DOE/NRC Natural Phenomena Hazards Meeting

October 24, 2018, US NRC Headquarters, Rockville

UCLA Samueli School of Engineering

Next Generation Liquefaction Case History Database

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October 24, 2018

NGL NEXT GENERATION LIQUEFACTION

Engineer Change.

Outline

Introduction and NGL project vision

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

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, …

NGL Project Vision

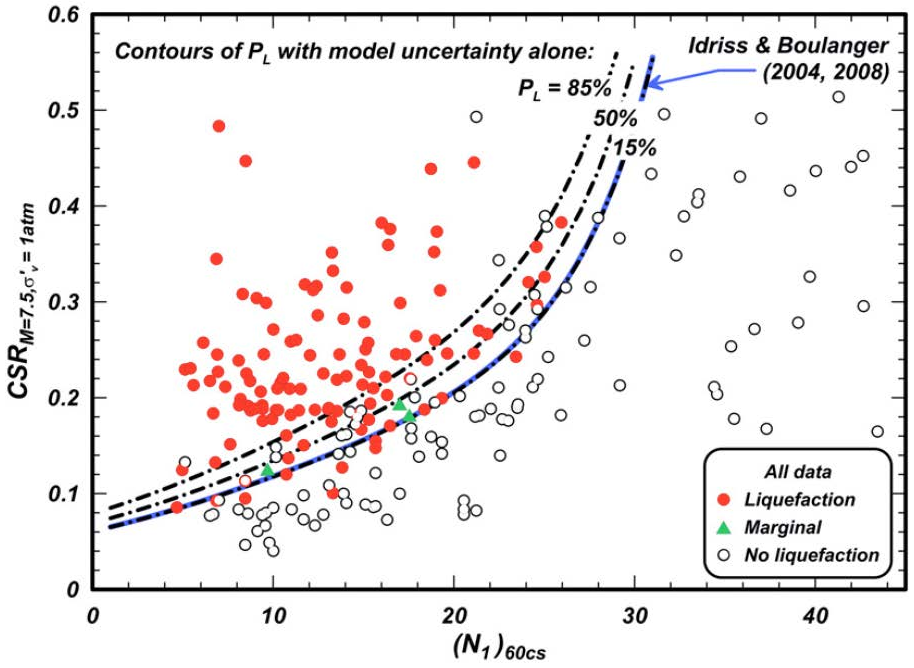
What motivated the formation of NGL?

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

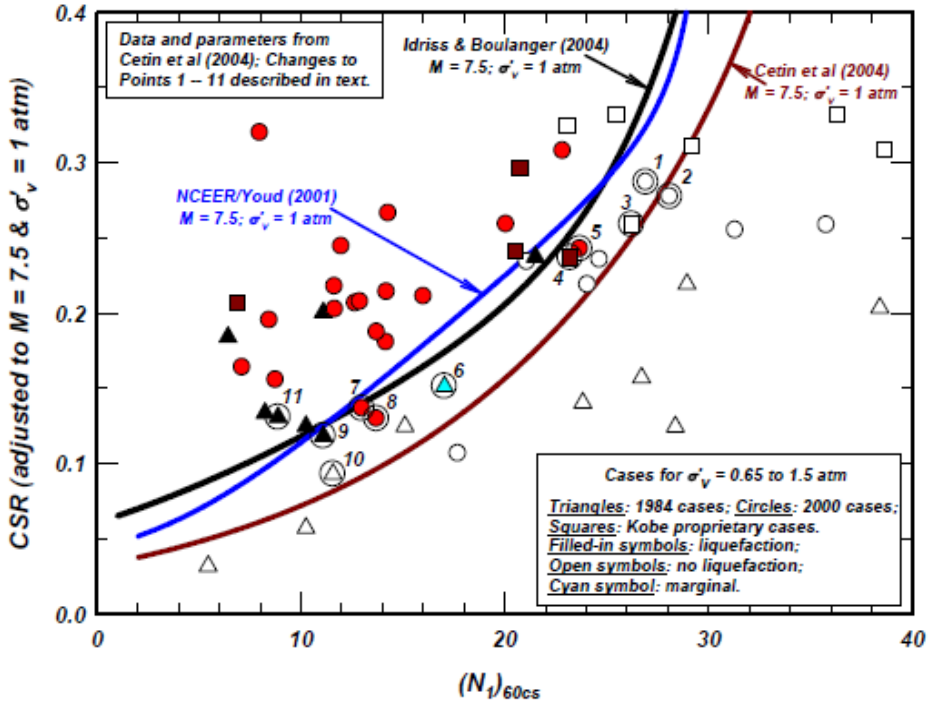


Figure: Idriss and Boulanger, 2010

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

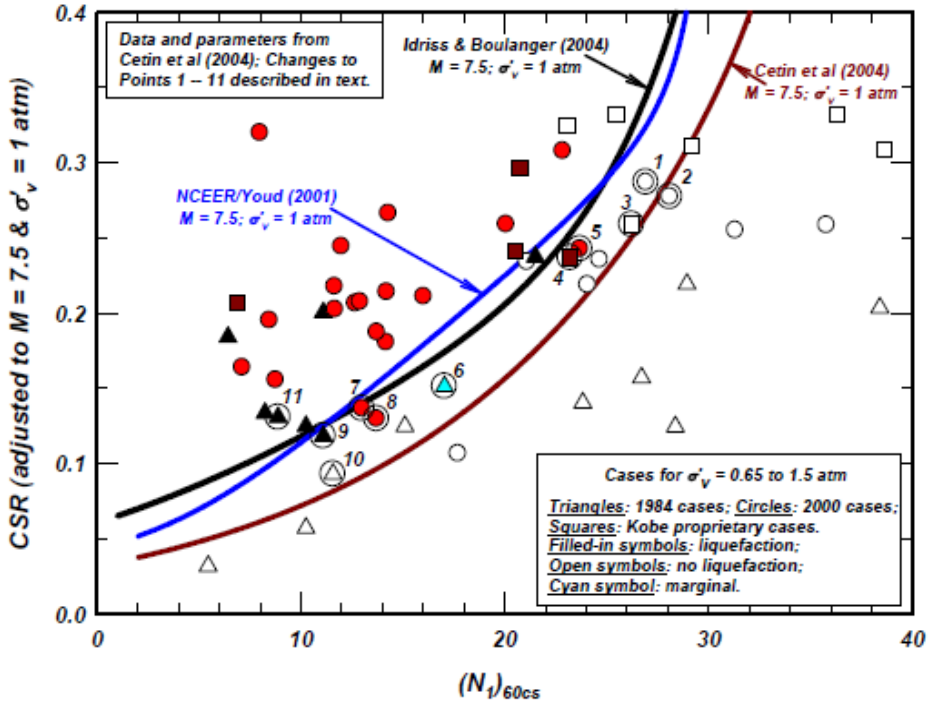


Figure: Idriss and Boulanger, 2010

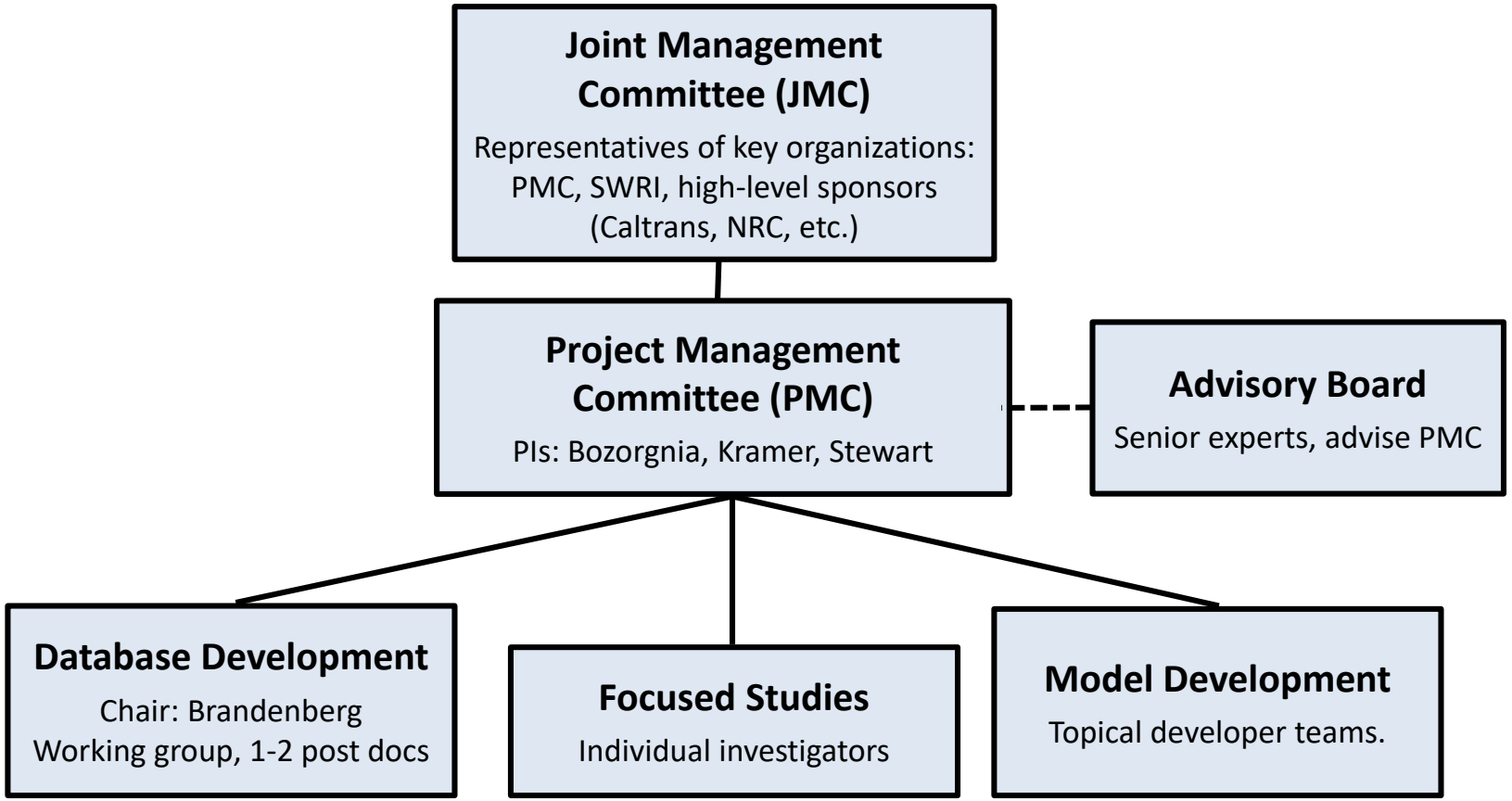
NRC Liquefaction Committee

- 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	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)

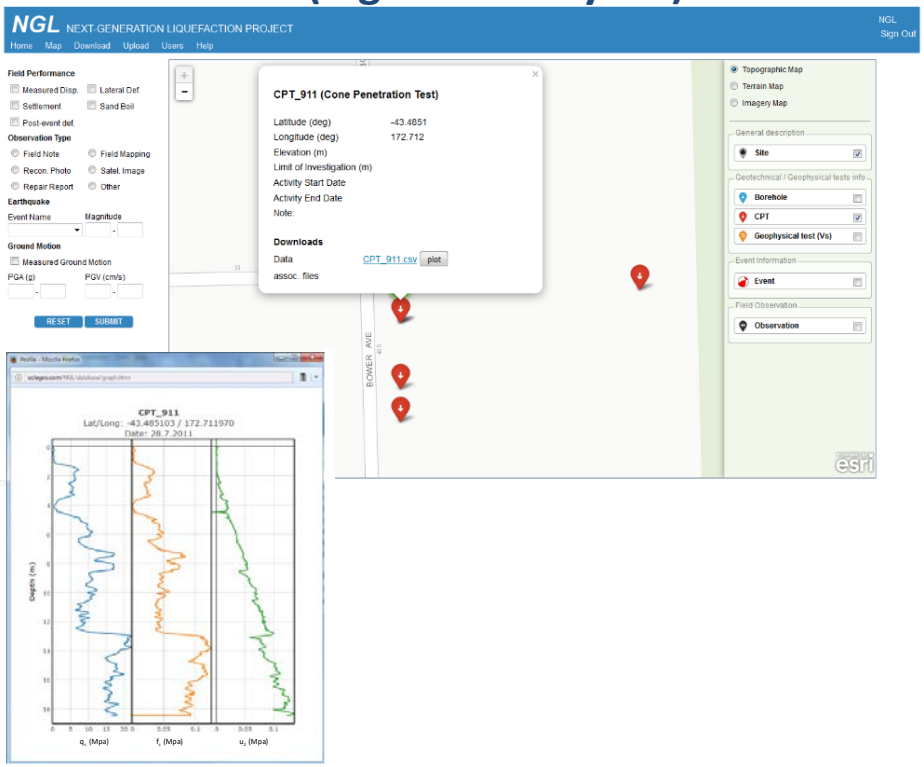
	A	B	C	D	E	F
1	Record Sequence Number	EQID	Earthquake Name	YEAR	MODY	HRMN
2	1	0001	Helena, Montana-01	1935	1031	1838
3	2	0002	Helena, Montana-02	1935	1031	1918
4	3	0003	Humbolt Bay	1937	0207	0442
5	4	0004	Imperial Valley-01	1938	0606	0242
6	5	0005	Northwest Calif-01	1938	0912	0610
7	6	0006	Imperial Valley-02	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

PSA_H2_d005 | Sa_H2_d005

	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

PSA_H2_d005 | Sa_H2_

To relational database
(big-data analytics)



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

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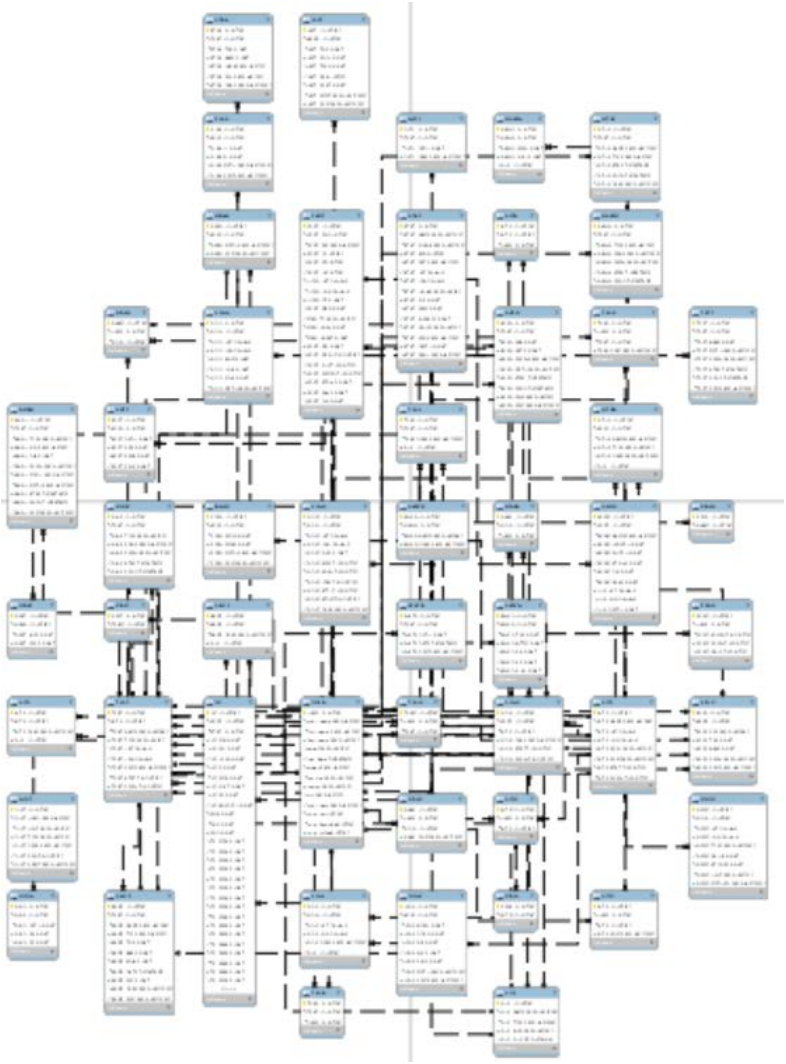
NGL Database Schema

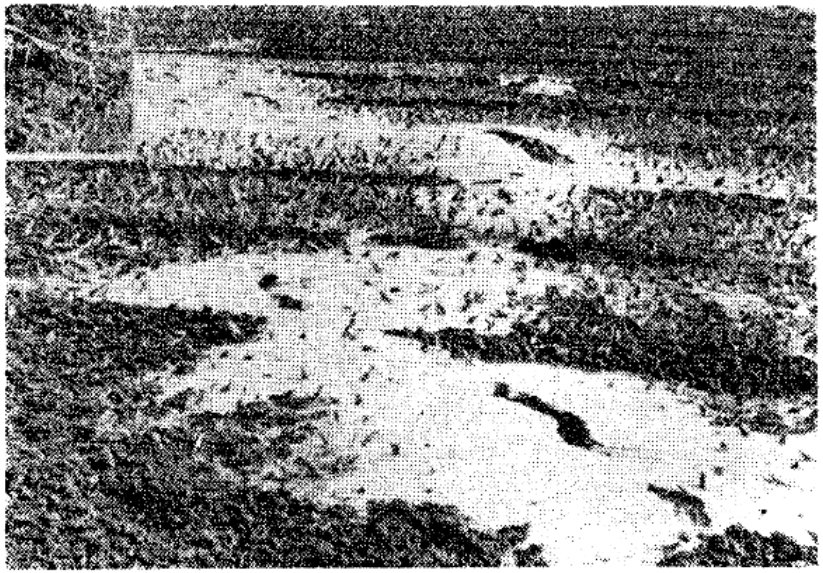


- 53 Tables
- Linked through Primary/Foreign keys
- Use of access indexes to improve query tools and accessibility
- Four Sections:
  1. General
  2. Site
  3. Observation
  4. Event

Benefits of the NGL Database

Old case-histories

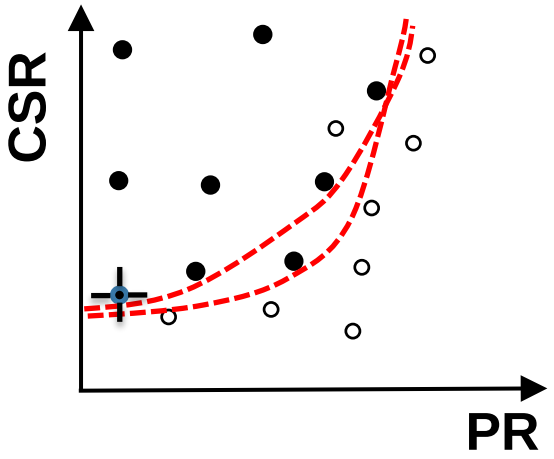
face clay silt layer. Following the 1977 earthquake, signs of liquefaction such as ejection of fine sand through the fissures or cracks were observed here and there in this area. Photo. 2 shows typical sand ejection



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

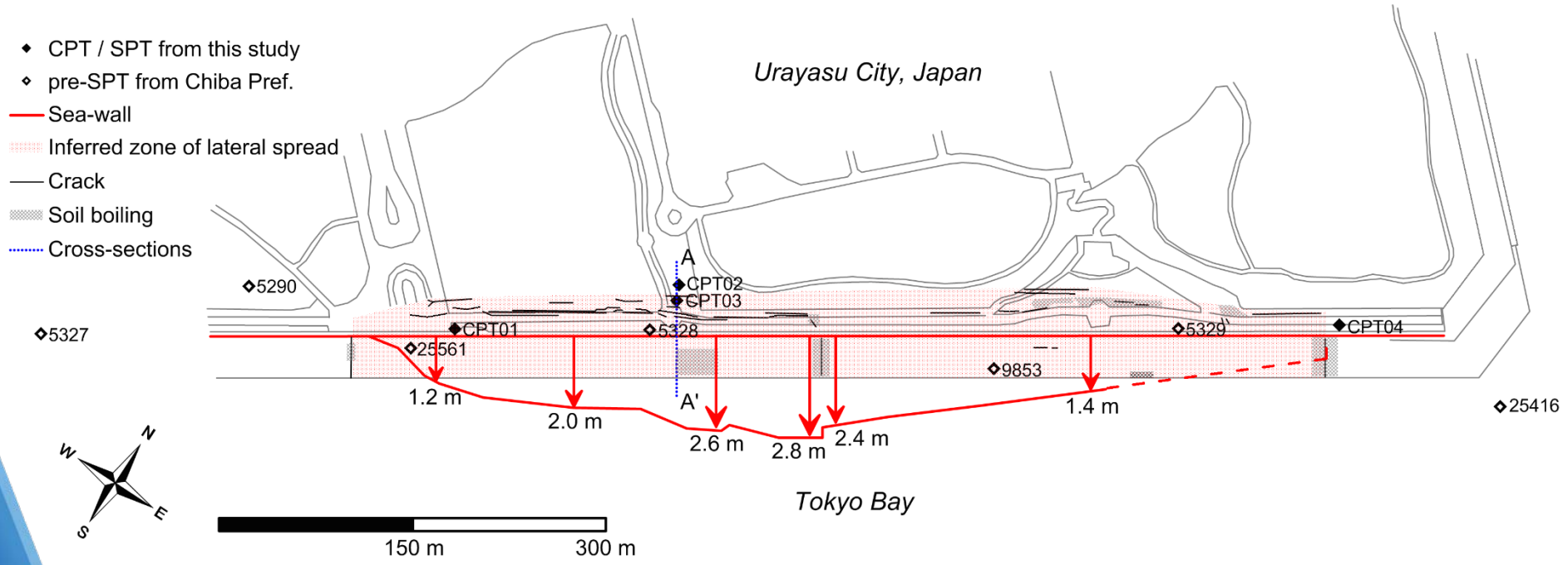
Earthquake	M_w
1977 Vrancea, Romania	7.20±0.11
Site	Liquefied?
Site 2	No

- Liquefaction
- No Ground Failure



Benefits of the NGL Database

Recent case-histories

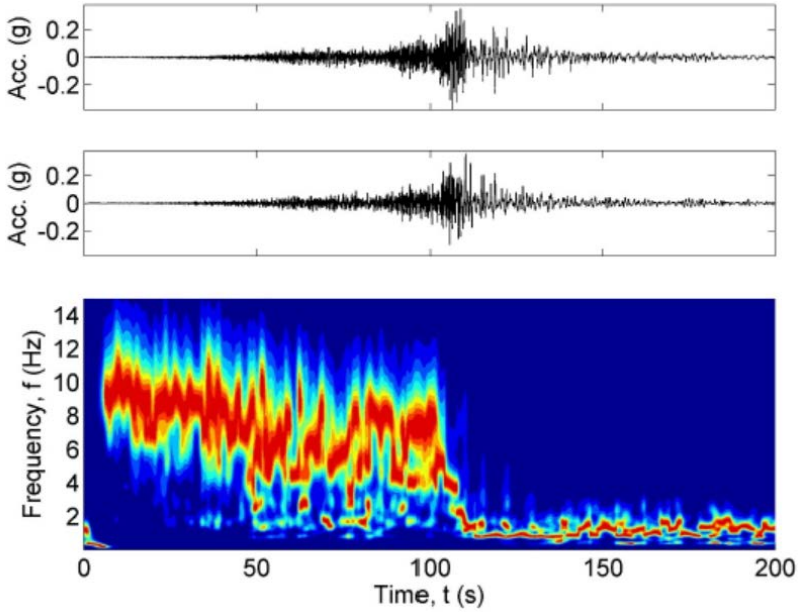


Urayasu, Japan (2011 – **M**9.0 Tohoku-Oki event)
From Stewart et al. (2016)

Benefits of the NGL Database

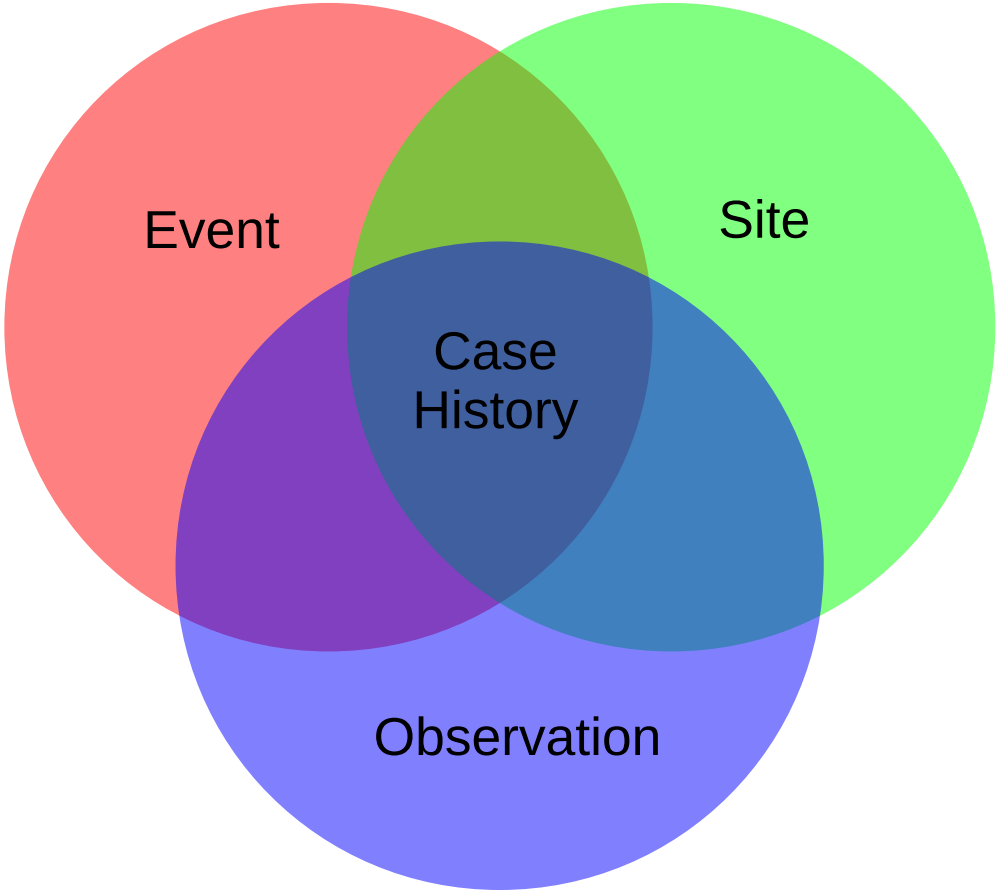
Recent case-histories

Motion-based data



Ibaraki, Japan (2011 – **M**9.0 Tohoku-Oki)
From Kramer et al. (2016)
and M. Greenfield pers. comm.

NGL Case History Definition



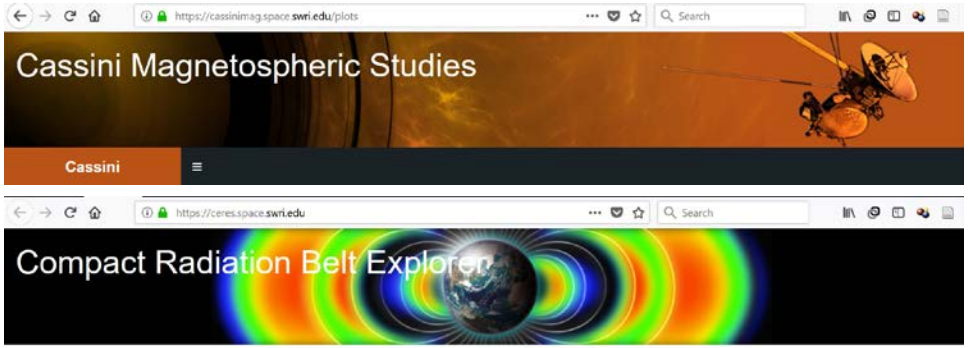
NGL Database GUI development

NRC-funded SwRI-UCLA collaboration

UCLA Samueli School of Engineering

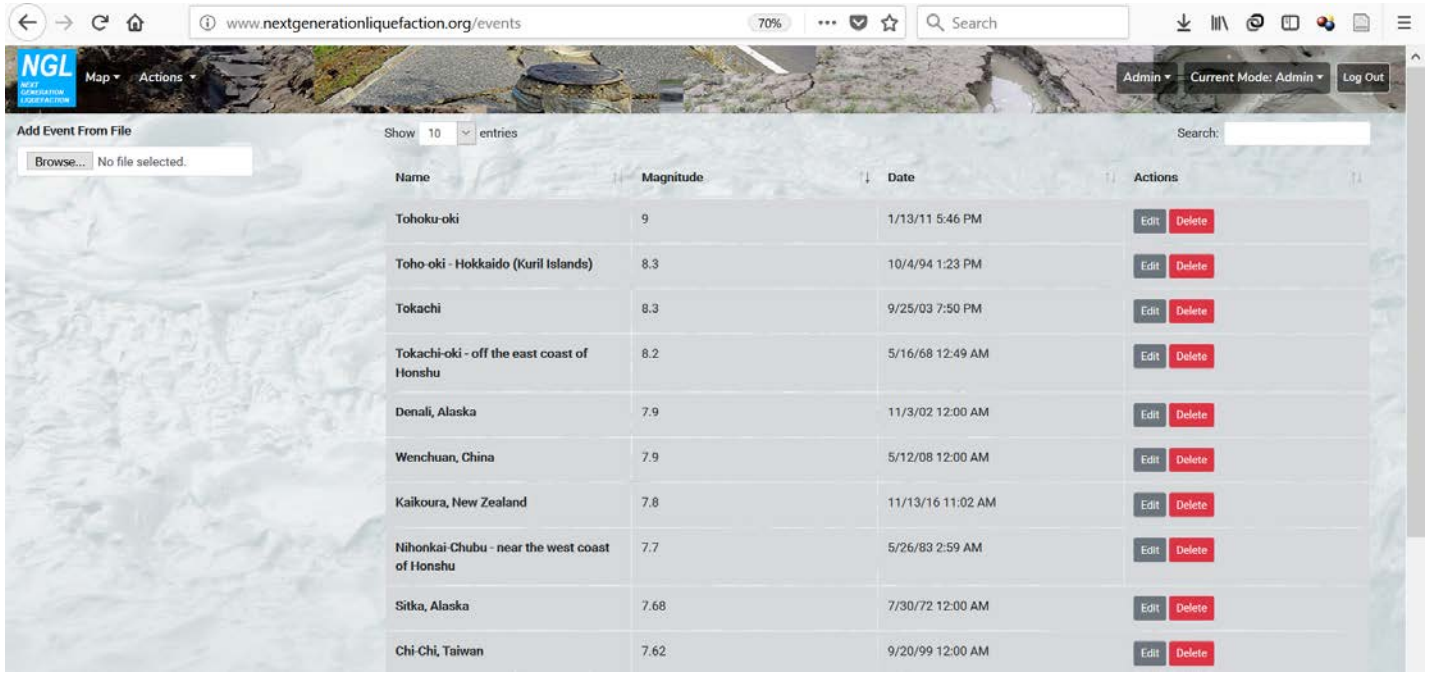
U.S.NRC

SwRI



www.nextgenerationliquefaction.org

NGL Database GUI Earthquake Events



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PEER Ground Motion Database
Pacific Earthquake Engineering Research Center

NGA West 2 Database
NGA Subduction (soon…)

NGL Database GUI (Map view)

www.nextgenerationliquefaction.org

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

Site – Geotechnical characterization

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NGL Database GUI (Map view)

www.nextgenerationliquefaction.org

Earthquake events (that produced observations)

NGL Database GUI (Map view)

www.nextgenerationliquefaction.org

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

- Christchurch (New Zealand) 2010-2011 sequence:

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

Tonkin + Taylor case histories (Van Ballegooy and Liu)

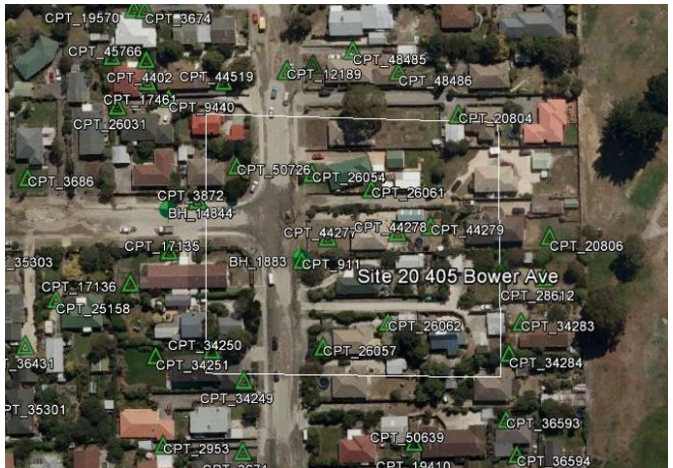
UC Berkeley sites (Bray and Beyzaei)

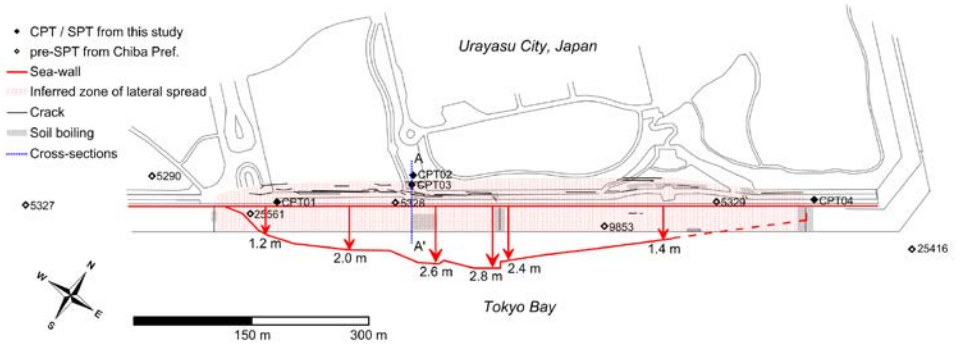
- Tohoku (Japan) 2011 **M**9.0 event – Unpublished

Tohoku + Mihama - UCLA

Instrumented levee arrays - UCLA

Additional lateral spread sites – UCLA-BYU





Database Current Status

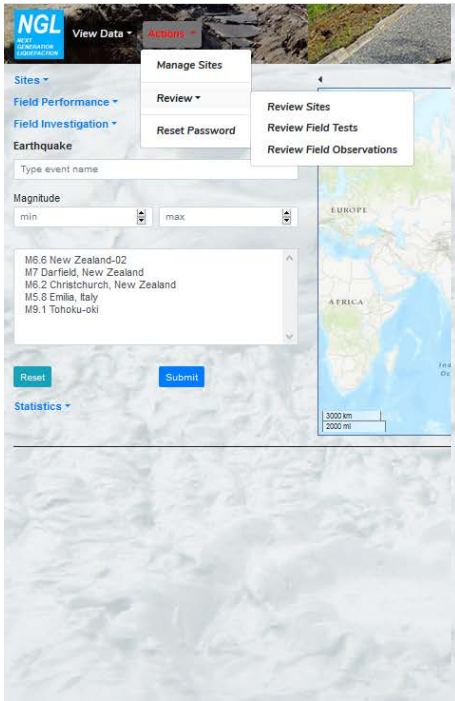
Case histories with relatively small magnitude (data collection)

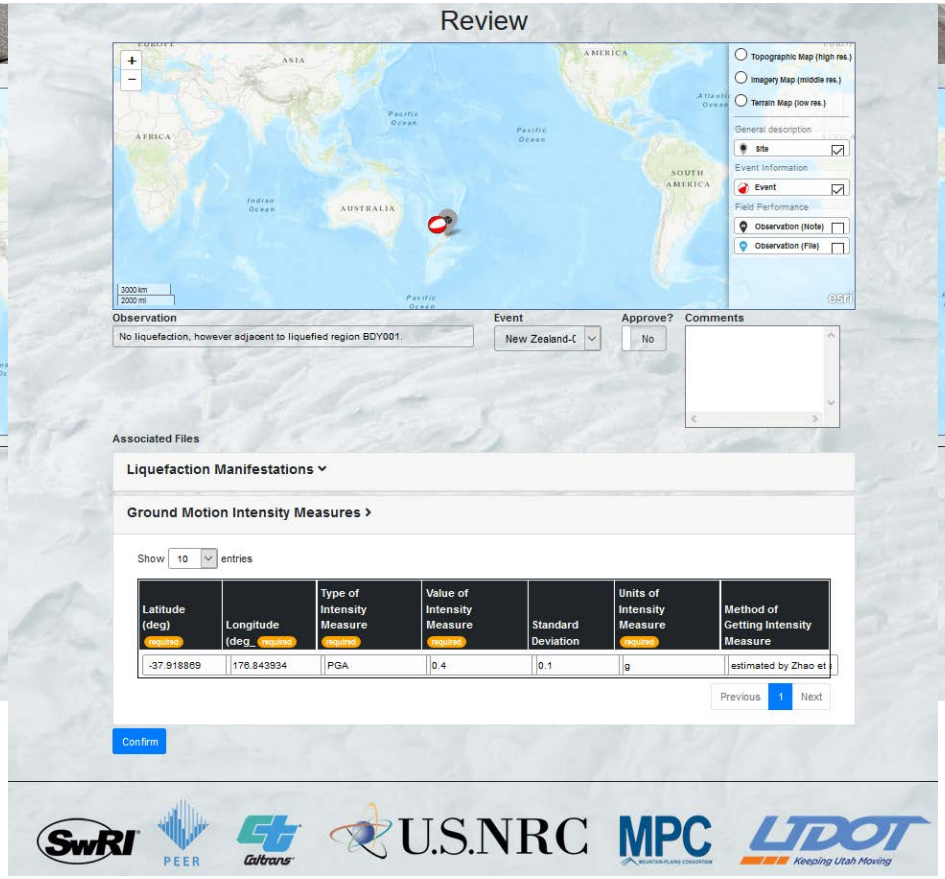
- Emilia (Italy), 2012 **M**5.8 earthquake – UCLA
- Au Sable Forks, NY 2002 **M**5.0 earthquake – Gingery (2003)
- Pawnee, OK, 2016 **M**5.8 earthquake – Clayton et al. (2016)
- Olancha, CA, 2009 **M**5.2 earthquake – Holzer et al. (2010)
- Others...

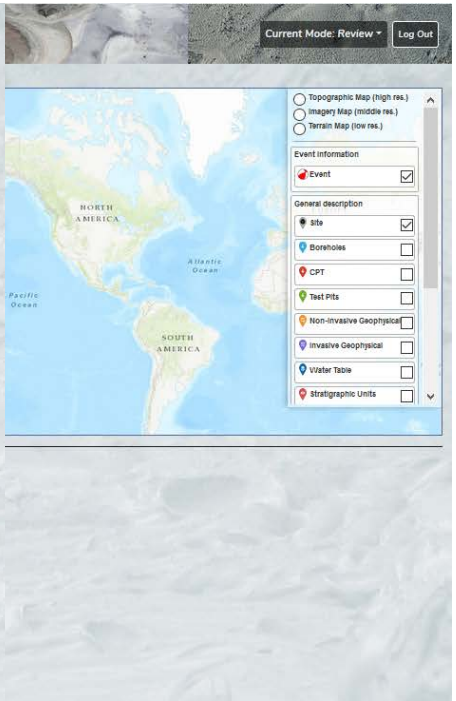
Review/Vetting Process

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

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







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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).

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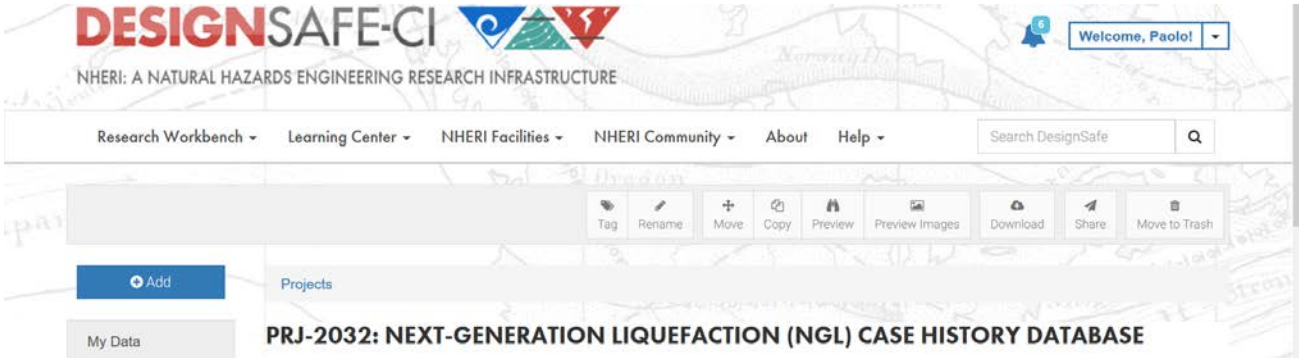

Vision for Community Access
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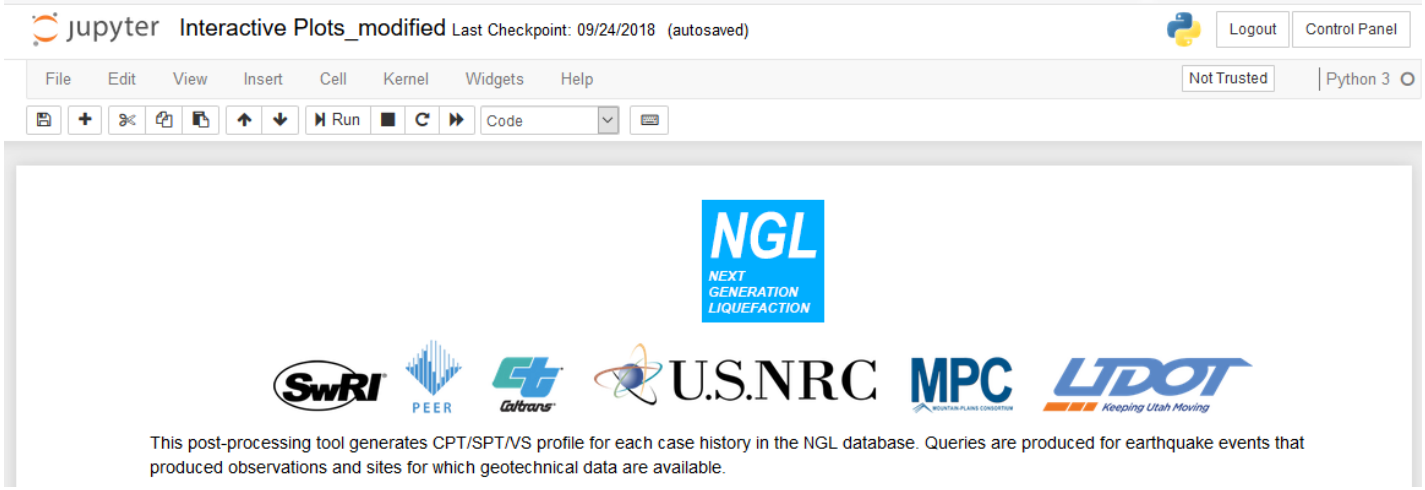

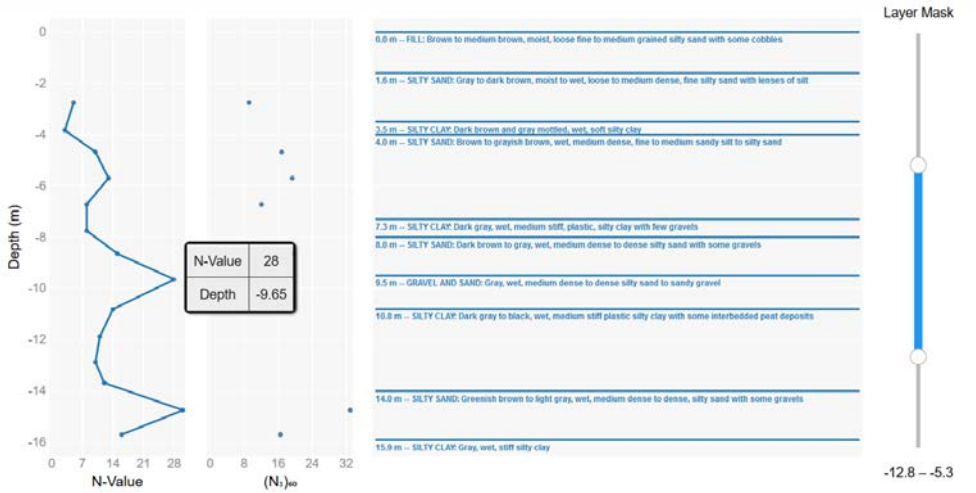

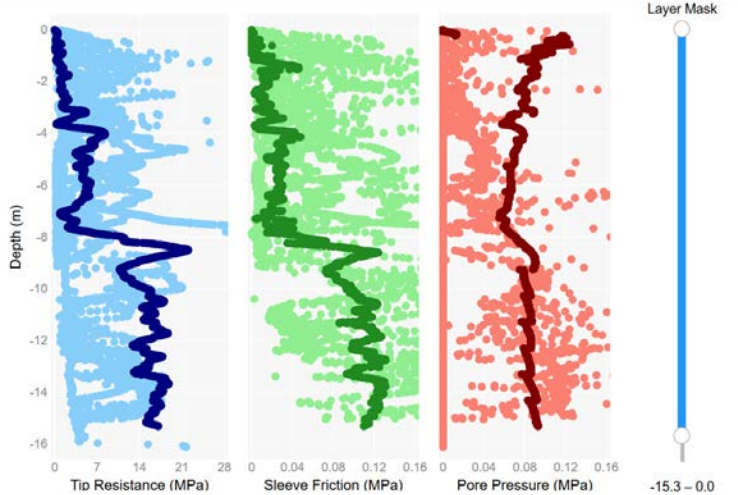

Final Remarks

- 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

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SwRI

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.

NGL NEXT GENERATION LIQUEFACTION

Project homepage:

https://uclageo.com/NGL/

Database:

http://nextgenerationliquefaction.org

Engineer Change.