Primary funding is provided by

The SPE Foundation through member donations and a contribution from Offshore Europe

The Society is grateful to those companies that allow their professionals to serve as lecturers

Additional support provided by AIME
First-Ever Environmental Characterization of Hydraulic Fracturing for Shale Oil and Gas Production

Daniel Tormey, Ph.D., P.G.
President
Catalyst Environmental Solutions Corporation
Los Angeles, California
Local Study With Global Implication

- **Global Importance**
  - Countries with shale basins following US lead
  - Economic, geopolitical, and climate change advantages to shale oil and gas production
  - Concerns about Social License to Operate

- **This Study provides**
  - Data-rich response to fear-based concerns
  - Ability to scale study results globally
Hydraulic Fracturing Environmental Study

• Largest urban oil field in the world, in the center of Los Angeles, California

• Feasibility and environmental impacts of hydraulic fracturing

• Peer-reviewed, data-driven information on the effects of hydraulic fracturing

Concerns of a diverse urban community required a comprehensive study design
Environmental Baseline:

Urban growth overlain on Historic oil development

Venice Beach, California in 1930's
Los Angeles Basin is the richest in oil worldwide by size

A need for coexistence
Comprehensive Measurements before, during, and after hydraulic fracturing:

- Hydrogeology
- Water Use
- Water Quality
- Containment of Fractures
- Well Integrity
- Slope Stability
- Subsidence
- Ground Movement
- Induced Seismicity
- Methane
- Air Emissions
- Noise
- Vibration
- Community Health*

Results applicable to other parts of the world

www.eenews.net/assets/2012/10/11/document_ew_01.pdf
Hydraulic Fracturing of Shales

Geological Cross Section of Petroleum Deposits

- Conventional non-associated gas
- Coalbed methane
- Conventional associated gas
- Sandstone
- Seal
- Tight sand gas
- Oil
- Gas-rich shale
Fluids Used in Hydraulic Fracturing

Water and Sand: 99.51%

Other: 0.49%

Surfactant: 0.085%

KCl: 0.06%

Friction Reducer: 0.088%

Gelling Agent: 0.056%

Acid: 0.123%

Scale Inhibitor: 0.043%

pH Adjusting Agent: 0.011%

Breaker: 0.01%

Crosslinker: 0.007%

Iron control: 0.004%

Corrosion Inhibitor: 0.002%

Biocide: 0.001%

Oil Field consists of shales and sandstones, folded and faulted.
Nodular Shale: Fracturing Target
Newport-Inglewood Fault (Strike-Slip)

Thrust Faults

1 Mile
Newport-Inglewood Fault (Strike-Slip)

Normal Faults

Thrust Faults

1 Mile
Base of Fresh Water
Discontinuous Groundwater Lenses
Discontinuous Groundwater Lenses

Hydrocarbon Seal

1 Mile
The zone affected by hydraulic fracturing is approximately 2,500 m feet beneath fresh water (1 ½ miles).
Discontinuous Water Bodies
Newport Inglewood Fault
Pico Surface (Freshwater Base)
Vickers "H" Sand
Rindge Surface
Rubel Surface
Sentous Surface
Well 2 Microseismic
& Frac Model
Well 1 Microseismic Events & Frac Model

Nodular Shale: Target Zone
"... the Baldwin Hills [were modeled as a no-flow cell." (USGS 2003)

"The Baldwin Hills form a complete barrier to groundwater movement where the essentially nonwater-bearing Pico formation crops out." (DWR 1961)
Water Quality

- 2/3 of water for the vicinity of Oil Field comes from 560 km (350 miles) away
- Remainder is from sources greater than 1.5 miles away
- All public water is:
  - Tested quarterly and reported
  - Must meet drinking standards

Further Information: http://www.westbasin.org/water-reliability2020/groundwater/overview
Groundwater quality consistently meets drinking water standards, before and after hydraulic fracturing.
Ground Movement and Induced Seismicity

- Microseismic effects: Richter M 0.01 to 0.001
- Insufficient to induce tectonic earthquakes
- Tectonic quakes have deeper source

- Induced seismicity linked to injection at few sites
- Field has operated a water flood since 1971 without seismicity
Oklahoma seismicity linked to wastewater injection into deep formation overlying crystalline basement

- Large volumes of produced water injected into Arbuckle formation, overlying crystalline basement.
- Increased fluid pressure penetrates already-stressed existing faults in crystalline basement.
Methane Migration

- Oil Field is adjacent to known “Methane Zone”
- Methane in shallow soil gas is biogenic
- Methane detected in groundwater has been thermogenic
- No change due to hydraulic fracturing
Measurements before, during, and after hydraulic fracturing did not detect effects to:

- Hydrogeology
- Water Use
- Water Quality
- Containment of Fractures
- Well Integrity
- Slope Stability
- Subsidence
- Ground Movement
- Induced Seismicity
- Methane (soil gas and groundwater)
- Air Emissions
- Noise
- Vibration
- Community Health*

Study Provides Data-Rich Source Responding to Public Concerns
Application of the Study So Far

• First Study to address all environmental concerns of hydraulic fracturing quantitatively; finding no new adverse effects compared to current oil and gas operations

• Local public agency with jurisdiction over the Oil Field did not require additional protective measures for hydraulic fracturing
California Council on Science and Technology (Tormey co-lead):

- **Effects of Hydraulic Fracturing are Small and Manageable**

- **Indirect effects of oil and gas development warrant further study and regulation**
Review Draft

Minor effects to water supply and water quality
Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation
Visit SPE.org/dl