Land Subsidence Monitoring, San Joaquin Valley

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Land Subsidence in the San Joaquin Valley Aquifer-System Compaction

- Concentrated in the fine-grained deposits (clays/silts)
- Inelastic (permanent) compaction occurs when the critical head is exceeded
- Critical head ≈ previous lowest groundwater level
- Storage capacity is reduced
Groundwater Level Declines

Water level data from USGS and Luhdorff and Scalmanini Consulting Engineers; Preliminary and subject to revision.
Clay-Rich Aquifer Systems

clay
silt
sand
gravel
soils
Subsidence Monitoring

► Can result in early detection
► Provides a measure of water-resources sustainability within relevant planning horizons
► Produces data needed for subsidence management
Subsidence Measurements: Space and Time

Spatial Resolution

• One to Several Points
  – Borehole Extensometer*

• 10’s of Points
  – Spirit Leveling
  – GPS (RTK/static/continuous)

• 1000’s-1,000,000’s of Points
  – InSAR (space and airborne)
  – LiDAR
  – Radar Altimetry

Temporal Resolution

• <Several measurements/year
  – Spirit Leveling
  – GPS (RTK, Static)

• Several measurements/year
  – InSAR (space and airborne)
  – LiDAR
  – Radar Altimetry

• 1000’s measurements/year
  – Borehole Extensometer*
  – GPS (continuous)

* Measures aquifer-system compaction
InSAR: High Spatial Resolution

CGPS: High Temporal Resolution

Focus limited resources

CGPS data from UNAVCO; survey data from DWR
Extensive withdrawal of groundwater caused widespread subsidence (1920s-1970)

Surface-water deliveries caused widespread recovery and slowing or cessation of subsidence, except when deliveries were curtailed and groundwater pumping increased to meet demand.

Galloway and others, 1999; USGS Circular 1182
Recent Subsidence

- Renewed subsidence concern during the 2007-09 drought initiated investigations
  - Reduced surface water importation
  - More reliance on the groundwater resources
  - As it turns out...this is not just a problem during droughts for some areas with limited surface-water access

CGPS data from UNAVCO; water level data from DWR, USGS, and Luhdorff and Scalmanini Consulting Engineers
Historical Subsidence

EXPLANATION

Selected water conveyance features.

Land Subsidence (1926-70)

Feet

1 - 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 24
24 - 28
> 28

0 10 20 40 Miles

0 10 20 40 Kilometers

USGS

science for a changing world
Water Conveyance Infrastructure

EXPLANATION
- Selected water conveyance features

Land Subsidence (2008-10)
- Inches
  - 1, Estimated
  - 1 - 2
  - 2 - 4
  - 4 - 6
  - 6 - 11
  - 11 - 16
  - 16 - 21
  - > 21

- California Aqueduct
- Eastside Bypass
- San Joaquin River
- Delta-Mendota Canal

Merced
Madera
Periodic Leveling/GPS Surveys

Eastside Bypass

Survey data from Bureau of Reclamation
Periodic Leveling/GPS Surveys

Eastside Bypass

Survey data from Caltrans, Bureau of Reclamation, and DWR
Continuous GPS Stations in CA

http://www.unavco.org/instrumentation/networks/status/pbo

http://sopac.ucsd.edu/map.shtml
Continuous GPS Time Series

CGPS data from UNAVCO and SOPAC

Rate increases during droughts

P303

P304

P307

Subsidence only during droughts
Continuous GPS Time Series

CGPS data from UNAVCO and SOPAC
Continuous Compaction: Extensometers

Data are preliminary and subject to revision
Extensometer and water-level data from USGS and Luhdorff and Scalmanini Consulting Engineers
Continuous Compaction: Extensometers

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Extensometer and water-level data from USGS and Luhdorff and Scaimmanini Consulting Engineers
Compa ction Depths (Mendota)

- Extensometer is anchored in the top of Corcoran Clay
- GPS reflects subsidence relative to the center of the Earth
- GPS measured much more deformation than the extensometer

**Conclusion:** most of deformation is occurring below the top of the Corcoran Clay

CGPS data from UNAVCO; extensometer data from Luhdorff and Scalmanini Consulting Engineers and USGS
Recoverable or Permanent?

**Compaction & Groundwater Levels above the Corcoran Clay**
- Water levels have remained above the critical head except for a short period in 2016
  - Likely mostly recoverable

**Subsidence & Groundwater Levels below the Corcoran Clay**
- Water levels have remained below the critical head
  - Likely mostly permanent

GPS data from UNAVCO; water level and extensometer data from Luhderff and Scalmanini Consulting Engineers and USGS.
Subsidence Monitoring Summary

- Measuring subsidence/compaction AND groundwater levels is essential to understanding aquifer-system behavior
  - Estimate critical head and aquifer-system storage properties (model input)

- High spatial resolution of subsidence provided by InSAR data can help focus monitoring resources
  - Design ground-based networks to improve temporal resolution

- High temporal resolution of subsidence provided by continuous GPS or extensometers can help managers determine how various management strategies affect subsidence (decision support)

- Extensometers are the only measurement technique that will indicate depth intervals of compaction
  - Understanding compacting intervals is critical in subsidence management
Thanks!

For more information:

http://ca.water.usgs.gov/land_subsidence/