

Ridgecrest M 7.1 Earthquake of July 5 2019 Performance of Gas Lifeline

March 2 2022
Jeff Bachhuber (PG&E)
John Eidinger (G&E)

The material in this slideset is provided under the Creative Commons Deed. See [www. geEngineeringSystems.com](http://www.geEngineeringSystems.com) for details.
You may use this information, and make derivative works, provided you provide attribution, and make the information freely available, and only for non-commercial purposes.
You may not copyright any material in this presentation without first obtaining written authorization from the authors.
You may not include any material in this presentation in any copyrighted document without first obtaining written authorization from the authors.

Limitations. The authors, G&E and PG&E make no warranty or guaranty that any of the information in this document is suitable for any purpose.
If you download this document, or use any information, you agree to indemnify G&E, PG&E and the authors entirely.
Do not download or use this document unless you agree with these limitations.

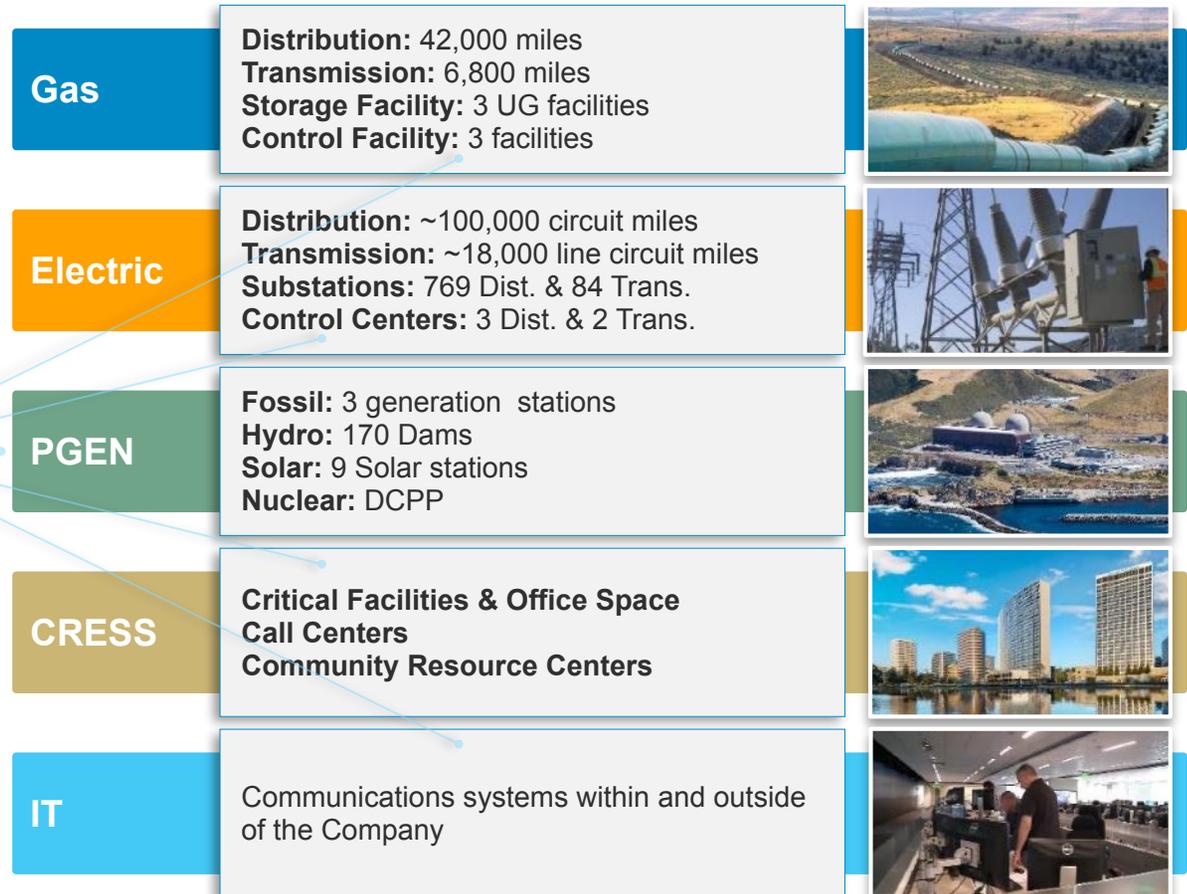


PG&E's Infrastructure & Operations Network

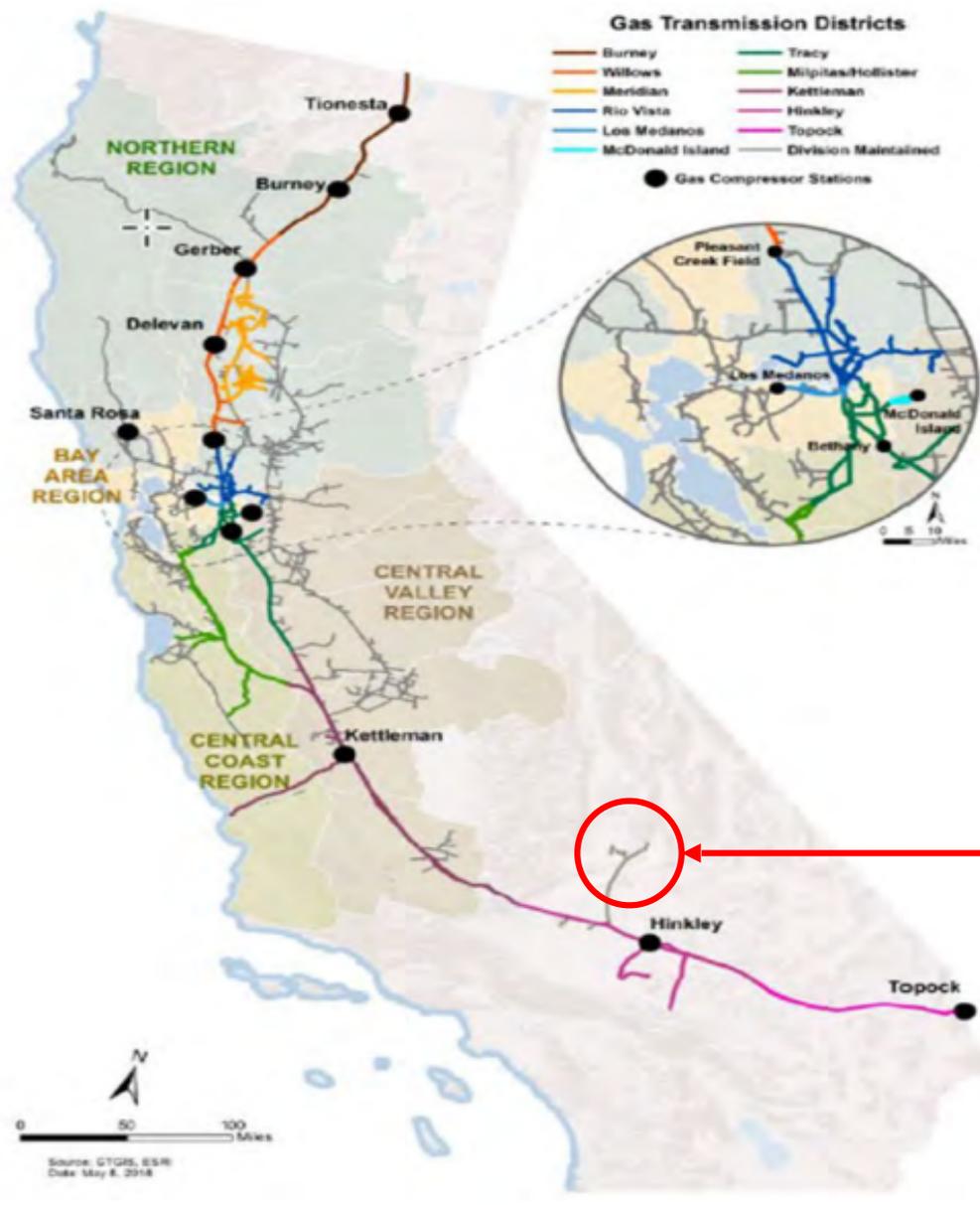
PG&E System is Broad & Complex with Interconnected Command & Control Network & Asset Interdependencies

Seismic events create both immediate and sustained impacts resulting from...

- Direct failure of assets
- Control network & IT outages
- Resource constraints – labor, material, and more



California Energy Sector Moving Towards Resiliency

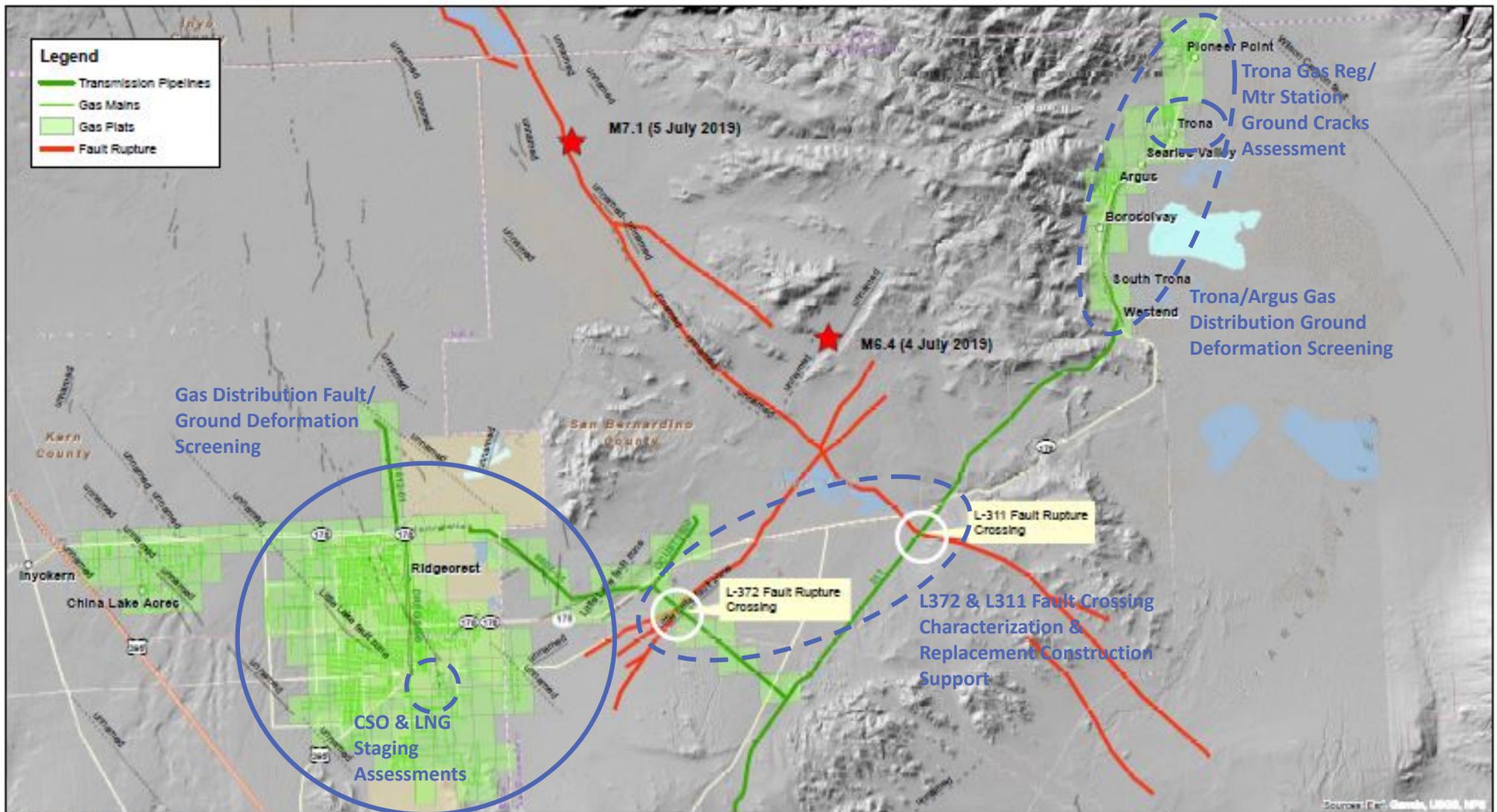


2019 Ridgecrest Earthquake Sequence Affected a Localized Part of PG&E's Gas System

Emergency Response was Managed Through an Operational Emergency Center & Local Crews Augmented by Gas Crews Mobilized From Across PG&E Service Territory

PG&E Ridgecrest/Trona Gas System is located in the Upper Mojave Desert. The Gas system was initially built in the 1950s

Initial Inspections & Observed Damage for Ground Deformation



Map Data Sources:
US Geological Survey, PG&E facility datasets.



Map projection and scale: WGS 84 / UTM Zone 10N

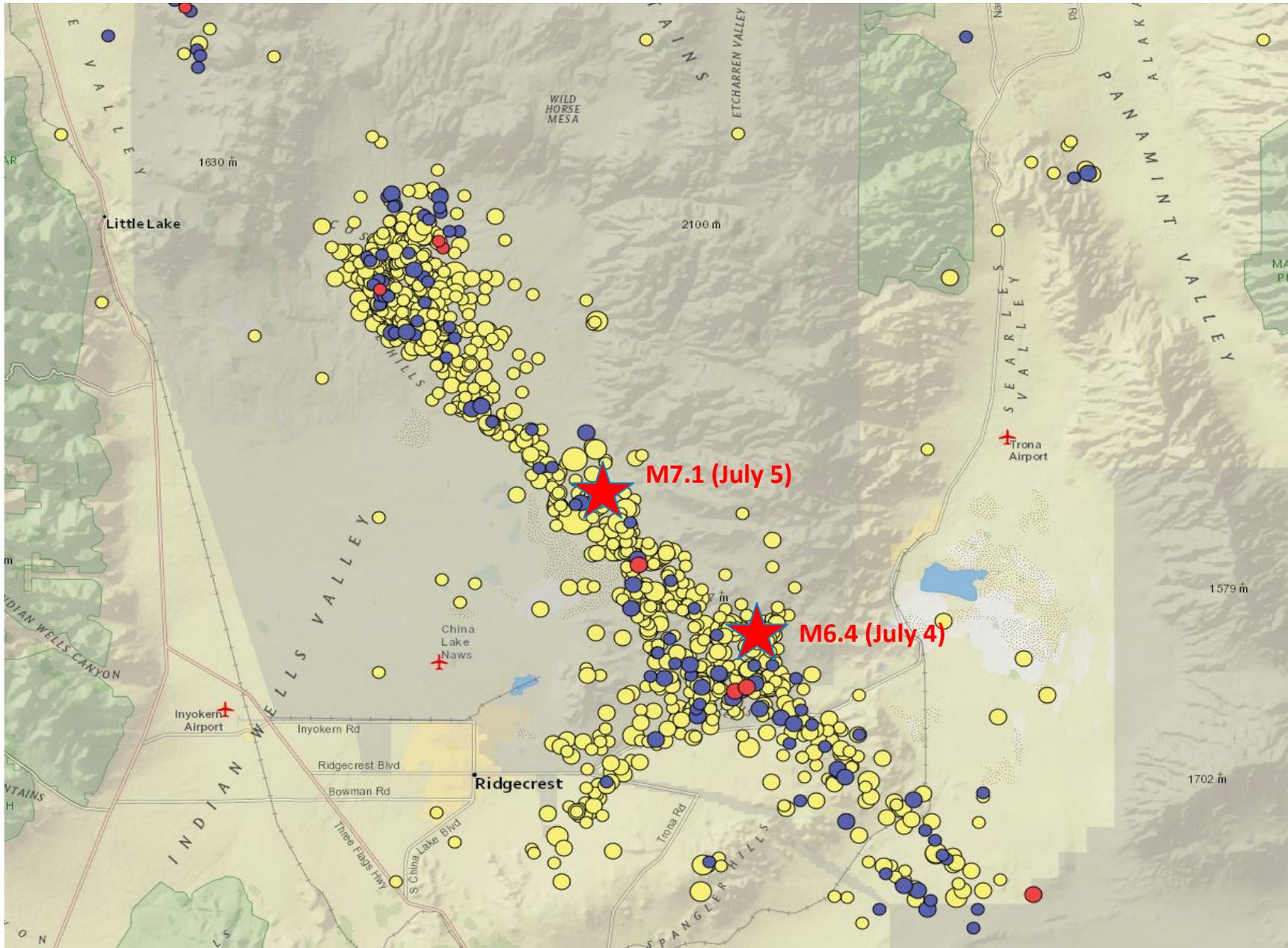
Fault Rupture with Gas Infrastructure

Ridgecrest Earthquake Response

PG&E GEOSCIENCES - PRELIMINARY

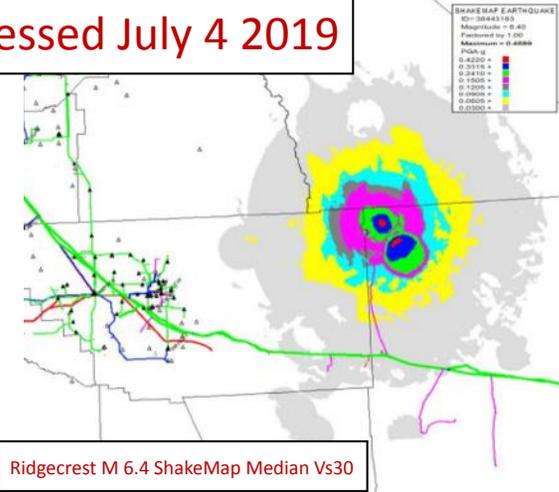
 Pacific Gas and Electric Company

Primary Shocks and Aftershock Sequence

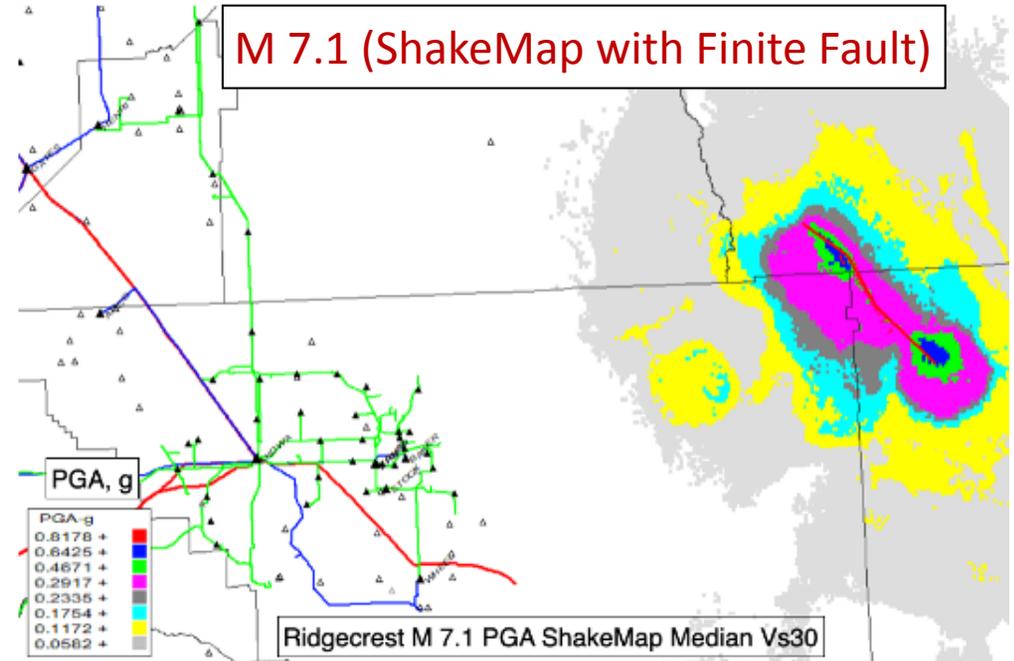


Ground Shaking Maps - ShakeMap vs SERA

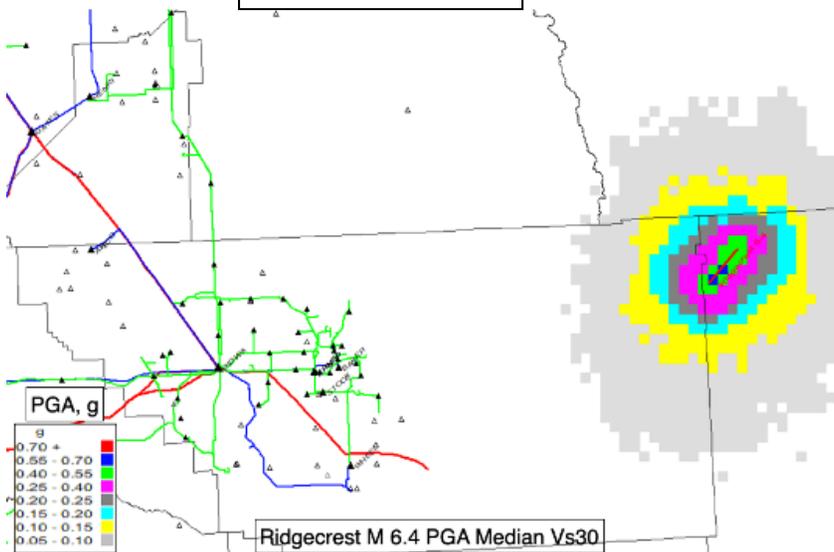
M 6.4 (ShakeMap)
Processed July 4 2019



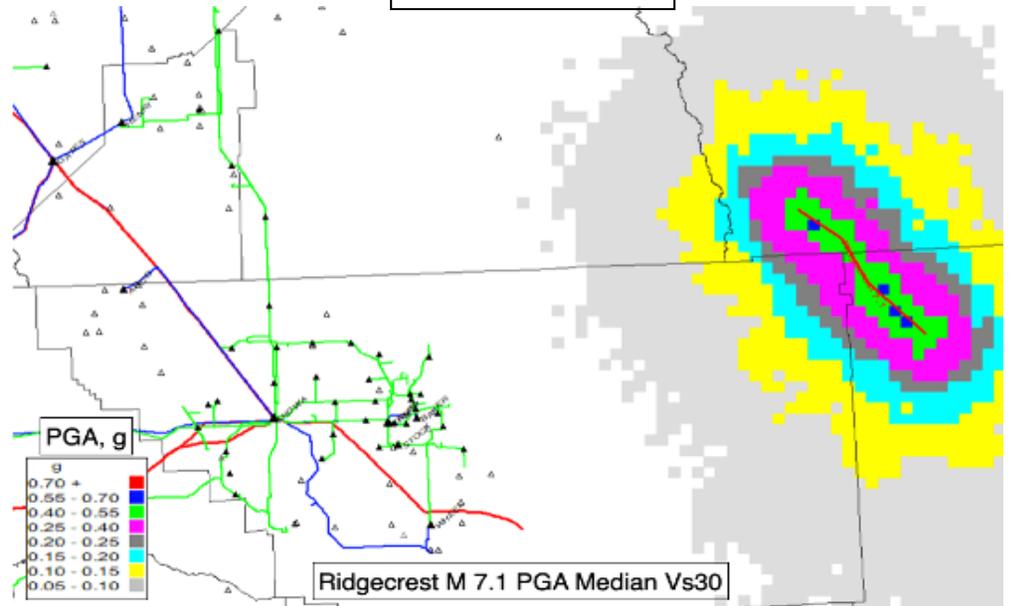
M 7.1 (ShakeMap with Finite Fault)



M 6.4 (SERA)



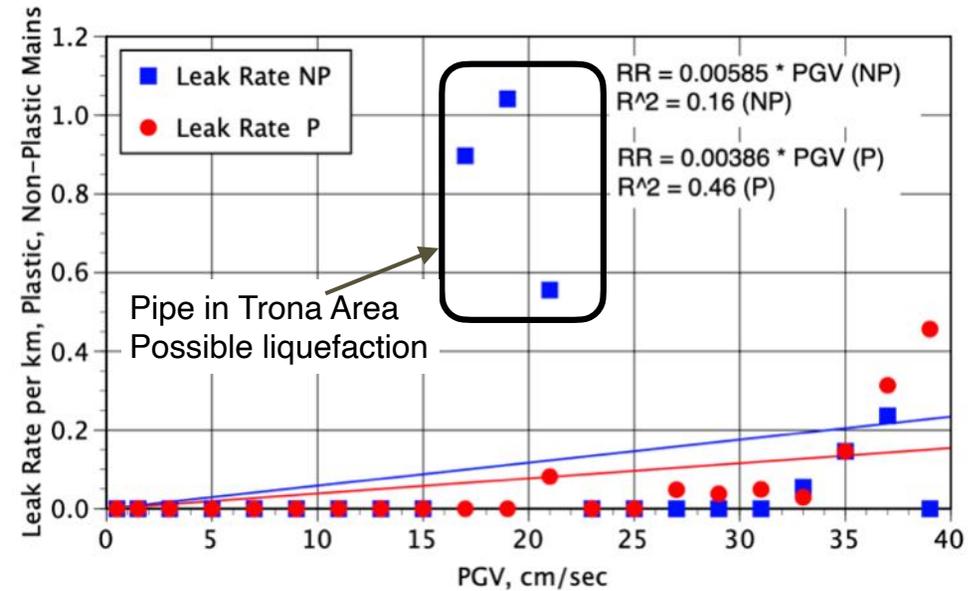
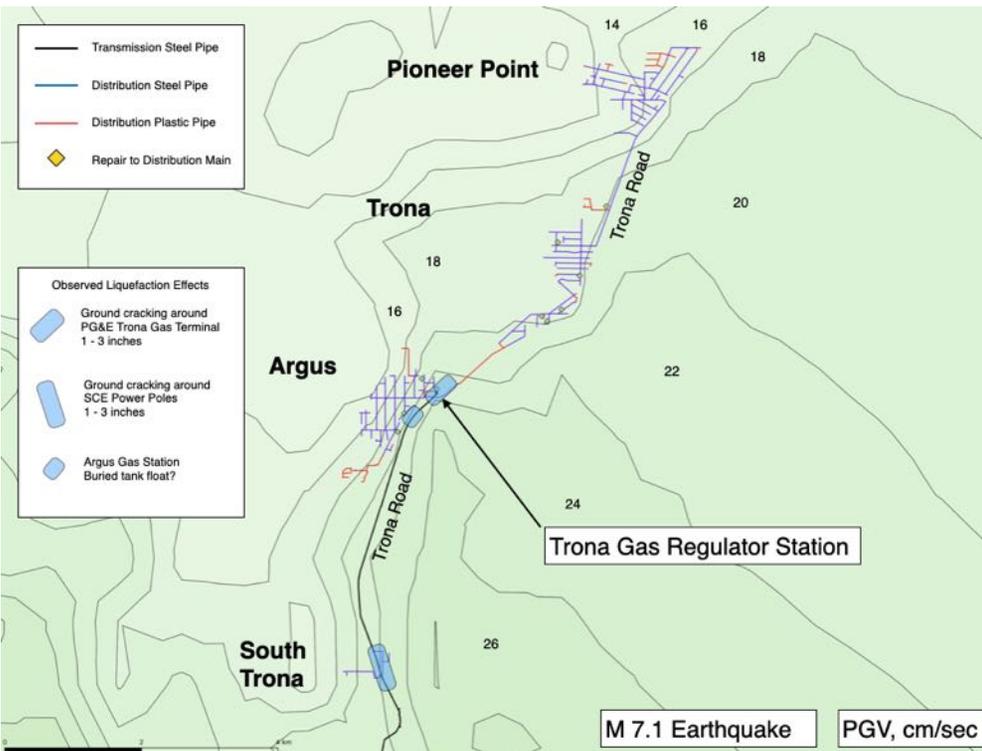
M 7.1 (SERA)



Damage to the Gas Distribution System



Ridgecrest

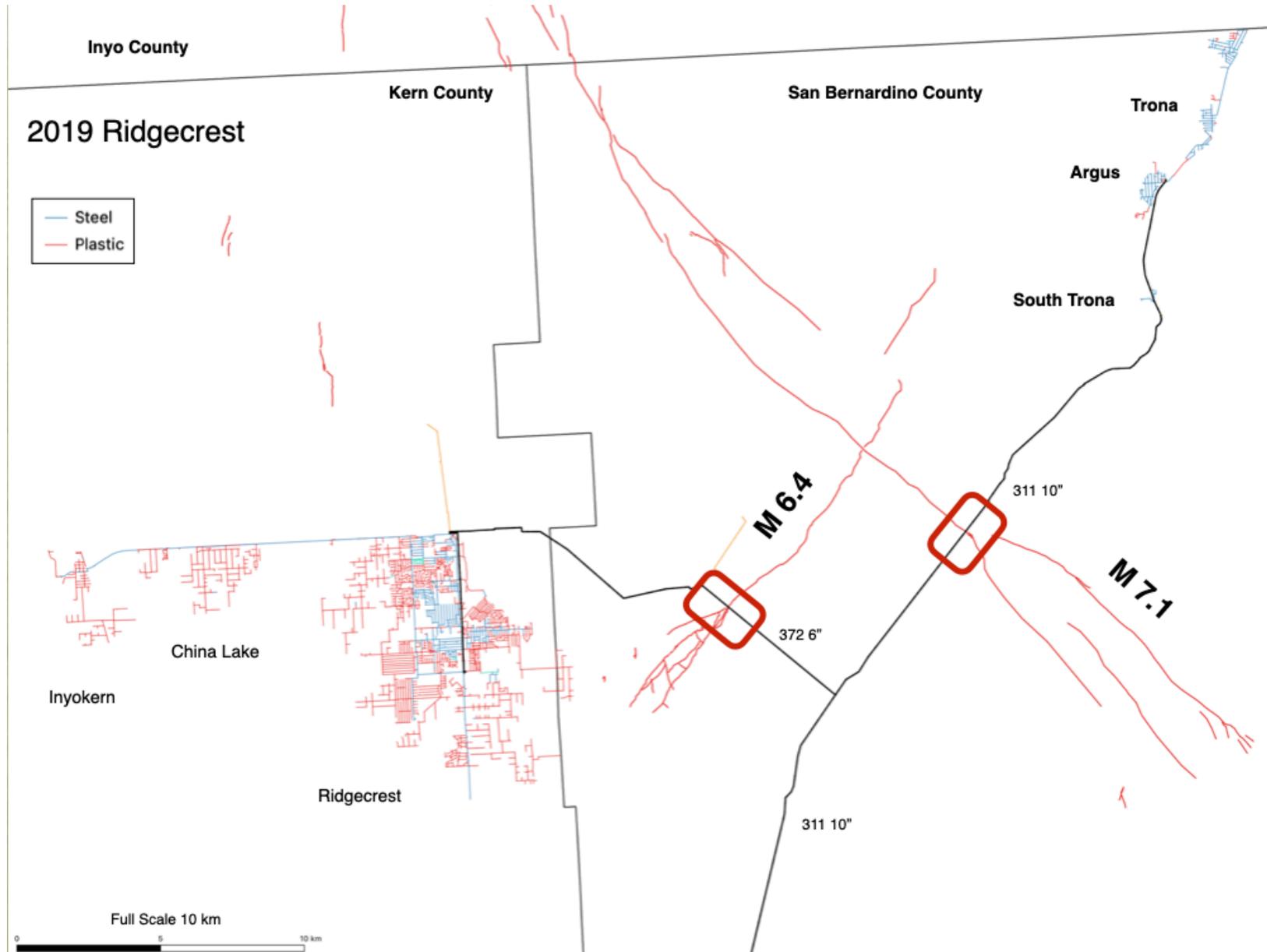


Distribution pipe
287 km plastic; 150 km steel

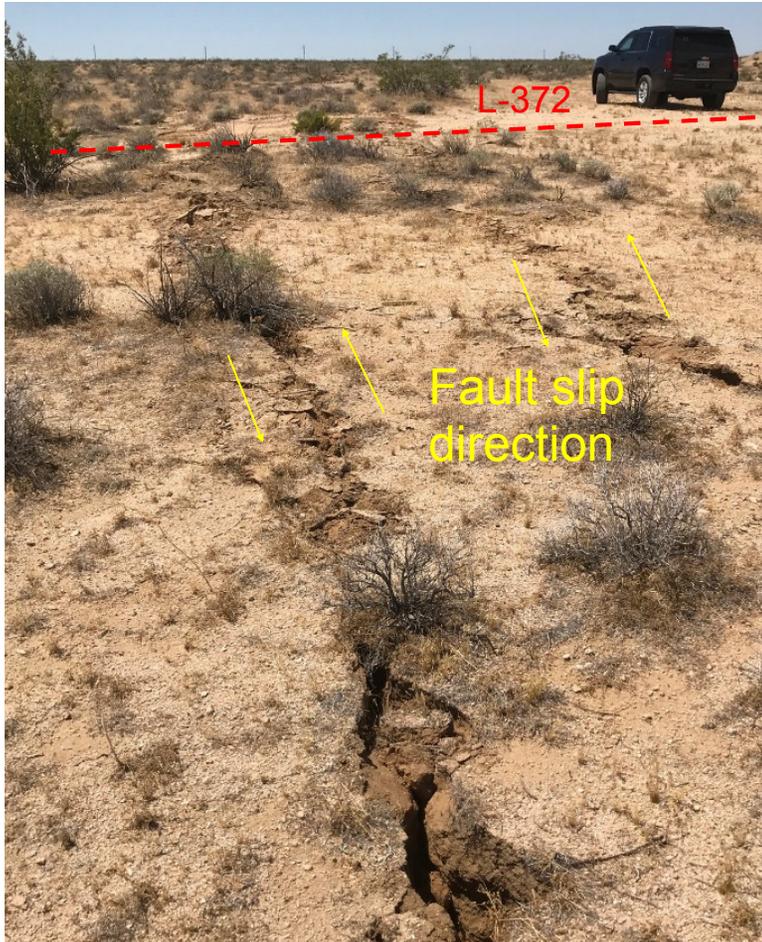
31 Gas Repairs (dots):
Steel: 16 (NP)
Plastic: 15 (P)
Liquefaction zones: blue boxes
324 leaks in services (not mapped)

Fragility models ideally should account for
PGV, PGD, Age, Corrosion

Damage to the Gas Transmission System (2 locations)



Surface rupture across pipeline alignment (pipeline alignment road at top of photo; southeast view); rupture is at a near-right angle to pipeline



Measurement of left lateral surface fault slip across paved road south of L-372 crossing (east view)





L-372: M6.4 EQ Rupture

Fault Displacement in Trench Walls & Pipeline Deflection: L-372

Fault displacement of original pipeline trench excavation wall after pipe backfill was partially removed by vacuum excavation to expose pipe at L-372 M6.4 fault crossing (south view).



Excavated L372 pipe showing left lateral bending at fault intersection (east view)





L311: M7.1 EQ Rupture

Photos of Surface Fault Rupture & Displacements: L-311

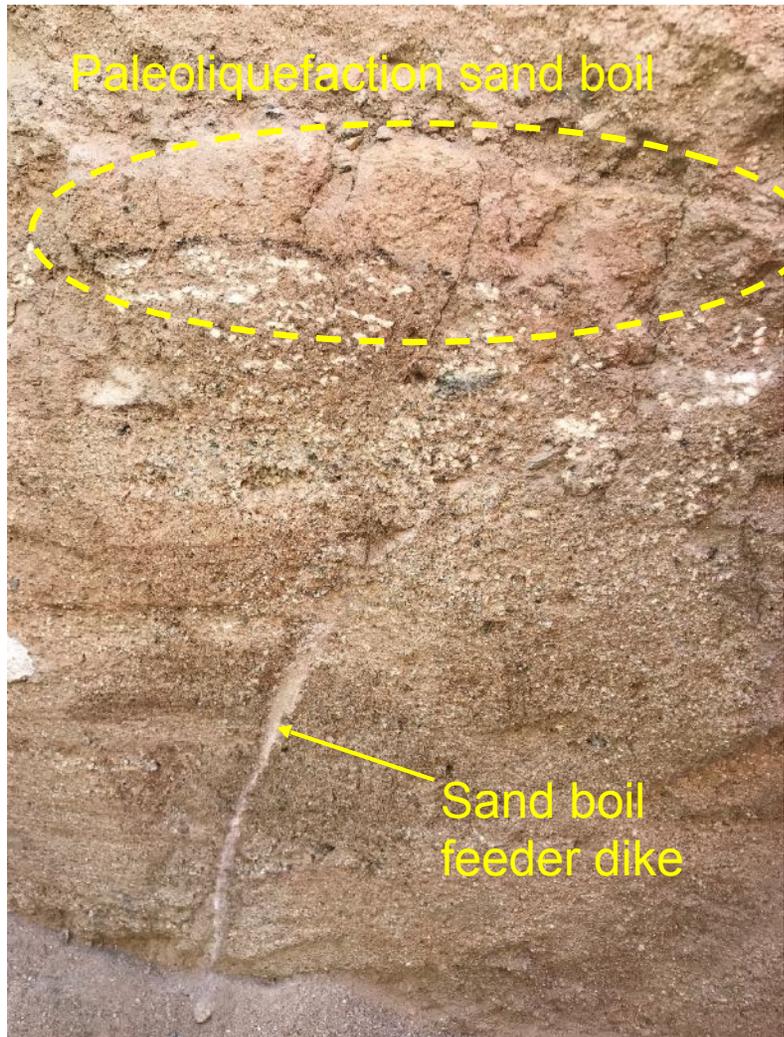
Surface fault rupture crossing L-311 pipeline (trending near-perpendicular to rupture at alignment road/geologists (southeast view)



Right lateral displacement of stream channel and ant hill indicating 1-1.5 feet of displacement



Evidence of past (pre-historic) earthquake indicated by paleoliquefaction sand boil and feeder dike in L-311 original pipeline trench wall



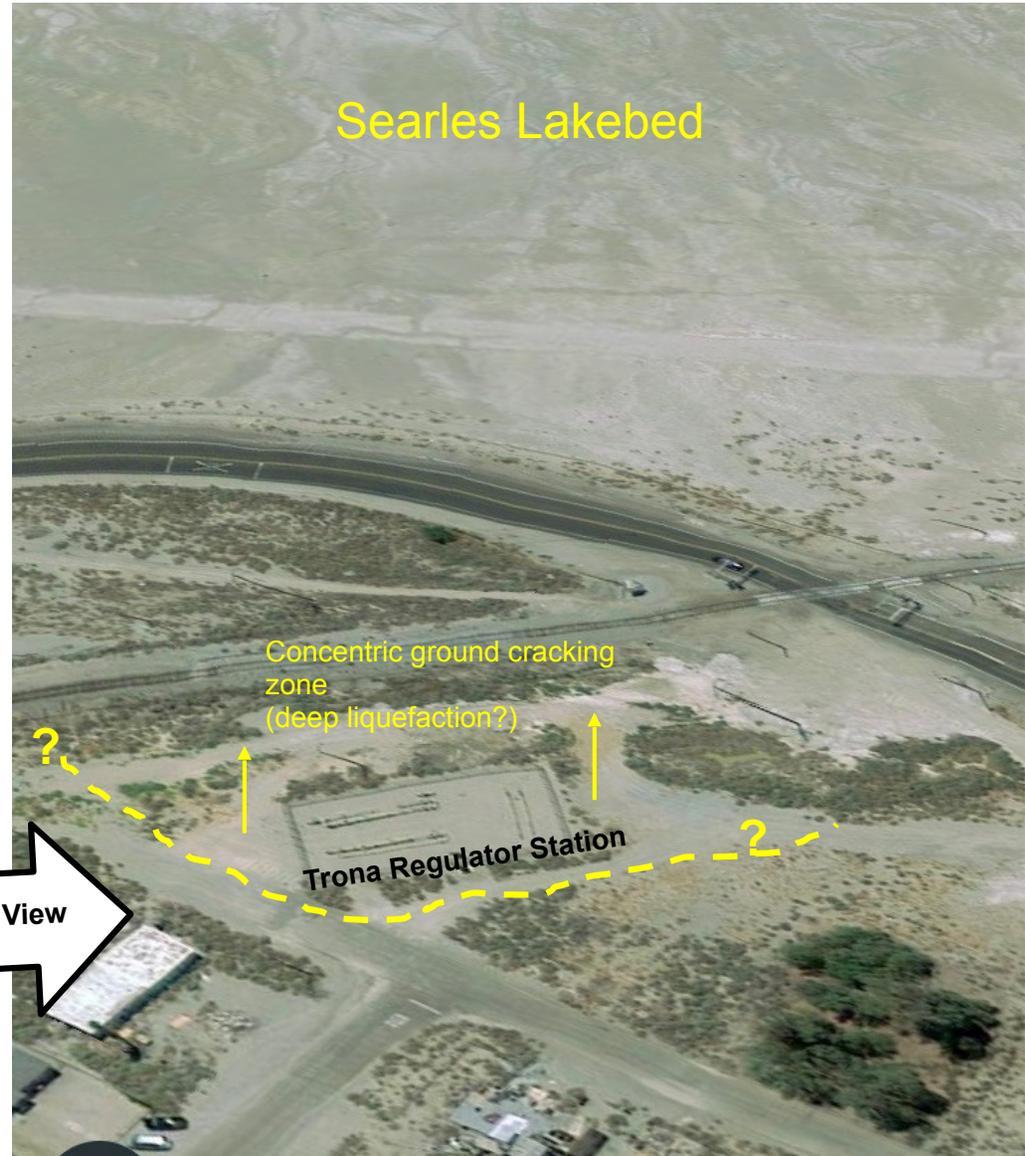
Excavated L-311 pipe showing right lateral bending at fault intersection (southwest view)





Trona Gas Regulator Station Damage Assessment

Extensive cracking and settlement zone at Trona Regulator Station (east view; map) and concentric “headscarp” crack (south view; photo)





Trona Gas Regulator Station Damage Assessment



Settlement and lateral movements in station pad fills removed support for piping/valves. Settlement & lateral displacement is up to 0.5-1 foot.



Apparent settlement/lateral spread headscarp at northwest corner of station. Searles Lake is off the photo to the left (east), and crack patterns and direction of extension suggest lateral movements toward the lake.

General cracking is pervasive throughout station pad fill.



Differential settlement and lateral displacement across the station pad and foundations



Earthquake Documentation and Reporting – Gas System

L-311/L-372 Fault Crossing Evaluation

- PG&E conveyed initial fault characteristics to evaluate fitness of existing pipeline for planning initial gas response and pipeline mitigation options.
- Estimates for possible future fault displacements were increased to 3-feet to accommodate uncertainties and provide a safety margin for the replacement pipe design.
- Confirmation mapping and documentation were performed in L-372 and L-311 pipeline excavation trenches. This work confirmed the locations and estimates for future fault displacement which were well-defined by offset of the original pipeline trench excavation walls in cemented soils.
- Displacements of the trench wall were measured as 20-inches along the primary fault splay and 7-inches along secondary fault splays for L-372, and 10-inches primary and 3-inches secondary for L-311.
- Both existing stressed pipes were removed and replaced with new unstressed pipes



Earthquake Documentation and Reporting – Gas System

Trona Pipe and Surface Regulator/Metering Stations

- Due diligence field reconnaissance was performed along a steel pipe and associated gas regulator/metering stations outside of M6.4 and M7.1 fault rupture areas to check for possible ground failure or triggered rupture. No significant fault rupture was observed at these facilities.
- Extensive cracking, and up to 0.5-1 foot of settlement and lateral movement was observed at the Trona Regulator Station that appears to be caused by fill compaction and possible deep liquefaction/lateral spreading.

Gas Distribution Piping at other mapped locations.

- PG&E inspected 84 sites along gas distribution lines of which 67 were along previously-mapped faults/crossings (which did not experience significant surface rupture during M6.4/M7.1 earthquakes) in Ridgecrest and Inyokern. No damage was observed.



Summary

Gas Transmission 6” and 10” Steel pipes

- 2 1955-vintage steel pipes underwent ~1 to 2 feet of fault offset. Both deformed. Neither leaked. Both were replaced with new pipes. These lines had common D/t ratios of 57 (10" line) or 35 (6" line) in the fault crossing zones. These D/t ratios are much lower than commonly used for low pressure steel water pipes of similar diameter, which have common D/t ratios of 125 to 150. The low D/t ratios, coupled with lack of appurtenances in the fault crossing zone, coupled with corrosion protection and quality construction, are all factors that led to successful performance (no leak) under fault offset.

Gas Distribution Plastic and Steel pipes and service laterals

- 31 repairs along mains. 324 leaks at service laterals / meter sets. 1 leak at a regulating station.

Thank You!