

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

Introduction and NGL project overview

The NGL database graphical interface

Current status of the database

Final remarks and path forward

NGL Database Contributors

- **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

- ***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 Overview

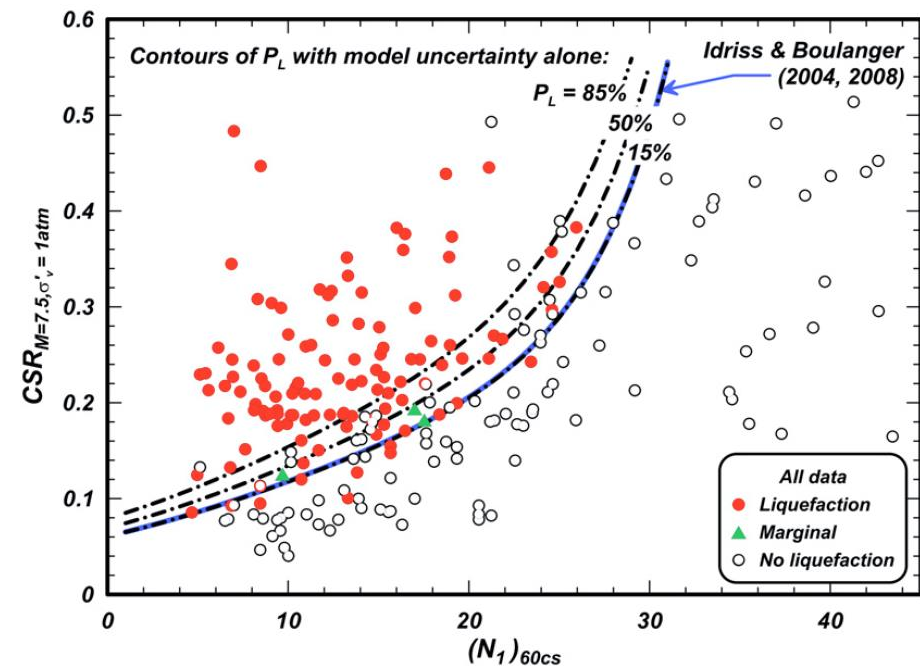
What motivated the formation of NGL?

Project elements

Organization

Project Need

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



Boulanger and Idriss, 2012

Project Need

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

Small data sets – a few sites are especially consequential

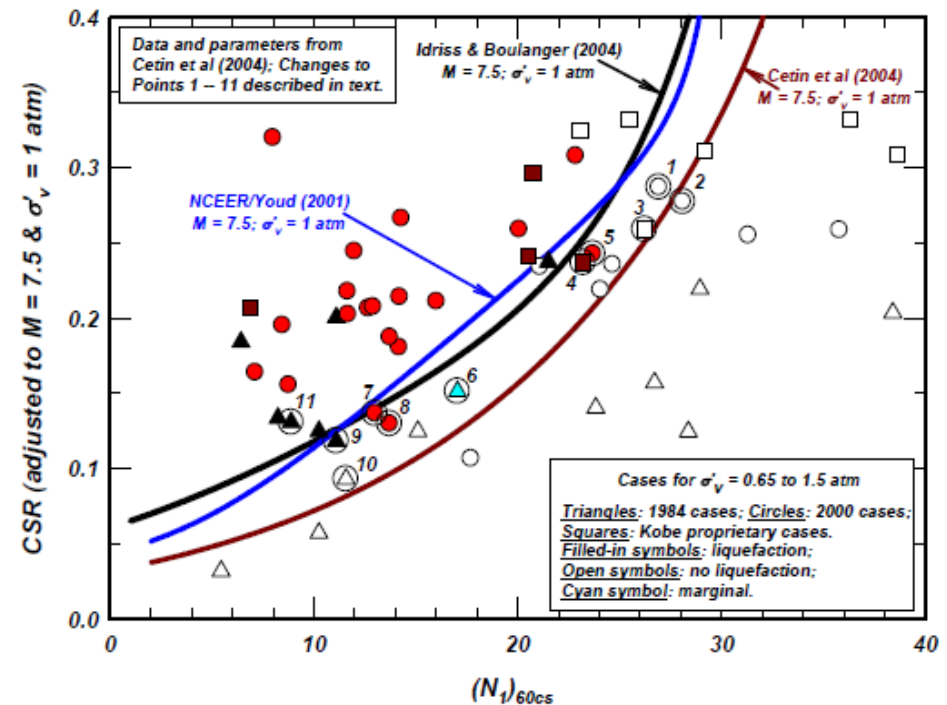


Figure: Idriss and Boulanger, 2010

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

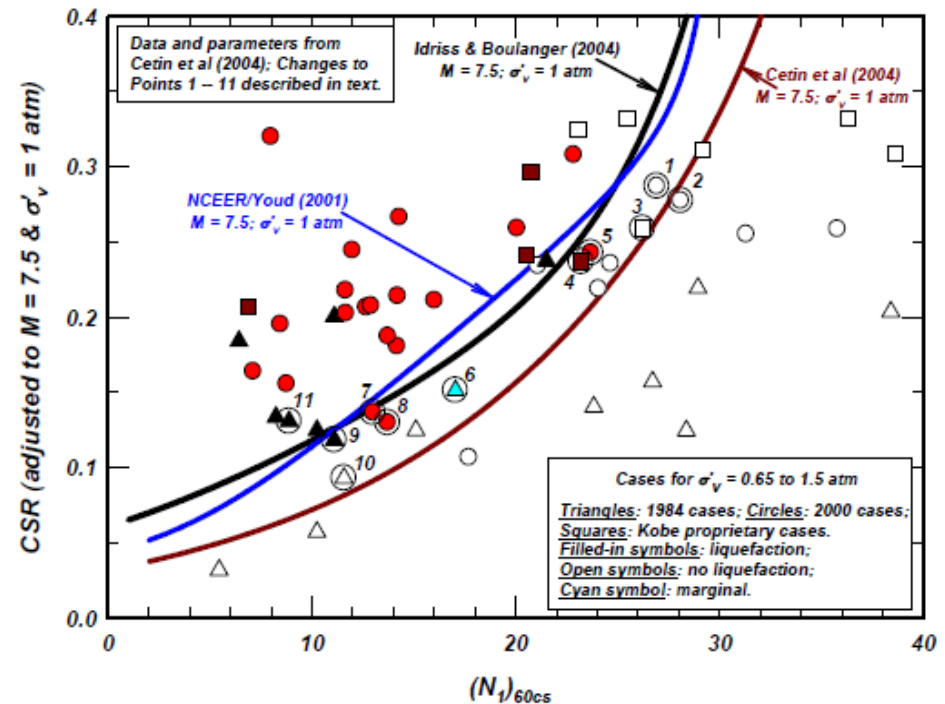


Figure: Idriss and Boulanger, 2010

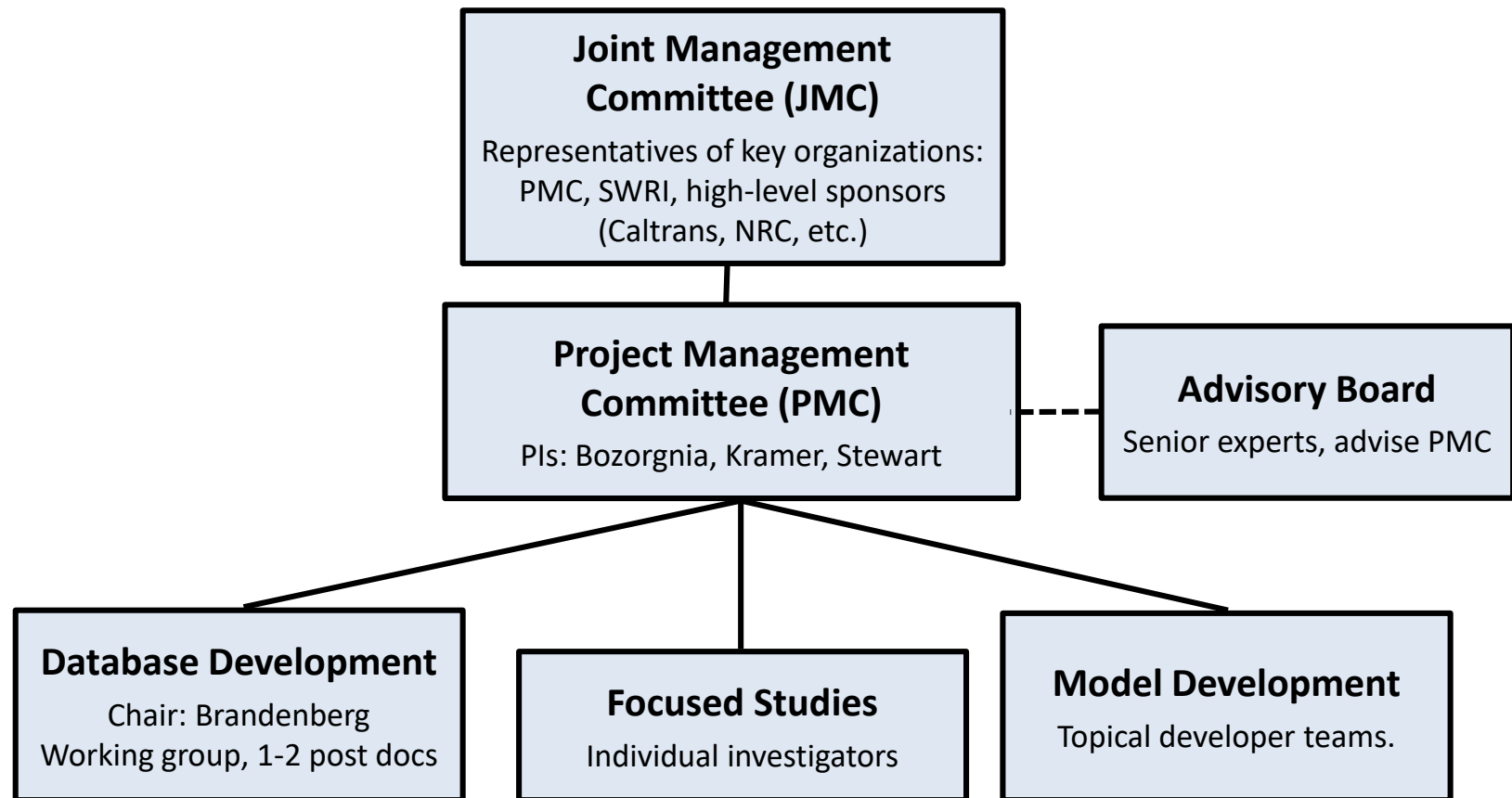
NRC Liquefaction Committee

- 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

- 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?

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	Epicaltral Latitude	Epicaltral 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

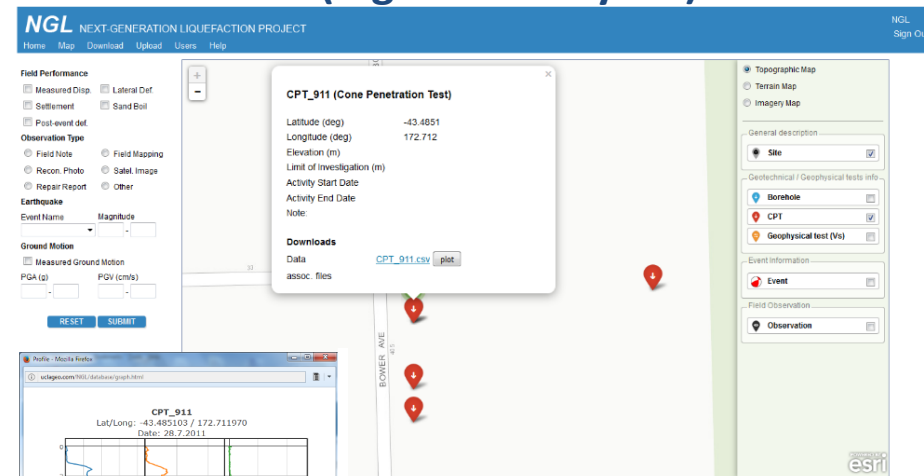
From *spreadsheet*
(Traditional data analysis)



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

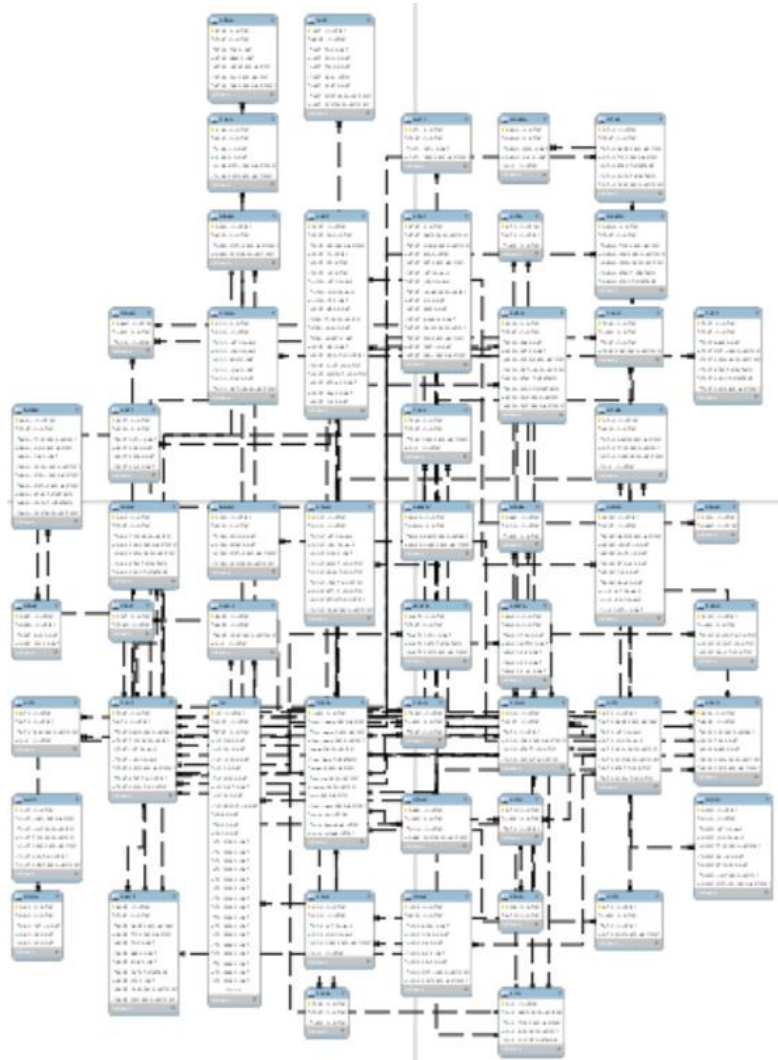
	A	B	C	D	E	F
	Record Sequence Number	EQID	Earthquake Name	YEAR	MODY	HRMN
2	1	0001	Helena, Montana-01	1935	1031	1838
3	2	0002	Helena, Montana-02	1935	1031	1918
4	3	0003	Humbolt Bay	1937	0207	0442
5	4	0004	Imperial Valley-01	1938	0606	0242
6	5	0005	Northwest Calif-01	1938	0912	0610
7	6	0006	Imperial Valley-02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



Next-Generation Liquefaction Database, Zimmaro et al. (2018a, SSA),
Brandenberg et al. (2018b, GEESD) **UCLA** Samuelli

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

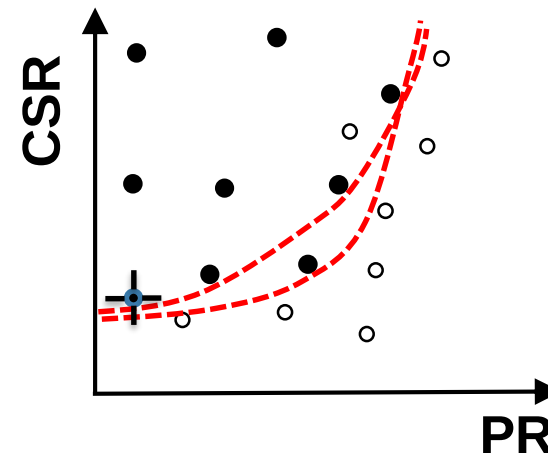
face clay silt layer. Following the 1977 earthquake, signs of liquefaction such as ejection of fine sand through the fissures or cracks were observed here and there in this area. Photo.2 shows typical sand ejection



Bucarest (1977, M7.2 Vrancea event)
From Ishihara and Perlea (1984)

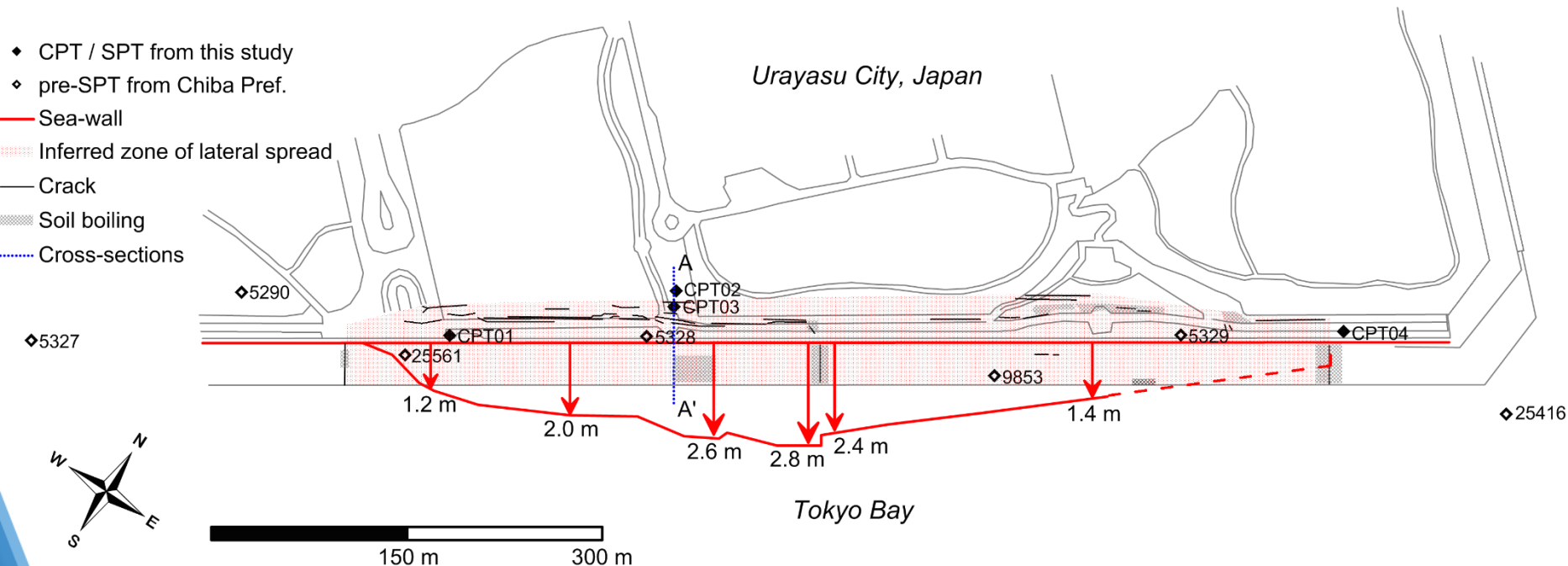
Earthquake	M _w
1977 Vrancea, Romania	7.20±0.11
Site	Liquefied?
Site 2	No

- Liquefaction
- No Ground Failure



Benefits of the NGL Database

Recent case-histories



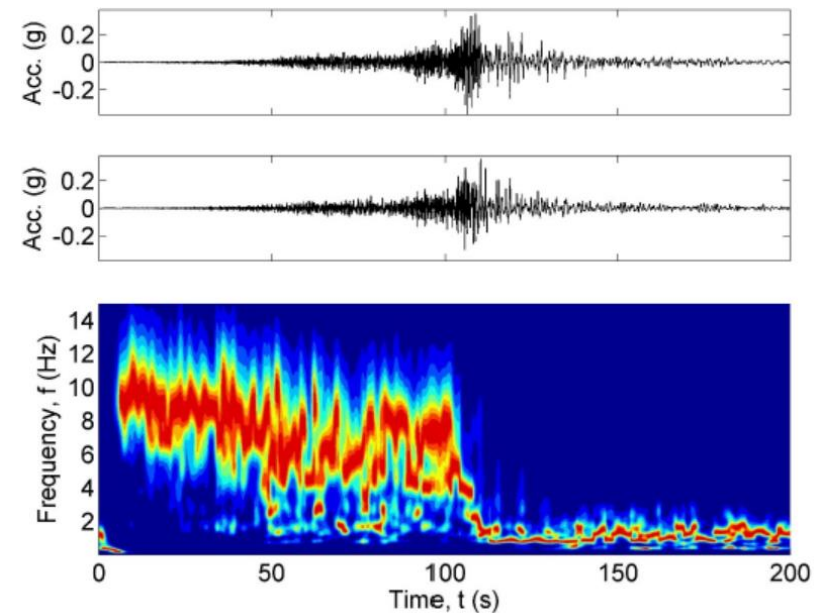
Urayasu, Japan (2011 – M9.0 Tohoku-Oki event)
From Stewart et al. (2016)

Benefits of the NGL Database

Recent case-histories

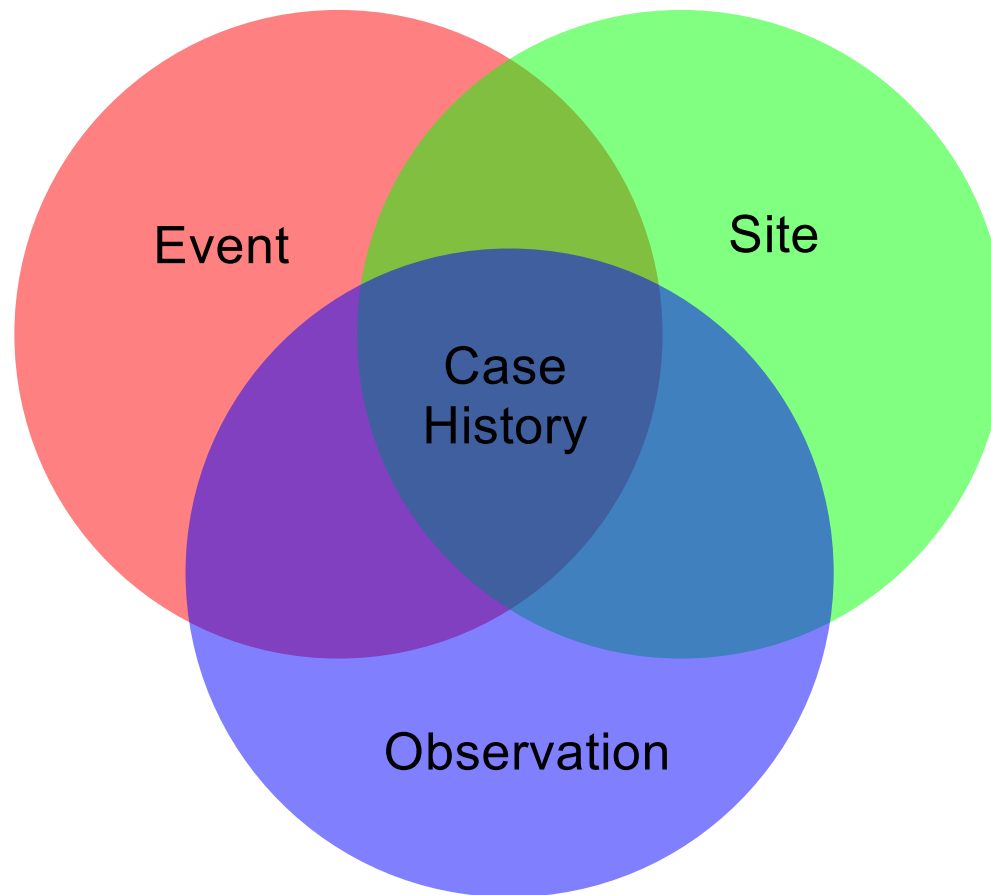


Motion-based data



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

NGL Case History Definition



NGL Database GUI development

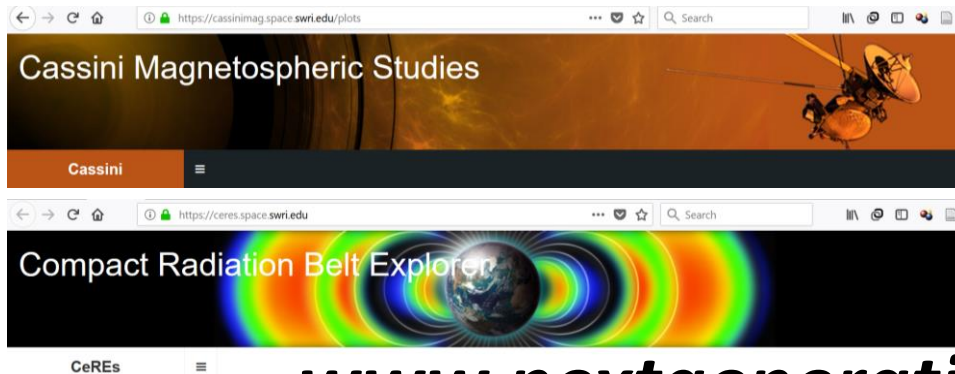
NRC-funded SwRI-UCLA collaboration



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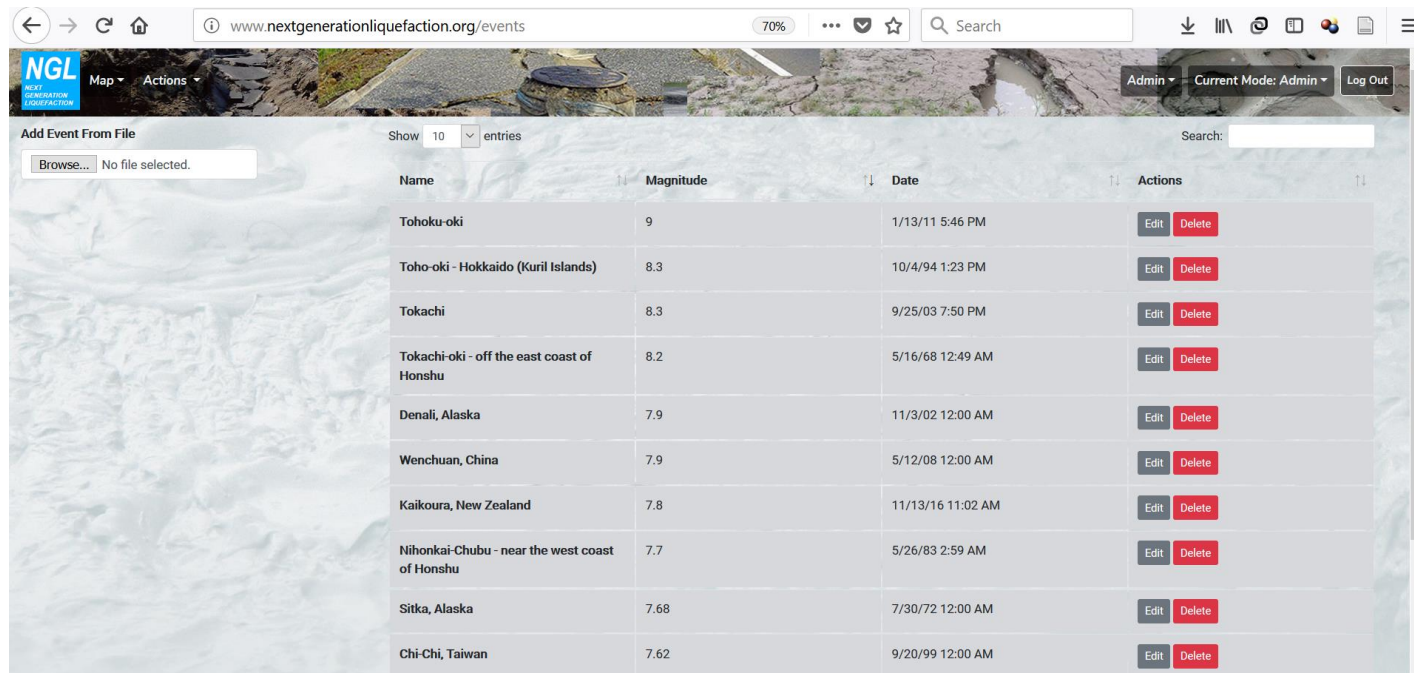
www.nextgenerationliquefaction.org



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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)

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NGL
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Map Actions

Admin Current Mode: Admin Log Out

Sites

Field Performance

Field Investigation

Earthquake

Type event name

Magnitude

min max

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
M6.9 Obihiro - Hokkaido
M6.9 N. Sumatra-Andaman

Reset Submit

Statistics

Event

General description

Site

Boreholes

CPT

Test Pits

Non-Invasive Geophysical

Invasive Geophysical

Water Table

Stratigraphic Units

Detailed Soil Description

Samples

Other

3000 km
2000 mi

SwRI PEER Caltrans U.S.NRC MPC LT DOT

Site – Geotechnical characterization

NGL Database GUI (Map view)

www.nextgenerationliquefaction.org

The screenshot displays the NGL Database GUI in Map view. The interface includes a top navigation bar with links for Introduction, NGL Database GUI, NGL Database Current status, and Final remarks. The main content area features a world map with several earthquake event markers (red and white spheres) plotted across the Pacific Ocean, North America, and Asia. On the left side, there is a sidebar with navigation links: Sites, Field Performance, Field Investigation, and Earthquake. The Earthquake section is currently selected, showing a search form with a text input for 'Type event name', a 'Magnitude' filter with 'min' and 'max' dropdowns, and a list of recent 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. On the right side, there is a panel for 'Event Information' and 'General description'. The 'Event Information' section has a radio button for 'Event' which is checked. The 'General description' section includes checkboxes for various observation types: 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

The screenshot displays the NGL Database GUI in Map view. The interface is divided into several sections:

- Header:** Includes the NGL logo and navigation links: Map, Actions, Admin, Current Mode: Admin, and Log Out.
- Left Sidebar:** Contains filters for Sites, Field Performance, Field Investigation, and Earthquake. The Earthquake filter is active, showing a list of events with their magnitudes and locations (e.g., M6.9 Kobe, Japan; M6.5 Imperial Valley-06; M7.2 El Mayor-Cucapah; M7.7 Nihonkai-Chubu - near the west coast; M6.2 Hokkaido; M8.3 Tokachi; M6.9 Obihiro - Hokkaido).
- Main Map:** A world map showing the distribution of earthquakes. Markers are placed on the map, with numbers indicating the count of events in specific regions (e.g., 11, 6, 27, 8).
- Right Sidebar:** A list of data types with checkboxes for selection. The 'Field Performance' section is highlighted, showing 'Observation (Note)' and 'Observation (File)' both checked.



Post-earthquake observations

Database Current Status

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

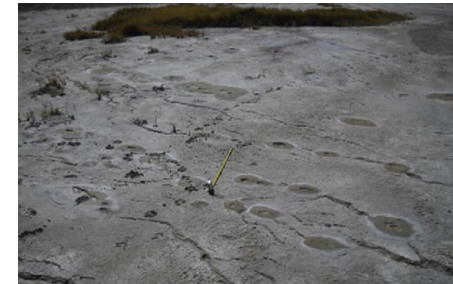
- 1964 Niigata (Japan)
- 1979 Imperial Valley
- 1987 Superstition Hills
- 1989 Loma Prieta
- 1995 Kobe (Japan)
- 1999 Chi Chi (Taiwan)
- 1999 Kocaeli (Turkey)
- U. Utah + BYU lateral spread sites
- Etc...

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

Database Current Status

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.

Review

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
-37.918809	176.843934	PGA	0.4	0.1	g	estimated by Zhao et al.

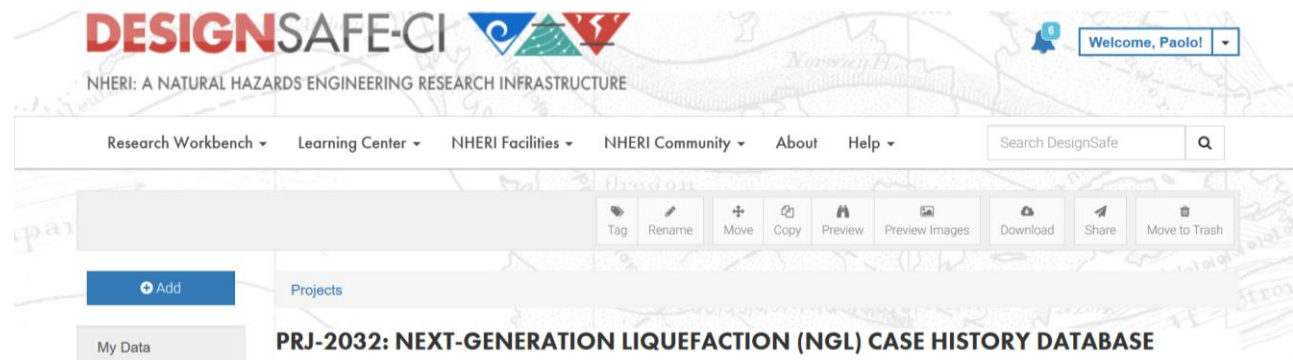
Previous 1 Next

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). Users will be able to process data on the cloud using SQL queries in Jupyter notebook Python scripts (*off-the-shelf* libraries).



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

jupyter Interactive Plots_modified Last Checkpoint: 09/24/2018 (autosaved)

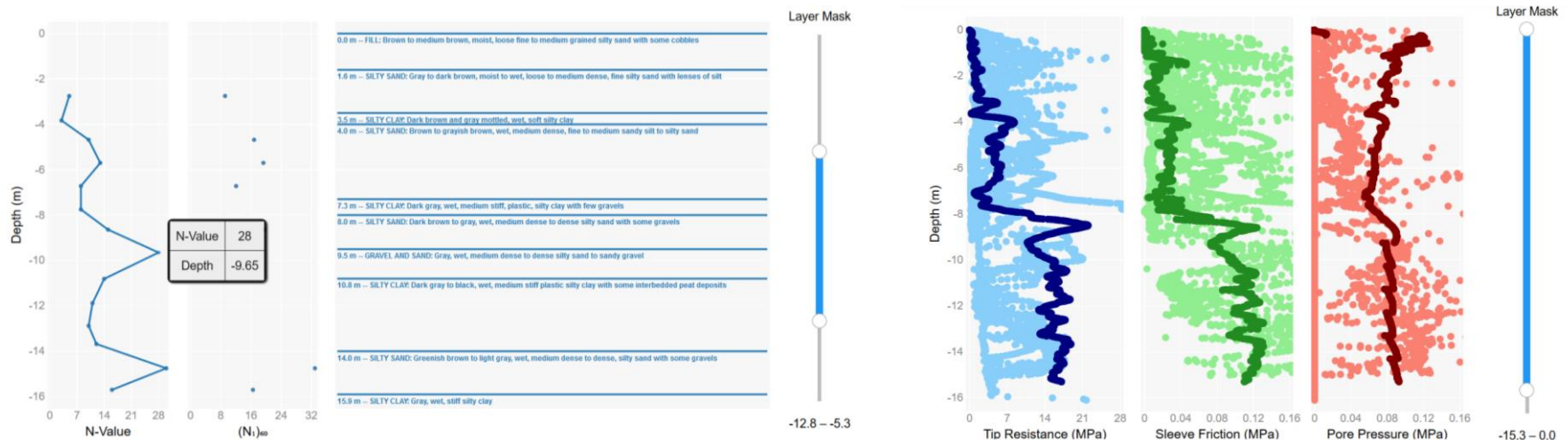
File Edit View Insert Cell Kernel Widgets Help Not Trusted Python 3

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

- 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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