NGL: Open Source Global Database and Model Development for Next-Generation of Liquefaction Assessment Procedures

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- Russell Green & Kristin Ulmer
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Outline

- Project need and vision
- Data resources
- Supporting studies
- Model development

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Project Need

Steps in liquefaction risk assessment:

(1) Susceptibility;

(2) Triggering;

(3) Effects

Each is *empirical* or *semi-empirical*, and hence is reliant on available data.

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Project Need

Small data sets – a few sites are especially consequential

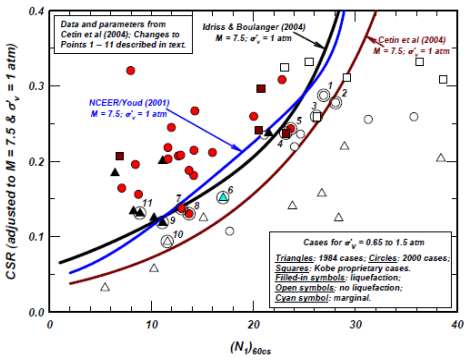

Figure: Idriss and Boulanger, 2010

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Project Need

Small data sets – a few sites are especially consequential

Existing data sets are necessarily incomplete, especially:

Depth > 10 m

M > 7.5

FC > 30%

CSR > 0.4

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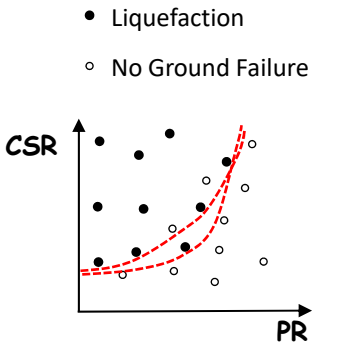
Present situation

Alternate liquefaction models provide different outcomes.

Why?

1. Inconsistent data sets
2. Different methods for data interpretation
3. Different models for extrapolation beyond data range
4. Potential errors in data analysis
5. Minimal between-developer interaction



Graphic: Kramer

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Project Vision

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

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Data Resources

- Database
- Flatfile

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Database: GIS platform with liquefaction, ground failure, and non-ground failure case histories.

Intent is that database contains *objective* data.

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Database: GIS platform with liquefaction, ground failure, and non-ground failure case histories.

Intent is that database contains *objective* data.

Flatfile: Synthesis of parameters used for model development.

Involves higher degree of interpretation and is necessarily *subjective*.

NGL Database

Original development by Kwak, Brandenberg, Stewart

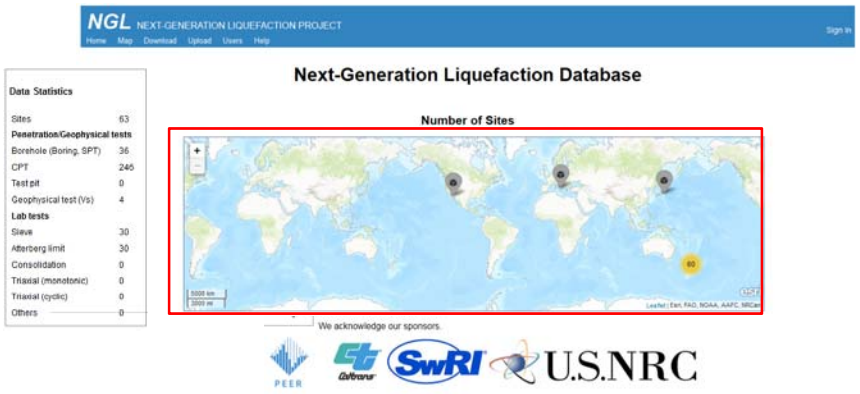
PHP platform, GIS-based mapping tool, AGS4 database format

To be hosted at DesignSafe (UT NHERI site)

Data uploads to date by DYK, PZ, ML, KU… 63 sites

http://uclageo.com/NGL/database/index.php

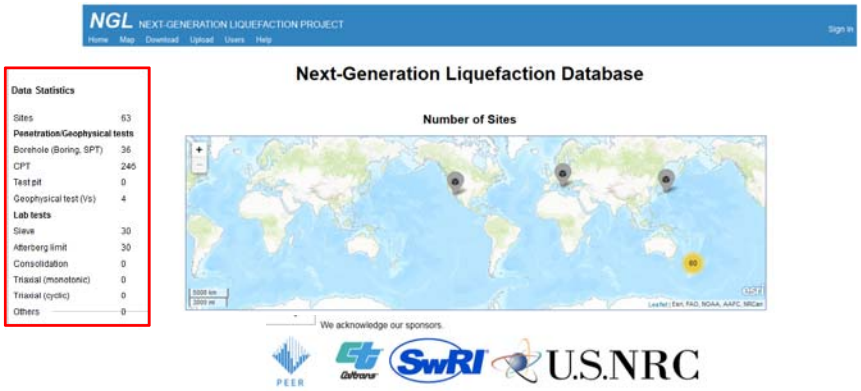
NGL Database



Site locations

http://uclageo.com/NGL/database/index.php

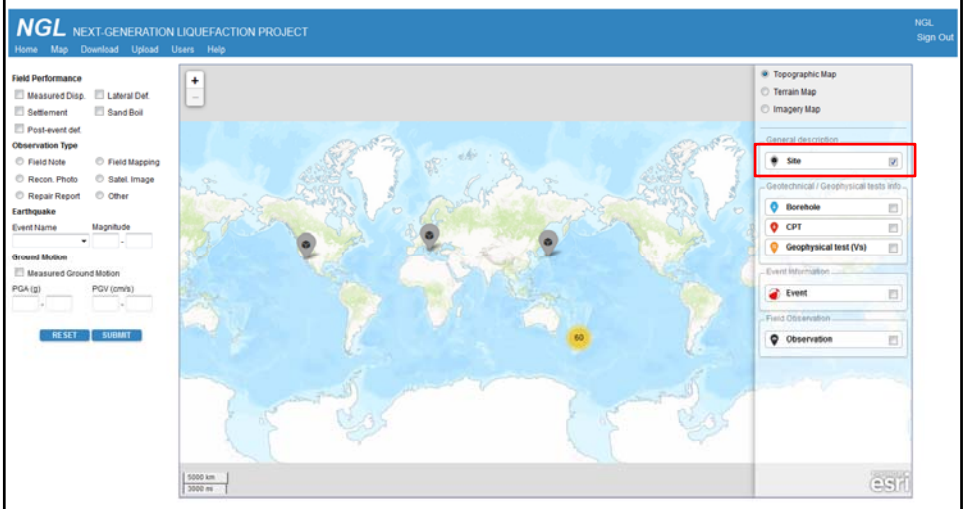
NGL Database



Data count overview

http://uclageo.com/NGL/database/index.php

NGL Database



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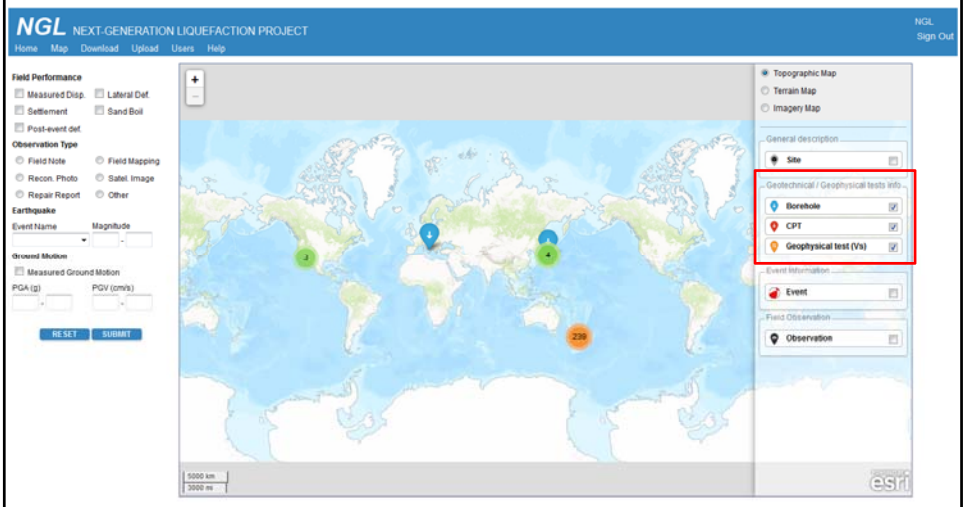

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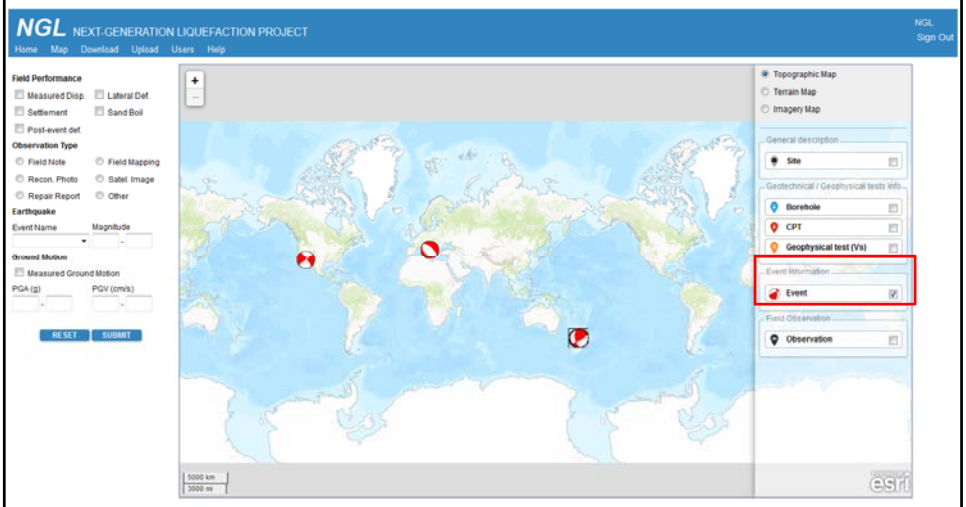
NGL Database



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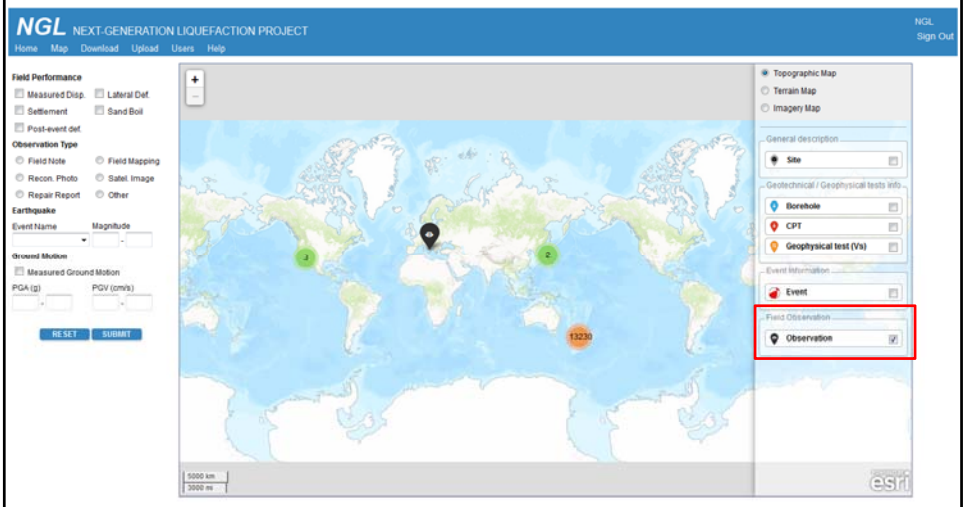

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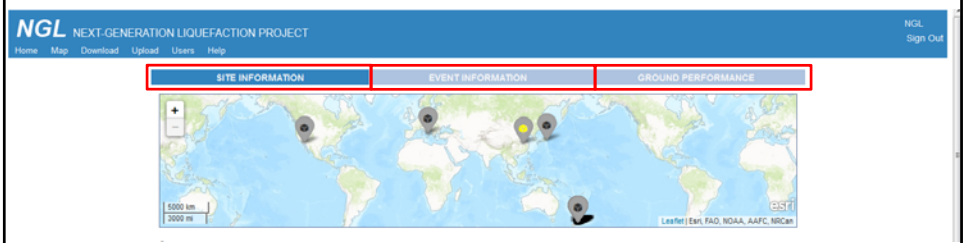
What constitutes a case history?

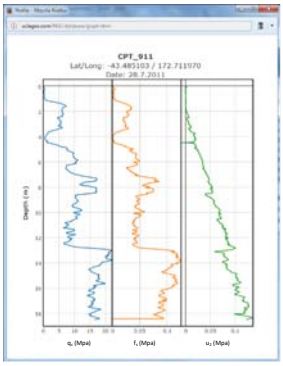
- Site information
- Event information
- Ground performance

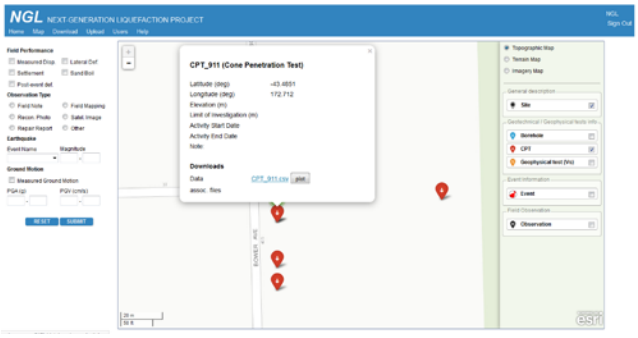


What constitutes a case history?

Site information

Minimum requirements:
- Soil stratigraphy
- Ground water depth
- Details pertaining to soil type
- Penetration resistance or V_S





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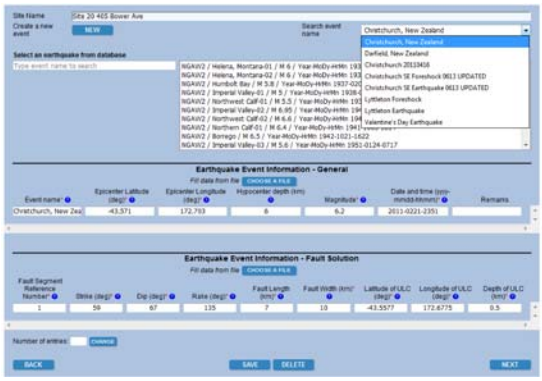

Minimum requirements:
- Horizontal, median-component, PGA
- Moment magnitude, **M**

What constitutes a case history?

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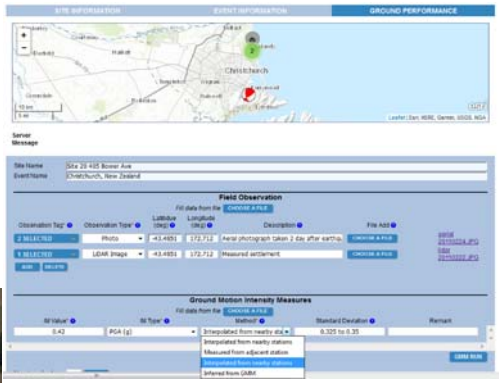
Event information

Ground performance



Minimum requirements:
- Written, mapped, or imaged observations
- Date/time of reconnaissance
- Location (lat/long)

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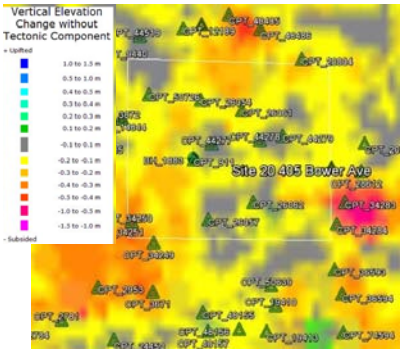
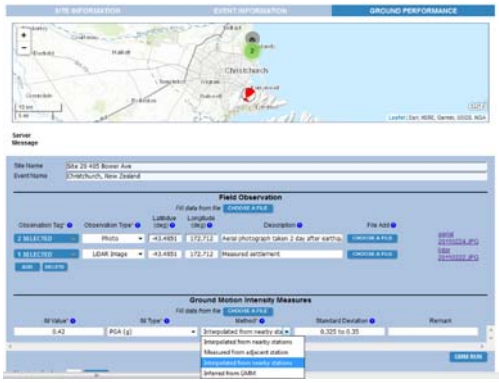
Ground performance





Minimum requirements:
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NGL database: GIS platform with liquefaction, ground failure, and non-ground failure case histories.

NGL flatfile: Synthesis of parameters used for model development.

- Selection of critical layer
- Demand characterization
- Penetration resistance (or V_S)

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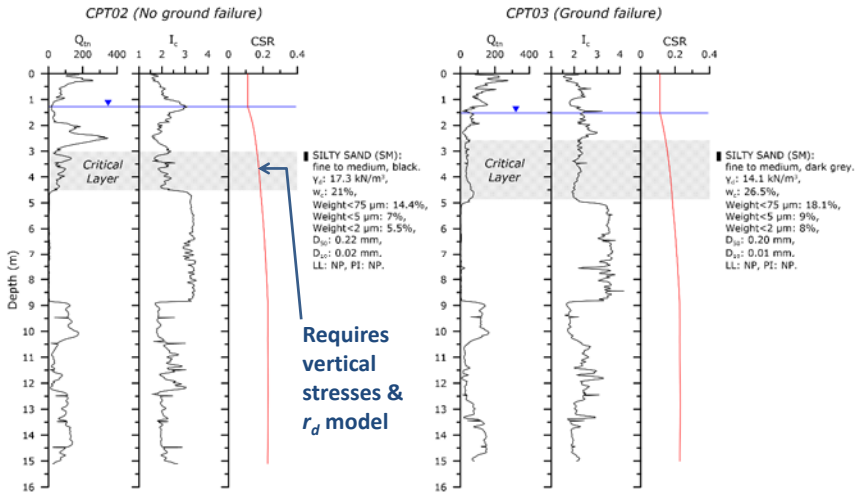
Location of critical layer

Shear demands in that layer



Location of critical layer

Shear demands in that layer

Demand modified to CSR*

$$CSR^* = 0.65 \frac{\sigma_v \, PGA/g}{\sigma'_v} r_d \frac{1}{K_\sigma K_\alpha C_M}$$

Each comprises a model.

Subjectivity

Case Histories Targeted for Uploading

Christchurch sites

- 2010-2011, 2016 events
- TT, VT, UCB-UC, etc.

Japan sites

- 2003, 2004, 2007, 2011 events
- MLIT, Tokimatsu group, UCLA

Critical data collection was NGL supported, 2013-2015

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Case Histories Targeted for Uploading

Lateral spread sites

- Pool-funded (Utah, California, Washington)
- PIs: Bartlett, Franke, Kramer

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Case Histories Targeted for Uploading

Data sets used in development of existing models:

- SPT-based models:

  Cetin et al 2000; Boulanger et al. 2012 (230)

- CPT-based models:

  Moss et al. 2003; Boulanger and Idriss, 2014 (268)

- V_s-based models:

  Kayen et al. 2013 (422)

- Flow slides:

  Olson and Stark, 2002 (33)

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Case Histories Targeted for Uploading

M 7.4 1999 Kocaeli event case history sites
http://peer.berkeley.edu/publications/turkey/adapazari/

M 7.6 1999 Chi-Chi event case history sites
http://peer.berkeley.edu/lifelines/research_projects/3A02/index.html

Both:

- PEER projects with strong local collaboration
- Most sites have high FC
- Well-documented effects on buildings

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Case Histories Targeted for Uploading

Others:

2010 **M**8.8 Maule and 2015 **M**8.3 Illapel (Chile)

2010 **M**7.2 El Mayor-Cucapah

CPT re-testing (Moss)

2012 Emilia **M**5.9 and 1980 **M**6.9 Irpinia (Italy)

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Supporting Studies

- ***Need:*** Models must be applicable over range of conditions required for applications:
  - Stress conditions: depths of 1-100 m; α = 0-0.3.
  - Seismic demands: **M** 5-9.5, PGA 0-1.0 g
  - Soil types: FC 0-100%; nonplastic to limiting plasticity for liquefaction susceptibility; gravels; non-quartz minerologies of course particles
- Parameter space covered by case histories is narrower
- Extrapolation guided by supporting studies

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Supporting Studies

- Laboratory:
  - Stress effects on triggering, deformations
  - Soil compositional factors (plasticity, minerology, etc.)
  - Ageing
- Wave propagation analysis:
  - Stress reduction factor, r_d
  - Leverage significant advances in nonlinear site response

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Supporting Studies

- Physical model test data:
  - Centrifuge, shake table, etc.
  - Possible applications: lateral spreading, $S_{u\text{-}liq}$, partial drainage effects
- Critical layer selection

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Model Development

- Modeler participation:
  - Generally unrestricted
  - Meeting attendance required
  - Must share results with other modelers
  - Coordinated publication

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Model Development

- Model types:
  - Susceptibility, triggering
  - $S_{u\text{-}liq}$
  - Deformations: ε_v, γ_{max}, lateral spread disp.
- Applicability:
  - 'Average' soil conditions at case history sites (ergodic)
  - Expected to correspond to quartz sands with various fines
  - Subsequent work to focus on 'material-specific models' (non-ergodic)

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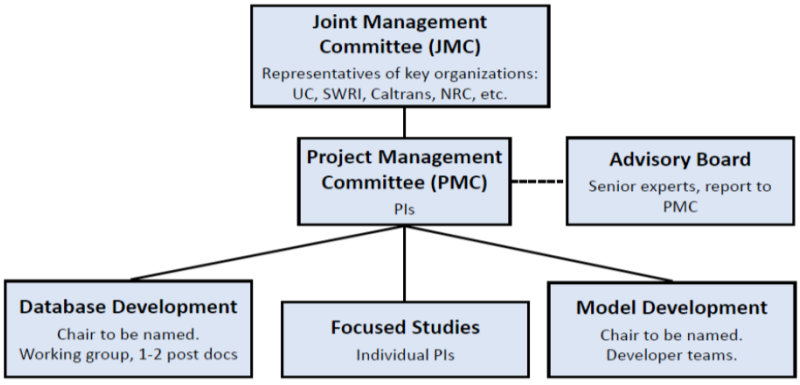
Closing Thoughts

- Project organization



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Closing Thoughts

- Project organization
- National Academies endorsement
  - Database (Rec 1)
  - Judicious use of supporting studies (Recs 4, 7, 9)
  - Model development activities, including consideration of uncertainties (Rec 8)
- In process of outreach to national & international potential funding agencies

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Next-Generation
NGL
Liquefaction

Interim NGL web site

http://uclageo.com/NGL/

Summary paper in SDEE (2016)

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