0007

USING GIS AS A TOOL TO EXECUTE THE FARMLAND RELEASE POLICY WITH CONSIDERING FIELD CONDITIONS

Hui-Mi HSU[1] And Sao-Jeng CHAO[2]

SUMMARY

Taiwan is applying for being a member of WTO. Once Taiwan is accepted by the WTO officials, it will directly cause a great impact to the agriculture. Meanwhile, the more framers demand less restriction for the farmland use in recent years. In other words, the social and economic developments have gradually affected the policy of farmland use. This study emphasizes to determine the methodology for executing the farmland release policy with considering the field conditions such as recharge ability of groundwater, soil liquefaction potential, and groundwater depth. Within the study area, the Lan-Yang Plain, data are collected and analyzed with the aids of Geographic Information System (GIS). Three major items of results are incorporated into the GIS software, ArcView, for the final determination of eight types of sub-region where individual expression is precise. The whole methodology not only takes accounts of various possible parametric studies but also provides a systematic approach through the use of GIS. The authors believe that the Taiwan authorities may or may not officially consider the proposed results but the proposed methodology should be seriously considered for preparing the farmland release policy.

INTRODUCTION

Taiwan is currently applying for an official member of WTO. It's commonly believed that the application will be approved within this year. Due to the coming impact to the agriculture, the Taiwan authorities are ambiguous to re-plan the farmland use. In other words, the quality of farmland will be quantlized by performing various parametric studies and then the different types of farmland can fit for different purposes accordingly. The parameters considered for this study are recharge ability of groundwater, soil liquefaction potential, and groundwater depth for the study area where is selected as the plain regions within Lan-Yang Plain (Figure 1). The results of the parametric studies are manipulated through the GIS tool, ArcView. Although the GIS preparation for each one of the parametric studies is quite time-consuming, it's worthwhile of doing it

considering the GIS convenience of analysis and presentation.

RECHARGE ABILITY OF GROUNDWATER

Data collection

Official Agricultural departments and other organizations such as Food Bureau, Agricultural Engineering Research Center, Association of Water Conservancy, Taiwan Bureau of Water Conservancy, and Council of Agriculture, Executive Yuan, have joined to prepare the PC ARC/INFO formatted version of data for digital maps (Hwang et al., 1997). This part of work takes a large number of time and people to obtain the PC ARC/INFO map for soil profile in the Lan-Yang Plain and the PC ARC/INFO map for provincial irrigated area.

[1] *Dept of Civil Engineering National I-Lan Institute of Technology, I-Lan City, Taiwan Email:hmhsu@mail.ilantech.edu.tw*
[2] *Dept of Civil Engineering National I-Lan Institute of Technology, I-Lan City, I, Taiwan Email:chao@mail.ilantech.edu.tw*

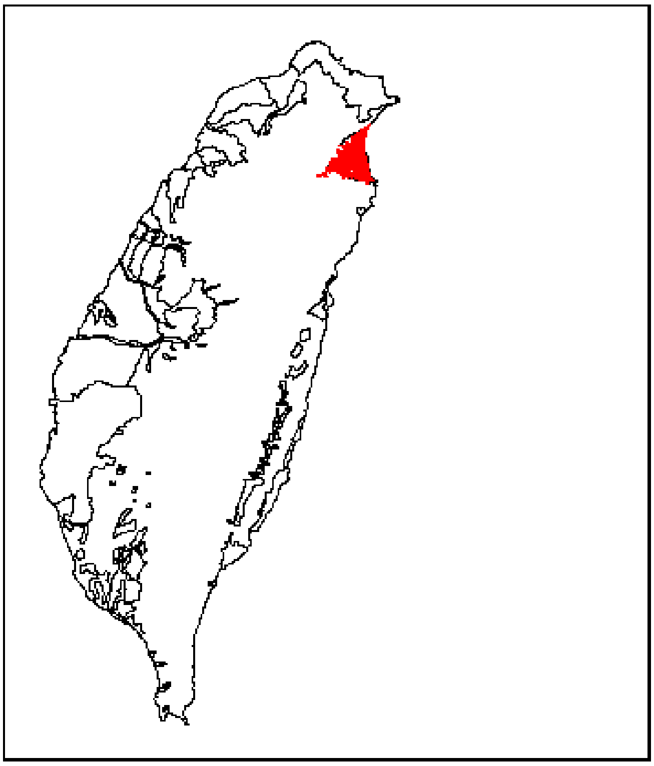

Figure 1: The map of study area

Evaluation

Many sets of 1.5-m Soil profile are collected and each one is divided into four layers of soil types: a) 0 - 30cm, b) 30 - 60cm, c) 60 - 90cm and, d) 90 - 150cm. For each layer of soil, the clay-size fraction determines its soil texture as well as the corresponding code number. For this purpose, eleven types of the soil textures are categorized as shown in Table 1. Taking clay-size fraction as a variable in curve-fitting equations, the permeability at each layer of soil can then be determined by using both Eqs.1 & 2 (Hsu, 1998a).

$$I = 0.932039 + 0.0362642 \times \text{clay-size fraction \%} - 0.000296759 \times \text{clay-size fraction \%}^2 \quad (1)$$

$$\text{Permeability(mm/day)} = 240 / (\text{clay-size fraction \%} \times I) \quad (2)$$

where I is a variable for using in Eq. 2.

Table 1: Eleven types of soil textures

Soil type	Code number	Clay-size fraction (%)	I	Permeability(mm/day)
Sandy gravel	1	1.6	1.0	150
Gravely sand	2	5.0	1.1	43.7
Sand	3	8.0	1.2	25.0
Loamy sand	4	11.6	1.3	15.9
Sandy loam	5	14.9	1.4	11.5
Loam	6	18.2	1.5	8.8
Clay loam	7	21.9	1.6	6.85
Loamy clay	8	27.0	1.7	5.24
Clay	9	33.0	1.8	4.04
Medium clay	10	40.0	1.9	3.16
High clay	11	49.0	2.0	2.45

The cumulative permeability of the whole four layers of soil is then calculated from the harmonic average value of permeability as indicated in Eq. 3.

$$Permeability_{0\text{-}150}=5.0/(1/\ per._{0\text{-}30}+1/\ per._{30\text{-}60}+1/\ per._{60\text{-}90}+2/\ per._{90\text{-}150}) \quad (3)$$

The recharge ability of groundwater at each location is classified according to its cumulative permeability (Table 2), then the classification of recharge ability of groundwater for the whole area can be shown on the map (Figure 2) through ArcView.

Table 2: Grades' table of the cumulative permeability

Grade		Range (mm/day)	Range (Code No.)
1	Good	8.8≤Inf.	1-6
2	Poor	Inf.≤8.8	7-11

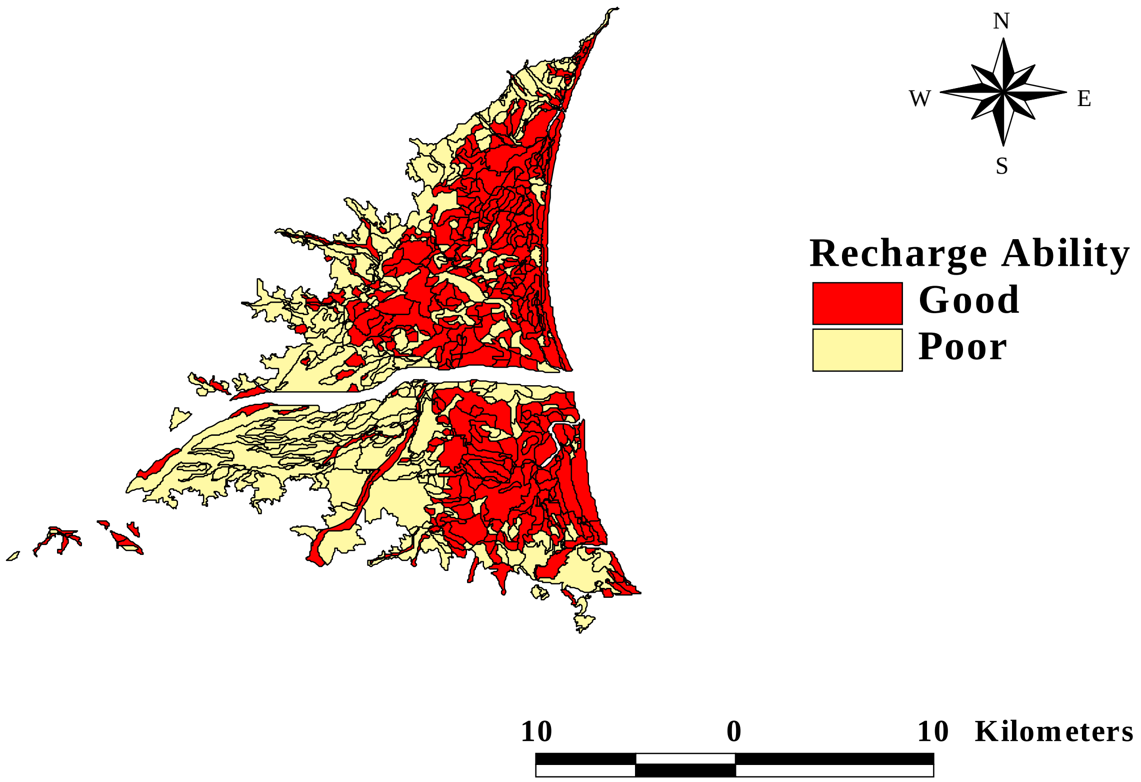

Figure 2: The classification of recharge ability of groundwater

SOIL LIQUEFACTION POTENTIALS

Lan-Yang Plain in which subsurface conditions generally contains several layers of loose uniform grained soils and high groundwater table is located in the northeastern Taiwan area where earthquakes are known as the most potential natural hazard. Liquefaction is one of the most important topics in geotechnical earthquake engineering. Evaluation of the liquefaction potential is thus important to provide information for preventing damage at each particular site of the study area.

The use of the standard penetration resistance as an index of soil resistance during earthquake shaking has been increasingly adopted. In the Lan-Yang Plain and most other parts of Taiwan, the standard penetration test (SPT) has been the most commonly used for characterization of liquefaction resistance. In this paper, we use the relationship between Cyclic Stress Ratio (CSR) and SPT $(N_1)_{60}$-values to predict the potential liquefaction hazards (Seed et al. 1985).

The GIS software, ARC/INFO and ArcView, are utilized to geographically present the evaluations of liquefaction potentials. From the view of practical purposes, the Building Code specifications for the Lan-Yang Plain may take into account of the soil liquefaction effect by referring to the GIS map of soil liquefaction potential resulted from this study.

Data collection

The area of the Lan-Yang Plain is about 400 km^2 in which 518 boring logs were collected at various locations to develop information on subsurface conditions (Hsu and Chao, 1998c). These borings are mainly located in the urban regions (including Tou-Cheng, Chiao-His, I-Lan, Lo-Tung, Suao) with high ground water levels, which are covered about 200 km^2. The subsurface soils for these areas are similar and generally contain several layers of loose uniform grained soils, which are potentially liquefiable. The primary constituent is fine-grained deposits with rather low SPT blow counts. The essential differences between these areas are merely depth, stratigraphic position, and the penetration resistance.

Local ground accelerations

By means of numerical simulations through the SHAKE calculations as well as seismic hazard analyses, the maximum horizontal ground acceleration within the area of the Lan-Yang Plain was reported as 0.29g from the previous study by the authors (Chao and Hsu, 1997). Besides, it is commonly believed that the earthquake magnitude for the Lan-Yang Plain is 7.5. Those results are taken in this study as seismic input.

Evaluation of liquefaction potentials

Some of the most spectacular examples of earthquake damage have occurred when soil deposits have lost their strength and induced building foundation failures. Because it only occurs in saturated soils, liquefaction is most commonly observed near rivers, bays, and other bodies of water.

Liquefaction is a complicated phenomenon, but research has progressed to the point where an integrated framework of understanding is developed. Soil deposits with uniform grain size distributions and in loose states are evaluated most liquefaction susceptibility. Liquefaction occurs only in saturated soils, so the depth to groundwater influences liquefaction susceptibility. Thus, the Lan-Yang Plain where groundwater is within a few meters and soils were deposited in loose states is likely to be susceptible to liquefaction.

In the 1960s and 1970s, many advances in the state of knowledge of liquefaction phenomena resulted from the pioneering work of H. B. Seed and his colleagues at the University of California at Berkeley. The uniform cyclic shear stress amplitude for level site can be estimated from a simplified procedure (Seed and Idriss, 1971) as

$$\tau_{av} = 0.65 \frac{a_{\max}}{g} \sigma_v r_d \tag{4}$$

where $a_{\max}$ is the peak ground surface acceleration, g is the acceleration of gravity, σ_v is the total vertical stress, and r_d is the value of a stress reduction factor at the depth of interest.

An alternative approach to laboratory tests, first described by Whitman, is to use liquefaction case histories to characterize liquefaction resistance in terms of measured in situ test parameters. In the Lan-Yang Plain and most other parts of Taiwan, the Standard Penetration Test (SPT) has been the most commonly used in situ test for characterization of liquefaction resistance. Factors that tend to increase liquefaction resistance (e.g., density, prior seismic straining, overconsolidation ratio, lateral earth pressures, and time under sustained pressure) also tend to increase SPT resistance. Seed et al. (1983) compared the corrected SPT resistance and cyclic stress ratio for clean sand and silty sand sites to determine the cyclic stress ratio by a given SPT resistance. The presence of fines can affect SPT resistance and therefore must be accounted for in the evaluation of liquefaction resistance (Seed et. al., 1985).

Using the definition of cyclic stress ratio, the shear stress require to initial liquefaction is given by

$$\tau_f = CRS \cdot \sigma_v^{'} \tag{5}$$

where τ_f is the liquefaction resistance, and σ'_v is the effective vertical stress.

Once the cyclic loading imposed by an earthquake and the liquefaction resistances of the soils have been characterized, liquefaction potential can be evaluated. Liquefaction potential can thus be expressed as the factor of safety written as

$$FS = \frac{\tau_f}{\tau_{av}} \tag{6}$$

when the factor of safety for liquefaction potential is less than 1, it means that the situation of soil liquefaction would occur during the earthquake.

Evaluation

The Data of these boring holes are converted to the GIS format, both attributes and maps. In this study, the EXCEL is used to build up a tabular data file, which is then converted to a DBase file of attributes. Then digitizing the boring holes map (points), which then links the attribute table to become a point Theme in ArcView. The point Theme with the points' liquefaction information needs to transfer to the polygon Theme with area's liquefaction determination by using spatial analyst techniques. In fact, the job can be done in three different ways (Chao et al., 1998). In final view, a polygon Theme is shown to present the liquefaction potentials in Figure 3 according to the whole depth of subsurface soils for 0.29g of seismic input.

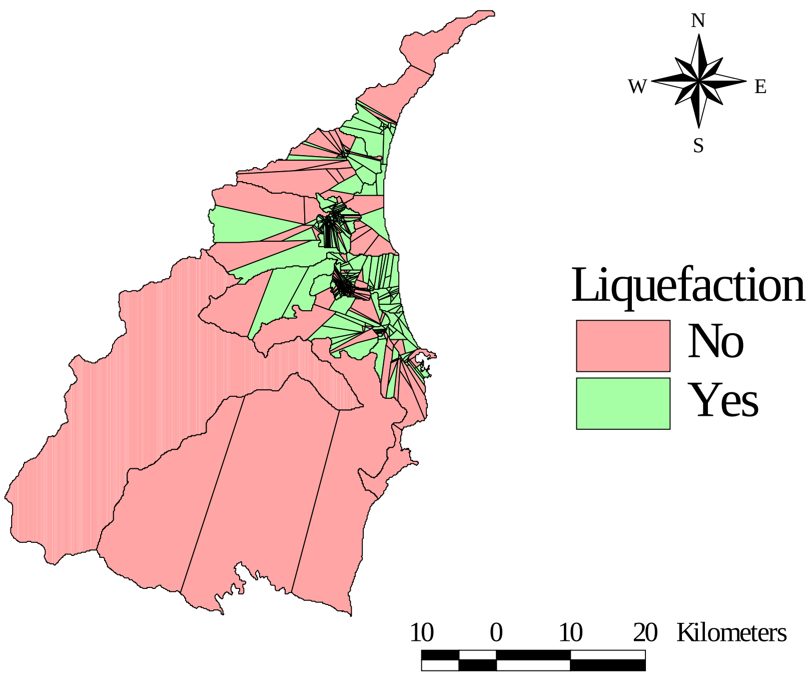

Figure 3: The map of liquefaction potentials

GROUNDWATER DEPTHS

The Data of boring holes are same as the ones used in the liquefaction potentials. The point Theme with the points' groundwater depths needs to transfer to the polygon Theme with area's interpolating values by using the GIS 3D techniques (Hsu et al. 1998b). As final, a polygon Theme is shown in Figure 4 to present the average groundwater depths on the basis of the whole 518 boring logs.

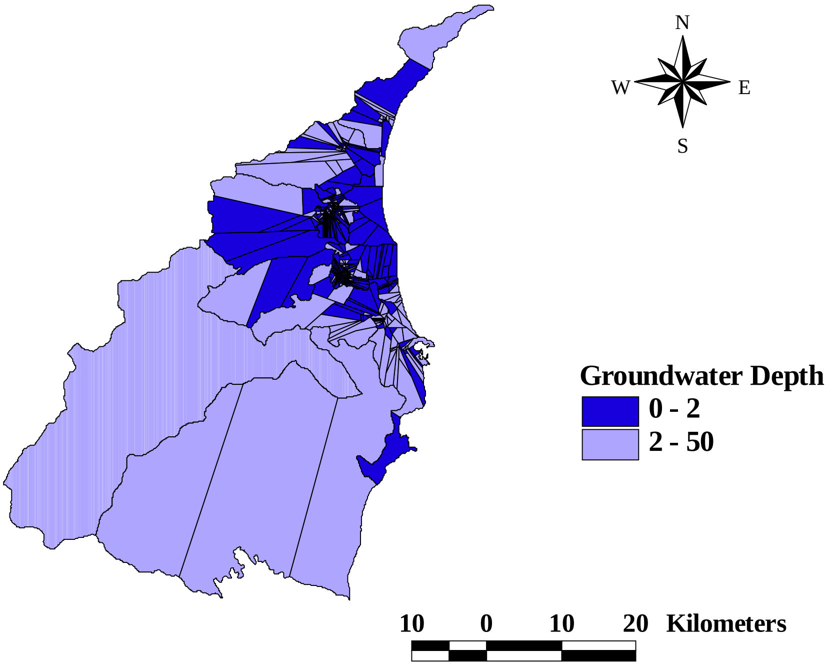

Figure 4: The map of groundwater depths

THE GIS ANALYSES

The results from the three parametric studies in the map format of SHP files are recharge ability of groundwater, soil liquefaction potential, and groundwater depth. Both source and resulting map of the first one are in terms of polygons. The source maps of the other two are in terms of points while the resulting maps are in terms of polygons with the use of spatial analyst techniques (Chao et al., 1998). Therefore, it's easy to perform the GIS analysis since all the resulting maps are classified as the same format Because the different polygons of maps, it still needs to take the process of topology, which overlaps three maps of polygons into a single map of polygons. In other words, the final polygons are largely increased (Chao et al., 1998).

The attribute table corresponding to the final map of polygons consists of the three major data; namely, recharge ability, liquefaction potential, and groundwater depth, which can be summarized as the eight different combination cases as listed in Table 3. The map areas corresponding to the eight tabulated cases are then identified through ArcView as shown in Figure 5, which in turn represents the eight different properties of farmland.

Table 3: The summary of parametric studies

Case	Liquefaction Potential (considering PGA=0.29g)	Recharge Ability (taking Inf. = 8.8 mm/day)	Groundwater Depth (taking Dep. = 2 m)
1	Yes	Good	Low
2	No	Poor	High
3	Yes	Good	High
4	No	Poor	Low
5	Yes	Poor	Low
6	No	Good	High
7	Yes	Poor	High
8	No	Good	Low

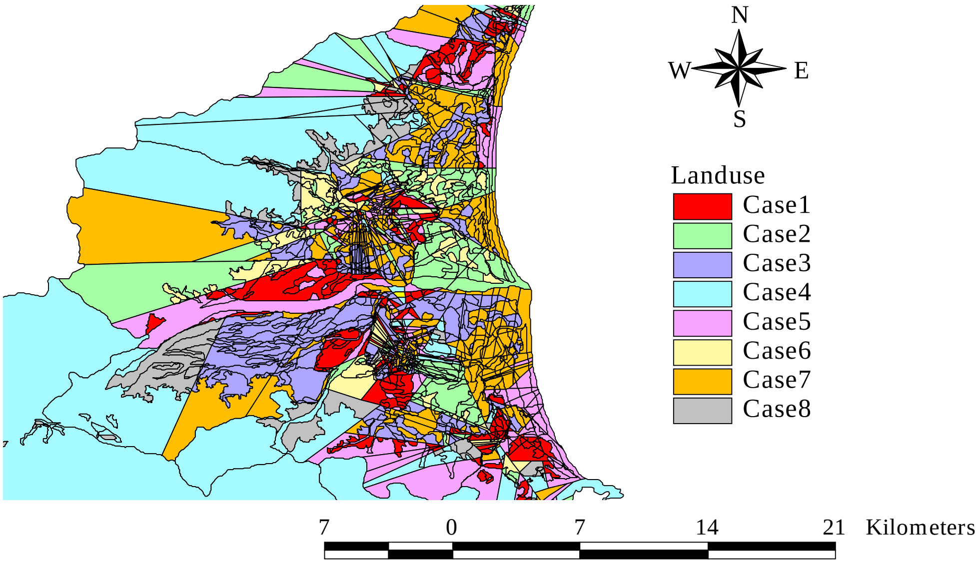

Figure 5: The map of the eight cases of landuse

CONCLUSIONS

This study considers the three parametric studies; namely, recharge ability of groundwater, soil liquefaction potential, and groundwater depth, to execute release policy of farmland. The GIS software is used to incorporate the results of parametric studies to provide the eight possible grades of farmland, from which the release order of farmland can be decided scientifically. Therefore, the whole procedure provides a systematic method to quantitilize the land quality of a large area. The whole Lan-Yang plain is included for the study area. Thus, it should be pointed out that the analyses are applied for the whole area, in which only the farmland is interested in this study.

It is easy of incorporating the effects of other parameters through the use of GIS. For example, if the DTM data are included, it can easily calculate slopes and aspects, which may be added to interpret the result in the consideration of elevations. Similarly, other considerations can be easily included in the analyses as long as the GIS format of data is well prepared. However, although the use of GIS is powerful, it needs to carefully justify the result. In other words, preliminary planning is much important to the GIS applications.

Considering the investigation of landuse, GIS is a powerful tool to interpret the outcome of analyses. Moreover, the statistics can be easily performed in the GIS software. These advantages are fully useful for the process of landuse. Therefore, this study not only investigates the practical development of GIS but also demonstrates the functional use of GIS. Accordingly, this study provides two types of results, the GIS map of farmland use and the process of GIS analyses.

ACKNOWLEDGEMENT

This study was supported by two projects. The authors would like to express their thanks for the finical assistance of the Council of Agriculture, Executive Yuan and the National Center of Research for Earthquake Engineering.

REFERENCES

Chao, S. J. and Hsu, H. M. (1997), “Nonlinear Site Response Analysis for a Gymnasium in I-Lan,” *Proceedings of the 7th Conference on Current Researches in Geotechnical Engineering in Taiwan*, pp. 191-198.

Chao S.J., Hsu, H.M., and Yang H.C. (1998) “The Discussion of GIS Spatial Analyst between Points and Polygons”*Proceedings of 98'ESRI & ERDAS Conference* ESRI.

Environmental System Research Institute (ESRI), *PC ARC/INFO 3.5* and *ArcView 3.1*, ESRI GIS Software Package.

Hsu, H.M., Hwang, T.L., and Hwang S.T. (1998a) “ The Application of GIS to the Soil Infiltration”*Proceedings of the 9th Taiwan Hydraulic Engineering Conference,* ESRI.

Hsu, H.M., Chao S.J., and Hwang S.T. (1998b) “The Application of GIS 3D to the Groundwater”*Proceedings of the 98'ESRI & ERDAS Conference*, ESRI.

Hsu, H. M. and Chao, S. J. (1998c), “Evaluation of Soil Liquefaction Potential in the Northeastern Taiwan Area with the Aid of GIS,” *Proceedings of the Thirteen Southeast Asian Geotechnical Conference*, pp. 59-64.

Hwang, S.T., Hsu, H.M., and You, Y.C. (1997), “Evaluation of Groundwater Recharge for I-Lan Area Using the Technique of GIS”, *Proceedings of GIS AM/FM Asia’97 & GeoInformatics’97*, pp221-228

Seed, H. B. and Idriss, I. M. (1971), “Simplified Procedure for evaluating Soil Liquefaction Potential,” *Journal of the Soil Mechanics and Foundations Division*, ASCE, Vol. 97, No. SM9, pp. 1249-1273.

Seed, H. B., Idriss, I. M., and Arango, I. (1983), “Evaluation of Liquefaction potential Using Field Performance Data,” *Journal of Geotechnical Engineering Division*, ASCE, Vol. 109, No. 3, pp. 458-482.

Seed, H. B., Tokimatsu, K., Harder, L. F., and Chung, R. M. (1985), “Influence of SPT Procedures in Soil Liquefaction Resistance Evaluations,” *Journal of Geotechnical Engineering Division*, ASCE, Vol. 111, No. 12, pp. 1425-1445.