

Annual Project Summary

**Liquefaction Hazard Mapping
Ventura County, California**

Program Element: I

Key words: Liquefaction; Regional Seismic Hazards; Surficial Deposits; Site Effects

U.S. Geological Survey
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NON-TECHNICAL SUMMARY

Liquefaction-related ground failure historically has caused extensive structural and lifeline damage in urbanized areas around the world. Recent examples of these destructive effects include damage produced during the 1989 Loma Prieta, 1994 Northridge, 1995 Kobe, 1999 Taiwan, and 1999 Turkey earthquakes. These and other historical earthquakes show that the distribution of liquefaction-related damage generally is restricted to flat-lying areas that contain young, sandy soils. Extensive young gravel, sand, and silt deposits in the Oxnard Plain and along the Santa Clara River, shallow groundwater, and the presence of nearby potentially active faults, indicate that much of Ventura County in southern California is susceptible to liquefaction-related hazards. This ongoing study is identifying specific areas in Ventura County that are susceptible to liquefaction. Through geologic and geotechnical analysis of sediments in the Oxnard plain and Santa Clara River Valley, we are producing 1:24,000-scale maps showing areas underlain by sediments that may liquefy during an earthquake. These maps are being digitized for use in computer-based geographic information systems (GIS), and will be used for emergency response, planning, engineering, and risk mitigation purposes.

INVESTIGATIONS UNDERTAKEN

We are conducting a one-year program funded in part by NEHRP and by Ventura County to assess liquefaction susceptibility hazards within Ventura County. The County of Ventura is currently characterizing geologic hazards along onshore oil and gas pipelines within Ventura County. We are assisting the County in this effort by preparing in a series of 1:24,000-scale Quaternary geologic maps (Figure 1). It is these geologic maps that will be used, in cooperation with the Department of Conservation, Division of Mines and Geology (CDMG), to prepare detailed seismic hazard maps for the County of Ventura. The ongoing study follows our general Quaternary geologic mapping and zonation approaches developed during current and recent work performed by WLA in California for other NEHRP- and NSF-funded studies and accepted by CDMG and the USGS.

The liquefaction susceptibility mapping involves four main tasks:

- (1) Characterize late Quaternary geologic deposits;
- (2) Compile and evaluate existing geologic and geotechnical data;
- (3) Characterize ground water depths;
- (4) Evaluate liquefaction susceptibility of geologic units.



Figure 1. Generalized tectonic map of Ventura County showing areas of Quaternary surficial mapping. Yellow areas show alluvial plains, which contain saturated Holocene alluvial sediments. Purple hatched boxes show Simi West and Simi East 7.5' quadrangles mapped by WLA in cooperation with CDMG (Hitchcock et al, 1996; Hitchcock and Wills, 1998) with finalized liquefaction hazard zone maps available from CDMG (CDMG, 1997, 1998).

Status of geologic mapping (Task 1)

Quaternary geologic and liquefaction susceptibility maps are being constructed at a scale of 1:24,000 for parts of twenty-one 7.5-minute quadrangles that contain alluviated areas within Ventura County with conditions conducive to liquefaction (Figure 1). The development of Quaternary geologic maps, shallow ground water contour maps, and hazard zonation maps will provide a valuable set of references for planning and engineering purposes in Ventura County. Our approach assesses the relative susceptibility of surficial deposits based on the peak ground acceleration (PGA) values required to initiate liquefaction within a deposit for a given depth to groundwater. Geological, geotechnical, and hydrological data compiled during the course of the study, and digitized into a database compatible with that of the County of Ventura and CDMG, are being entered into our in-house GIS system and formatted to meet requirements of CDMG's Seismic Hazards Mapping Program.

We are characterizing deposits on the basis of published geologic maps, aerial photographic interpretation, soil information, existing borehole data, and limited field observations. As shown in the table below, our progress during the past year included completion of final versions of all 7.5-minute quadrangles (16 total) in southern Ventura County containing valley deposits susceptible to liquefaction. We currently are completing our mapping of the five quadrangles in northern Ventura County.

Table 1: Progress of Quaternary Geologic maps for Ventura County (as of 11/30/99):

Quadrangle	Aerial Photographic Interpretation	Field Checking Of Map	Preparation For Digitization	Digitization	Review	Final Map Completed
Moorpark	COMPLETE	COMPLETE	COMPLETE	COMPLETE	COMPLETE	X
Santa Paula	COMPLETE	COMPLETE	COMPLETE	COMPLETE	COMPLETE	X
Thousand Oaks	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Newbury Park	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Camarillo	COMPLETE	COMPLETE	COMPLETE	COMPLETE	COMPLETE	X
Saticoy	COMPLETE	COMPLETE	COMPLETE	COMPLETE	COMPLETE	X
Ventura	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Pitas Point	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Pt. Mugu	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Oxnard	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Matilija	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Val Verde	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Piru	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Fillmore	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Ojai	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Santa Paula Peak	COMPLETE	COMPLETE	COMPLETE	COMPLETE	ONGOING	X
Cuyama Peak	50%	ONGOING				
Rancho Nuevo	50%	ONGOING				
Reyes Peak	50%	ONGOING				
Lockwood Valley	COMPLETE	COMPLETE				
Cuddy Valley	50%	ONGOING				

Status of Geologic, Geotechnical, and Groundwater Data Compilation (Tasks 2 and 3)

Collection and evaluation of existing shallow borehole data will provide the primary means to assess the geotechnical and seismic response properties of Quaternary geologic map units. Information on near-surface deposits will be obtained from existing borehole

data as available from private and government sources. Geotechnical boring logs and water well logs provide lithologic and engineering data that are useful for assessing liquefaction susceptibility. For example, geotechnical borings commonly include Standard Penetration Test (SPT) data, soil color, and texture, (e.g. USCS) from field observations and laboratory particle size distribution analyses. Geotechnical properties include dry unit weight, penetration resistance, and relative compaction. Available SPT and Cone Penetrometer Test (CPT) data from boring logs will be compiled and digitized for the study area. These data will be used for quantitative analyses of liquefaction susceptibility for each map unit using WLA's in-house liquefaction software code. Construction of cross-sections using lithologic and soils data derived from the boring logs will allow for extrapolation and correlation of borehole lithologic and soils test data across the proposed study area.

To date, we have compiled shallow borehole data from the California Department of Transportation, the California Department of Water Resources, Ventura County, the City of Oxnard, and private consultants. Available data is being entered into our digital GIS database program that is compatible with that of CDMG and the County of Ventura. We do not propose to collect all the available subsurface data but rather to collect representative data in cooperation with CDMG, as we have done during our previous studies. We will augment the CDMG database, where appropriate, and focus on collecting any other existing subsurface data needed to assess liquefaction susceptibility throughout the study area.

Near-surface groundwater data is being compiled from well and borehole data, published reports, and other sources as available. Sources of data include local Regional Water Quality Control Boards, the County of Ventura Public Works Department, California Department of Water Resources (DWR), U.S. Geological Survey Water Resources Division, and published and unpublished consultant reports on vadose-zone groundwater conditions.

INITIAL RESULTS

We currently are in the process of data compilation. However, based on our preliminary Quaternary geologic mapping, the anticipated liquefaction hazards are primarily located within the Oxnard Plain near Ventura and Oxnard, much of the Santa Clara River Valley, and portions of other populated valleys in Ventura County (Figure 2). These areas are underlain by historic and Holocene sediments within stream deposits, alluvial floodplains and estuarine sediments, and natural beach deposits. These sediments typically contain abundant sand and silty sand. Observations from historical earthquakes shows that Holocene sediments deposited in all these environments are highly susceptible to liquefaction. With incorporation of the subsurface data, and depth to groundwater information, we will be able to better refine this in-progress working map.

Our final liquefaction susceptibility maps will integrate existing subsurface data, surficial geologic mapping, and depth to groundwater and will be compatible with CDMG's seismic hazard mapping program. We will analyze the liquefaction susceptibility of surficial deposits in Ventura County on the basis of occurrence of historical liquefaction;

sediment texture; density; age; depositional environment, and groundwater conditions. Borehole logs, Standard Penetration Test (SPT) data, and Cone Penetrometer Test (CPT) data provide a functional means of establishing material strengths and the potential for liquefaction. Quantitative analysis of liquefaction susceptibility will be performed for the uppermost 12 m (40 ft) of sediment based on the Seed "simplified procedure" and subsequent revisions.

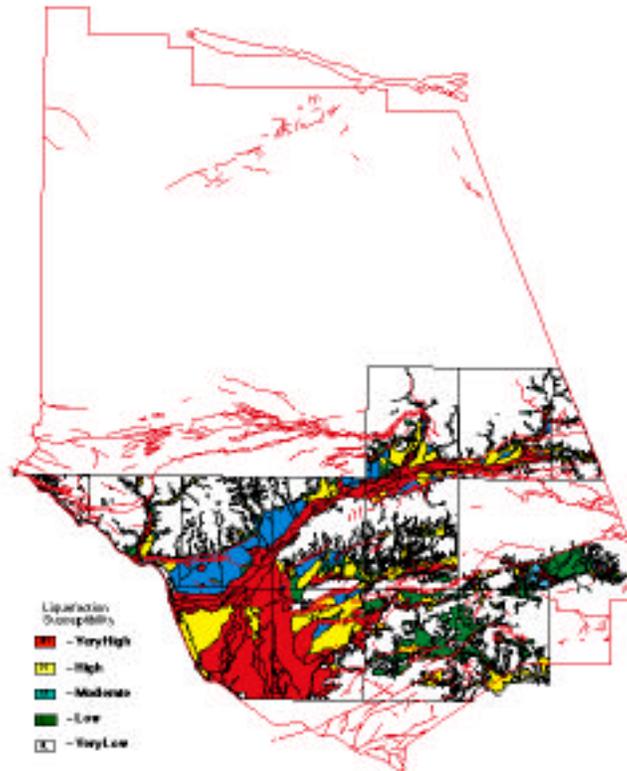


Figure 2. Draft liquefaction susceptibility map.

TECHNICAL AND NON-TECHNICAL REPORTING

The target audiences for data derived from this study are the planning and government agencies responsible for earthquake hazards reduction and risk mitigation in Ventura County. The primary products of this research are the digitized Quaternary geologic maps and liquefaction susceptibility maps. The final maps and subsurface data compiled for this study will be provided to Ventura County, CDMG for use in their liquefaction hazard program, and published as a final technical report for the US Geological Survey. In addition, copies of the geologic and liquefaction hazard maps, funded in part by the County of Ventura program to characterize hazards along onshore oil and gas pipelines, will be made available to the public by the County. The Resource Management Agency of the County of Ventura ultimately plans on making results of the overall study accessible on the internet.

The final maps produced by this study will be supplemented by technical and non-technical reports that provide documentation of the sources of information, methods of data collection and analysis, and recommendations for use and application of the maps. We anticipate conducting formal and/or informal presentations with local municipalities (e.g., Ventura County, City of Oxnard, City of Camarillo, etc.) and at USGS-sponsored or other workshops relevant to earthquake hazards. Lastly, we anticipate producing a refereed journal article and presenting the results at a major professional society meeting.

Preliminary results of this study, including raw data and draft maps, are in ESRI Arcview 3.1 format. Compiled subsurface data is being compiled in Microsoft Excel 4.0 format.

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