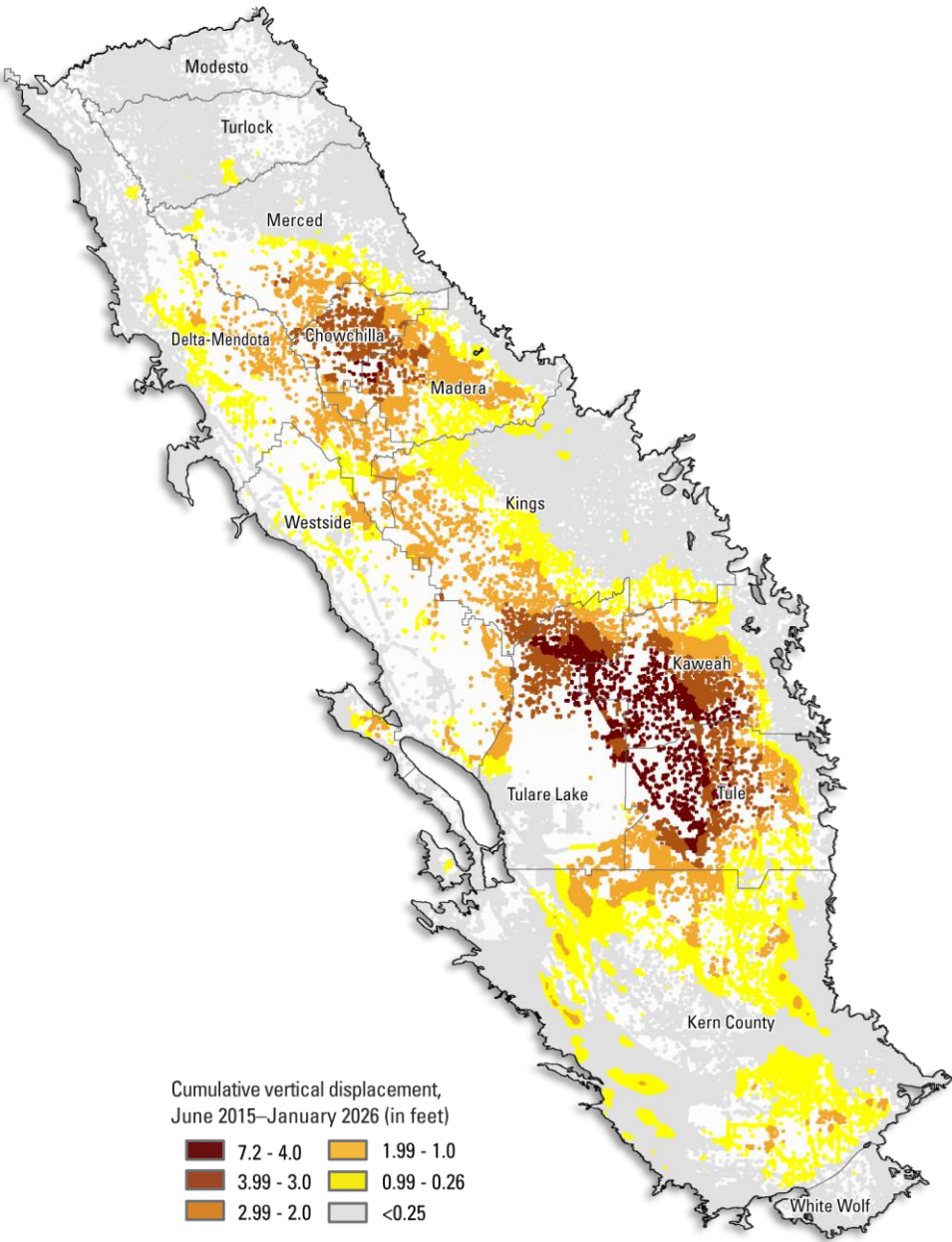


Critical Heads, Critical Decisions:

Subsidence and Critical Head Trends in the Central Valley

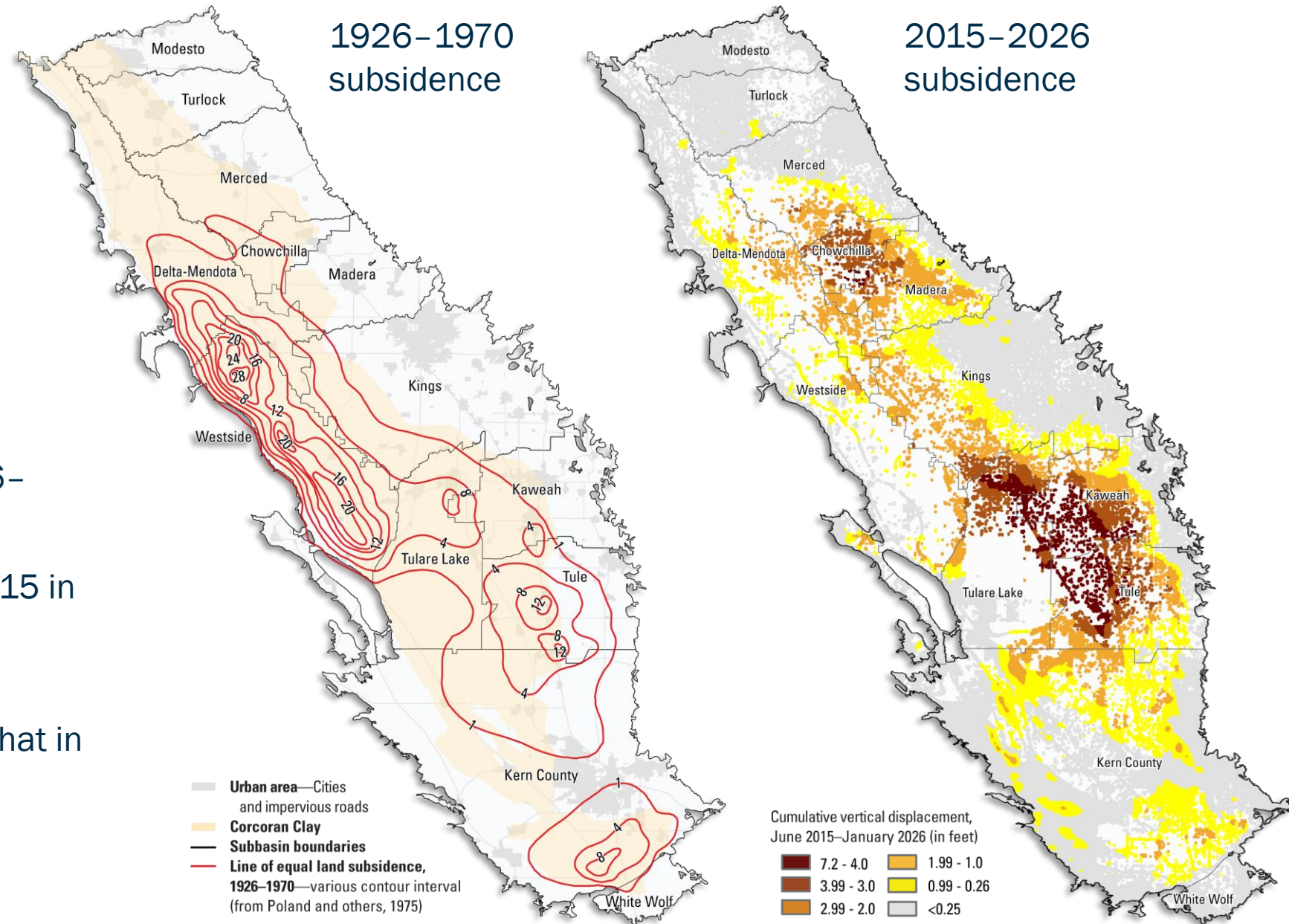
John Ellis, PG
Leila Saberi, PhD



The subsidence problem

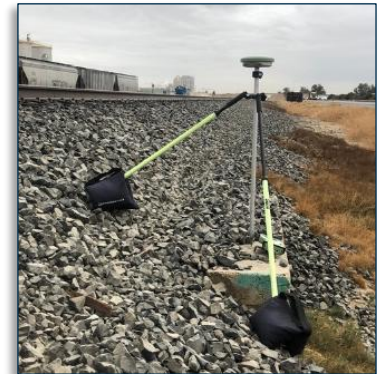
California's San Joaquin Valley

- Land subsidence, driven predominantly by groundwater extraction, presents complex challenges for many areas of California.
- 28 feet of subsidence from 1926–1970 in some locations
- 7.0+ feet of subsidence since 2015 in some locations
- How much total subsidence has happened? We'll have a look at that in a bit.



Why does the long-term data matter?

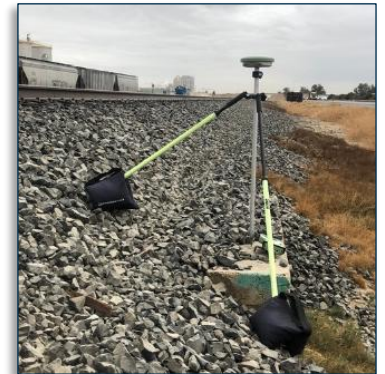
- The long-term stress history of aquifer system can influence present day subsidence
- Provide a better estimate of critical head
- Provides context for the 2015–present subsidence rates
- Provide an estimate of residual compaction from previous periods
- Better constrain model parameters during calibration...more on this in the next presentation



Assessing Subsidence

How do we construct a long-term picture of subsidence?

- Combine subsidence data (InSAR, GPS, leveling, extensometers)
- Analyze groundwater level data in nearby area
- Correlate subsidence and groundwater level trends

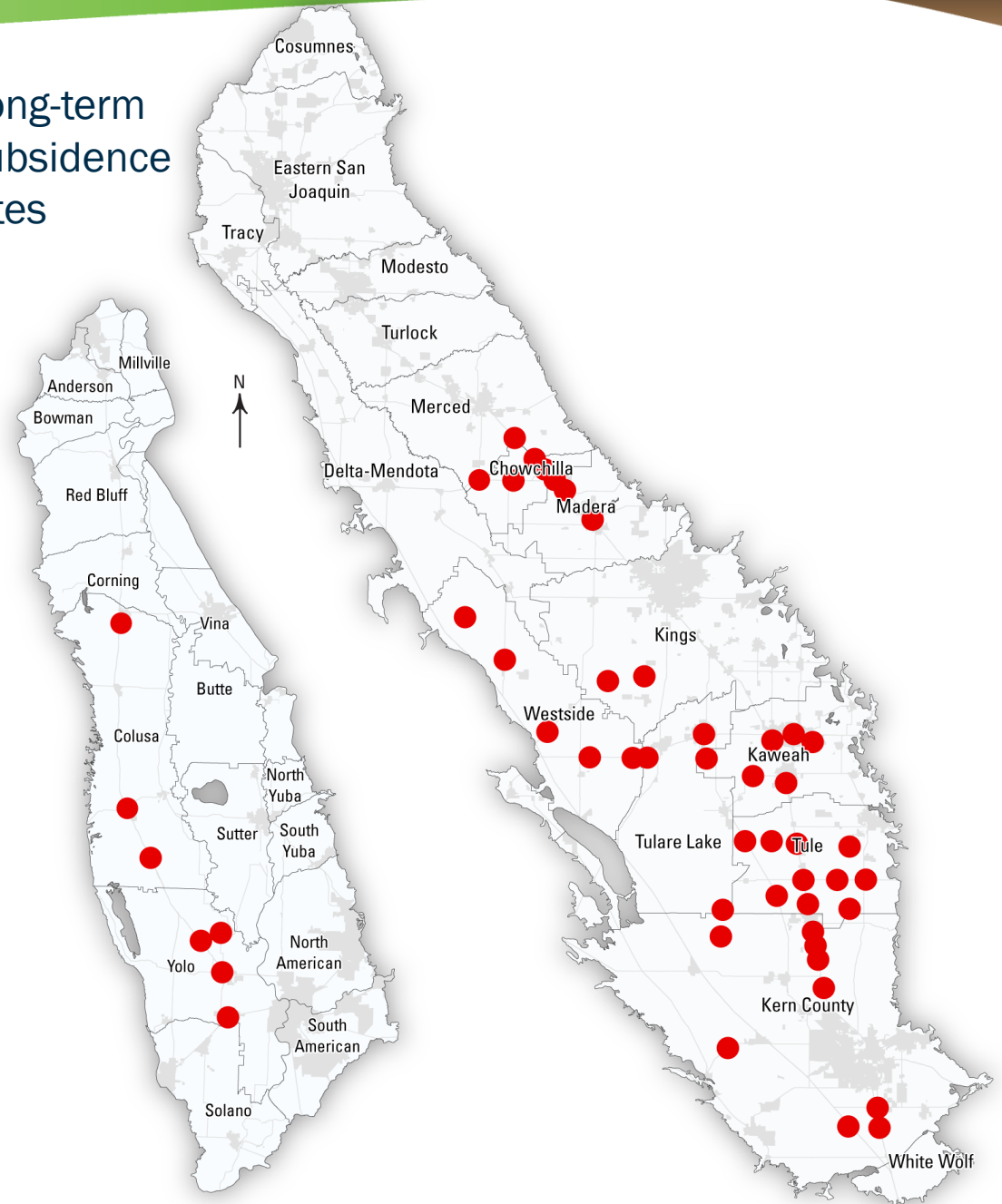


Subsidence Methods

Data Analysis

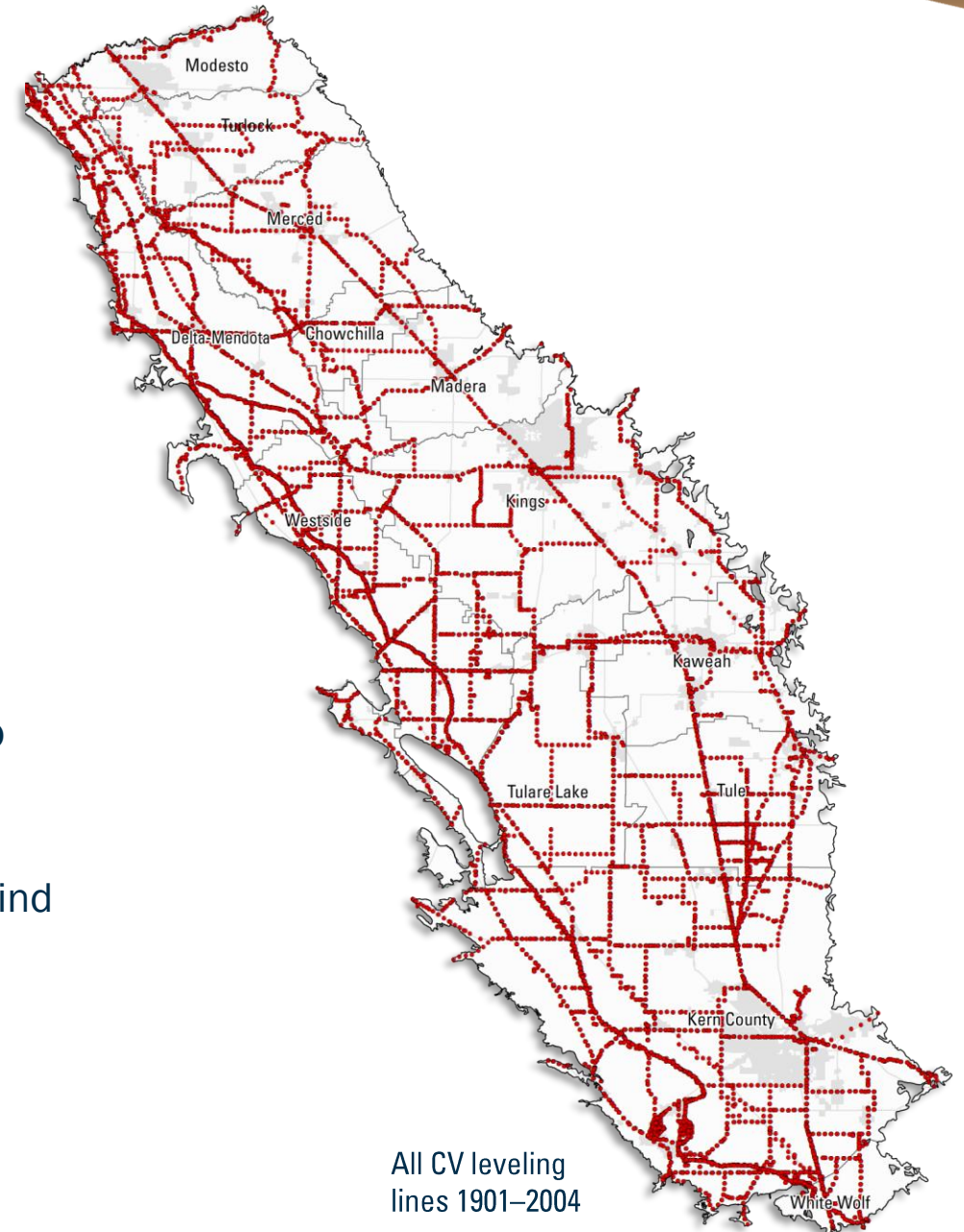
- Picked 50 sites in the Central Valley—availability of long-term subsidence and GWL data
- Combined leveling, GPS, InSAR, extensometer data into a long-term time series
- Process water levels from wells in ~3 mi radius around long-term sites from various depth intervals
- Correlate water level and subsidence trends

Long-term
subsidence
sites



Leveling Data

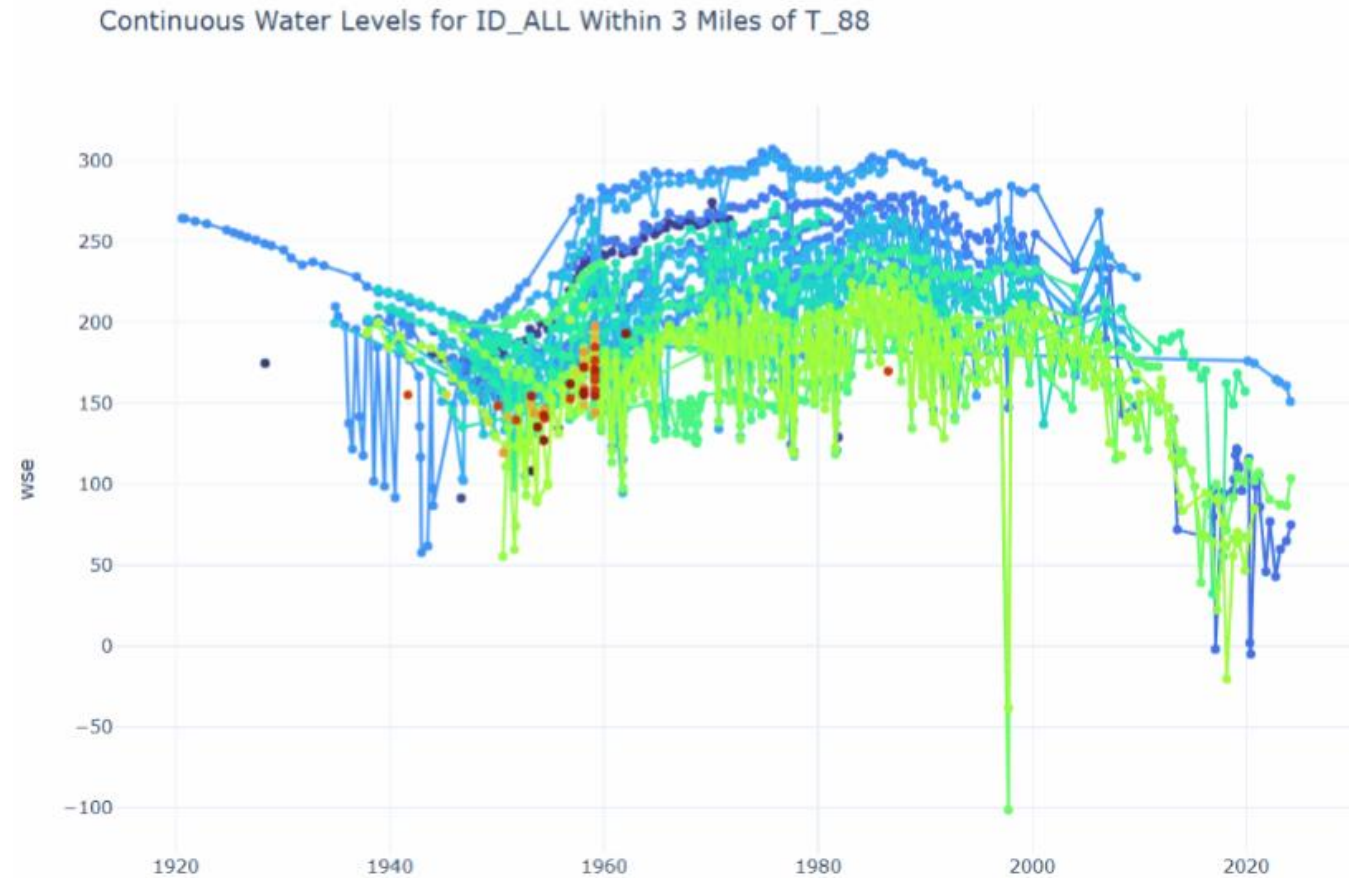
- A lot of benchmark elevations collected historically—mostly from NGS, USGS, Caltrans, USBR. The basis for long-term subsidence estimates for the 50 long-term sites
- Carry elevation from a known reference point to other points using telescope and leveling rod. Difference of elevations at the same benchmark through time = subsidence record.
- NGS unadjusted elevations (field heights) not easily useable due to floating lines, where a leveling line began in a subsiding area.
- Must either start from scratch and adjust to a common (stable) mark or find the NGS paper files. Here, we did both.



All CV leveling
lines 1901–2004

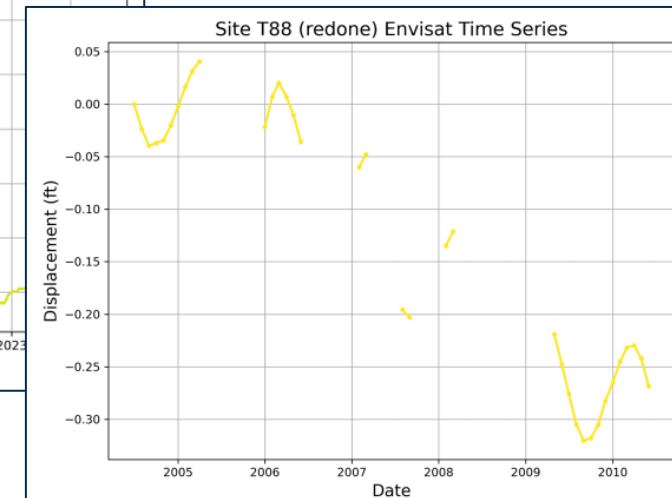
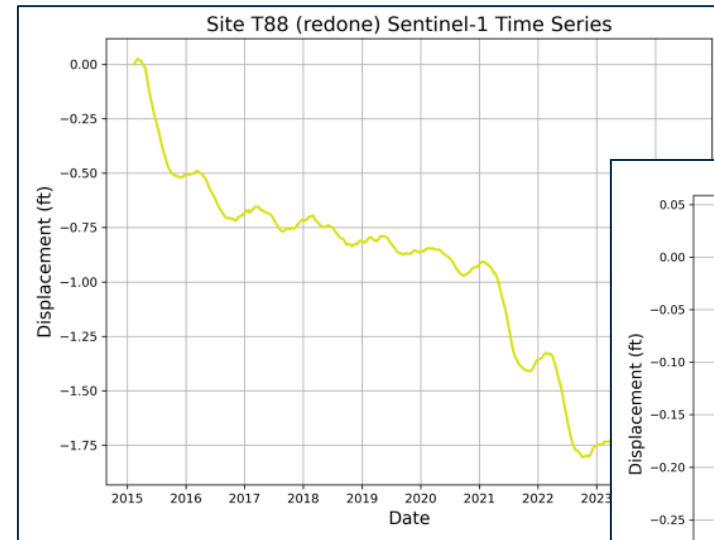
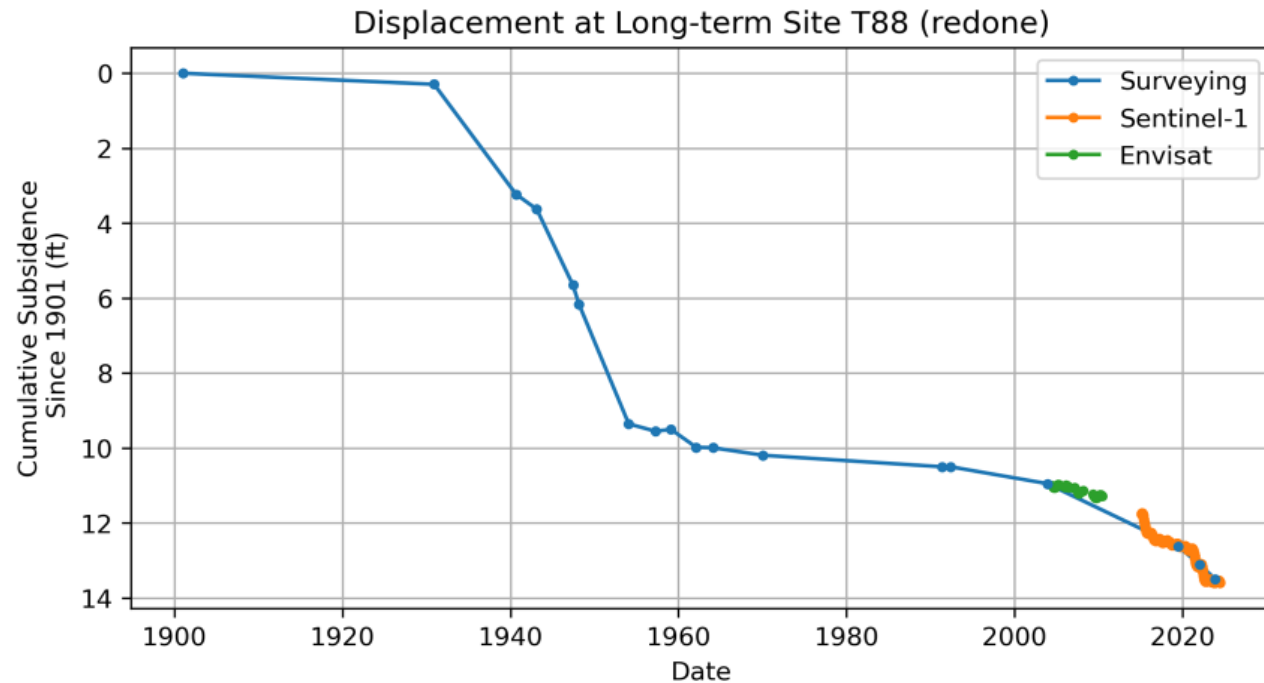
Water Level Data

- Correlated water level patterns across 1,000+ feet vertically in many areas
- Can see correlated trends across larger areas—can often capture local trends from wells generally in a 2-3 miles radius



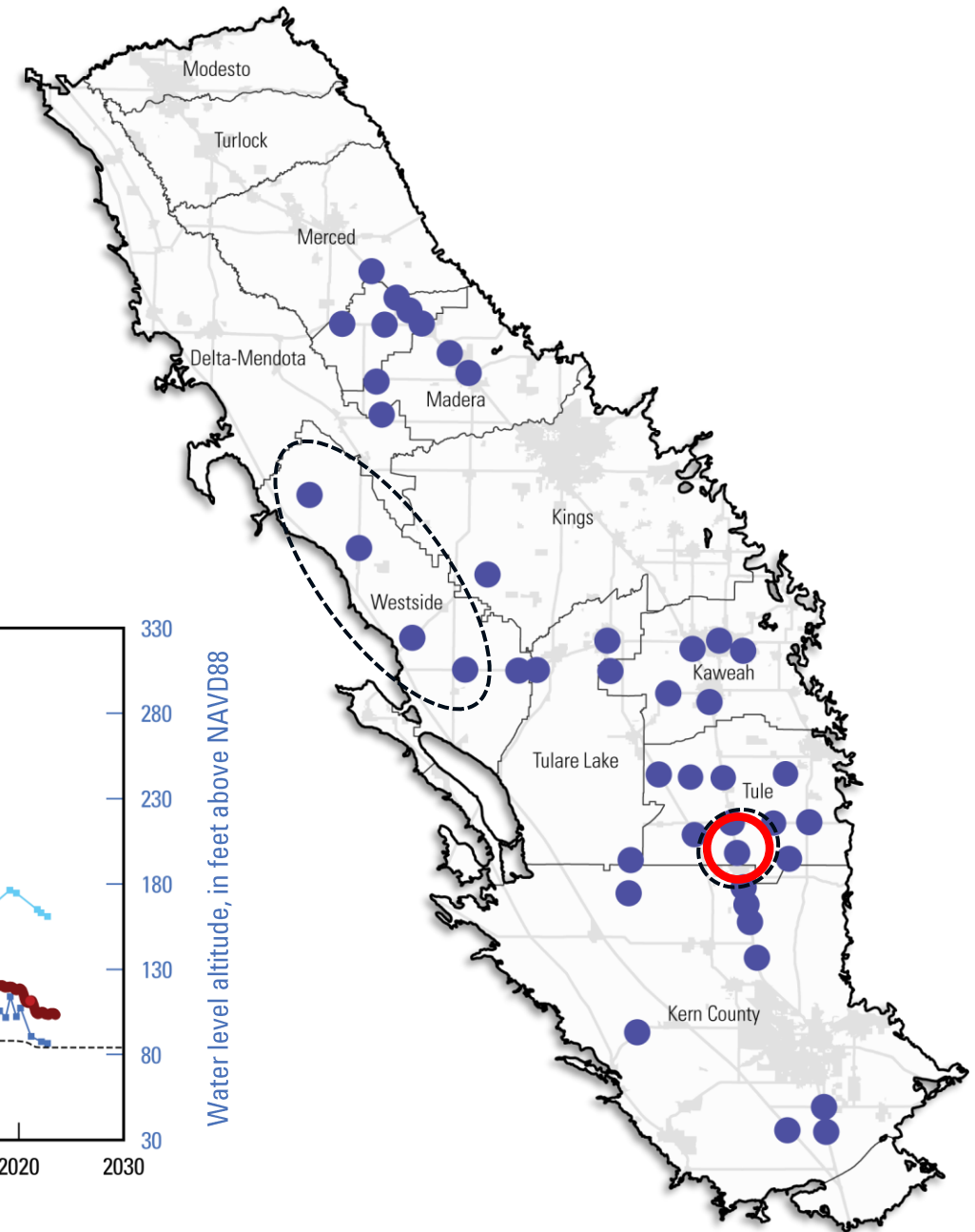
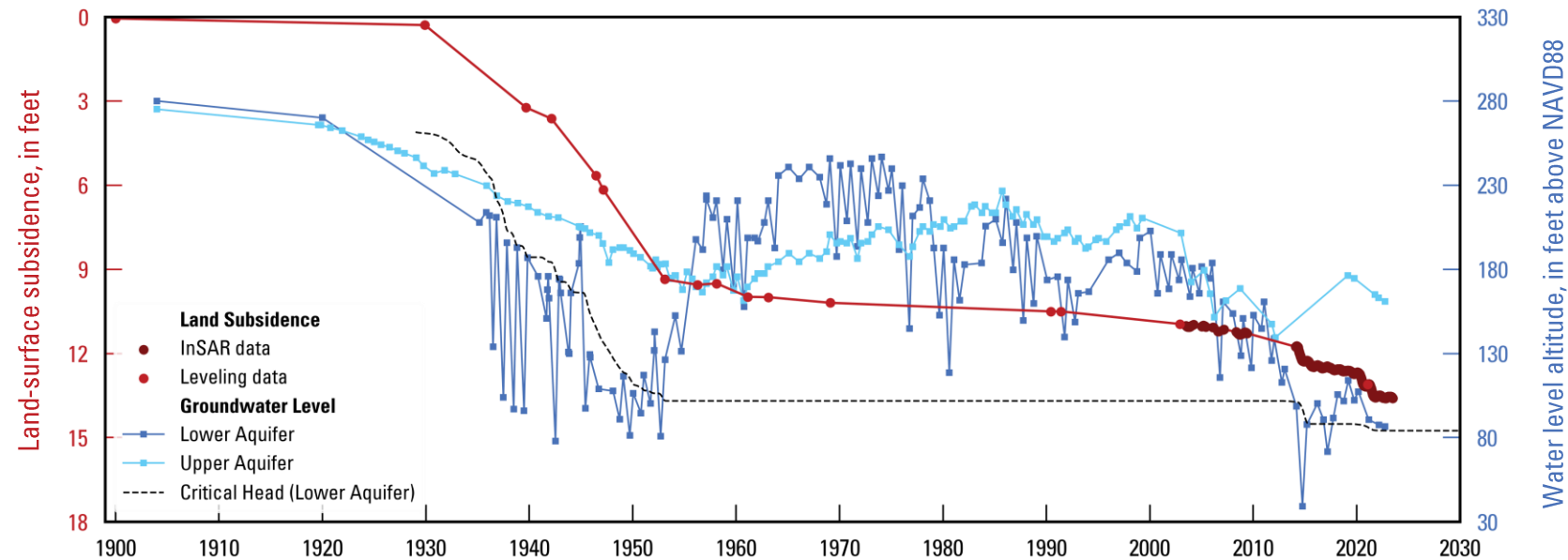
InSAR and GPS Data

- InSAR (2003-2010 and 2015 to present—monthly datasets)
- For cumulative time series, the InSAR data is registered to cumulative subsidence at known leveling measurement.
- Shift InSAR timeseries to align with interpolated or measured leveling values.
- Similar approach used to process GPS data from UNAVCO



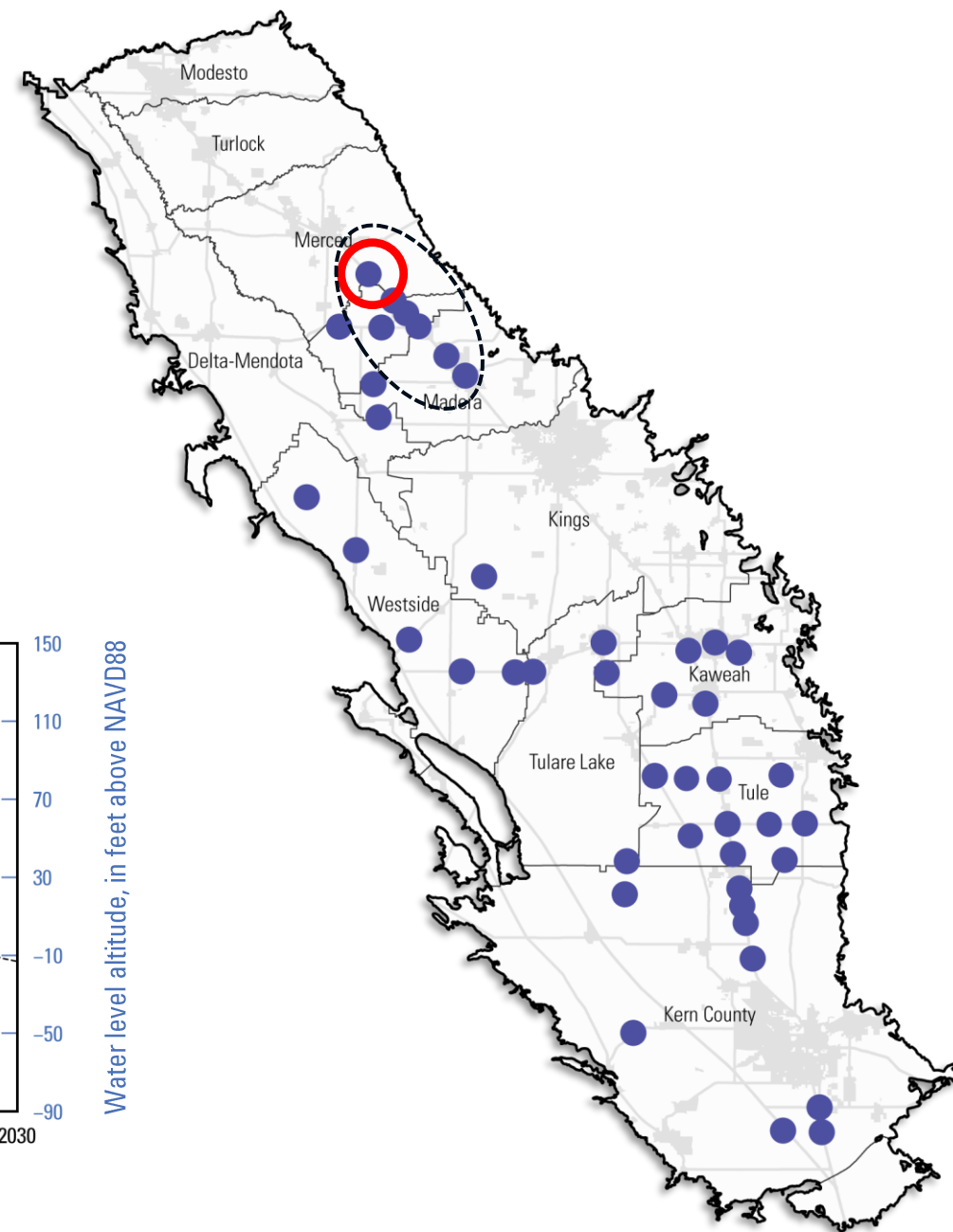
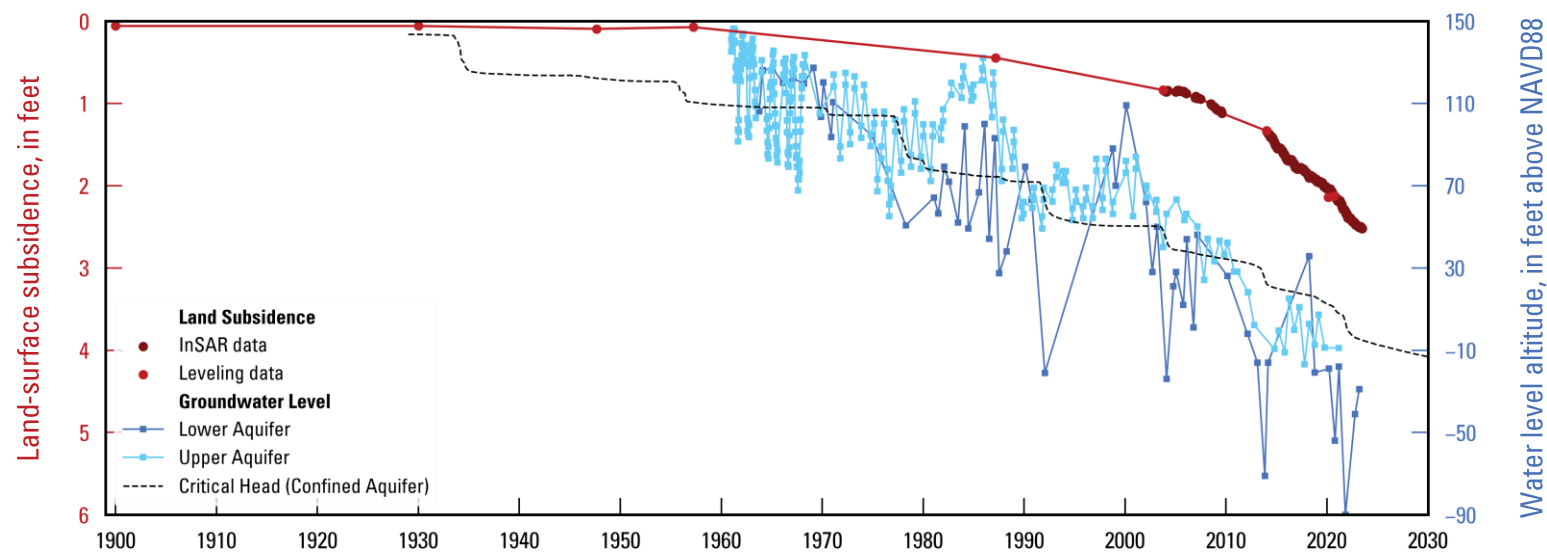
Subsidence Record

- 13.5 feet of subsidence, epicenter of subsidence in CA prior to 1953.
- Not much subsidence since 1953...why?
 - Large groundwater level recovery after 1953
 - Large critical head declines <1953
 - These two items created a water level buffer



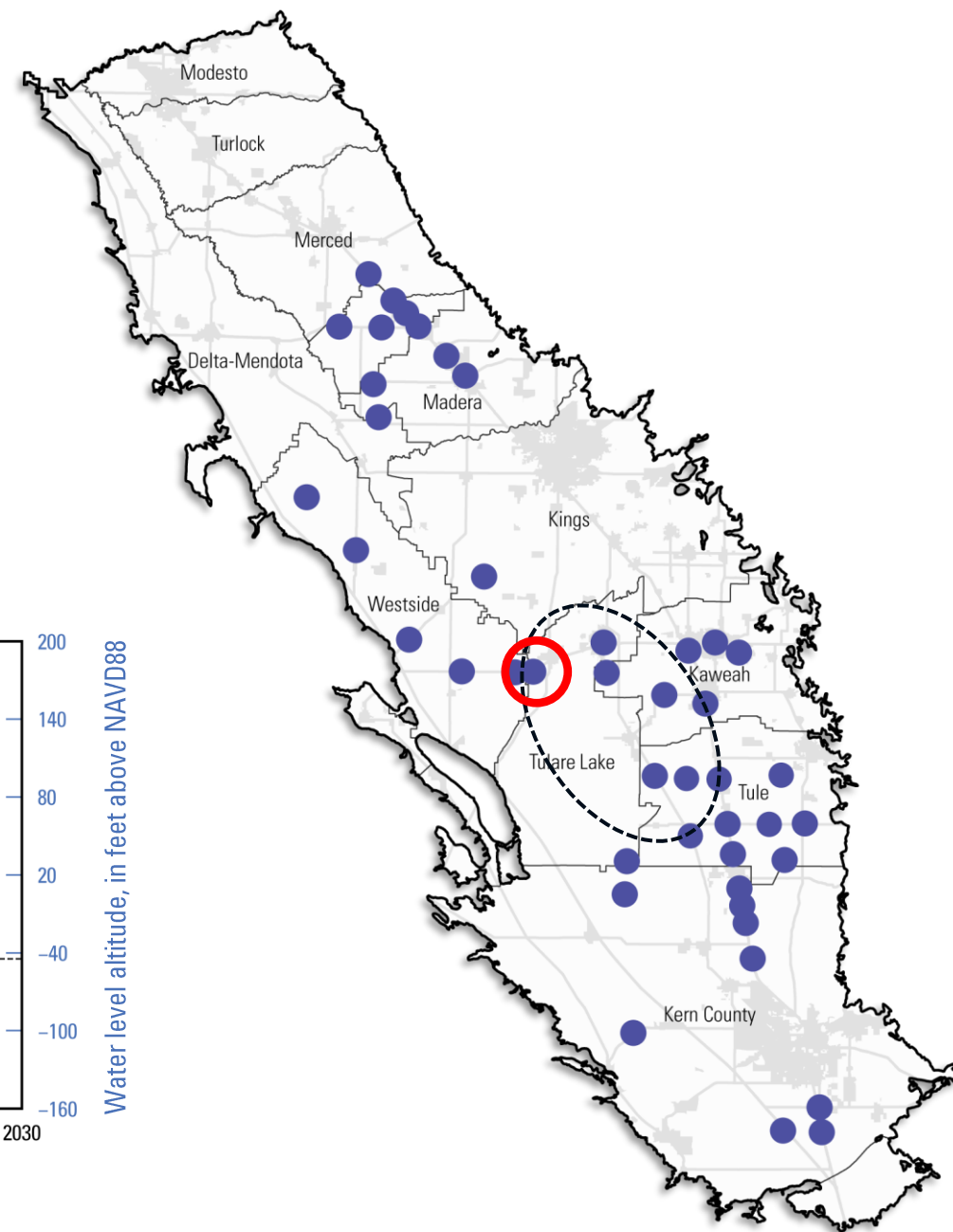
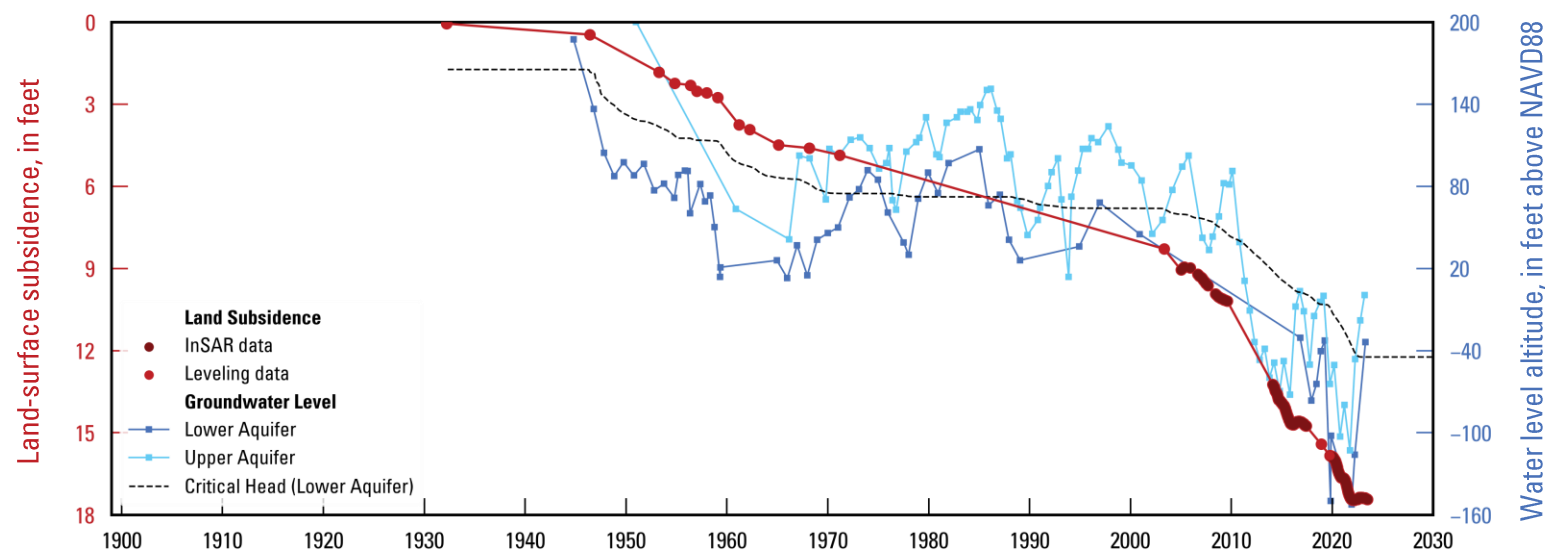
Subsidence Record

- 2.5 feet of subsidence, 0.9 ft subsidence prior to 2008
- More rapid subsidence rate since ~2005...why?
 - Large groundwater level declines and reaching new lows continually
 - Critical head continually getting exceeded



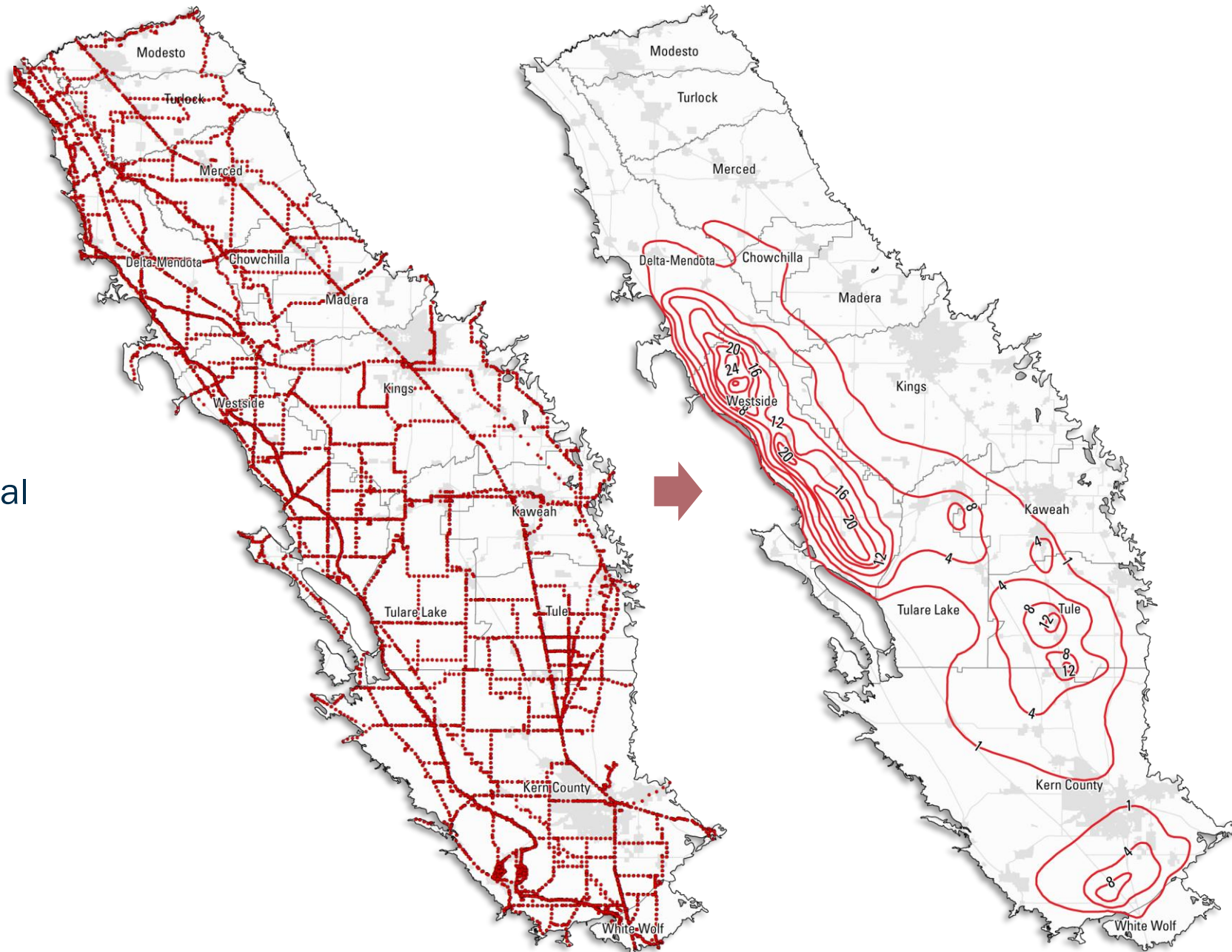
Subsidence Record

- 17.8 feet of subsidence, ~5 feet by 1970
- More rapid subsidence rate since ~2005...why?
 - Large groundwater level declines and reaching new lows continually
 - Critical head continually getting exceed until very recently—then sharp GWL rebound



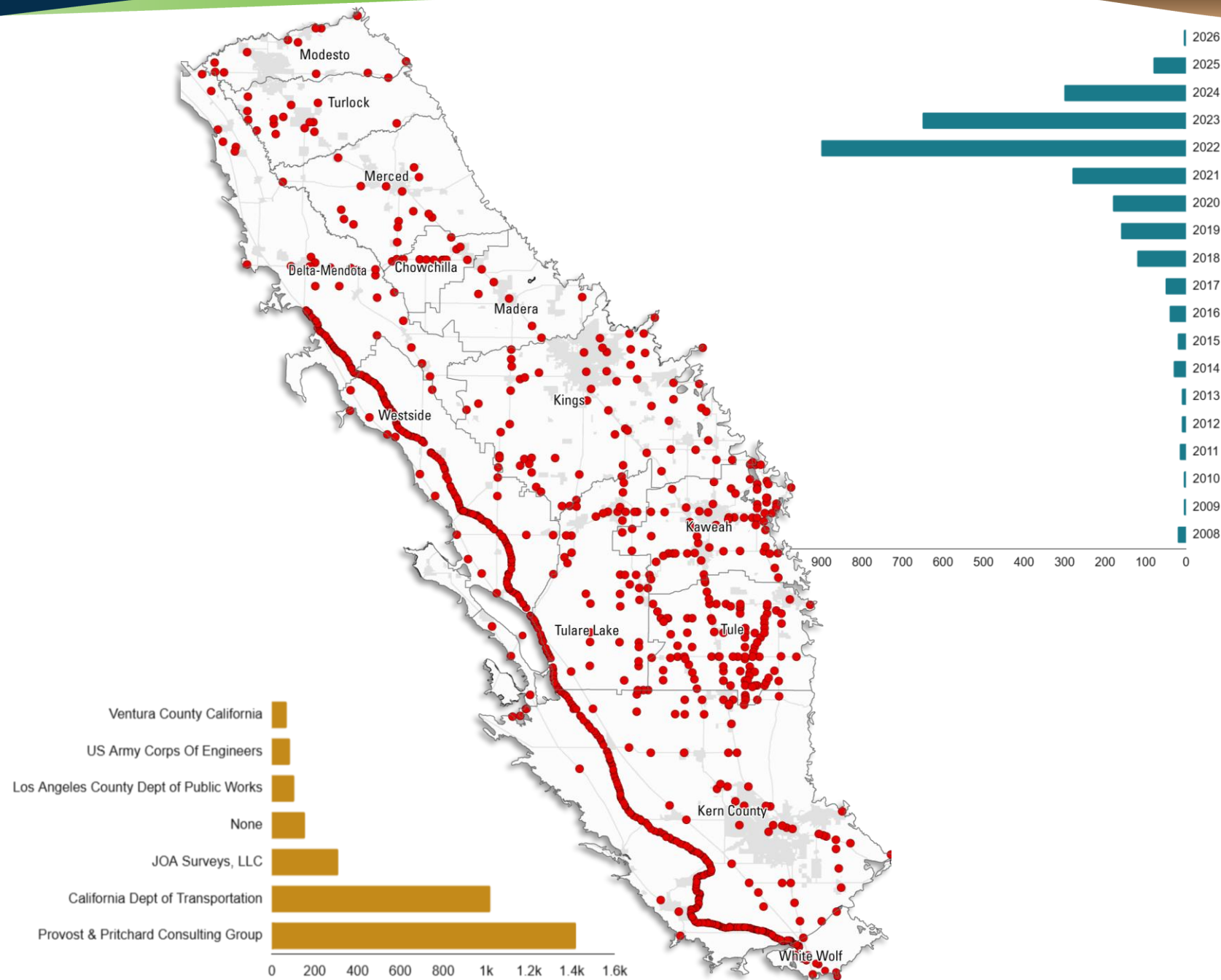
Cumulative Subsidence

- A lot of benchmark elevations collected historically—mostly from NGS, USGS, Caltrans, USBR
- USGS made 1926–1970 subsidence contours from historical data (Poland and others, 1975)
- Create raster of 1926–1970 subsidence contours



Leveling and GPS Data

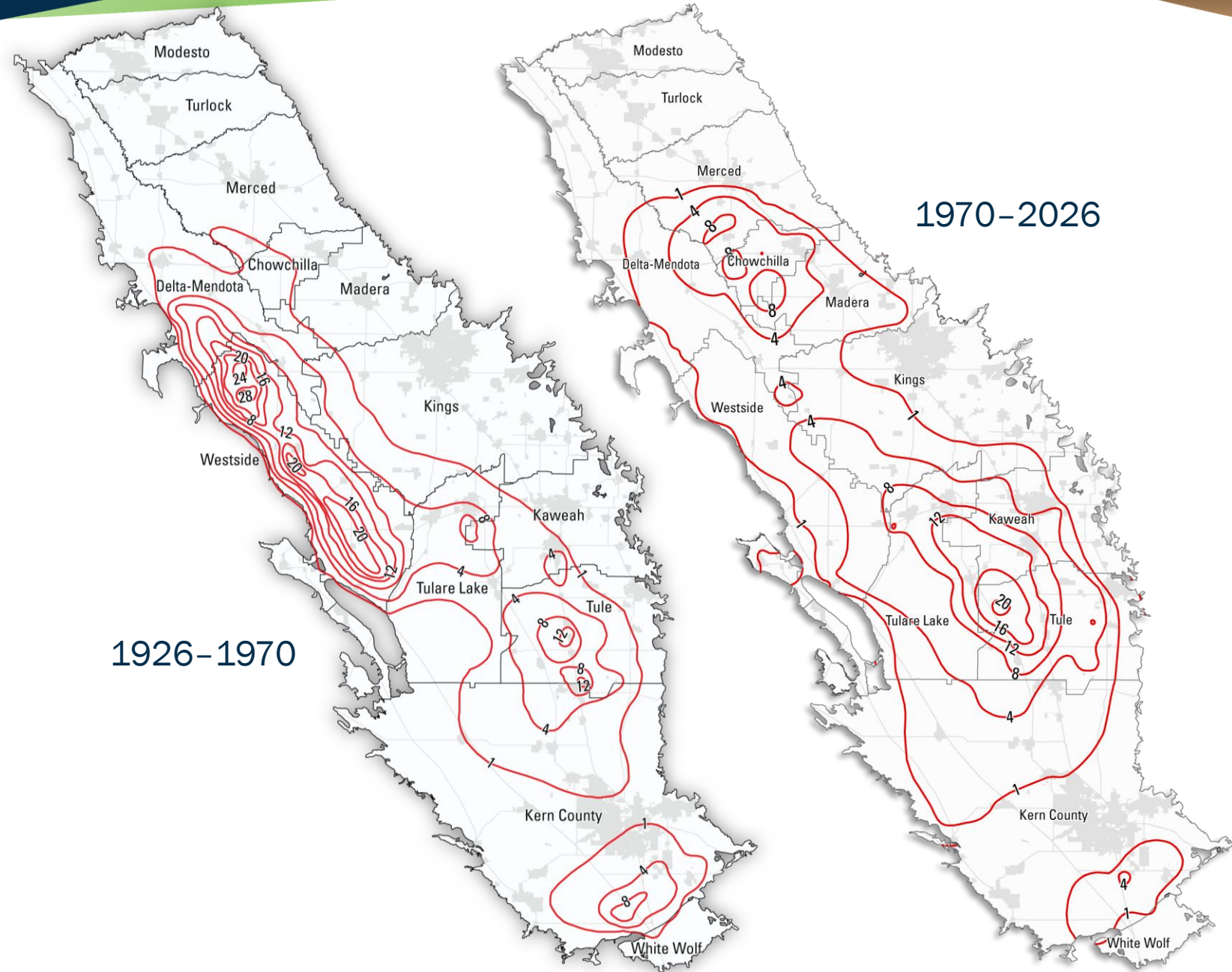
- Over 700 benchmarks recovered and resurveyed since 2015 included in the OPUS database
- Detailed subsidence studies along the CA Aqueduct from CASP program (another ~660 marks).
- Historical elevations adjusted to common (stable) benchmarks to make data useable
- Combine point data with 1926–1970 subsidence from raster
- Old resurveyed 1920s and 1930s benchmarks used as control points.



The subsidence problem

The changing locations of land subsidence

- Up to 28 feet of subsidence from 1926–1970 in Westside, but no longer the subsidence hotspot
- Subsidence has shifted northeast to Madera and Chowchilla and continued in the Tule Subbasin
- Maximum subsidence since 1970 (20 feet) has occurred in the northwest Tule Subbasin
- Land area inside 1-ft subsidence contour: 4,300 mi²



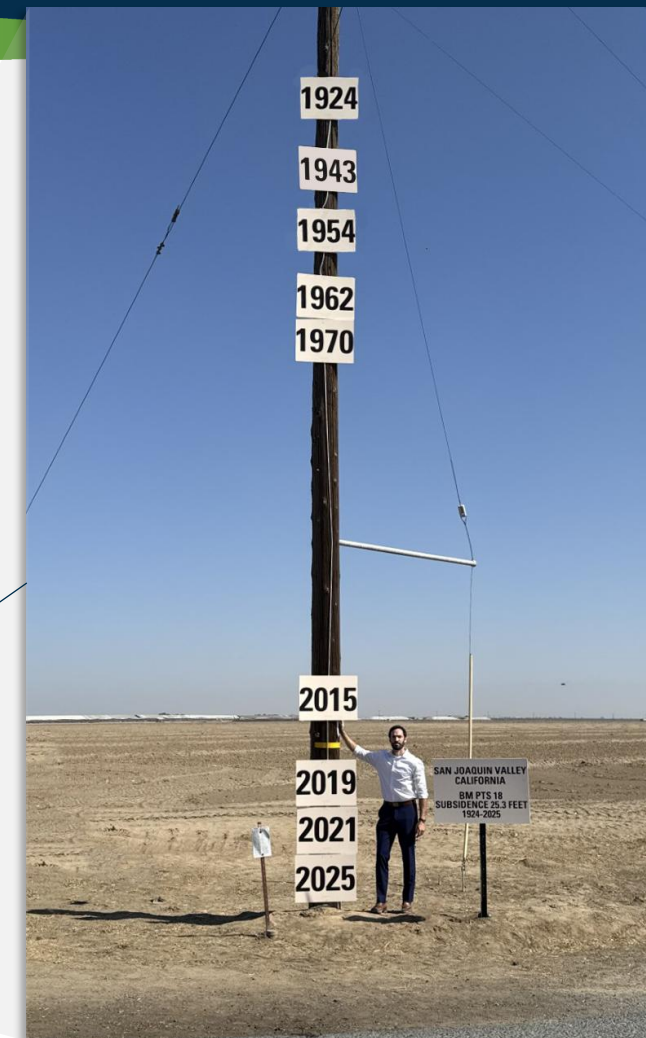
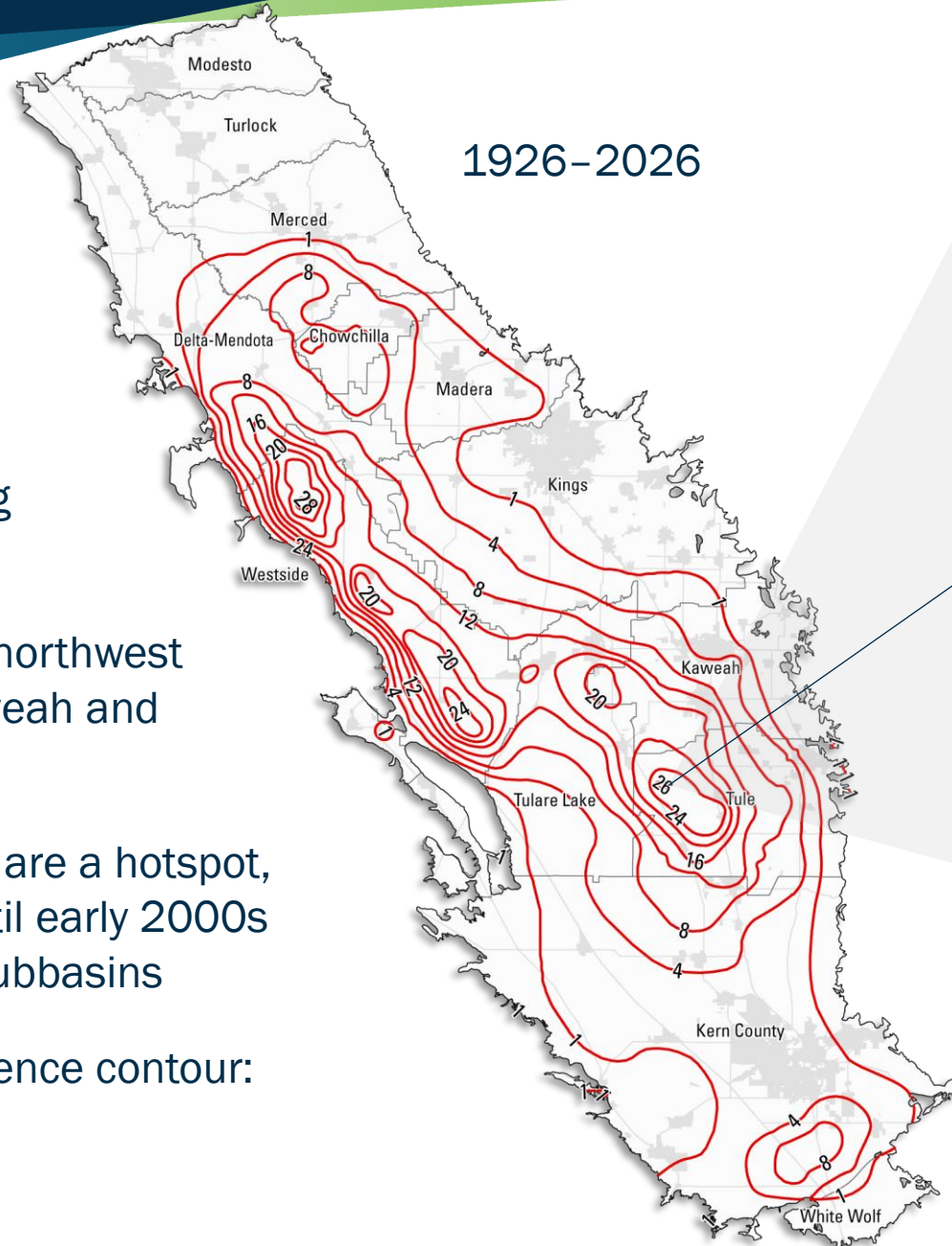
1926–1970

1970–2026

Cumulative Subsidence

The changing face of land subsidence

- Westside still the maximum subsidence area of the SJV (29 feet), but Tule is catching up (26 feet)
- Subsidence hotspot shifted northwest in Tule and expanded in Kaweah and Kern
- Madera/Chowchilla/Merced are a hotspot, but most subsidence not until early 2000s other than western part of subbasins
- Land area inside 1-ft subsidence contour: 7,160 mi²



Benchmark PTS 18
25.4 ft of subsidence



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