Hwang et al. [13,14].

The fundamental static properties of soils required for the study include unit weight, coefficient of lateral earth pressure, relative density, shear strength, etc. The most important dynamic properties for seismic study include: (1) low-strain shear modulus, (2) high-strain non-linear dynamic behavior, and (3) damping of soils. These dynamic properties are determined based on Seed et al. as recommended in the MASH program [11] and the results of dynamic tests on several typical soils in the study area by Chang [15].

2.3 Liquefaction Characteristics of Soils

The parameters that affect the liquefaction characteristics of soils include permeability, in situ density, volume compressibility, and degree of saturation. All granular soil layers are assumed to be saturated since liquefaction only takes place in saturated soils. In fact, based on the boring logs collected, the water tables in the study area are generally in or above the granular soils. Coefficients of permeability of various soils suggested by Creager et al. [16] are used in this study. They range from 0.3×10^{-6} cm/sec for clay to 1.8 cm/sec for fine sand. The coefficient of volume compressibility m_v is found to be greatly influenced by both relative density and grain size [17-19]. The coefficients of volume compressibility corresponding to relative density of soils suggested by Lee and Albeisa [17] are used in this study.

TABLE 2-I Summary of 22 Selected Sites for Stress Analysis and Liquefaction Potential Study

NO. OF SITE	:22
NO. OF TARGET SOIL	:53
SOIL TYPE	**NO.**
Sand	:34
Silty Sand	:17
Clayey Sand	:16
Sand and Gravel	:7
Silt	:3
Sandy Silt	:0
AT DEPTH (FT)	
0-20	:13
20-50	:29
50-100+	:11
THICKNESS (FT)	
0-5	:2
5-20	:31
20-40	:13
>40	:7
DENSITY (N VALUES)	
<4	:2
4-10	:2
10-30	:24
>30	:41
TOP CONDITIONS	
Free	:5
Cohesive Soil	:36
Sand or Silty Sand	:25
Silt or Sandy Silt	:2
Gravel	:0
BOTTOM CONDITIONS	
Cohesive Soils	:14
Sand or Silty Sand	:39
Silty Sand or Sand	:5
Clayey Sand	:0
Gravel	:10

LIST OF SELECTED SITES:

1) LL51
2) SS19
3) CC11
4) SS27
5) P20
6) S50
7) C19
8) O(-4)
9) F9
10) U(-13)
11) O12
12) BB30
13) EE40
14) L36
15) L0
16) F19
17) C29
18) M(-4)
19) N(-3)
20) I15
21) N23
22) G10

The liquefaction resistance is defined as the number of stress cycles required to cause liquefaction of granular soils. The liquefaction resistance can be determined in the laboratory by performing undrained cyclic torsional test, shaking table test, or by other techniques under simulated field conditions [2,3,19,20]. The liquefaction resistance of various soils in this study are determined based on the literature by Seed et al. [2,3], and Ueng and Chang [21], as shown in figures 2-2 to 2-4. The key parameters controlling the liquefaction resistance of granular soils are relative density D_r and percentage of fine (i.e., silt or clay) in the soils [2,3,4,18,19,21].

2.4 Scenario Earthquake Time History

Based on the results of probabilistic study by Johnston [22], two major earthquakes of moment magnitude M=7.5 and M=6.5 are selected as the scenario earthquakes of this study and are assumed to occur in the southern segment of the NMSZ. The bedrock acceleration in the study area due to these two earthquakes is discussed in Section 4.

In the engineering applications, earthquakes are usually represented by power spectral density functions (power spectra), acceleration time history or response spectra. Because of the lack of real strong ground motion records in central and eastern North America, a synthetic earthquake of M = 7.5 with an epicenter distance R = 50 km is generated using a seismologically-based model to describe horizontal bedrock motions at a site primarily subjected to shear waves propagated from a seismic zone [9,13]. The earthquake time history developed by this model has taken into account the source mechanism, media propagation velocity, and path attenuation. The synthetic earthquake time histories used in this study have a dominant frequency of 25 Hz and a duration of about 32 seconds. In this study, the earthquake time history can be scaled to any desired levels of peak acceleration.

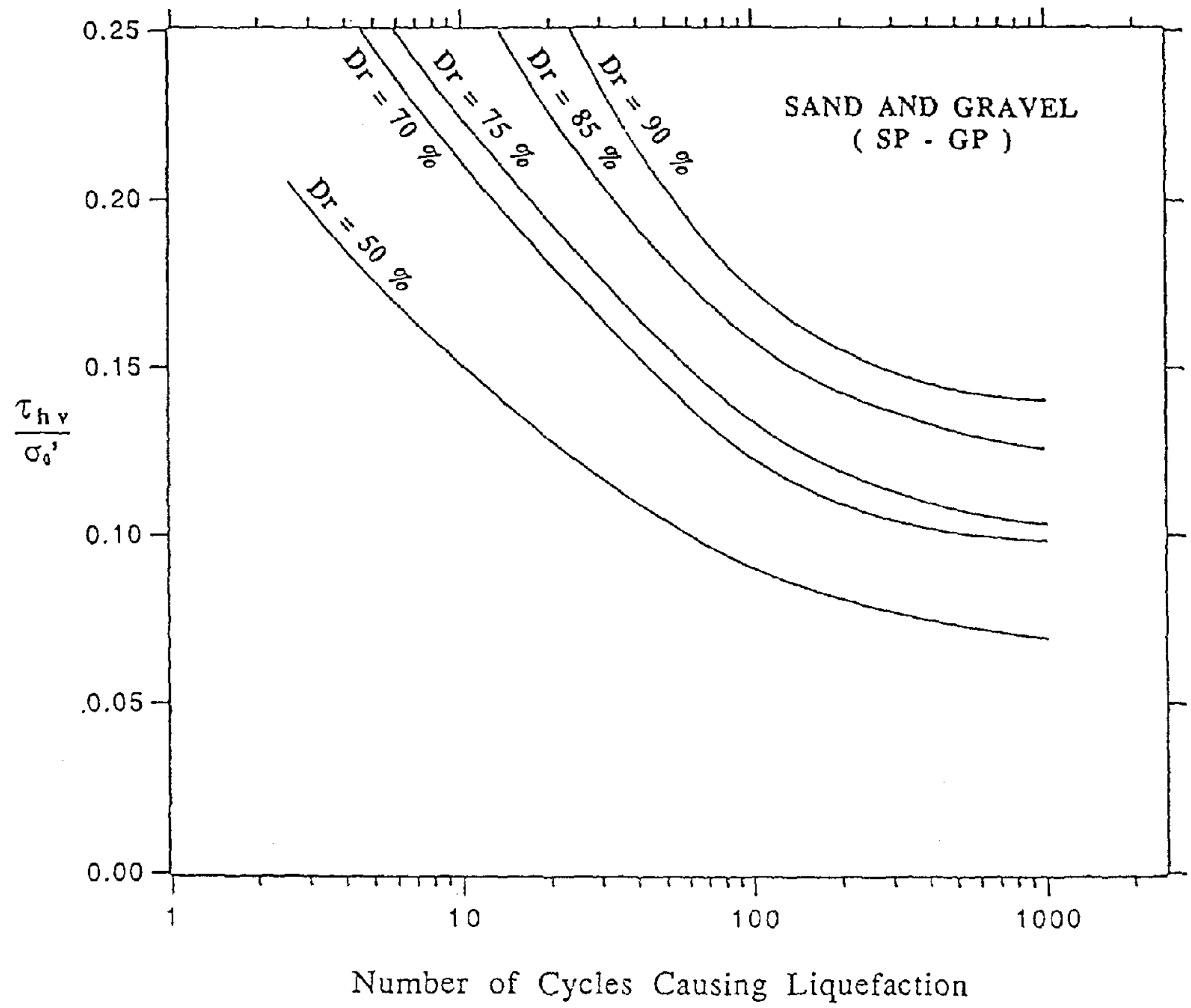


FIGURE 2-2 Cyclic Loading Test Data for Sand and Gravel
(after Seed et al., 1978, Ueng and Chang, 1982)

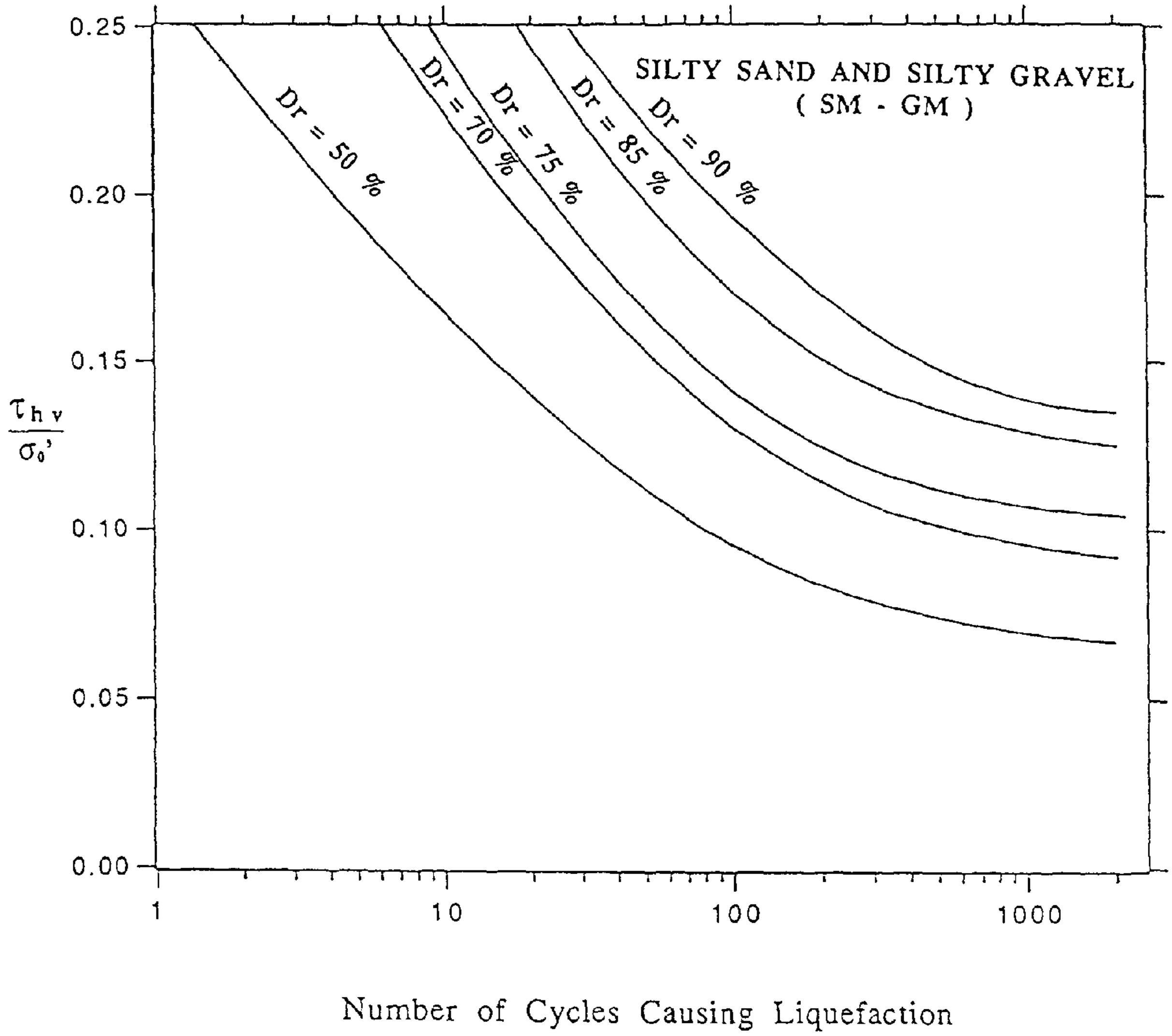


FIGURE 2-3 Cyclic Loading Test Data for Silty Sand and Silty Gravel (after Seed et al., 1978, Ueng and Chang, 1982)

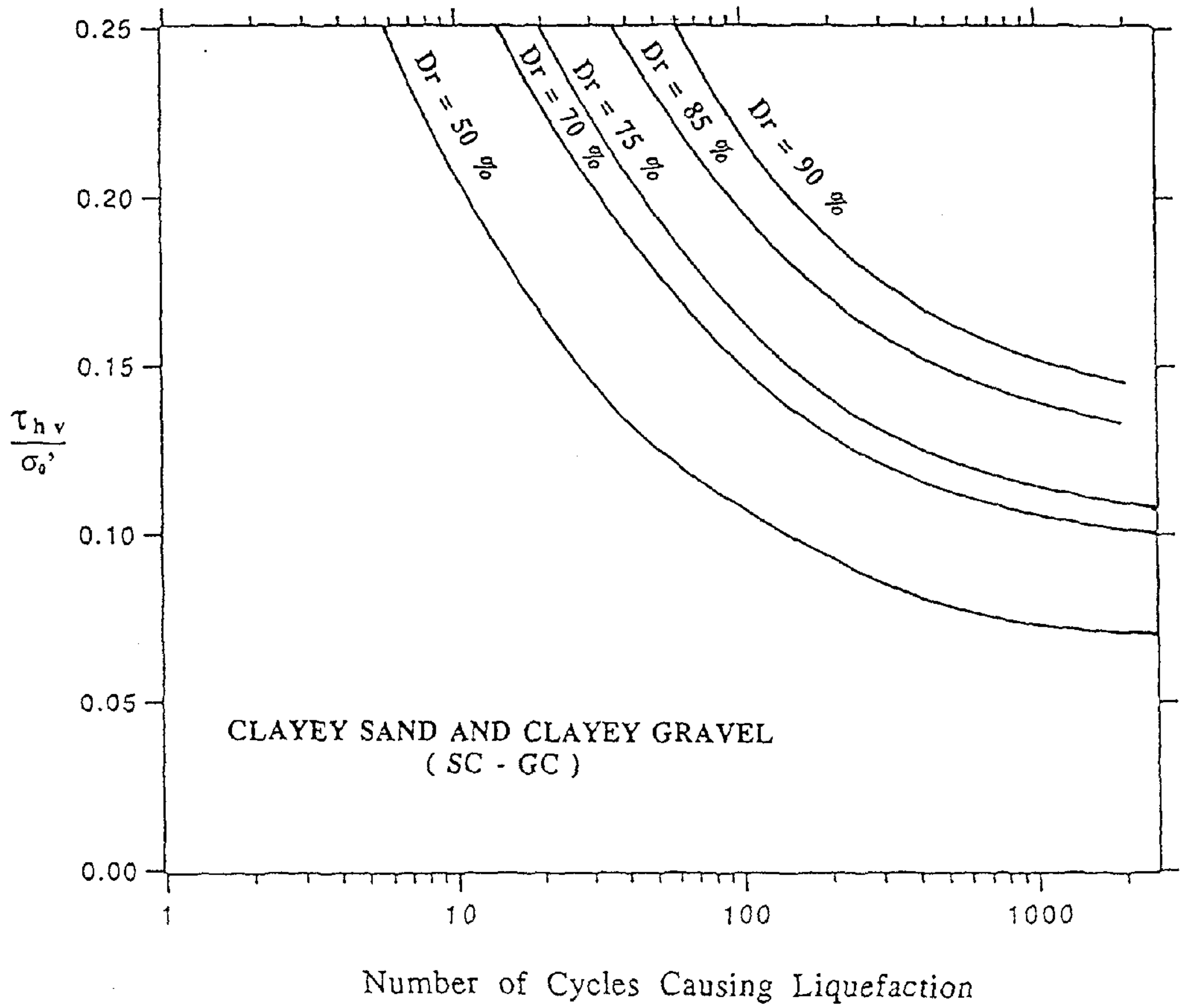


FIGURE 2-4 Cyclic Loading Test Data for Clayey Sand and Clayey Gravel (after Seed et al., 1978, Ueng and Chang, 1982)

2.5 Stress Analysis of Soil Layers Under Earthquakes

The stress analyses of soil layers in the 22 selected representative soil profiles under the scenario earthquakes are first performed using the MASH program. MASH is a program that analyzes the non-linear dynamic response of a soil profile subjected to horizontal bedrock excitations. The stress analyses are performed for each site at four acceleration levels: 0.08 g, 0.15 g, 0.25 g and 0.35 g. The shear stress induced in the soil layers varies significantly for various soil characteristics, site conditions, and peak bedrock accelerations of the earthquake.

An example of the stress analysis for Site LL51 (figure 2-5) is shown in figure 2-6. Under a bedrock acceleration of 0.15 g, soil element 4 (a granular soil (SM-SC) with Dr = 0.6) experiences a maximum shear stress of 339 lb/ft^2 and the highest stress ratio (shear stress/effective overburden stress) in the soil profile. Element No. 4 is designated as the source element and its number of irregular stress cycles is converted into a number of equivalent uniform cycles at the average shear stress (0.65 of the maximum shear stress) based on the method suggested by Seed and Idriss [3] as illustrated in figure 2-7 and equation (2.4):

$$N_{eq} = \sum_{i=0}^{k} N_{eqi} = \sum_{i=0}^{k} (N_i / N_{li}).N_{ref} \qquad (2.4)$$

where k = number of phases in the stress time history,

N_{eq} = number of equivalent cycles,

N_i = number of induced stress cycles at stress level τ_i,

N_{li} = number of equivalent cycles at stress level τ_i required to cause liquefaction,

N_{ref} = number of equivalent uniform stress cycles at 65% of the maximum shear stress in a soil sample required to cause liquefaction.

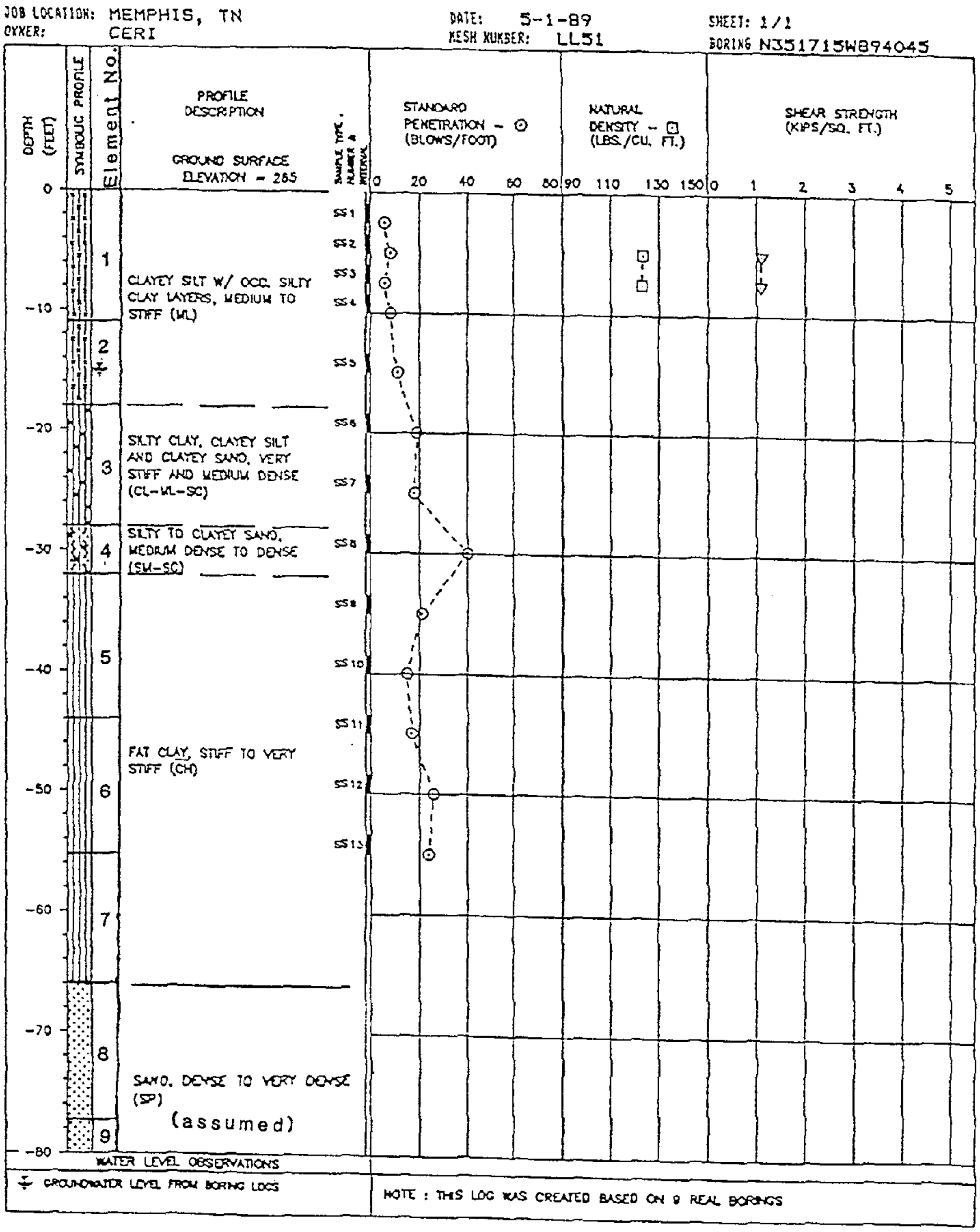


FIGURE 2-5 Boring Data of Site LL51

STRESS TIME HISTORY
PEAK BEDROCK ACCELERATION: 0.15 g
SITE: LL51
ELEMENT NO.: 4
SOIL TYPE: SM-SC
MAX. AMPLIFICATION: -339 (LBS/FT^2)

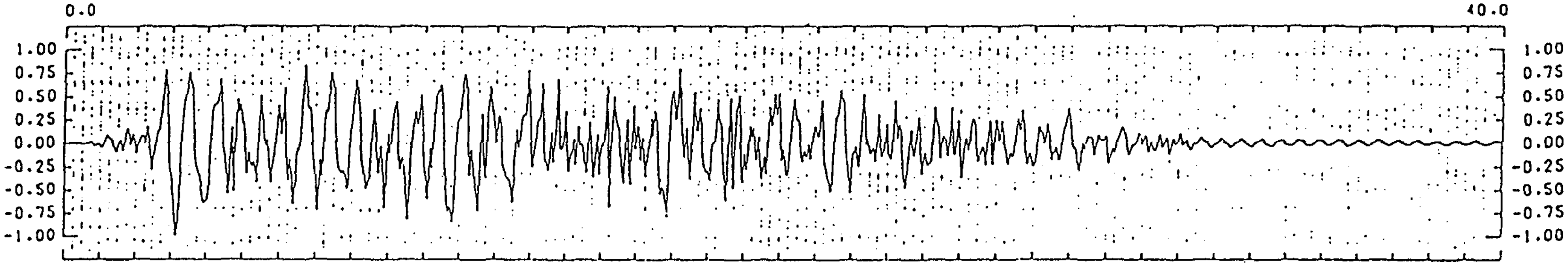
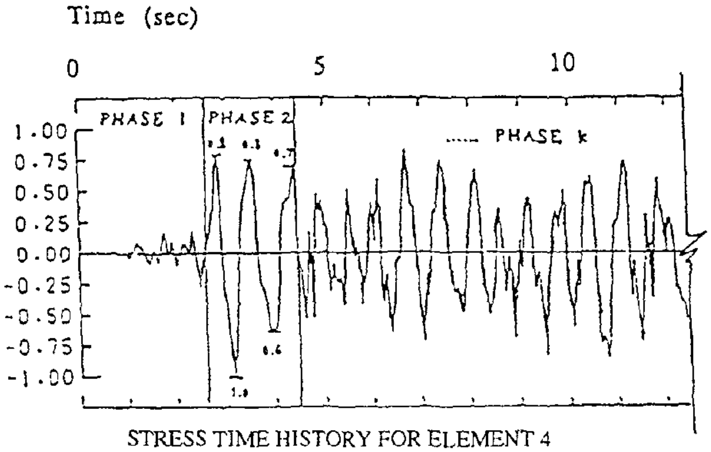


FIGURE 2-6 Stress Time History of Soil Element No. 4 (SM-SC) of Site LL51

SITE : LL51
ELEMENT NO. : 4
SOIL TYPE : SM-SC
Dr : 0.6



STRESS TIME HISTORY FOR ELEMENT 4
(SITE LL 51)
PEAK EARTHQUKAE ACCELERATION = 0.15 g
MAXIMUM AMPLIFICATION = 339 LBS/FT^2

For phase 2:

τ_{max} = -339 lbs/ft^2

τ_{ave} = -220 lbs/ft^2

$\frac{\tau_{ave}}{\sigma_0'}$ = 0 146

Refer to Figure 2-3, N_{ref} = 30

τ_i = Normalized stress x τ_{max}

$N_{eq} = \frac{N_i}{N_{li}} . N_{ref}$

No. of Cycles (N_i)	@ τ_i (lbs/ft^2)	$\frac{\tau_i}{\sigma_0'}$	N_{li}	N_{eq}
0.5	271	0.18	13	1.2
0.5	339	0.23	7	2.1
0.5	271	0.18	13	1.2
0.5	203	0.14	33	0.5
0.5	237	0.16	21	0.7
				ΣN_{eq} = 5.7

FIGURE 2-7 Example Using Method Suggested by Seed and Idriss to Convert Irregular Stress Cycles to Equivalent Uniform Stress Cycles

The N_{eq} of the source element of each of the 22 selected sites at various acceleration levels is determined and used as earthquake-induced stress cycles for pore pressure analysis at each corresponding site using the APOLLO program.

2.6 Pore Pressure Analysis

Using the results of the stress analysis, the pore pressure buildup in each granular soil layer due to the input stress cycles for the 22 soil profiles under various acceleration levels can be determined by using the APOLLO program. Based on the results of the soil pore pressure analysis, the relative density (void ratio) and volume compressibility appear to be the major factors controlling the pore pressure buildup. In addition, permeability and the drainage condition of soil layers also affect the pore pressure buildup because of their influence on the rate of pore water dissipation.

The results of pore pressure analysis of site LL51 are presented for illustration as shown in figure 2-8. Results show that pore pressure is induced by the input stress cycle in all elements and reaches the peak pore pressure between about 20 to 30 seconds and gradually decreases with time as pore water dissipates from the soil layer. In this example, element 4 has the highest pore pressure ratio of about 0.7, while the other denser granular or cohesive soil elements have significantly lower pore pressure under a bedrock acceleration of 0.15 g.

In this study, a total of 53 granular soil elements with various site conditions from the selected 22 representative profiles are investigated. The results of the soil pore pressure analyses for each element with respect to peak bedrock acceleration of 0.08 g, 0.15 g, 0.25 g and 0.35 g are summarized and discussed in Section 3.

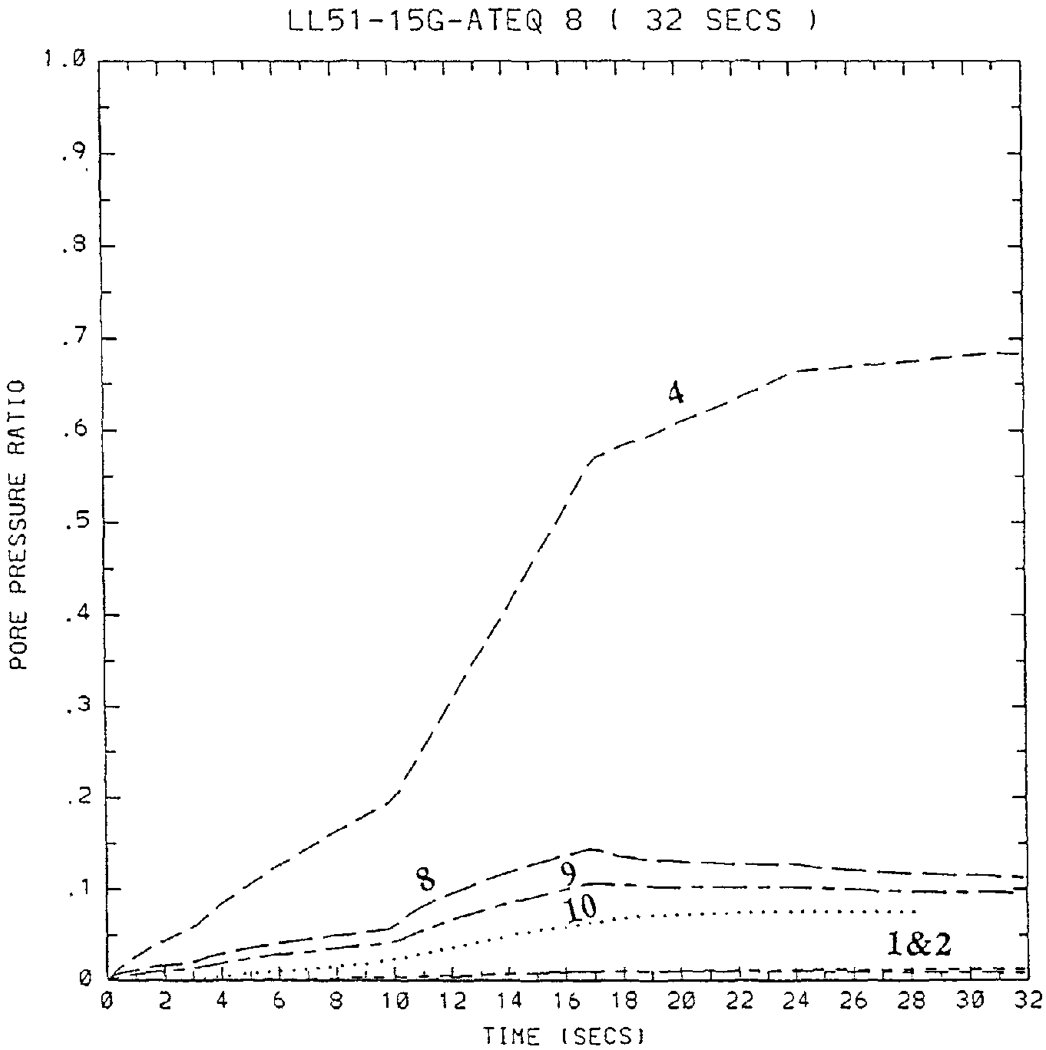


FIGURE 2-8 Pore Pressure Buildup with Time of Granular Soil Elements Number 1, 2, 4, 8, 9, and 10 of Site LL51 Subjected to 0.15 g Earthquake Expressed in Terms of Pore Pressure Ratio

SECTION 3

GENERAL LIQUEFACTION INDEX CRITERIA FOR REGIONAL EVALUATION

From the stress and pore pressure analyses of the 22 selected sites, the responses of the soil elements in terms of shear stress and pore pressure ratio are obtained. The next task is to study their characteristics by relating the maximum pore pressure ratio of the soils under various boundary conditions and different earthquake accelerations to the corresponding in situ density (N-values), depth, and also thickness of the soil elements.

3.1 Development of General Criteria Based on Results of Pore Pressure Analysis

The results of the study show that there is no clear correlation between depth and the pore pressure ratio in the soil elements. However, the results do indicate that there is correlation between the in situ N-values and pore pressure ratio despite the scattering data. Further study indicates that the soils can be categorized into two groups that exhibit similar pore pressure buildup behavior:

Group 1: clayey sand and clayey gravel (SC-GC)
Group 2: sand, silty sand, gravel, and silt (SP-SM-GP-ML)

Figures 3-1 to 3-8 show the relationship between the pore pressure ratio and the in situ N-values for SC-GC and SP-SM-GP-ML, under one-way drainage and while subjected to earthquake accelerations of 0.08 g, 0.15 g, 0.25 g, 0.35 g. A curve representing the average soil behavior is defined for each case. Other cases are shown in the Appendix A.

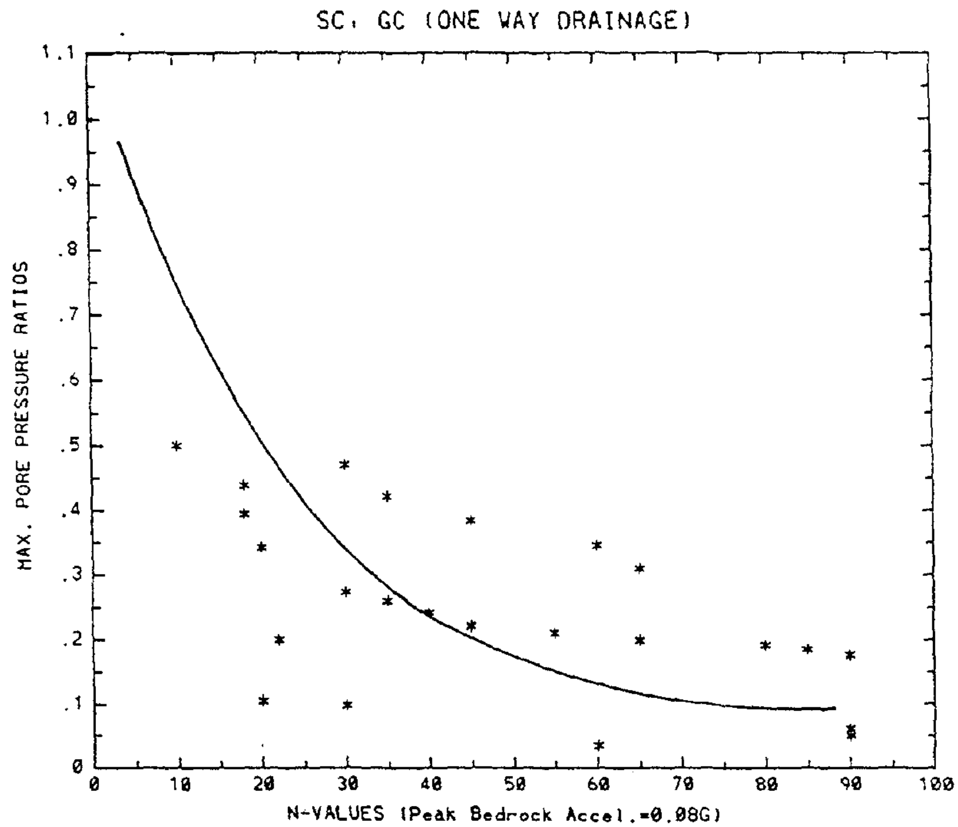


FIGURE 3-1 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (One-Way Drainage, 0.08 g)

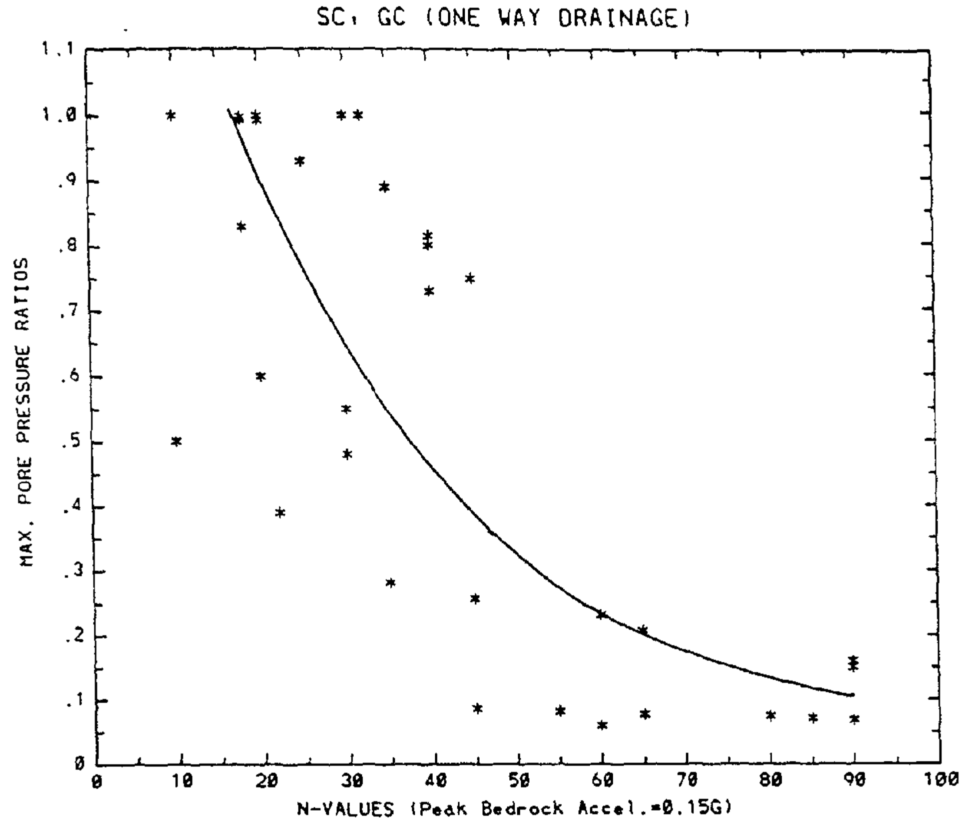


FIGURE 3-2 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (One-Way Drainage, 0.15 g)

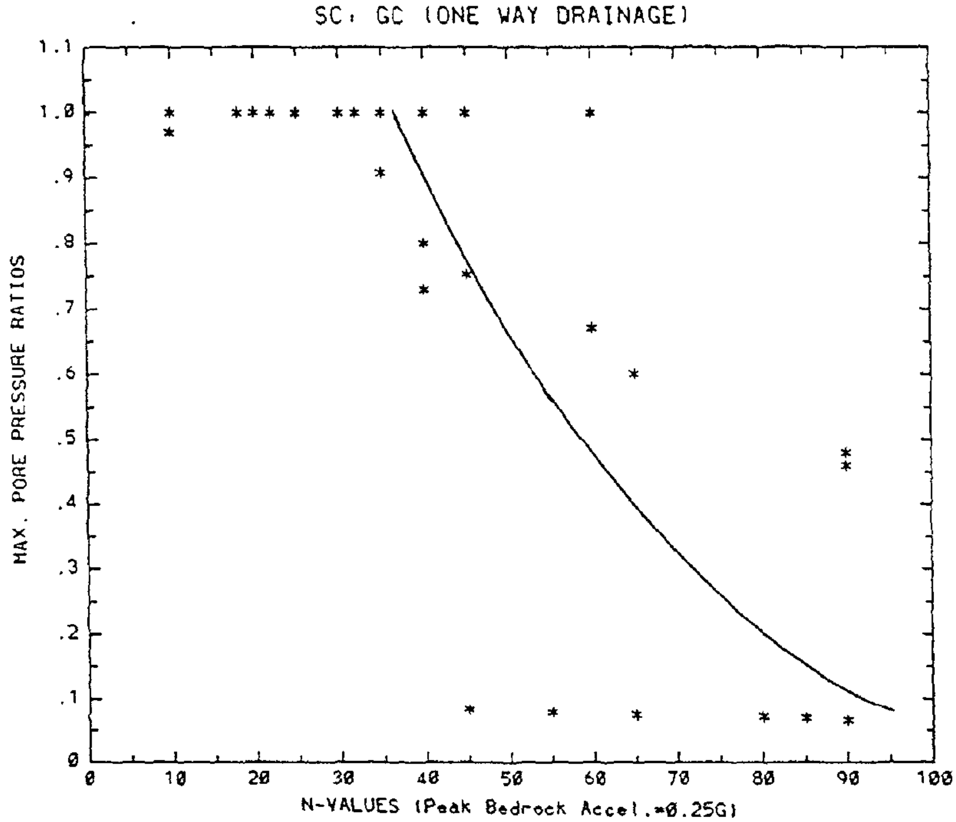


FIGURE 3-3 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (One-Way Drainage, 0.25 g)

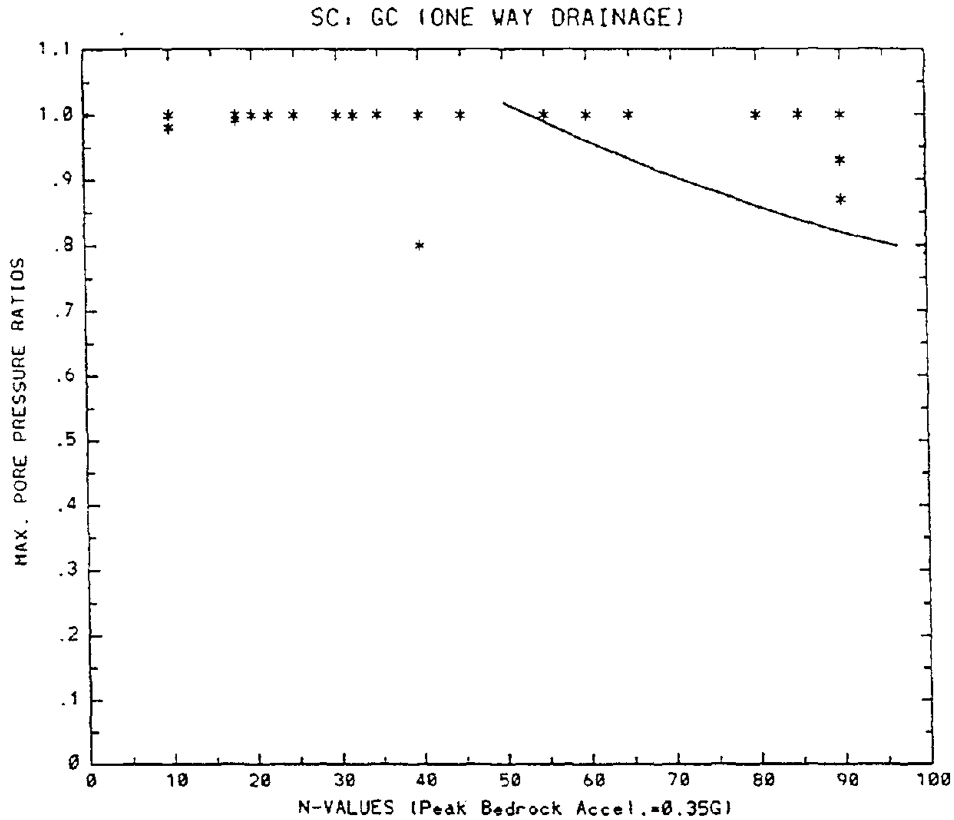


FIGURE 3-4 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (One-Way Drainage, 0.35 g)

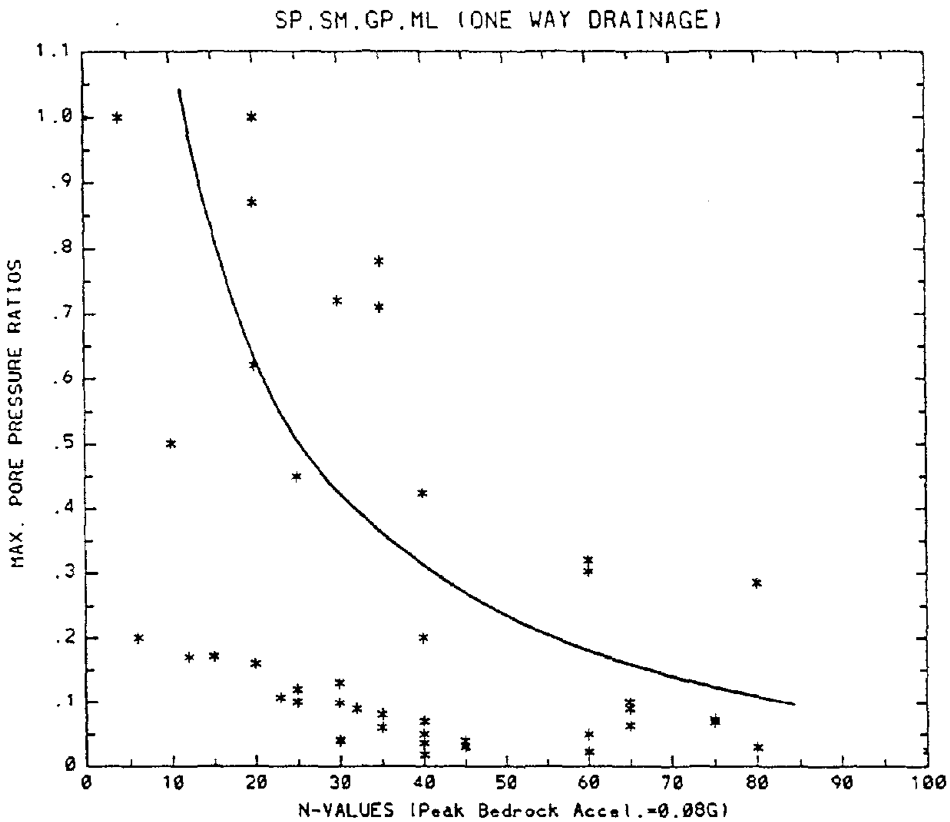


FIGURE 3-5 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (One-Way Drainage, 0.08 g)

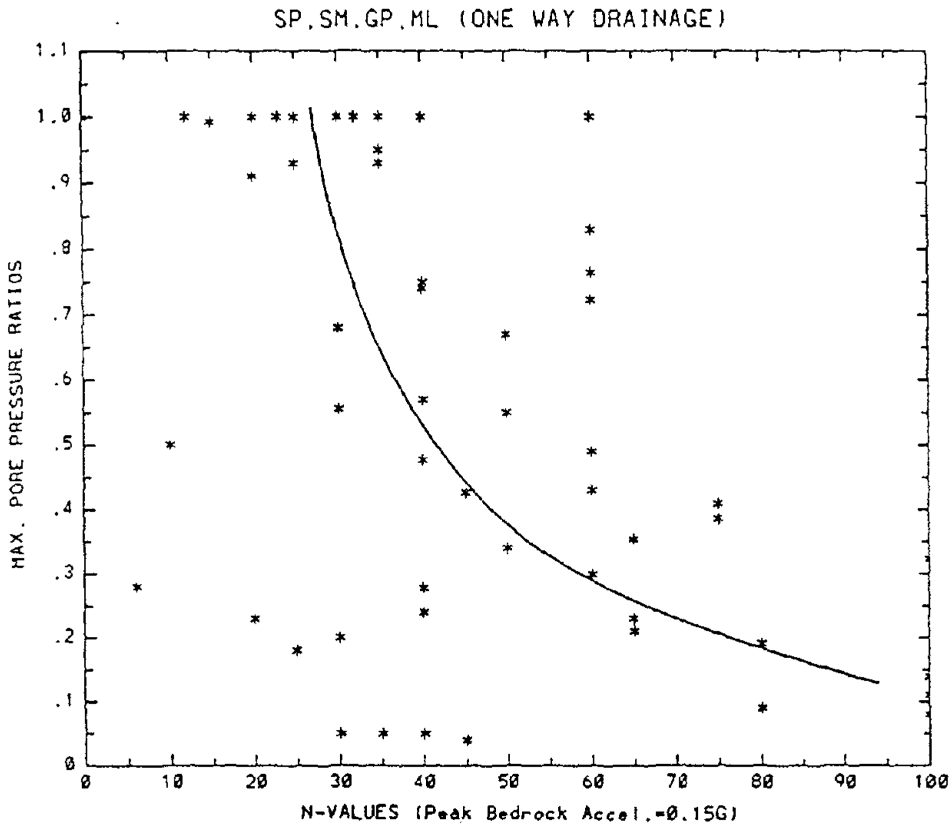


FIGURE 3-6 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (One-Way Drainage, 0.15 g)

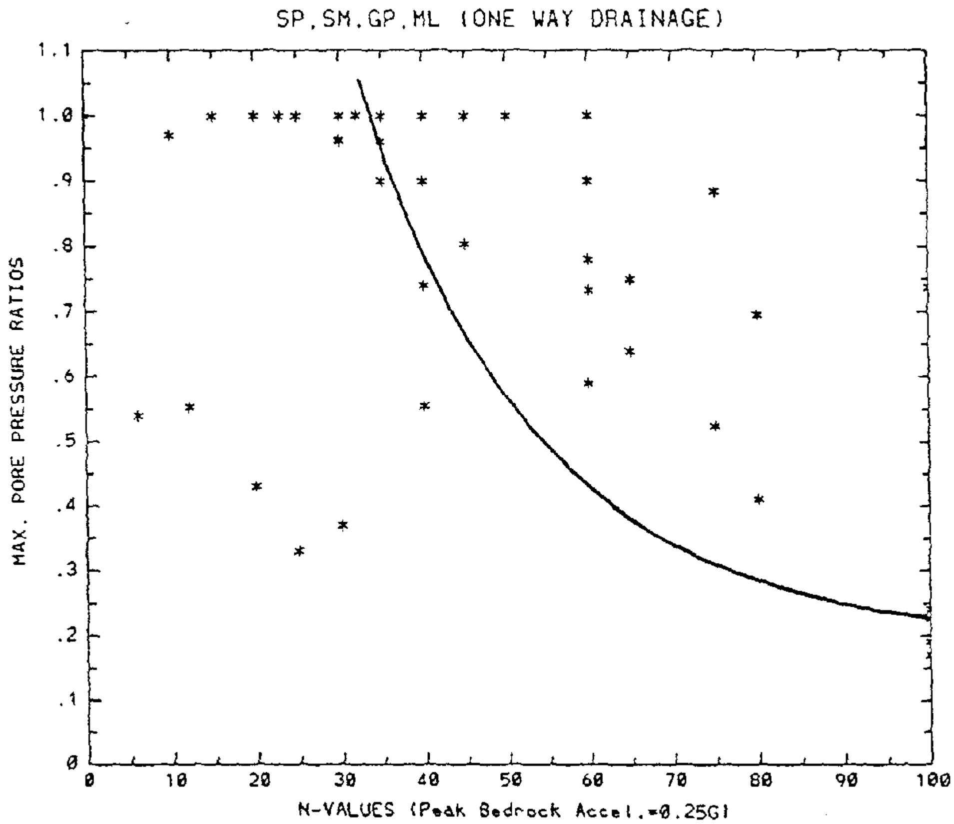


FIGURE 3-7 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (One-Way Drainage, 0.25 g)

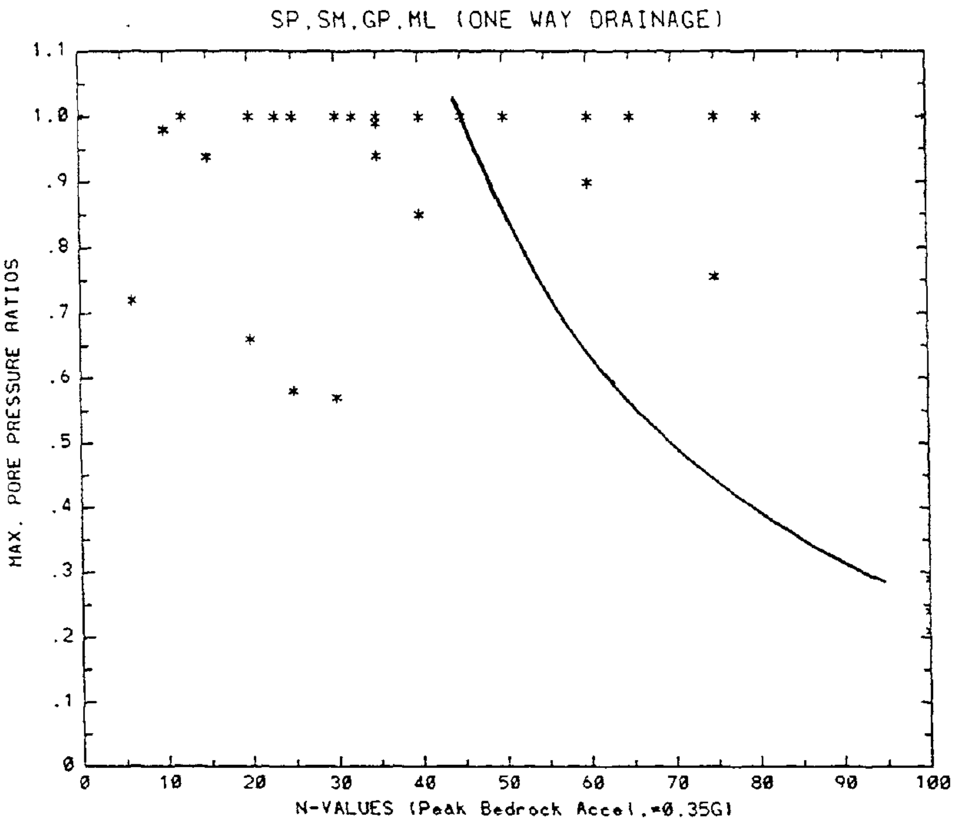


FIGURE 3-8 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (One-Way Drainage, 0.35 g)

The next requirement for creating the general liquefaction index criteria is to determine a range of pore pressure ratios from which the liquefaction potential levels for regional evaluation can be defined. Seed [23] suggested that liquefaction may be triggered at a high enough pore pressure, say r_u exceeds 60%. He further suggested that if the soil does not liquefy at a high pore pressure ratio, it is because the soil retains adequate shear strength to resist the collapse of the soil skeleton and there is no serious deformation problem [23]. Thus, emphasis is placed on the degree of pore pressure development to trigger liquefaction in a soil. In this study, the pore pressure ratio of 90% is defined as the threshold where liquefaction is likely to be triggered. Three liquefaction potential levels are established in this study as shown in table 3-I.

TABLE 3-I Liquefaction Potential Level According to Pore Pressure Ratio

Pore Pressure Ratio (%) (r_u)	Liquefaction Potential
0 - 60	Unlikely to liquefy
60 - 90	Marginal
90 - 100	Likely to liquefy

Finally, the general liquefaction index criteria are created by relating the different liquefaction potential levels for the soil groups under various boundary conditions to the corresponding N-values and peak earthquake accelerations. For the SC-GC soil group, both the one-way and two-way drainage that exhibit similar liquefaction potential are grouped together. The final general liquefaction index criteria are presented in figures 3-9 to 3-13.

3.2 Comparison Between CERI's and Seed's Liquefaction Criteria

To examine the established criteria based on the liquefaction potential study, the results of the CERI liquefaction study are compared with that of Seed's field liquefaction correlation. Soils with a pore pressure ratio that exceeds 90% is defined as being under

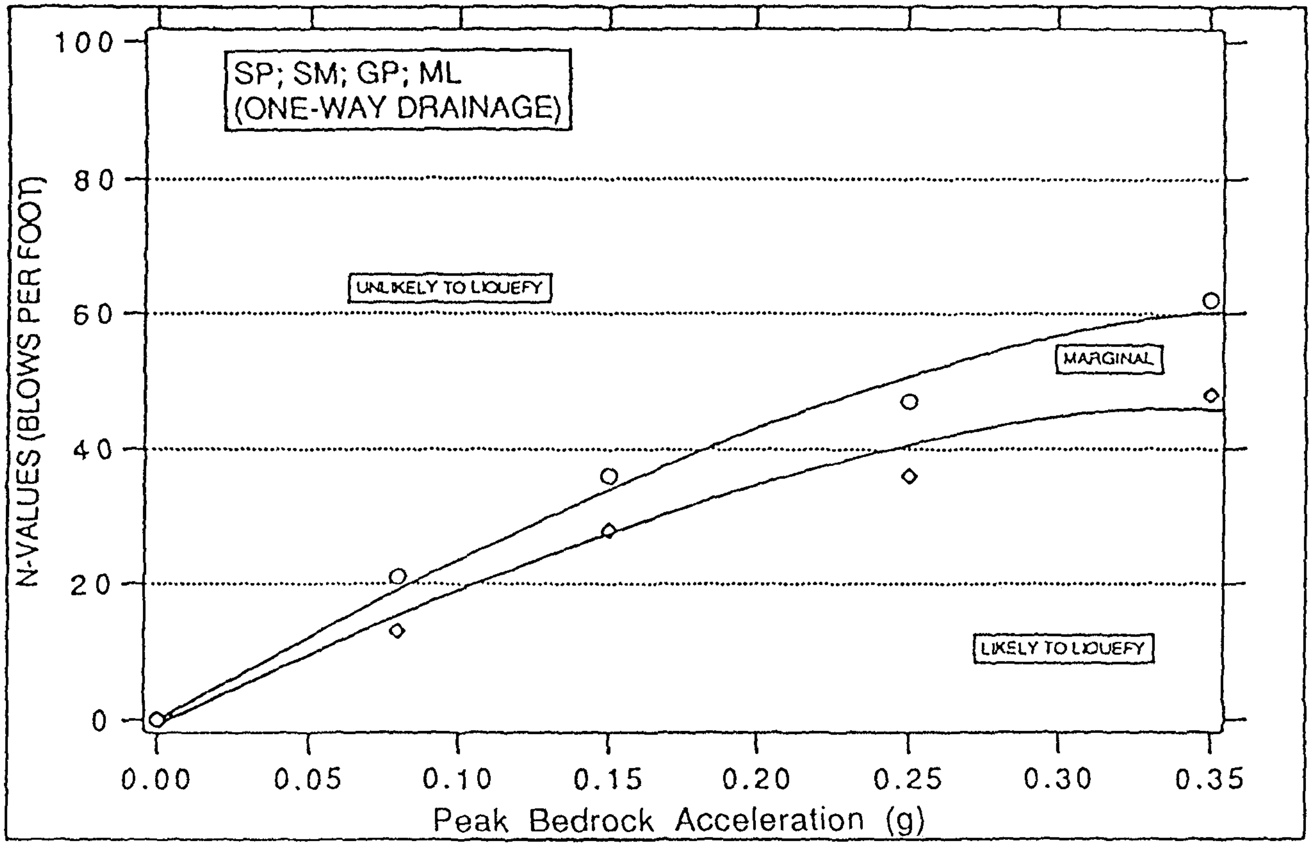


FIGURE 3-9 Liquefaction Index Criteria for SP-SM-GP-ML
(Drained in One-Way)

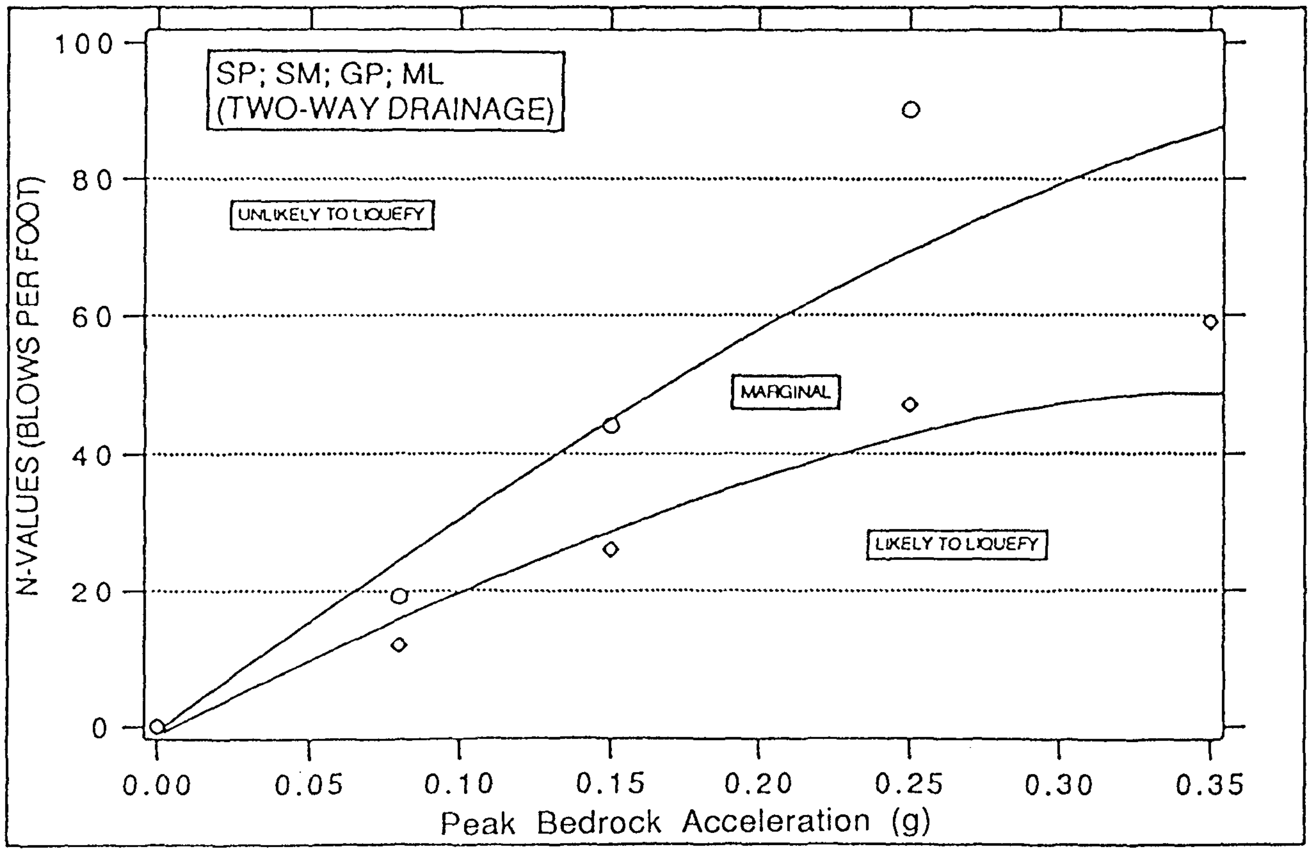


FIGURE 3-10 Liquefaction Index Criteria for SP-SM-GP-ML
(Drained in Two Way)

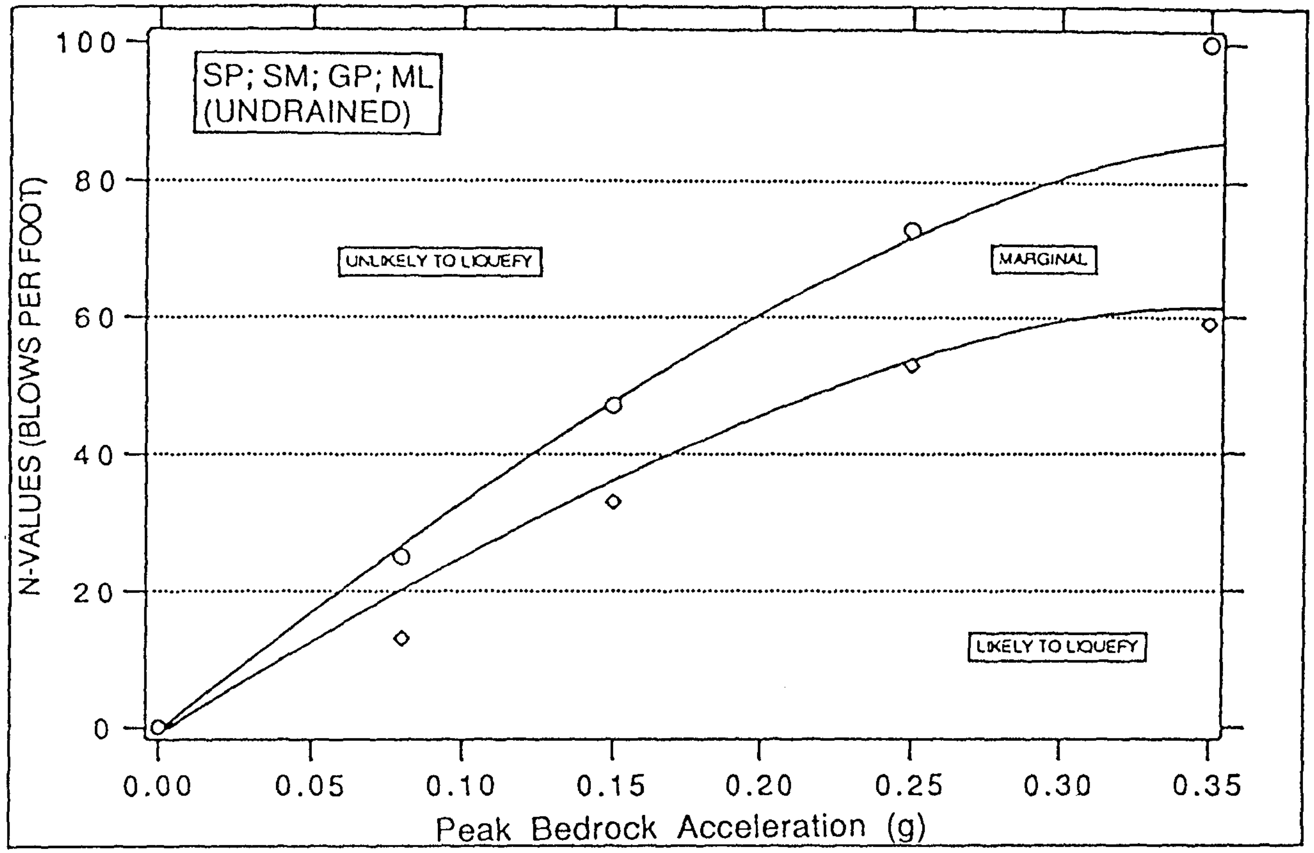


FIGURE 3-11 Liquefaction Index Criteria for SP-SM-GP-ML (Undrained)

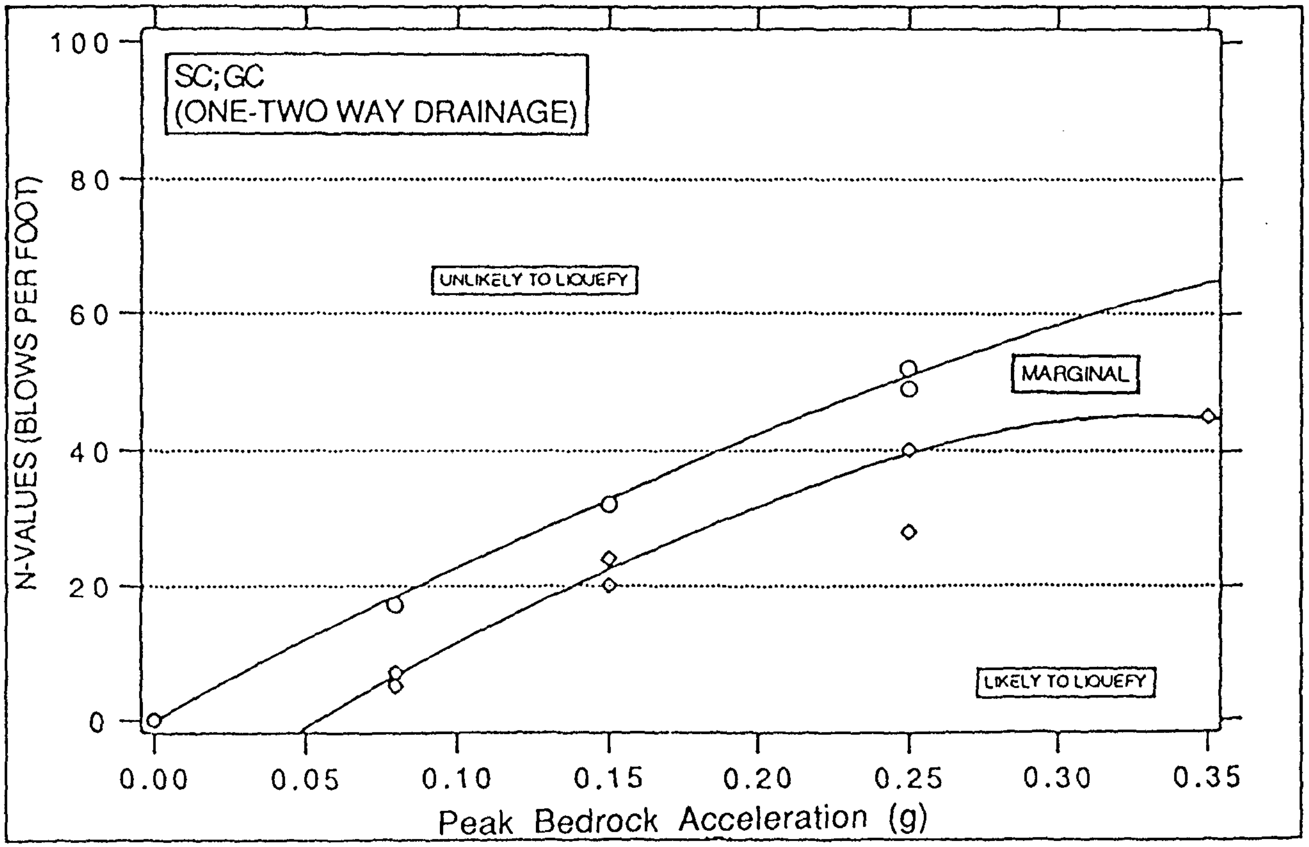


FIGURE 3-12 Liquefaction Index Criteria for SC-GC
(Drained in One and Two Way)

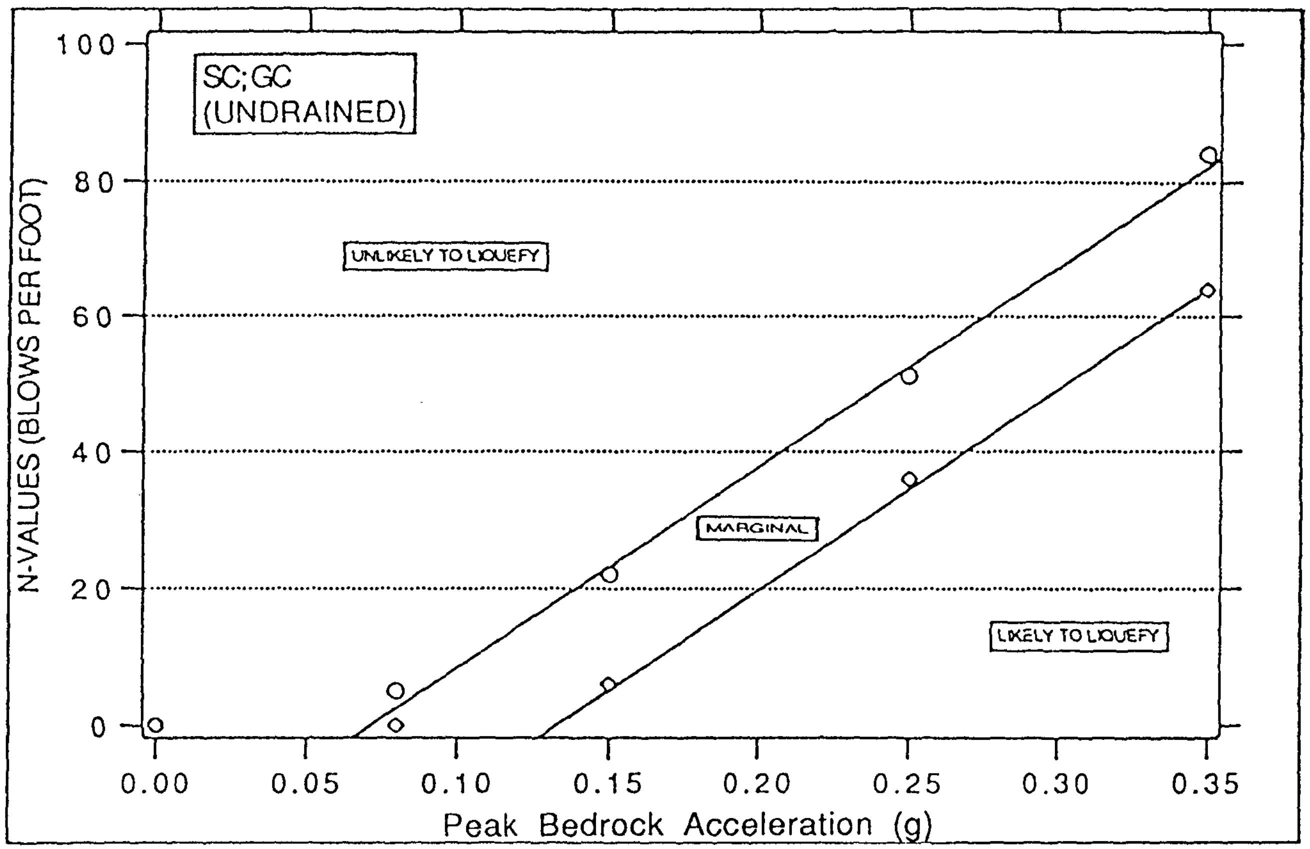


FIGURE 3-13 Liquefaction Index Criteria for SC-GC (Undrained)

liquefaction condition. Granular soils from sites S50, M(-4), C29, and N23 are used for this comparison. The induced shear stress and pore pressure obtained from the results of stress analysis and soil pore pressure analysis of the four selected sites are listed in Table 3-II.

TABLE 3-II Liquefaction Potential of the Granular Soils Corresponding to Stress Ratios, Pore Pressure Ratio, and N-Values for Sites S50, M(-4), C29, and N23

SITE S50								
Corrected N-Value	0.08 g		0.15 g		0.25 g		0.35 g	
	SR	LIQ	SR	LIQ	SR	LIQ	SR	LIQ
53	0.09	NO	0.14	NO	0.18	YES	0.24	YES
21	0.09	NO	0.14	NO	0.18	YES	0.24	YES
19	0.09	NO	0.15	NO	0.18	YES	0.24	YES
14	0.09	NO	0.15	NO	0.20	YES	0.25	YES
SITE M(-4)								
Corrected N-Value	0.08 g		0.15 g		0.25 g		0.35 g	
	SR	LIQ	SR	LIQ	SR	LIQ	SR	LIQ
20	0.07	NO	0.12	YES	0.15	YES	0.18	NO
13	0.12	NO	0.20	YES	0.25	YES	0.29	YES
17	0.11	NO	0.19	YES	0.26	YES	0.31	YES
19	0.11	NO	0.19	YES	0.28	YES	0.32	YES
19	0.11	NO	0.19	YES	0.28	YES	0.32	YES
SITE C29								
Corrected N-Value	0.08 g		0.15 g		0.25 g		0.35 g	
	SR	LIQ	SR	LIQ	SR	LIQ	SR	LIQ
19	0.11	NO	0.17	YES	0.25	YES	0.29	YES
32	0.11	NO	0.18	YES	0.26	YES	0.32	YES
34	0.12	NO	0.18	NO	0.25	NO	0.32	YES
SITE N23								
Corrected N-Value	0.08 g		0.15 g		0.25 g		0.35 g	
	SR	LIQ	SR	LIQ	SR	LIQ	SR	LIQ
27	0.10	NO	0.14	NO	0.20	NO	0.25	YES
35	0.11	NO	0.16	NO	0.23	NO	0.28	YES

Abbreviations: SR : Stress ratio
LIQ: Liquefaction assessment

The liquefaction potential of the granular soils corresponding to stress ratios and N-values presented in Table 3-II are plotted and shown in figure 3-14 and the boundary between the liquefied soils ($r_u >$ 90%) and non-liquefied soils ($r_u <$ 90%) is defined. The comparison between CERI's and Seed's criteria is also shown in figure 3-14. It can be seen that the CERI liquefaction potential study based

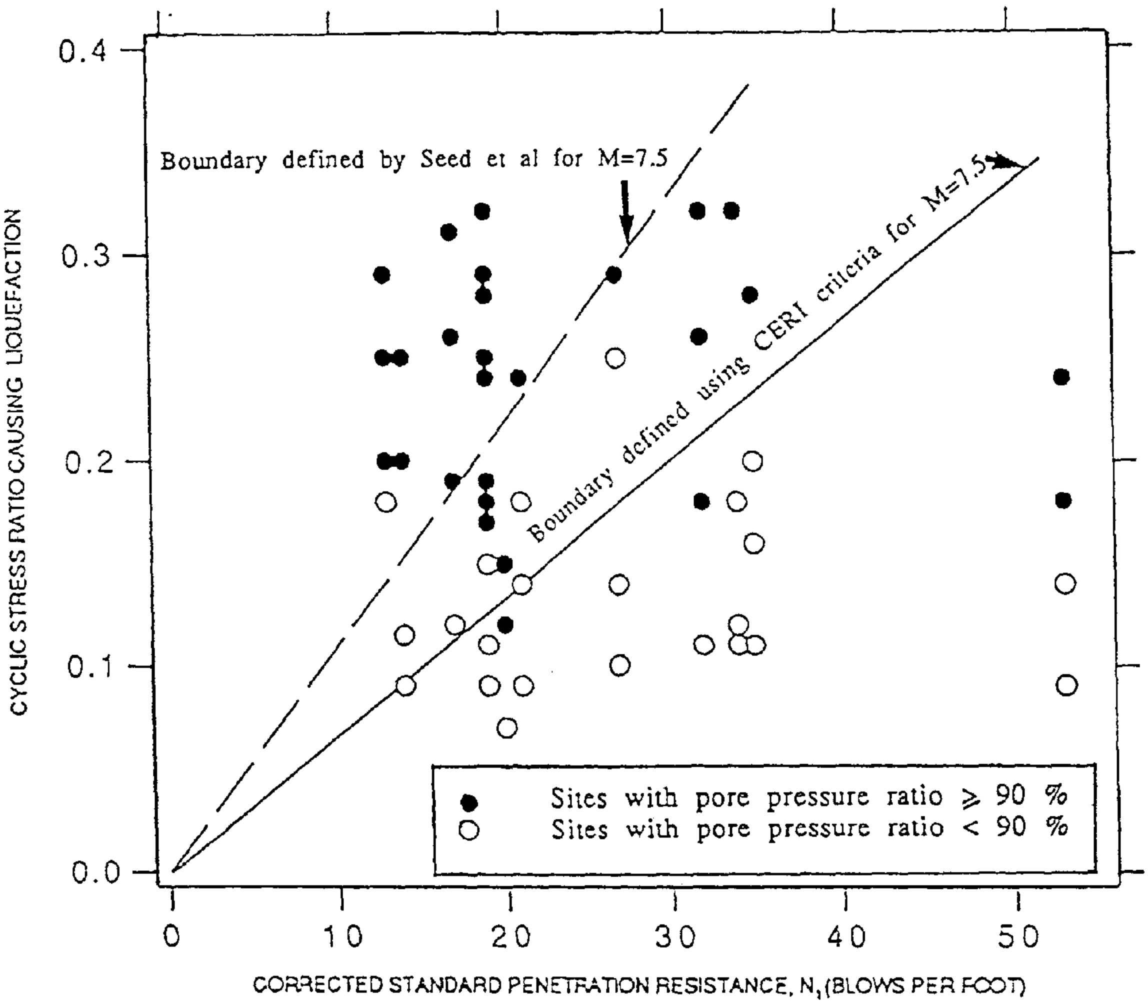


FIGURE 3-14 Comparison between the CERI Liquefaction Correlation and Seed's Field Liquefaction Correlation

on actual soil data and the synthetic earthquakes results in a more stringent liquefaction potential evaluation than the Seed's criteria. The difference between the two criteria is contributed by the following factors:

1. The synthetic bedrock acceleration time histories used in this study have a duration of 32 seconds and a dominant frequency of 25 Hz. It is noted that the basement rock in the study area is very competent and thus the synthetic time histories are rich in high-frequency contents [9]. These earthquake time histories generate a much larger number of equivalent uniform stress cycles for an M = 7.5 earthquake than as suggested by Seed [3]. For example, Seed suggests 15 equivalent stress cycles for an M = 7.5 earthquake while the design earthquake used in this study induced at least 30 to more than 100 cycles of uniform stress.

2. Seed's field liquefaction correlation is developed based on the observed field failures of past post earthquakes. However, a high pore pressure ratio (in this case, r_u = 90%) may not cause soil structure damage which is observable from the ground surface.

SECTION 4

LIQUEFACTION POTENTIAL IN MEMPHIS AND SHELBY COUNTY

Liquefaction phenomena in granular deposit is one of the most significant damaging effects that causes structure failure and loss of lives once a major earthquake occurs. An accurate liquefaction potential evaluation is essential for regional seismic hazard assessment and earthquake preparedness plans.

4.1 Controlling Factors in Regional Liquefaction Potential Evaluation

The quality and accuracy of an overall regional liquefaction evaluation depend on three major factors: (1) knowledge of local site conditions, (2) regional seismicity and (3) utilization of proper evaluating criteria. For the evaluation of liquefaction potential in Memphis and Shelby County, these three major factors are studied and proper data are selected and used for this study as discussed below.

4.1.1 Local Site Conditions

The subsurface conditions in Memphis and Shelby County were well studied by CERI based on data from more than 8,500 engineering bore holes throughout the study area [1]. The subsurface conditions were presented in a series of representative boring logs in accordance with a grid system applied to the target area [1]. These boring logs, which contain necessary engineering data such as soil type and stratification, in situ strength, and ground water level, are the essential data base for this study. The collection, compilation, and accuracy of these soil data are discussed by Chang et al. [24]. These data, which can be updated as more soil data are available, are the most complete information at this time regarding the general subsurface conditions in the study area. As shown in figure 4-1, the

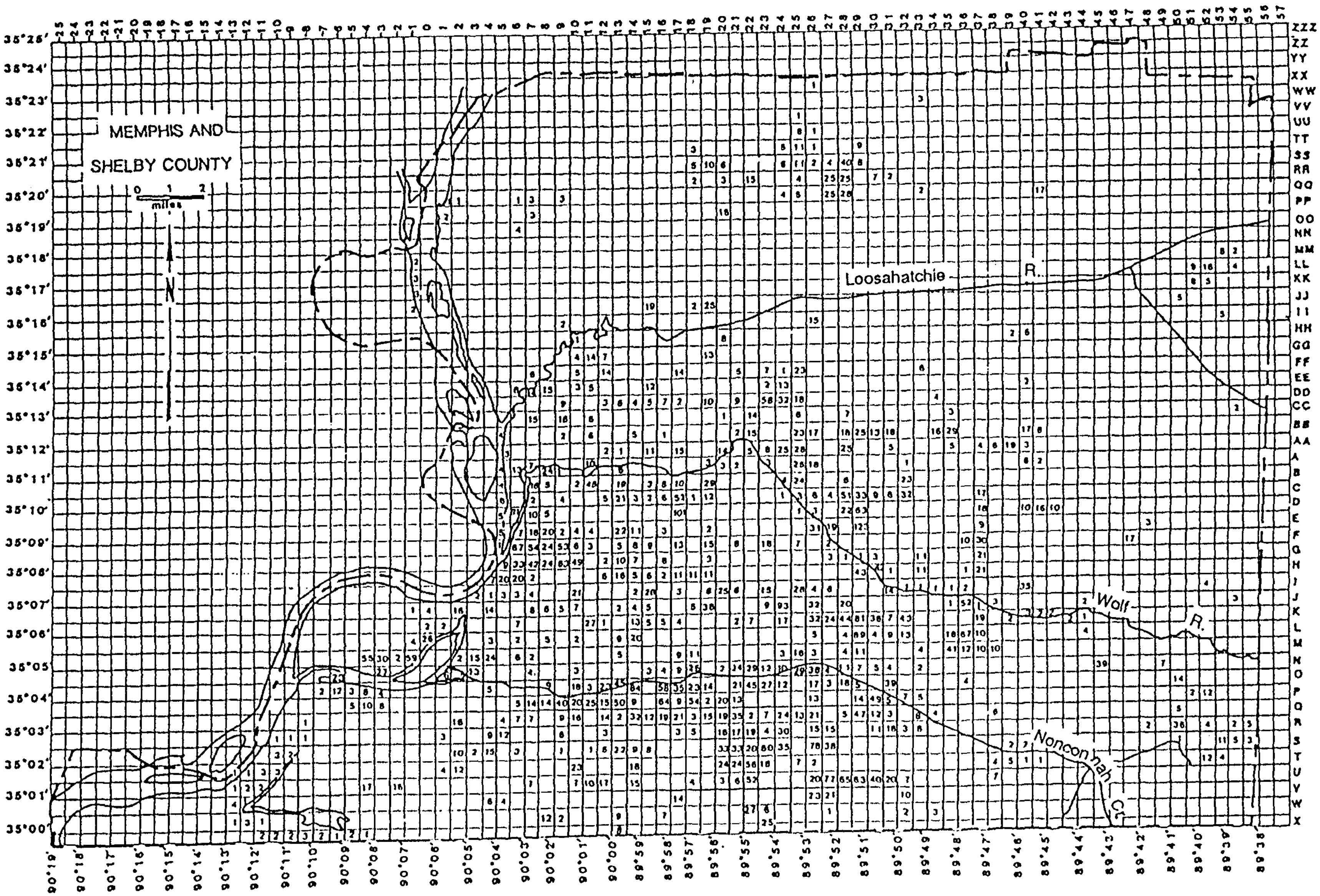


FIGURE 4-1 Boring Data Distribution of Memphis and Shelby County, Tennessee

number in each cell indicates the actual boring logs available from which the final representative soil log is developed. It should be noted that no soil data are available for several areas. The site liquefaction potential is evaluated for each cell where soil data are available. The liquefaction potential of the sites without data is categorized as "undefined" or estimated based on the soil conditions in the adjacent areas and our general understanding of the geology of the study area. The clayey materials (ML-CL, CL), which are commonly encountered near the ground surface in the study area, are considered nonliquefiable. In this study, liquefaction potential evaluation is performed only for the granular soils (SW, SP, SM, SC, GP, ML) encountered in the study area.

4.1.2 Regional Seismicity

Earthquakes that occur in the southern segment of the NMSZ apparently have significant impacts and impose severe threats to the study area. On the basis of results from a probabilistic study of the NMSZ earthquakes by Johnston [22], the liquefaction evaluation in this study targets two major earthquakes assumed to occur in the southern NMSZ.

1. M = 7.5 earthquake: an extreme case with a low probability of occurrence (compared with an M_S = 7.6 having a 5.4%-8.7% chance of occurrence by the year 2000 [22]).
2. M = 6.5 earthquake: an event likely to occur in the foreseeable future with a moderate probability of occurrence (compared with an M_S = 6.3 earthquake having a chance of about 40%-63% of occurrence by the year 2000 [22]).

The contour maps of peak bedrock acceleration corresponding to the two scenario earthquakes were developed by Hwang et al. [9] as shown in figures 4-2 and 4-3. These maps indicate decreasing bedrock acceleration from the northwest corner to the southeast

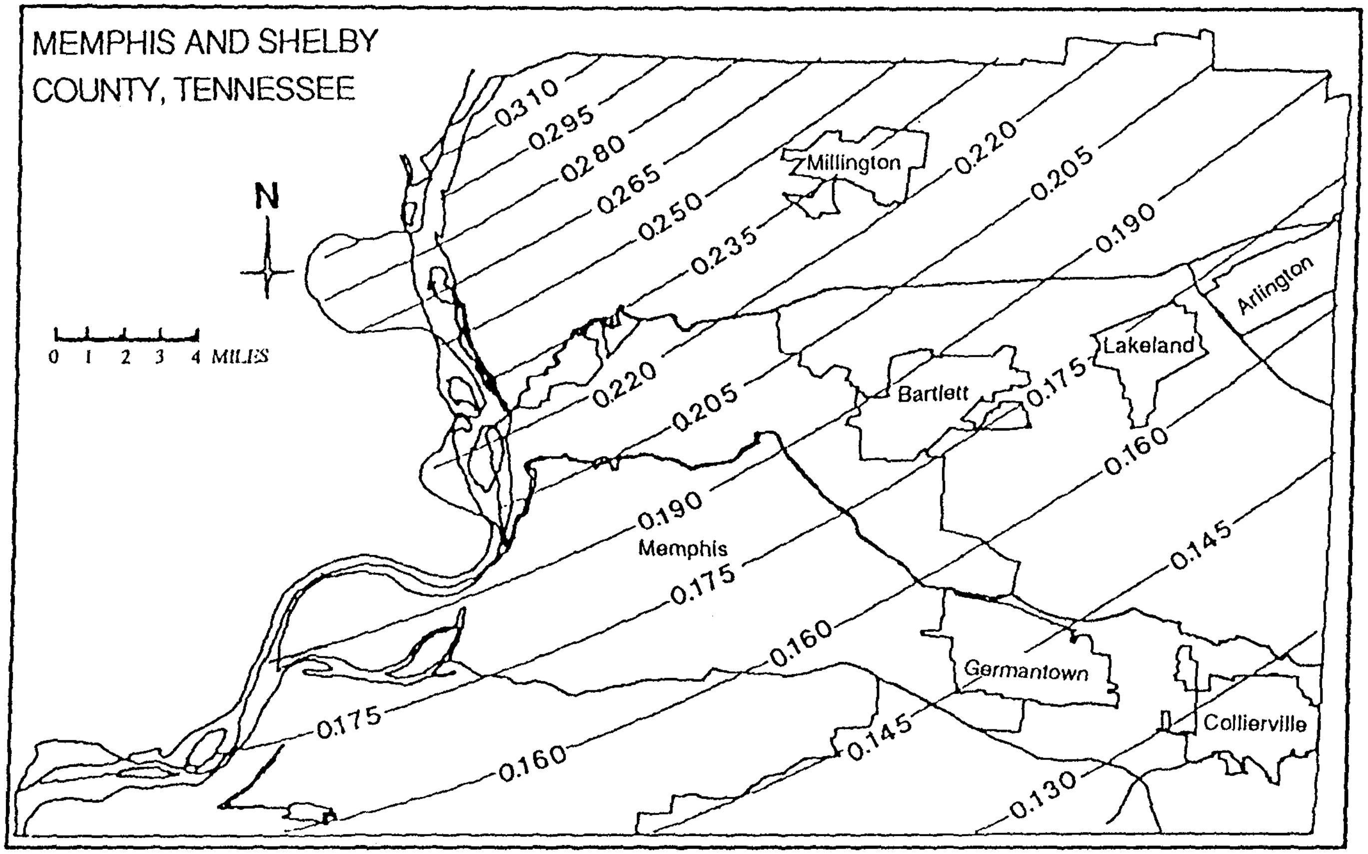


FIGURE 4-2 Bedrock Acceleration (g) Contour Map of Mean + S.D. Accelerations in Memphis and Shelby County (M = 7.5, Southern NMSZ, after Hwang et al)

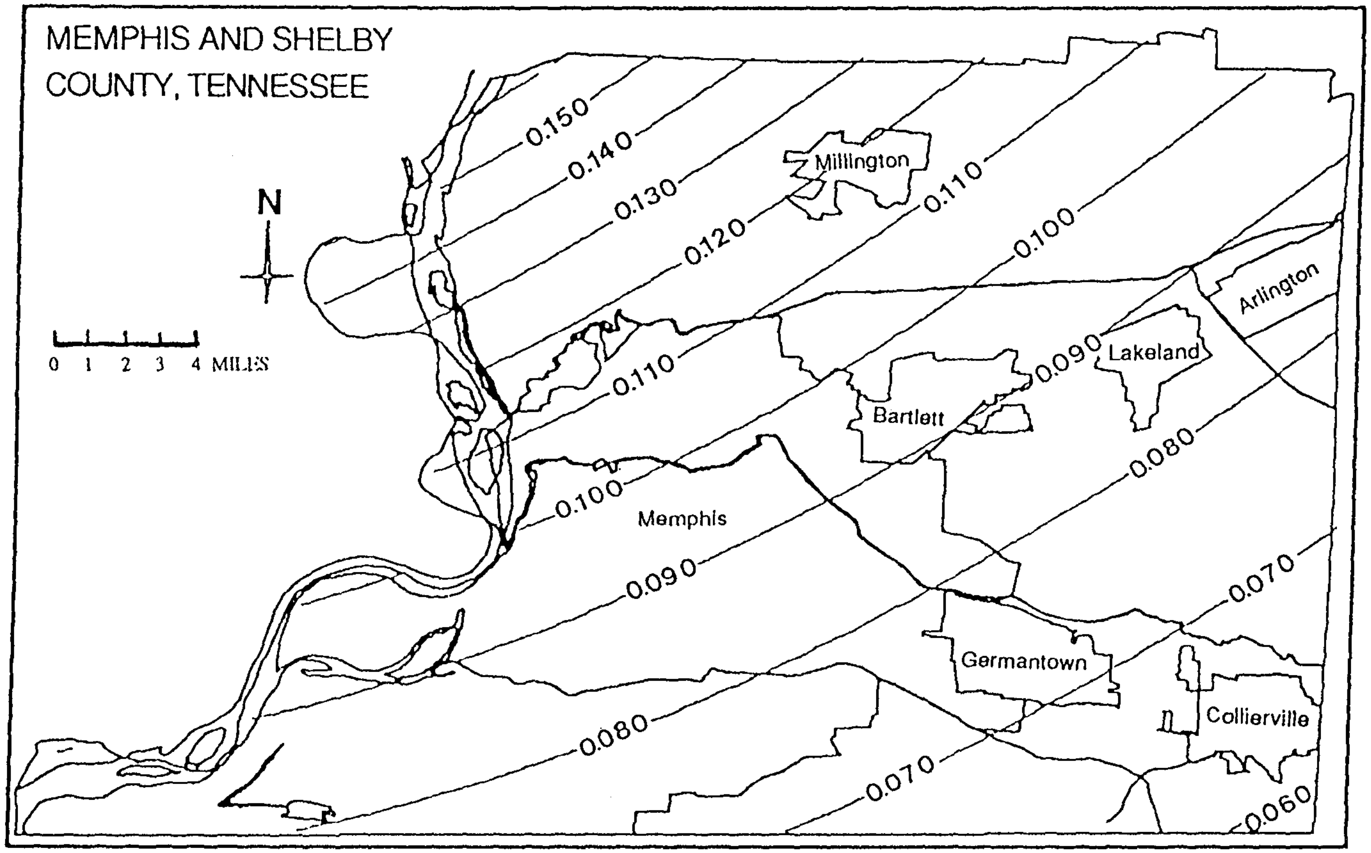


FIGURE 4-3 Bedrock Acceleration (g) Contour Map of Mean + S.D. Accelerations in Memphis and Shelby County (M = 6.5, Southern NMSZ, after Hwang et al)

corner of the study area due to attenuation of the seismic waves traveling radially outward from the earthquake epicenter, i.e., southern NMSZ in this study. The peak bedrock acceleration shown in the contour maps is the "input earthquake" for the overall liquefaction evaluation in the study area. On the basis of these maps, peak bedrock acceleration can be determined for each site (cell) subjected to the scenario earthquakes (M = 7.5 or M = 6.5 earthquake).

4.1.3 Criteria for Regional Liquefaction Evaluation

The overall liquefaction potential evaluations are based on the liquefaction index criteria developed from the results of the soil pore-pressure study of the 22 selected sites as discussed in Section 3 (figure 3-9 to figure 3-13). For comparison purposes, the criteria developed by Seed et al. [3,7,8] are also used for the M = 7.5 earthquake. The site by site liquefaction potential evaluations are presented in Appendix B.

4.2 Liquefaction Potential Map Corresponding to the M = 7.5 Earthquake

Using the available soil data and bedrock acceleration contour map, the overall liquefaction potential map of Memphis and Shelby County are developed as shown in figures 4-4 and 4-5, for CERI and Seed's criteria, respectively. It is discussed in Section 3 that the CERI criteria are developed based on an earthquake with a dominant frequency of 25 Hz and a duration of about 32 seconds, which induced a significantly higher number of stress cycles in the soil layers. This may explain the differences between the results of liquefaction potential using the two criteria in this study. Figures 4-4 and 4-5 show the overall liquefaction potential of the sites by identifying any liquefied granular soils within a depth of 100 feet in the profile regardless of the depth, thickness, and total number of liquefied soil layers. In fact, the damage potential of structures at a liquefiable site should depend on the number, thickness, and depth

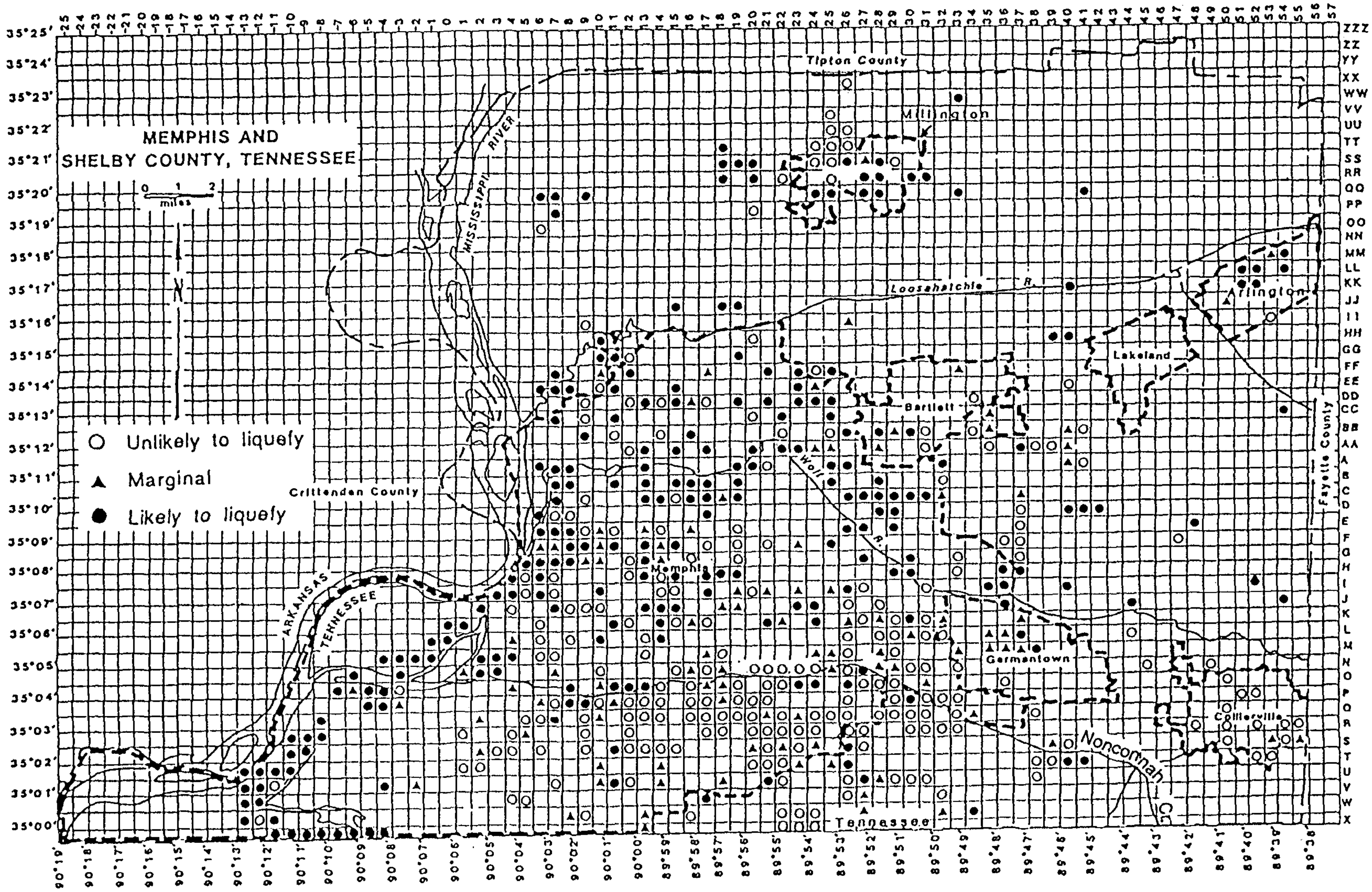


FIGURE 4-4 Overall Site Liquefaction Potential of Memphis and Shelby County Based on CERI Criteria (M = 7.5, Southern NMSZ)

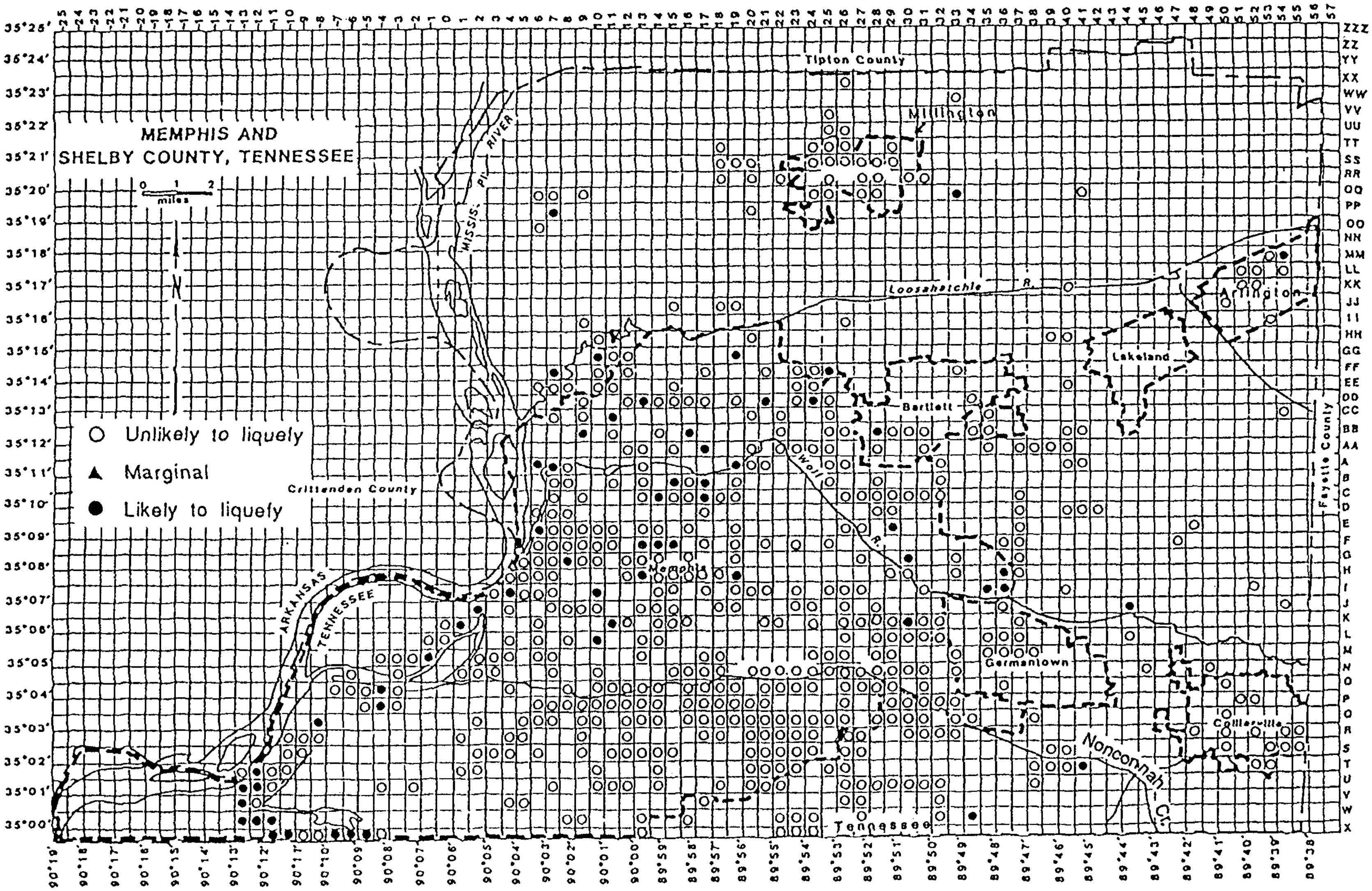


FIGURE 4-5 Overall Site Liquefaction Potential of Memphis and Shelby County Based on Seed's Criteria (M = 7.5)

of the liquefiable soil layers. Therefore, these maps do not necessarily imply directly the damage potential of structures at each site due to liquefaction. The structural damage potential due to liquefaction in the study area is discussed in Section 5.

A series of liquefaction potential maps for three depth zones (0-25 feet, 25-50 feet and 50-100 feet) are presented in figures 4-6 to 4-8, which provide more practical information for estimating the damage potential of structures that can be caused by liquefaction. Based on the available soil data, a total of 1137 liquefiable granular soil layers are identified in the study area. For the M = 7.5 earthquake, a total of 386 layers (about one third) are classified as "likely to liquefy" ($r_u >$ 90%). As shown in Tables 4-I and 4-II, about 62% of the total identified liquified soil layers are less than 10 feet in thickness, and about 60% of the total liquefied soil layers are below a depth of 25 feet.

TABLE 4-I Thickness of the Liquefied Soil Layers
(M = 7.5 NMSZ Earthquake)

THICKNESS (FT)	NO. OF LAYERS	% OF THE 386 LIQUEFIED SOIL
0-5	72	18.7
5-10	166	43
10-20	101	26.2
>20	47	12.1

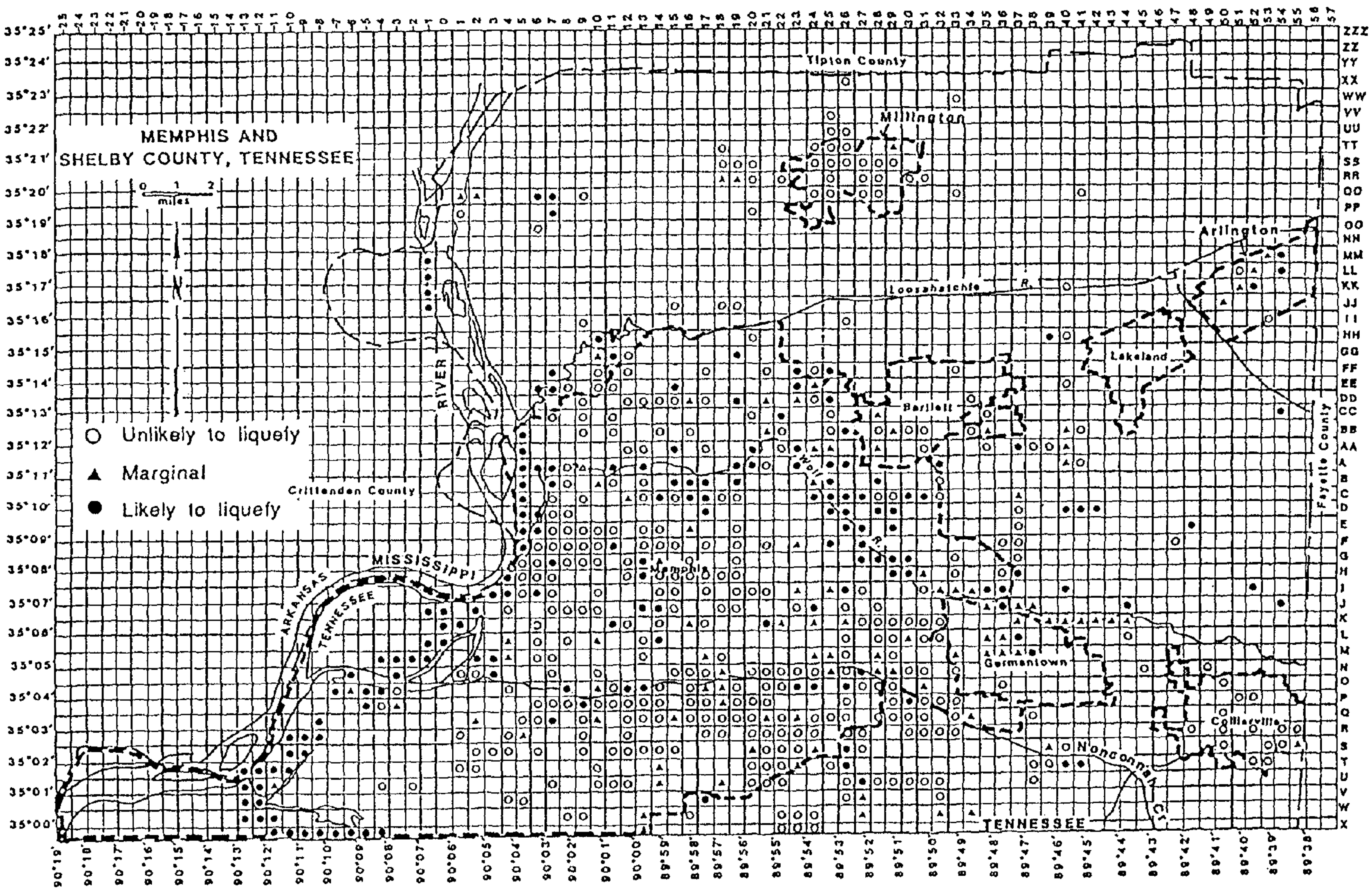


FIGURE 4-6 Site Liquefaction Potential of Memphis and Shelby County for Soils Between 0-25 Feet Based on CERI Criteria (M = 7.5, Southern NMSZ)

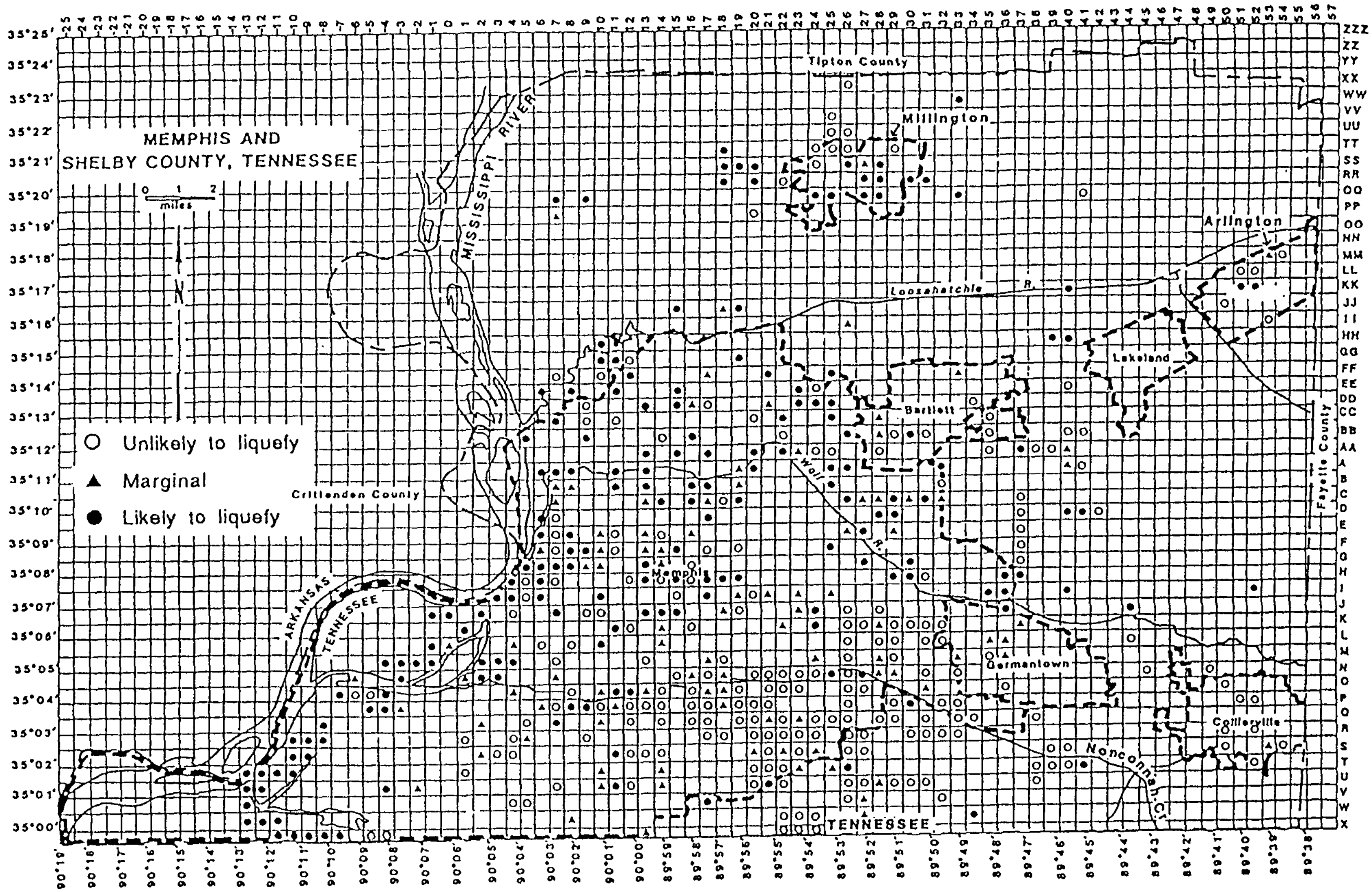


FIGURE 4-7 Site Liquefaction Potential of Memphis and Shelby County for Soils Between 25-50 Feet Based on CERI Criteria (M = 7.5, Southern NMSZ)

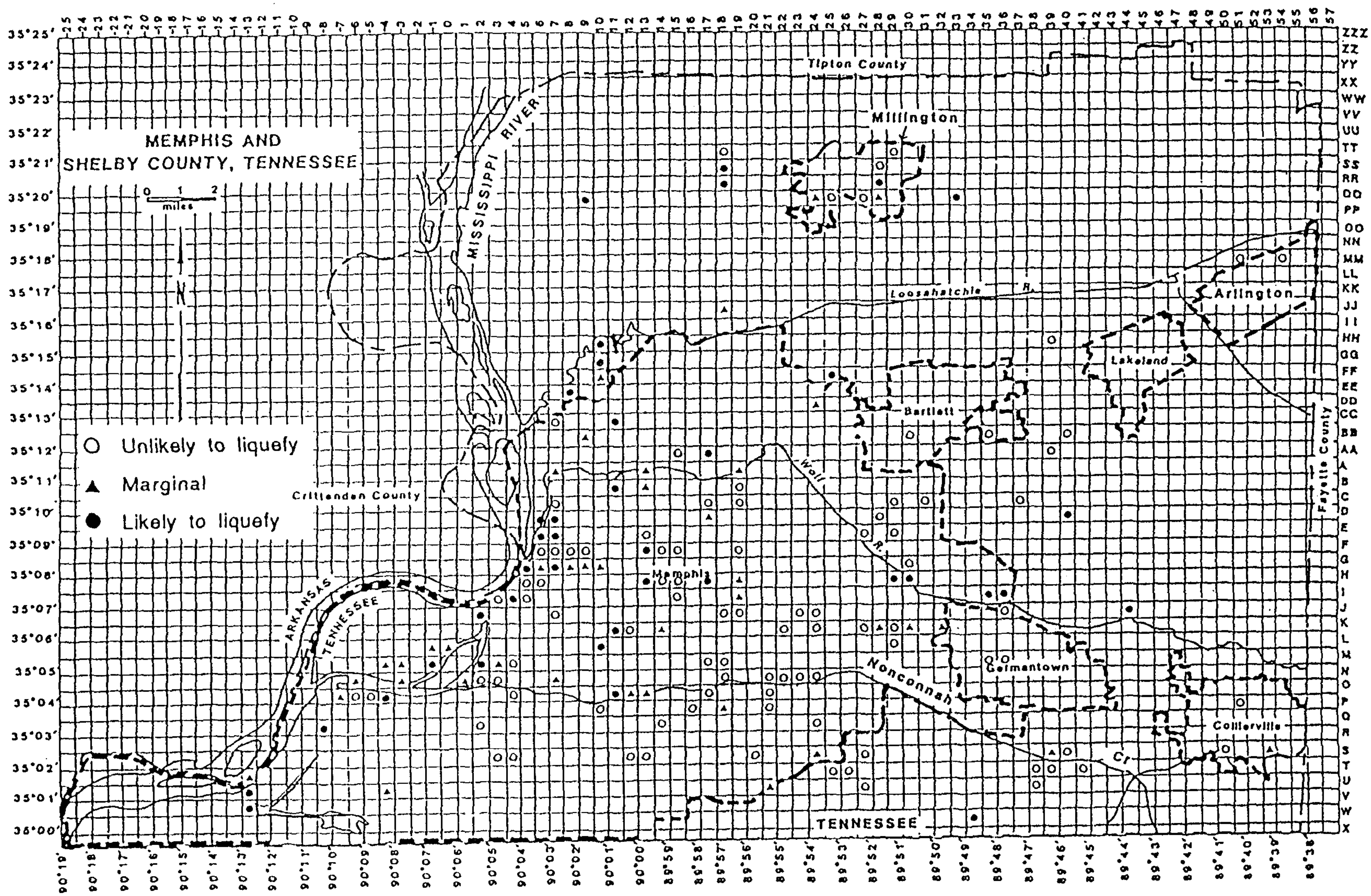


FIGURE 4-8 Site Liquefaction Potential of Memphis and Shelby County for Soils Between 50-100 Feet Based on CERI Criteria (M = 7.5, Southern NMSZ)

TABLE 4-II Depth of the Liquefied Soil Layers
(M = 7.5 NMSZ Earthquake)

DEPTH (FT)	NO. OF LAYERS	% OF THE 386 LIQUEFIED SOIL
<25	155	40.2
25-50	181	46.8
>50	50	13.0

On the basis of the evaluation results and our understanding of the general geology of the study area, if an M = 7.5 earthquake occurs in the southern NMSZ, we estimate the high liquefaction potential areas include the west side of Memphis along the Mississippi River, and the central and southwest corner of Memphis and Shelby County. These areas are generally in the Mississippi Alluvial Plain and some areas along the three main tributaries of the Mississippi River and between the Wolf River and Loosahatchie River. The low liquefaction potential areas include the central south area and southeast corner of Shelby County including Collierville, part of Germantown, and east of Whitehaven (see figure 4-9). The moderate potential areas are the rest of the study area between the high and low potential region (see figure 4-9). The undefined areas are those areas without adequate soil data.

4.3 Liquefaction Potential Map Corresponding to the M = 6.5 Earthquake

As shown in figure 4-10, the liquefaction potential of the study area is significantly reduced when subjected to an M = 6.5 earthquake using CERI criteria. In general, the high liquefaction potential areas are in the Mississippi Alluvial Plain and the moderate potential area is greatly reduced and limited to several areas in the central north

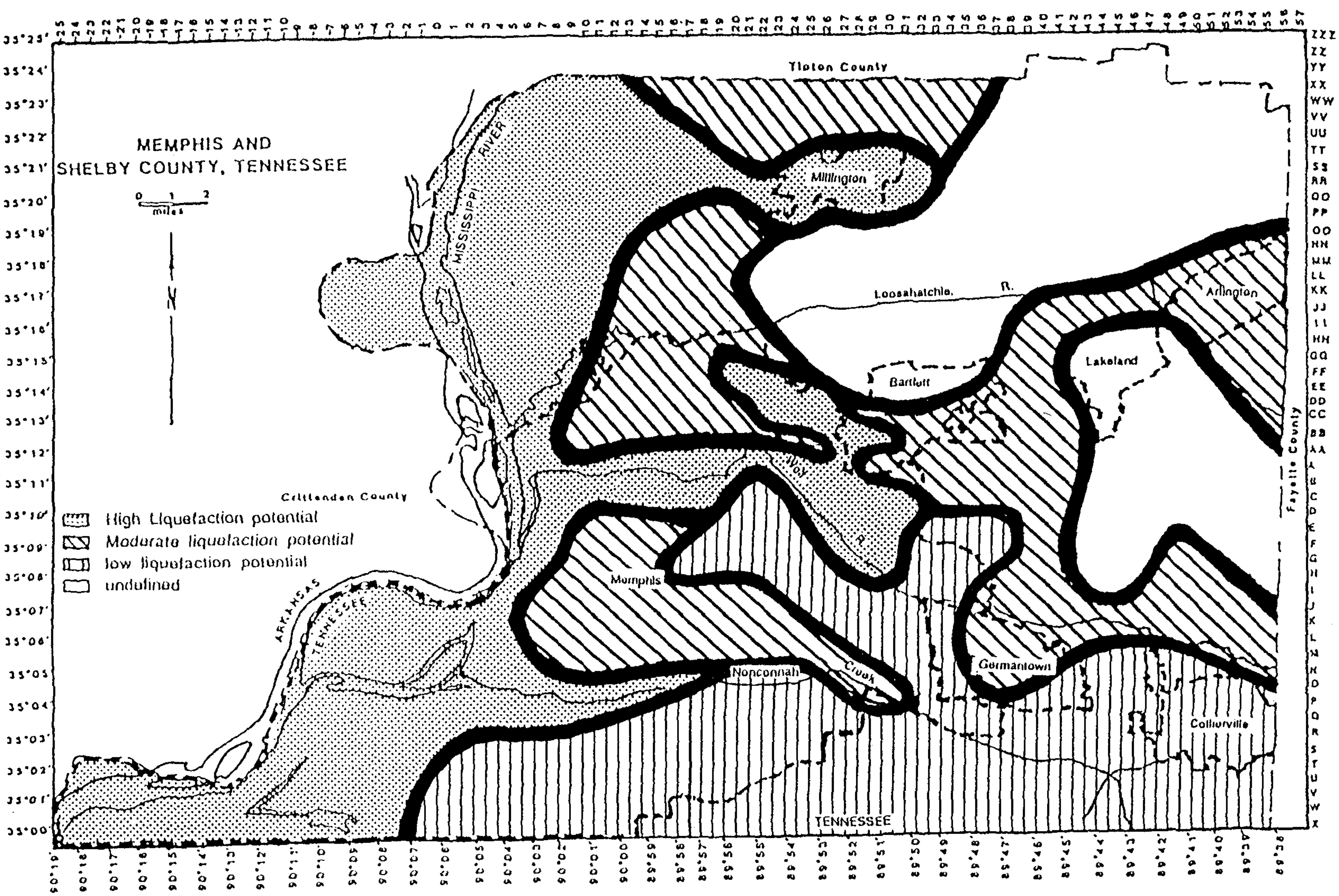


FIGURE 4-9 Liquefaction Potential Map of Memphis and Shelby County Based on CERI Criteria (M = 7.5, Southern NMSZ)

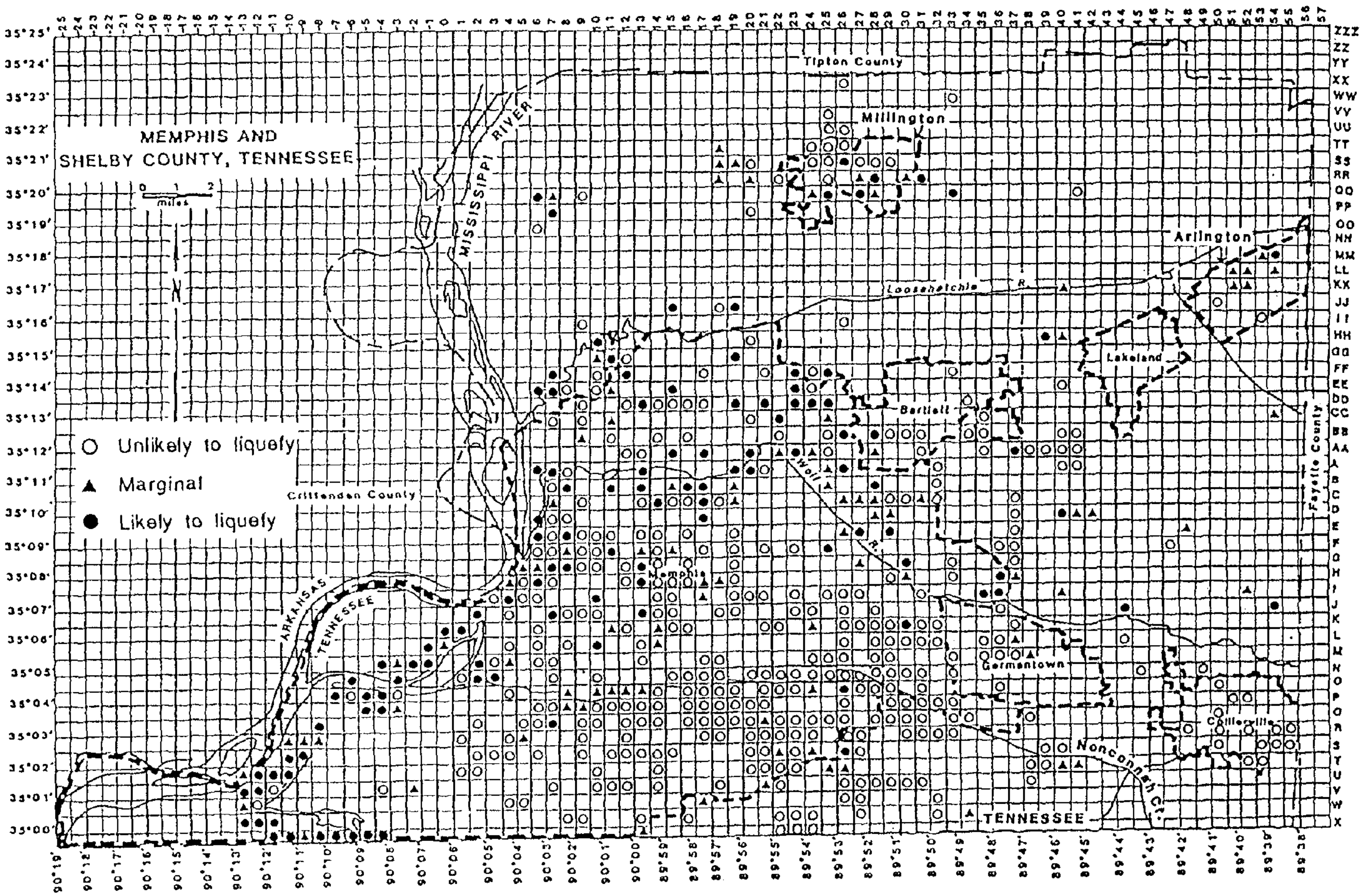


FIGURE 4-10 Overall Site Liquefaction Potential of Memphis and Shelby County Based on CERI Criteria (M = 6.5, Southern NMSZ)

part of the study area. Liquefaction potential maps for depths of 0-25 feet and 25-50 feet are presented in figures 4-11 and 4-12, respectively. On the basis of available soil data, for the M = 6.5 earthquake, a total of 146 liquefied soil layers are identified (about 13% of the total 1137 granular soil layers). As shown in Tables 4-III and 4-IV, about 62% of the liquefied soil layers are less than 10 feet in thickness, and about half (44%) of the liquefied soil layers are below a depth of 25 feet. Since an M = 6.5 earthquake may occur in a foreseeable future, a detailed liquefaction potential evaluation for each individual project site may be required for the design of structures in the high and moderate liquefaction potential areas as indicated in figure 4-13.

TABLE 4-III. Thickness of the Liquefied Soil Layers (M = 6.5 NMSZ Earthquake)

THICKNESS (FT)	NO. OF LAYERS	% OF THE 146 LIQUEFIED SOIL
0-5	23	15.8
5-10	70	47.9
10-20	36	24.7
>20	17	11.6

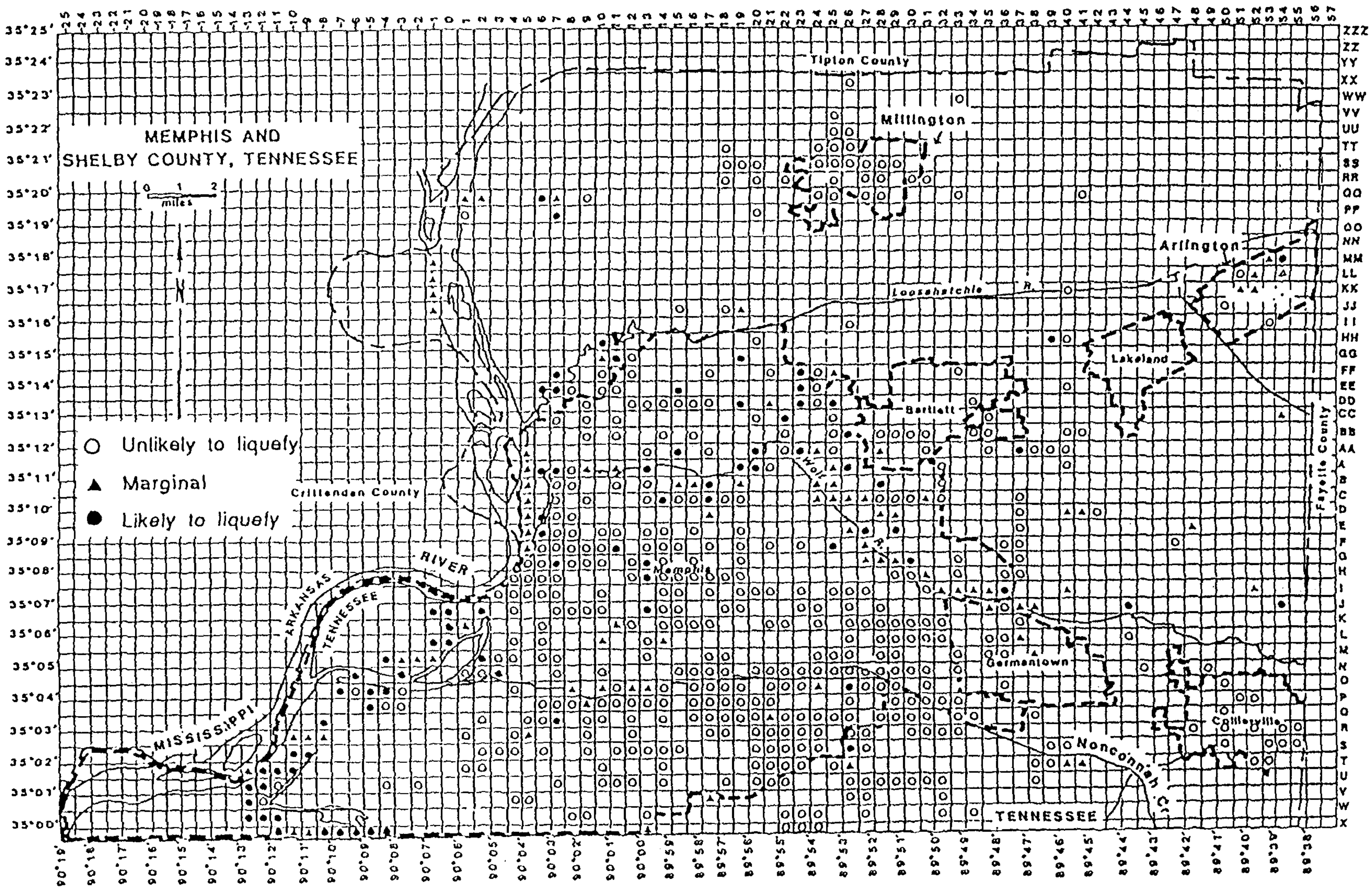


FIGURE 4-11 Site Liquefaction Potential of Memphis and Shelby County for Soils Between 0-25 Feet Based on CERI Criteria (M = 6.5, Southern NMSZ)

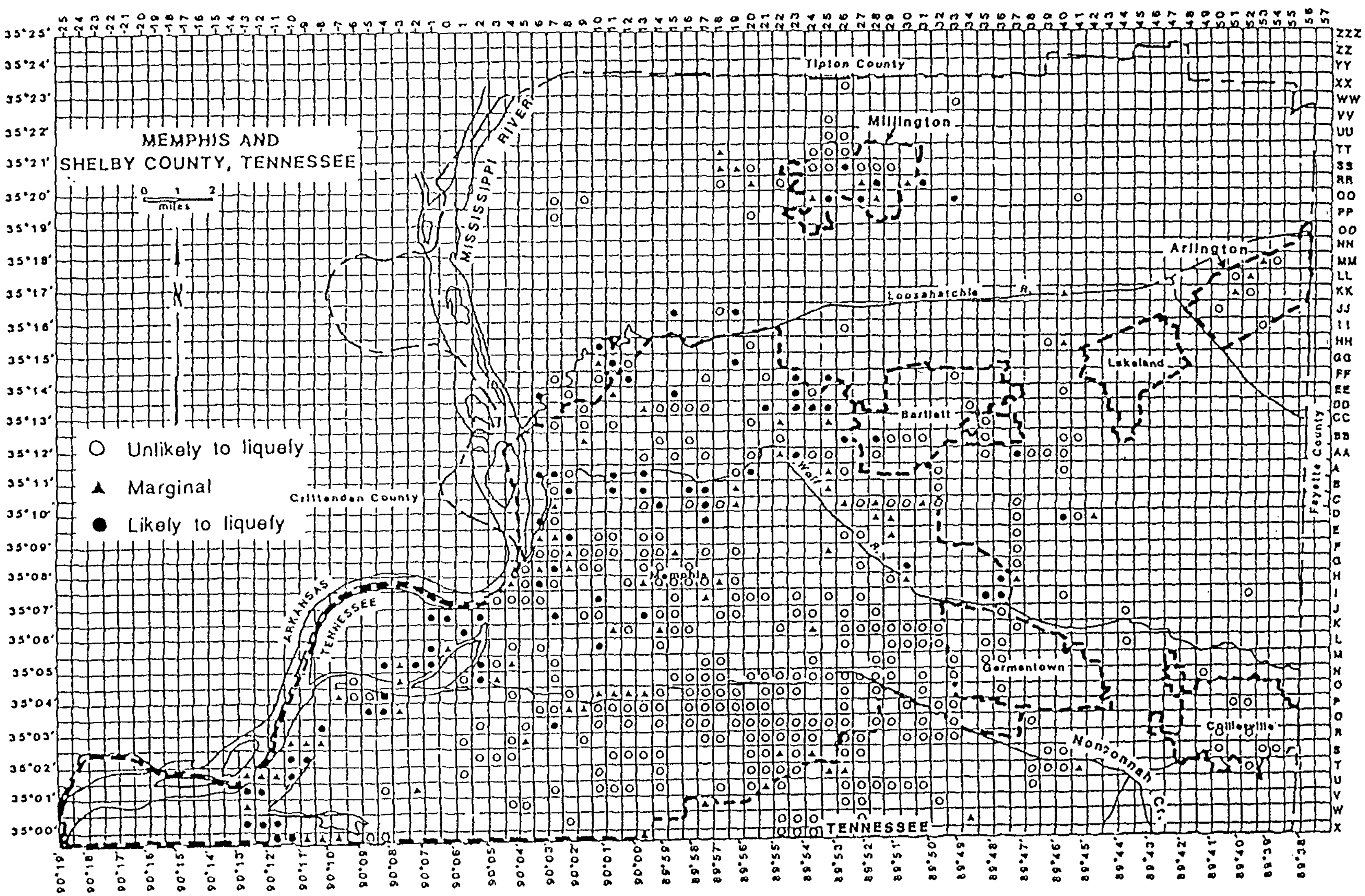


FIGURE 4-12 Site Liquefaction Potential of Memphis and Shelby County for Soils Between 25-50 Feet Based on CERI Criteria (M = 6.5, Southern NMSZ)

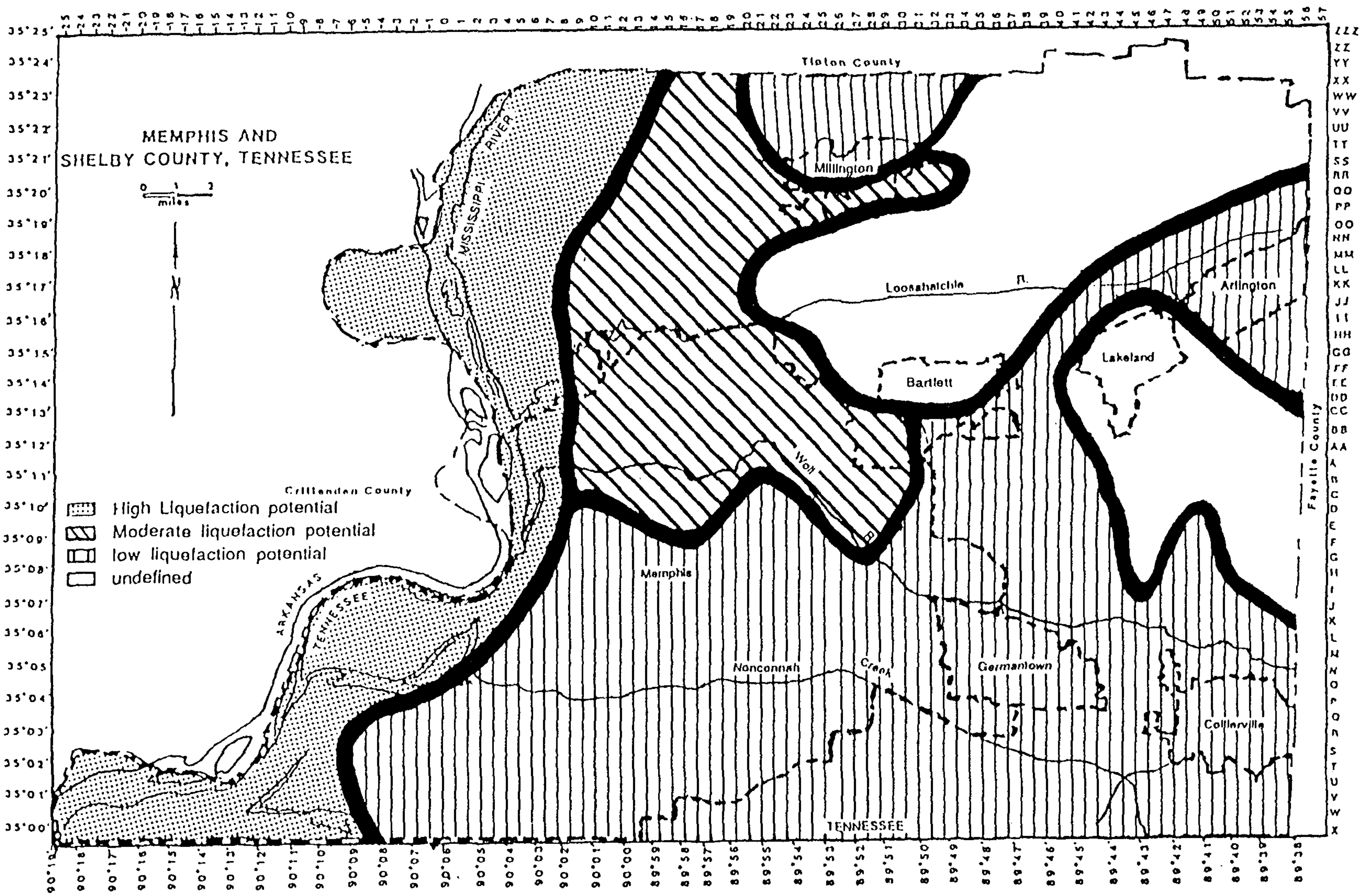


FIGURE 4-13 Liquefaction Potential Map of Memphis and Shelby County Based on CERI Criteria (M = 6.5, Southern NMSZ)

TABLE 4-IV. Depth of the Liquefied Soil Layers (M = 6.5 NMSZ Earthquake)

DEPTH (FT)	NO. OF LAYERS	% OF THE 146 LIQUEFIED SOIL
<25	82	56.2
25-50	52	35.6
>50	12	8.2

SECTION 5

DAMAGE POTENTIAL DUE TO LIQUEFACTION IN MEMPHIS AND SHELBY COUNTY

Several major types of structural or earth failures due to liquefaction have been identified by engineers from postearthquake investigations [2,3,19,25-27]. These include: (1) sink or overturn of structures (total loss of bearing capacity of the foundations as revealed in Niigata earthquake [2,3]), (2) excessive or differential settlement (partial loss of bearing capacity of the foundations), (3) sand boils (liquefied surficial granular soil or artificial granular fill), (4) earth lateral spreading, and (5) landslide.

5.1 Sink or Overturn of Structure (Quick-Condition Failure)

In general, most of the study area is covered by a layer of cohesive material (such as loess (ML, ML-CL) and silty clay (CL)) from the ground surface to a depth to about 30 feet. Obermier [4] indicated quick-condition failures are generally found only in thick sand deposits that extend from below the water table to the ground surface. On the basis of the evaluation results and the general soil conditions, this quick-condition failure is very unlikely to occur in most of the study area. This quick-condition failure, if it happens, is expected to be within the confines of the Mississippi Alluvial Plain area and some areas along the three major tributaries, depending on the site conditions. Nevertheless, the potential of this type of failure is very low in the general study area.

5.2 Excessive or Differential Settlement (Partial Failure)

This type of failure might be the most common failure of foundations that could be caused by liquefaction in the study area. Structures may suffer this type of failure when a major NMSZ earthquake does occur to cause site liquefaction in the Memphis and Shelby County area. The damage of the structure will depend on how much the excess or differential settlement the structure could tolerate. The partial failure of low-rise buildings supported by shallow footings is more likely to occur in the area where liquefied soil layers are within a depth of 25 feet as shown in figures 4-6 and 4-11. This type of failure may also result in cracking and buckling of pavements and floor slabs. The shallow-buried underground utilities (such as water, gas, or sewer lines) are at higher risk of damage in the moderate or high liquefaction potential areas in the event of liquefaction at shallow depths. The liquefaction of granular soils at depths below 25 feet may have significant impacts on spread footings and utilities embedded at the depths close to these liquefied soil layers, say at depths of about 15 feet or below, depending on the size and type of the footings and utilities.

5.3 Sand Boils

Sand boils are expected to occur only in the areas of the Mississippi Alluvial Plain or areas where liquefied granular soils are exposed. Engineering granular fills that were not adequately compacted may be the most commonly encountered sand boils in the study area once a major earthquake occurs.

5.4 Landslide and Lateral Earth Spreading

This type of earth movements strongly depend on the site liquefaction potential and site topography. Youd [28] indicated that limited flow can take place on slopes between 0.5% and 5% underlain by sands or silt that are too dense to flow freely, and landslide can take place on slopes higher than 5%. By combining the liquefaction potential map and topography map in the study area [29], the areas of high potential of lateral earth spread or landslide can be identified as shown in figure 5-1. In addition to these areas, some areas immediately along the main channels in the study area including the bluff between the Mississippi Alluvial Plain and the Gulf Coastal Plain may also have high earth movement potential, even though

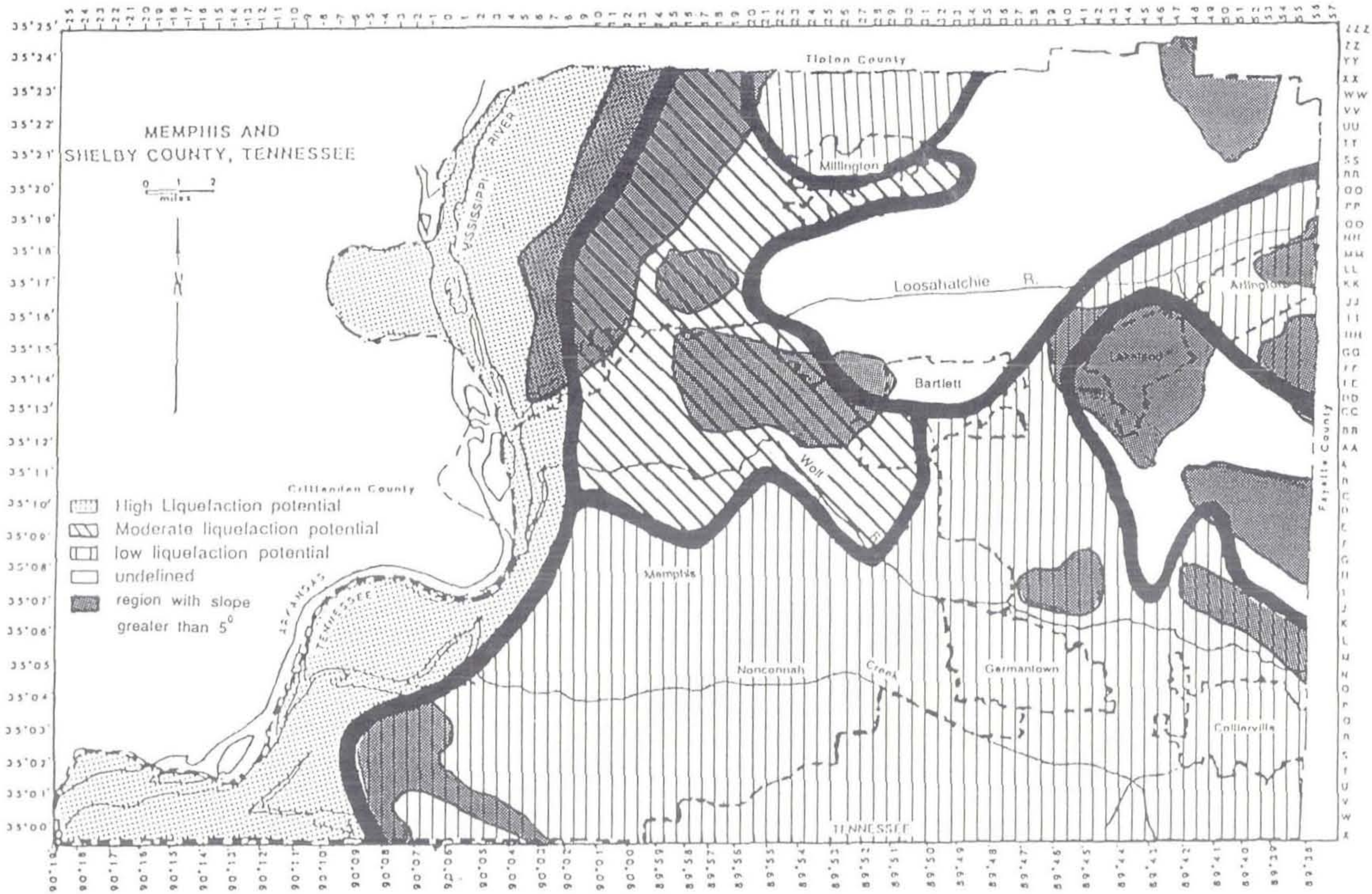


FIGURE 5-1 Potential of Liquefaction and Lateral Earth Movement in Memphis and Shelby County (M = 6.5, Southern NMSZ)

they are located in a low liquefaction potential area, because of critical slope stability condition.

5.5 Mitigation of Damage Due to Liquefaction

For a practical project, when the evaluation indicates that liquefaction potential at the site is high (i.e., liquefaction is likely when subjected to a design earthquake), the damage due to liquefaction should be adequately mitigated. Several possible mitigation measures are discussed below.

5.5.1 Design with Higher Safety Factor

Results of the study indicates that many high liquefaction potential sites in the study area have relatively thin liquefiable soil layers (thickness < 10 feet) situated at depths below 25 feet. The relatively thin granular soil layers contribute only a fraction of the bearing capacity of conventional shallow footings and deep foundations. A proper design with a higher safety factor may be the simplest way to reduce the risk of foundation failure due to liquefaction in some thin layers of the supporting soils.

5.5.2 Earth Retaining Structure

For the high liquefaction potential sites where topography is not flat, e.g., slopes steeper than 3° as recommended by Youd [16], the lateral earth movements such as lateral spread or landslide should be studied to understand the stability of the slopes if liquefaction were to occur in the earth mass. Earth-retaining structures should be constructed when necessary to reduce the risk of slope failure during earthquakes.

5.5.3 Site Improvements

The liquefaction potential of sites can be significantly reduced by many geotechnical field techniques. One or more of the following can be used for liquefaction-prone sites based on the particular site conditions and proposed construction:

1. In situ densification of liquefaction vulnerable soils by means of dynamic compaction, vibratory compaction, surcharging, or other suitable methods.

2. Chemical grouting to solidify the soil structure of liquefaction-susceptible soils.

3. Removal and replacement of liquefaction-susceptible soils.

SECTION 6

CONCLUSIONS

The overall liquefaction potential evaluations in Memphis and Shelby County are performed using both Seed's general criteria and the criteria developed by CERI from the results of a soil pore pressure study of 22 selected representative sites. By using the selected criteria, available soil boring data containing in situ density (N-blow counts) of granular soils and contour maps of peak bedrock acceleration, the general liquefaction potential maps are derived for M = 7.5 and M = 6.5 earthquakes in southern NMSZ. For the M = 7.5 NMSZ earthquake, the high potential areas are the Mississippi Alluvial Plain, and the central and northwest corner of Shelby County. The low potential areas are in the central south and southeast corner of the study area. Results also show most of the liquefied granular soil layers have a thickness of less than 10 feet and are situated at depths below 25 feet. The results show the liquefaction potential is significantly reduced in the study area subjected to an M = 6.5 earthquake (see figures 4-9 and 4-13).

Results also show that very few sites have liquefied soil layers with a thickness of more than 30 feet extending from below ground water level to the ground surface. This indicates the mode of foundation failure due to liquefaction in the study area may be limited to the partial failure of supporting soils, causing excessive or differential settlement of structures, cracking, and buckling of pavements and floor slab on grade. The damage potential of low-rise structures and shallow-buried facilities may be high in the moderate to high liquefaction potential areas as indicated in the liquefaction potential maps of 0-25 feet (figures 4-6 and 4-11). The potential of earth movements such as land slide or lateral earth spreading are identified by combining the liquefaction potential map and the topography map of the study area (figure 5-1). Such areas include the bluff areas along the Mississippi River, the northwest and southwest corners of Shelby County, the areas west of Bartlett and between the Loosahatchie River and the Wolf River, and some areas immediately along the three main tributaries of the Mississippi Rivers.

In general, the results of the evaluation are in good agreement with our understanding of geological conditions in the study areas. The liquefaction potential strongly depends on the proximity of the sites to the NMSZ and the presence of granular alluvial soils deposited on sites along the main channels (the Wolf River, Nonconnah Creek and Loosahatchie River) and in the Mississippi Alluvial Plain (west of the bluff and approximately parallel to the Mississippi River). Detailed site liquefaction evaluations for particular construction projects at particular locations should be performed if the project sites are located in the moderate or high potential areas.

SECTION 7

REFERENCES

1. Ng, K. W., Chang, T. S., Hwang, H. H. M., "Subsurface Conditions of Memphis and Shelby County," Technical Report NCEER-89-0021, National Center for Earthquake Engineering Research, SUNY, Buffalo, N. Y., July, 1989.

2. Committee on Earthquake Engineering, "Liquefaction of Soils During Earthquakes," Commission on Engineering and Technical Systems, National Research Council, N. W., Washington D. C., 1985.

3. Seed, H. B., Idriss, I. M., "Ground Motions and Soil Liquefaction During Earthquakes," Earthquake Engineering Research Institute, Berkeley, CA, 1982.

4. Obermeier, S. F., "Liquefaction Potential in the Central Mississippi Valley," Technical Report 1832, U. S. Geological Survey Bulletin, Denver, CO, 1988, pp. 1-6.

5. Jibson, R. W., Keefer, D. K., "Landslides Triggered by Earthquakes in the Central Mississippi Valley, Tennessee and Kentucky," Professional Paper 1336-C, U. S. Geological Survey, Denver, CO, 1988, pp. C1-C9.

6. Ohsaki, Yoshiko, "Niigata earthquakes, 1964, Building Damage and Soil Conditions," Soil and Foundation, Vol. VI No. 2, March, 1966, pp. 14-37.

7. Seed, H. B., Idriss, I. M., "Simplified Procedure for Evaluating Soil Liquefaction Potential," ASCE, Vol. 97, SM9, September, 1971.

8. Seed, H. B., Idriss, I. M., "Evaluation of Liquefaction Potential using Field Performance Data," Jnl. Geotechnical Div., ASCE, 1982.

9. Hwang, H. H. M., Chen, C. H., Yu, G., "Bedrock Accelerations in Memphis Area Due to Large New Madrid Earthquakes," Technical Report NCEER-89-0029, National Center for Earthquake Engineering Research, SUNY, N. Y., November, 1989.

10. Seed, H. B., Lee, K. L., "Liquefaction of Saturated Sands During Cyclic Loading," Journal of the Soil Mechanics and Foundations Division, ASCE Vol. 97, 1966.

11. Martin, P. P., Seed, H. B., "MASH---A Computer Program for the Non-linear Analysis of Vertically Propagating Shear Waves in Horizontally layered Deposits," Report No. EERC 72-12, Earthquake Engineering Research Center, University of California, CA, December, 1972.

12. Martin, P. P., Seed, H. B., "Apollo---A Computer Program for the Analysis of Pore Pressure Generation and Dissipation in Horizontal Sand layers During Cyclic or Earthquake Loading," Report No. EERC 78 - 21, Earthquake Engineering Research Center, U. of C., Berkeley, CA, Oct., 1978.

13. Hwang, H. H. M., Lee, C. S., Ng, K. W., Chang, T. S., "Soil Effects on Earthquake Ground Motions in the Memphis Areas," NCEER Technical Report (to be published).

14. Hwang, H. H. M., Lee, C. S., "Site-Specific Response Spectra for Memphis Sheahan Pumping Station," Technical Report NCEER-90-0007, National Center for Earthquake Engineering Research, SUNY, N. Y., May, 1990.

15. Chang, T.S., "Dynamic Properties of Typical Mamphis Soils," Technical Report CERI-90-02, Center for Earthquake Research and Information, Memphis State University, Memphis, TN, September 15, 1990.

16. Creager, W. P., Justin, J. D., Hinds, T., "Engineering for Dams," Vol. III, John Wiley and Sons, London, 1947.

17. Lee, K. L., Albeisa, A., "Earthquake Induced Settlements in Saturated Sands," Report No. GT-4, Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 100, April, 1974.

18. Budhu, M., "Liquefaction Potential of Surficial Deposits in the City of Buffalo, New York," Technical Report NCEER-87-0036, National Center for Earthquake Engineering Research, SUNY, N. Y., January, 1989.

19. Castro, G., "On the Behavior of Soils During Earthquakes -- Liquefaction," in Soil Dynamics and Liquefaction, Development in Geotechnical Engineering, Vol. 42, 1987, pp. 169-205.

20. Richart, F. E. Jr., Hall, J. R. Jr., Woods, R. D., "Vibrations of Soils and Foundations," Prentice Hall, Inc., Englewood Cliffs, N. J., 1970.

21. Ueng, T. S., Chang, C. S., "The Effect of Clay Contents on Liquefaction of Fulung Sand, "Proceedings of the Seventh Southeast Asian Geotechnical Conference, November, 1982.

22. Johnston, A. C., "Seismic Ground Motions in Shelby County, Tennessee, Resulting from Large New Madrid Earthquakes," Technical Report of Center for Earthquake Research and Information, Memphis State University, January, 1988.

23. Seed, H. B., "Design Problems in Soil Liquefaction," Report No. NSF/ENG-86-011, National Science Foundation, U. of California, Richmond, CA, February, 1986.

24. Chang, T. S., Hwang, H., Ng, K. W., Lee, C. S., "Subsurface Conditions in Memphis and Shelby County, Tennessee," Second International Conference on Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, MO., March, 1991.

25. Obermeier, Stephen F., "The New Madrid Earthquakes: An Engineering Geologic Interpretation of Relict Liquefaction Features," Professional Report 1336-B, U. S. Geological Survey, 1989.

26. Ferrito, John M., "Evaluation of Earthquake-Induced Ground Failures," Report No. 82-880, U. S. Geological Survey, 1982.

27. Schuster, Robert L., Raymond, J. Krizek, "Landslides--Analysis and Control," Special Report 176, National Academy of Sciences, Washington, D. C., 1978.

28. Youd, T. L., "Geologic Effects--Liquefaction and Associated Ground Failures," Report No. 84-760, Proceedings of Geologic and Hydraulic Hazards Training Program, U. S. Geological Survey, 1984, pp. 210-232.

29. Whittenberg, P. L., et al., "Natural and Physical Characteristics of Memphis and Shelby County," Office of Planning and Development, Memphis and Shelby County, November, 1977.

APPENDICES

APPENDIX A
Results of Parametric Liquefaction Potential Study

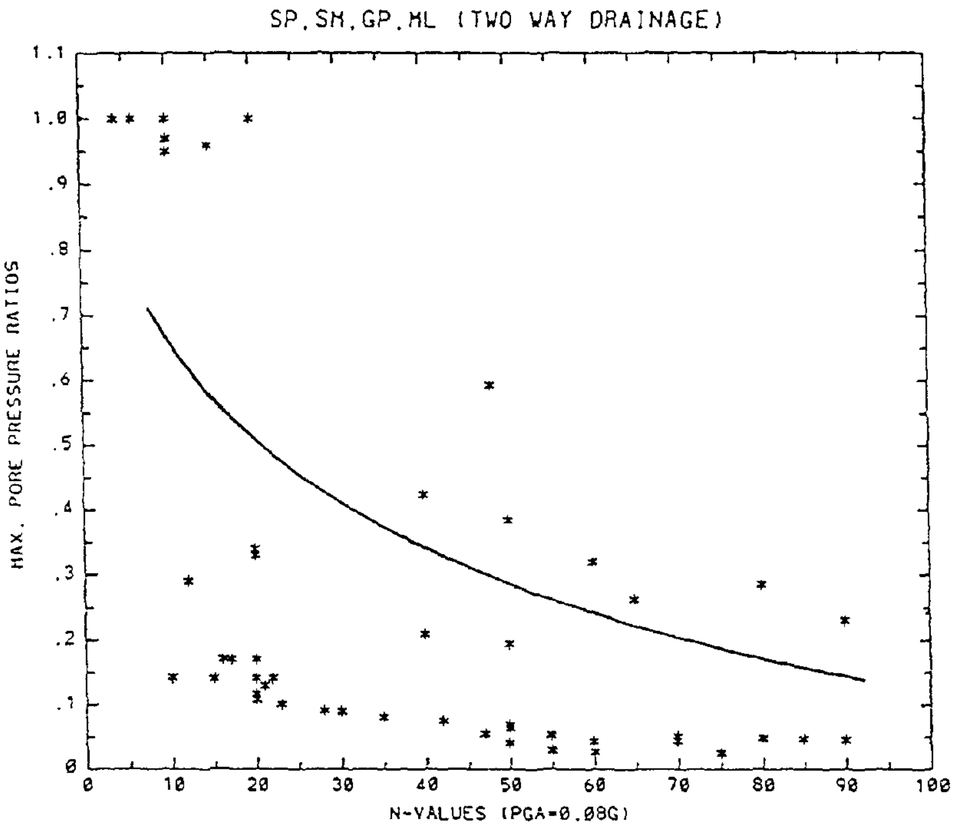


FIGURE A-1 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (Two-Way Drainage,0.08 g)

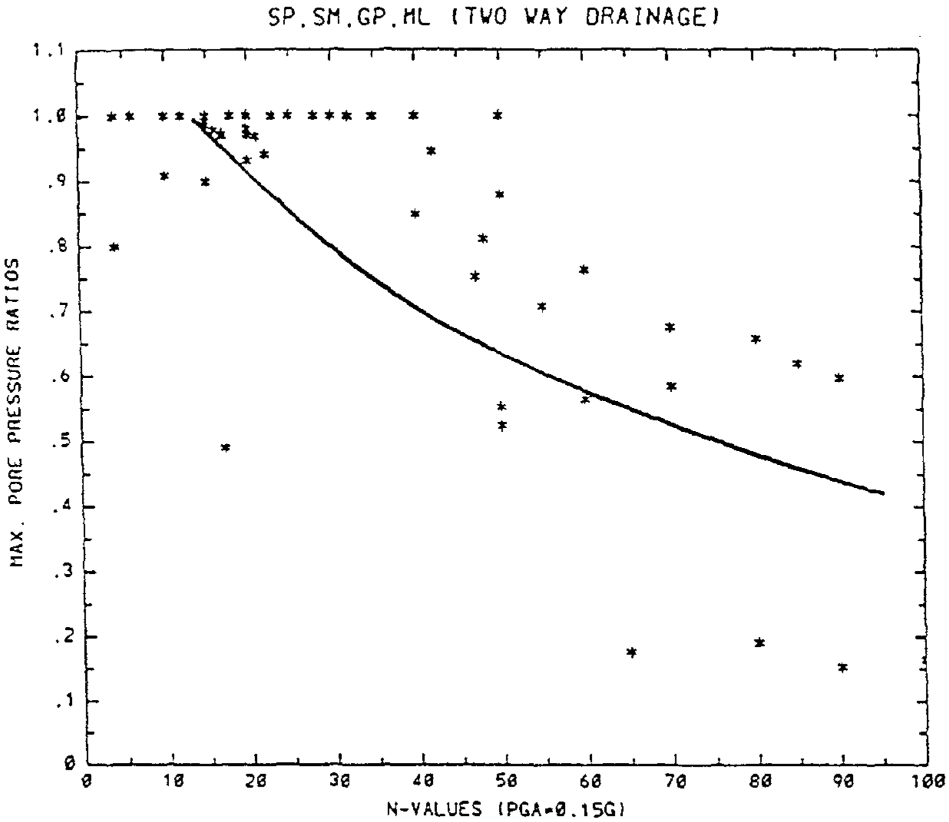


FIGURE A-2 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (Two-Way Drainage, 0.15 g)

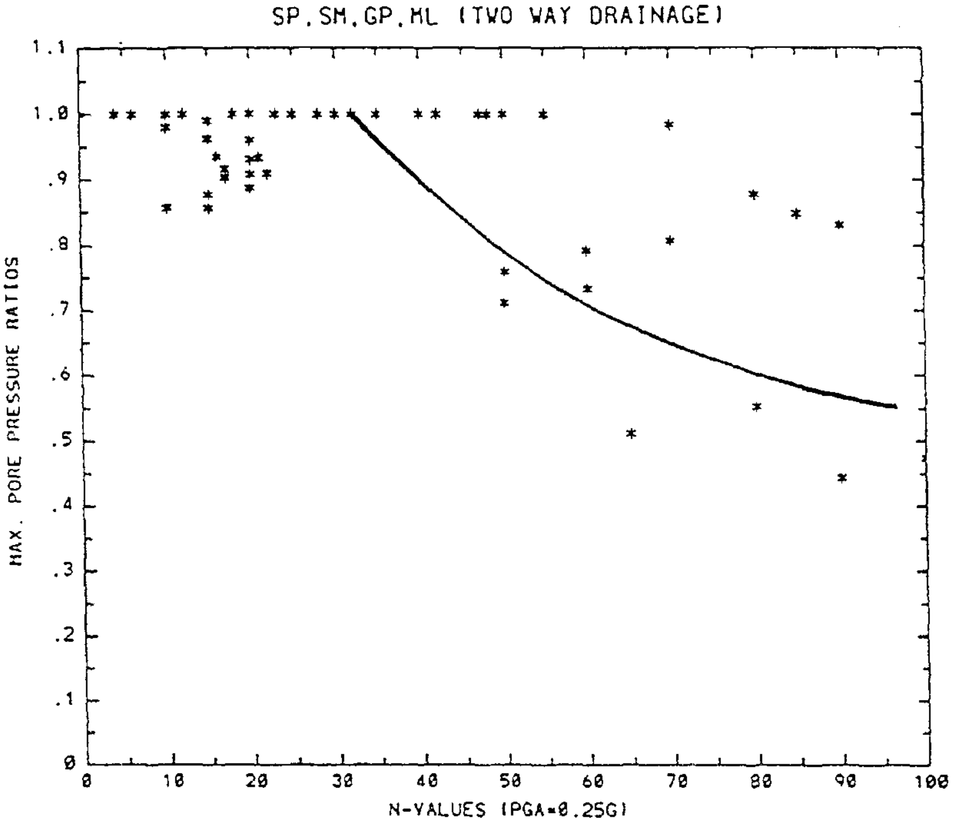


FIGURE A-3 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (Two-Way Drainage, 0.25 g)

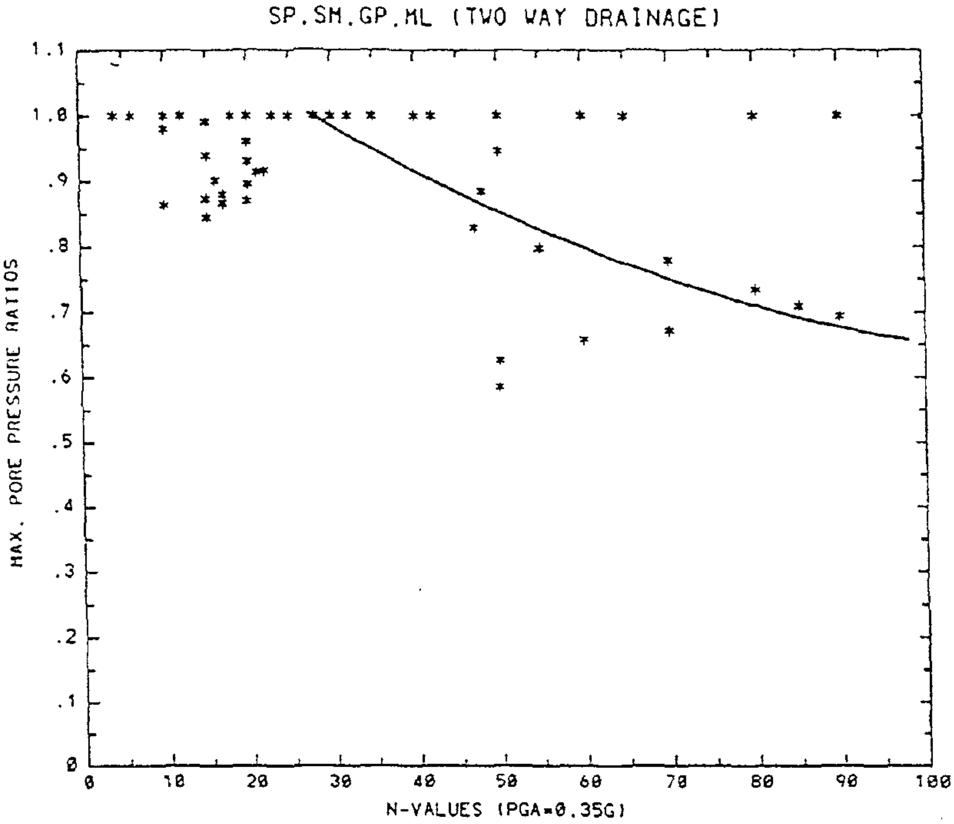


FIGURE A-4 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (Two-Way Drainage, 0.35 g)

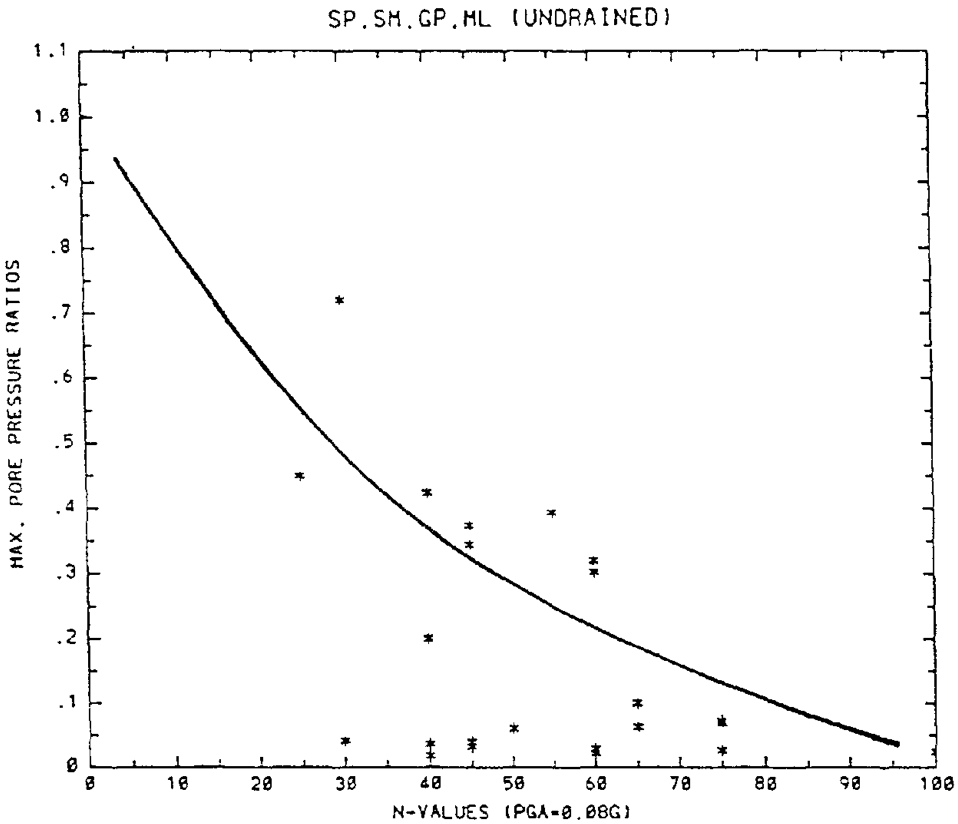


FIGURE A-5 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (Undrained, 0.08 g)

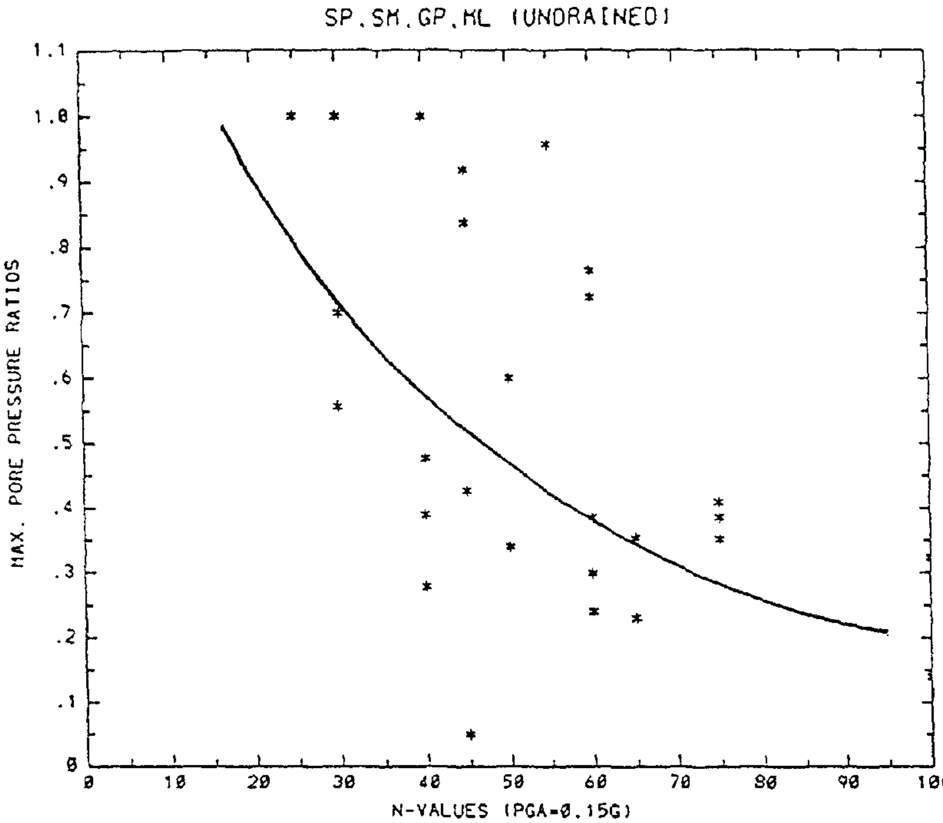


FIGURE A-6 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (Undrained, 0.15 g)

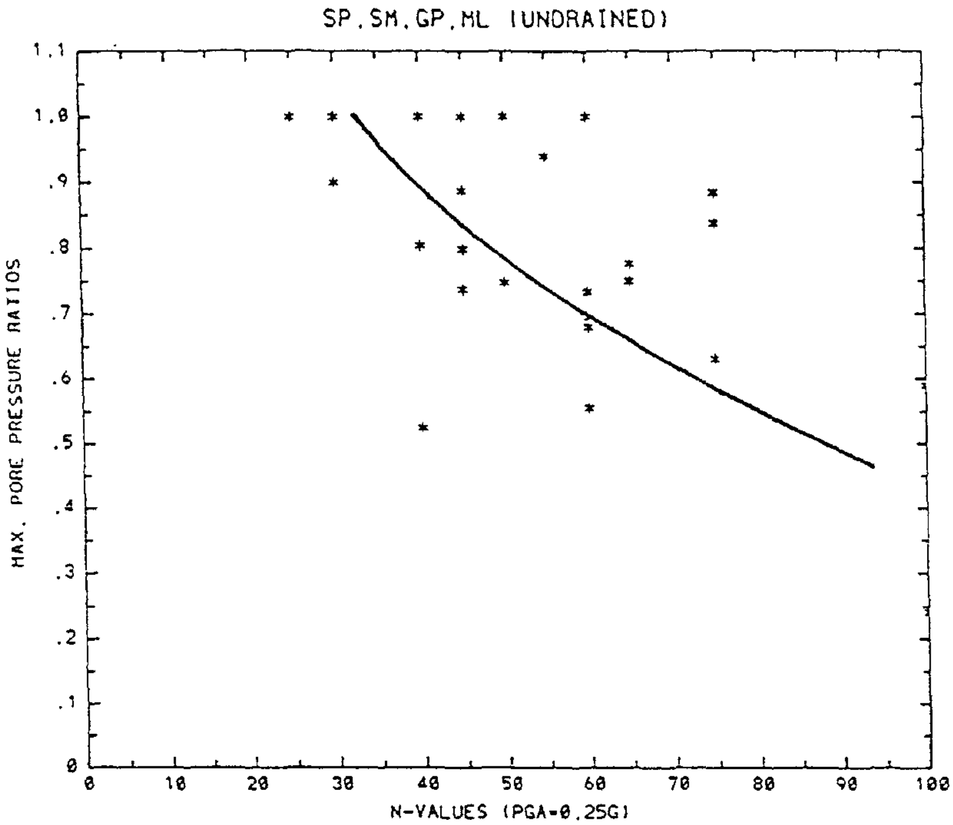


FIGURE A-7 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (Undrained, 0.25 g)

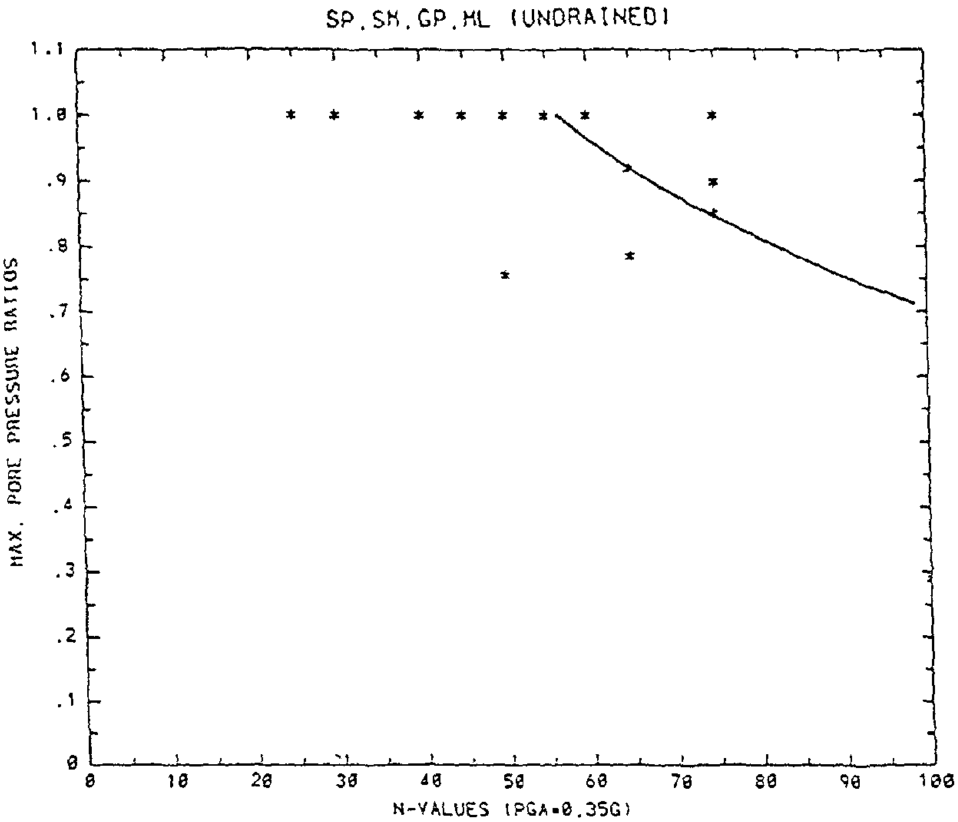


FIGURE A-8 Pore Pressure Ratios vs. In Situ N-Values for SP-SM-GP-ML (Undrained, 0.35 g)

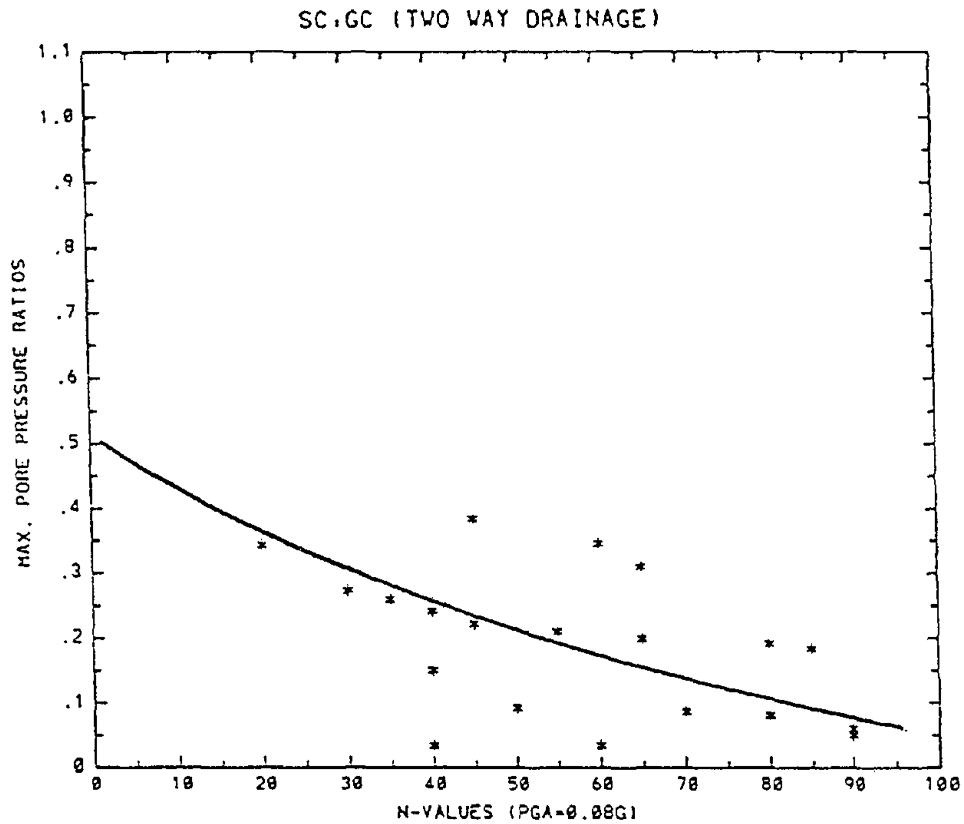


FIGURE A-9 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (Two-Way Drainage, 0.08 g)

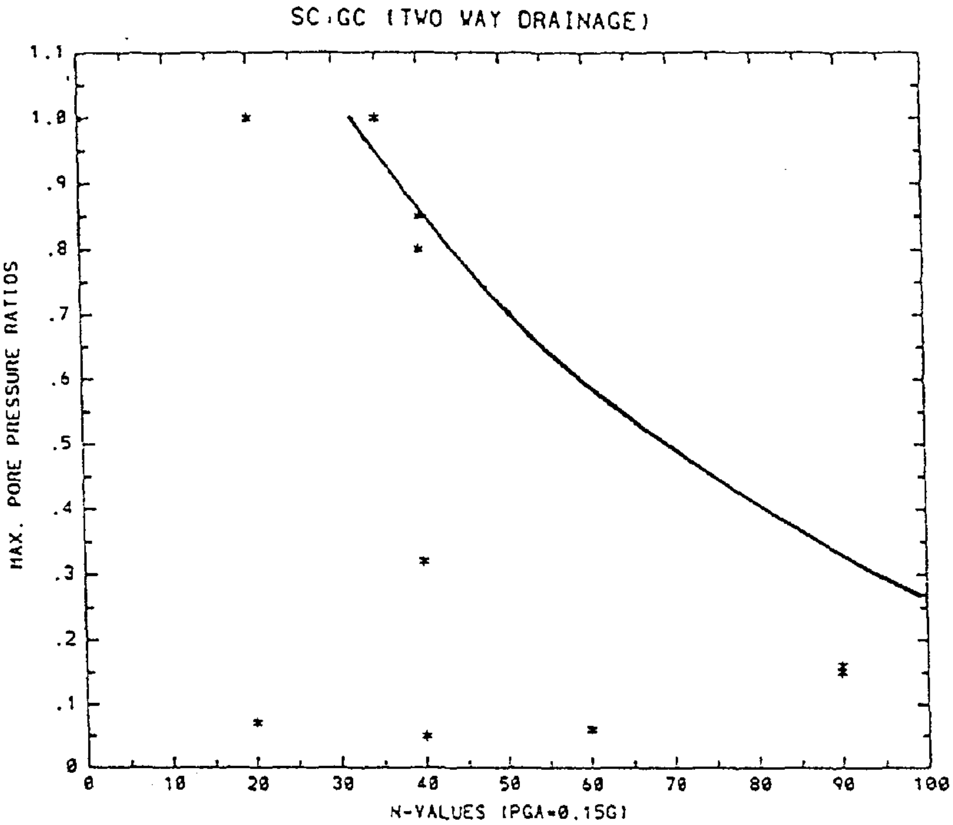


FIGURE A-10 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (Two-Way Drainage, 0.15 g)

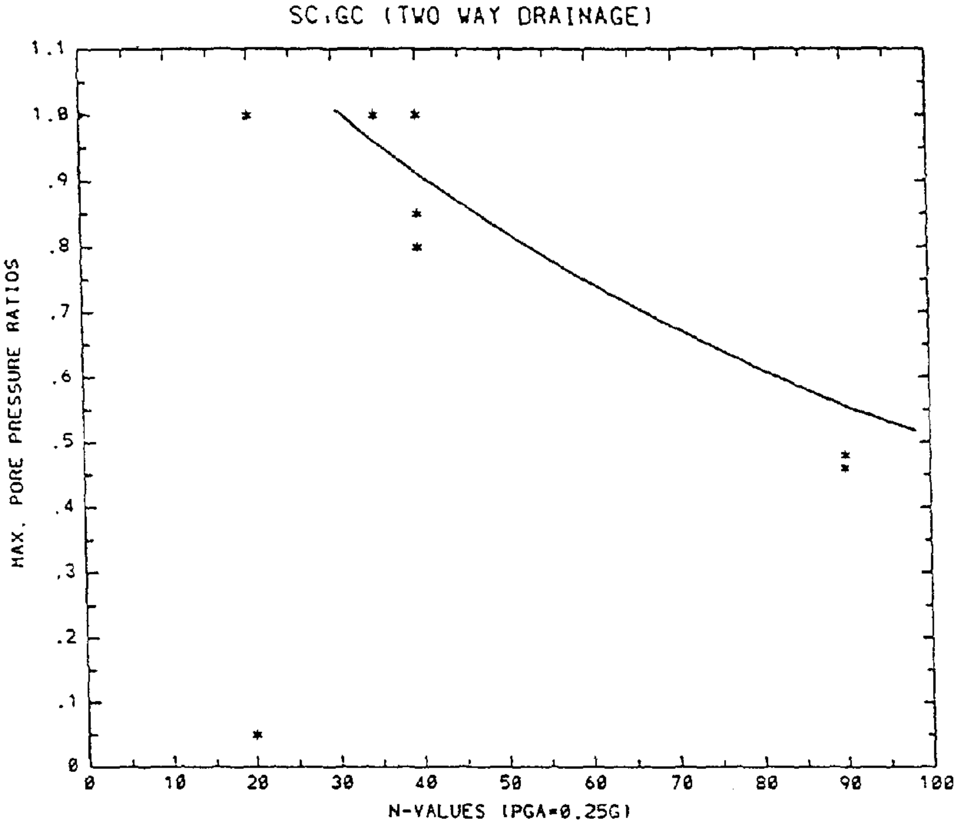


FIGURE A-11 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (Two-Way Drainage, 0.25 g)

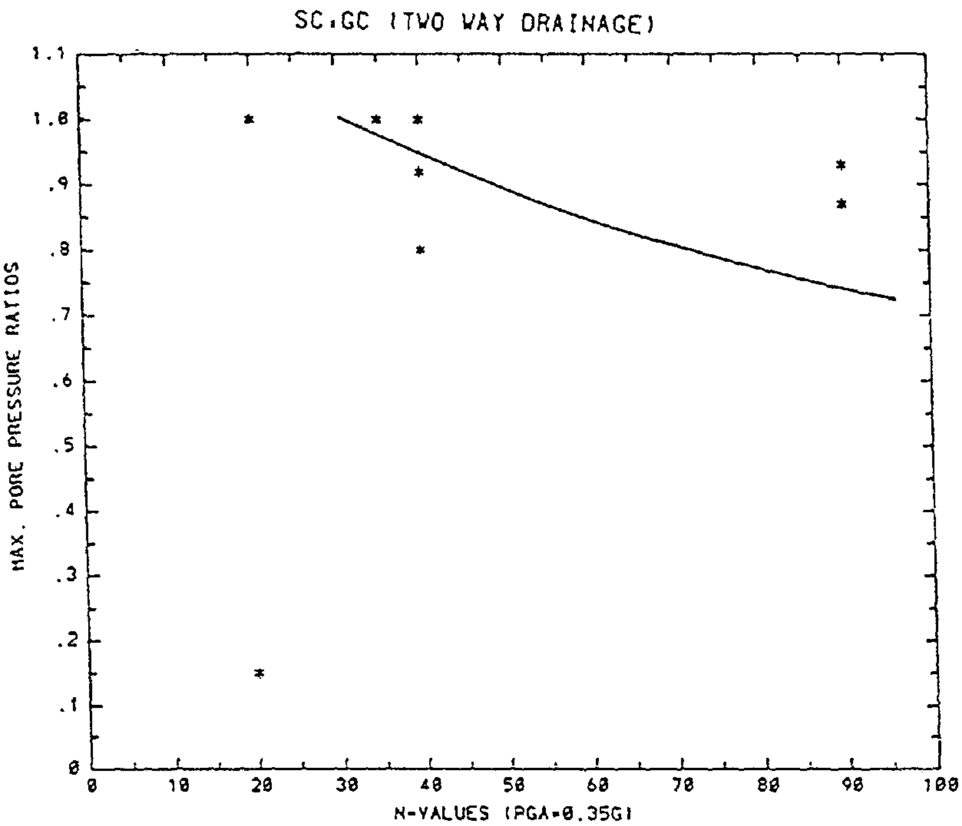


FIGURE A-12 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (Two-Way Drainage, 0.35 g)

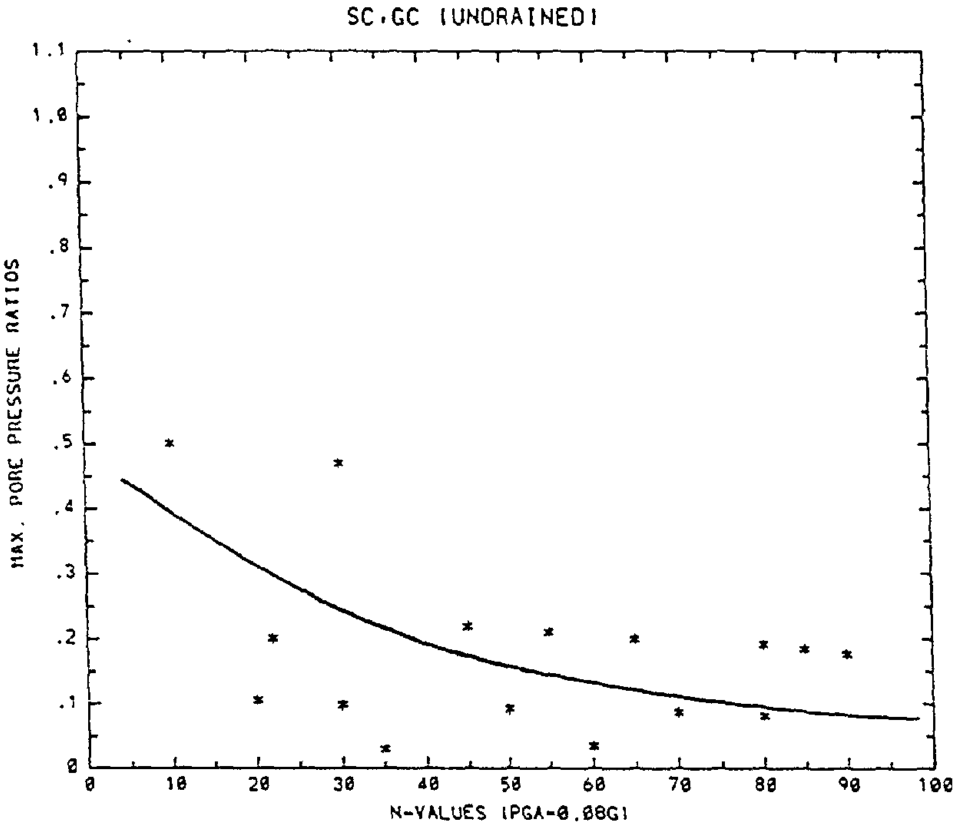


FIGURE A-13 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (Undrained, 0.08 g)

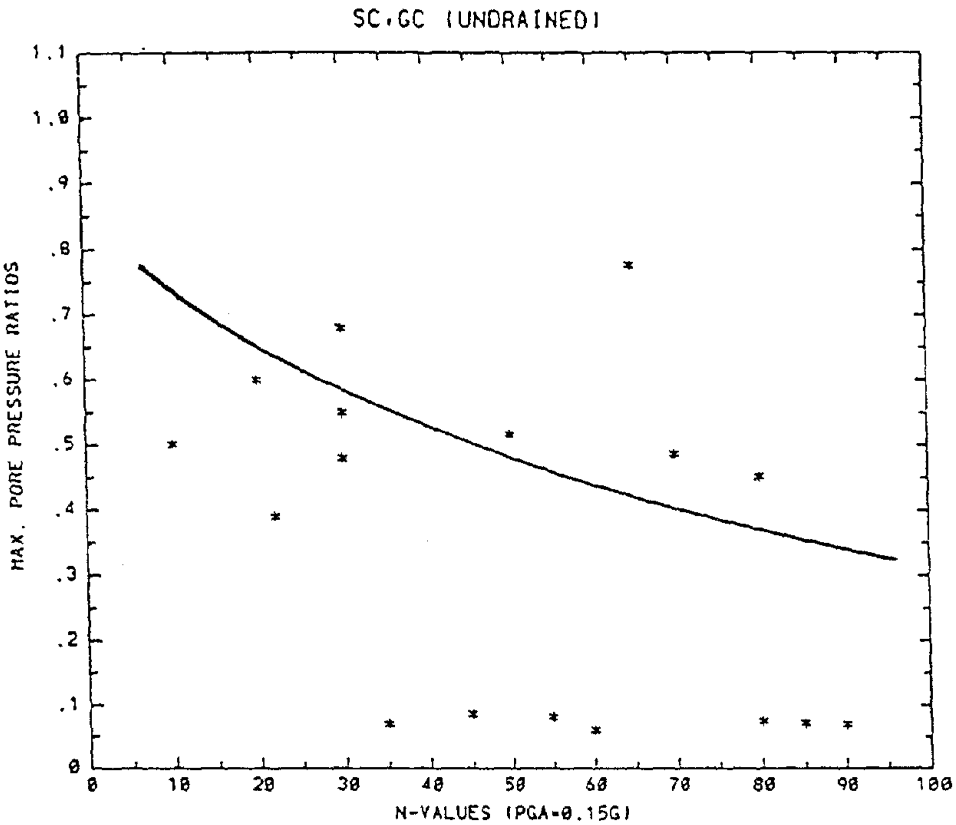


FIGURE A-14 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (Undrained, 0.15 g)

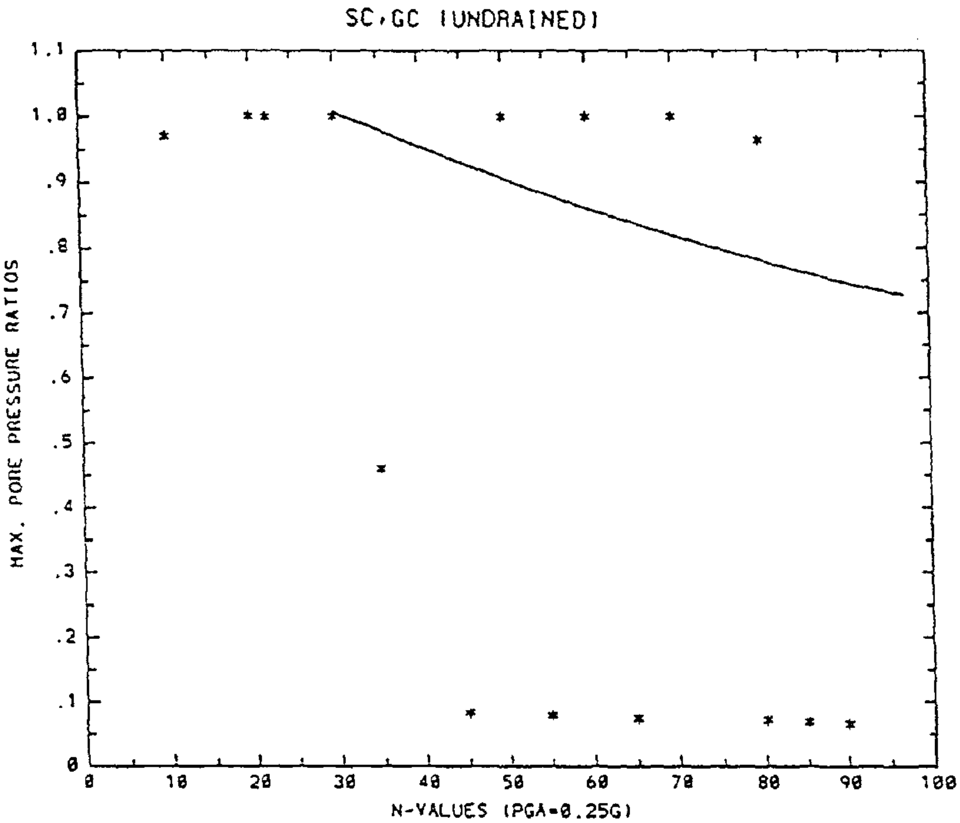


FIGURE A-15 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (Undrained, 0.25 g)

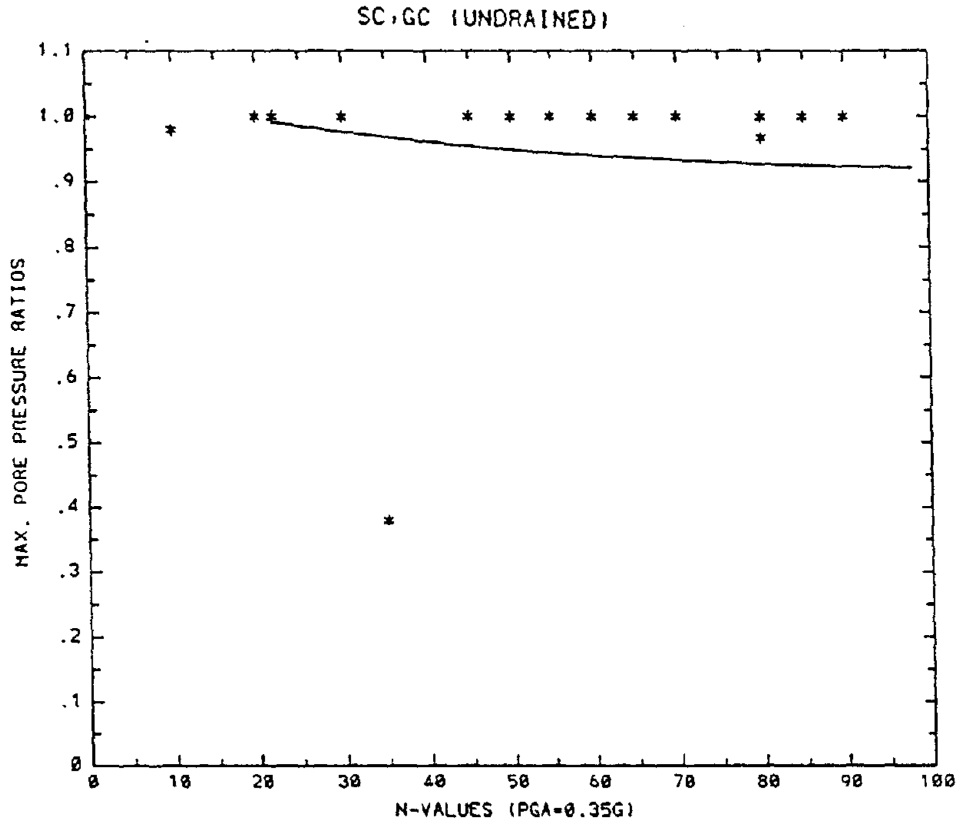


FIGURE A-16 Pore Pressure Ratios vs. In Situ N-Values for SC-GC (Undrained, 0.35 g)

Appendix B

Summary of Site Liquefaction Potential Evaluation in Memphis and Shelby County

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
K31	41	SC/SP	50	21.5	17	D1	0.128/0.154	Un	N	0.079	Un		
		SC/SP	50	35.5	11	D1	0.128/0.152	Un	N		Un		
K32	50	SC/SM	60	24	12	D1	0.159/0.153	Un	N	0.0785	Un		
		SC/SM	40	36.5	13	D2	0.159/0.153	Un	N		Un		
		SM/SP	35	46.5	7	D2	0.159/0.153	M	N		Un		
K37	40	SC	16	25	6	UD	0.162/0.148	M	N	0.0765	Un		
K39	20												No data
K40	25												No data
K41	25												No data
K42	25												No data
K43	25												No data
K44	25												No data
L(-1)	61	SP	12	4	8	D2	0.159/0.186	L	N	0.0955	L		
		SP	28	15.5	15	D2		L	N		M		
		SM	15	26.5	7	D2		L	N		L		
		SP/SM	22	36.5	13	D2		L	N		M		
		SP	40	52	18	D2		M	N		Un		

CERI Criteria:
- Un: Unlikely to Liquefy
- M: Marginal
- L: Likely to Liquefy

Seed's Criteria:
- N: Not Liquefied
- Y: Liquefied

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
LO	100	SP	18	14	28	D1	0153/0.185	L	N	0.0945	M		
		SM/SP	28	43	10	D1		M	N		Un		
		SP	43	61	26	D2		M	N		Un		
		SP	60	79	10	D2		Un	N		Un		
		SP	55	92	16	D2		Un	N		Un		
L4	28	SC	30	25	6	D1	0.155/0.18	M	N	0.0925	Un		
L6	28	SC	60	25	6	D1	0.157/0.159	Un	N	0.091	Un		
L8	30	ML/CL											All Clay
L10	100	SM/GP	20	19.5	15	D1	0.122/0.175	M	N	0.0895	M		
		SP/SC	16	32	10	D2		L	N		L		
		SC/SP	20	44.5	15	D2		M	N		M		
L10	100	SP	22	64	24	D2	0.122/0.175	L	N	0.0895	M		
		SP	42	82	12	D2	0.122/0.175	Un	N		Un		
		SP	18	94	12	D2	0.122/0.175	L	Y		M		
L13	15	ML/CL											All Clay
L14	48	SC	18	22	8	D1	0.165/0.170	L	N	0.0875	M		
		SP	45	37	22	D2	0.165/0.170	M	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
L26	26	SP/SC	38	19.5	13	D1	0.152/0.165	Un	N	0.081	Un		
L28	22	SP/GP	60	19	7	D1	0.14/0.158	Un	N	0.0795	Un		
L29	78	SC	95	25.5	15	D1	0.128/0.154	Un	N	0.079	Un		
		SP	110	40.5	15	D1	0.128/0.154	Un	N		Un		
		SP	55	63	30	D2	0.128/0.154	Un	N		Un		
L30	24	SC	23	19	10	D1	0.14/0.153	M	N	0.0785	Un		
L31	28	SP/SC	75	20	16	D1	0.15/0.152	Un	N	0.078	Un		
L32	26	SP/SC	50	22	8	D1	0.16/0.15	Un	N	0.0775	Un		
L35	50	SC/SP	25	21.5	13	D1	0.17/0.148	M	N	0.0765	Un		
		SC/SP	35	39	22	D2	0.17/0.148	M	N		Un		
L36	43	SC/CL	35	23.5	11	D1	0.169/0.147	M	N	0.076	Un		
L37	21	SC/SP	16	15	12	D1	0.14/0.14	L	N	0.0755	M		
L44	27	SC	30	24	6	D1	0.108/0.139	Un	N	0.072	Un		
M(-4)	120	SP	18	12.5	25	D2	0.151/0.186	L	N	0.0945	L		
		SP	17	30	10	D1		L	N		L		
		SP	30	50	10	D1		M	N		Un		
		SP	38	60.5	11	D2		M	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
M(-4)	120	SP	45	71.5	11	D2		Un	N		Un		
		SP	50	82.5	11	D2		Un	N		Un		
		SP	90	98	20	D2		Un	N		Un		
		SP	50	114	12	D2		Un	N		Un		
M(-3)	86	SP	21	14	28	D1	0.149/0.185	L	N	0.094	M		
		CL/SC	18	34	12	D2		L	N		M		
		SP	22	44.5	9	D1		L	N		Un		
		SP	43	59.5	21	D2		M	N		Un		
		SP	60	78	16	D2		Un	N		Un		
M(-2)	38	SP	18	10.5	21	D1	0.152/0.184	L	N	0.0935	M		
		SP	16	33.5	9	D1		L	N		L		
M(-1)	73	SP	18	11	22	D1	0.134/0.183	L	N	0.093	M		
		SM	7	38	10	D1		L	Y		L		
		SP	20	49.5	13	D2		L	N		M		
		SP	40	64.5	17	D2		Un	N		Un		
M2	73	SP	13	4	8	D1	0.187/0.180	L	N	0.0915	L		
		SP/ML	12	18	20	D1		L	N		L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
M2	73	SP	30	50	22	UD	0.187/0.180	L	N	0.0915	Un		
M3	103	SP	22	27	12	D1	0.136/0.179	L	N	0.091	Un		
		SP	45	46	26	D2		Un	N		Un		
		SM/SP	40	65	12	D2		M	N		Un		
		SP	90	87	32	D2		Un	N		Un		
M4	54	SM/ML	18	28	10	D1	0.145/0.178	M	N	0.0905	M		
		SP/GP	20	36.5	7	D1		L	N		M		
		SP/GP	45	47	14	D2		Un	N		Un		
M6	23	ML/CL											All Clay
M7	48	SM/SP	60	38	20	D1	0.14/0.175	Un	N	0.0895	Un		
M13	27	ML/CL											All Clay
M17	52	SC/SP	15	26	8	UD	0.137/0.165	M	N	0.0845	Un		
M18	58	SC/SM	30	26.5	11	D1	0.131/0.164	Un	N	0.084	Un		
		GP	45	37	10	D2		Un	N		Un		
		SM/SP	40	50	16	D1		Un	N		Un		
M24	33	SC/SP	25	18.5	13	D1	0.139/0.158	M	N	0.081	Un		
M25	23	SC/SP	20	20	6	D1	0.145/0.156	M	N	0.080	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
M26	25	SC/SP	35	18	13	D1	0.15/0.155	Un	N	0.0795	Un		
M28	38	SC/SP	27	28	20	D1	0.152/0.154	M	N	0.0785	Un		
M29	36	ML/CL											All Clay
M33	30	SM/SC	30	24	12	D1	0.155/0.149	M	N	0.0765	Un		
M35	57	SM/SP	35	16.5	9	UD	0.171/0.147	M	N	0.0755	Un		
		SM	65	52	10	D1		Un	N		Un		
M36	55	SM/SP	25	15	14	UD	0.178/0.146	M	N	0.0745	Un		
		SP	40	38	10	UD		M	N		Un		
M37	22	SC	25	15.5	15	D1	0.165/0.155	M	N	0.074	Un		
M38	22	SM/SP	15	15.5	13	D1	0.168/0.155	L	N	0.0735	M		
N(-6)	100	SM/SC	10	13.5	11	UD	0.123/0.185	L	N	0.0935	L		
		SM	30	38	20	D1		M	N		Un		
		SP	30	58	20	D2		M	N		Un		
		SP	45	84	32	D2		Un	N		Un		
N(-3)	67	SP	13	5	10	D2	0.146/0.182	L	N	0.0925	L		
		SP	20	14.5	9	D2		L	N		M		
		SP	22	25.5	13	D2		M	N		M		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
N(-3)	67	SM/SP	20	39.5	15	D2	0.146/0.182	L	N	0.0925	M		
		SP	35	57	20	D2		M	N		Un		
N1	63	SP/CL	35	34	10	D1	0.166/0.178	M	N	0.091	Un		
		SP	33	51	24	D1		M	N		Un		
N2	73	SP	20	42.5	27	UD	0.140/0.177	L	N	0.090	L		
		SP/CL	45	64.5	17	D2		Un	N		Un		
N3	63	SP/GP	13	4	8	D1	0.169/0.176	L	N	0.0895	L		
		SP	23	29	10	UD		L	N		M		
		SC/SM	40	48	12	UD		Un	N		Un		
N7	54	SP/GP	40	41	26	D1	0.153/0.173	M	N	0.089	Un		
N10	23	ML/CL											All Clay
N15	38	SP/GP	50	31	16	D1	0.146/0.165	Un	N	0.0845	Un		
N16	34	SP	30	31	6	D1	0.147/0.164	M	N	0.0835	Un		
N17	51	SP/SC	35	30	12	UD	0.149/0.163	Un	N	0.0825	Un		
N18	72	SP/GP	35	32.5	21	UD	0.135/0.162	M	N	0.0825	Un		
N20	42	SP/SM	40	20	8	D1	0.143/0.160	Un	N	0.0815	Un		
		SP/SM	68	33	18	D2		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
N21	63	SP	40	24	12	D1	0.146/0.159	Un	N	0.0805	Un		
		SP	60	39	18	D2		Un	N		Un		
N22	63	SP/GP	40	34	22	D1	0.148/0.158	Un	N	0.080	Un		
		SP/GP	60	54	18	D2		Un	N		Un		
N23	65	SP/GP	40	29	22	D1	0.145/0.157	Un	N	0.0795	Un		
		SP/GP	90	49	18	D1		Un	N		Un		
N24	77	SP	45	27	10	D1	0.149/0.156	Un	N	0.079	Un		
		SP	100	41	18	D2		Un	N		Un		
		SP	150	63.5	27	D2		Un	N		Un		
N25	46	SC/SM	38	17	12	D1	0.150/0.155	Un	N	0.0785	Un		
		SM/SP	42	29	12	D2		M	N		Un		
		SM/SP	115	40.5	11	D2		Un	N		Un		
N26	40	SM/SC	35	31	18	D1	0.134/0.154	Un	N	0.0782	Un		
N27	29	SP/SM	23	23.5	11	D1	0.133/0.153	L	N	0.078	Un		
N28	34	SP	30	26.5	15	D1	0.133/0.152	M	N	0.0775	Un		
N29	33	SM/SP	30	27.5	11	D1	0.130/0.151	M	N	0.077	Un		
N30	20	ML/CL											All Clay

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
N31	40	GP	50	33	14	D1	0.122/0.142	Un	N	0.076	Un		
N33	29	SC	30	23	12	D1	0.119/0.139	Un	N	0.0745	Un		
N45	22	SC/SP	30	15.5	13	D1	0.116/0.135	Un	N	0.069	Un		
N49	43	SC/GC	130	23	18	D1	0.114/0.132	Un	N	0.068	Un		
		SM/SP	60	37.5	11	D2		Un	N		Un		
O(-7)	54	SM	18	4.5	9	D2	0.141/0.182	L	N	0.093	L		
		SM	10	18.5	19	D2		L	N		L		
		SM	35	41	26	D2		M	N		Un		
O(-6)	76	SP	30	5	10	D2	0.135/0.181	M	N	0.0925	Un		
		SP	45	16	12	D1		Un	N		Un		
O(-5)	73	SP	12	8	16	D1	0.132/0.181	L	N	0.0915	L		
		SP	40	63.5	19	D1		Un	N		Un		
O(-4)	58	SP/SM	10	10	20	D2	0.140/0.179	L	N	0.091	L		
		SP/SM	13	30	20	D2		L	Y		L		
		SP/SM	20	49	18	D2		L	N		M		
O(-3)	30	ML/CL											All Clay
O4	57	SM/SC	25	35.5	15	D1	0.153/0.173	M	N	0.0885	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
O4	57	SP	50	50	14	D1	0.153/0.173	Un	N	0.0885	Un		
O8	33	SP	17	6	12	D1	0.169/0.169	L	N	0.087	M		
O10	43	SM/SC	20	33	20	D1	0.142/0.167	M	N	0.0855	M		
O11	63	SM/CL	19	48	30	D1	0.153/0.166	L	N	0.0845	M		
O12	103	SP/SM	25	27	22	UD	0.142/0.165	L	N	0.084	M		
		SM/SP	36	54.5	11	D1		M	N		Un		
		SP	42	69	18	D2		M	N		Un		
		SP	41	89.5	23	D2		M	N		Un		
O13	54	SP/SM	17	23	10	D1	0.144/0.164	L	N	0.0835	M		
		SP	33	41	26	D2		M	N		Un		
O14	43	SP	45	34	18	D1	0.148/0.163	Un	N	0.083	Un		
O16	43	SP	46	33	20	D1	0.126/0.161	Un	N	0.0825	Un		
O17	63	SP	35	28.5	13	UD	0.126/0.160	M	N	0.0815	Un		
O18	54	SP	30	28	18	UD	0.126/0.160	M	N	0.081	Un		
O19	38	SP/SM	45	31	14	D1	0.118/0.159	Un	N	0.0805	Un		
O21	84	SC/SM	35	22	10	D1	0.112/0.157	Un	N	0.080	Un		
		SM/SP	55	39	22	D2		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
O21	84	SM/SP	45	55	10	D2	0.112/0.157	Un	N	0.080	Un		
		SM/SP	60	65	10	D2		Un	N		Un		
		SM/SP	40	77	14	D2		Un	N		Un		
O22	36	SP	45	28.5	15	D1	0.11/0.156	Un	N	0.079	Un		
O23	40	SP	21	21.5	7	D1	0.115/0.155	L	N	0.0785	Un		
		SP	80	32.5	15	D2		Un	N		Un		
O24	25	SP	16	18.5	13	D1	0.120/0.153	L	N	0.078	M		
O26	36	SP/SM	12	18.5	9	D1	0.124/0.152	L	N	0.0775	L		
		SP	50	29.5	13	D2		Un	N		Un		
O27	22	ML/CL											All Clay
O28	28	ML/CL											All Clay
O29	22	ML/CL											All Clay
O31	48	SM/SP	25	24	10	UD	0.105/0.147	M	N	0.0755	Un		
O36	30	SC	65	26	8	D1	0.155/0.142	Un	N	0.073	Un		
O50	22	SC	40	17	10	D1	0.14/0.150	Un	N	0.067	Un		
P(-5)	28	SM	15	23	10	D1	0.13/0.160	L	N	0.090	L		
P(-4)	38	SC/ML	8	33	10	D1	0.12/0.17	L	Y	0.0895	L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
P(-3)	46	SC/SM	18	34.5	23	D1	0.11/0.176	M	N	0.089	M		
P6	43	SC/SP	22	33.5	19	D1	0.128/0.169	M	N	0.0865	Un		
P7	43	SP/GP	30	36	14	D1	0.110/0.168	Un	N	0.0855	Un		
P8	43	SP/SM	17	35.5	15	D1	0.132/0.167	L	N	0.0850	M		
P9	43	SP/GP	16	4.5	9	D1	0.145/0.166	L	N	0.0845	M		
		SP/SM	18	35.5	15	D1		L	N		M		
P10	63	SM/SP	38	27.5	11	D1	0.138/0.165	Un	N	0.084	Un		
		SP	50	41.5	17	D1		Un	N		Un		
		SP	100	56.5	13	D2		Un	N		Un		
P11	43	SC/SM	23	28	8	D1	0.136/0.164	M	N	0.0835	Un		
		SP	35	37	12	D1		Un	N		Un		
P12	36	SP/GP	50	32	8	D1	0.135/0.163	Un	N	0.0830	Un		
P13	43	SP/SM	50	32.5	21	D1	0.132/0.162	Un	N	0.0825	Un		
P14	43	SP	40	32.5	21	D1	0.126/0.161	Un	N	0.082	Un		
P16	51	SP/SM	35	23.5	11	D1	0.125/0.159	Un	N	0.081	Un		
		SP	55	40	22	D2		Un	N		Un		
P17	43	SC/SM	65	30.5	25	D1	0.124/0.158	Un	N	0.0805	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
P18	54	SC/SM	25	18.5	15	D1	0.123/0.157	M	N	0.080	Un		
		SP	33	41	26	D2		M	N		Un		
P19	24	ML/CL											All Clay
P20	43	SP/GP	60	34.5	27	D1	0.127/0.156	Un	N	0.079	Un		
P21	54	SP	60	29.5	13	D1	0.122/0.155	Un	N	0.0785	Un		
		SP	100	45	18	D2		Un	N		Un		
P26	26	SP	45	18.5	9	D1	0.118/0.150	Un	N	0.077	Un		
P29	23	SP/SC	45	18.5	9	D1	0.116/0.148	Un	N	0.0755	Un		
P30	29	SP	20	25	8	D1	0.118/0.146	L	N	0.0745	Un		
P31	22	ML/CL											All Clay
P32	31	SP	30	27	8	D1	0.105/0.144	Un	N	0.0735	Un		
P33	31	SP	30	28	10	D1	0.102/0.144	Un	N	0.0730	Un		
P51	54	SC/SM	90	38	30	D1	0.102/0.128	Un	N	0.0665	Un		
P52	30	SC/SP	45	24	12	D1	0.118/0.128	Un	N	0.066	Un		
Q(-8)	100	SM	3	11	22	D1	0.133/0.178	L	Y	0.090	L		
		SP	13	51	26	D1		L	Y		L		
		SP	40	82	36	D2		Un	Y		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
Q2	73	SC/SM	18	29.5	11	UD	0.151/0.169	M	N	0.0875	Un		
Q5	43	SC/SP	50	38	10	D1	0.138/0.167	Un	N	0.0855	Un		
Q6	28	ML/CL											All Clay
Q7	26	SC/SM	12	22	8	D1	0.133/0.164	L	N	0.0845	L		
Q9	22	ML/CL											All Clay
Q10	44	SP/SM	30	34	20	D1	0.128/0.163	M	N	0.0825	Un		
Q12	36	SP	40	31	10	D1	0.124/0.161	Un	N	0.0815	Un		
Q13	22	ML/CL											All Clay
Q14	65	SM/SC	40	20.5	17	D1	0.124/0.159	Un	N	0.0805	Un		
		SC/SP	60	38	18	D2		Un	N		Un		
		SC/SP	60	56	18	D2		Un	N		Un		
Q15	40	GP		19	18								No Data
Q16	36	SM/SP	45	27.5	17	D1	0.127/0.157	Un	N	0.0795	Un		
Q17	43	SC/SP	60	34	18	D1	0.126/0.156	Un	N	0.079	Un		
Q18	22	ML/CL											All Clay
Q19	32	ML/CL											All Clay
Q20	34	SP	55	28	12	D1	0.12/0.153	Un	N	0.0779	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
Q21	44	ML/SP	18	21	10	D1	0.123/0.153	M	N	0.775	M		
		SP	30	31	10	D1		M	N		Un		
		SP	50	40	8	D1		Un	N		Un		
Q22	36	SP	40	27	18	D1	0.12/0.15	Un	N	0.0772	Un		
Q23	34	SP	35	28	12	D1	0.12/0.15	M	N	0.077	Un		
Q24	53	SP/SC	30	27	10	D1	0.117/0.150	Un	N	0.0765	Un		
		SP	70	42.5	21	D2		Un	N		Un		
Q25	28	SM/SC	45	20	16	D1	0.116/0.148	Un	N	0.076	Un		
Q26	31	SM/SP	38	24.5	13	D1	0.115/0.147	Un	N	0.0759	Un		
Q28	28	SC/SP	100	20	16	D1	0.114/0.146	Un	N	0.075	Un		
Q29		SC/SM	47	26	24	UD	0.104/0.145	Un	N	0.0745	Un		
Q30	22	CL/ML											All Clay
Q31	34	SP	30	21.5	25	D1	0.095/0.144	Un	N	0.0735	Un		
Q33	43	SC/SP	60	23	20	D1	0.104/0.142	Un	N	0.073	Un		
		SP	45	38	10	D2	0.104/0.142	Un	N		Un		
Q34	23	SC/SM	18	21	4	D1	0.10/0.140	M	N	0.0725	Un		
Q38	28	SP/GP	95	18.5	19	D1	0.094/0.142	Un	N	0.070	Un		

Site	Total Depth (ft)	Soil* Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
Q50	22	ML/CL											All Clay
R(-10)	42	SP	20	25	34	D1	0.106/0.176	L	N	0.0895	M		
R(-9)	42	SC	15	3	6	D1	0.135/0.173	L	N	0.089	M		
		SP	18	28	28	D1		L	N		M		
R(-8)	43	SP	17	31	24	D1	0.14/0.17	L	N	0.0885	M		
R1	32	ML/CL											All Clay
R4	32	SM/SC	38	25	14	D1	0.149/0.165	Un	N	0.0845	Un		
R5	30	SC/SP	18	24	12	D1	0.14/0.63	M	N	0.084	M		
R9	42	SC/SM	30	25	14	D1	0.121/0.61	Un	N	0.082	Un		
		SC/SP	40	37	10	D2		Un	N		Un		
R12	22	ML/CL											All Clay
R17	35	SC	60	29	12	D1	0.119/0.154	Un	N	0.079	Un		
R18	36	SP/GP	90	32	8	D1	0.115/0.153	Un	N	0.0785	Un		
R20	32	SC/GP	55	25	14	D1	0.105/0.152	Un	N	0.078	Un		
R21	30	SP/SM	34	25.5	9	D1	0.095/0.151	Un	N	0.775	Un		
R22	32	SP	56	27	10	D1	0.105/0.150	Un	N	0.0765	Un		
R23	30	SC	40	26	8	D1	0.113/0.149	Un	N	0.0764	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
R24	41	SC	37	26	10	D1	0.113/0.148	Un	N	0.0762	Un		
		SP	50	36	10	D2		Un	N		Un		
R26	30	SC/SP	40	26	8	D2	0.110/0.146	Un	N	0.075	Un		
R27	35	SC	40	31	6	D1	0.108/0.145	Un	N	0.0745	Un		
R30	42	SM/SC	100	28	28	D1	0.116/0.143	Un	N	0.0735	Un		
R31	37	SM/SC	85	22.5	29	D1	0.115/0.142	Un	N	0.0733	Un		
R32	42	SP/SC	100	34.5	15	D1	0.095/0.141	Un	N	0.0730	Un		
R33	26	SC	70	22	8	D1	0.101/0.136	Un	N	0.0725	Un		
R48	22	ML/CL											All Clay
R50	52	SM/SC	40	23	10	D1	0.112/0.126	Un	N	0.066	Un		
		SP	50	40	24	D2	0.112/0.126	Un	N		Un		
R52	42	SM/SC	25	19.5	15	UD	0.112/0.124	Un	N	0.0645	Un		
R54	22	ML/CL											All Clay
R55	25	SP	33	19.5	11	D1	0.107/0.122	Un	N	0.063	Un		
S(-10)	42	SP	14	25	34	D1	0.123/0.173	L	N	0.0885	L		
S(-9)	32	SP	16	19	26	D1	0.135/0.17	L	N	0.088	L		
S2	38	SC/SP	27	30	16	D1	0.147/0.165	M	N	0.084	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
S3	62	SC/SP	40	22	10	UD	0.145/0.164	Un	N	0.0835	Un		
S4	62	SC/SM	70	25	8	UD	0.139/0.163	Un	N	0.0833	Un		
		SC/SM	55	65	14	D1		Un	N		Un		
S6	27	ML/CL											All Clay
S9	32	ML/CL											All Clay
S11	52	SP	22	33	10	D1	0.180/0.157	L	N	0.0795	Un		
		SP	40	45	14	D2		M	N		Un		
S12	66	SM/SP	50	25	12	D1	0.164/0.156	Un	N	0.079	Un		
		SP	65	41	20	D1		Un	N		Un		
		SP/SC	39	63	6	D1		Un	N		Un		
S13	77	SM/SP	50	36	16	UD	0.149/0.156	Un	N	0.0789	Un		
		SP	45	48	8	U1		Un	N		Un		
		SP/SC	75	70.5	13	D1		Un	N		Un		
S14	38	SM/SC	40	32.5	11	D1	0.151/0.155	Un	N	0.0785	Un		
S15	32	ML/CL											All Clay
S20	58	SM/SC	16	21	10	UD	0.117/0.150	M	N	0.077	Un		
		SM/SC	14	41	10	UD		M	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
S21	28	SC/SP	26	20	16	D1	0.114/0.148	Un	N	0.0769	Un		
S22	32	GC	70	20	12	D1	0.099/0.148	Un	N	0.0763	Un		
		SP/SC	15	29	6	D2		M	N		M		
S23	29	SC/SP	55	14	10	D1	0.099/0.147	Un	N	0.0755	Un		
		SP/SC	100	24	10	D2		Un	N		Un		
S24	77	SC/SM	22	17.5	15	D1	0.099/0.146	M	N	0.0748	Un		
		SP/CL	18	33	16	D2		M	N		M		
		SP	19	50.5	19	D2		M	N		M		
		SP	20	68.5	17	D2		M	N		M		
S26	30	SC/SM	10	18	10	D1	0.112/0.144	L	N	0.074	L		
		SP/GP	40	26.5	7	D2		Un	N		Un		
S27	55	SC/SM	30	21	14	UD	0.110/0.144	Un	N	0.0738	Un		
S39	54	SL/CL	20	16	4	D1	0.095/0.133	M	N	0.0690	Un		
		SM/SP	25	20.5	5	D2		M	N		Un		
		GP	30	25	4	D1		Un	N		Un		
		SM	55	40.5	9	D1		Un	N		Un		
		SM/SP	33	49.5	9	D2		M	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake PGA/PBA (g)	M=7.5 Earthquake CERI Criteria	M=7.5 Earthquake Seed's Criteria	M=6.5 Earthquake PBA (g)	M=6.5 Earthquake CERI Criteria	M=6.5 Earthquake Seed's Criteria	Remarks
S40	75	SC	60	21.5	3	D1	0.098/0.133	Un	N	0.0685	Un		
S50	72	SP	80	29	10	D1	0.109/0.124	Un	N	0.0645	Un		
		SP	40	37	6	D2		Un	N		Un		
		SP	45	45	10	D2		Un	N		Un		
		SP	55	61	22	D2		Un	N		Un		
S53	52	SC	18	15	8	UD	0.090/0.122	Un	N	0.064	Un		
		SP/SC	21	40	24	D1		M	N		Un		
S54	36	SC	38	22	8	D1	0.107/0.121	Un	N	0.0635	Un		
		SP/SC	50	31	10	D2		Un	N		Un		
S55	22	SC	18	17	10	D1	0.110/0.138	M	N	0.063	Un		
T(-13)	42	SP	17	27	30	D1	0.113/0.155	L	N	0.088	M		
T(-12)	124	SM	12	4.5	3	UD	0.116/0.172	L	N	0.0875	L		
		SM	4	11	4	UD		L	Y		L		
		SM	15	23	10	D1		L	N		L		
		SP	18	36	16	D2		L	N		M		
		SP	25	53	18	D2		M	N		M		
		SP	22	74	24	D2		M	N		N		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
T(-12)	124	SP	37	96	20	D2	0.116/0.172	M	N	0.0875	Un		
		SP	40	115	18	D2		M	N		Un		
T(-11)	42	SP/SM	12	17	18	D1	0.125/0.169	L	N	0.087	L		
		SM/ML	18	34	16	D2		L	N		M		
T(-10)	42	SP	12	24	36	D1	0.135/0.166	L	N	0.0868	L		
T1	32	SP/GP	70	27	10	D1	0.146/0.163	Un	N	0.083	Un		
T2	22	ML/CL											All Clay
T10	45	SC	30	38.5	13	D1	0.13/0.16	M	N	0.079	Un		
T14	32	SM	23	22	20	D1	0.138/0.153	M	N	0.0782	Un		
T20	42	SP/SC	25	31.5	21	D1	0.110/0.148	Un	N	0.0755	Un		
T21	34	SP/SC	40	26	16	D1	0.105/0.147	Un	N	0.075	Un		
T22	32	SM/SC	35	25	14	D1	0.099/0.146	Un	N	0.0745	Un		
T23	32	SP/GP	38	16	32	D2	0.118/0.145	M	N	0.074	Un		
T25	61	SP	50	24	12	D1	0.102/0.144	Un	N	0.0735	Un		
		SP	22	40	20	D2		M	N		M		
		SP	35	55.5	11	D2		Un	N		Un		
T26	66	SP	20	27.5	11	UD	0.113/0.143	L	N	0.073	M		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
T26	66	SP	70	64	4	D1	0.113/0.143	Un	N	0.073	Un		
T38	212	GP	50	32.5	21	UD	0.097/0.133	Un	N	0.0685	Un		
		SM	35	115	50	D2		Un	N		Un		
T39	202	SP	80	24.5	3	D1	0.009/0.132	Un	N	0.068	Un		
		GP	130	33	14	D2		Un	N		Un		
		GP	135	46.5	13	D2		Un	N		Un		
		SM	115	59	12	D2		Un	N		Un		
		SP	110	68.5	7	D2		Un	N		Un		
		SM	140	77	10	D2		Un	N		Un		
T40	47	SM	16	18.5	3	UD	0.10/0.131	L	N	0.0678	M		
		GP	20	21.5	3	UD		L	N		M		
		SM	50	44.5	5	D1		Un	N		Un		
T41	168	SM	28	6.5	3	UD	0.112/0.130	M	N	0.0675	Un		
		GP	20	20.5	7	UD		L	N		M		
		SM	19	33	10	UD		L	N		M		
		SM	30	42.5	3	UD		M	N		Un		
		SP	80	87.5	25	D1		Un	Y		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
T52	26	SM/SC	35	19	14	D1	0.111/0.145	Un	N	0.063	Un		
T53	22	ML/CL											All Clay
U(-13)	100	SP	14	14	12	D1	0.112/0.17	L	N	0.087	L		
		SP	30	30	20	D2		M	N		Un		
		SP	15	50	20	D2		L	Y		L		
		SP	35	70	20	D2		M	N		Un		
		SP	50	85	10	D2		Un	N		Un		
U(-12)	42	SP/SM	7	24	36	D1	0.110/0.168	L	Y	0.0865	L		
U(-11)	16	ML/CL											All Clay
U(-4)	76	SP	23	29	10	D1	0.105/0.164	L	N	0.0838	Un		
		SP	35	44.5	21	D2		M	N		Un		
		SP	38	60	10	D2		M	N		Un		
		SP	42	71	11	D2		Un	N		Un		
U(-2)	52	SC/SM	15	47	10	D1	0.127/0.163	M	N	0.083	M		
U7	36	ML/CL											All Clay
U10	42	SC/SP	30	35	14	D1	0.138/0.154	M	N	0.0785	Un		
U11	42	SP/SM	20	35.5	13	D1	0.126/0.153	L	N	0.078	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
U12	40	SP/SC	60	31	18	D1	0.131/0.152	Un	Un	0.0775	Un		
U14	38	SM/SC	20	28.5	19	D1	0.123/0.151	M	N	0.0770	Un		
U18	25	SM/SC	35	19	13	UD	0.115/0.149	M	N	0.075	Un		
U20	30	ML/CL											All Clay
U21	225	SP/SC	40	30.5	19	D1	0.104/0.145	Un	N	0.074	Un		
		SP/SC	20	45.5	11	D2		L	N		M		
		SM/SP	30	55.5	9	D2		M	N		Un		
		SM/SP	50	75.5	31	D2		Un	N		Un		
U22	52	SC	22	30	16	UD	0.112/0.144	Un	N	0.0735	Un		
U26	44	SC	25	41	6	D1	0.105/0.141	Un	N	0.0725	Un		
U27	62	SC/SM	20	18.5	13	D1	0.116/0.140	L	N	0.0715	Un		
		SM/SP	30	33.5	17	D1		Un	N		Un		
U28	36	SC/SM	50	20.5	17	D1	0.106/0.139	Un	N	0.071	Un		
		SC/ML	20	32.5	7	D2	0.106/0.139	M	N		Un		
U29	28	SM/SP	40	20	16	D1	0.10/0.139	Un	N	0.0705	Un		
U30	32	SC/SM	60	24.5	15	D1	0.098/0.138	Un	N	0.070	Un		
U31	31	SC	35	24.5	13	D1	0.096/0.137	Un	N	0.0695	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
U32	27	ML/CL											All Clay
U38	114	SC	25	22.5	3	UD	0.102/0.131	Un	N	0.068	Un		
		SP	100	28.5	9	UD		Un	N		Un		
		GP	100	41.5	17	UD		Un	N		Un		
V(-13)	120	SP	20	48.5	23	D1	0.121/0.167	L	Y	0.0855	M		
		SP	20	70	20	D2		L	Y		M		
		SP	20	90	20	D2		L	Y		M		
V(-12)	18	SP	20	12	12	D1	0.13/0.164	L	N	0.085	Un		
V4	32	ML/CL											All Clay
V5	38	ML/CL											All Clay
V17	31	SC/SP	15	26	10	D1	0.112/0.146	L	N	0.0745	M		
V26	30	SC/GP	30	23	14	D1	0.105/0.14	Un	N	0.071	Un		
V27	42	SC/SM	22	23.5	11	D1	0.099/0.138	M	N	0.0705	Un		
		SP	40	35.5	13	D2		Un	N		Un		
V32	32	SP	30	25.5	13	D1	0.097/0.135	Un	N	0.0685	Un		
W(-13)	42	SC	7	3	6	D2	0.116/0.164	L	N	0.084	L		
		SP	8	16	20	D1		L	Y		L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake PGA/PBA (g)	M=7.5 Earthquake CERI Criteria	M=7.5 Earthquake Seed's Criteria	M=6.5 Earthquake PBA (g)	M=6.5 Earthquake CERI Criteria	M=6.5 Earthquake Seed's Criteria	Remarks
W(-13)	42	SP	10	40	6	D1	0.116/0.164	L	Y	0.084	L		
W(-12)	42	ML/SP	11	24	36	D1		L	Y		L		
W(-11)	42	SP	15	24	36	D1	0.13/0.154	L	Y	0.083	L		
W8	42	SC	25	37	10	D1	0.14/0.151	M	N	0.077	Un		
W9	22	ML/CL											All Clay
W13	25	GM	30	19.5	11	D1	0.134/0.147	M	N	0.0755	Un		
W16	22	ML/CL											All Clay
W22	32	SC/SP	30	22	20	D1	0.12/0.143	Un	N	0.072	Un		
W23	27	SC	50	22	10	D1	0.11/0.14	Un	N	0.0715	Un		
W24	32	SC	30	21	8	D1	0.108/0.139	Un	N	0.0705	Un		
		SC	40	28.5	7	D2		Un	N		Un		
W27	26	GC	100	20	6	D1	0.106/0.136	Un	N	0.069	Un		
		SC	20	24.5	3	D2	0.106/0.136	M	N		Un		
W32	25	SC	20	23.5	3	D1	0.106/0.133	M	N	0.0685	Un		
W34	62	SC	25	21	6	D1	0.103/0.13	M	N	0.0665	Un		
		SC	50	29	10	D2		Un	N		Un		
		SC	30	36	4	D2		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
W34	62	SP	20	50	24	D2	0.103/0.13	L	Y	0.0665	M		
X(-11)	42	SP	15	27	30	D1	0.120/0.161	L	Y	0.083	L		
X(-10)	42	SP	16	23	14	D1	0.115/0.16	L	N	0.0825	M		
		SP	12	36	12	D2		L	Y		L		
X(-9)	42	SP	18	23.5	37	D1	0.113/0.16	L	N	0.0815	M		
X(-8)	42	SP	12	13	12	D1	0.11/0.159	L	N	0.0805	L		
		SP	16	30.5	23	D2		L	N		M		
X(-7)	42	SM/SP	7	8	8	D1	0.107/0.159	L	Y	0.080	L		
		SP	15	27	30	D2	0.107/0.159	L	N		M		
X(-6)	18	SP	8	11	14	D1	0.11/0.158	L	Y	0.0795	L		
X(-5)	42	SP/SC	4	9	6	UD	0.11/0.158	L	Y	0.079	L		
X(-4)	37	ML/SC	12	4.5	9	D1	0.114/0.157	L	N	0.0785	L		
X13	30	SC/ML	15	24.5	11	D1	0.11/0.158	M	N	0.074	M		
X22	32	SC/SM	30	24.5	15	D1	0.11/0.15	Un	N	0.072	Un		
X23	32	SC/SM	30	24.5	15	D1	0.11/0.15	Un	N	0.071	Un		
X24	32	SC/SM	30	24.5	15	D1	0.11/0.15	Un	N	0.071	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
XX26	30	ML/CL											All Clay
WW33	50	SC	38	35.5	7.0	D1	0.209/0.230	M	N	0.118	Un		
		SP-GP	30	44.5	11.0	D1		L	N		Un		
VV25	30	ML/CL											All Clay
UU25	30	ML/CL											All Clay
UU26	30	ML/CL											All Clay
TT18	62	ML-SM	25	42.5	9.0	D1	0.203/0.26	L	N	0.134	M		
		GP	60	54.5	15.0	D1		Un	N		Un		
TT24	31	ML											All Clay
TT25	42	ML											All Clay
TT26	30	CL											All Clay
TT29	120												No Data
SS18	62	SP-GP	32	54.5	15.0	UD	0.197/0.256	L	N	0.133	M		
SS19	51	SP	32	48.0	6.0	UD	0.192/0.254	L	N	0.131	M		
SS20	50.0	SP-GW	42	46.0	8.0	UD	0.196/0.251	L	N	0.130	Un		
SS24	30.0	ML/CL											All Clay
SS25	27	ML/CL											All Clay

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
SS26	51.0	SP-SC	26.0	40.0	10.0	D1	0.193/0.236	L	N	0.121	M		
		SP-GP	22.0	48.0	6.0	D1		L	N		L		
SS27	50.0	SC	41.0	38.5	7.0	D1	0.174/0.234	M	N	0.118	Un		
		SP	63.0	46.0	8.0	D1		Un	N		Un		
SS28	62.0	SM-SC	30	43.0	10.0	D1	0.172/0.2311	L	N	0.115	Un		
		SP	80	55.0	14.0	D1		Un	N		Un		
SS29	28	ML/CL											All Clay
RR18	66.0	GW	30	49.5	9.0	D1	0.1592/0.2523	L	N	0.129	Un		
		SC	26	55.5	3.0	D2		L	N		M		
		SP	58	61.5	9.0	D1		L	N		Un		
RR20	51.0	SP	28	39.5	11.0	D1	0.195/0.247	L	N	0.127	M		
		GW	68	48.0	5.0	D1		L	N		Un		
RR22	32	ML/CL											All Clay
RR25	20	ML/CL											All Clay
RR27	50.0	SM-SC	25	39.5	11.0	D1	0.151/0.23	L	N	0.117	M		
		SP	50	47.5	5.0	D1		M	N		Un		
RR28	72.0	ML-SM	18	32.5	9.0	UD	0.155/0.228	L	N	0.115	L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
RR28	72.0	SM-SC	50	42.5	11.0	D1	0.155/0.228	Un	N	0.115	Un		
		SP-GP	52	53.0	10.0	D2		M	N		Un		
		SP	22	65.0	14.0	D1		L	N		M		
RR30	30.0	GC	30	26.5	7.0	UD		L	N	0.113	M		
RR31	50.0	SC-GC	20	41.5	9.0	D1	0.182/0.221	L	N	0.112	L		
		SP-GP	57	48.0	4.0	D1		Un	N		Un		
QQ1	68												No Data
QQ2	70												No Data
QQ6	21.0	SC	17	15.0	4.0	D1	0.190/0.2811	L	N	0.144	L		
		SP	48	19.0	4.0	D1		M	N		Un		
QQ7	30.0	SP-GW	30	6.5	5.0	D1	0.194/0.278	L	N	0.141	M		
		SP-GW	42	15.0	12.0	D1		L	N		Un		
QQ9	73.0	SC	37	58.0	4.0	D1	0.184/0.275	L	N	0.140	Un		
		SP	40	66.5	13.0	D1		L	N		Un		
QQ24	62.0	SP-GP	30	38.5	11.0	D1	0.167/0.234	L	N	0.119	Un		
		SP	30	49.0	10.0	D2		L	N		M		
		SP	55	58.0	8.0	D1		M	N		Un		
QQ25	60.5	SC-SP	17	37.0	10.0	D1	0.154/0.232	L	N	0.118	L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
QQ25	60.5	SP-GP	60	51.25	18.5	D1	0.154/0.232	Un	N	0.118	Un		
QQ27	75.0	ML-SM	20	35.0	10.0	D1	0.166/0.227	L	N	0.116	L		
		GW-SP	56	47.5	15.0	D1		M	N		Un		
		SP	62	61.0	12.0	D1		Un	N		Un		
QQ28	77.0	SM-SC	22	39.0	8.0	D1	0.155/0.225	L	N	0.114	M		
		SP-GP	41	50.5	15.0	D2		L	N		Un		
		SP-GP	44	65.0	14.0	D1		M	N		Un		
		SP-CL	50	74.5	5.0	D1		M	N		Un		
QQ33	77.0	ML-SP	12	34.0	12.0	D1	0.164/0.214	L	Y	0.108	L		
		SP	50	43.5	7.0	D1		M	N		Un		
		SC-SP	21	56.0	18.0	D2		L	Y/N		L		
		SC-SP	50	71.0	12.0	D1		Un	N		Un		
QQ41	32.0	CL-SC	30	24.5	5.0	D1	0.152/0.198	M	N	0.102	Un		
		SP	91	29.5	5.0	Un		Un	N		Un		
PP1	67												No Data
PP7	36.0	ML-SM	3	2.0	4.0	D1	0.191/0.274	L	Y	0.138	L		
		CL-SM	47	14.0	10.0	UD		L	N		Un		
		SM-SP	48	23.5	9.0	D1		M	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
PP7	36.0	SM-SP	70	32.0	8.0	D1	0.191/0.274	Un	N	0.138	Un		
PP20	28.0	SC	57	25.0	6.0	UD	0.1572/0.2398	Un	N	0.123	Un		
OO6	22	ML/CL											All Clay
MM(-1)	43												No Data
MM53	54.0	SM-SC	22	29.0	14.0	UD	0.130/0.170	M	N	0.087	M		
MM54	128.0	SM	12	3.0	6.0	D1	0.132/0.168	L	N	0.086	L		
		SM	7	21.0	8.0	UD		L	Y		L		
		SC-ML	42	79.0	10.0	D1		Un	N		Un		
		SM	42	88.0	8.0	D2		M	N		Un		
		SM	>100	100.5	17.0	D2		Un	N		Un		
		SC	>100	113.5	9.0	D2		Un	N		Un		
		SP	>100	123.0	10.0	D1		Un	N		Un		
LL(-1)	58												No Data
LL51	63.0	CL-ML-SC	19	23.0	10.0	D1	0.1361/0.171	L	N	0.088	M		
	63.0	SM-SC	40	30.0	4.0	UD		Un	N		Un		
LL52	32.0	SP	20	25.0	6.0	D1	0.110/0.169	L	N	0.087	M		
		SP	56	30.0	4.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
LL54	22	ML-GC	16	9.5	5.0	D1	0.12/0.1667	L	N	0.085	M		
		SP-GP	24	15.0	6.0	D2		L	N		M		
		SP-GP	38	20.0	4.0	D1		Un	N		Un		
KK(-1)	58												No Data
KK40	54.0	GP	21.0	30.5	5.0	D1	0.14/0.1857	L	N	0.096	M		
		GP	61	35.5	5.0	D2		Un	N		Un		
		GP	20	39.5	3.0	D2		L	N		M		
		SP	22	44.5	7.0	D2		L	N		M		
		SP	29	51	6.0	D1		L	N		Un		
KK51	33.0	SM-SC	17	13.5	3.0	D1	0.128/0.169	L	N	0.087	M		
		SP	42	21.0	12.0	D1		Un	N		Un		
		CL-SM	20	30.0	6.0	D1		L	N		M		
KK52	33.0	CL-SC	15	16.5	9.0	D1	0.115/0.168	L	N	0.086	M		
		SC	21	24.5	7.0	UD		L	N		Un		
JJ(-1)	58												No Data
JJ15	42.0	SM	19	34.5	5.0	D1	0.167/0.230	L	N	0.117	L		
		SM	40	39.5	5.0	D1		L	N		Un		
JJ18	62.0	SC	39	45.5	5.0	D1	0.162/0.224	M	N	0.114	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
JJ18	62.0	SP	36	51.0	6.0	D2	0.162/0.224	L	N	0.114	Un		
		SP	70	58.0	8.0	D1		M	N		Un		
JJ19	54.0	SM-SP	25	27.5	11.0	D1	0.154/0.221	L	N	0.113	M		
		SP	20	37.5	9.0	D1		L	N		L		
		SP	37	48.0	12.0	D1		L	N		Un		
JJ50	31.0	SC-SP	32	22.5	9.0	D1		M	N	0.086	Un		
		SC-SP	60	29.0	4.0	D1		Un	N		Un		
II9	18	ML/CL											All Clay
II26	40.0	SC-SP	30	32.0	4.0	D1	0.134/0.205	M	N	0.106	Un		
		SC-SP	84	37.0	6.0	D1		Un	N		Un		
II53	33.0	ML/CL											All Clay
HH10	75.0	SC	13	23.0	12.0	D1	0.185/0.233	L	N	0.117	L		
		SP	33	33.5	9.0	D2		L	N		M		
		GP	43	41.0	6.0	D2		M	N		Un		
		SM-SP	93	48.5	9.0	D1		Un	N		Un		
		SM	47	64.0	10.0	UD		L	N		Un		
HH20	26	ML/CL											All Clay

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
HH39	60.0	GP	15	9.5	5.0	D1		L	N	0.094	L		
		SC	22	27.5	31.0	D2		L	N		Un		
		SP	78	51.5	17.0	D1		Un	N		Un		
HH40	35.0	SC-GC	40	23.5	13.0	UD	0.114/0.179	Un	N	0.092	Un		
		SC-CL	18	32.5	5.0	D1		L	N		M		
GG10	86	SC-ML	8.0	30.5	15.0	UD	0.165/0.229	L	Y	0.116	M		
		SC-ML	19	40.5	5.0	D1		L	N		M		
		SP	44	47.5	9.0	D1		M	N		Un		
		SP	31	55.0	6.0	D2		L	N		M		
		SP	74	60.5	5.0	D2		Un	N		Un		
		SP-GP	>100	65.5	5.0	D2		Un	N		Un		
		SP-GP	58	70.5	5.0	D2		M	N		Un		
		SP-GP	23	75.5	5.0	D2		L	N		M		
		SP-GP	90	82.0	8.0	D1		Un	N		Un		
GG11	33.0	SP	20.0	28.0	10.0	UD	0.16/0.2272	L	N	0.115	L		
GG12	33	ML/CL											All Clay
GG19	40.0	ML-SM	13	21.5	5.0	D1	0.168/0.212	L	Y	0.108	L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
GG19	40.0	SM-SC	18	28.0	8.0	D1	0.168/0.212	L	N	0.108	L		
		GP	62	36.0	8.0	D1		Un	N		Un		
FF7	33.0	SP	6	19.0	6.0	UD	0.183/0.231	L	Y	0.116	L		
FF10	63.0	SC-SP	45	38.0	8.0	UD	0.178/0.226	Un	N	0.115	Un		
		SP	40	50.0	4.0	D1		M	N		Un		
		GP	40	57.5	11.0	D1		M	N		Un		
FF12	46.0	SP-GP	20	39.5	13.0	D1	0.180/0.222	L	N	0.113	L		
FF17	52.0	SC	38	26.0	6.0	D1	0.143/0.213	M	N	0.108	Un		
		SP	38	40.5	23.0	D1		M	N		Un		
FF21	48.0	SC-SM	24	32.0	12.0	D1		L	N	0.105	Un		
		SP	46	43.0	10.0	D1		M	N		Un		
FF23	29.0	SM-SC	18.0	26.0	6.0	UD	0.15/0.2019	L	N	0.103	L		
FF24	18	ML/CL											All Clay
FF25	101.0	SC	12	32.5	25.0	D1	0.154/0.198	L	Y	0.101	M		
		SC-SM	18	55.0	20.0	D1		L	Y		L		
		SM-SC	32	82.5	15.0	UD		M	N		M		
FF33	33.0	SC	30	28.0	10.0	UD	0.171/0.185	M	N	0.097	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
EE6	45.0	SM-SP	20	26.5	7.0	D1	0.203/0.2295	L	N	0.116	L		
		SP	25	36.0	12.0	D2		L	N		M		
		SP	48	43.5	3.0	D1		M	N		Un		
EE7	25.0	SM-SP	18	22.5	5.0	UD	0.182/0.2276	L	N	0.115	L		
EE8	85.0	SP-SM	35	32.5	15.0	D1	0.1796/0.2257	L	N	0.114	Un		
		GP-SP	41	47.5	15.0	D2		M	N		Un		
		SM-SP	60	57.5	5.0	D2		L	N		Un		
		GP	68	66.5	13.0	D2		Un	N		Un		
		SM	51	76.5	7.0	D1		Un	N		Un		
EE10	21.0	ML/CL											All Clay
EE11	47.0	SP	22	34.0	10.0	D1	0.1874/0.2202	L	N	0.111	M		
		SP-GP	58	43.0	8.0	D1		Un	N		Un		
EE15	28.0	SP	20	25.0	6.0	UD	0.1512/0.213	L	N	0.109	L		
EE23	28.0	SM-SC	22	23.5	9.0	UD	0.1508/0.199	L	N	0.102	L		
EE24	32.0	SC-SP	37	26.0	4.0	D1	0.1509/0.1974	M	N	0.101	Un		
		SC-SP	90	30.0	4.0	D1		Un	N		Un		
EE40	32.0	SP	>100	17.0	10.0	D1	0.1291/0.1727	Un	N	0.088	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
EE40	32.0	SP-GP	>100	27.0	10.0	D1	0.1291/0.1727	Un	N	0.088	Un		
DD9	36.0	ML/CL											All Clay
DD12	20	ML/CL											All Clay
DD13	52.0	SP-GP	38	31.0	6.0	D1	0.1713/0.2133	L	N	0.108	Un		
		SC	4	36.0	4.0	D1		L	Y		L		
		SC	20	43.0	10.0	D2		L	Y		M		
		SC	60	50.0	4.0	D1		Un	N		Un		
DD14	26.0	ML/CL											All Clay
DD15	42.0	SC-SM	35	32.5	9.0	D1	0.1981/0.2098	M	N	0.106	Un		
		SP	32	39.5	5.0	D1		L	N		Un		
DD16	28.0	SC	20	25.0	6.0	UD	0.185/0.2081	M	N	0.105	Un		
DD17	33.0	SC	50	26.0	4.0	D1	0.1728/0.2064	Un	N	0.105	Un		
		SC	61	30.5	5.0	D1		Un	N		Un		
DD19	22.0	SM-SC-SP	22	17.0	10.0	UD	0.1582/0.203	L	N	0.103	L		
DD21	45.0	SC-ML	23	31.0	22.0	UD	0.15/0.1996	M	N	0.102	M		
		SC-ML	10	43.5	3.0	UD		L	Y		L		
DD23	43.0	SM-SC	19	27.0	10.0	D1	0.1432/0.1964	L	N	0.101	L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
DD23	43.0	SC-SP	22	37.5	11.0	D1	0.1432/0.1964	L	N	0.101	M		
DD24	63.0	SM-SC	18	40.5	13.0	D1	0.1763/0.1947	L	Y	0.100	L		
		SM-SC	43	49.5	5.0	D2		Un	N		Un		
		SM-SC	27	57.5	11.0	D1		M	N		Un		
DD25	26.0	SM-SC	18	21.5	9.0	UD	0.159/0.1931	L	N	0.097	L		
DD34	27.0	SC	37	24.5	5.0	UD	0.158/0.1792	Un	N	0.092	Un		
CC7	73.0	SP	30	50.0	10.0	D1	0.1897/0.2204	L	N	0.113	Un		
		SP	>100	60.0	10.0	D2		Un	N		Un		
		GP	57	69.0	8.0	D1		Un	N		Un		
CC9	33.0	ML/CL											All Clay
CC11	76.0	SC-ML	48.0	35.5	5.0	UD	0.1892/0.2135	Un	N	0.109	Un		
		SC-SM	90	48.5	7.0	D1		Un	N		Un		
		SC-SM	46	56.0	8.0	D2		Un	N		Un		
		SP	22	64.0	8.0	D2		L	Y		M		
		SP	50	72.0	8.0	D1		M	N		Un		
CC20	42.0	ML/CL											All Clay
CC22	37.0	ML-SC	18	21.5	7.0	D1	0.1627/0.1953	L	N	0.099	L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
CC22	37.0	SC	22	27.5	5.0	D2	0.1627/0.1953	L	N	0.099	M		
		SP	50	33.5	7.0	D1		Un	N		Un		
CC25	41.0	SP	20	34.5	7.0	D1	0.1467/0.1905	L	N	0.098	M		
		SP	50	39.5	3.0	D1		Un	N		Un		
CC28	40												No Data
CC35	41.0	SP	33	35.0	4.0	D1	0.1597/0.1756	M	N	0.091	Un		
		SP	56	39.50	5.0	D1		Un	N		Un		
CC54	20.0	SM	20	12.5	5.0	UD	0.1315/0.1508	L	N	0.078	M		
BB5	73												No Data
BB9	103.0	SP	24.0	44.5	7.0	D1	0.168/0.214	L	N	0.109	M		
		SP	40.0	64.0	32.0	D2		M	N		Un		
		SP	61.0	91.5	23.0	D1		Un	Y		Un		
BB11	22.0	ML/CL											All Clay
BB14	28.0	ML/CL											All Clay
BB16	43.0	SC	15	37.5	11.0	UD	0.1675/0.2021	L	Y	0.103	Un		
BB21	30												No Data
BB22	32	ML/CL											All Clay

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
BB25	26	ML/CL											All Clay
BB26	40.5	SP-GP	100.0	19.5	5.0	D1	0.1569/0.1865	Un	N	0.095	Un		
		SP-GP	17	25.0	6.0	D2		L	N		L		
		SP-GP	38	30.5	5.0	D2		M	N		Un		
		SP-GP	45	37.0	8.0	D1		Un	N		Un		
BB28	42.0	SC-SP	42	31.5	13.0	D1	0.156/0.1835	Un	N	0.094	Un		
		SC-SP	14	40.0	4.0	D1		L	Y		L		
BB29	50.0	SP-GP	32	21.5	5.0	D1	0.157/0.182	M	N	0.094	Un		
		SP-GP	48	26.0	4.0	D2		M	N		Un		
		SP-GP	63	32.0	8.0	D2		Un	N		Un		
		SP	70	39.0	6.0	D2		Un	N		Un		
		SP	52	46.0	8.0	D1		Un	N		Un		
BB30	54.0	SC-GC	40	22.5	11.0	D1	0.153/0.181	Un	N	0.093	Un		
		SP	32	33.5	11.0	D2		L	N		Un		
		GP	84	43.0	8.0	D2		Un	N		Un		
		GP	50	51.0	8.0	D1		Un	N		Un		
BB31	33.0	SC	50	24.5	5.0	D1	0.147/0.1791	Un	N	0.092	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
BB31	33.0	SC	71	30.0	6.0	D1	0.147/0.1791	Un	N	0.092	Un		
BB34	23	ML/CL											All Clay
BB35	54.0	SM-SC	30	24.0	10.0	D1	0.1573/0.1734	M	N	0.090	Un		
		SP	70	36.0	14.0	D2		Un	N		Un		
		SP	45	48.5	11.0	D1		Un	N		Un		
BB40	53.0	SC	26	25.0	6.0	D1	0.0997/0.1667	M	N	0.087	Un		
		SC	62	32.5	9.0	D2		Un	N		Un		
		SC-GC	60	40.5	7.0	D2		Un	N		Un		
		SC-GC	89	48.5	9.0	D1		Un	N		Un		
BB41	26.0	SC	70	21.5	9.0	UD	0.10/0.160	Un	N	0.086	Un		
AA5	61.0												No Data
AA12	18	ML/CL											All Clay
AA13	35.0	SP	38	31.5	7.0	UD	0.16/0.205	L	N	0.105	Un		
AA15	63.0	SP	16	16.0	4.0	D1	0.167/0.2007	L	N	0.102	L		
		SP	30	33.0	30.0	D1		L	N		Un		
AA17	73.0	SP	50	40	4.0	D1	0.1813/0.1976	Un	N	0.100	Un		
		SP	30	45.5	7.0	D2		L	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
AA17	73.0	SM-SP	18	53.5	9.0	D2	0.1813/0.1976	L	Y	0.100	L		
		SM-SP	30	63.5	11.0	D1		M	N		Un		
AA20	42.0	SP	18	17.5	9.0	D1	0.1694/0.193	L	N	0.098	L		
		SP	27	27.0	10.0	D1		L	N		Un		
AA22	58.0	SP	38	39.0	6.0	D1	0.1519/0.190	L	N	0.097	Un		
		SP	22	45.5	7.0	D1		L	N		M		
AA23	32	SM-SP	18	23.5	9.0	D1	0.1613/0.1885	L	N	0.096	L		
		SM-SP	30	30.0	4.0	D1		M	N		Un		
AA24	31.0	SP	20	15	4.0	D1	0.16/0.187	M	N	0.095	M		
		SP	35	22.0	10.0	D2		M	N		Un		
		SP	86	29.0	4.0	D1		Un	N		Un		
AA25	30.0	SC-SM	38	18.5	13.0	D1	0.1579/0.1855	M	N	0.095	Un		
		SP	80	27.5	5.0	D1		Un	N		Un		
AA28	31.0	SP-GP	20	15.0	4.0	D1	0.1539/0.1811	M	N	0.093	M		
		SP-GP	38	22.0	10.0	D2		M	N		Un		
		SP-GP	80	29.0	4.0	D1		Un	N		Un		
AA31	18.0	ML/CL											All Clay

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake PGA/PBA (g)	M=7.5 Earthquake CERI Criteria	M=7.5 Earthquake Seed's Criteria	M=6.5 Earthquake PBA (g)	M=6.5 Earthquake CERI Criteria	M=6.5 Earthquake Seed's Criteria	Remarks
AA35	42.0	SP	92	34.0	16.0	UD	0.148/0.1713	Un	N	0.089	Un		
AA37	26.0	SM	14	21.5	9.0	UD	0.148/0.1686	L	N	0.088	L		
AA38	28.0	SM-SC	56	12.5	7.0	D1	0.12/0.1673	Un	N	0.087	Un		
		SM-SC	39	22.0	12.0	D1		Un	N		Un		
AA39	52.0	SM-SC	40	28.0	20.0	UD	0.102/0.166	Un	N	0.086	Un		
AA40	30.0	SC-GC	32	15.5	13.0	D1		M	N	0.084	Un		
		SM	30	26.0	8.0	D1		M	N		Un		
A5	73												No Data
A6	40.0	SM	8	19.5	15.0	D1	0.171/0.2117	L	Y	0.108	L		
		SM	19	33.5	13.0	D1		L	N		L		
A7	71.0	SP-SM	5	19.0	10.0	D1	0.198/0.210	L	Y	0.108	L		
		SP-SM	20	27.5	7.0	D2		L	N		L		
		SP-SM	42	41.0	20.0	D1		M	N		Un		
A8	45.0	SP	32	33.0	10.0	D1	0.178/0.209	L	N	0.106	Un		
		SP	45	41.5	7.0	D1		M	N		Un		
A9	21.0												No Data
A11	61.0												No Data

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
A13	85.0	SM-SP	20	28.0	30.0	UD	0.172/0.20	L	N	0.103	L		
		SC-SP	38	75.5	19.0	UD		M	N		Un		
A19	60.0	SP	6	5.0	10.0	D1	0.2/0.192	L	Y	0.099	L		
		ML-SM	3	13.5	7.0	D2		L	Y		L		
		SP	12	20.5	7.0	D1		L	Y		L		
		SP	35	31.0	14.0	D2		M	N		Un		
		SP	60	39.5	3.0	D1		Un	N		Un		
		SP	35	49.5	9.0	UD		L	N		Un		
A20	41.0	ML-SP	18	22.5	13.0	D1	0.161/0.19	L	N	0.098	L		
		SP	22	35.0	12.0	UD		L	N		L		
A21	16.0	ML/CL											
A23	25.0												No Data
A25	41.0	SM-ML	19	22.0	20.0	D1	0.159/0.183	L	N	0.094	M		
		SP	28	36.5	9.0	UD		L	N		M		
A26	30.0	SM-SC	12	18.0	10.0	D1	0.154/0.182	L	N	0.094	L		
		SP	27	26.5	7.0	D1		L	N		Un		
A32	26.0	SP	39	24.0	4.0	UD	0.16/0.173	L	N	0.090	Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
A40	31.0	SC	20	22.5	9.0	UD	0.1084/0.1627	M	N	0.084	Un		
A41	40	ML/CL											All Clay
B5	85.0												No Data
B7	35.0	SP-SM	25	25.5	5.0	D1	0.166/0.207	L	N	0.106	Un		
		SP-SM	48	31.5	7.0	D1		M	N		Un		
B8	51.0	SP-ML	18	31.0	4.0	D1	0.167/0.205	L	N	0.105	L		
		SP-ML	36	38.0	10.0	D2		M	N		Un		
		SP	58	47.5	9.0	D1		Un	N		Un		
B10	50.0												No Data
B11	116.0	SP-SC	23	51.0	20.0	UD	0.163/0.20	L	N	0.102	L		
		SP-SM SC-GP	32.0	77.0	6.0	D1		M	N		Un		
		SP-SM SC-GP	42	90.5	21.0	D1		M	N		Un		
B13	61.0	SP-SM	18	37.0	12.0	D1	0.154/0.198	L	N	0.101	L		
		SP-SM	40	50.5	15.0	D2		M	N		Un		
		SP-SM	57	59.5	3.0	D1		Un	N		Un		
B15	20.0	SC	6	18.0	4.0	UD	0.16/0.195	L	Y	0.100	M		
B16	40.0	SP-ML	16	28.5	11.0	UD	0.161/0.194	L	N	0.098	L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
B17	39.0	SP	12	26.0	6.0	UD	0.1622/0.192	L	Y	0.098	L		
B19	56.0	SM-SP	20	28.0	12.0	D1	0.161/0.189	L	N	0.097	M		
		SP-SM	33	39.0	10.0	D1		M	N		Un		
		SP-SM	60	46.0	4.0	D2		Un	N		Un		
		SP-SM	32.0	50	4.0	D2		M	N		Un		
		SP-SM	78.0	54.0	4.0	D1		Un	N		Un		
B24	25.0												No Data
B25	31.0	SM-SC	18	14.0	10.0	D1	0.168/0.181	L	N	0.094	M		
		SP-SM	21	25.0	12.0	D1		L	N		M		
B28	21.0	SC-SP	20	17.5	7.0	UD	0.155/0.177	L	N	0.091	L		
B32	35	SM-SP	60	30.0	4.0	D1	0.148/0.171	Un	N	0.089	Un		
		SM-SP	50	33.5	3.0	D1		Un	N		Un		
C5	77.0												No Data
C7	70.0	SP	45	38.5	7.0	D1	0.176/0.204	Un	N	0.105	Un		
		SP	25	45.0	6.0	D2		L	N		M		
		SP	45	50.5	5.0	D2		M	N		Un		
		SP	77	57.5	9.0	D2		Un	N		Un		
		SP	82	66.0	8.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
C9	21.0	ML/CL											All Clay
C12	55.0												No Data
C13	41.0	SP-SC	27	35.0	4.0	D1	0.156/0.195	L	N	0.100	Un		
		SP-SC	48	39.0	4.0	D1		M	N	0.100	Un		
C14	30.0	SP-SC	11	23.5	13.0	UD	0.157/0.194	L	Y	0.099	L		
C15	21.0	ML/CL											All Clay
C16	40.0	SP-GP	26	28.0	12.0	D1	0.158/0.191	L	N	0.097	Un		
		SP-GP	56	37.0	6.0	D1		M	N		Un		
C17	65.0	ML-SM	12	24.5	9.0	D1	0.157/0.189	L	Y	0.097	L		
		SC-GC	38	31.5	5.0	D1		M	N		Un		
		SC-GC	62	39.5	11.0	D1		Un	N		Un		
		SP	68	60.0	10.0	UD		Un	N		Un		
C18	41.0	GP	61	32.5	9.0	D1	0.1498/0.188	Un	N	0.095	Un		
		GP	42	39.0	4.0	D1		M	N		Un		
C19	61.0	SC-SP	21	32.0	8.0	D1	0.151/0.187	L	N	0.095	M		
		SP	70	42.0	12.0	D2		Un	N		Un		
		SP	57	52.5	9.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
C24	25.0												No Data
C25	25.0												No Data
C26	40.0	SP	20	25.5	13.0	D1	0.152/0.177	L	N	0.091	M		
		SP	40	36.0	8.0	D1		M	N		Un		
C27	45.0	SP	18	18.0	12.0	D1	0.161/0.176	L	N	0.090	M		
		SP-GP	35	28.5	9.0	D2		M	N		Un		
		SP-GP	50	37.5	9.0	D2		M	N		Un		
		SP-GP	23	43.5	3.0	D1		L	N		Un		
C28	50.0	SP-SM	17	30.0	4.0	D1	0.1602/0.1742	L	N	0.090	M		
		SP-SM	40	35.0	6.0	D2		M	N		Un		
		SP-GP	56	40.0	4.0	D2		M	N		Un		
		SP-GP	82	46.0	8.0	D1		Un	N		Un		
C29	120	SP-SM	25	28.5	9.0	D1	0.1561/0.1799	L	N	0.090	Un		
		SP-SM	50	38.0	10.0	D2		M	N		Un		
		SP-SM	60	48.5	11.0	D1		Un	N		Un		
		SC-SP	55	77.5	5.0	D1		Un	N		Un		
		SC-SP	77	88.0	16.0	D2		Un	N		Un		
		SC-SP	91	99.5	7.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
C30	45.0	SP-GP	21	21.5	13.0	D1	0.158/0.172	L	N	0.089	Un		
		SP-GP	40	33.0	10.0	D2		M	N		Un		
		SP-GP	100	40.0	4.0	D2		Un	N		Un		
		SP-GP	60	43.5	3.0	D1		Un	N		Un		
C31	61.0	SP-SM	20	24.5	11.0	D1	0.163/0.17	L	N	0.088	M		
		SP-GP	55	33.5	7.0	D2		M	N		Un		
		SP-GP	68	39.5	5.0	D2		Un	N		Un		
		SP-GP	81	44.5	5.0	D2		Un	N		Un		
		SP-GP	62	49.5	5.0	D2		Un	N		Un		
		SP-GP	84	54.0	4.0	D2		Un	N		Un		
		SP-GP	56	58.5	5.0	D1		Un	N		Un		
C32	45.0	SP-GP	42	29.5	7.0	D1	0.159/0.169	M	N	0.087	Un		
		SP-GP	80	35.5	5.0	D2		Un	N		Un		
		SP-SC	78	40.0	4.0	D2		Un	N		Un		
		SP-SC	100	43.5	3.0	D1		Un	N		Un		
C37	53.0	SC-SP	42	15.5	5.0	D1	0.133/0.163	M	N	0.084	Un		
		SC-SP	63	20.5	5.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
D5	102.0												No Data
D6	146.0	SM-SP	7	6.0	12.0	D1	0.141/0.202	L	N	0.104	L		
		SM-SP	13	21.5	19.0	D1		L	N		L		
		SM-SC	23	70.0	34.0	UD		L	N		L		
D7	31.0	ML/CL											All Clay
D8	20.0	ML/CL											All Clay
D17	70.0	SM-SC-ML	18	24.5	5.0	D1	0.152/0.137	L	N	0.097	L		
		SM-SC-ML	38	30.5	7.0	D2		L	N		Un		
		SM-SC	55	39.0	10.0	D2		M	N		Un		
		SP-GP	78	48.5	9.0	D2		Un	N		Un		
		SP-GP	45	61.5	17.0	D1		M	N		Un		
D25	25.0												No Data
D26	25.0												No Data
D28	52.0	SC-SM	18	22.5	9.0	D1	0.166/0.172	L	N	0.089	M		
		SP	23	32.5	11.0	D2		L	N		M		
		SP	50	45.0	14.0	D1		Un	N		Un		
D29	77.0	SM-SC	18	17.5	13.0	D1	0.165/0.171	L	N	0.089	M		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
D29	77.0	SP-SC	22	28.5	9.0	D2	0.165/0.171	L	N	0.089	M		
		SP-SC	35	38.0	10.0	D2		M	N		Un		
		SP-SC	61	48.0	10.0	D1		Un	N		Un		
D37	35.0	SP-SC	42	14.5	5.0	D1	0.102/0.161	Un	N	0.083	Un		
		SP-SC	74	22.0	10.0	D2		Un	N		Un		
		SP-SC	62	31.0	8.0	D1		Un	N		Un		
D40	61.0	SP-SC	18	10.0	6.0	D1	0.117/0.157	L	N	0.081	M		
		SP-SC	30	18.0	10.0	D1		M	N		Un		
		SP-SM	19	41.5	21.0	UD		L	N		L		
D41	40.0	SP-SM	17	19.5	7.0	D1	0.115/0.156	L	N	0.080	M		
		SP-SM	23	26.0	6.0	D1		L	N		Un		
D42	32.0	SC-SP	15	24.5	5.0	D1	0.104/0.155	L	N	0.079	M		
		SC-SP	38	29.5	5.0	D1		Un	N		Un		
E5	110.0												No Data
E6	101.0	ML-SM	7	6.5	13.0	D1	0.1486/0.1988	L	Y	0.102	L		
		SP	20	45	16.0	D1		L	N		M		
		SM-SP	20	55.5	5.0	D2		L	Y		L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
E6	101.0	SM-SP	16	63.0	10.0	D2	0.1486/0.1988	L	Y	0.102	L		
		GP	15	72.5	9.0	D2		L	Y		L		
		GP	23	82.5	11.0	D2		L	Y		M		
		SC	58	90.5	5.0	D1		Un	Y		Un		
E7	105	GP-SP	50	47.0	10.0	D1	0.1649/0.1974	Un	N	0.101	Un		
		SP-SM	>100	55.0	6.0	D2		Un	N		Un		
		SP-SM	32	63.0	10.0	D1		L	N		Un		
		SP-SM	42	85.5	11.0	UD		M	N		Un		
E8	31.0	SM	20	29.5	1.5	UD	0.1961/0.1282	L	N	0.100	L		
E9	21.0	ML/CL											All Clay
E10	35.0	SP-GP	36	32.5	5.0	UD	0.145/0.1934	M	N	0.098	Un		
E11	40.0	SC-SP	47	30.0	6.0	D1	0.142/0.192	Un	N	0.098	Un		
		SP-GP	63	35.0	4.0	D2		Un	N		Un		
		SP-GP	83	38.5	3.0	D1		Un	N		Un		
E13	61.0	SP-GP	57	30.0	6.0	D1	0.1406/0.1894	Un	N	0.097	Un		
		SM-SP	42	37.5	9.0	D1		M	N		Un		
		SM	>100	56.5	9.0	UD		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
E14	36.0	ML/CL											All Clay
E16	25.0	SC	27	23.5	3.0	UD	0.142/0.1854	M	N	0.095	Un		
E19	21.0	ML/CL											All Clay
E26	31.0	SP-SM	17	15.0	8.0	D1	0.151/0.172	L	N	0.089	M		
		SP	26	21.0	4.0	D2		L	N		M		
		SP	37	27.0	8.0	D1		M	N		Un		
E27	60.0	SM-SC-SP	10	9.0	6.0	D1	0.158/0.171	L	N	0.088	L		
		SP	17	14.5	5.0	D2		L	N		M		
		SP	22	22.0	10.0	D2		L	N		M		
		SP-GP	25	33.5	13.0	D1		L	N		Un		
		SC	77	50.5	3.0	D1		Un	N		Un		
		SC	42	54.5	5.0	D2		Un	N		Un		
		SC	63	58.5	3.0	D1		Un	N		Un		
E29	53.0	SM-SC	8	15.5	7.0	D1	0.154/0.1685	L	Y	0.087	L		
		SP-SM	20	21.0	4.0	D2		L	N		M		
		SP-SM	63	25.5	5.0	D2		Un	N		Un		
		SP-SM	9	29.5	3.0	D1		L	Y		L		
		SP-SC	85	48.0	10.0	UD		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
E37	37.0	SC	37	25.0	4.0	D1	0.121/0.159	Un	N	0.081	Un		
		SC	49	29.5	5.0	D2		Un	N		Un		
		GP	>100	34.5	5.0	D1		Un	N		Un		
E48	21.0	SC-SP	24.0	16.5	9.0	UD	0.113/0.146	L	N	0.075	M		
F5	90.0												No Data
F6	128.0	SP-SC-SM	37	40.5	5.0	D1	0.141/0.1957	M	N	0.100	Un		
		SP-SC-SM	61	45.0	4.0	D2		Un	N		Un		
		SP-SC-SM	79	49.5	5.0	D2		Un	N		Un		
		SP-SC-SM	86	63.5	23.0	D2		Un	N		Un		
		SP-GP-CL	55	85.0	20.0	D1		Un	N		Un		
F7	100.0	SP-SM	50	49.0	6.0	D1	0.165/0.197	Un	N	0.099	Un		
		SP-SM	41	55.0	6.0	D2		M	N		Un		
		SP-SM	54	60.0	4.0	D2		Un	N		Un		
		SP-SM	62	70.0	16.0	D1		Un	N		Un		
		SP-CL	88	96.5	7.0	UD		Un	N		Un		
F8	56.0	SC-SM	20	30.5	7.0	D1	0.1315/0.193	L	N	0.098	M		
		SP-SM	45	38.5	9.0	D2		M	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
F8	56.0	SP	60	48.0	10.0	D2	0.1315/0.193	Un	N	0.098	Un		
		SP	87	54.5	3.0	D1		Un	N		Un		
F9	150.0	SC-SM-ML	23	30.5	13.0	D1	0.14/0.191	L	N	0.098	Un		
		SC-SM	42	45.0	16.0	D2		M	N		Un		
		SC-SM	58	55.5	5.0	D2		Un	N		Un		
		SP-GP	62	69.0	22.0	D2		Un	N		Un		
		SP-GP	>100	88.0	16.0	D2		Un	N		Un		
		SP	85	104.5	17.0	D2		Un	N		Un		
F10	51.0	SP-SC	48.0	45.5	11.0	UD	0.14/0.191	M	N	0.098	Un		
F11	26.0	SC-SP	18	20.0	6.0	D1	0.145/0.1892	L	N	0.097	L		
		SC-SP	41	24.5	3.0	D1		Un	N		Un		
F13	101	SP-SM	38	41.0	4.0	D1	0.1578/0.1866	M	N	0.095	Un		
		SP-SM	79	45.5	5.0	D2		Un	N		Un		
		SP-SM	56	50.0	4.0	D2		Un	N		Un		
		SP	70	58.0	12.0	D2		Un	N		Un		
		SP	25	63.0	10.0	D2		L	Y		M		
		SP	77	70.5	5.0	D2		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
F13	101	SP	>100	75.0	4.0	D2	0.1578/0.1866	Un	N	0.095	Un		
		SP	28	82.5	11.0	D2		L	Y		M		
		SP	42	94.5	13.0	D1		Un	N		Un		
F14	156.0	SP	40	41.5	11.0	D1	0.147/0.185	M	N	0.094	Un		
		SP	57	50.0	6.0	D2		Un	N		Un		
		SP	>85	56.5	7.0	D2		Un	N		Un		
		SP	72	64.0	8.0	D2		Un	N		Un		
		SP	>80	73.0	10.0	D2		Un	N		Un		
		SP	62	80.5	5.0	D2		Un	N		Un		
		SP-SC	77	85.5	5.0	D2		Un	N		Un		
		SP-SC	37	90.5	5.0	D2		M	Y		Un		
		SP-SC	59	97.5	9.0	D1		Un	Y		Un		
F15	103.0	SC	10	39.0	12.0	D1	0.14/0.184	L	Y	0.094	M		
		SP	>83	49.0	8.0	D2		Un	N		Un		
		SP	57	60.5	15.0	D2		Un	N		Un		
		SP	78	71.5	7.0	D2		Un	N		Un		
		SC-GP	77	81.0	12.0	D2		Un	N		Un		
		SC-GP	22	88.5	3.0	D2		L	Y		M		
		SP	78	96.5	13.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
F17	28.0	ML/CL											All Clay
F19	67.0	SC-SM	63	40.5	13.0	D1	0.14/0.179	Un	N	0.093	Un		
		SP-SM	86	49.5	5.0	D2		Un	N		Un		
		SP-SM	62	55.0	6.0	D2		Un	N		Un		
		SP-SM	>100	60.0	4.0	D2		Un	N		Un		
		GP	81	64.5	5.0	D1		Un	N		Un		
F21	21.0	ML/CL											All Clay
F23	26.0	SP-GP	47	24.0	4.0	UD	0.138/0.174	M	N	0.090	Un		
F25	31.0	SP	18	15.0	4.0	D1	0.1398/0.1713	L	N	0.089	M		
		SP	11	21.5	9.0	D2		L	N		L		
		SP	19	28.5	5.0	D1		L	N		M		
F27	25.0												No Data
F36	20.0	ML/CL											All Clay
F37	41.0	SP-SC	38	19.0	10.0	D1	0.122/0.157	Un	N	0.080	Un		
		SP-GP	>81	32.5	17.0	UD		Un	N		Un		
F47	25.0	SP-GP	35	14.0	10.0	D1	0.114/0.146	Un	N	0.075	Un		
		SP-GP	40	22.0	6.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
G5	75.0	SC	22	51.0	4.0	D1	0.153/0.194	L	N	0.099	M		
		SC	43	58.0	10.0	D2		Un	N		Un		
		SP	58	65.0	4.0	D2		Un	N		Un		
		SP	74	71.0	8.0	D1		Un	N		Un		
G6	135.0	SM-SC	22	43.0	8.0	D1	0.1533/0.194	L	N	0.098	M		
		SM-SC	62	51.0	8.0	D2		Un	N		Un		
		SP-GP	42	59.5	9.0	D2		M	N		Un		
		SP-GP	64	69.5	11.0	D2		Un	N		Un		
		SP-GP	41	82.0	14.0	D1		M	N		Un		
G7	84.0	SM-SC	16	24.0	10.0	D1	0.1385/0.1915	L	N	0.098	L		
		SP-SC	35	33.5	9.0	D2		M	N		Un		
		SP-SC	55	43.0	10.0	D2		M	N		Un		
		SP-GP	61	55.5	15.0	D2		Un	N		Un		
		SP-GP	78.0	68.0	10.0	D2		Un	N		Un		
		SP-GP	82	75.5	5.0	D2		Un	N		Un		
		SP-GP	30	81.0	6.0	D1		L	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
G8	62.0	SM-SC	13	30.0	4.0	D1	0.153/0.19	L	Y	0.097	L		
		SM-SC	27	35.0	6.0	D2		L	N		M		
		SP-SM	60	47.0	18.0	D2		Un	N		Un		
		SP-SM	40	59.0	6.0	D1		M	N		Un		
G9	120.0	SM-SC	38	30.5	13.0	D1	0.129/0.189	M	N	0.097	Un		
		SP	42	45.0	16.0	D2		M	N		Un		
		SP	57	59.0	12.0	D2		Un	N		Un		
		SP	41	78.0	26.0	D2		M	N		Un		
G10	77.0	SC-SP	38	35.5	3.0	D1	0.1495/0.188	M	N	0.096	Un		
		SC-SP	81	40.5	7.0	D2		Un	N		Un		
		SM-SP	78	48.5	9.0	D2		Un	N		Un		
		SM-SP	81	55.5	5.0	D2		Un	N		Un		
		SM-SP	50	60.5	5.0	D1		M	N		Un		
G12	21.0	ML/CL											All Clay
G13	40.0	SM-SC	15	19.0	10.0	D1	0.1246/0.1839	L	N	0.094	L		
		SM	30	26.0	4.0	D2		L	N		Un		
		SM	42	30.0	4.0	D2		M	N		Un		
		SM	22	36.0	8.0	D1		L	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
G14	35.0	SP	38	24.5	5.0	D1	0.14/0.1827	M	N	0.093	Un		
		SP	56	31.0	8.0	D1		Un	N		Un		
G16	46.0	SP	62	39.0	14.0	UD	0.1504/0.1802	Un	N	0.093	Un		
G19	16.0	ML/CL											All Clay
G27	41.0	SP-CL	37	20.0	14.0	UD	0.1385/0.1667	L	N	0.087	M		
G28	25.0												No Data
G29	25.0												No Data
G30	52.0	ML-SM	6	4.5	9.0	D1	0.159/0.1632	L	Y	0.084	L		
		SP	14	19.5	21.0	D1		L	N		L		
		SP	39.0	36.5	13.0	D1		Un	N		Un		
G33	20.0	ML/CL											All Clay
G37	35.0	SC-SP	38	20.0	4.0	D1	0.111/0.155	Un	N	0.079	Un		
		SC-SP	62	25.0	6.0	D2		Un	N		Un		
		SC-SP	93	30.0	4.0	D2		Un	N		Un		
		SC-SP	77	33.5	3.0	D1		Un	N		Un		
H4	31.0	SP-GP	22	25.5	3.0	D1	0.167/0.1922	L	N	0.098	M		
		SP-GP	32	29.0	4.0	D1		L	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake PGA/PBA (g)	M=7.5 Earthquake CERI Criteria	M=7.5 Earthquake Seed's Criteria	M=6.5 Earthquake PBA (g)	M=6.5 Earthquake CERI Criteria	M=6.5 Earthquake Seed's Criteria	Remarks
H5	62.0	SM-SP	58	55.0	6.0	D1	0.171/0.191	Un	N	0.098	Un		
		SM-SP	79	60.0	4.0	D1		Un	N		Un		
H6	70.0	SC-SM	18	39.0	14.0	D1	0.1445/0.1898	L	N	0.097	L		
		SP-GP	70	51.5	11.0	D2		Un	N		Un		
		SP-GP	43	63.5	13.0	D1		Un	N		Un		
H7	36.0	ML/CL											All Clay
H12	36.0	SC-SP	59	30.0	6.0	D1	0.15/0.1825	Un	N	0.094	Un		
		SC-SP	91	34.5	3.0	D1		Un	N		Un		
H13	68.0	SC-SM	11	19.5	7.0	D1	0.152/0.1813	L	Y	0.094	L		
		SC-SM	20	28.0	10.0	D2		L	N		M		
		SP	57	35.0	4.0	D2		Un	N		Un		
		SP	39	40.0	6.0	D2		M	N		Un		
		SP	60	50	14	D2		Un	N		Un		
		SP	46	60.0	6.0	D2		M	N		Un		
		SP	28	65.5	5.0	D1		L	N		Un		
H14	53.0	SP-SC	42	35.5	3.0	D1	0.144/0.18	Un	N	0.094	Un		
		SP-SC	61	42.0	10.0	D2		Un	N		Un		
		SP-SC	50	50	6.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
H15	53.0	SC-SP	25	37.5	11.0	D1	0.161/0.1789	L	N	0.092	Un		
		SC-SP	53	45.5	5.0	D2		Un	N		Un		
		SC-SP	79	50.5	5.0	D1		Un	N		Un		
H16	28.0	ML/CL											All Clay
H17	55.0	SP	18	31.0	4.0	D1	0.143/0.1765	L	N	0.090	M		
		SP	37	40.5	15.0	D2		M	N		Un		
		SP	21	51.5	7.0	D1		L	N		M		
H18	50.0	SC-SP	20	33.0	10.0	D1	0.1518/0.1753	L	N	0.090	M		
		SC-SP	43	42.5	9.0	D2		M	N		Un		
		SC-SP	72	48.5	3.0	Di		Un	N		Un		
H19	92.0	SM-SP	30	31.5	11.0	D1	0.154/0.174	L	N	0.090	Un		
		SM-SP	45	45.0	16.0	D2		M	N		Un		
		SM-SP	40	58.0	10.0	D2		M	N		Un		
		SM-SP	60	68.0	10.0	D2		Un	N		Un		
		SM-SP	40	82.5	19.0	D1		Un	Y		Un		
H29	95.0	SP	23	25.0	6.0	D1	0.099/0.162	L	N	0.084	Un		
		SP	31	33.0	10.0	D2		M	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
H29	95.0	SP	30	43.0	10.0	D2	0.099/0.162	L	N	0.084	Un		
		CL-SP	30	64.0	32.0	D2		L	N		Un		
		CL-SP	40	87.5	15.0	D1		Un	N		Un		
H30	100.0	SP	22	18.5	7.0	D1	0.101/0.161	L	N	0.083	Un		
		SP	30	33.0	22.0	D2		L	N		Un		
		SM-SP	23	54.5	21.0	D2		L	N		M		
		SP	21	70.0	10.0	D2		L	N		M		
		SP	56	81.5	13.0	D1		Un	N		Un		
H31	23.0												No Data
H33	20.0	ML/CL											
H36	50.0	SP	62	34.0	6.0	D1	0.125/0.154	Un	N	0.079	Un		
		SP	11	40.0	6.0	D2		L	Y		L		
		SP	60	46.5	7.0	D1		Un	N		Un		
H37	50.0	SP-GP	23	25.5	5.0	UD	0.118/0.153	L	N	0.078	M		
I3	76.0	SM-SC-SP	28	28.5	17.0	D1	0.132/0.190	L	N	0.097	Un		
		SM-SP	42	47.0	20.0	D2		M	N		Un		
		SP	80	59.5	5.0	D2		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
I3	76.0	SP	70	65.0	6.0	D2	0..132/0.190	Un	N	0.097	Un		
		SP	>93	70.5	5.0	D2		Un	N		Un		
		SP	79	74.5	3.0	D1		Un	N		Un		
I4	62.0	SP	30	20.5	5.0	D1	0.189/0.209	L	N	0.097	Un		
		SP	>100	28.0	10.0	D2		Un	N		Un		
		SP	78	35.0	4.0	D2		Un	N		Un		
		SP	>100	42.5	11.0	D2		Un	N		Un		
		SP	12	51.0	6.0	D2		L	Y		L		
		SP	>100	56.0	4.0	D1		Un	N		Un		
I5	60.0	SC-GC	60	51.5	7.0	D1	0.156/0.188	Un	N	0.097	Un		
		SC-GC	>100	57.5	5.0	D1		Un	N		Un		
I6	31.0	SP	27	25.0	6.0	D1	0.1499/0.187	L	N	0.096	Un		
		SP	77.0	29.5	3.0	D1		Un	N		Un		
I7	25.0	ML/CL											All Clay
I10	51.0	SC-SM	20	43.5	15.0	UD	0.1449/0.1823	L	Y	0.094	L		
I14	21.0	ML/CL											All Clay
I15	60.0	SC-SP	41	47.5	9.0	D1	0.1453/0.1764	Un	N	0.090	Un		
		SP-GP	58	56.0	8.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
I17	46.0	SM-SP	18	35.0	4.0	D1	0.138/0.174	L	N	0.090	M		
		SM-SP	50	40.0	6.0	D2		M	N		Un		
		SM-SP	27	44.5	3.0	D1		L	N		Un		
I19	60	SC	43	34.0	12.0	D1	0.142/0.172	Un	N	0.088	Un		
		SP	49	43.5	7.0	D2		M	N		Un		
		SP	35	52.0	10.0	D2		M	N		Un		
		SP	78	58.5	3.0	D1		Un	N		Un		
I20	50.0	SC	57	37.0	10.0	D1	0.148/0.171	Un	N	0.087	Un		
		SC-SM	60	44.5	5.0	D2		Un	N		Un		
		SC-SM	78	48.5	3.0	D1		Un	N		Un		
I21	52.0	SC	41	35.5	3.0	D1	0.142/0.1694	Un	N	0.086	Un		
		SC	32	40.5	7.0	D2		M	N		Un		
		SC-SP	47	48.0	8.0	D1		M	N		Un		
I23	40.0	SC	33	23.0	12.0	D1	0.142/0.1671	M	N	0.086	Un		
		SP	57	31.0	4.0	D2		Un	N		Un		
		SP	62	35.0	4.0	D2		Un	N		Un		
		SP	71	38.5	3.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
I25	50.0	SM-SC	31	28.0	10.0	D1	0.138/0.165	M	N	0.085	Un		
		SM-SC	41	34.5	3.0	D2		M	N		Un		
		SP	>82	43.0	14.0	D1		Un	N		Un		
I26	25.0	SM-SC	28	15.5	5.0	D1	0.138/0.163	L	N	0.084	Un		
		SM-SC	84	21.5	7.0	D1		Un	N		Un		
I27	30.0	ML/CL											All Clay
I31	20.0	ML/CL											All Clay
I32	26.0												No Data
I33	25.0												No Data
I34	25.0												No Data
I35	90.0	SP-GP	38	16.0	4.0	D1	0.0896/0.154	Un	N	0.079	Un		
		SP-GP	23	22.5	9.0	D2		L	N		M		
		SP-GP	62	30.0	6.0	D2		Un	N		Un		
		SP-GP	38	35.5	5.0	D2		M	N		Un		
		SC-SM	11	50.5	25.0	D1		L	Y		L		
		SC	21	81.5	11.0	D1		L	Y		Un		
		SC	57	88.5	3.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
I36	90.0	SP	10	11.0	4.0	D1	0.0918/0.1526	L	N	0.078	L		
		SP	20	20.5	15.0	D2		L	N		M		
		SP	38	32.5	9.0	D2		M	N		Un		
		SM-SC	12	46.0	18.0	D2		L	Y/N		L		
		SC	11	62.0	14.0	D1		L	Y		M		
		SC-SP	22	84.0	12.0	UD		L	Y		M		
I40	51.0	SC	17	15.5	5.0	D1	0.1013/0.1483	L	N	0.075	M		
		SC	21	20.5	5.0	D2		L	N		Un		
		SC	24	28	10	D2		M	N		Un		
		SC-SP	51	38.5	11.0	D2		Un	N		Un		
		SC-SP	30	47.5	7.0	D1		L	N		Un		
I52	31.0	SP-SM	23	15.0	4.0	D1	0.102/0.1362	L	N	0.069	Un		
		SP-SM	13	20.0	6.0	D2		L	N		M		
		SP-SM	20	27.0	8.0	D1		L	N		Un		
J(-1)	40.0												No Data
J0	65.0												No Data

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
J2	152.0	SC-SM	11	15.0	30.0	D1	0.1433/0.1886	L	N	0.097	L		
		SM-SP	11	37.5	15.0	D2		L	Y		L		
		SC-SP	18	49.0	8.0	D2		L	Y/N		L		
		SC-SP	30	58.0	10.0	D2		L	N		Un		
		SC-SP	36	70.0	14.0	D2		M	N		Un		
		SC-SP	40	88.5	23.0	D1		M	N		Un		
J4	52.0	ML/CL											All Clay
J7	61.0	SC-SP	17	35.5	5.0	D1	0.156/0.183	L	Y/N	0.094	L		
		SC-SP	47	40.5	5.0	D2		M	N		Un		
		SC-SP	78	45.0	4.0	D2		Un	N		Un		
		SC-SP	94	49.5	5.0	D2		Un	N		Un		
		SP	63	56.5	9.0	D1		Un	N		Un		
J8	20.0	ML/CL											All Clay
J9	40.0	SC	62	36.5	7.0	UD	0.156/0.181	Un	N	0.093	Un		
J10	31.0	ML/CL											All Clay
J13	30.0	SM-SC	18	26.0	8.0	UD	0.145/0.176	L	N	0.090	L		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
J14	50.0	SM-SP	28	29.0	14.0	D1	0.152/0.175	L	N	0.090	Un		
		SP	40	39.0	6.0	D2		M	N		Un		
		SP	55	46.0	8.0	D1		Un	N		Un		
J15	43.0	SM-SP	43	30.5	5.0	D1	0.152/0.174	Un	N	0.089	Un		
		SM-SP	32	35.5	5.0	D2		L	N		Un		
		SM-SP	42	40.5	5.0	D1		Un	N		Un		
J18	61.0	SC-SM-SP	56	27.0	10.0	D1	0.156/0.171	Un	N	0.087	Un		
		SC-SM-SP	42	34.0	4.0	D2		M	N		Un		
		SP-GP	48	42	12.0	D2		M	N		Un		
		SP-GP	62	53.0	10.0	D2		Un	N		Un		
		SP-GP	84	59.5	3.0	D1		Un	N		Un		
J19	95.0	SC	43	29.5	5.0	D1	0.153/0.169	Un	N	0.087	Un		
		SC	70	36.5	9.0	D2		Un	N		Un		
		SP-SM	77	46.5	10.0	D2		Un	N		Un		
		SP	>81	57.0	12.0	D2		Un	N		Un		
		SP	77	68.0	10.0	D2		Un	N		Un		
		SP	43	75.0	4.0	D2		M	N		Un		
		SP	>82	86.0	18.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
J23	52.0	SC-SP	42	30.0	4.0	D1	0.149/0.165	Un	N	0.086	Un		
		SC-SP	32	34.5	5.0	D2		M	N		Un		
		SP	48	39.5	5.0	D2		M	N		Un		
		SP	30	44.5	5.0	D2		L	N		Un		
		SP	57	49.5	5.0	D1		Un	N		Un		
J24	52.0	SC-SM	20	23.0	10.0	D1	0.137/0.164	L	N	0.084	Un		
		SC-SM	38	30.0	4.0	D2		M	N		Un		
		SP	68	37.0	10.0	D2		Un	N		Un		
		SP	>89	47.0	10.0	D1		Un	N		Un		
J26	31.0	SC-GC	77	25.0	4.0	D1	0.135/0.160	Un	N	0.083	Un		
		SC-GC	>82	29.0	4.0	D1		Un	N		Un		
J28	31.0	SC-GC	58	21.0	4.0	D1	0.132/0.159	Un	N	0.082	Un		
		SC-GC	>83	25.0	4.0	D2		Un	N		Un		
		SC-GC	70	29.0	4.0	D1		Un	N		Un		
J35	26.0												No Data
J36	63.0	ML-SM-SC	20	19.0	14.0	D1	0.162/0.151	L	N	0.077	Un		
		SP	21	32.0	12.0	D1		L	N		Un		
		SP	40	40.5	5.0	D2		M	N		Un		
		SP	57	45.0	4.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
J37	26.0												No Data
J38	25.0												No Data
J44	51.0	SP	3	11.0	4.0	D1	0.117/0.143	L	Y	0.074	L		
		SP	20	22.5	19.0	D1		L	N		Un		
J54	26.0	SP-SM	11	19.0	14.0	UD	0.099/0.135	L	N	0.068	L		
K0	25	SP	10	6.0	12.0	D1	0.154/0.188	L	N	0.097	L		
		SP	22	15.0	6.0	D2		L	N		M		
		SP	17	21.5	7.0	D1		L	N		L		
K1	35.0	SP	17	6.0	12.0	D1	0.148/0.187	L	N	0.096	L		
		SP	21	15.0	6.0	D2		L	N		M		
		SP	16	20.5	5.0	D2		L	N		L		
		SP	6	25.5	5.0	D2		L	Y		L		
		SM	3	31.5	7.0	D1		L	Y		L		
K6	26.0	ML/CL											All Clay
K11	90.0	SC-SM	25	21.0	10.0	UD	0.146/0.176	L	N	0.090	M		
		SC-SM	26	47.5	9.0	UD		L	N		M		
		SP-SM	38	70.0	6.0	D1		M	N		Un		
		SP-SM	22	76.5	7.0	D1		L	Y/N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
K12	65.0	SP-GP	43	27.5	11.0	D1	0.174/0.175	Un	N	0.090	Un		
		SP-GP	71	35.0	4.0	D2		Un	N		Un		
		SP-GP	60	42.5	11.0	D2		Un	N		Un		
		SP-GP	86	51.5	7.0	D1		Un	N		Un		
K14	54.0	SP-SC	18	35.0	4.0	D1	0.1633/0.1726	L	N	0.089	M		
		SP-SC	65	42.5	11.0	D2		Un	N		Un		
		SP-SC	37	51.0	6.0	D1		M	N		Un		
K15	28.0	ML/CL											All Clay
K16	32.0	SC	29	25.0	6.0	D1	0.1286/0.1704	M	N	0.088	Un		
		SC	64	30.0	4.0	D1		Un	N		Un		
K17	22.0	ML/CL											All Clay
K21	22.0	SM-SC	23	19.0	6.0	UD	0.13/0.168	L	N	0.085	Un		
K22	54.0	SC	32	27.5	11.0	D1	0.1322/0.164	M	N	0.084	Un		
		SC	72	35.0	4.0	D2		Un	N		Un		
		SC-SP	31	39.5	5.0	D2		M	N		Un		
		SC-SP	43	45.0	6.0	D2		M	N		Un		
		SC-SP	63	51.0	6.0	D1		Un	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
K24	54.0	SC-SP	32	25.0	4.0	D1	0.132/0.162	M	N	0.083	Un		
		SC-SP	21	29.5	5.0	D2		L	N		M		
		SC-SP	>83	43.0	22.0	D1		Un	N		Un		
K26	50.0	SC	30	20.0	6.0	D1	0.1361/0.1596	M	N	0.083	Un		
		SC	57	26.0	6.0	D2		Un	N		Un		
		SC-CL	63	36.5	15.0	D2		Un	N		Un		
		SP	38	45.5	3.0	D2		M	N		Un		
		SP	70	48.5	3.0	D1		Un	N		Un		
K27	54.0	SC-SP	53	21.0	4.0	D1	0.1334/0.159	Un	N	0.081	Un		
		SC-SP	82	25.5	5.0	D2		Un	N		Un		
		SC-SP	73	30.5	5.0	D2		Un	N		Un		
		SC-GC	68	37.5	9.0	D2		Un	N		Un		
		SC-GC	58	48.0	12.0	D1		Un	N		Un		
K28	51.0	SC-SM	48	19.5	7.0	D1	0.141/0.1574	Un	N	0.080	Un		
		SC-SM	62	25.5	5.0	D2		Un	N		Un		
		SC-SM	70	33.5	11.0	D2		Un	N		Un		
		SC-SM	43	41.0	4.0	D2		M	N		Un		
		SC-SM	30	47.0	8.0	D1		M	N		Un		

Site	Total Depth (ft)	Soil Type	N_{spt}	Mid-Depth (ft)	Thick-ness (ft)	Site Drainage	M=7.5 Earthquake			M=6.5 Earthquake			Remarks
							PGA/PBA (g)	CERI Criteria	Seed's Criteria	PBA (g)	CERI Criteria	Seed's Criteria	
K29	63.0	SC-CL	43	20.5	5.0	D1	0.139/0.1563	Un	N	0.080	Un		
		SC-CL	57	26.0	6.0	D2		Un	N		Un		
		SP-SM	60	31.0	4.0	D2		Un	N		Un		
		SP-SM	68	48.0	30.0	D1		Un	N		Un		
K30	63.0	SC-CL	39	16.0	4.0	D1	0.127/0.155	Un	N	0.079	Un		
		SC-CL	48	25.0	14.0	D2		Un	N		Un		
		SP-SM	65	42.5	21.0	D2		Un	N		Un		
		SP-SM	10	55.5	5.0	D2		L	Y		L		
		SP-SM	30	60.5	5.0	D1		M	N		Un		

NATIONAL CENTER FOR EARTHQUAKE ENGINEERING RESEARCH
LIST OF TECHNICAL REPORTS

The National Center for Earthquake Engineering Research (NCEER) publishes technical reports on a variety of subjects related to earthquake engineering written by authors funded through NCEER. These reports are available from both NCEER's Publications Department and the National Technical Information Service (NTIS). Requests for reports should be directed to the Publications Department, National Center for Earthquake Engineering Research, State University of New York at Buffalo, Red Jacket Quadrangle, Buffalo, New York 14261. Reports can also be requested through NTIS, 5285 Port Royal Road, Springfield, Virginia 22161. NTIS accession numbers are shown in parenthesis, if available.

NCEER-87-0001 "First-Year Program in Research, Education and Technology Transfer," 3/5/87, (PB88-134275/AS).

NCEER-87-0002 "Experimental Evaluation of Instantaneous Optimal Algorithms for Structural Control," by R.C. Lin, T.T. Soong and A.M. Reinhorn, 4/20/87, (PB88-134341/AS).

NCEER-87-0003 "Experimentation Using the Earthquake Simulation Facilities at University at Buffalo," by A.M. Reinhorn and R.L. Ketter, to be published.

NCEER-87-0004 "The System Characteristics and Performance of a Shaking Table," by J.S. Hwang, K.C. Chang and G.C. Lee, 6/1/87, (PB88-134259/AS). This report is available only through NTIS (see address given above).

NCEER-87-0005 "A Finite Element Formulation for Nonlinear Viscoplastic Material Using a Q Model," by O. Gyebi and G. Dasgupta, 11/2/87, (PB88-213764/AS).

NCEER-87-0006 "Symbolic Manipulation Program (SMP) - Algebraic Codes for Two and Three Dimensional Finite Element Formulations," by X. Lee and G. Dasgupta, 11/9/87, (PB88-219522/AS).

NCEER-87-0007 "Instantaneous Optimal Control Laws for Tall Buildings Under Seismic Excitations," by J.N. Yang, A. Akbarpour and P. Ghaemmaghami, 6/10/87, (PB88-134333/AS).

NCEER-87-0008 "IDARC: Inelastic Damage Analysis of Reinforced Concrete Frame - Shear-Wall Structures," by Y.J. Park, A.M. Reinhorn and S.K. Kunnath, 7/20/87, (PB88-134325/AS).

NCEER-87-0009 "Liquefaction Potential for New York State: A Preliminary Report on Sites in Manhattan and Buffalo," by M. Budhu, V. Vijayakumar, R.F. Giese and L. Baumgras, 8/31/87, (PB88-163704/AS). This report is available only through NTIS (see address given above).

NCEER-87-0010 "Vertical and Torsional Vibration of Foundations in Inhomogeneous Media," by A.S. Veletsos and K.W. Dotson, 6/1/87, (PB88-134291/AS).

NCEER-87-0011 "Seismic Probabilistic Risk Assessment and Seismic Margins Studies for Nuclear Power Plants," by Howard H.M. Hwang, 6/15/87, (PB88-134267/AS).

NCEER-87-0012 "Parametric Studies of Frequency Response of Secondary Systems Under Ground-Acceleration Excitations," by Y. Yong and Y.K. Lin, 6/10/87, (PB88-134309/AS).

NCEER-87-0013 "Frequency Response of Secondary Systems Under Seismic Excitation," by J.A. HoLung, J. Cai and Y.K. Lin, 7/31/87, (PB88-134317/AS).

NCEER-87-0014 "Modelling Earthquake Ground Motions in Seismically Active Regions Using Parametric Time Series Methods," by G.W. Ellis and A.S. Cakmak, 8/25/87, (PB88-134283/AS).

NCEER-87-0015 "Detection and Assessment of Seismic Structural Damage," by E. DiPasquale and A.S. Cakmak, 8/25/87, (PB88-163712/AS).

NCEER-87-0016 "Pipeline Experiment at Parkfield, California," by J. Isenberg and E. Richardson, 9/15/87, (PB88-163720/AS). This report is available only through NTIS (see address given above).

NCEER-87-0017 "Digital Simulation of Seismic Ground Motion," by M. Shinozuka, G. Deodatis and T. Harada, 8/31/87, (PB88-155197/AS). This report is available only through NTIS (see address given above).

NCEER-87-0018 "Practical Considerations for Structural Control: System Uncertainty, System Time Delay and Truncation of Small Control Forces," J.N. Yang and A. Akbarpour, 8/10/87, (PB88-163738/AS).

NCEER-87-0019 "Modal Analysis of Nonclassically Damped Structural Systems Using Canonical Transformation," by J.N. Yang, S. Sarkani and F.X. Long, 9/27/87, (PB88-187851/AS).

NCEER-87-0020 "A Nonstationary Solution in Random Vibration Theory," by J.R. Red-Horse and P.D. Spanos, 11/3/87, (PB88-163746/AS).

NCEER-87-0021 "Horizontal Impedances for Radially Inhomogeneous Viscoelastic Soil Layers," by A.S. Veletsos and K.W. Dotson, 10/15/87, (PB88-150859/AS).

NCEER-87-0022 "Seismic Damage Assessment of Reinforced Concrete Members," by Y.S. Chung, C. Meyer and M. Shinozuka, 10/9/87, (PB88-150867/AS). This report is available only through NTIS (see address given above).

NCEER-87-0023 "Active Structural Control in Civil Engineering," by T.T. Soong, 11/11/87, (PB88-187778/AS).

NCEER-87-0024 Vertical and Torsional Impedances for Radially Inhomogeneous Viscoelastic Soil Layers," by K.W. Dotson and A.S. Veletsos, 12/87, (PB88-187786/AS).

NCEER-87-0025 "Proceedings from the Symposium on Seismic Hazards, Ground Motions, Soil-Liquefaction and Engineering Practice in Eastern North America," October 20-22, 1987, edited by K.H. Jacob, 12/87, (PB88-188115/AS).

NCEER-87-0026 "Report on the Whittier-Narrows, California, Earthquake of October 1, 1987," by J. Pantelic and A. Reinhorn, 11/87, (PB88-187752/AS). This report is available only through NTIS (see address given above).

NCEER-87-0027 "Design of a Modular Program for Transient Nonlinear Analysis of Large 3-D Building Structures," by S. Srivastav and J.F. Abel, 12/30/87, (PB88-187950/AS).

NCEER-87-0028 "Second-Year Program in Research, Education and Technology Transfer," 3/8/88, (PB88-219480/AS).

NCEER-88-0001 "Workshop on Seismic Computer Analysis and Design of Buildings With Interactive Graphics," by W. McGuire, J.F. Abel and C.H. Conley, 1/18/88, (PB88-187760/AS).

NCEER-88-0002 "Optimal Control of Nonlinear Flexible Structures," by J.N. Yang, F.X. Long and D. Wong, 1/22/88, (PB88-213772/AS).

NCEER-88-0003 "Substructuring Techniques in the Time Domain for Primary-Secondary Structural Systems," by G.D. Manolis and G. Juhn, 2/10/88, (PB88-213780/AS).

NCEER-88-0004 "Iterative Seismic Analysis of Primary-Secondary Systems," by A. Singhal, L.D. Lutes and P.D. Spanos, 2/23/88, (PB88-213798/AS).

NCEER-88-0005 "Stochastic Finite Element Expansion for Random Media," by P.D. Spanos and R. Ghanem, 3/14/88, (PB88-213806/AS).

NCEER-88-0006 "Combining Structural Optimization and Structural Control," by F.Y. Cheng and C.P. Pantelides, 1/10/88, (PB88-213814/AS).

NCEER-88-0007 "Seismic Performance Assessment of Code-Designed Structures," by H.H-M. Hwang, J-W. Jaw and H-J. Shau, 3/20/88, (PB88-219423/AS).

NCEER-88-0008 "Reliability Analysis of Code-Designed Structures Under Natural Hazards," by H.H-M. Hwang, H. Ushiba and M. Shinozuka, 2/29/88, (PB88-229471/AS).

NCEER-88-0009 "Seismic Fragility Analysis of Shear Wall Structures," by J-W Jaw and H.H-M. Hwang, 4/30/88, (PB89-102867/AS).

NCEER-88-0010 "Base Isolation of a Multi-Story Building Under a Harmonic Ground Motion - A Comparison of Performances of Various Systems," by F-G Fan, G. Ahmadi and I.G. Tadjbakhsh, 5/18/88, (PB89-122238/AS).

NCEER-88-0011 "Seismic Floor Response Spectra for a Combined System by Green's Functions," by F.M. Lavelle, L.A. Bergman and P.D. Spanos, 5/1/88, (PB89-102875/AS).

NCEER-88-0012 "A New Solution Technique for Randomly Excited Hysteretic Structures," by G.Q. Cai and Y.K. Lin, 5/16/88, (PB89-102883/AS).

NCEER-88-0013 "A Study of Radiation Damping and Soil-Structure Interaction Effects in the Centrifuge," by K. Weissman, supervised by J.H. Prevost, 5/24/88, (PB89-144703/AS).

NCEER-88-0014 "Parameter Identification and Implementation of a Kinematic Plasticity Model for Frictional Soils," by J.H. Prevost and D.V. Griffiths, to be published.

NCEER-88-0015 "Two- and Three- Dimensional Dynamic Finite Element Analyses of the Long Valley Dam," by D.V. Griffiths and J.H. Prevost, 6/17/88, (PB89-144711/AS).

NCEER-88-0016 "Damage Assessment of Reinforced Concrete Structures in Eastern United States," by A.M. Reinhorn, M.J. Seidel, S.K. Kunnath and Y.J. Park, 6/15/88, (PB89-122220/AS).

NCEER-88-0017 "Dynamic Compliance of Vertically Loaded Strip Foundations in Multilayered Viscoelastic Soils," by S. Ahmad and A.S.M. Israil, 6/17/88, (PB89-102891/AS).

NCEER-88-0018 "An Experimental Study of Seismic Structural Response With Added Viscoelastic Dampers," by R.C. Lin, Z. Liang, T.T. Soong and R.H. Zhang, 6/30/88, (PB89-122212/AS).

NCEER-88-0019 "Experimental Investigation of Primary - Secondary System Interaction," by G.D. Manolis, G. Juhn and A.M. Reinhorn, 5/27/88, (PB89-122204/AS).

NCEER-88-0020 "A Response Spectrum Approach For Analysis of Nonclassically Damped Structures," by J.N. Yang, S. Sarkani and F.X. Long, 4/22/88, (PB89-102909/AS).

NCEER-88-0021 "Seismic Interaction of Structures and Soils: Stochastic Approach," by A.S. Veletsos and A.M. Prasad, 7/21/88, (PB89-122196/AS).

NCEER-88-0022 "Identification of the Serviceability Limit State and Detection of Seismic Structural Damage," by E. DiPasquale and A.S. Cakmak, 6/15/88, (PB89-122188/AS).

NCEER-88-0023 "Multi-Hazard Risk Analysis: Case of a Simple Offshore Structure," by B.K. Bhartia and E.H. Vanmarcke, 7/21/88, (PB89-145213/AS).

NCEER-88-0024 "Automated Seismic Design of Reinforced Concrete Buildings," by Y.S. Chung, C. Meyer and M. Shinozuka, 7/5/88, (PB89-122170/AS).

NCEER-88-0025 "Experimental Study of Active Control of MDOF Structures Under Seismic Excitations," by L.L. Chung, R.C. Lin, T.T. Soong and A.M. Reinhorn, 7/10/88, (PB89-122600/AS).

NCEER-88-0026 "Earthquake Simulation Tests of a Low-Rise Metal Structure," by J.S. Hwang, K.C. Chang, G.C. Lee and R.L. Ketter, 8/1/88, (PB89-102917/AS).

NCEER-88-0027 "Systems Study of Urban Response and Reconstruction Due to Catastrophic Earthquakes," by F. Kozin and H.K. Zhou, 9/22/88, (PB90-162348/AS).

NCEER-88-0028 "Seismic Fragility Analysis of Plane Frame Structures," by H.H-M. Hwang and Y.K. Low, 7/31/88, (PB89-131445/AS).

NCEER-88-0029 "Response Analysis of Stochastic Structures," by A. Kardara, C. Bucher and M. Shinozuka, 9/22/88, (PB89-174429/AS).

NCEER-88-0030 "Nonnormal Accelerations Due to Yielding in a Primary Structure," by D.C.K. Chen and L.D. Lutes, 9/19/88, (PB89-131437/AS).

NCEER-88-0031 "Design Approaches for Soil-Structure Interaction," by A.S. Veletsos, A.M. Prasad and Y. Tang, 12/30/88, (PB89-174437/AS).

NCEER-88-0032 "A Re-evaluation of Design Spectra for Seismic Damage Control," by C.J. Turkstra and A.G. Tallin, 11/7/88, (PB89-145221/AS).

NCEER-88-0033 "The Behavior and Design of Noncontact Lap Splices Subjected to Repeated Inelastic Tensile Loading," by V.E. Sagan, P. Gergely and R.N. White, 12/8/88, (PB89-163737/AS).

NCEER-88-0034 "Seismic Response of Pile Foundations," by S.M. Mamoon, P.K. Banerjee and S. Ahmad, 11/1/88, (PB89-145239/AS).

NCEER-88-0035 "Modeling of R/C Building Structures With Flexible Floor Diaphragms (IDARC2)," by A.M. Reinhorn, S.K. Kunnath and N. Panahshahi, 9/7/88, (PB89-207153/AS).

NCEER-88-0036 "Solution of the Dam-Reservoir Interaction Problem Using a Combination of FEM, BEM with Particular Integrals, Modal Analysis, and Substructuring," by C-S. Tsai, G.C. Lee and R.L. Ketter, 12/31/88, (PB89-207146/AS).

NCEER-88-0037 "Optimal Placement of Actuators for Structural Control," by F.Y. Cheng and C.P. Pantelides, 8/15/88, (PB89-162846/AS).

NCEER-88-0038 "Teflon Bearings in Aseismic Base Isolation: Experimental Studies and Mathematical Modeling," by A. Mokha, M.C. Constantinou and A.M. Reinhorn, 12/5/88, (PB89-218457/AS).

NCEER-88-0039 "Seismic Behavior of Flat Slab High-Rise Buildings in the New York City Area," by P. Weidlinger and M. Ettouney, 10/15/88, (PB90-145681/AS).

NCEER-88-0040 "Evaluation of the Earthquake Resistance of Existing Buildings in New York City," by P. Weidlinger and M. Ettouney, 10/15/88, to be published.

NCEER-88-0041 "Small-Scale Modeling Techniques for Reinforced Concrete Structures Subjected to Seismic Loads," by W. Kim, A. El-Attar and R.N. White, 11/22/88, (PB89-189625/AS).

NCEER-88-0042 "Modeling Strong Ground Motion from Multiple Event Earthquakes," by G.W. Ellis and A.S. Cakmak, 10/15/88, (PB89-174445/AS).

NCEER-88-0043 "Nonstationary Models of Seismic Ground Acceleration," by M. Grigoriu, S.E. Ruiz and E. Rosenblueth, 7/15/88, (PB89-189617/AS).

NCEER-88-0044 "SARCF User's Guide: Seismic Analysis of Reinforced Concrete Frames," by Y.S. Chung, C. Meyer and M. Shinozuka, 11/9/88, (PB89-174452/AS).

NCEER-88-0045 "First Expert Panel Meeting on Disaster Research and Planning," edited by J. Pantelic and J. Stoyle, 9/15/88, (PB89-174460/AS).

NCEER-88-0046 "Preliminary Studies of the Effect of Degrading Infill Walls on the Nonlinear Seismic Response of Steel Frames," by C.Z. Chrysostomou, P. Gergely and J.F. Abel, 12/19/88, (PB89-208383/AS).

NCEER-88-0047 "Reinforced Concrete Frame Component Testing Facility - Design, Construction, Instrumentation and Operation," by S.P. Pessiki, C. Conley, T. Bond, P. Gergely and R.N. White, 12/16/88, (PB89-174478/AS).

NCEER-89-0001 "Effects of Protective Cushion and Soil Compliancy on the Response of Equipment Within a Seismically Excited Building," by J.A. HoLung, 2/16/89, (PB89-207179/AS).

NCEER-89-0002 "Statistical Evaluation of Response Modification Factors for Reinforced Concrete Structures," by H.H-M. Hwang and J-W. Jaw, 2/17/89, (PB89-207187/AS).

NCEER-89-0003 "Hysteretic Columns Under Random Excitation," by G-Q. Cai and Y.K. Lin, 1/9/89, (PB89-196513/AS).

NCEER-89-0004 "Experimental Study of 'Elephant Foot Bulge' Instability of Thin-Walled Metal Tanks," by Z-H. Jia and R.L. Ketter, 2/22/89, (PB89-207195/AS).

NCEER-89-0005 "Experiment on Performance of Buried Pipelines Across San Andreas Fault," by J. Isenberg, E. Richardson and T.D. O'Rourke, 3/10/89, (PB89-218440/AS).

NCEER-89-0006 "A Knowledge-Based Approach to Structural Design of Earthquake-Resistant Buildings," by M. Subramani, P. Gergely, C.H. Conley, J.F. Abel and A.H. Zaghw, 1/15/89, (PB89-218465/AS).

NCEER-89-0007 "Liquefaction Hazards and Their Effects on Buried Pipelines," by T.D. O'Rourke and P.A. Lane, 2/1/89, (PB89-218481).

NCEER-89-0008 "Fundamentals of System Identification in Structural Dynamics," by H. Imai, C-B. Yun, O. Maruyama and M. Shinozuka, 1/26/89, (PB89-207211/AS).

NCEER-89-0009 "Effects of the 1985 Michoacan Earthquake on Water Systems and Other Buried Lifelines in Mexico," by A.G. Ayala and M.J. O'Rourke, 3/8/89, (PB89-207229/AS).

NCEER-89-R010 "NCEER Bibliography of Earthquake Education Materials," by K.E.K. Ross, Second Revision, 9/1/89, (PB90-125352/AS).

NCEER-89-0011 "Inelastic Three-Dimensional Response Analysis of Reinforced Concrete Building Structures (IDARC-3D), Part I - Modeling," by S.K. Kunnath and A.M. Reinhorn, 4/17/89, (PB90-114612/AS).

NCEER-89-0012 "Recommended Modifications to ATC-14," by C.D. Poland and J.O. Malley, 4/12/89, (PB90-108648/AS).

NCEER-89-0013 "Repair and Strengthening of Beam-to-Column Connections Subjected to Earthquake Loading," by M. Corazao and A.J. Durrani, 2/28/89, (PB90-109885/AS).

NCEER-89-0014 "Program EXKAL2 for Identification of Structural Dynamic Systems," by O. Maruyama, C-B. Yun, M. Hoshiya and M. Shinozuka, 5/19/89, (PB90-109877/AS).

NCEER-89-0015 "Response of Frames With Bolted Semi-Rigid Connections, Part I - Experimental Study and Analytical Predictions," by P.J. DiCorso, A.M. Reinhorn, J.R. Dickerson, J.B. Radziminski and W.L. Harper, 6/1/89, to be published.

NCEER-89-0016 "ARMA Monte Carlo Simulation in Probabilistic Structural Analysis," by P.D. Spanos and M.P. Mignolet, 7/10/89, (PB90-109893/AS).

NCEER-89-P017 "Preliminary Proceedings from the Conference on Disaster Preparedness - The Place of Earthquake Education in Our Schools," Edited by K.E.K. Ross, 6/23/89.

NCEER-89-0017 "Proceedings from the Conference on Disaster Preparedness - The Place of Earthquake Education in Our Schools," Edited by K.E.K. Ross, 12/31/89, (PB90-207895).

NCEER-89-0018 "Multidimensional Models of Hysteretic Material Behavior for Vibration Analysis of Shape Memory Energy Absorbing Devices, by E.J. Graesser and F.A. Cozzarelli, 6/7/89, (PB90-164146/AS).

NCEER-89-0019 "Nonlinear Dynamic Analysis of Three-Dimensional Base Isolated Structures (3D-BASIS)," by S. Nagarajaiah, A.M. Reinhorn and M.C. Constantinou, 8/3/89, (PB90-161936/AS).

NCEER-89-0020 "Structural Control Considering Time-Rate of Control Forces and Control Rate Constraints," by F.Y. Cheng and C.P. Pantelides, 8/3/89, (PB90-120445/AS).

NCEER-89-0021 "Subsurface Conditions of Memphis and Shelby County," by K.W. Ng, T-S. Chang and H-H.M. Hwang, 7/26/89, (PB90-120437/AS).

NCEER-89-0022 "Seismic Wave Propagation Effects on Straight Jointed Buried Pipelines," by K. Elhmadi and M.J. O'Rourke, 8/24/89, (PB90-162322/AS).

NCEER-89-0023 "Workshop on Serviceability Analysis of Water Delivery Systems," edited by M. Grigoriu, 3/6/89, (PB90-127424/AS).

NCEER-89-0024 "Shaking Table Study of a 1/5 Scale Steel Frame Composed of Tapered Members," by K.C. Chang, J.S. Hwang and G.C. Lee, 9/18/89, (PB90-160169/AS).

NCEER-89-0025 "DYNA1D: A Computer Program for Nonlinear Seismic Site Response Analysis - Technical Documentation," by Jean H. Prevost, 9/14/89, (PB90-161944/AS).

NCEER-89-0026 "1:4 Scale Model Studies of Active Tendon Systems and Active Mass Dampers for Aseismic Protection," by A.M. Reinhorn, T.T. Soong, R.C. Lin, Y.P. Yang, Y. Fukao, H. Abe and M. Nakai, 9/15/89, (PB90-173246/AS).

NCEER-89-0027 "Scattering of Waves by Inclusions in a Nonhomogeneous Elastic Half Space Solved by Boundary Element Methods," by P.K. Hadley, A. Askar and A.S. Cakmak, 6/15/89, (PB90-145699/AS).

NCEER-89-0028 "Statistical Evaluation of Deflection Amplification Factors for Reinforced Concrete Structures," by H.H.M. Hwang, J-W. Jaw and A.L. Ch'ng, 8/31/89, (PB90-164633/AS).

NCEER-89-0029 "Bedrock Accelerations in Memphis Area Due to Large New Madrid Earthquakes," by H.H.M. Hwang, C.H.S. Chen and G. Yu, 11/7/89, (PB90-162330/AS).

NCEER-89-0030 "Seismic Behavior and Response Sensitivity of Secondary Structural Systems," by Y.Q. Chen and T.T. Soong, 10/23/89, (PB90-164658/AS).

NCEER-89-0031 "Random Vibration and Reliability Analysis of Primary-Secondary Structural Systems," by Y. Ibrahim, M. Grigoriu and T.T. Soong, 11/10/89, (PB90-161951/AS).

NCEER-89-0032 "Proceedings from the Second U.S. - Japan Workshop on Liquefaction, Large Ground Deformation and Their Effects on Lifelines, September 26-29, 1989," Edited by T.D. O'Rourke and M. Hamada, 12/1/89, (PB90-209388/AS).

NCEER-89-0033 "Deterministic Model for Seismic Damage Evaluation of Reinforced Concrete Structures," by J.M. Bracci, A.M. Reinhorn, J.B. Mander and S.K. Kunnath, 9/27/89.

NCEER-89-0034 "On the Relation Between Local and Global Damage Indices," by E. DiPasquale and A.S. Cakmak, 8/15/89, (PB90-173865).

NCEER-89-0035 "Cyclic Undrained Behavior of Nonplastic and Low Plasticity Silts," by A.J. Walker and H.E. Stewart, 7/26/89, (PB90-183518/AS).

NCEER-89-0036 "Liquefaction Potential of Surficial Deposits in the City of Buffalo, New York," by M. Budhu, R. Giese and L. Baumgrass, 1/17/89, (PB90-208455/AS).

NCEER-89-0037 "A Determinstic Assessment of Effects of Ground Motion Incoherence," by A.S. Veletsos and Y. Tang, 7/15/89, (PB90-164294/AS).

NCEER-89-0038 "Workshop on Ground Motion Parameters for Seismic Hazard Mapping," July 17-18, 1989, edited by R.V. Whitman, 12/1/89, (PB90-173923/AS).

NCEER-89-0039 "Seismic Effects on Elevated Transit Lines of the New York City Transit Authority," by C.J. Costantino, C.A. Miller and E. Heymsfield, 12/26/89, (PB90-207887/AS).

NCEER-89-0040 "Centrifugal Modeling of Dynamic Soil-Structure Interaction," by K. Weissman, Supervised by J.H. Prevost, 5/10/89, (PB90-207879/AS).

NCEER-89-0041 "Linearized Identification of Buildings With Cores for Seismic Vulnerability Assessment," by I-K. Ho and A.E. Aktan, 11/1/89.

NCEER-90-0001 "Geotechnical and Lifeline Aspects of the October 17, 1989 Loma Prieta Earthquake in San Francisco," by T.D. O'Rourke, H.E. Stewart, F.T. Blackburn and T.S. Dickerman, 1/90, (PB90-208596/AS).

NCEER-90-0002 "Nonnormal Secondary Response Due to Yielding in a Primary Structure," by D.C.K. Chen and L.D. Lutes, 2/28/90.

NCEER-90-0003 "Earthquake Education Materials for Grades K-12," by K.E.K. Ross, 4/16/90.

NCEER-90-0004 "Catalog of Strong Motion Stations in Eastern North America," by R.W. Busby, 4/3/90.

NCEER-90-0005 "NCEER Strong-Motion Data Base: A User Manuel for the GeoBase Release (Version 1.0 for the Sun3)," by P. Friberg and K. Jacob, 3/31/90.

NCEER-90-0006 "Seismic Hazard Along a Crude Oil Pipeline in the Event of an 1811-1812 Type New Madrid Earthquake," by H.H.M. Hwang and C-H.S. Chen, 4/16/90.

NCEER-90-0007 "Site-Specific Response Spectra for Memphis Sheahan Pumping Station," by H.H.M. Hwang and C.S. Lee, 5/15/90.

NCEER-90-0008 "Pilot Study on Seismic Vulnerability of Crude Oil Transmission Systems," by T. Ariman, R. Dobry, M. Grigoriu, F. Kozin, M. O'Rourke, T. O'Rourke and M. Shinozuka, 5/25/90.

NCEER-90-0009 "A Program to Generate Site Dependent Time Histories: EQGEN," by G.W. Ellis, M. Srinivasan and A.S. Cakmak, 1/30/90.

NCEER-90-0010 "Active Isolation for Seismic Protection of Operating Rooms," by M.E. Talbott, Supervised by M. Shinozuka, 6/8/9.

NCEER-90-0011 "Program LINEARID for Identification of Linear Structural Dynamic Systems," by C-B. Yun and M. Shinozuka, 6/25/90.

NCEER-90-0012 "Two-Dimensional Two-Phase Elasto-Plastic Seismic Response of Earth Dams," by A.N. Yiagos, Supervised by J.H. Prevost, 6/20/90.

NCEER-90-0013 "Secondary Systems in Base-Isolated Structures: Experimental Investigation, Stochastic Response and Stochastic Sensitivity," by G.D. Manolis, G. Juhn, M.C. Constantinou and A.M. Reinhorn, 7/1/90.

NCEER-90-0014 "Seismic Behavior of Lightly-Reinforced Concrete Column and Beam-Column Joint Details," by S.P. Pessiki, C.H. Conley, P. Gergely and R.N. White, 8/22/90.

NCEER-90-0015 "Two Hybrid Control Systems for Building Structures Under Strong Earthquakes," by J.N. Yang and A. Danielians, 6/29/90.

NCEER-90-0016 "Instantaneous Optimal Control with Acceleration and Velocity Feedback," by J.N. Yang and Z. Li, 6/29/90.

NCEER-90-0017 "Reconnaissance Report on the Northern Iran Earthquake of June 21, 1990," by M. Mehrain, 10/4/90.

NCEER-90-0018 "Evaluation of Liquefaction Potential in Memphis and Shelby County," by T.S. Chang, P.S. Tang, C.S. Lee and H. Hwang, 8/10/90.