Final Project Summary— PEER Lifelines Program

Project Title—**ID Number**	*Pilot Application of Regional Liquefaction Ground Deformation Models*—**3G01**		
Start/End Dates	7/1/01 – 6/30/04	Budget/ Funding Source	$103,999 / PG&E/CEC
Project Leader (boldface) and Other Team Members	**Knudsen, K.L. (CGS),** Rosinski, A. (CGS), Wiegers, M. (CGS), Real, C. (CGS), Wu, J. (UC Berkeley), Seed, R.B. (UC Berkeley)		

1. Project goals and objectives

The goals of this project include:

(1) To identify the most appropriate and best available methods of developing regional hazard maps showing liquefaction-induced surface deformation.

(2) To develop a detailed, GIS-based, three-dimensional depiction of subsurface geology for a part of the Santa Clara Valley.

(3) If feasible, to produce liquefaction *deformation* hazard maps for both vertical and lateral movements for a part of the Santa Clara Valley.

(4) Based on the results of our work, examine the feasibility of developing regional maps of liquefaction-induced deformation hazard with existing technology and knowledge.

2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

CDMG's Seismic Hazard Mapping Program is interested in the possibility of using deformation-based models as the basis for its zones of required investigation. Additionally, ground deformation due to liquefaction-induced lateral spreading and settlement are earthquake hazards that adversely impact the performance of lifelines such as utility pipelines and highway roadways/bridges. New methods for the reliable prediction of the location and extent of such deformation would immediately be applied by those organizations interested in increasing lifeline-network reliability after major earthquakes.

3. Brief description of the accomplishments of the project

To date, we have presented the working results of our project at 3 conferences and published papers in the related proceedings volumes:

1) Geo-Trans 2004 in Los Angeles during the summer of 2004

2) The 11th International Conference on Soil Dynamics & Earthquake Engineering in Berkeley during January of 2004, and

3) the Technical Council on Lifeline Earthquake Engineering in Long Beach in August of 2003.

We are presently finalizing the final report and have produced a variety of liquefaction hazard maps of part of the Santa Clara Valley using a variety of approaches. Our report describes the data needs, uncertainties, and relative merits of the different approaches.

Lastly, two graduate students have been partially supported by this project: Dr. Jiaer Wu at UC Berkeley recently completed his phd, and Anne Rosinski at San Jose State University is nearing completion of her MS degree in the geology department.

4. Describe any instances where you are aware that your results have been used in industry

Since the project is just being wrapped up the results are not yet being used in industry. However, we (California Geological Survey, Seismic Hazard Mapping Program) are beginning to reevaluate the way we produce maps of liquefaction hazards using the results of this study. We also are discussing a project with CALTRANS in which the results of this project would be applied in helping CALTRANS identify their most at-risk bridges.

5. Methodology employed

The two main methods applied in developing regional maps of potential liquefaction induced ground surface displacement are: (1) estimation of lateral spread displacements using empirical methods developed by Youd and colleagues, and Bardet and colleagues; and (2) estimation of horizontal and vertical displacement using the concept of limiting strain. Data needed for these analyses include. geotechnical, geologic, seismologic and topographic. The analyses have been done utilizing geographic information systems (GIS) and an extensive electronic database of geotechnical borings. A significant part of this project is researching alternative methods of characterizing the area's geology for the purposes of assessing liquefaction hazard. The dynamic depositional processes and variability in sediment properties has caused us to investigate and develop new methods of relating three-dimensional geologic and geotechnical information to two-dimensional hazard maps.

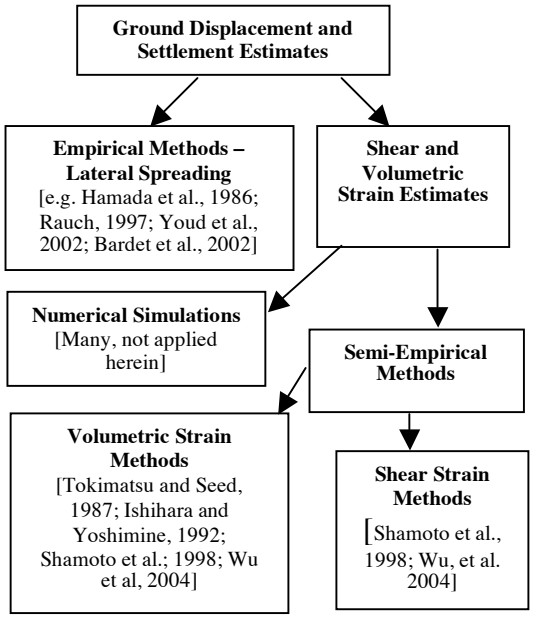

Fig 1. Methods of predicting liquefaction-induced deformation

An example of a sample map product is attached at the end of this document

6. Other related work conducted within and/or outside PEER

We are making use of several recent PEER studies that were conducted to improve the ability to assess liquefaction on a site specific basis and applying these methods to our regional hazard assessment. Additional, realted projects inlcude: (1) The CDMG SHMP is synthesizing vast subsurface data sets for key urbanized regions (LA and Bay Areas) as part of its effort to develop maps of liquefaction zones of required investigation for these regions (as mandated under the 1990 Seismic Hazards Act). These maps identify microzones within which liquefaction may occur, but do not predict either the likelihood of liquefaction nor the extent of deformation.

(2) Scientists and engineers at the U.S. Geological Survey are developing new methods of estimating deformation based on Cone Penetrometer (CPT) data. They are acquiring new data with a CPT rig in order to have sufficient data for making hazard maps. Our proposed approach is based on the use of existing geotechnical data.

(3) Scientists at William Lettis & Associates, CDMG and USGS are developing 1:24,000-scale original maps of Quaternary deposits and derivative liquefaction susceptibility maps for the core San Francisco Bay area. Production of these maps includes very little evaluation of subsurface data.

We are familiar with all of these efforts and directly involved in two of them (1 and 3). Additionally, we have strong ties with other scientists and engineers working on liquefaction-related issues.

7. Recommendations for the future work: what do you think should be done next?
We will continue exploring application of the methods developed during this project to hazard mapping. In particular, we are exploring integrating these methods into the mapping performed by the CGS Seismic Hazrds Mapping Program. We also plan to use these methods to assist CALTRANS in prioritizing structures for more detailed investigations and mitigation. Related research that would improve our ability to produce regional maps of hazard would include incorporating topographic parameters in predictions of shear and volumetric strain induced by liquefaction. To date, the most current relationships to predict strain assume a ground surface that has little to no slope and do not account for proximity to a free face.

8. <u>Author(s), Title, and Date</u> for the final report for this project
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Tentative title: Assessment, development, and application of methods to produce regional maps of liquefaction-induced deformation
Date: September 2004

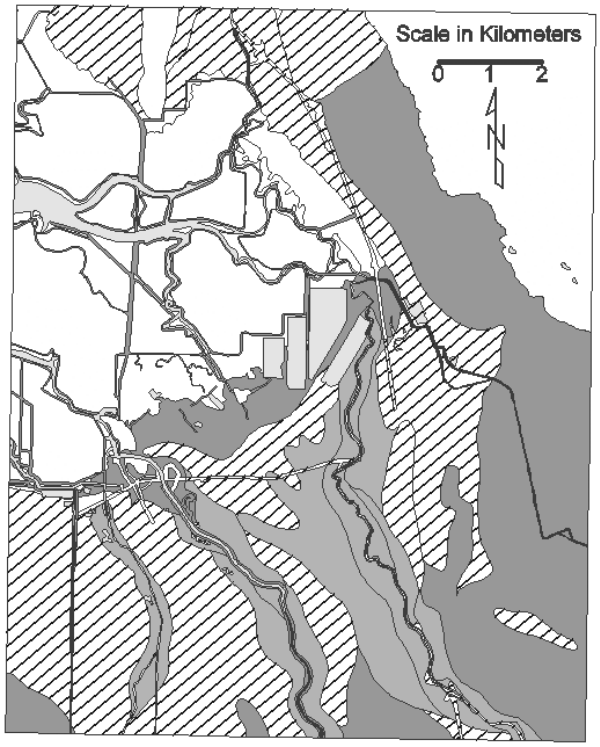

Fig. 2. Liquefaction-induced ground settlement (ft), Milpitas 7.5-minute Quadrangle, California (settlement calculated using Wu et al., 2003 method)

- 0 – 0.20 ft (Qf, af, Qhc, Qhff, Qhl)
- 0.21 - 0.40 ft (Qhfy, Qhly, Qhty)
- 0.41 - 0.60 ft (alf, Qhfe, Qhf)
- 0.61 - 0.80 ft (ac)
- NOT EVALUATED