

# MPC-524

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## **Project Title**

Development of Next Generation Liquefaction (NGL) Database for Liquefaction-Induced Lateral Spread

## **University**

University of Utah

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## Research Needs

This research will be conducted in conjunction with the Pacific Earthquake Engineering Research (PEER) Center and various state DOTs via a pool-fund study managed by the Utah Department of Transportation (UDOT). The research topic addresses the need to improve empirical, semi-empirical, analytical and numerical methods to estimate the amount of permanent ground displacement associated with liquefaction-induced lateral spread resulting from major earthquakes. The project will be executed in two or three phases: (1) database development and collection, (2) gathering additional subsurface and topographical data, and (3) predictive model development. This proposal addresses the work associated with Phase (1). The scope and work plan for Phases (2) and (3) will be addressed in a subsequent project following the completion of Phase (1).

Liquefaction-induced lateral spread is a type of permanent ground deformation resulting from the horizontal movement of surficial soil resulting from liquefaction that has occurred at depth. It generally is the most pervasive and damaging type of liquefaction-induced ground failure occurring during major earthquakes. Lateral spread displacement has caused significant damage to transportation infrastructure and other facilities during major earthquakes. Examples of such damage can be found in the engineering literature from the following earthquakes: 1964 Alaska; 1964 Niigata, Japan; 1983 Nihonkai-Chu, Japan; 1989 Loma Prieta, California; 1999 Kocaeli, Turkey; 1999 Chi-Chi, Taiwan; 2004 Northridge, California; 2005 Kobe, Japan; 2010 Chile; 2011 Tohoku, Japan; 2011 Christchurch New Zealand. During these and other earthquakes, lateral spread horizontal ground displacement ranging from a few tenths of a meter to several meters was common in liquefaction prone areas. These displacements resulted in millions of dollars of damage to transportation facilities such as bridges, embankments, culverts and pavements.

Recent liquefaction-induced ground failures from earthquakes in Japan and New Zealand have raised questions about the profession's ability to assess, delineate and quantify the lateral spread hazard in vulnerable locations. The best defense against such damage is to first, identify areas prone to lateral spread ground failure, estimate the expected amount of ground displacement, and establish planning or other engineering countermeasures to mitigate the hazard and ensure more earthquake resilient infrastructure. Nonetheless, many regions in the U.S. (e.g., California, Pacific Northwest, Intermountain West, mid-America and Northeastern and Central Atlantic seaboard) remain vulnerable to liquefaction damage associated with future, major earthquakes.

To address the need for improvement in liquefaction research and practice, the National Research Council (NRC) has formed an ad hoc committee to critically examine the technical issues regarding liquefaction hazard evaluation and consequence assessment (<http://www8.nationalacademies.org/cp/projectview.aspx?key=49573>). Amongst other items, the NRC committee is assessing the adequacy and accuracy of empirical and mechanistic methods to evaluate liquefaction triggering and post-liquefaction deformations of earth structures and structures founded on or in the earth, such as large embankment dams, levees, dikes, pipelines, highway embankments, bridges, pile-supported decks, and other structural foundations. The NRC study included a workshop in on data gathering, vetting of field and laboratory data, and new developments in the assessment of earthquake induced soil liquefaction which was held in March 10th and 11th, 2014 in Tempe, Arizona at Arizona State University. All the PIs included

in this study attended this workshop. It is expected that the NRC final report, which is not yet released, will comment on the state-of-the-art and practice for liquefaction analyses. It will also address the recommended directions for future research and practice related to: (i) collecting, reporting, and assessing the sufficiency and quality of field case history observations as well as in situ field, laboratory, and model test data; (ii) addressing the spatial variability and uncertainty of these data; and (iii) and developing more accurate tools for assessing liquefaction triggering and its consequences. Thus, the NRC final report will summarize the major issues associated with liquefaction assessments, but will not provide recommendations on the use of current analysis procedures. However, the NRC findings will establish the “blue print” for future developments and improvements in liquefaction evaluations.

Important to this proposal, it is expected that the NRC final report will endorse the efforts of PEER in establishing a community database for evaluating liquefaction effects, including lateral spread. Recently, PEER has initiated the next generation liquefaction (NGL) database project, which began work with a workshop at the University of California Berkeley in April 2014. This workshop consisted of presentations and discussions regarding additions to and improvement of the liquefaction effects database, primarily focusing on data gathering and documentation of recent earthquakes conditions and effects in Japan and New Zealand.

Phase 1 of the project described herein is part of the PEER NGL effort and will be reviewed by senior PEER researchers and their stake holders (e.g., CALTRANS). Our efforts in this proposal will focus on gathering, documenting and archiving information regarding liquefaction-induced lateral spread. The collected information will include: soil properties, site characteristics (soil layering, topography, etc.), earthquake strong ground motion, and observations and measurements of soil response (e.g., post liquefaction ground deformations) for important, well-documented historical earthquakes. Included in this data gathering will be an assessment of the inherent characteristics associated with the data (e.g., quality, uneven distribution, scarcity, uncertainty, etc.). In addition, the data will be warehoused in a spatial database, and archival and dissemination tools will be developed for future assessment and model development by interested researchers (i.e., Phases 2 and 3— new subsurface and topographic data gathering and model development). No funding is requested for Phases 2 and 3 in this proposal.

### **Research Objectives**

The following objectives are put forth for Phase I: (1) develop peer-reviewed and consistent methods for data documentation and archiving, (2) develop quality assurance protocols for assessing and documenting data quality, (3) develop methods/protocols to quantify uncertainties associated with the collected data, (4) populate the database with well-documented case histories of liquefaction-induced lateral spread, (5) disseminate this database for general use using web-based software tools.

Phase (2) will consist of gathering new geotechnical subsurface data and topographical data at limited sites identified in phase 1 where data quality could be improve to produce a “well” documented case history.

Phase (3) will subsequently develop additional research objectives and plans for model development consisting potentially of empirical, semi-empirical, analytical and numerical methods.

## **Research Methods**

The documentation and archiving of geologic and geotechnical factors associated with liquefaction effects will be done in an ArcGIS™ database. The case history data from several historical earthquakes will come from relatively large geographical areas, and these investigations were carried out using various investigative methods that have spatial context. Hence, a spatial database is required to represent these data.

In addition, the documentation of the data sources and their quality is of prime importance. The highest quality of data will have site-specific subsurface geotechnical data for a mapped geologic unit which generally consists of subsurface data from standard penetration test (SPT) boreholes, or from cone penetration tests (CPT), or from downhole or surface geophysical measurements of shear wave velocity. Also included with this type of data are corresponding soil descriptions, measurements of soil properties (e.g., density, fines and clay content, mean grain size and Atterberg limits) and depth to water table. Other types of spatial/raster data that will be collected consist of: (1) surface damage photographs, (2) aerial photography, (3) topographical maps, (4) geologic maps, (5) digital elevation terrain models, (6) light-radar (LIDAR) topographical surveys, and remote sensing techniques such as synthetic aperture (SAR) and interferometric synthetic aperture radar (inSAR).

## **Expected Outcomes**

The primary outcome of this research is a vetted and community database for further research and model development pertaining to liquefaction-induced lateral spread. Secondary outcomes will be the software development and support required to host and disseminate this information.

## **Relevance to Strategic Goals**

This research is relevant to the MPC strategic goals in two areas: (1) safety and (2) sustainability. Potential earthquake damage to transportation systems will affect the operation and safety of such systems. This research will lead to methods to make such systems more resilient to such damage. Also, it will contribute to developing methods to proactively identify, quantify, visualize, prioritize and mitigate risk resulting from earthquake hazards.

## **Educational Benefits**

The research will fund approximately 3 graduate students, one student from each institution represented by the PIs. In addition, the database content and information can be used to develop instructional materials (photos, maps, etc.) for classroom dissemination regarding topics related to earthquake engineering.

## **Work Plan**

Description of Tasks:

- (1) Procurement of software and kickoff meeting (1 month)
- (2) Development of database protocols and quality assurance procedures (2 months)
- (3) Structuring of database (1 month)
- (4) Draft and review progress report pertaining to Tasks 1 and 2 (0 months)

- (5) Selection of case histories to populate dataset (1 month). The initial earthquakes that will be reviewed for inclusion in the database are, but will not be limited to: 1906 San Francisco, California; 1964 Alaska; 1964 Niigata, Japan; 1971 San Fernando, California; 1979 Imperial Valley, California; 1983 Nihonkai-Chu, Japan; 1983 Borah Peak, Idaho; 1987 Superstition Hills, California; 1989 Loma Prieta, California; 1999 Kocaeli, Turkey; 1999 Chi-Chi, Taiwan; 2004 Northridge, California; 2005 Kobe, Japan; 2010 Chile; 2011 Tohoku, Japan; 2011 Christchurch New Zealand.
- (6) Population of database and review of data (15 months)
- (7) Draft technical report (3 months)
- (8) Final technical report (2 months)

### **Project Cost**

Total Project Costs:	\$162,036
MPC Funds Requested:	\$51,682
Matching Funds:	\$110,354

### **TRB Keywords**

Earthquake Engineering, Liquefaction, Data Collection