

# DOE/NRC Natural Phenomena Hazards Meeting

*October 24, 2018, US NRC Headquarters, Rockville*

**UCLA** **Samueli**  
School of Engineering

## Next Generation Liquefaction Case History Database

Zimmaro P., Kwak D.Y., Stewart J.P., Brandenberg S.J., Stamatakos J., Juckett M., Weaver T., Kramer S.L.

**Presenters: Paolo Zimmaro, Ph.D., Jonathan P. Stewart, Ph.D., P.E.**

October 24, 2018



Engineer Change.

# Outline

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Introduction and NGL project vision

The NGL database graphical interface

Current status of the database

Final remarks and path forward

# NGL Database Contributors

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- **PIs:** Jonathan Stewart, Steven Kramer, Yosef Bozorgnia
- **Database working group:** Scott Brandenberg (chair), Robb E.S. Moss (Cal Poly), K. Onder Cetin (METU), Kevin Franke (BYU), Paolo Zimmaro (UCLA), and Dong Youp Kwak (Hanyang University)
- **Southwest Research Institute:** John Stamatakos, Miriam Juckett, Bis Dasgupta, Joey Mukherjee, Zackary Murphy, Steven Ybarra
- **Nuclear Regulatory Commission:** Thomas Weaver
- **Caltrans:** Tom Shantz



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# NGL Database Contributors

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- ***U. of Utah***: Steve Bartlett, Masoud Hosseinali
- ***Virginia Tech***: Russell Green, Kristin Ulmer
- ***UC Berkeley***: Jonathan Bray, Christine Beyzaei
- ***Tonkin & Taylor***: Sjoerd Van Ballegooey, Mike Liu
- ***BYU***: Heidi Dacayanan, Lila Lasson
- ***METU***: Gizem Can, Makbule Ilgac
- ***UCLA***: Omar Issa, Chris Nicas, Trini Inouye, Arielle Sanghvi, Tristan Buckreis, Naoto Inagaki, Wyatt Iwanaga, Michael Winders, Bryan Ong, Siddhant Jain, Allison Lee, Honor Fisher
- ***Others***: Mike Greenfield, Teruo Nakai, Hideo Sekiguchi, ...



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# NGL Project Vision

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What motivated the formation of NGL?

Project elements

Organization

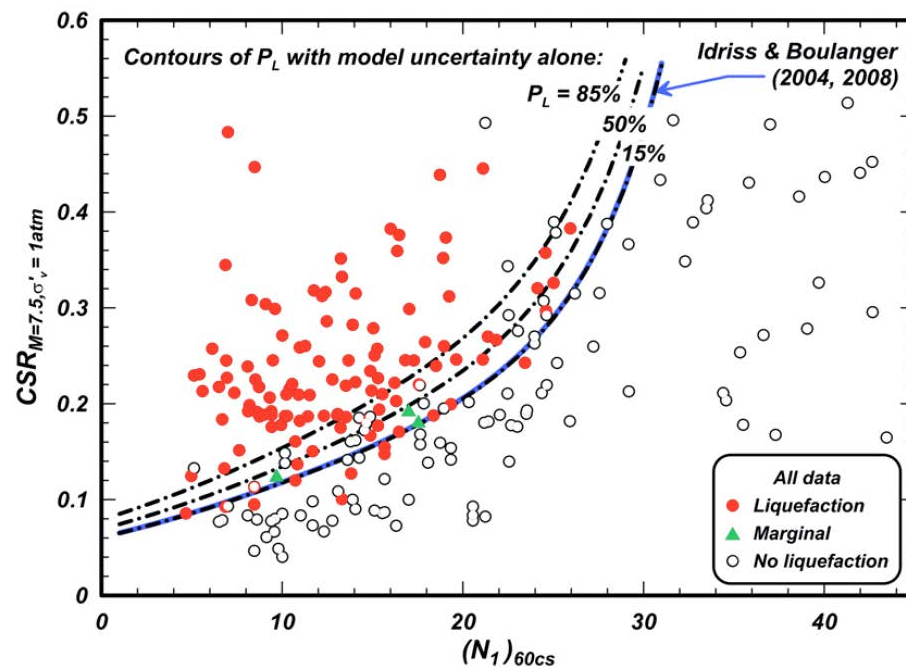


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# Project Need

Most analysis techniques for ground failure are empirical or semi-empirical



*Boulanger and Idriss, 2012*

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Most analysis techniques for ground failure are empirical or semi-empirical

Small data sets – a few sites are especially consequential

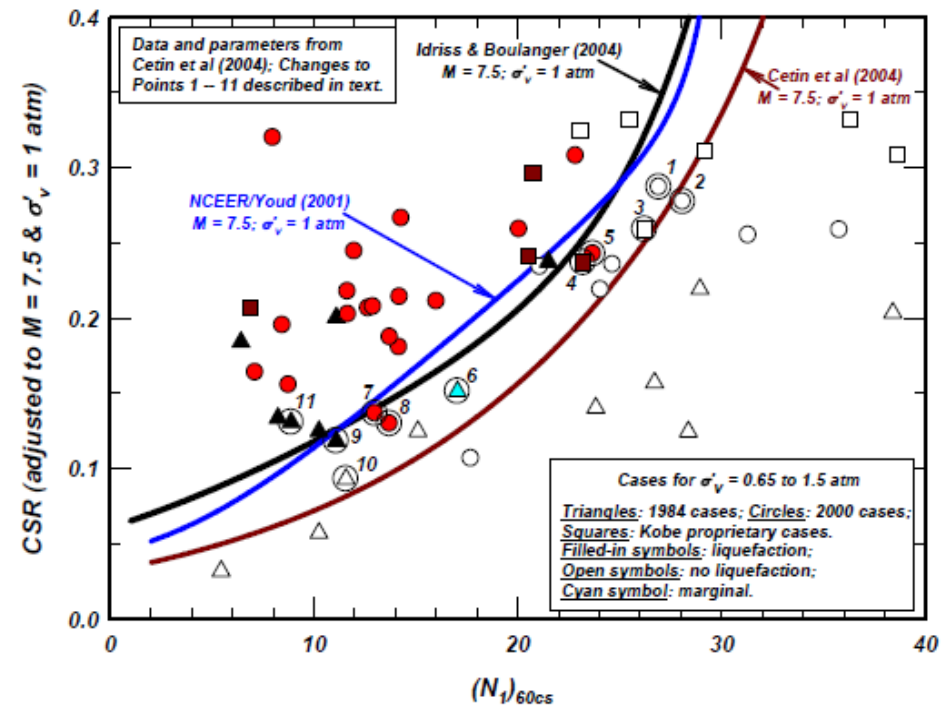


Figure: Idriss and Boulanger, 2010

# Project Need

Most analysis techniques for ground failure are empirical or semi-empirical

Small data sets – a few sites are especially consequential

Alternate models provide different outcomes –

- Derived from different data
- Data interpreted differently

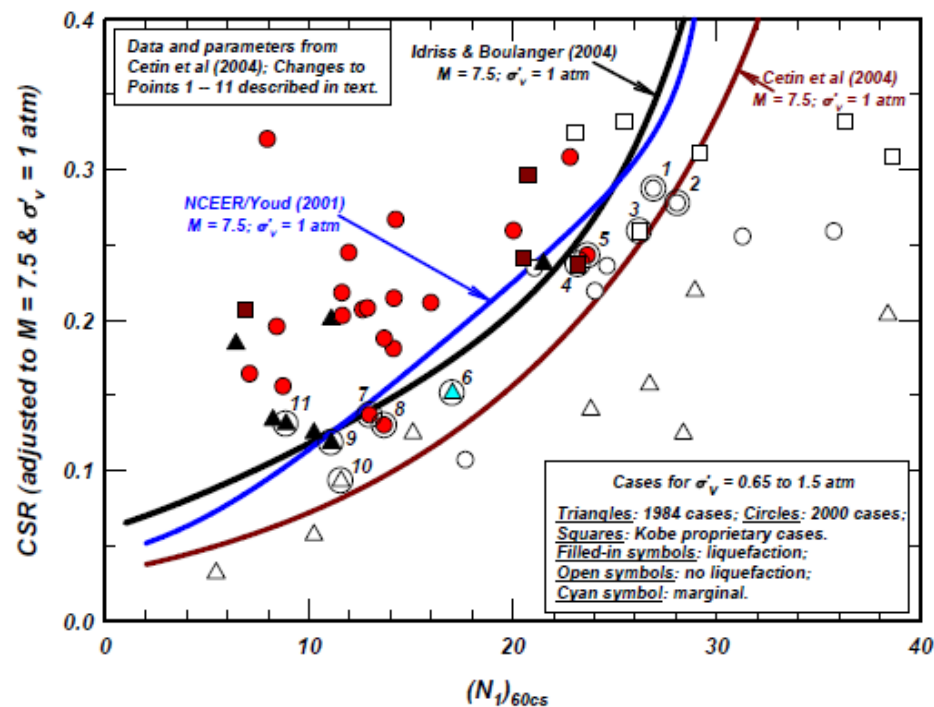


Figure: Idriss and Boulanger, 2010



# NRC Liquefaction Committee

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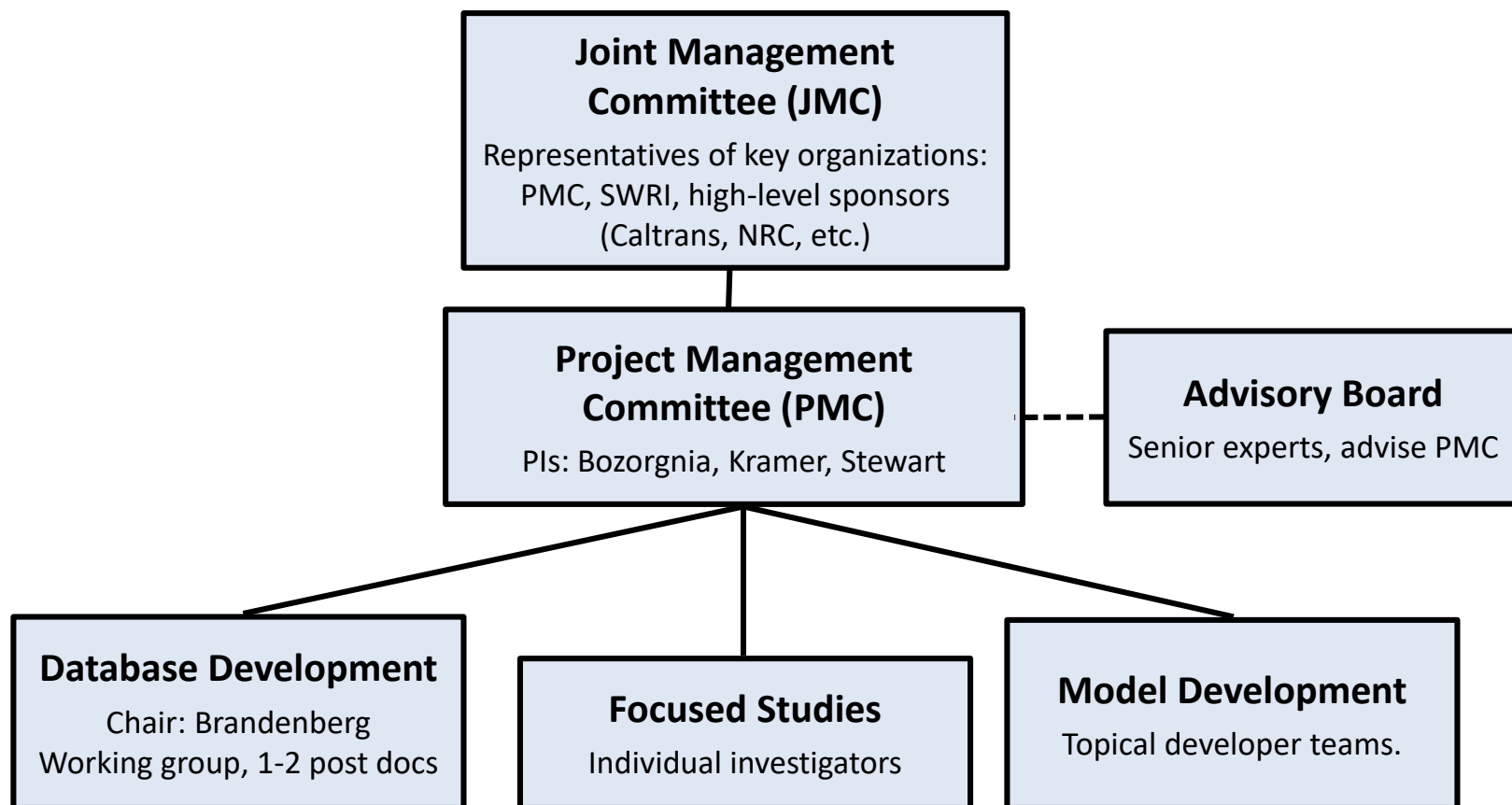
- Multi-year assessment of state of the art and practice in liquefaction
- Report completed Feb 2017
- Primary recommendation was development of public database on liquefaction case histories
- Additional recommendations related to development of improved models

# Project Elements

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- Community field **case history database**
- **Supporting studies** of critical effects poorly constrained by data
- **Model development:** team meetings, common resources, required parameter space

# Project Organization



# What is a Database?

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## Definition Used by Engineers: “*A Collection of Data*”

- Examples include experimental data archived in DesignSafe (formerly NEEShub), or ground motion records made available through various NGA projects (**typically spreadsheets**).
- This is not a database according to the data science community, who reserve the word “database” for a **relational database** (e.g., MySQL, Microsoft Access).

# Example Database

Event Name	Magnitude	Epicentral Latitude	Epicentral Longitude	Station Name	$V_{S30}$ (m/s)	$R_{jb}$ (km)	PGA (g)
Westwood Hills	6.3	34.0689	118.4452	Factor Building	380	2	0.84
Westwood Hills	6.3	34.0689	118.4452	Santa Monica Courthouse	215	14	0.28
Hollywood Valley	7.2	34.1027	118.3404	Factor Building	380	20	0.61
Hollywood Valley	7.2	34.1027	118.3404	Santa Monica Courthouse	215	30	0.32

Event



Station





Ground Motion



# Example Database Schema


## Event Table

 Event_id	Event Name	Magnitude	Epicentral Latitude	Epicentral Longitude
1	Westwood Hills	6.3	34.0689	118.4452
2	Hollywood Valley	7.2	34.1027	118.3404




 Primary Key

 Foreign Key

## Station Table

 Station_id	Station Name	$V_{S30}$ (m/s)
1	Factor Building	380
2	Santa Monica Courthouse	215

## Motion Table

 Motion_id	 Event_id	 Station_id	$R_{jb}$ (km)	PGA (g)
1	1	1	2	0.84
2	1	2	14	0.28
3	2	1	20	0.61
4	2	2	30	0.32

**Relationships set through shared fields (keys)**

**Primary key:** unique identifier for each record

**Foreign key:** field in one table that identifies a record in another table

**Benefits of relational databases:**

***Smart database (query, advanced tools)***

***Faster (it uses indexes)***

***Minimize duplicated fields***

***Avoid null fields***

# Traditional vs Next-Generation Databases

From *spreadsheet*  
(Traditional data analysis)

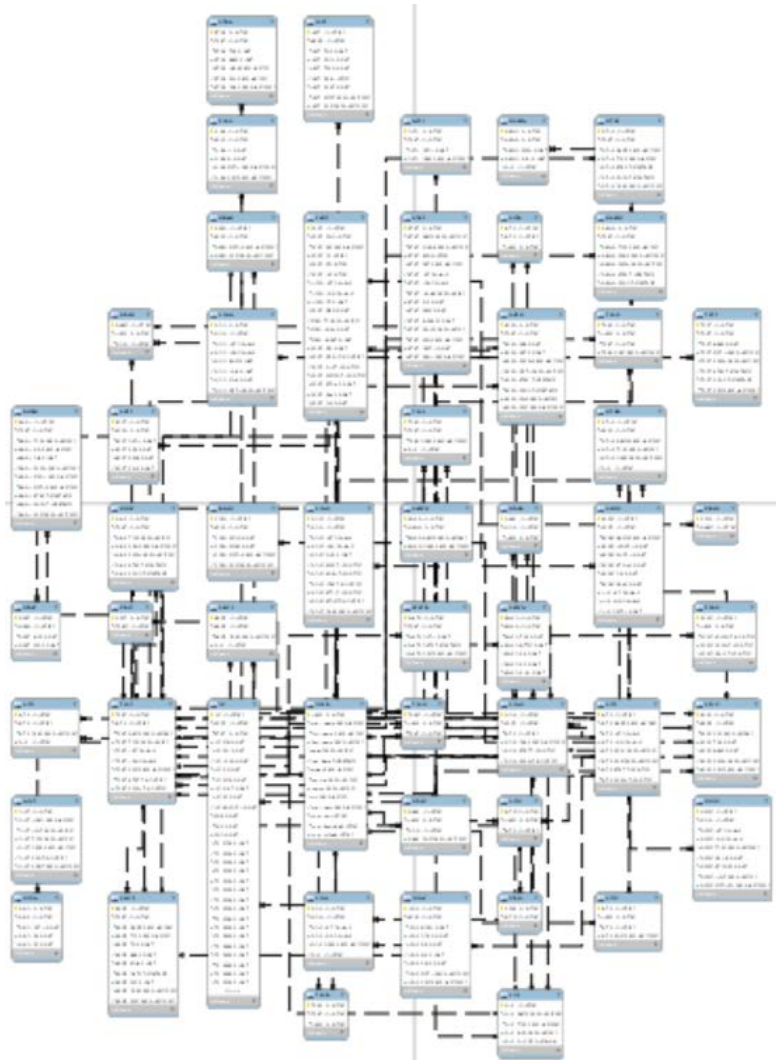


To **relational database**  
(big-data analytics)

	A	B	C	D	E	F
	Record Sequence Number	EQID	Earthquake Name	YEAR	MODY	HRMN
1	1	0001	Helena, Montana-01	1935	1031	1838
2	2	0002	Helena, Montana-02	1935	1031	1918
3	3	0003	Humbolt Bay	1937	0207	0442
4	4	0004	Imperial Valley-01	1938	0606	0242
5	5	0005	Northwest Calif-01	1938	0912	0610
6	6	0006	Imperial Valley-02	1940	0519	0437
7	7	0007	Northwest Calif-02	1941	0209	0945
8	8	0008	Northern Calif-01	1941	1003	1614
9	9	0009	Borrego	1942	1021	1622
10	10	0010	Imperial Valley-03	1951	0124	0717
11	11	0011	Northwest Calif-03	1951	1008	0411
12	12	0012	Kern County	1952	0721	1153
13	13	0012	Kern County	1952	0721	1153
14	14	0012	Kern County	1952	0721	1153
15	15	0012	Kern County	1952	0721	1153
16	16	0012	Kern County	1952	0721	1153

	HZ	IA
1	T7.500S	T8.000S
8151	0.000247	0.000231
8152	0.003331	0.003473
8153	0.000661	0.000639
8154	0.000486	0.000700
8155	0.001060	0.001011
8156	0.001217	0.001057
8157	0.000836	0.000772
8158	0.008571	0.007123
8159	0.011123	0.009935
8160	0.002338	0.001956
8161	0.134076	0.112643
8162	0.298595	0.233477
8163	0.002516	0.002555
8164	0.004065	0.005418
8165	0.004065	0.005418

# NGL Database Schema



- 53 Tables
- Linked through Primary/Foreign keys
- Use of access indexes to improve query tools and accessibility
- Four Sections:
  1. General
  2. Site
  3. Observation
  4. Event



# Benefits of the NGL Database

## Old case-histories

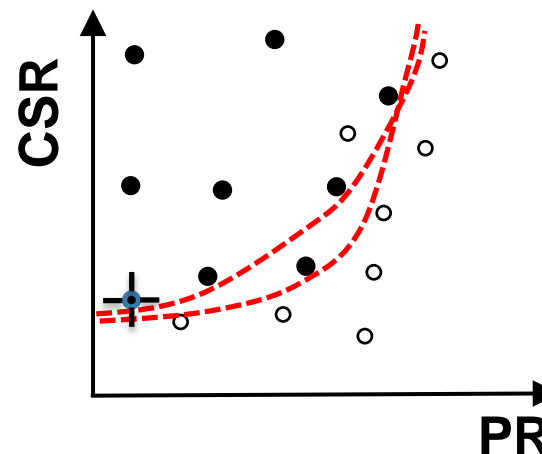
face clay silt layer. Following the 1977 earthquake, signs of liquefaction such as ejection of fine sand through the fissures or cracks were observed here and there in this area. Photo.2 shows typical sand ejection



Bucarest (1977, **M**7.2 Vrancea event)  
From Ishihara and Perlea (1984)

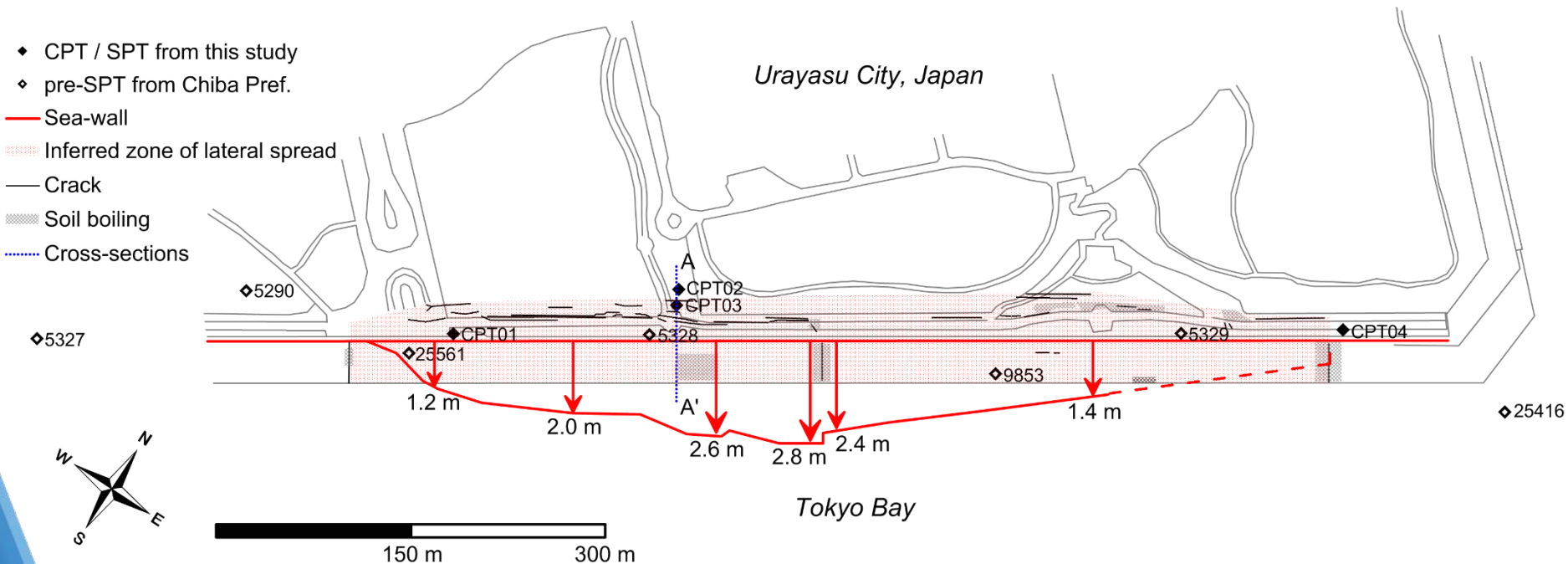
Earthquake	$M_w$
1977 Vrancea, Romania	$7.20 \pm 0.11$
Site	Liquefied?
Site 2	No

- Liquefaction
- No Ground Failure



# Benefits of the NGL Database

## Recent case-histories



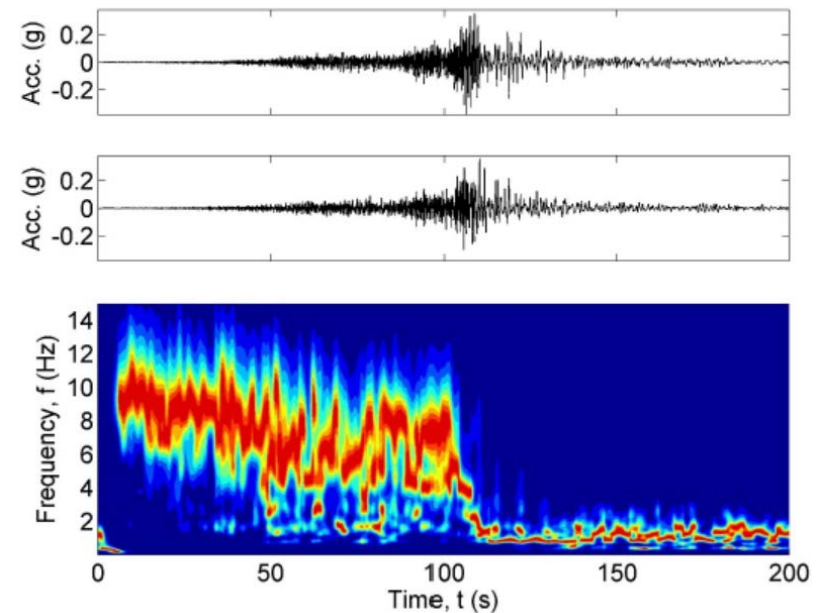
Urayasu, Japan (2011 – **M**9.0 Tohoku-Oki event)  
 From Stewart et al. (2016)

# Benefits of the NGL Database

## Recent case-histories



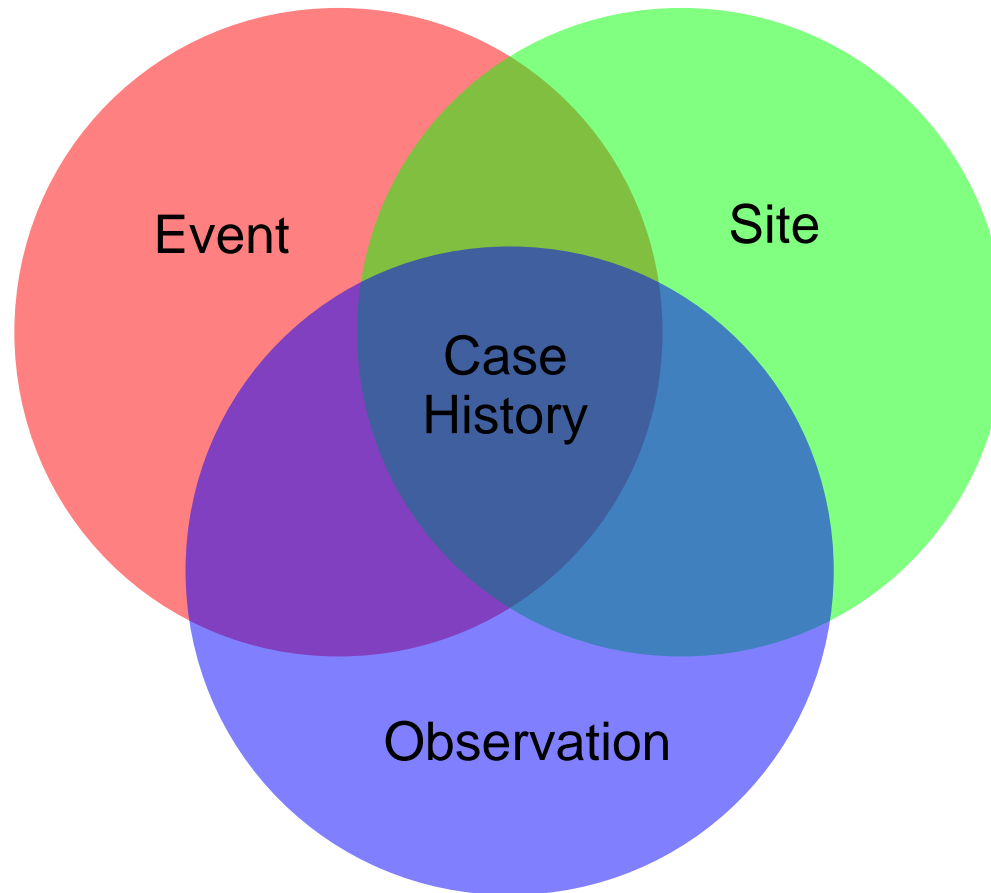
### Motion-based data



Ibaraki, Japan (2011 – **M9.0** Tohoku-Oki)  
From Kramer et al. (2016)  
and M. Greenfield pers. comm.

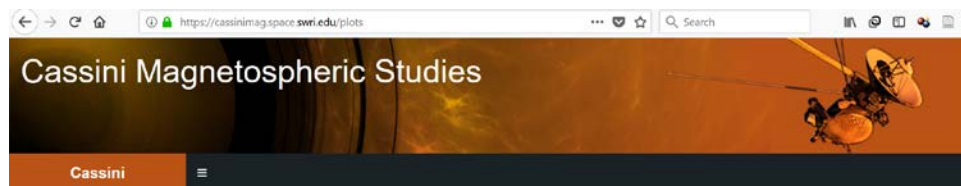
# NGL Case History Definition

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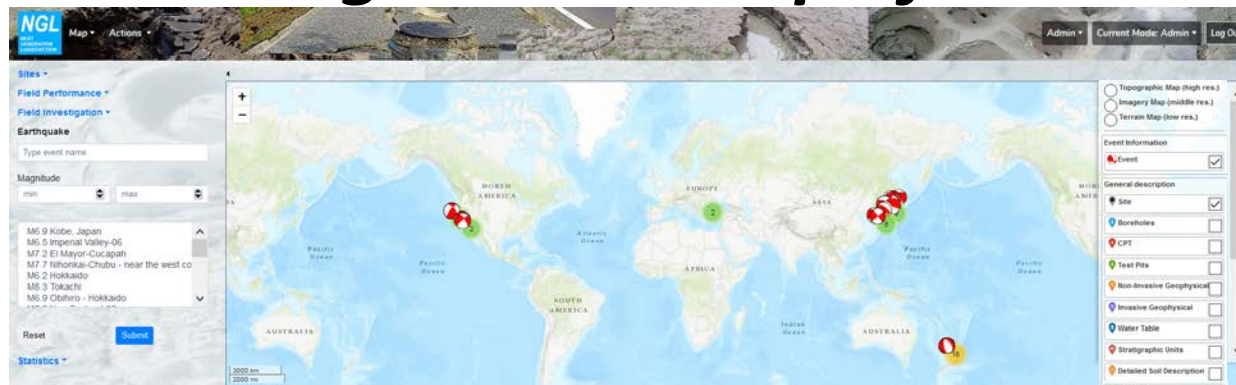
# NGL Database GUI development

*NRC-funded SwRI-UCLA collaboration*

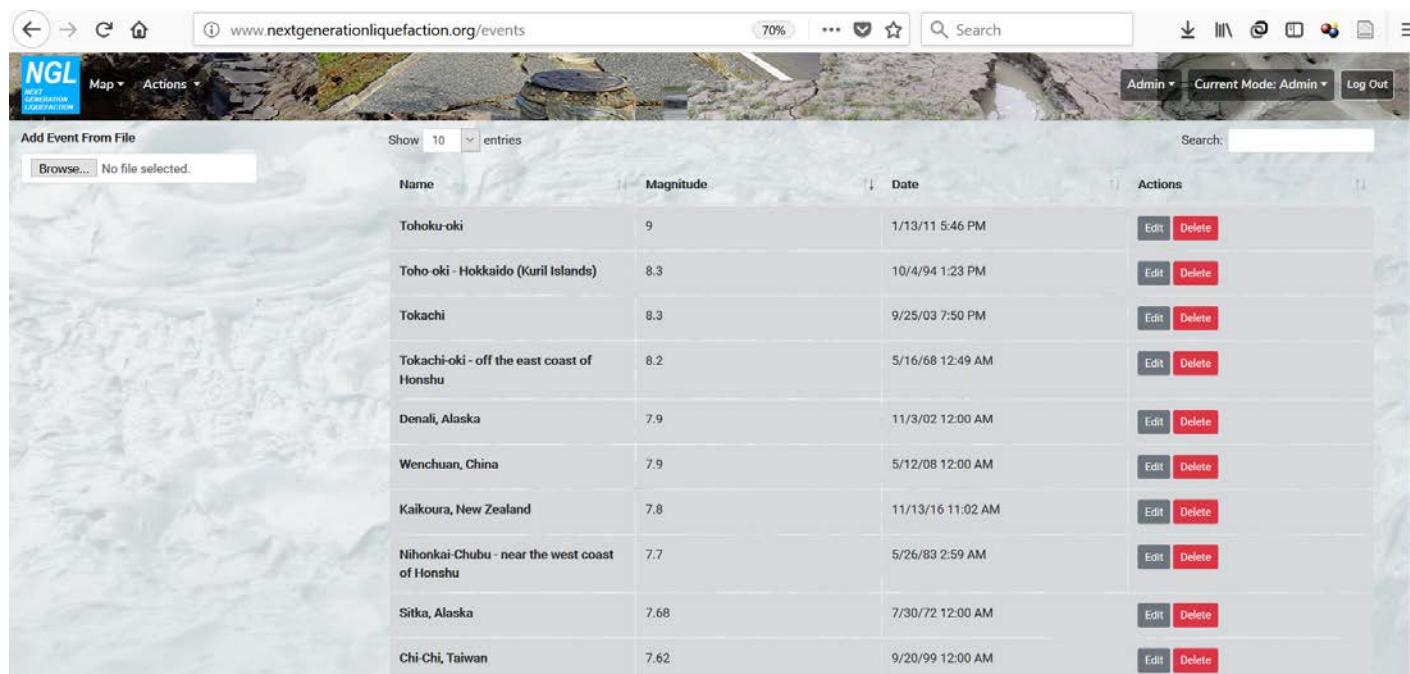


CeREs

## www.nextgenerationliquefaction.org



# NGL Database GUI Earthquake Events



Name	Magnitude	Date	Actions
Tohoku-oki	9	1/13/11 5:46 PM	Edit Delete
Toho-oki - Hokkaido (Kuril Islands)	8.3	10/4/94 1:23 PM	Edit Delete
Tokachi	8.3	9/25/03 7:50 PM	Edit Delete
Tokachi-oki - off the east coast of Honshu	8.2	5/16/68 12:49 AM	Edit Delete
Denali, Alaska	7.9	11/3/02 12:00 AM	Edit Delete
Wenchuan, China	7.9	5/12/08 12:00 AM	Edit Delete
Kaikoura, New Zealand	7.8	11/13/16 11:02 AM	Edit Delete
Nihonkai-Chubu - near the west coast of Honshu	7.7	5/26/83 2:59 AM	Edit Delete
Sitka, Alaska	7.68	7/30/72 12:00 AM	Edit Delete
Chi-Chi, Taiwan	7.62	9/20/99 12:00 AM	Edit Delete



PEER Ground Motion Database  
Pacific Earthquake Engineering Research Center

NGA West 2 Database  
NGA Subduction (soon...)

# NGL Database GUI (Map view)

[www.nextgenerationliquefaction.org](http://www.nextgenerationliquefaction.org)

The screenshot displays the NGL Database GUI in its map view. The interface is organized into several sections:

- Top Bar:** Contains the NGL logo, navigation links for 'Map' and 'Actions', and user controls for 'Admin', 'Current Mode: Admin', and 'Log Out'.
- Left Panel:**
  - Sites:** A dropdown menu.
  - Field Performance:** A dropdown menu.
  - Field Investigation:** A dropdown menu.
  - Earthquake:** A search box for 'Type event name' and a 'Magnitude' filter with 'min' and 'max' dropdowns. Below this is a list of earthquake events, including 'M6.9 Kobe, Japan', 'M6.5 Imperial Valley-06', 'M7.2 El Mayor-Cucapah', 'M7.7 Nihonkai-Chubu - near the west co', 'M6.2 Hokkaido', 'M8.3 Tokachi', and 'M6.9 Obihiro - Hokkaido'. A 'Submit' button is located below the list.
  - Statistics:** A dropdown menu.
- Map:** A world map showing several site locations marked with colored icons and numbers (e.g., 3, 13, 15, 16). The map includes a scale bar for 3000 km and 2000 mi.
- Right Panel:** A 'General description' sidebar with a list of data types and checkboxes, all of which are checked and highlighted with a red box:
  - Event
  - Site
  - Boreholes
  - CPT
  - Test Pits
  - Non-Invasive Geophysical
  - Invasive Geophysical
  - Water Table
  - Stratigraphic Units
  - Detailed Soil Description
  - Samples
  - Other



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**Site – Geotechnical characterization**

# NGL Database GUI (Map view)

[www.nextgenerationliquefaction.org](http://www.nextgenerationliquefaction.org)

The screenshot displays the NGL Database GUI in Map view. The interface includes a top navigation bar with 'Introduction', 'NGL Database GUI', 'NGL Database Current status', and 'Final remarks'. The main content area features a world map with several earthquake events marked by red and white circular icons with numbers (e.g., 2, 6, 16). A search and filter panel on the left is highlighted with a red box, showing the 'Earthquake' section with a search field, a 'Magnitude' range selector (min to max), and a list of events including 'M6.9 Kobe, Japan', 'M6.5 Imperial Valley-06', 'M7.2 El Mayor-Cucapah', 'M7.7 Nihonkai-Chubu - near the west co', 'M6.2 Hokkaido', 'M8.3 Tokachi', and 'M6.9 Obihiro - Hokkaido'. A 'Submit' button is visible below the list. On the right side, there is a 'General description' panel with a red box around the 'Event Information' section, which includes a checked 'Event' checkbox. Other checkboxes in the 'General description' panel include 'Site', 'Boreholes', 'CPT', 'Test Pits', 'Non-Invasive Geophysical', 'Invasive Geophysical', 'Water Table', 'Stratigraphic Units', 'Detailed Soil Description', 'Samples', and 'Other'. Below the map, there are logos for SwRI, PEER, Caltrans, U.S.NRC, MPC, and LT DOT. The bottom of the page features the text 'Earthquake events (that produced observations)' and the UCLA Samueli logo.

**Earthquake events (that produced observations)**



# NGL Database GUI (Map view)

[www.nextgenerationliquefaction.org](http://www.nextgenerationliquefaction.org)



# Database Current Status

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Legacy case-histories (used in the past for model development) include:

- 1964 Niigata (Japan)
- 1979 Imperial Valley
- 1987 Superstition Hills
- 1989 Loma Prieta
- 1995 Kobe (Japan)
- 1999 Chi Chi (Taiwan)
- 1999 Kocaeli (Turkey)
- U. Utah + BYU lateral spread sites
- Etc...

***Total ~300 case histories (work in progress...)***

# Database Current Status

- Christchurch (New Zealand) 2010-2011 sequence:

Green et al. (2014) case histories (VTech Green and Ulmer)

Tonkin + Taylor case histories (Van Ballegooy and Liu)

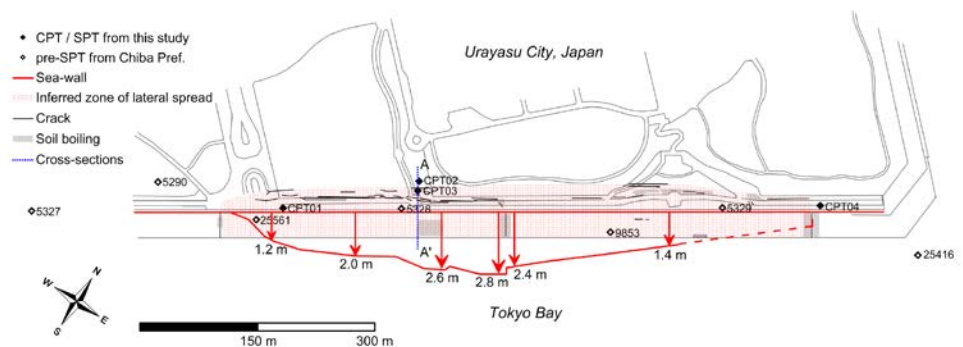
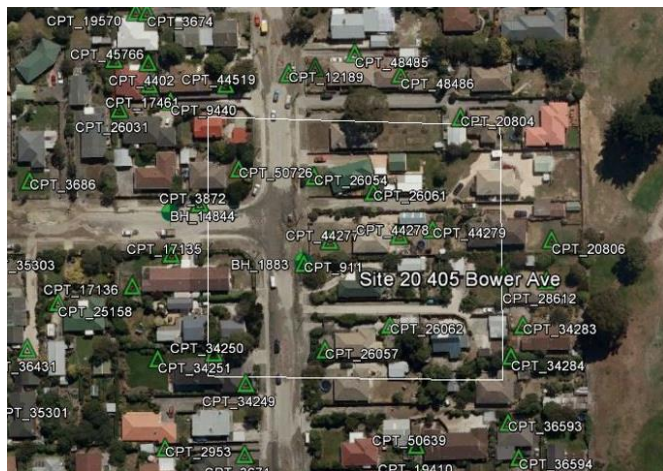
UC Berkeley sites (Bray and Beyzaei)

- Tohoku (Japan) 2011 **M**9.0 event – Unpublished

Tohoku + Mihama - UCLA

Instrumented levee arrays - UCLA

Additional lateral spread sites – UCLA-BYU



# Database Current Status

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Case histories with relatively small magnitude (data collection)

- Emilia (Italy), 2012 **M**5.8 earthquake – UCLA
- Au Sable Forks, NY 2002 **M**5.0 earthquake – Gingery (2003)
- Pawnee, OK, 2016 **M**5.8 earthquake – Clayton et al. (2016)
- Olancho, CA, 2009 **M**5.2 earthquake – Holzer et al. (2010)
- Others...



# Review/Vetting Process

**Database working group** (Brandenberg (chair), Cetin, Moss, Franke, Kwak, Zimmaro)

Purpose: to verify that required fields are present and the inputs match source materials.

The screenshot shows the 'Review' interface for an event in the NGL Database. The interface includes a sidebar with navigation options, a central map, and a right sidebar with map controls and a checklist. Below the map is a form for event details and a table of associated ground motion intensity measures.

**Event Information:**

- Event:
- Observation (Note):
- Observation (File):

**General description:**

- Site:
- Boreholes:
- CPT:
- Test Pits:
- Non-invasive Geophysical:
- Invasive Geophysical:
- Water Table:
- Stratigraphic Units:

**Event Details:**

Observation: No liquefaction, however adjacent to liquefied region BDY001.

Event: New Zealand-C

Approve?  No

Comments:

**Associated Files:**

Liquefaction Manifestations

Ground Motion Intensity Measures

Show 10 entries

Latitude (deg)	Longitude (deg)	Type of Intensity Measure	Value of Intensity Measure	Standard Deviation	Units of Intensity Measure	Method of Getting Intensity Measure
-37.918889	176.843934	PGA	0.4	0.1	g	estimated by Zhao et al

Previous 1 Next

Confirm

# Vision for Community Access

## *(to cloud or not to cloud?)*

- Due to **large amount of data**, downloading data and processing them on a laptop is inefficient and undesirable (though still possible).
- The database is mirrored onto **DesignSafe** ([www.designsafe-ci.org](http://www.designsafe-ci.org)). Users will be able to process data on the cloud using SQL queries in Jupyter notebook Python scripts (*off-the-shelf* libraries).



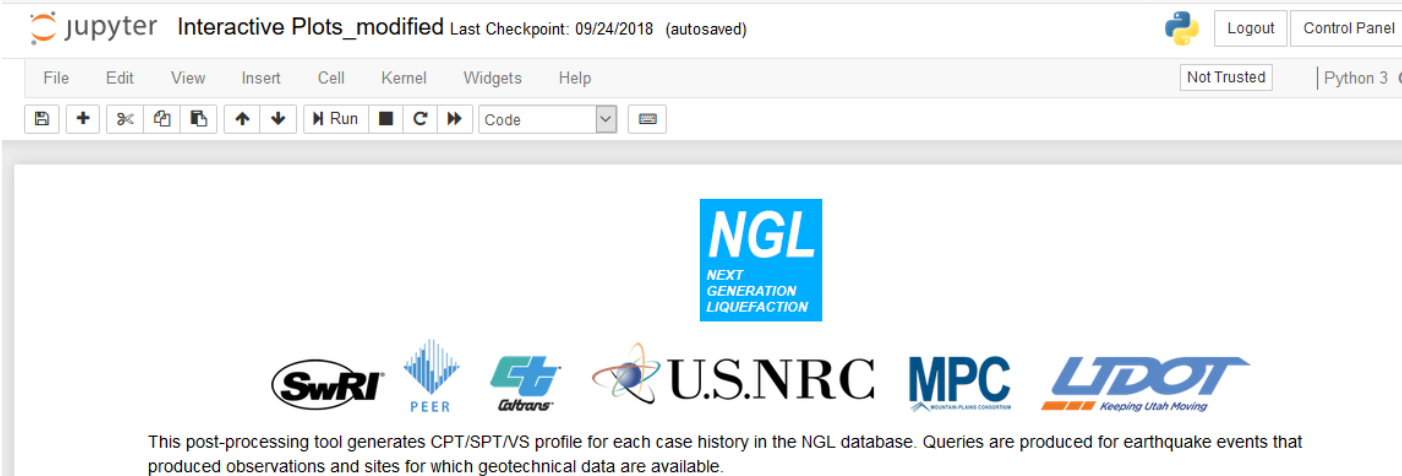
A screenshot of the DesignSafe-CI web interface. The header includes the "DESIGNSAFE-CI" logo and the text "NHRI: A NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE". A navigation menu contains "Research Workbench", "Learning Center", "NHRI Facilities", "NHRI Community", "About", and "Help". A search bar is on the right. Below the menu is a toolbar with icons for "Tag", "Rename", "Move", "Copy", "Preview", "Preview Images", "Download", "Share", and "Move to Trash". A "Projects" section is visible, showing a project titled "PRJ-2032: NEXT-GENERATION LIQUEFACTION (NGL) CASE HISTORY DATABASE". A "Welcome, Paolo!" message is in the top right corner.

# Vision for Community Access (to cloud or not to cloud?)

jupyter Interactive Plots\_modified Last Checkpoint: 09/24/2018 (autosaved) Logout Control Panel

File Edit View Insert Cell Kernel Widgets Help Not Trusted | Python 3

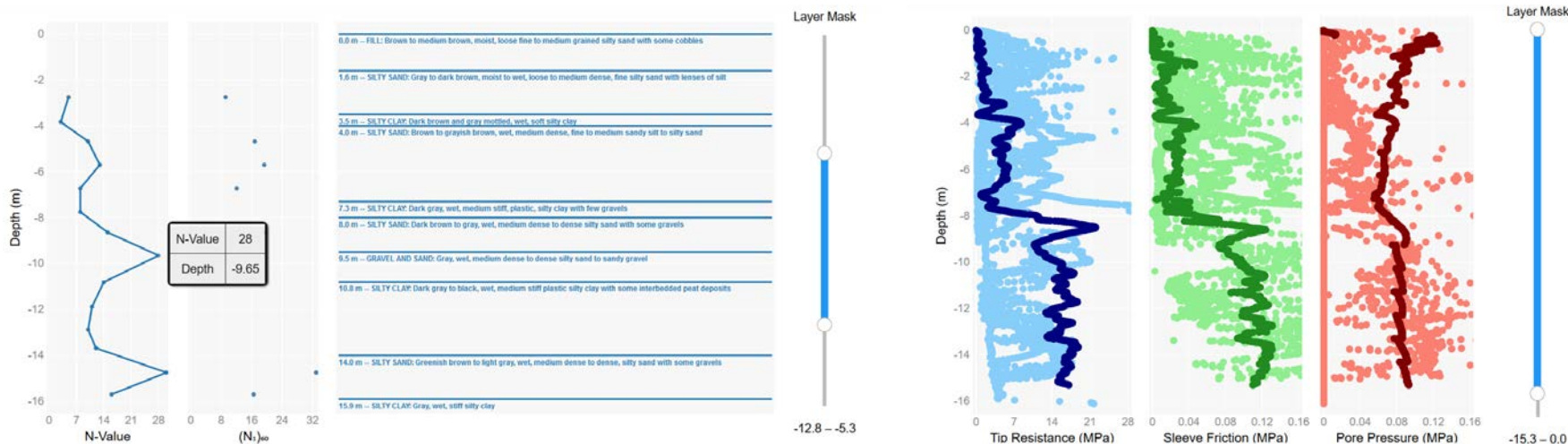
Code



**NGL**  
NEXT  
GENERATION  
LIQUEFACTION

**SwRI** **PEER** **Caltrans** **U.S. NRC** **MPC** **LTDOT**  
Keeping Utah Moving

This post-processing tool generates CPT/SPT/VS profile for each case history in the NGL database. Queries are produced for earthquake events that produced observations and sites for which geotechnical data are available.



# Final Remarks

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- The NGL relational database (being populated): capabilities for big data analytics and incorporation of uncertainty
- Vetted database (NGL working group)
- NGL-NGA interaction – earthquake events
- The NGL database is mirrored onto DesignSafe – Cloud-based analytics



# Thank you!

## Questions?

## Relevant References

- Brandenberg S.J., Kwak D.Y., Zimmaro P., Bozorgnia Y., Kramer S.L., Stewart J.P. (2018). Next-Generation Liquefaction (NGL) Case History Database Structure. Fifth decennial Geotechnical Earthquake Engineering and Soil Dynamics Conference, Earthquake Engineering and Soil Dynamics Committee of the Geo-Institute. Austin, TX (USA), June 10-13.
- Zimmaro P., Kwak D.Y., Brandenberg S.J., Stewart J.P. (2018). NGL: An Open Source Global Database for Next-Generation of Liquefaction Assessment. SSA-LACSC scientific conference - Seismology of the Americas. Miami, FL (USA), May 14-17.
- Stewart J.P., Kramer S.L., Kwak D.Y., Greenfield M.W., Kayen R.E., Tokimatsu K., Bray J.D., Beyzaei C.Z., Cubrinovski M., Sekiguchi T., Nakai S., Bozorgnia Y. (2016). PEER-NGL project: Open source global database and model development for the next-generation of liquefaction assessment procedures. Soil Dyn. Earthquake Eng., 91, 317–328.



Project homepage:

<https://uclageo.com/NGL/>

Database:

<http://nextgenerationliquefaction.org>

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