The California Landslide Inventory Database

Chris Wills, California Geological Survey

This talk:

- Landslide hazard maps
- Landslide mapping at CGS
- What we would like to know about every landslide
- Landslide database fields
- Uses for a statewide landslide database
- Need for additional data

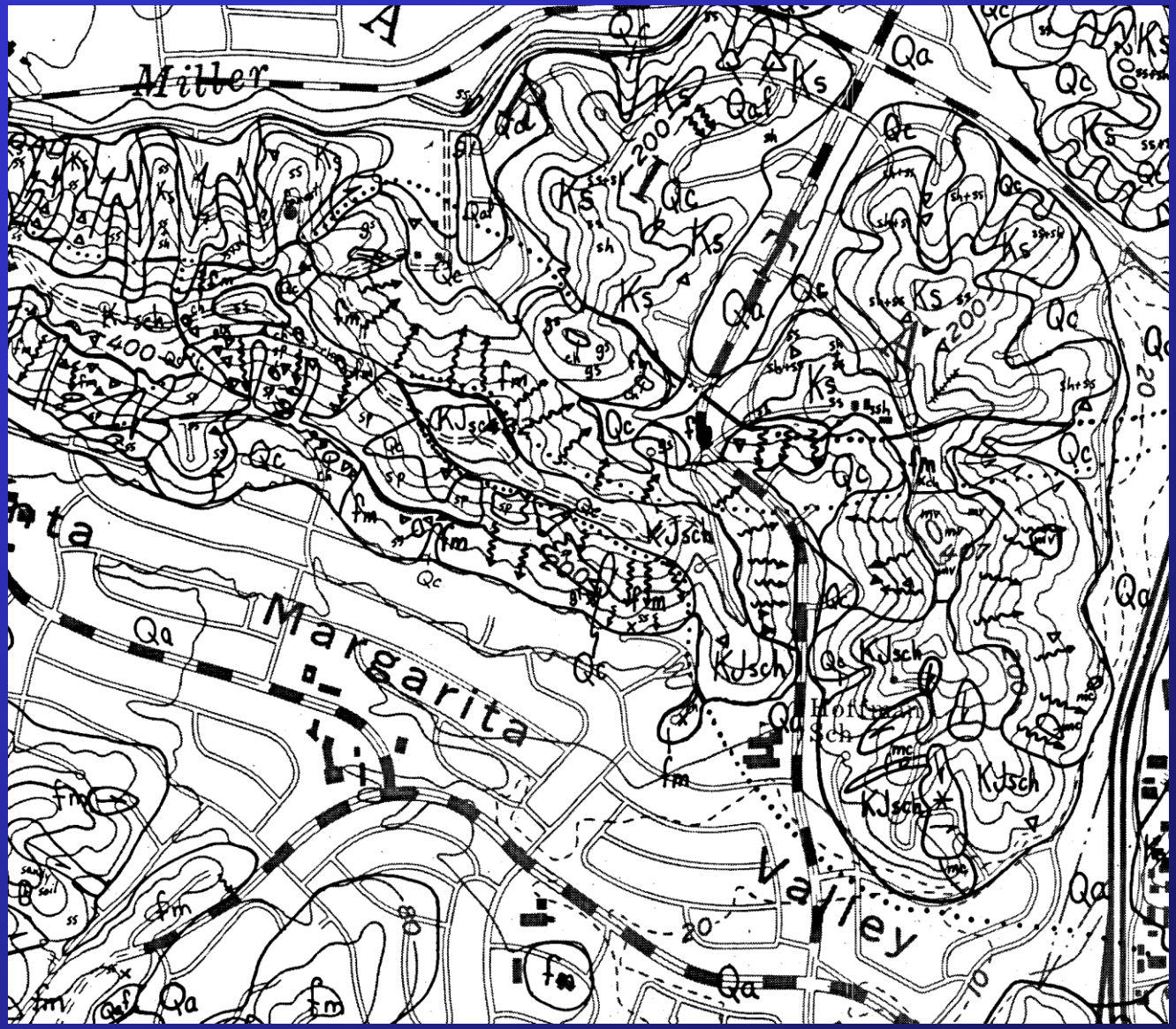
Types of Landslide Maps

1. **Landslide-inventory maps**, the most basic landslide maps, portray the location of existing landslides.
2. **Landslide-hazard maps** show where landslides are more likely. There are two general types of landslide-hazard maps, each of which provides a different level of information and detail:
    a. **Landslide-susceptibility maps** describe the relative likelihood of future landsliding based solely on the intrinsic properties of a locale or site. Prior failure (from a landslide inventory), rock or soil strength, and steepness of slope are the three site factors that most determine susceptibility.
    b. **Landslide-potential maps** describe the likelihood of landsliding based on susceptibility, jointly with the occurrence of a triggering event (opportunity).
3. **Landslide-risk maps** describe landslide potential jointly with the expected losses to life and property if a failure was to occur.
4. **Landslide-zone maps** depict areas with a higher probability of landsliding, within which specific actions are mandated by California law prior to any development.

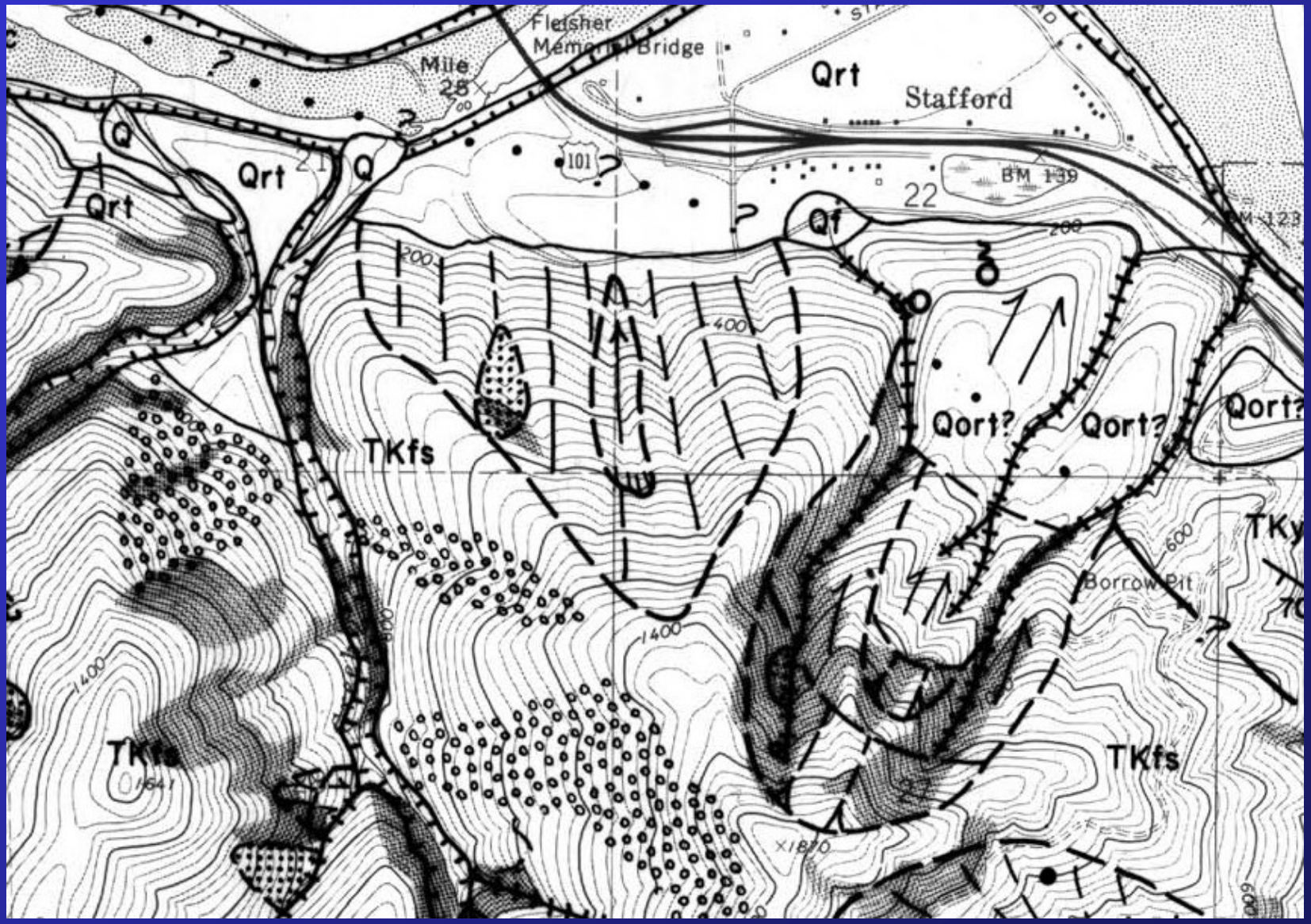
Milestones in landslide mapping at CGS:

- 1971- state requires safety and seismic safety elements in local general plans – CGS works with local government to develop hazard maps, including landslide maps.
- 1973- state requires consideration of landslide hazards in forestry (logging) – CGS works with other state agencies to map landslides in forested areas
- 1982- Storms trigger debris flows in Bay Area. State establishes Landslide Hazard Identification Program.
- 1989- Loma Prieta earthquake triggers landslides in Santa Cruz Mountains. State enacts Seismic Hazard Zoning act.

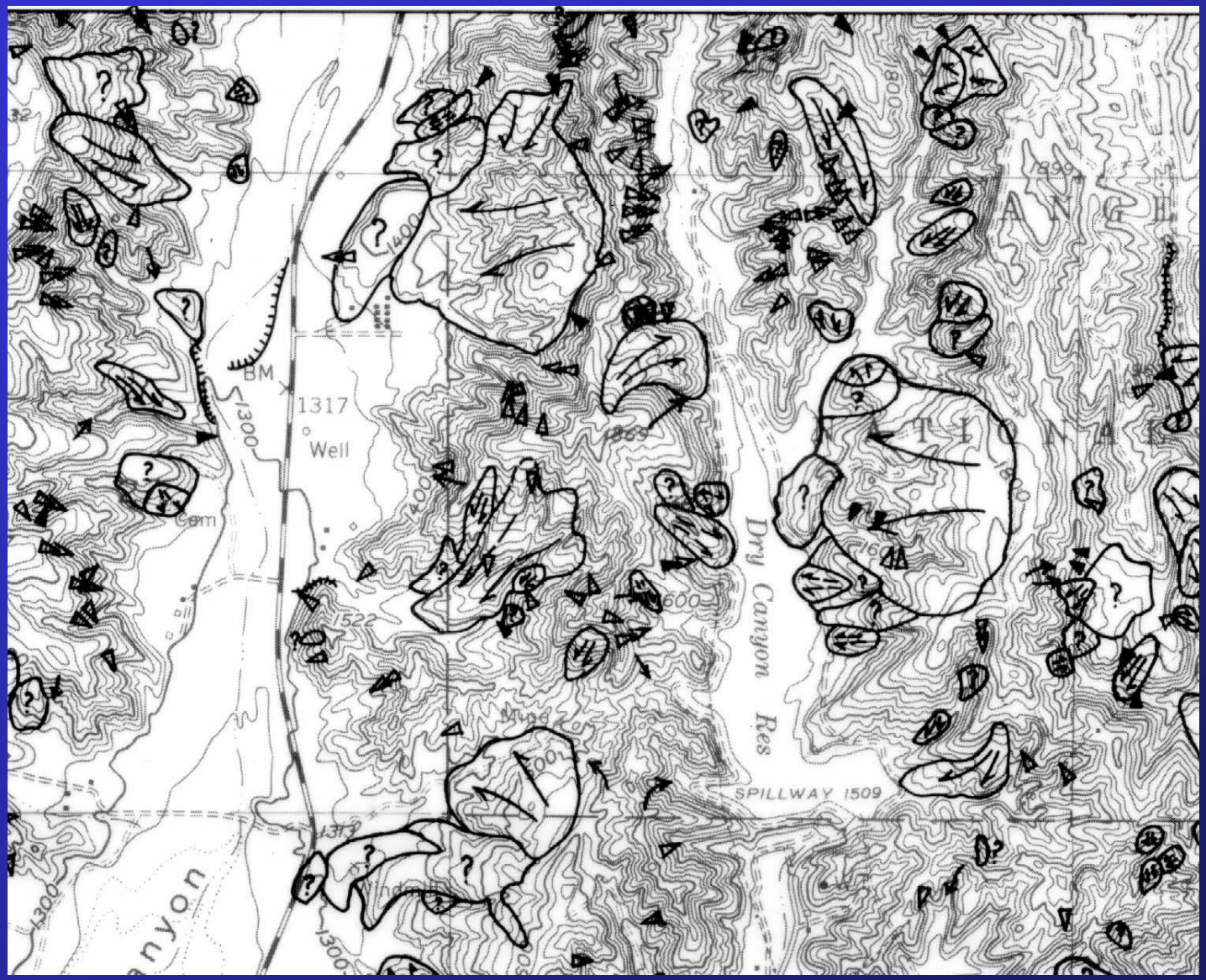
A progression of landslide inventory maps



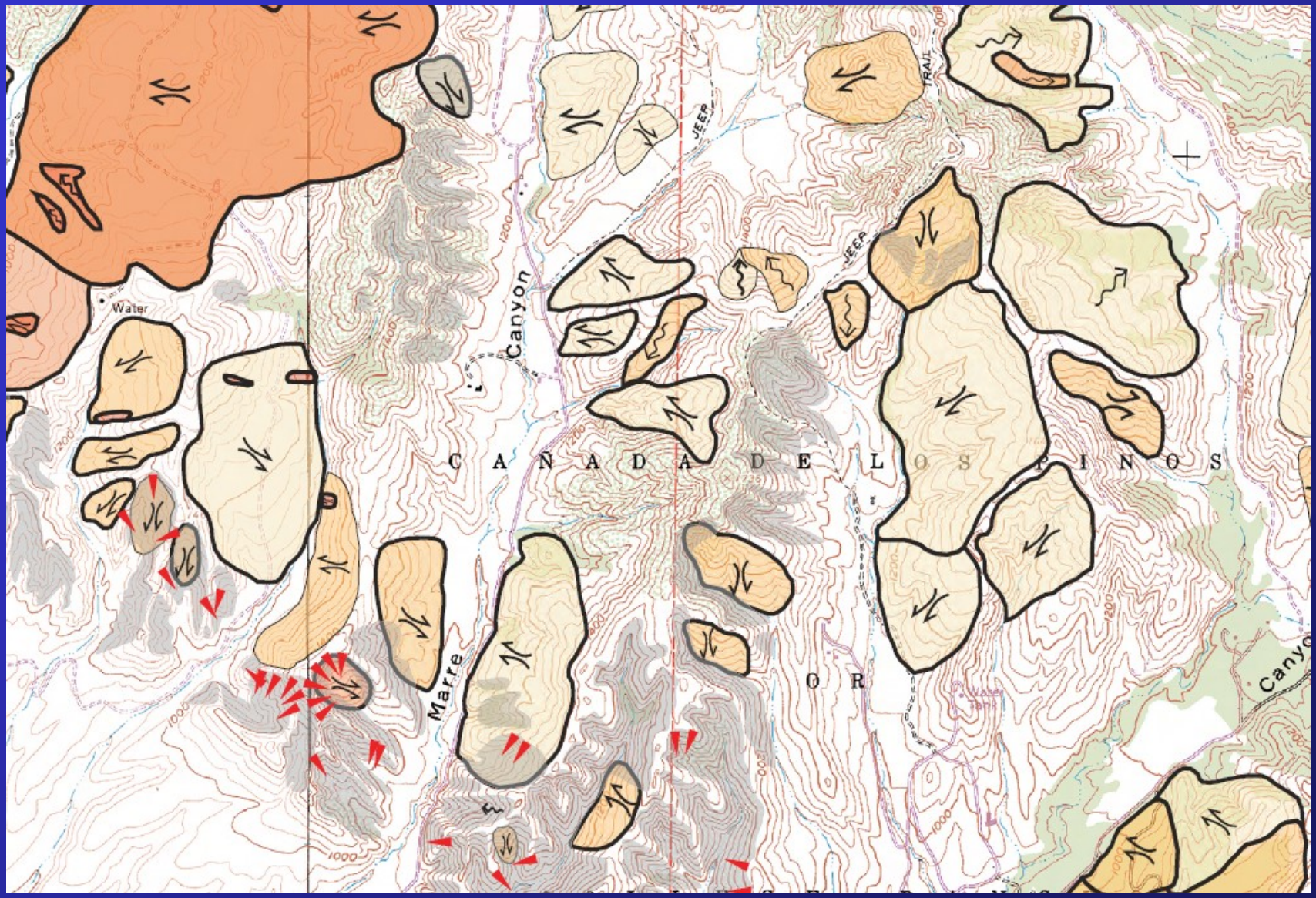
A progression of landslide inventory maps



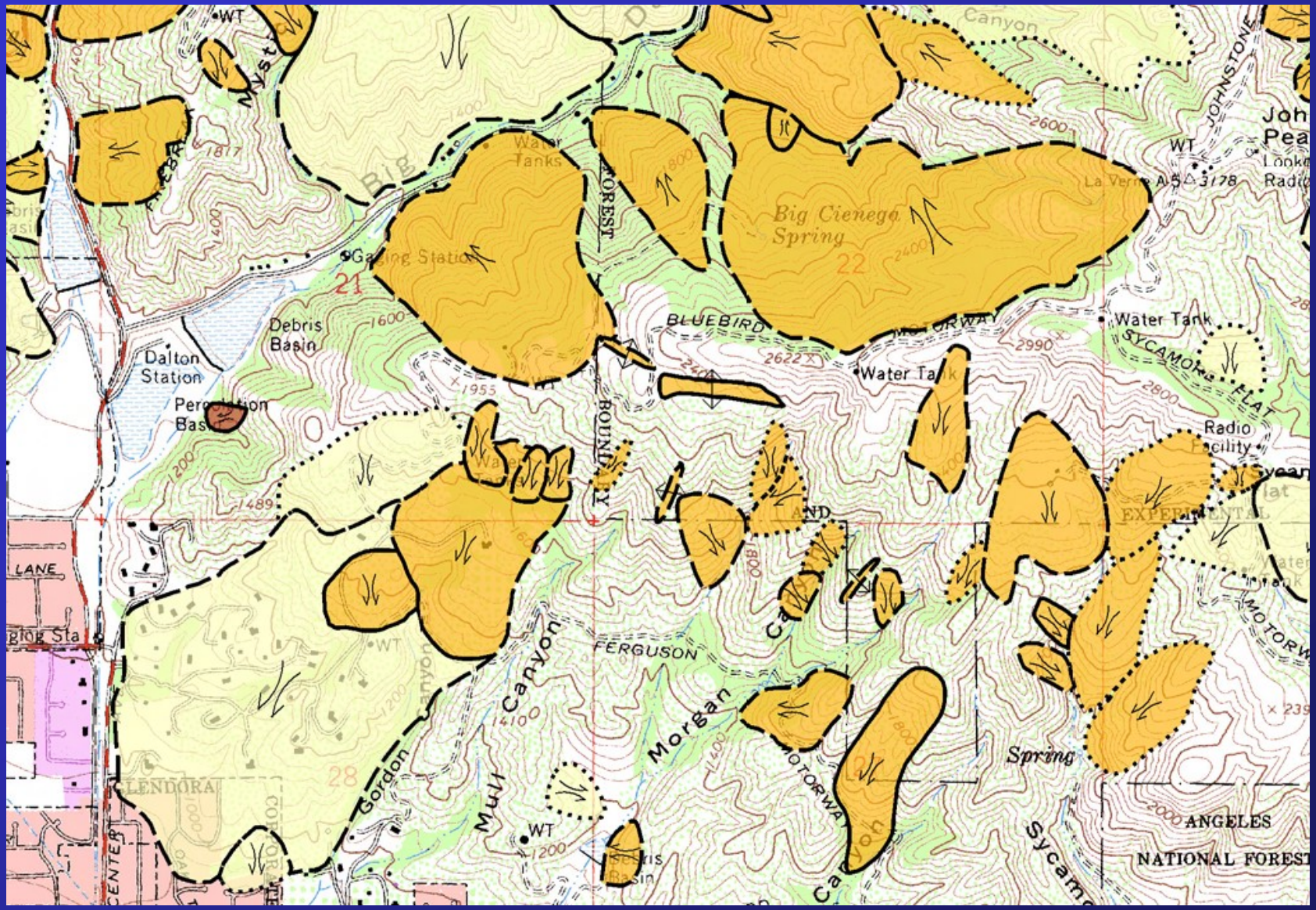
A progression of landslide inventory maps



A progression of landslide inventory maps



A progression of landslide inventory maps



From the beginning, there has been an attempt to record more than just “a landslide occurred here”.

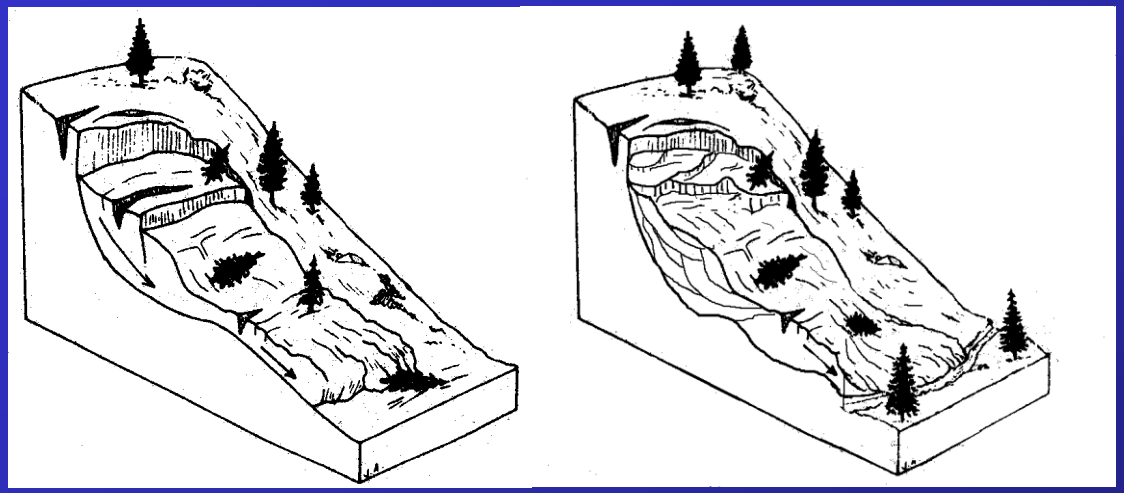
Most maps show type of slide, and some show the author’s confidence that it is a slide, more recently most show relative activity.

Since the early 1990’s CGS has recorded basic information about landslides in a GIS database. Fields include:

- Type
- Activity
- Confidence
- Author/interpreter
- Depth
- Geologic unit & lithology
- and many other fields (details later)

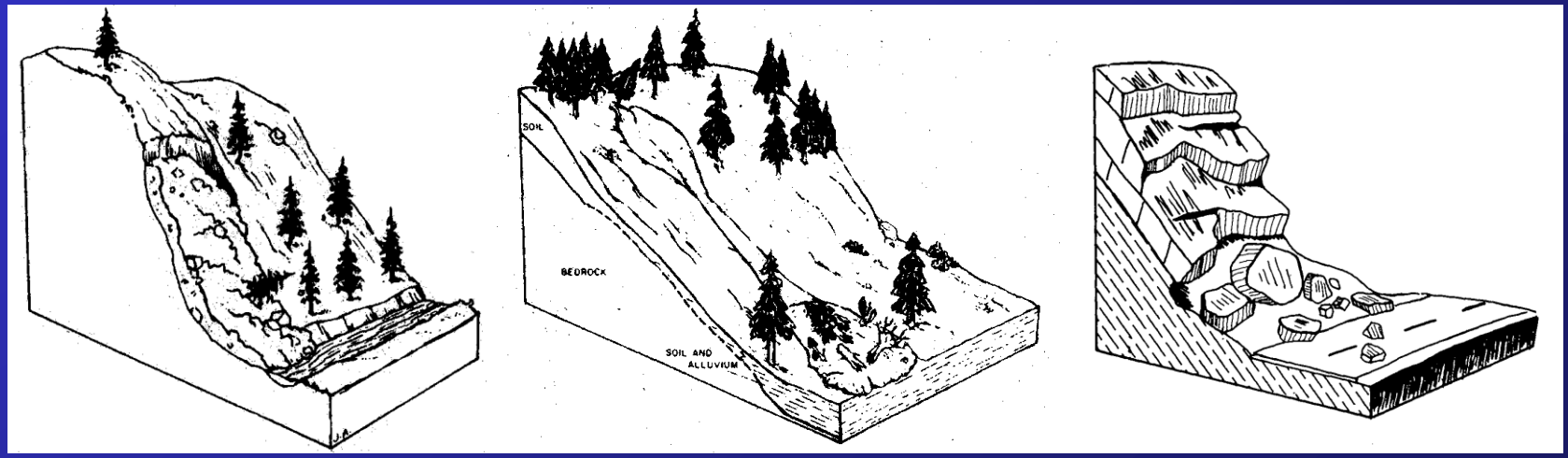
Seismic hazards program and Forest and Watershed Geology program used slightly different database structures.

Types of Landslides



Rock slide

Earth flow

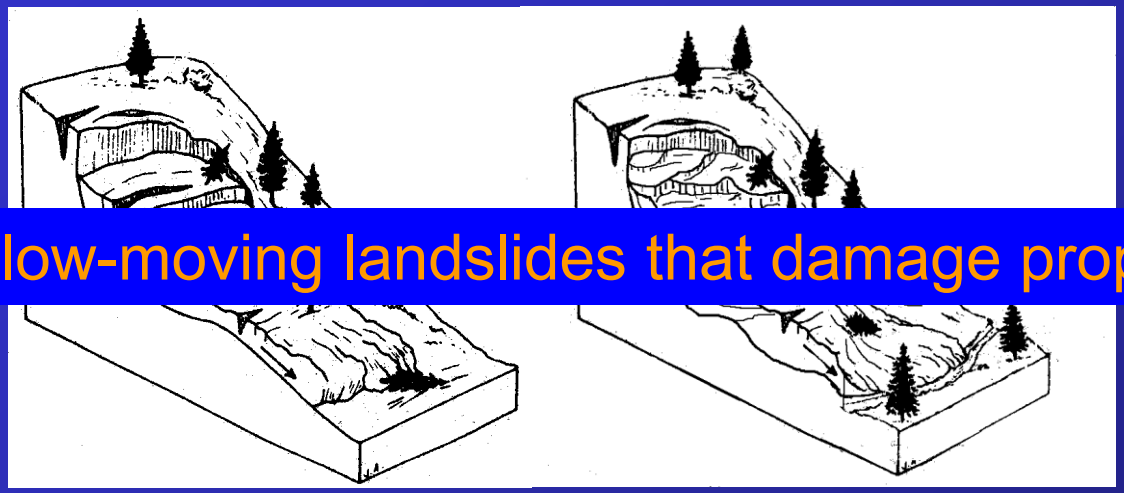


Debris slide

Debris flow

Rock fall

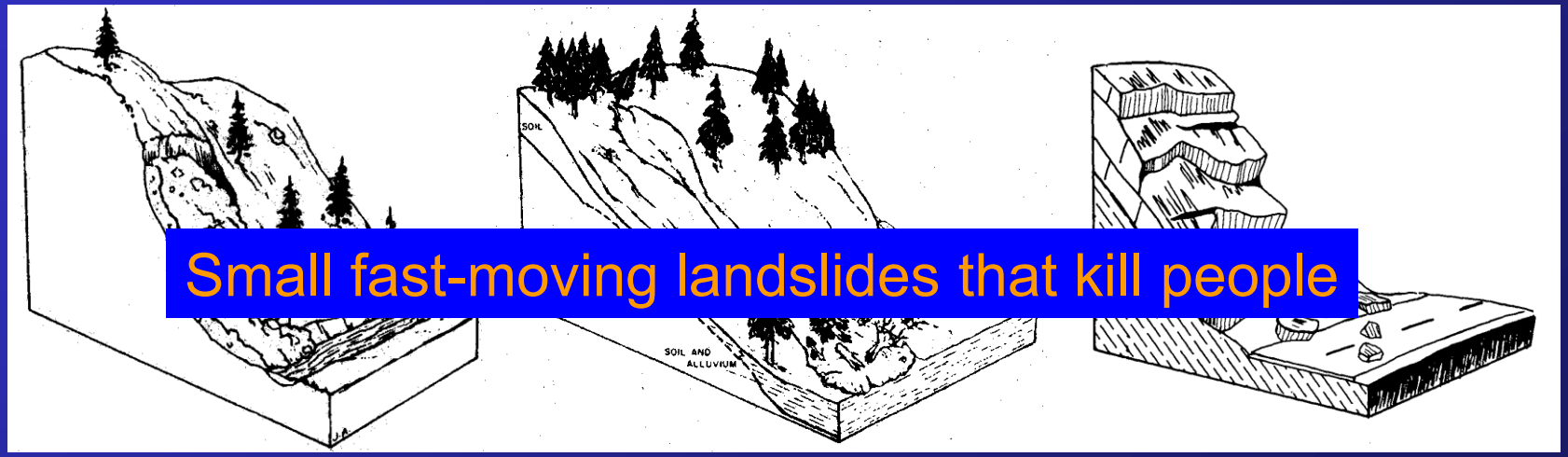
Types of Landslides



Big slow-moving landslides that damage property

Rock slide

Earth flow

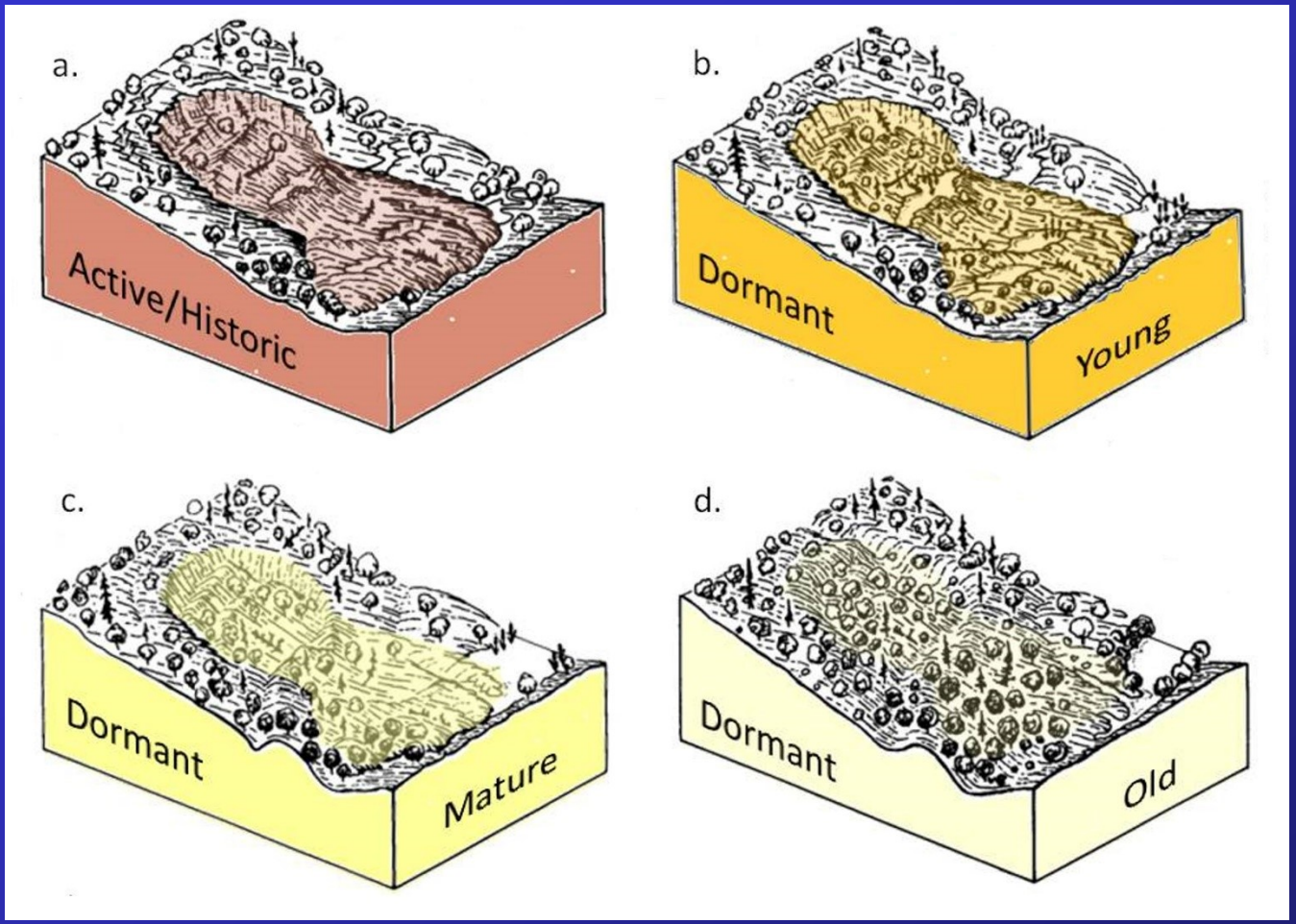


Small fast-moving landslides that kill people

Debris slide

Debris flow

Rock fall



Activity is an interpretation of the recency of movement based on how erosionally degraded the landslide appears. Ideally, we would like to know when each landslide moved. That information is rarely available.

Feature Names:	LS_DEPOSIT_POLY, LS_DEPOSIT_LINE, LS_DEPOSIT_POINT					
Feature Descriptions:	Landslide deposit features. Features are polygons, lines or points. Line features are for long narrow landslides less than 150 feet wide. Points exist for features covering less than a quarter acre.					
Attribute	Description	Type	L	Null	Units	Domain
CREATION_ DATE	Date of record creation	DATETIME				default: SYSDATE
REVISION_ DATE	Date of record revision	DATETIME				
GEOM_REV_ DATE	Date of landslide geometry revision	DATETIME				
GEOM_REV_ STAFF	Staff who updated landslide geometry	NVARCHAR	8			
LS_ID (PK)	The landslide id is composed of the 4 or 5 character quad abbreviation and a four digit sequential number, i.e. lgat0045. For notable named single landslides, put notable name in remarks, e.g. Rio Nido landslide	NVARCHAR	15	N		
LS_MASTER	Entered if the landslide is part of a complex and would carry the local name of the complex to which it belongs, e.g. Mission Peak Landslide.	NVARCHAR	40			
ACTIVITY	Landslide activity. Acceptable values are h (historically active, dormant historic), d (unspecified dormant), dy (dormant young), dm (dormant mature), do (dormant old/relict)	NVARCHAR	2	N		Activity
INIT_TYPE	Initial movement type. Combine material type (r-rock, s-soil, e-earth, d-debris) with movement type (s-slide, f-flow, t-topple, p-spread, l-fall) or multiple movement types (composite-cl).	NVARCHAR	3	N		MovementType
SUBS_TYPE	Type, subsequent movement.	NVARCHAR	3			MovementType
MVMT_MODE	Landslide movement mode.	NVARCHAR	2			MovementModeBase
CONFIDENCE	Confidence of interpretation; definite (d), probable (p), questionable (q).	NVARCHAR	1	N		InterpretationConfidence
THICKNESS	Maximum thickness estimate; s-shallow (0-10ft), m-moderate(11-50ft),d-deep(>50ft), ?-unknown.	NVARCHAR	1	N		SlipSurfaceDepthEstimate
DIR_MVMT	Azimuth direction estimate. Valid values are 1 to 360; North is 360, zero is not used.	SMALLINT		N	deg	between 1 and 360
BASE_MAP	Digital source used for compilation, i.e. the base used to locate identified landslides and digitize their boundaries.	NVARCHAR	10	N		BaseMapBase
MAP_YEAR	Year CGS interpreted/compiled landslide.	SMALLINT				
LS_DATA_ SOURCE_ TYPE	Type of source used to identify geomorphic features indicative of past landsliding; map, publication, report, air photos, field. If more than one source, enter one primary source and list additional sources in ls_data_source_desc. Default for this field should be IMG.	NVARCHAR	10	N		LsDataSourceType
LS_DATA_ SOURCE_ DESC	Description of data source used.	NVARCHAR	255			
PRIM_GEOL_ UNIT_MAP_ SYMB	Geologic unit abbreviation for map symbol identification. Geologic formation abbreviation for the formation most affected (area-wise) by the landslide.	NVARCHAR	20			
PRIM_GEOL_ UNIT_NAME	Full name for the primary geologic formation.	NVARCHAR	80			
SEC_GEOL_ UNIT_MAP_ SYMB	Geologic formation abbreviation for the second-most affected formation. If more than two formations involved add others in remarks.	NVARCHAR	10			
SEC_GEOL_ UNIT_NAME	Full name for the secondary geologic formation.	NVARCHAR	80			
GEOL_DATA_ SOURCE	Geologic map used for rock unit and lithology; publication series & number for CGS or USGS products, e.g. USGS OFRXX or CGS SRXX, etc. Authors and dates for other references. Null if no geologic data (4 previous fields)	NVARCHAR	80			

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SUBS_TYPE	Type, subsequent movement.
MVMT_MODE	Landslide movement mode.
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SEC_GEOL_ UNIT_MAP_ SYMB	Geologic formation abbreviation for the second-most affected formation. If more than two formations involved add others in remarks.
SEC_GEOL_ UNIT_NAME	Full name for the secondary geologic formation.
GEOL_DATA_ SOURCE	Geologic map used for rock unit and lithology; publication series & number for CGS or USGS products, e.g. USGS OFRXX or CGS SRXX, etc. Authors and dates for other references. Null if no geologic data (4 previous fields)
STRIKE_AZ	If available, the overall geologic strike direction, as an azimuth (USGS strike direction convention; valid values 0-360, North is 360, zero for flat beds)
DIP	If available, the overall geologic dip value estimate. Valid values 0 - 90.
ATTITUDE_ TYPE	Type of attitude measurement;
ATT_DATA_ SOURCE	Geologic map used for attitudes; publication series & number for CGS or USGS products, e.g. USGS OFRXX or CGS SRXX, etc. Authors and dates for other references. Null if no attitude data (3 previous fields).

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DATA_CLASS	Readiness of data for public release.
CITABLE_ PRODUCT	Publication series and number for CGS; authors and dates for other references. May contain hyperlink.
MVMT_DATE_YR	The year of the latest movement. For landslides that are moving continuously, the year used is the last date it moved.
MVMT_DATE_MON	The month of the latest movement. For landslides that are moving continuously, the month used is the last date it moved. Valid values 01-12.
MVMT_DATE_DAY	The day of the latest movement. For landslides that are moving continuously, the day used is the last date it moved. Valid values 01-31
TRIGGERING_EVENT	Comments on event that triggered the most recent phase of movement.
SUPERSEDED	Flag to indicate if this feature has been retired. Valid values are null or Y. Attribute value updates are not considered substantial enough to retire a feature. If there is a substantial change required for a landslide deposit boundary (> 50% of the perimeter needs to be modified) then the original feature is copied to create a new feature with a new ls_id and the new polygon is edited to reflect current mapping. The original feature is then flagged as superseded ("Y" in this field).

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Department of Conservation

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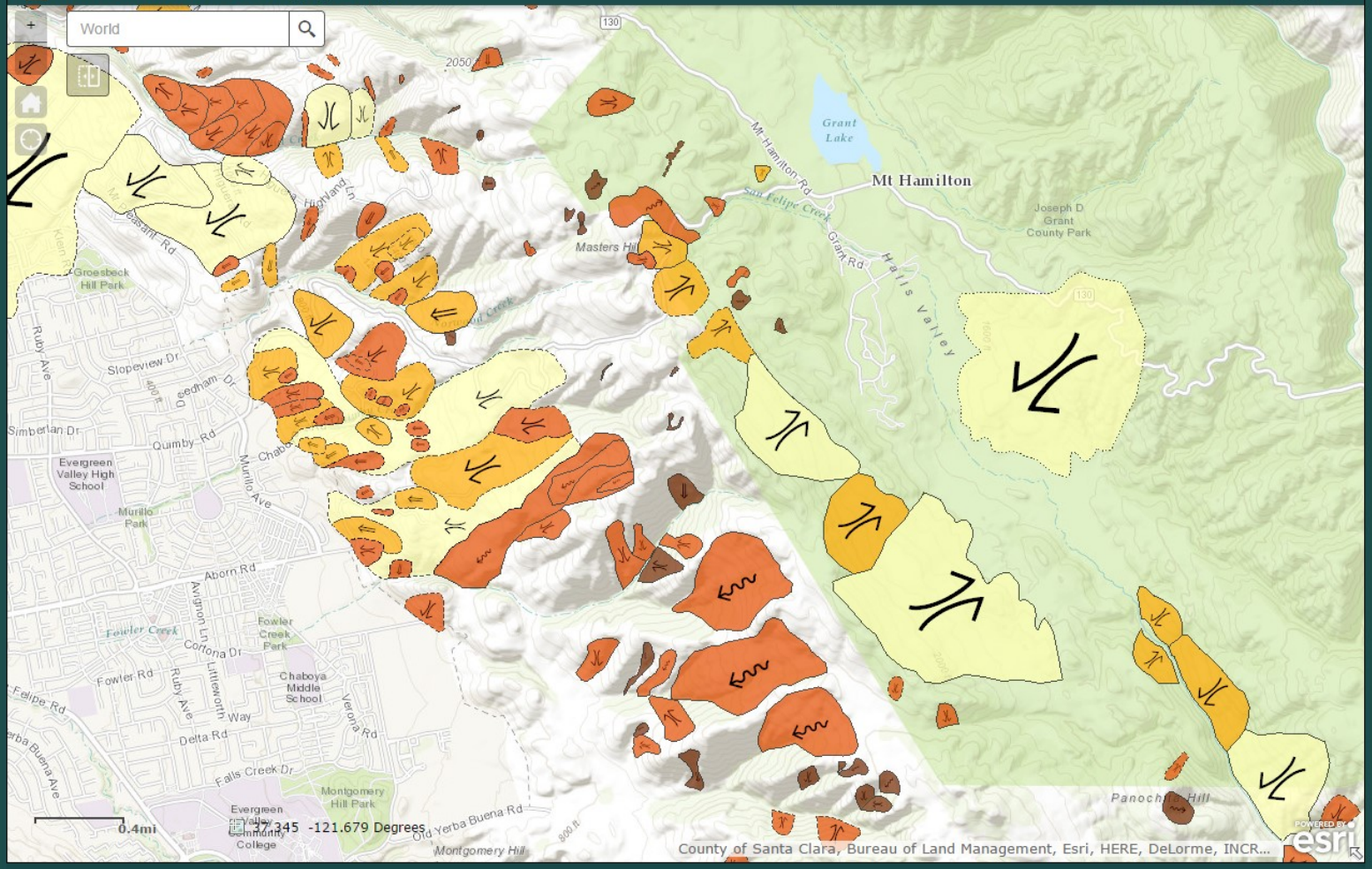
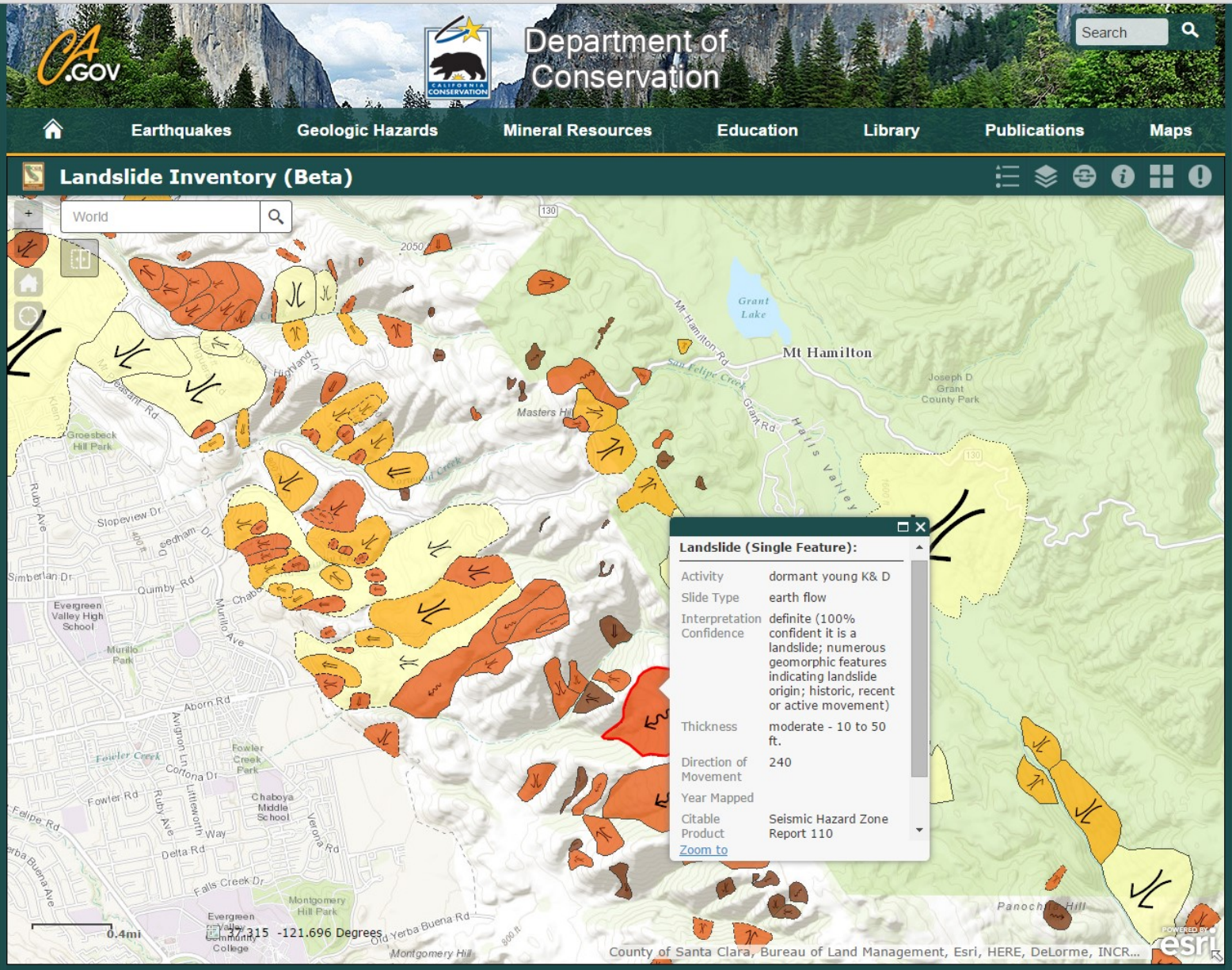
Landslide Inventory (Beta)

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Earthquakes
Geologic Hazards
Mineral Resources
Education
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Publications
Maps
Landslide Inventory (Beta)
World
Mt Hamilton
Grant Lake
Joseph D Grant County Park
Groesbeck Hill Park
Evergreen Valley High School
Murillo Park
Fowler Creek Park
Chaboya Middle School
Montgomery Hill Park
Landslide (Single Feature):
Activity
dormant young K& D
Slide Type
earth flow
Interpretation Confidence
definite (100% confident it is a landslide; numerous geomorphic features indicating landslide origin; historic, recent or active movement)
Thickness
moderate - 10 to 50 ft.
Direction of Movement
240
Year Mapped
Citable Product
Seismic Hazard Zone Report 110
Zoom to
0.4mi
-7.315 -121.696 Degrees
County of Santa Clara, Bureau of Land Management, Esri, HERE, DeLorme, INCR...
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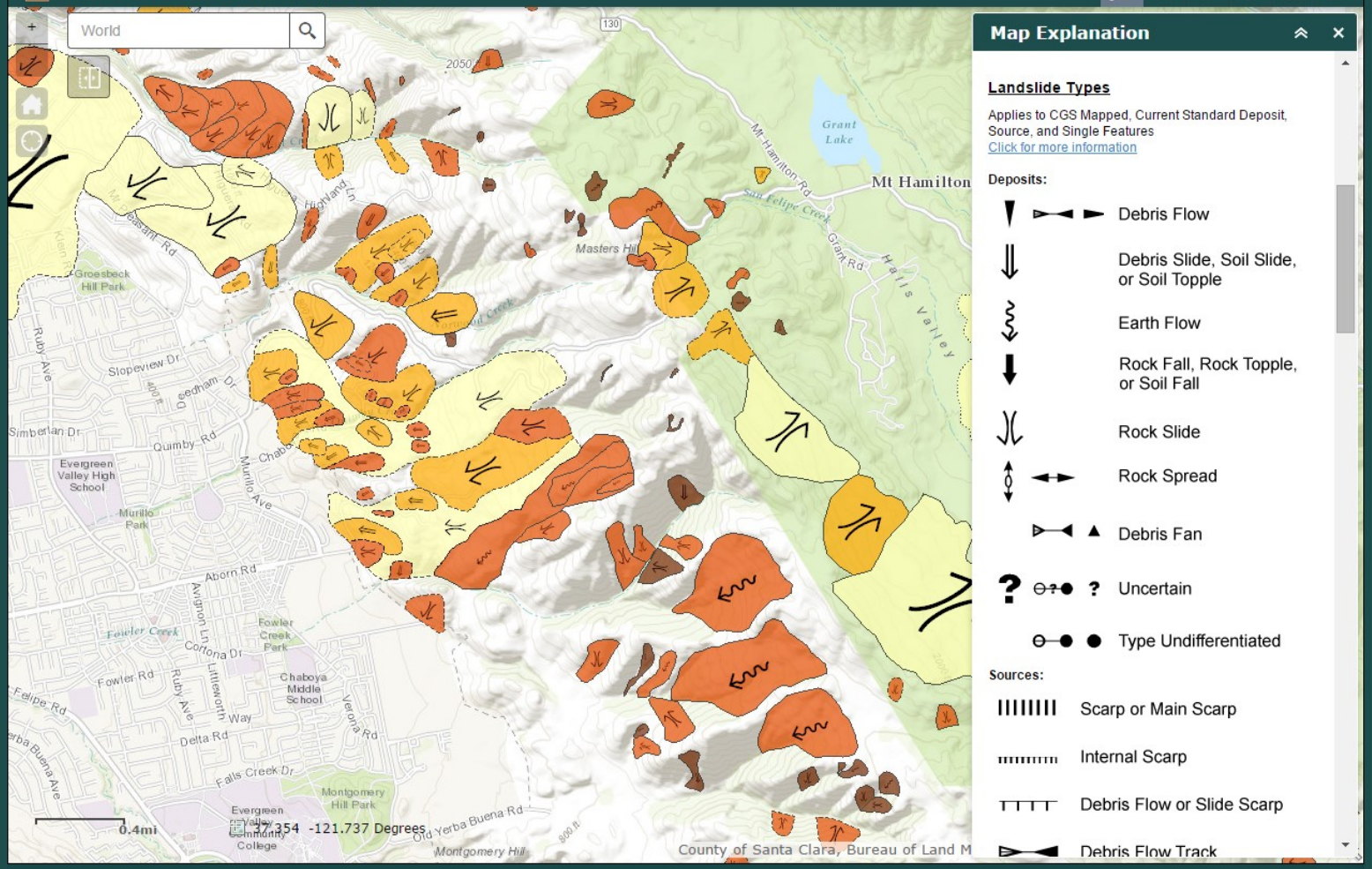
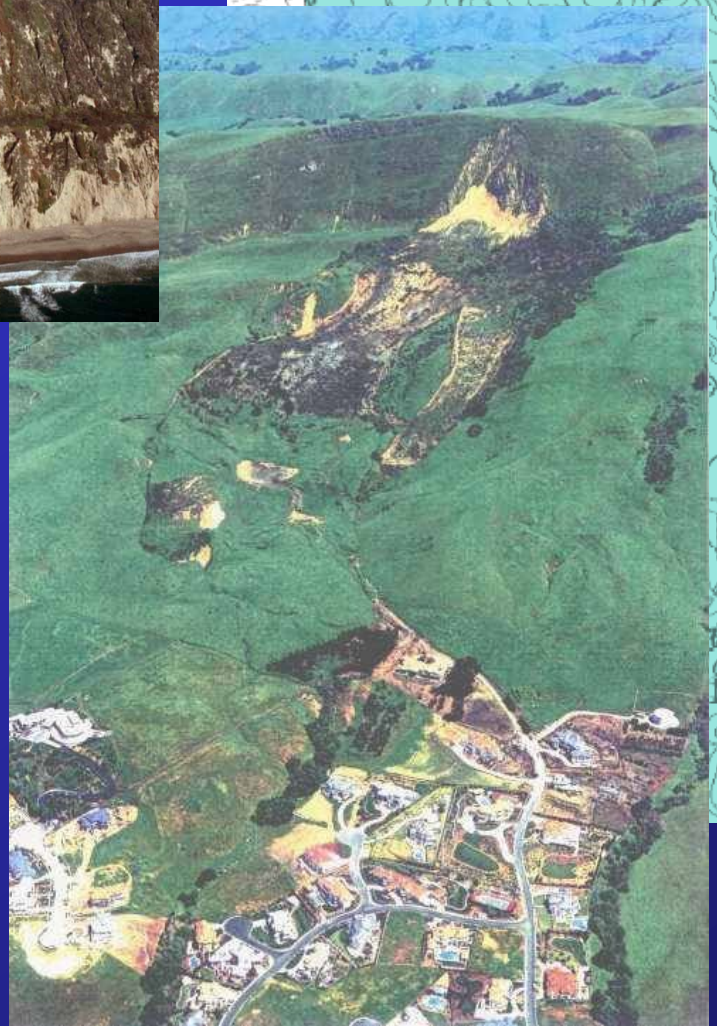
Landslide Inventory (Beta)



Landslide Hazard Zones maps result in detailed investigations and plans for mitigation prior to development



Landslide Susceptibility Map

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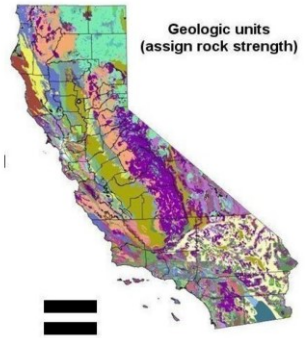

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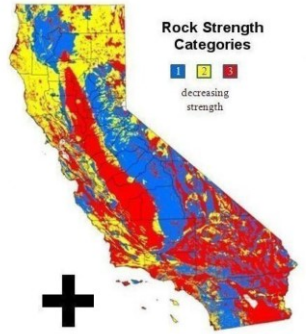

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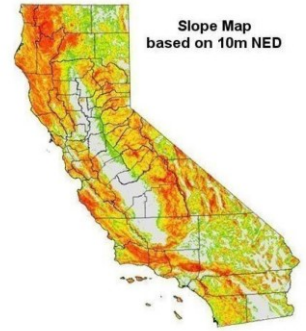
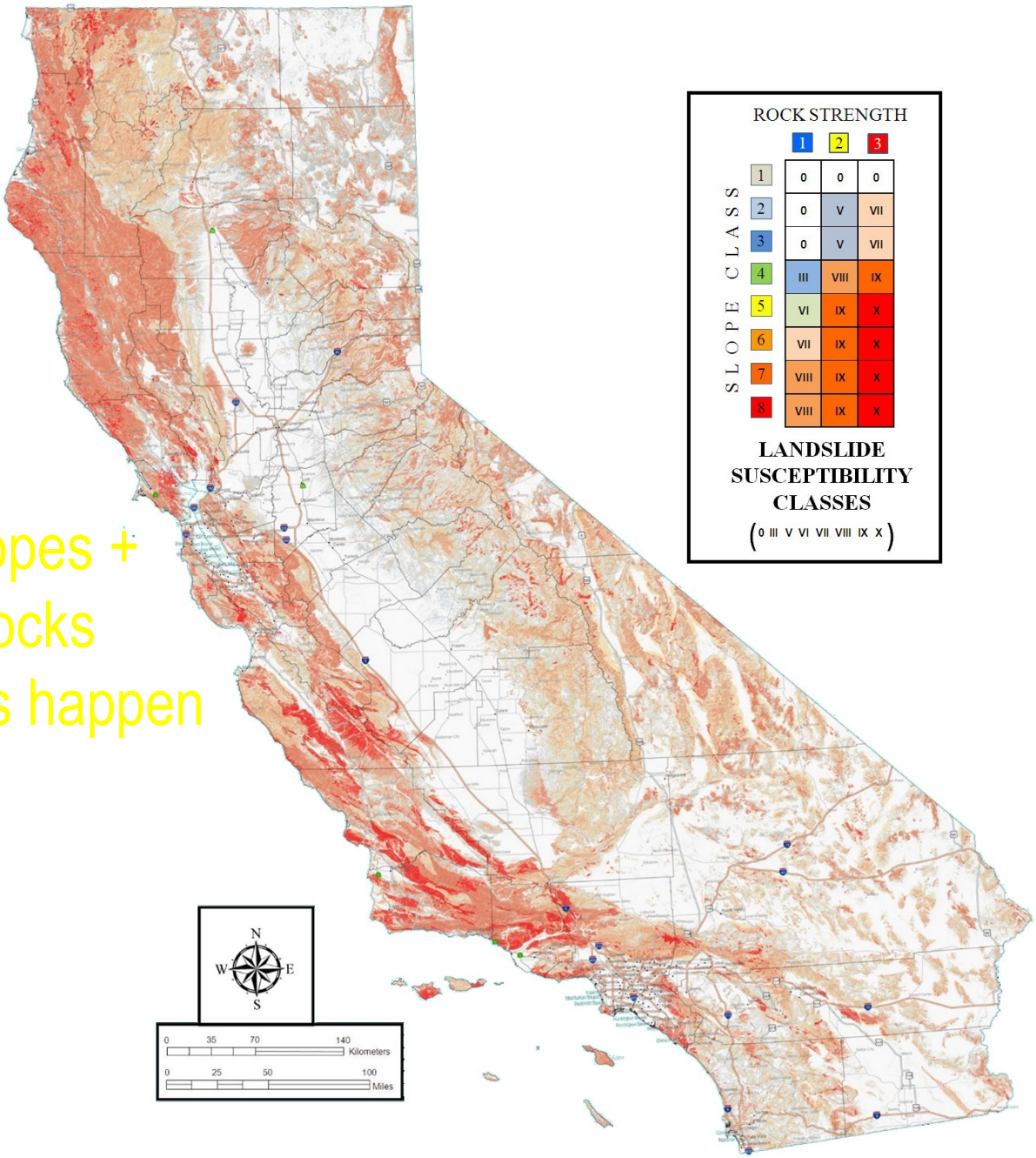
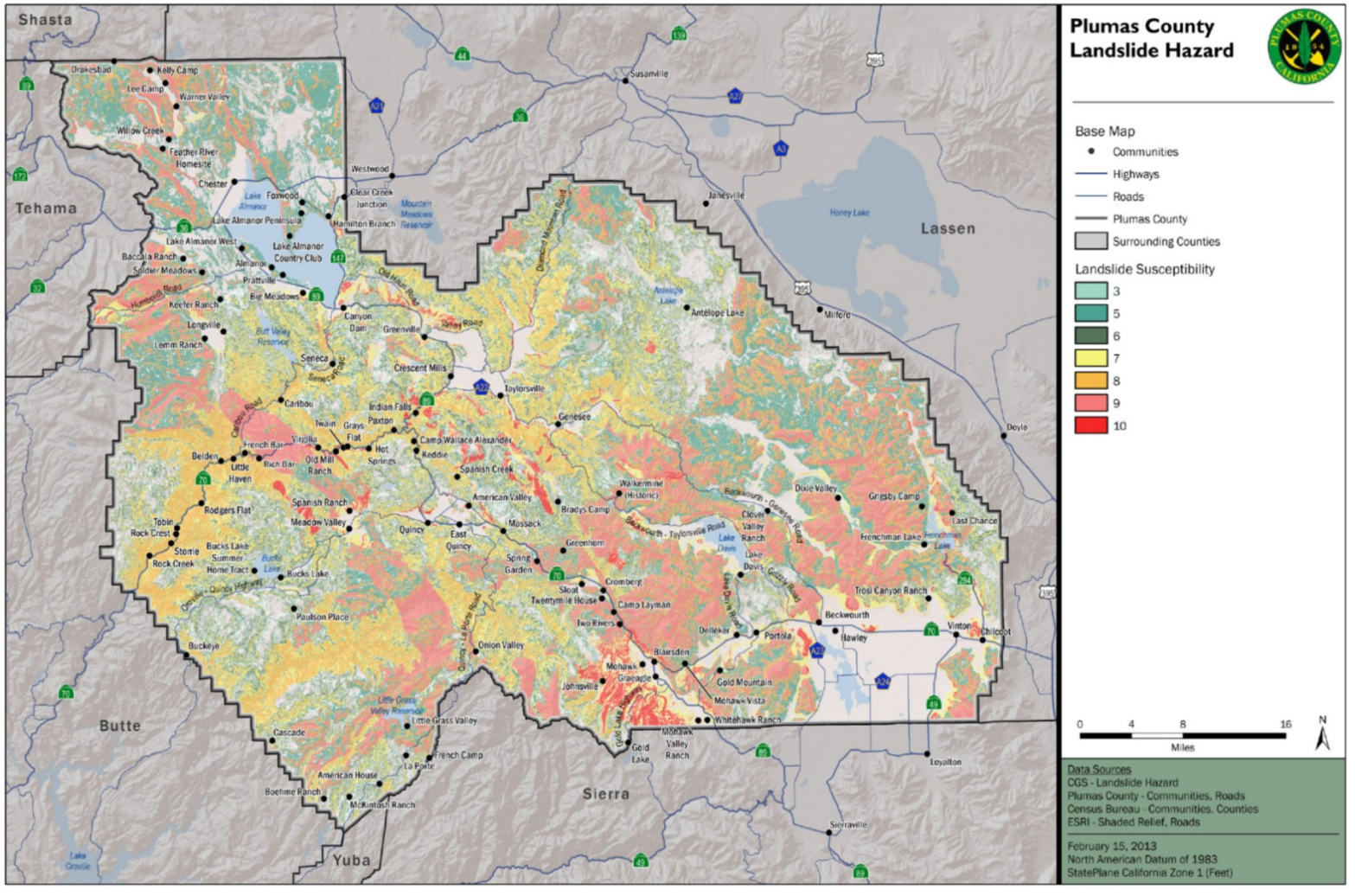
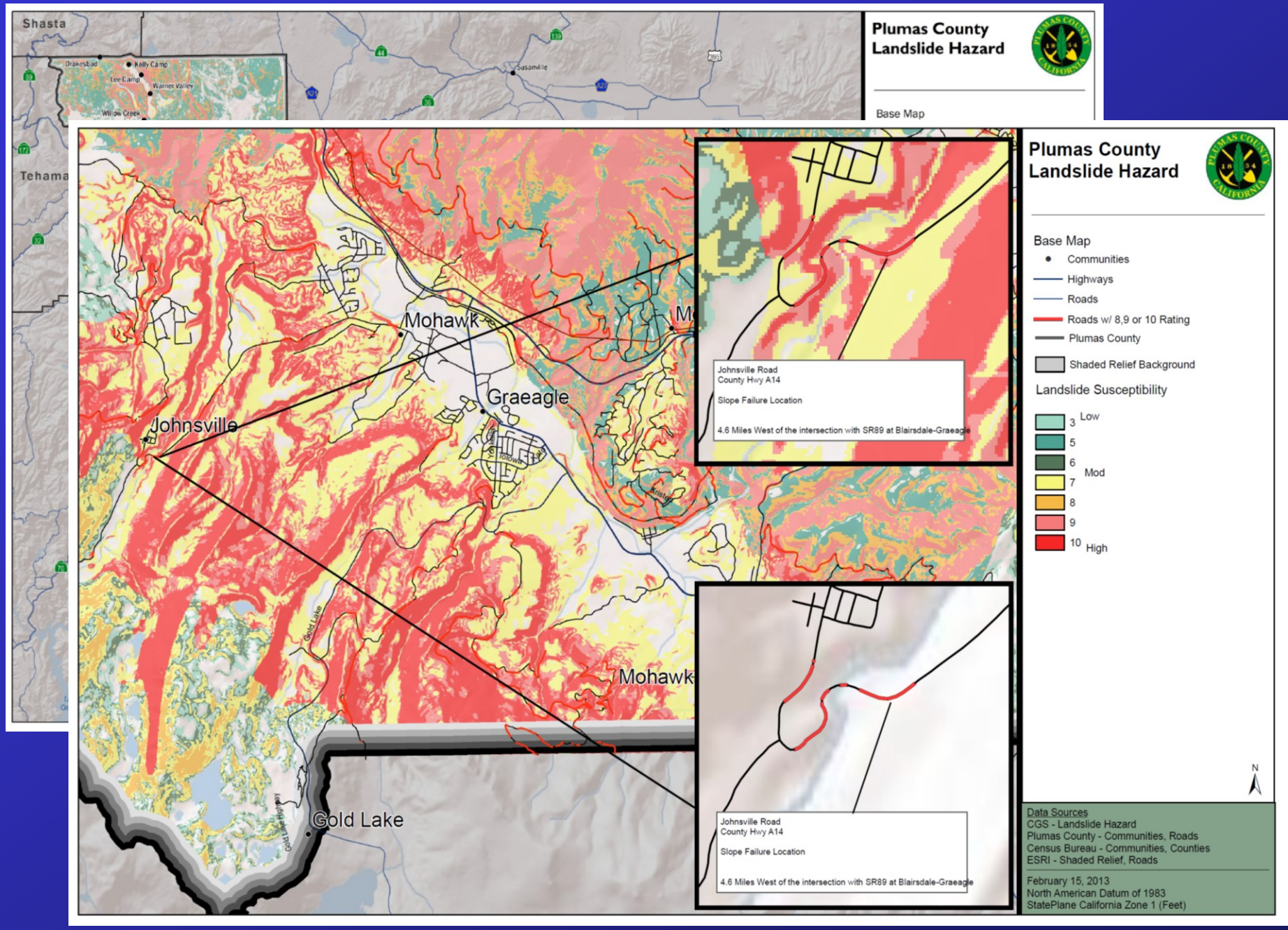


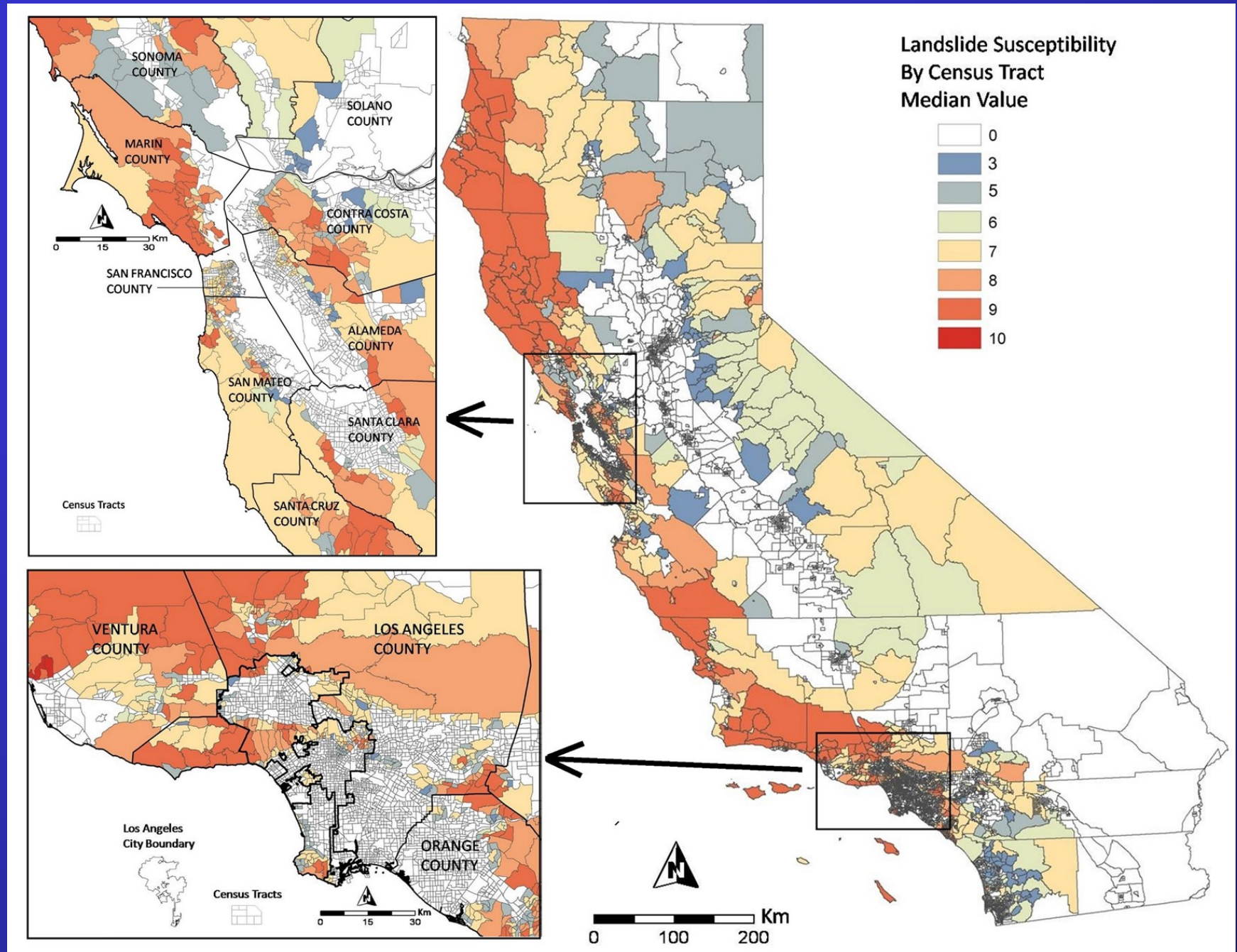
Steep slopes +
weak rocks
= bad things happen



CGS
CALIFORNIA
GEOLOGICAL SURVEY

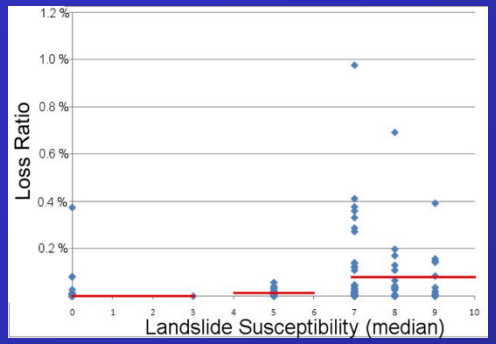

Plumas County
Landslide Hazard
Base Map
Communities
Highways
Roads
Plumas County
Surrounding Counties
Landslide Susceptibility
3
5
6
7
8
9
10
0 4 8 16
Miles
N
Data Sources
CGS - Landslide Hazard
Plumas County - Communities, Roads
Census Bureau - Communities, Counties
ESRI - Shaded Relief, Roads
February 15, 2013
North American Datum of 1983
StatePlane California Zone 1 (Feet)
Shasta
Tehama
Butte
Sierra
Yuba
Lassen
Drakesbad
Kelly Camp
Lee Camp
Warner Valley
Willow Creek
Feather River Homesite
Chester
Lake Almanor
Foxwood
Lake Almanor Peninsula
Lake Almanor West
Baccala Ranch
Soldier Meadows
Almanor
Prattville
Big Meadows
Keefer Ranch
Longville
Lamm Ranch
Westwood
Clear Creek Junction
Hamilton Branch
Mountain Meadows Reservoir
Lake Almanor Country Club
Old Highway 36
Humboldt Road
Butt Valley Reservoir
Canyon Dam
Greenville
Seneca
Seneca Road
Crescent Mills
Taylorsville
Caribou
Caribou Road
Indian Falls
Paxton
Twain
Grays Flat
Virgilio
French Bar
Belden
Little Rich Bar
Old Mill Ranch
Hot Springs
Camp Wallace Alexander
Keddie
Spanish Creek
Rodgers Flat
Spanish Ranch
Meadow Valley
Tobin
Rock Crest
Stonie Rock Creek
Bucks Lake Summer Home Tract
Bucks Lake
Oroville - Quincy Highway
Paulson Place
Buckeye
Quincy
East Quincy
American Valley
Massack
Bradys Camp
Greenhorn
Spring Garden
Cromberg
Sloat
Twentymile House
Camp Layman
Two Rivers
Onion Valley
Quincy - La Porte Road
Little Grass Valley Reservoir
Little Grass Valley
Cascade
La Porte
French Camp
American House
Boehme Ranch
McKinstry Ranch
Lake Oroville
Susanville
Janesville
Honey Lake
Antelope Lake
Milford
Doyle
Dixie Valley
Grigsby Camp
Last Chance
Frenchman Lake
Frenchman Lake
Clover Valley Ranch
Lake Davis
Davis Creek Road
Beckwourth - Genesee Road
Beckwourth - Taylorsville Road
Walkermine (Historic)
Trosi Canyon Ranch
Beckwourth
Delleker
Portola
Hawley
Vinton
Chilcott
Blairsden
Mohawk
Graeagle
Johnsville
Gold Mountain
Mohawk Vista
Whitehawk Ranch
Gold Lake Highway
Gold Lake
Mohawk Valley Ranch
Loyalton
Sierraville
Duncan Meadows Road
Old Highway 36
Valley Road
Antelope Lake
Dixie Mountain Road


Plumas County
Landslide Hazard
Base Map
Communities
Highways
Roads
Roads w/ 8,9 or 10 Rating
Plumas County
Shaded Relief Background
Landslide Susceptibility
3 Low
5
6 Mod
7
8
9
10 High
Mohawk
Graeagle
Johnsville
Gold Lake
Johnsville Road
County Hwy A14
Slope Failure Location
4.6 Miles West of the intersection with SR89 at Blairsdale-Graeagle
N
Data Sources
CGS - Landslide Hazard
Plumas County - Communities, Roads
Census Bureau - Communities, Counties
ESRI - Shaded Relief, Roads
February 15, 2013
North American Datum of 1983
StatePlane California Zone 1 (Feet)

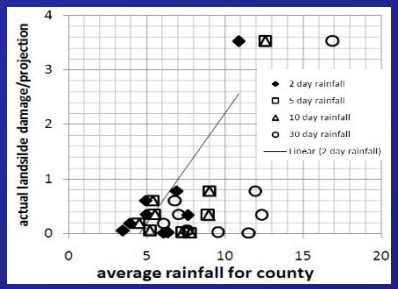

Landslide Susceptibility
By Census Tract
Median Value
0
3
5
6
7
8
9
10
SONOMA COUNTY
SOLANO COUNTY
MARIN COUNTY
CONTRA COSTA COUNTY
SAN FRANCISCO COUNTY
ALAMEDA COUNTY
SAN MATEO COUNTY
SANTA CLARA COUNTY
SANTA CRUZ COUNTY
Census Tracts
0 15 30 Km
VENTURA COUNTY
LOS ANGELES COUNTY
ORANGE COUNTY
Los Angeles City Boundary
Census Tracts
0 15 30 Km
0 100 200 Km

Wills, C., Perez, F., and Branum, D., 2014, New method for estimating landslide losses from major winter storms in California and application to the ARkStorm Scenario. Natural Hazards Review. 10.1061/(ASCE)NH.1527-6996.0000142.
developed a prototype landslide loss estimation system based on HAZUS, the earthquake, wind, and flood loss estimation program developed for FEMA.

The data collected regarding landslides and landslide damage in past storms have been sparse and inconsistent. Few previous studies have mapped landslides triggered by individual storms, and even fewer have tallied the amount of damage from landslides. The variation in loss with different storm intensities allows for estimates of loss for any given storm intensity, up to the highest recorded intensity.



Landslide susceptibility versus loss ratio by census tract for damage recorded by the City of Los Angeles following the 1978 storms: horizontal bars represent mean loss ratios for three general classes of landslide susceptibility



Comparison of county-averaged rainfall with ratio of actual landslide damage to landslide damage projected by using the loss ratios from the 1978 storm in Los Angeles for the 1982 storm in the San Francisco Bay Area. The relation between county averaged peak two-day rainfall and the ratio between actual and projected losses allows for estimation of landslide losses for counties based on peak 2-day rainfall.

Conclusion

- The California Landslide Database contains most of the landslides mapped by CGS over the past 50 years – over 100,000 features.
- Attributes included with each landslide database record include the source of the feature, along with basic information such as type, activity, confidence, depth…
- Some more recent records include data on the geologic setting of the landslide, dates of movement, and triggering event.
- A more complete database helps us and others make better landslide hazard and landslide zone maps.
- Landslide inventory maps by others can be incorporated in the CGS database, just send GIS files to chris.wills@conservation.ca.gov