



Maps of Quaternary Deposits and Liquefaction Susceptibility in the Central San Francisco Bay Region, California

Part 1: Introduction and Description of Database

in cooperation with the California Geological Survey

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This database, identified as 'Maps of Quaternary deposits and liquefaction susceptibility in the Central San Francisco Bay Region, California', has been approved for release and publication by the Director of the USGS. Although this database has been reviewed and is substantially complete, the USGS reserves the right to revise the data pursuant to further analysis and review. This database is released on condition that neither the USGS nor the U.S. Government may be held liable for any damages resulting from its use.

INTRODUCTION

This report presents a map and database of Quaternary deposits and liquefaction susceptibility for the central San Francisco Bay region. It supercedes the equivalent area of U.S. Geological Survey Open-File Report 00-444 (Knudsen and others, 2000), which covers the larger 9-county San Francisco Bay region. The report consists of (1) this text introduction the report and describing the spatial database, (2) a text describing the Quaternary map and liquefaction interpretation, (3) the spatial database, and (4) two small-scale colored maps (Quaternary deposits and liquefaction susceptibility). All parts of the report are digital; this pamphlet describes the database and digital files and how to obtain them by downloading across the internet.

The nine counties surrounding San Francisco Bay straddle the San Andreas fault system, which exposes the region to serious earthquake hazard (Working Group on California Earthquake Probabilities, 1999). Much of the land adjacent to the Bay and the major rivers and streams is underlain by unconsolidated deposits that are particularly vulnerable to earthquake shaking and liquefaction of water-saturated granular sediment. Map delineation of the different types and ages of Quaternary deposits supports evaluation of susceptibility to liquefaction, the immediate application of the work, but serves many other purposes as well. It provides a framework for interpreting the architecture and history of the Quaternary sedimentary basins, which is used in estimating earthquake shaking and modeling the groundwater system. The mapping is also useful in constraining the ages and histories of offsetting faults, in guiding geotechnical investigations, and in other engineering, geologic, and archeological applications.

This new map provides a consistent detailed treatment of the central part of the 9-county region in which much of the mapping of Open-File Report 00-444 was either at smaller (less detailed) scale or represented only preliminary revision of earlier work. (NOTE that the San Francisco North 7.5-minute quadrangle, which includes the northern part of the city of San Francisco, is not included.) Like Open-File Report 00-444, the current mapping uses geomorphic expression, pedogenic soils, inferred depositional environments, and geologic age to define and distinguish the map units. Further scrutiny of the factors controlling liquefaction susceptibility has led to some changes relative to Open-File Report 00-444: particularly the reclassification of San Francisco Bay mud (Qhbm) to have only MODERATE susceptibility and the rating of artificial fills according to the natural map units inferred to underlie them (other than dams – adf). The two colored maps provide a regional summary of the new mapping at a scale of 1:200,000, a scale that is sufficient to show the general distribution and relationships of the map units but not to distinguish the more detailed elements that are present in the database.

The report is the product of cooperative work by the National Earthquake Hazards Reduction Program (NEHRP) and National Cooperative Geologic Mapping Program of the U.S. Geological Survey, William Lettis and Associates, Inc. (WLA), and the California Geological Survey. An earlier version was submitted to the U.S. Geological Survey by WLA as a final report for a NEHRP grant (Witter and others, 2005). The mapping has been carried out by WLA geologists under contract to the NEHRP Earthquake Program (Grant 99-HQ-GR-0095) and by the California Geological Survey.

The report consists of six numbered parts that are represented by digital files, most of which are provided in two or three different formats. The parts and files are described in DATABASE CONTENTS (below), and their packaging for user access is described in Presentation (below).

Parts 1, 2, and 3 are texts:

1. this pamphlet, including description of the Quaternary deposits and liquefaction susceptibility database;
2. revision list, which lists the digital files as they are available over the Net and records version number and any revisions;

3. description of mapping, including description of mapping techniques and units and of the liquefaction interpretation.

Part 4 is the digital spatial database:

4. Quaternary deposits and liquefaction susceptibility database.

Parts 5 and 6 are graphic plot files for map sheets 1 and 2 at a scale of 1:200,000:

5. map sheet 1: plot file of the Quaternary deposits map, including an explanation of map units;
6. map sheet 2: plot file of the liquefaction susceptibility map.

Part 7 is the database package, consisting of the spatial database (either coverage or shape file format) together with the three text files and metadata file.

Part 8 is the plotfile package, with files in either postscript or PDF format.

Part 9 is the metadata file, which is also included in the spatial database.

The two colored maps are presented as digital plot files in PostScript and PDF format (image size 32 x 40 inches each). The PostScript map images (68.3 MB) can be used for viewing or plotting in computer systems with sufficient capacity, and the considerably smaller PDF files (30.4 MB) can be viewed or plotted in full or in part from Adobe ACROBAT running on Mac, PC, or UNIX platforms. The appearance of the maps in plots (colors and line weights) will depend on file type and the particular plotter that is used.

The map database is provided both as an uncompressed ARC/INFO export file and as ArcView Shape files.

The spatial database was compiled in vector form over the past several years using workstation ArcInfo, a commercial Geographic Information System (Environmental Systems Research Institute [ESRI], Redlands, California), and the menu interface ALACARTE (Fitzgibbon and Wentworth, 1991; Fitzgibbon, 1991; Wentworth and Fitzgibbon, 1991). The map plot files were assembled as graphics files in ARC/INFO from the spatial database, modified in Adobe Illustrator, and then converted to PostScript and PDF formats.

DIGITAL FILES AND PACKAGING

The report consists of digital files representing the nine parts of the database, most of which are presented in more than one format. The names of the files are unique designators based on the report identifier, of06-1037, followed by part numbers and an extension indicating the file type. Some of the files have been bundled in tape archive files (tar files: .tar extension) and the larger ones have been compressed with gzip, yielding a final .gz extension (see Presentation, below). The files and their identities are as follows:

1. Introduction and Description of Database: This text, which describes the database and how to obtain it.
 - a. of06-1037_1a.txt ASCII file, 0.03 MB.
 - b. of06-1037_1b.ps PostScript file, 0.1 MB.
 - c. of06-1037_1c.pdf PDF file, 0.06 MB
2. Revision List: A list of the parts of the report (including bundled packages of parts), indication of the current version number for the report and in which version each part was last revised (if at all), followed by a chronologic list describing any revisions (see REVISIONS, below).
 - a. of06-1037_2a.txt ASCII file

3. Description of Mapping and Liquefaction Interpretation: A 44-page text (2 color figures) that describes the Quaternary deposits of the region, the 60 map units, the estimates of liquefaction susceptibility, and the techniques and history of the work.
 - a. of06-1037_3a.txt ASCII file, 0.12 MB. (No figures included.)
 - b. of06-1037_3b.eps PostScript file, 0.3 MB
 - c. of06-1037_3c.pdf PDF file, 3.1 MB
4. Quaternary Deposits and Liquefaction Susceptibility Database: The data files representing the lines and polygons of the Quaternary deposits database (ARC export and ArcView Shape formats).
 - a. of06-1037_4a.e00.zip - Quaternary Deposits: a compressed ArcInfo export coverage containing lines and polygons (9.6 MB, uncompresses to 42.9 MB).
 - b. of06-1037_4b.shp.zip - Quaternary Deposits: ArcMap line and polygon shape files bundled as one compressed zip file (16.5 MB, uncompresses to 8 files totaling 57.3 MB). When opened, the zip file yields:
 - line files: sfq2lns.dbf, sfq2lns.shp, sfq2lns.shp.xml, and sfq2lns.shx
 - polygon files: sfq2pys.dbf, sfq2pys.shp, sfq2pys.shp.xml, and sfq2pys.shx
5. Plot File of Quaternary Deposits Map: image size 33 x 36 inches.
 - a. of06-1037_5a.eps.zip PostScript file, 11.9 MB, uncompresses to 68.3 MB
 - b. of06-1037_5b.pdf.zip PDF file, 12.1 MB, uncompresses to 30.0 MB
6. Plot File of Liquefaction Susceptibility Map: image size 33 x 36 inches.
 - a. of06-1037_6a.eps.zip PostScript file, 11.7 MB, uncompresses to 68.3 MB
 - b. of06-1037_6b.pdf.zip PDF file, 12.1 MB, uncompresses to 30.4 MB
7. Database Package
 - a. of06-1037_7a.zip ArcInfo coverage version: Assembled text (parts 1, 2, 3, 9), ArcInfo-export database (part 4), bundled as one compressed zip file, 12.4 MB
 - b. of06-1037_7b.zip ArcMap shape file version: Assembled text (parts 1, 2, 3, 9) and ArcMap shape files (part 4), bundled as one compressed zip file, 19.3 MB
8. Plotfile Package
 - a. of06-1037_8a.tar.zip Postscript version: plot files for the Quaternary deposits map (part 5) and the liquefaction susceptibility map (part 6) bundled as one compressed zip file, 23.6 MB
 - b. of06-1037_8b.zip PDF version: plot files for the Quaternary deposits map (part 5) and the liquefaction susceptibility map (part 6) bundled as one compressed zip file, 24.2 MB
9. Metadata file
 - a. of06-1037_9.meta ASCII file.

OBTAINING THE DIGITAL FILES

The report, including text, database, and image files, can be obtained from the US. Geological Survey publications server at:

<http://pubs.usgs.gov/of/2006/1037/>

PROCESSING THE FILES

Some of the files require initial processing before they are usable, both to open bundled and/or compressed files and to import the Arc export file.

Opening Tar and Gzip Files

Some of the files are assembled as tape archive files (tar files), and the larger files containing the databases and images have been compressed with gzip. Thus, gzip or equivalent is required to uncompress the files, and a tar utility is required to open the tar files. Once extracted from the compressed tar files, the Arc export file of06-10374a.e00 can be imported into workstation ArcInfo using the ARC import command. To match the descriptions herein, it should be named SF-QUAT2.

REVISIONS

Changes to any part of this report (parts are the numbered items described above in 'Database Contents' and listed in the revision list (of06-1037_2a.txt) may be made in the future if needed. This could involve, for example, fixing files that don't work properly, revising geologic details, adding new file formats, or adding other components to the report.

The report begins at version 1.0. Any revisions will be specified in the revision list and will result in the recording of a new version number for the report. Small changes will be indicated by decimal increments and larger changes by integer increments in the version number. Revisions will be announced and maintained on the Web page for this report on the U.S. Geological Survey publications web server. Consult the revision list there to determine if a revision is significant for your purposes.

MAP COMPILATION

The Quaternary deposits database was compiled digitally in vector form in workstation ArcInfo as individual 7.5-minute quadrangles at a scale of 1:24,000 in State Plane projection. Original linework was scanned, vectorized, and edited on-screen over the scanned raster background. The 68 individual quadrangles were then converted to UTM projection and assembled into a single regional layer. Quadrangle boundary problems were resolved where possible, although some remain. Much of the fine detail in the spatial database is too small for legible portrayal at the regional scale of the colored maps (1:200,000).

SPATIAL RESOLUTION

The digital database should not be used in ways that violate the spatial resolution of the data. Although the digital form of the data removes the physical constraint imposed by the scale of a paper map, the detail and accuracy inherent in map scale are also present in the digital data. Use of the database at a scale larger than 1:24,000 will not yield greater real detail, although it may reveal fine-scale irregularities below the intended resolution of the database. Similarly, where this database is used in combination with other data of higher resolution, the resolution of the combined output will be limited by the lower resolution of this data.

DESCRIPTION OF THE SPATIAL DATABASE

The spatial database consists of the data layer for Quaternary deposits and liquefaction susceptibility. The database structure follows the ALACARTE data model, such that the primary line attribute is LTYPE and the primary polygon attribute is PTYPE. Definition files are also included, however, after the SGM data model of Gautier (1999).

The ArcInfo layer (coverage) SF-QUAT2 is stored in UTM projection (table 1), whereas the shape files are in decimal degrees of longitude and latitude (NAD27). These were prepared by projecting SF-QUAT2 to decimal degrees as SFQ2 and converting this coverage using the Arc command arcshape. (Note that this procedure has resulted in the modification of the names of some database fields.) Descriptions of the coverage database fields (items) use the terms of table 2.

Table 1. Map Projection for Arc coverage

Projection	UTM	(Universal Transverse Mercator)
Units	METERS	
Zone	10	
Datum	NAD27	
Spheroid	CLARKE1866	

Table 2. Field Definition Terms

ITEM NAME	name of the database field (item)
WIDTH	maximum number of digits or characters stored
OUTPUT	output width
TYPE	B- binary integer, F- binary floating point number, I- ASCII integer, C- ASCII character string
N.DEC	number of decimal places maintained for floating point numbers

The Quaternary deposits layer contains attributed lines and polygons and requires polygon topology for effective use. The lines and polygons are described here through their feature attribute tables and associated definition tables (table 3).

Table 3. Definition Tables Included as INFO Files in the Arc Coverage SF-QUAT2

Table Name	Function
SF-QUAT2.LN	defines line types (LTYPE)
SF-QUAT2.UN	lists names of map units by PTYPE (polygon label)
SF-QUAT2.QDEF	defines polygon LIQ values
SF-QUAT2.LIQ	lists standard LIQ rating by PTYPE (map unit)

The attribute table for lines (SF-QUAT2.AAT, table 4) contains the topical attribute field LTYPE, the 12 different values of which are described in table 4 and in digital form as part of the sf-quat2 coverage in the INFO definition table SF-QUAT2.LN.

Table 4. Structure of the Arc Attribute Table (SF-QUAT2.AAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	
FNODE#	4	5	B	-	starting node of arc (from node)
TNODE#	4	5	B	-	ending node of arc (to node)
LPOLY#	4	5	B	-	polygon to the left of the arc
RPOLY#	4	5	B	-	polygon to the right of the arc
LENGTH	4	12	F	3	length of arc in meters
SF-QUAT#	4	5	B	-	unique internal control number
SF-QUAT-ID	4	5	B	-	unique identification number
LTYPE	35	35	C	-	line type

Table 5. Line Types Recorded in the Quaternary-Deposits LTYPE Field

This table lists the contents of the LTYPE definition table SF-QUAT2.LN.

LTYPE	LDEF
contact, well located	depositional contact, location uncertainty less than about 100 m
contact, approx. located	depositional contact, location uncertainty greater than about 100 m
contact, concealed	depositional contact concealed beneath water, fill, or levee
scratch boundary	boundary without geologic attribute, here connecting mismatch of contacts or units at 7.5-minute quadrangle boundary
water boundary	boundary of open water from 1:24,000 USGS DLGs and published paper topographic maps
water boundary, 1800s	landward margin of tidal marsh bordering San Francisco Bay in the late 19 th century, mainly from Nichols and Wright, 1971
water boundary, 1800s, concealed	concealed equivalent of water boundary, 1800s

contact, liq	depositional contact inferred beneath overlying fill, location uncertainty less than about 100 m
contact, liq, queried	depositional contact inferred beneath overlying fill, location uncertainty greater than about 100 m
liq boundary	arbitrary boundary between depositional or liquefaction (PTYPE2) units beneath overlying fill
county line	boundary of nine-county region, from 1:24,000 USGS DLGs and published paper topographic maps
map boundary	exterior boundary of 1:24,000 quadrangles composing the map area

The Quaternary-deposits polygon attribute table (SF-QUAT2.PAT, table 6) contains the topical field PTYPE, values of which are map-label representations of the Quaternary map units (such as Qt). These labels and their equivalent unit names are listed in table 8 and in the INFO definition table SF-QUAT2.UN, and are described in Appendix A of part 3. The Quaternary map unit(s) underlying each artificial fill is recorded in the PTYPE2 field as unit map labels in order to permit liquefaction susceptibility of fills to be represented by that of the underlying natural deposit. PTYPE2 for all natural deposits is the same as PTYPE. PTYPE2 for most narrow fills is a combination of adjacent natural units (such as Qhc-Qhf).

Table 6. Structure of the Quaternary-Deposits Polygon Attribute Table (SJ-GEOL.PAT)

ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	
FNODE#	4	5	B	-	starting node of arc (from node)
AREA	4	12	F	3	area of polygon in square meters
PERIMETER	4	12	F	3	length of perimeter in meters
SF-QUAT2#	4	5	B	-	unique internal control number
SF-QUAT2-ID	4	5	B	-	unique identification number
PTYPE	35	35	C	-	Quaternary unit label
PTYPE2	35	35	C	-	Quaternary unit underlying fills
LIQ	8	8	C	-	liquefaction susceptibility
LIQ-SOURCE	1	1	I	-	1 where custom LIQ value assigned, otherwise 0

The codes for liquefaction susceptibility in the LIQ field are defined in table 7 and in the INFO definition table SF-QUAT2.QDEF. The susceptibility ratings for most natural deposits are based on map unit (LIQ-SOURCE = 0), although some are assigned custom ratings (LIQ-SOURCE = 1) based on such local information as depth to ground water or historical occurrence of liquefaction. Susceptibility of fills other than dams (adf) is based on the underlying natural unit (PTYPE2; where PTYPE2 consists of dual (or triple) units, the highest susceptibility of those units is used); the minimum susceptibility of af is L, of alf is M, and of ac is L. The standard correlations between map unit and susceptibility are listed in Table 8 and the INFO definition table SF-QUAT2.LIQ, and are described in table 3 of Part 3, Description of Mapping.

Table 7. Meanings of liquefaction susceptibility codes in the LIQ field (SF-QUAT2.PAT)
 This table lists the contents of the LIQ definition table SF-QUAT2.QDEF.

LIQ CODE (LIQ)	DEFINITION (QDEF)
VH	VERY HIGH
H	HIGH
M	MODERATE
L	LOW
VL	VERY LOW
W	WATER
NM	AREA NOT MAPPED

Table 8. Unit PTYPEs, Liquefaction Susceptibility Ratings, and Unit Names

This table lists in stratigraphic order the combined contents of the PTYPE definition table (SF-QUAT2.UN) and the PTYPE/LIQ correlation table SF-QUAT2.LIQ.

PTYPE	LIQ	NAME
MODERN		
af	L	Artificial fill (historical)
afbm	VH	Artificial fill over San Francisco Bay mud (historical)
alf	H	Artificial levee fill (historical)
acf	VH	Artificial channel fill (historical)
adf	L	Artificial dam fill (historical)
gq	M	gravel quarries and percolation ponds
ac	H	Artificial stream channel (historical)
Qhc	VH	Modern stream channel deposits
LATEST HOLOCENE		
Qhfy	H	Latest Holocene alluvial fan deposits
Qhly	VH	Latest Holocene alluvial fan levee deposits
Qhty	H	Latest Holocene stream terrace deposits
Qhty1	H	Younger latest Holocene stream terrace deposits
Qhty2	H	Older latest Holocene stream terrace deposits
Qhay	H	Latest Holocene alluvial deposits, Undifferentiated
Qhbs	VH	Latest Holocene beach sand
HOLOCENE		
Qhds	M	Holocene dune sand
Qhbm	M	Holocene San Francisco Bay Mud
Qhed	H	Holocene estuarine delta deposits
Qhb	M	Holocene basin deposits
Qhfe	H	Holocene alluvial fan-estuarine complex deposits
Qhff	M	Holocene alluvial fan deposits, fine facies

Qhf	M	Holocene alluvial fan deposits
Qhf1	M	Younger Holocene alluvial fan deposits
Qhf2	M	Older Holocene alluvial fan deposits
Qhl	M	Holocene alluvial fan levee deposits
Qhl1	M	Younger Holocene alluvial fan levee deposits
Qhl2	M	Older Holocene alluvial fan levee deposits
Qht	M	Holocene stream terrace deposits
Qht1	M	Younger Holocene stream terrace deposits
Qht2	M	Older Holocene stream terrace deposits
Qha	M	Holocene alluvium, undifferentiated

HOLOCENE TO LATEST PLEISTOCENE

Qds	M	Latest Pleistocene to Holocene dune sand
Qb	L	Latest Pleistocene to Holocene basin deposits
Qf	M	Latest Pleistocene to Holocene alluvial fan deposits
Qt	M	Latest Pleistocene to Holocene stream terrace deposits
Qa	M	Latest Pleistocene to Holocene alluvium, undifferentiated

LATEST PLEISTOCENE

Qpf	L	Latest Pleistocene alluvial fan deposits
Qpt	L	Latest Pleistocene stream terrace deposits
Qpa	L	Latest Pleistocene alluvium, undifferentiated

PLEISTOCENE

Qmt	L	Pleistocene marine terrace deposits
Qmt1	L	Youngest (of 4) Pleistocene marine terrace deposits
Qmt2	L	Second youngest (of 4) Pleistocene marine terrace deposits
Qmt3	L	Second oldest (of 4) Pleistocene marine terrace deposits
Qmt4	L	Oldest (of 4) Pleistocene marine terrace Deposits
Qbt	L	Pleistocene bay terrace deposits

EARLY TO LATE PLEISTOCENE

Qop	VL	Early to late Pleistocene pediment deposits
Qof	VL	Early to late Pleistocene alluvial fan deposits
Qof1	VL	Younger early to late Pleistocene alluvial fan deposits
Qof2	VL	Older early to late Pleistocene alluvial fan deposits
Qot	VL	Early to late Pleistocene stream terrace deposits
Qoa	VL	Early to late Pleistocene alluvial deposits, undifferentiated

- Qoa1 VL Younger early to late Pleistocene alluvial
deposits, undifferentiated
- Qoa2 VL Older early to late Pleistocene alluvial
deposits, undifferentiated

PRE-QUATERNARY

- br VL pre-Quaternary deposits and bedrock

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