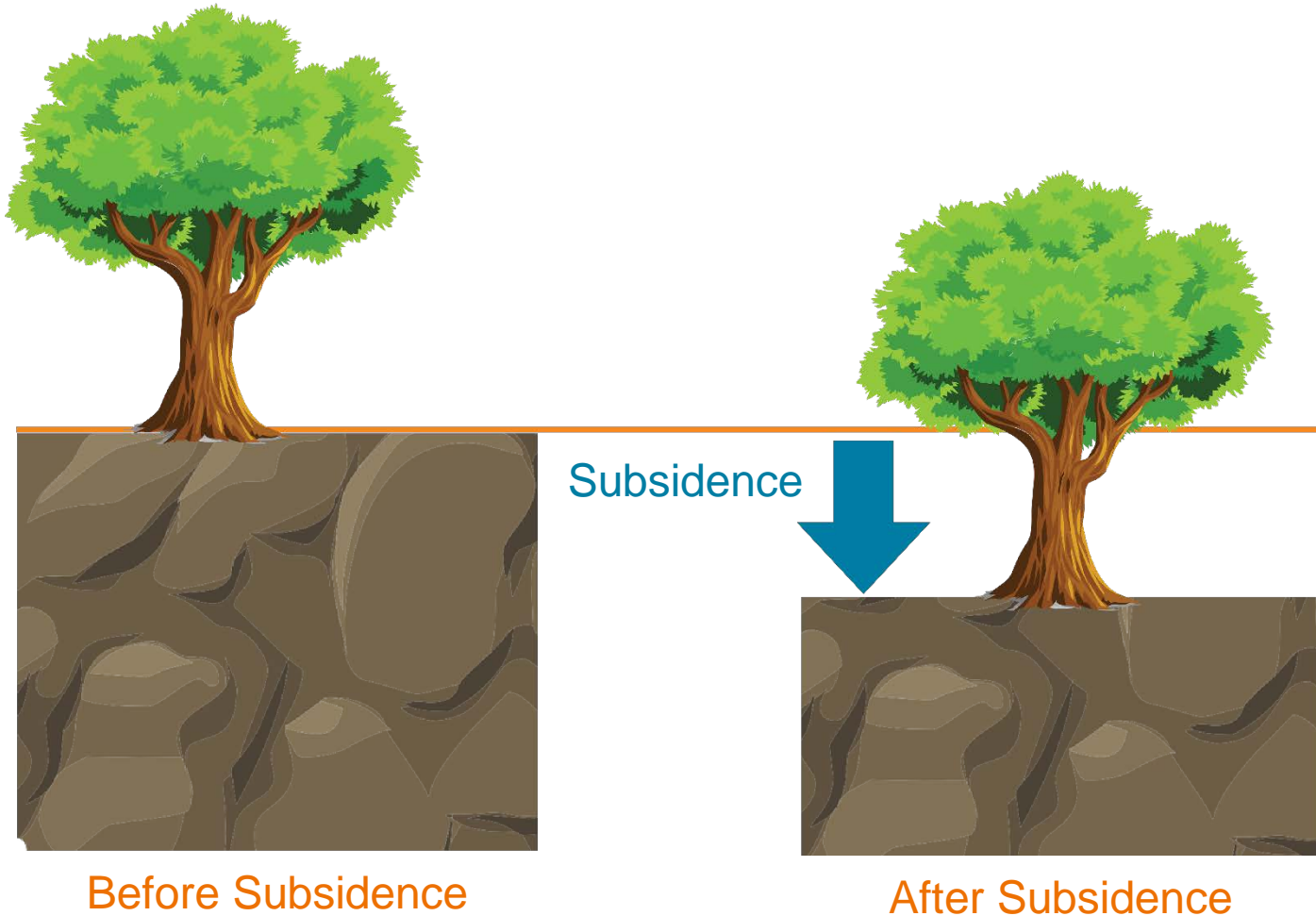




Informational Mini-Series:

**How Will the LADWP
Prevent Land
Subsidence at
Owens Lake?**

Subsidence is ground sinking because of underground compaction



Subsidence is most often caused by:

What causes Subsidence?

Pumping of fluids out of the ground



A Slow Process

Major earthquakes



A Rapid Process

Soil compaction



A Rapid Process

Subsidence due to pumping is typically a *slow* process, whereby fluid pressure between sediment particles is reduced, causing soil particles to compact



Before Subsidence



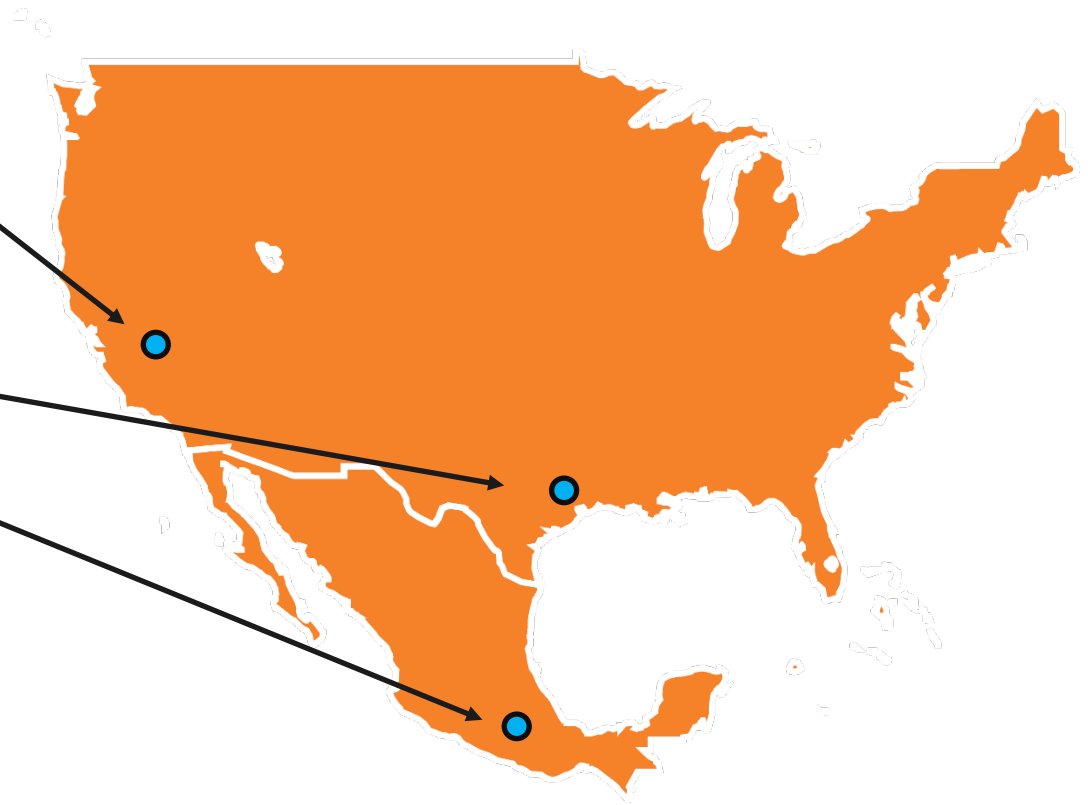
After Subsidence

Well-known cases of subsidence: how did they happen?

1) Central Valley, California

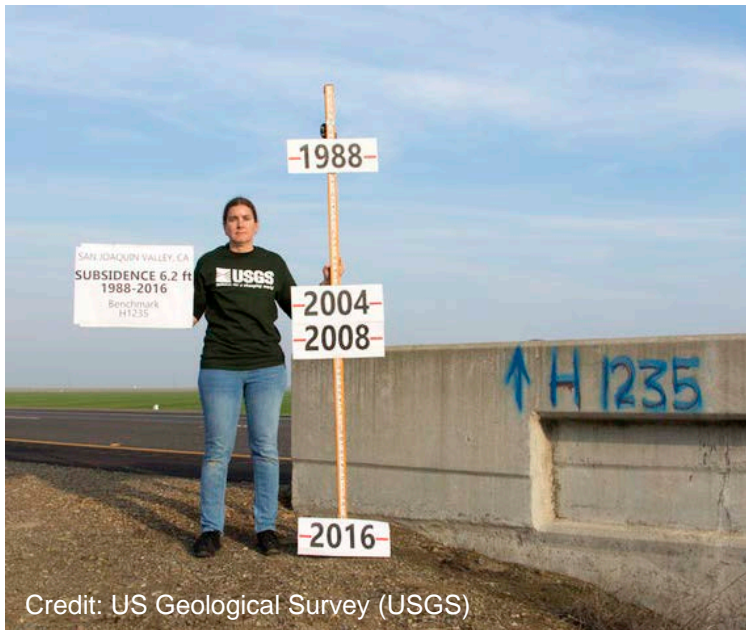
2) Houston, Texas

3) Mexico City, Mexico



1. Central Valley of California

- **Pumping Since:** 1920's
- **Amount of Subsidence:** Up to 30 feet
- **Contributing Causes:** Unregulated & excessive agricultural pumping - average of 2 million acre-feet per year



Credit: US Geological Survey (USGS)

USGS Worker Demonstrating 6.2 Feet of Subsidence in 28 Years



Credit: Brian van der Brug

Rupture of Canal in the Central Valley due to Subsidence

2. Houston, Texas

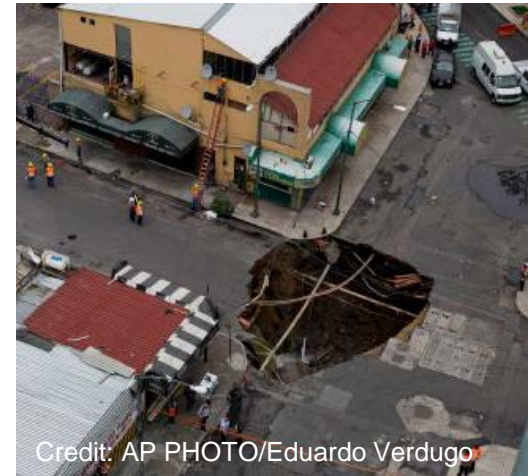
- **Pumping Since:** Early 1900's
- **Amount of Subsidence:** Up to 10 feet
- **Contributing Causes:** Unregulated groundwater withdrawals up to 500,000 acre-feet per year



Buckled Sidewalk and Water Well Pump Foundation Pushed Up Relative to the Surrounding Ground By Subsidence

3. Mexico City, Mexico

- **Pumping Since:** Early 1800's
- **Amount of Subsidence:** 32 feet
- **Contributing Causes:** Skyrocketing population and corresponding groundwater pumping for supply (800, 000 acre-feet per year)



Sink Hole in the Street (top), Buckled Sidewalk (left) and Leaning Historical Buildings Due to Subsidence

Common conditions that are present for large-scale subsidence to occur due to groundwater pumping:

1. **Thick subsurface layers** of compressible sediments such as organic deposits (peat) or clay*
2. **Large declines** in groundwater levels due to pumping (generally greater than 50 feet)
3. Continuous pumping for **long periods of time** (years or decades)

** Clay and organic materials are much more susceptible to compaction (causing subsidence) than gravels or sand because there is a higher percentage of fluid between individual soil particles prior to compaction*

Does subsidence always occur with changing groundwater levels?

No, there are many examples of groundwater basins that have varying groundwater levels in which subsidence has not be observed.

In fact, varying groundwater levels are a common groundwater management technique, whereby the aquifer is utilized for storage *similar to a surface reservoir*



Subsidence in the Owens Valley has not been observed

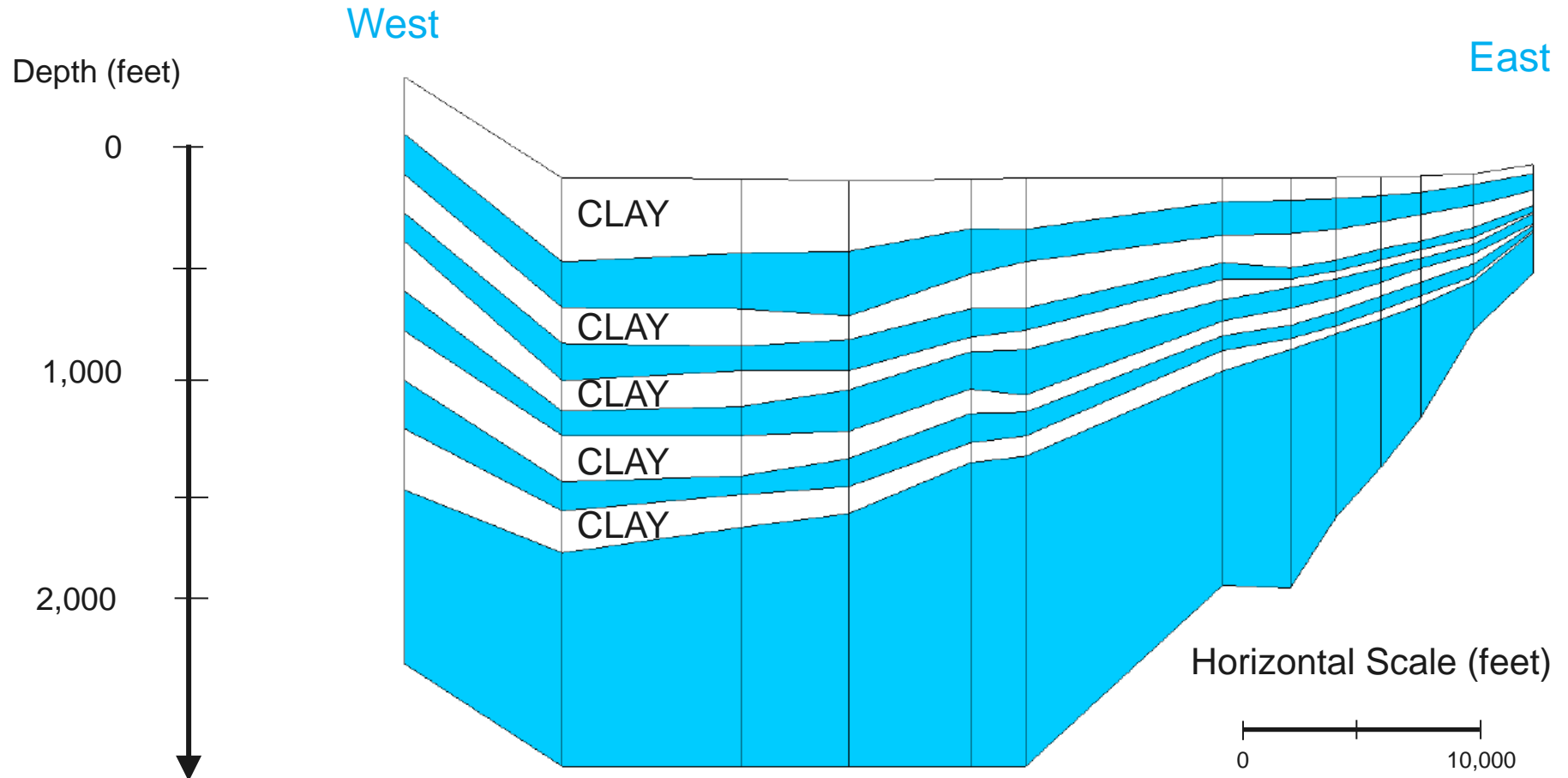
While:

- Groundwater pumping in the Owens Valley has occurred since the 1920s (and more extensively since the early 1970's)
- Pumping has been very well managed to prevent long-term groundwater level decline
- Compressible clay lenses are relatively thin and discontinuous



Is subsidence possible at Owens Lake?

Yes, it is possible because of the thick sequences of clay present beneath the lake



How will LADWP prevent subsidence at Owens Lake?

1. Implement smart management of groundwater pumping using Resource Protection Protocols (RPPs) with tiers to provide early warning
2. Utilize intermittent (non-continuous) pumping
3. Conduct careful monitoring for subsidence and modification of pumping if measurable subsidence is observed

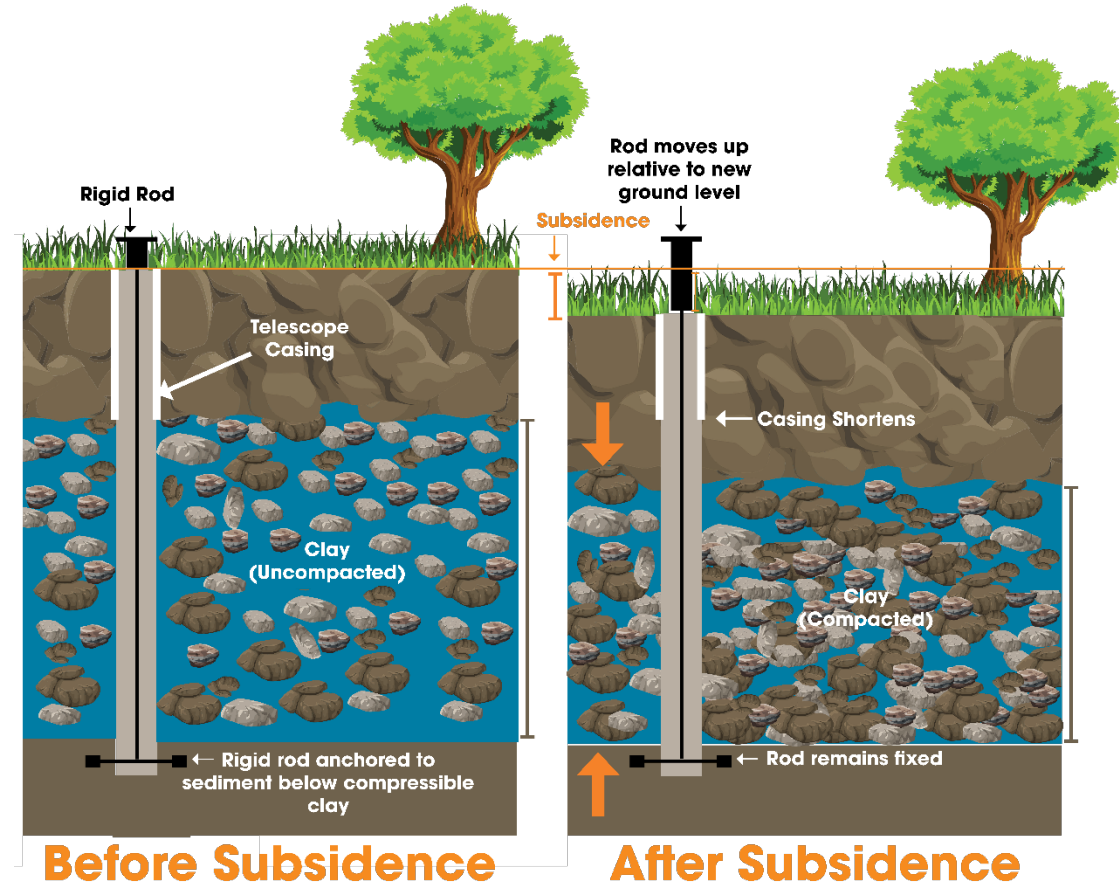
How will subsidence be monitored?

How to Monitor and Prevent Damage from Subsidence



Global Positioning System (GPS) Surveys

Land surface elevation monitoring using a global positioning network of survey points



Extensometers

Extensometers can measure subsidence with an accuracy of less than one inch

LADWP's goal is to prevent damaging subsidence at Owens Lake

Subsidence at
Owens Lake

Pumping will be limited to relatively low rates to observe how the environment reacts

1. Careful monitoring and adherence to RPPs

1. Cessation of pumping if evidence of subsidence is observed based on "early warning" monitoring to prevent undesirable results

For Further Information:

For any questions, comments, or suggestions,
please contact Dr. Saeed Jorat at:

Saeed.Jorat@LADWP.com