DRAFT WDWA Subsidence Review Part II

Area of Interest (AOI) 2

Aqueduct Milepost 195-215

April 2020

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Purpose

- Provide supplemental information requested by DWR on 2/7/20 in support of the WDWA Subsidence Review Part I, Area of Interest (AOI) 2, Aqueduct Mileposts 195 – 215
- Specific supplemental information includes:
  - Crop Acreage Over Time
  - Drought Surface Water Supply Deliveries
  - Perched Water Status
  - Classification of WDWA Soils and Concrete Durability

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Background

- 2/7/20 Part I Subsidence Review: WDWA and KGA present an alternative interpretation to DWR regarding likely causes of subsidence in KGA GSP Area of Interest (AOI) #2 (Aqueduct Mileposts 195-215)
- Key Conclusions & Recommendations of the Part I Review are:
  - Eastern flank of anticline likely extends beneath Aqueduct in places
  - Oil production causes groundwater to move up-flank towards anticline crest
  - MP 208: Anticline flank potentially beneath Aqueduct
  - MP 204: Topographic "high point" corresponds to pinchout of Tulare Zone production
  - Deep well pumping to the east of the WDWA and south of MP 213 may be a contributing factor

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Background (Cont.)

- Subsidence in AOI 2 is complex and has multiple potential causes
  - Geology/Soils/Aqueduct
  - Produced Water/Deep Well Pumping
- Coordination between all stakeholders (DWR,GSA/GSP, CalGEM (DOGGR), Agriculture and Oil) is necessary to comprehensively assess causes and solutions
- Recommend additional monitoring (InSAR, pumping and geodetic) in coordination with GSA/GSP, CalGEM, Oil and DWR

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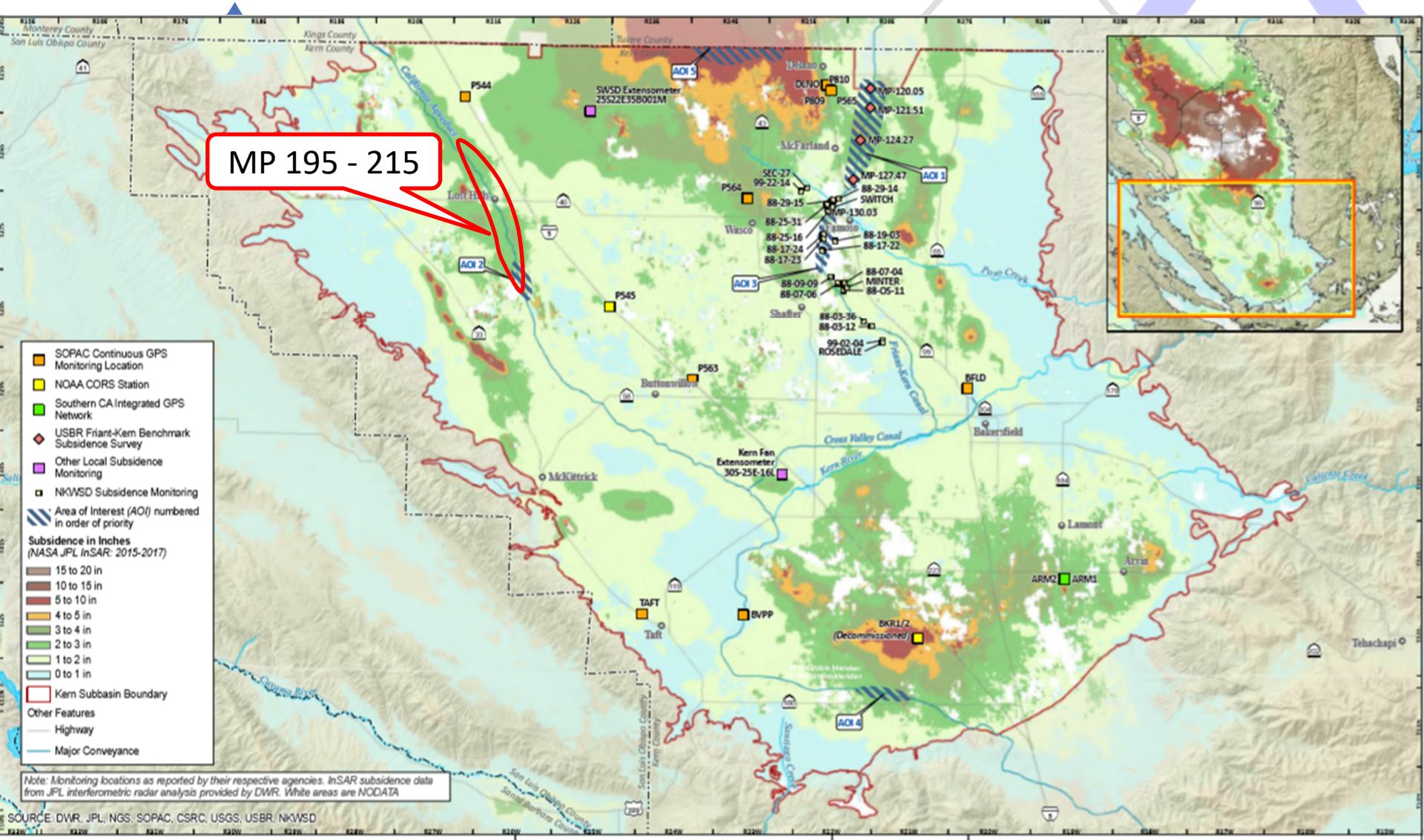
AOI 2 (MP 195 – 215)



Kern Groundwater Authority
Basin Setting

Kern County, California

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REGIONAL SUBSIDENCE MONITORING NETWORK

OCTOBER 2019

FIGURE 3-6

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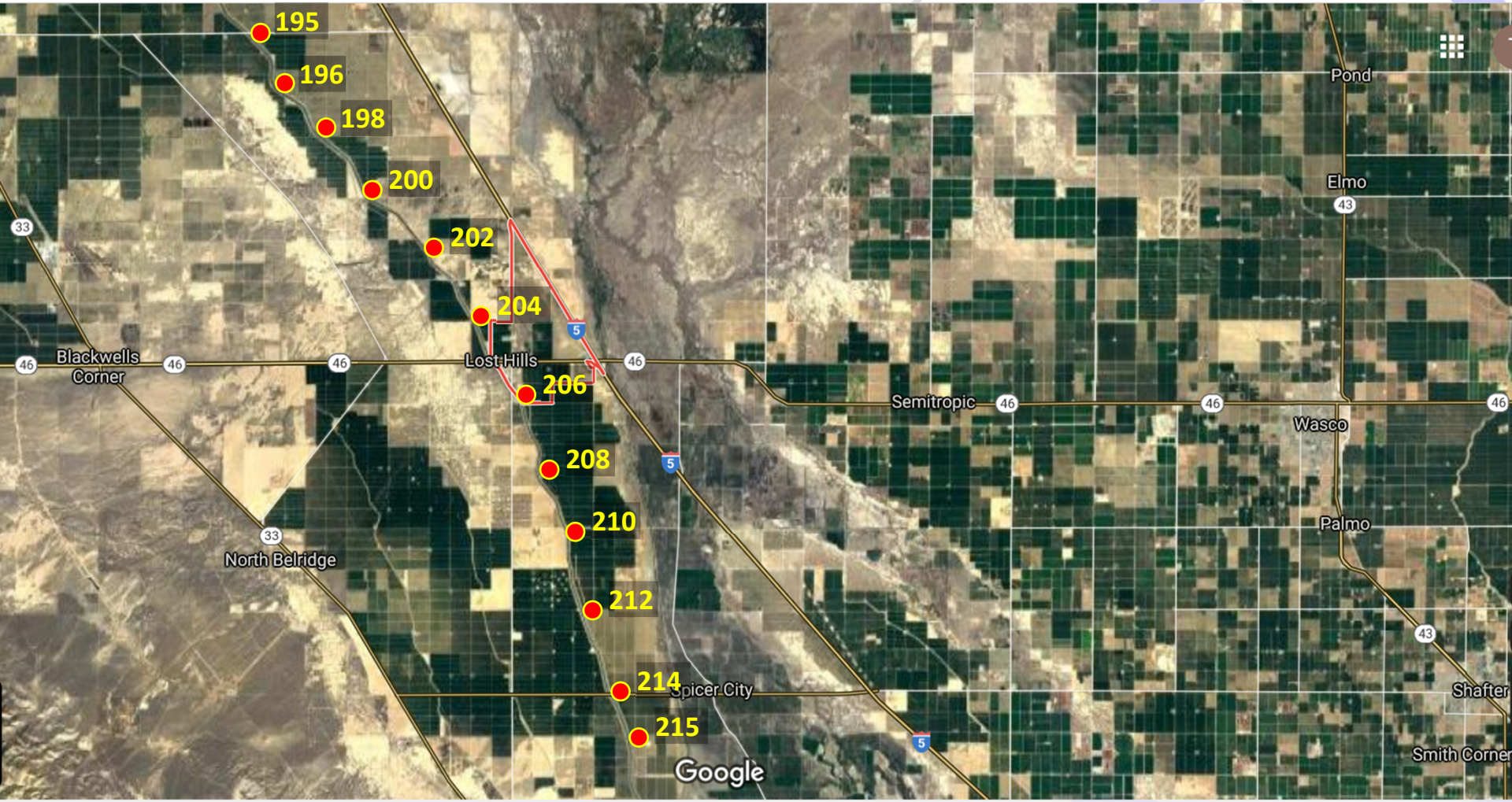
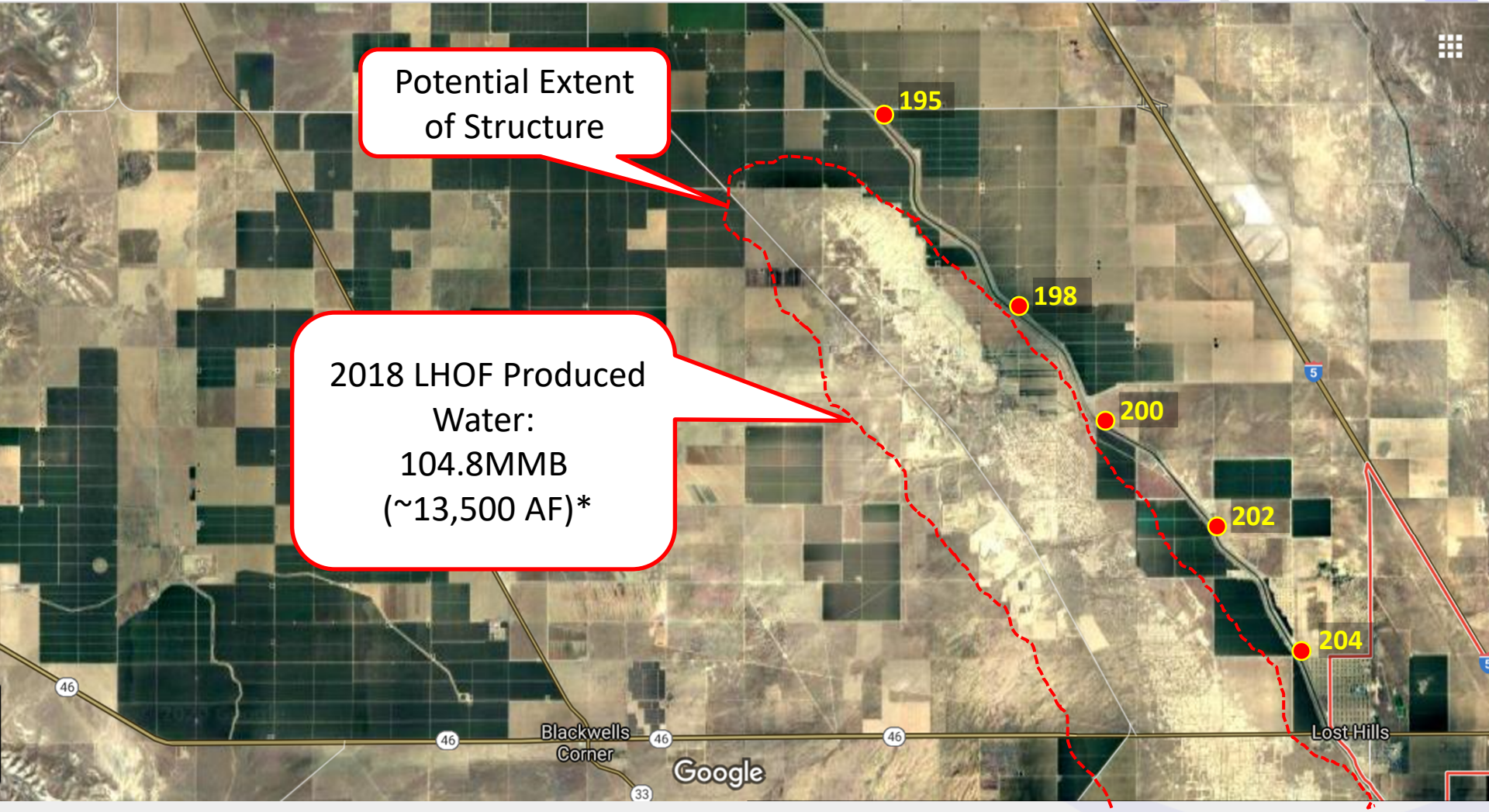
AOI 2 (MP 195 – 215)



Northern Lost Hills MP 195 – 204



*Source: DOGGR, 2018.

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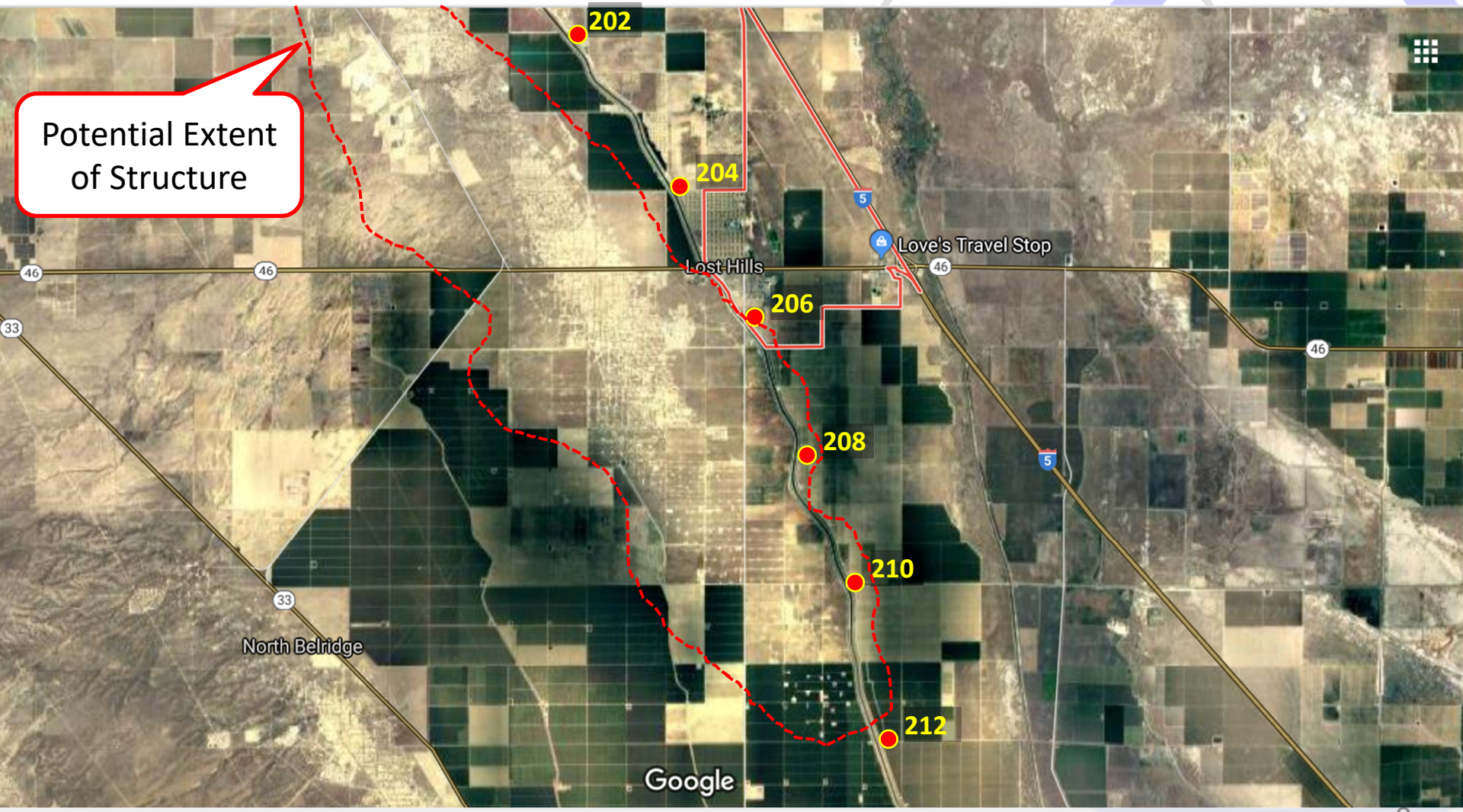
Southern Lost Hills MP 202 - 212



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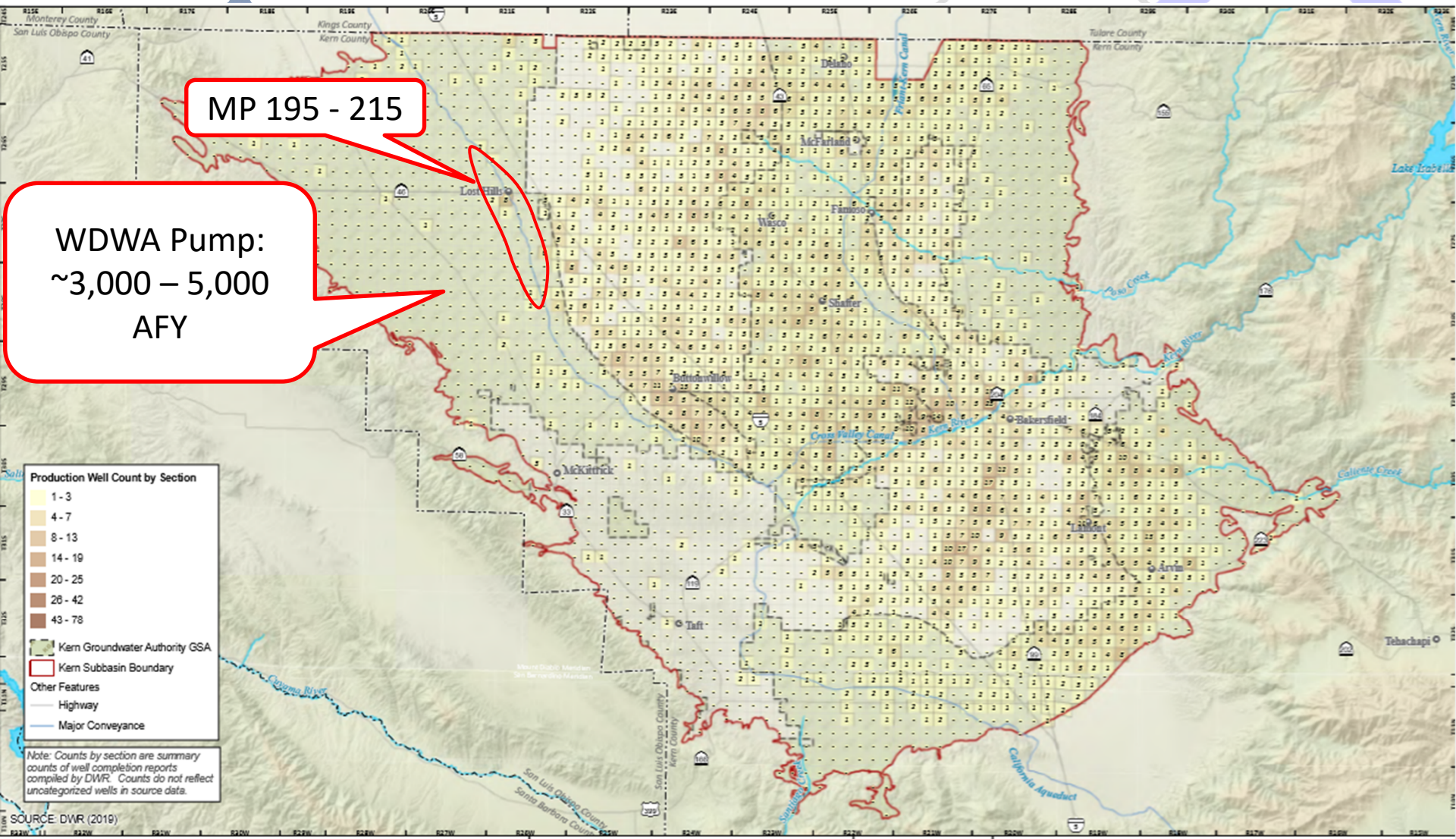
Production Well Density



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DENSITY OF WELLS PER SQUARE MILE
(PRODUCTION)

JULY 2019

FIGURE 2-4

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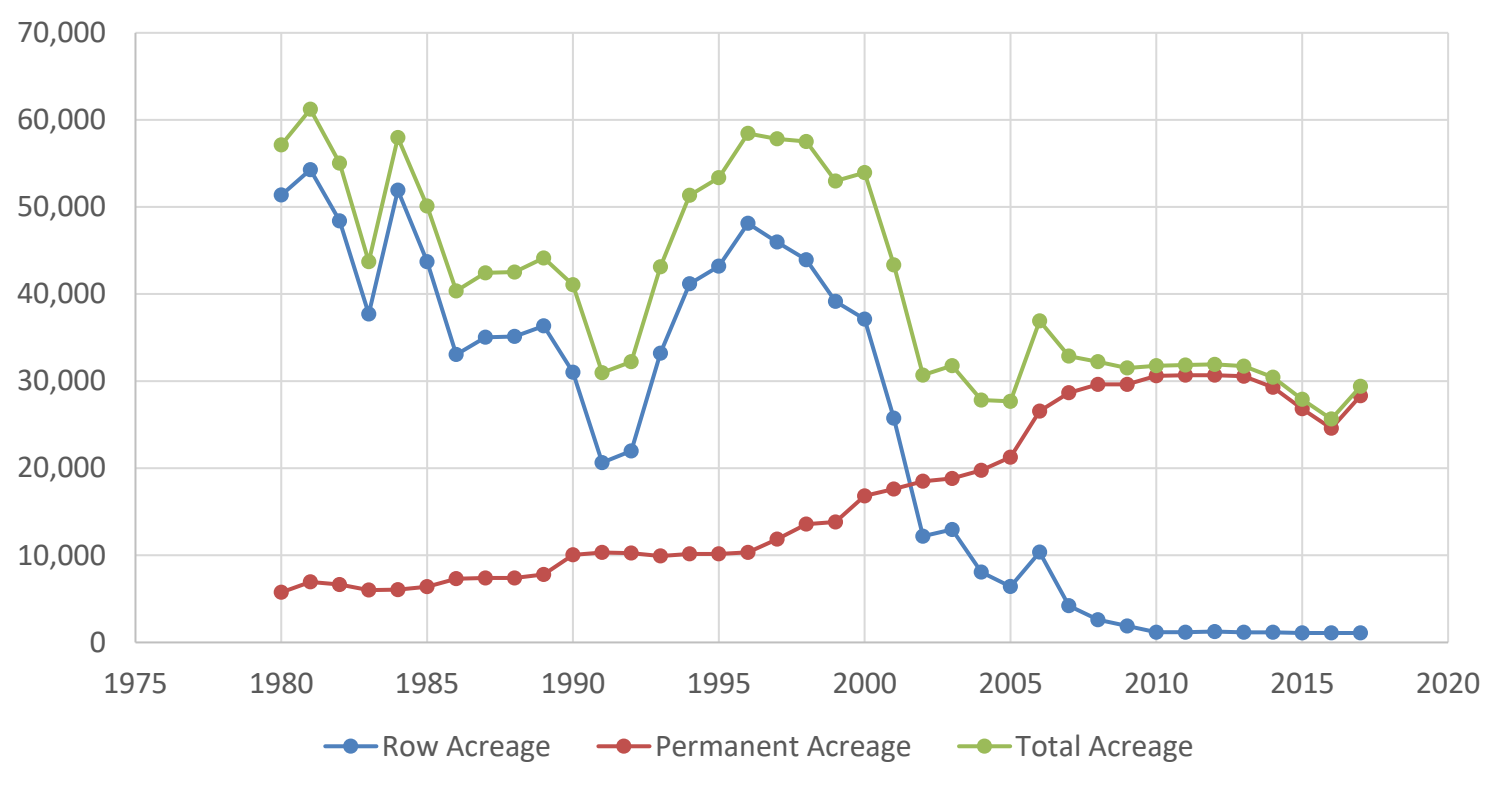
Summary Slides #2 – 9

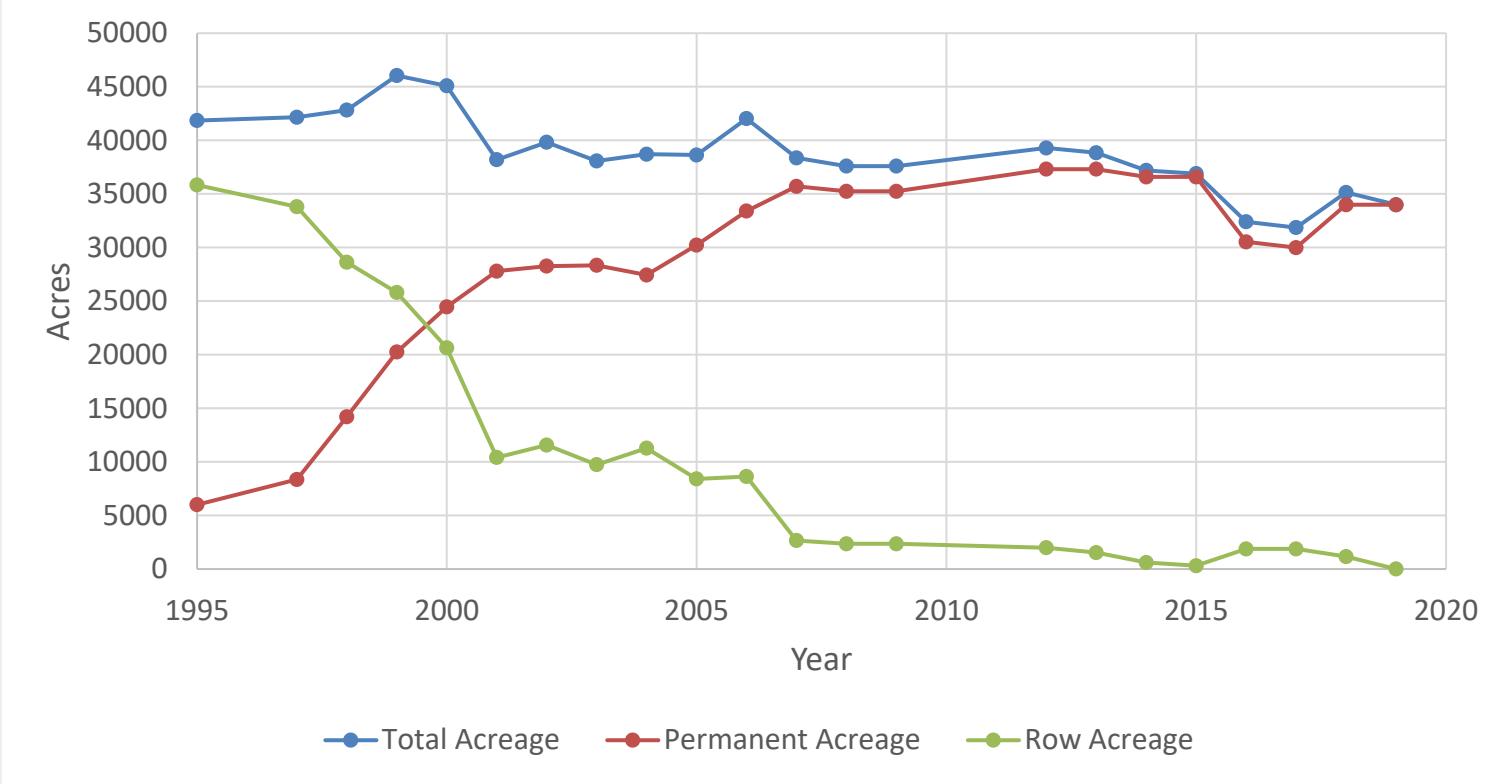
- 2015-2017 InSAR: 2 – 4 inches of subsidence concomitant with Aqueduct, Lost Hills Oil Field (LHOF) and Agriculture
- Sparse irrigation well density in AOI 2
- 2018 LHOF produced water volume (all sources): ~104.8 MMB (i.e.~13,500 AF)
- WDWA pumping is limited by poor quality: ~3,000 – 5,000 AFY
- LHOF activities appear to influence subsidence

LHWD – Crop Acreage Over Time



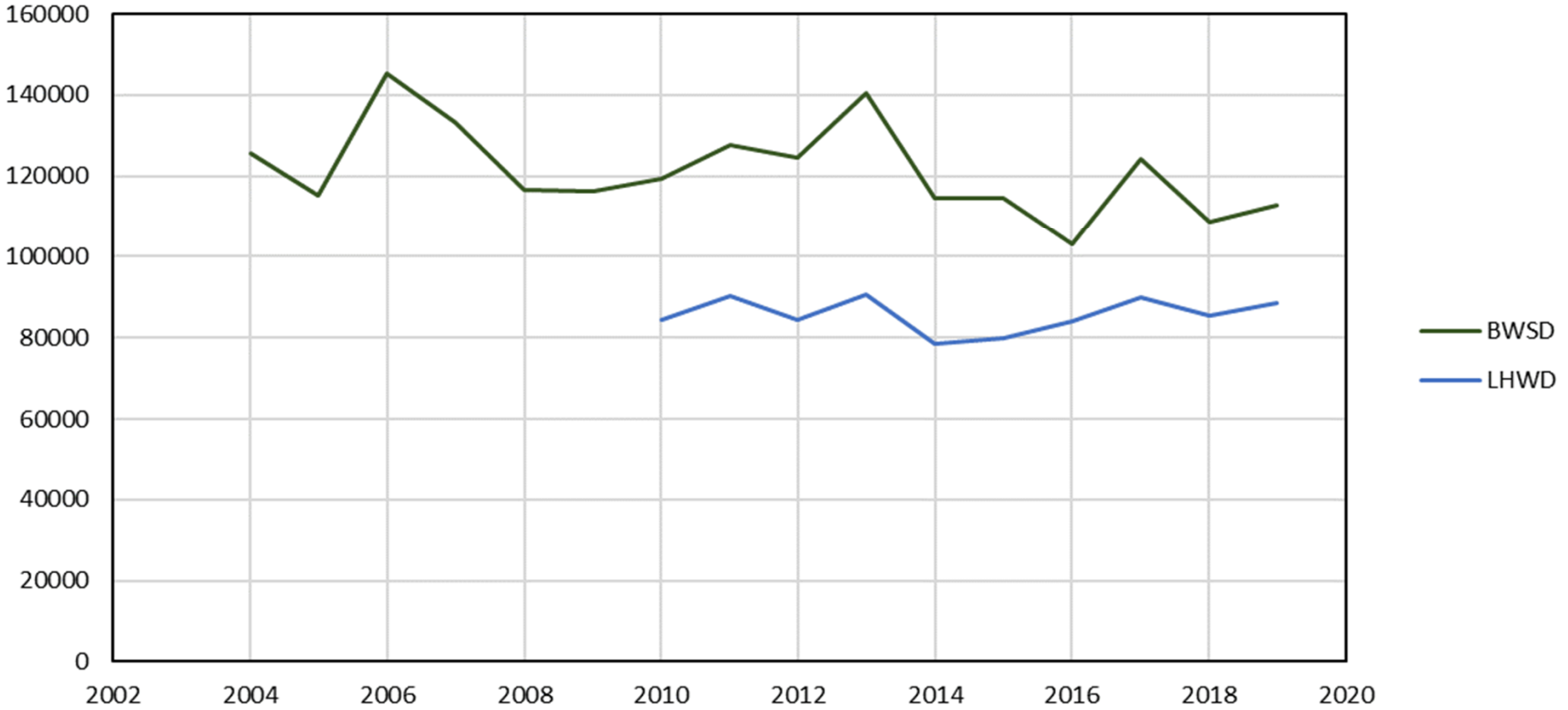
Source: WDWA, 2020

BWSD - Crop Acreage Over Time



Source: WDWA, 2020

District Drought Supply Deliveries



Source: WDWA, 2020

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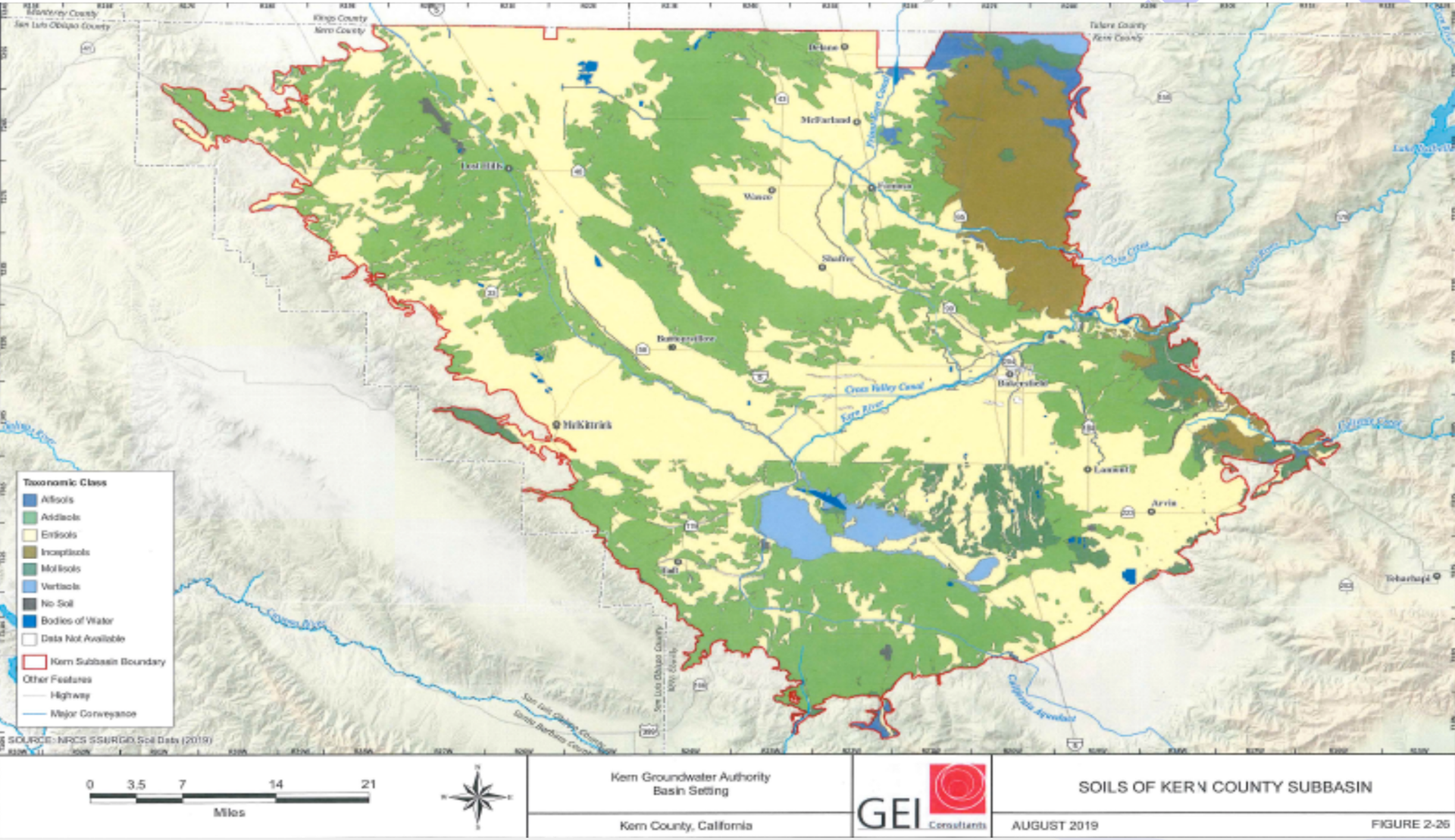
Summary: Slides # 11-13

- Shift to permanent crops and drip/micro-irrigation in ~1996
- Increase in permanent crop acreage counterbalanced by reduction in total cropped acreage
- Import/surface water is primary source of supply
- Drought surface water deliveries reflect relationship with crop acreage

Soils of the KCS



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Aridisol Characteristics

- Form in arid and semi-arid climates
- Common to the WDWA
- Water Deficient/Low Humus Content
- Calcium Carbonates/Gypsum/ Salts/ Sulfates are common
- Alkalinity typically high
- Susceptible to solubilization of salts/Hydrocollapse

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Soils of Northwestern Kern County

Series[1]	pH (s.u.)	Salinity (mmhos/cm)	Limitations
Buttonwillow	7.9 – 8.4	< 4	Drainage, Salinity
Kimberlina	6.6 – 8.4	<2 – 8	Fertility, Alkalinity
Lethent	>7.8 – 9.0	4 – 16	Saline-Alkaline
Lokern	6.6 – 9.0	<2 – 16	Saline-Alkali, Drainage
Milham	7.4 – 8.4	<2 – <8	Fertility
Nahrub	>7.4 – >7.8	4 – 16	Saline-Alkali, Drainage
Panoche	7.4 – 8.4	<2 – 16	Saline-Alkaline, Drainage
Twisselman	7.9 – 9.0	<2 – >16	Saline- Alkaline, Drainage
Yribarren	7.9 – 8.4	<2 – <8	Saline-Alkaline

Source: Amec Foster Wheeler, 2015

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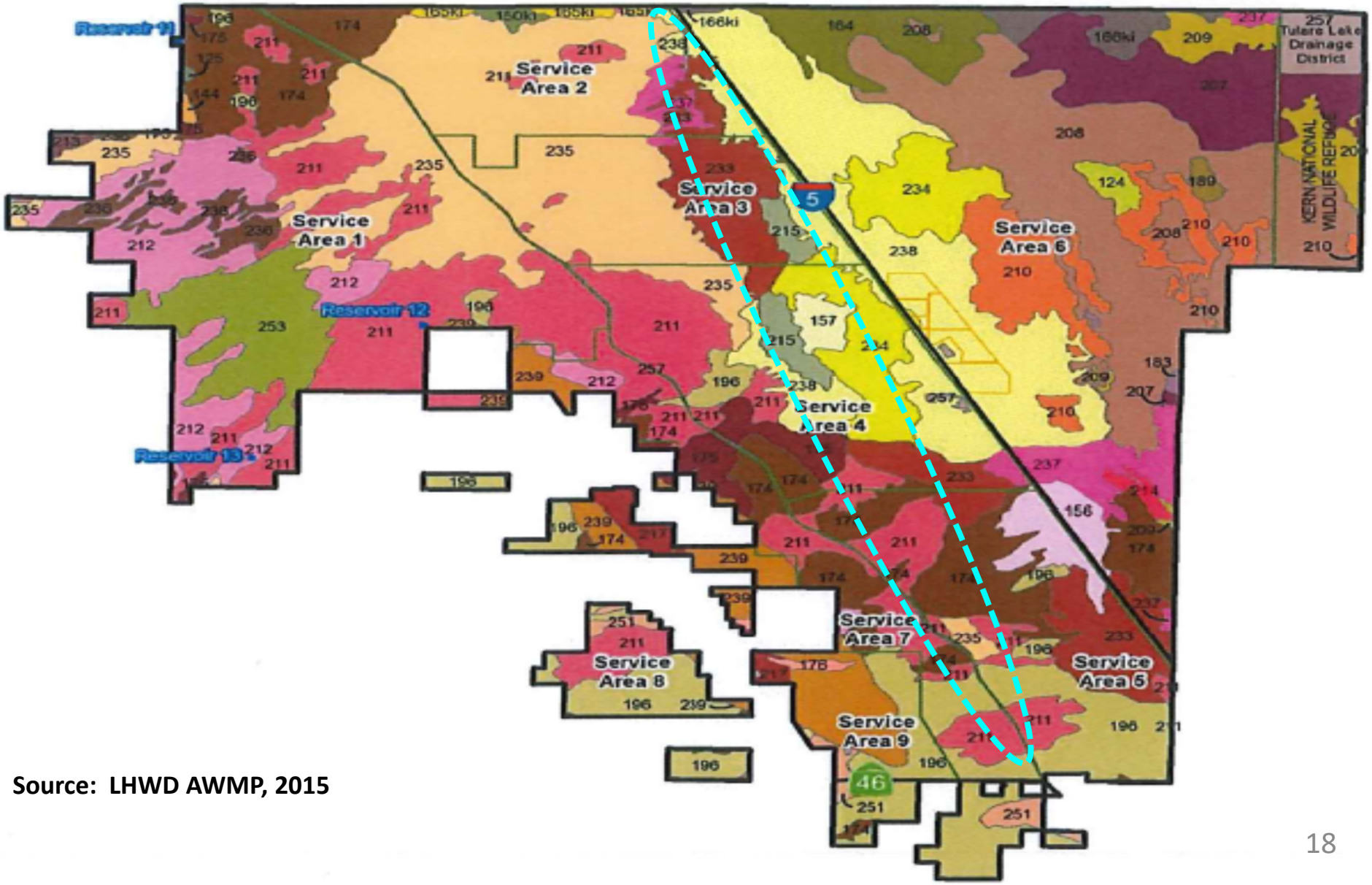
Lost Hills Water District Surface Soils



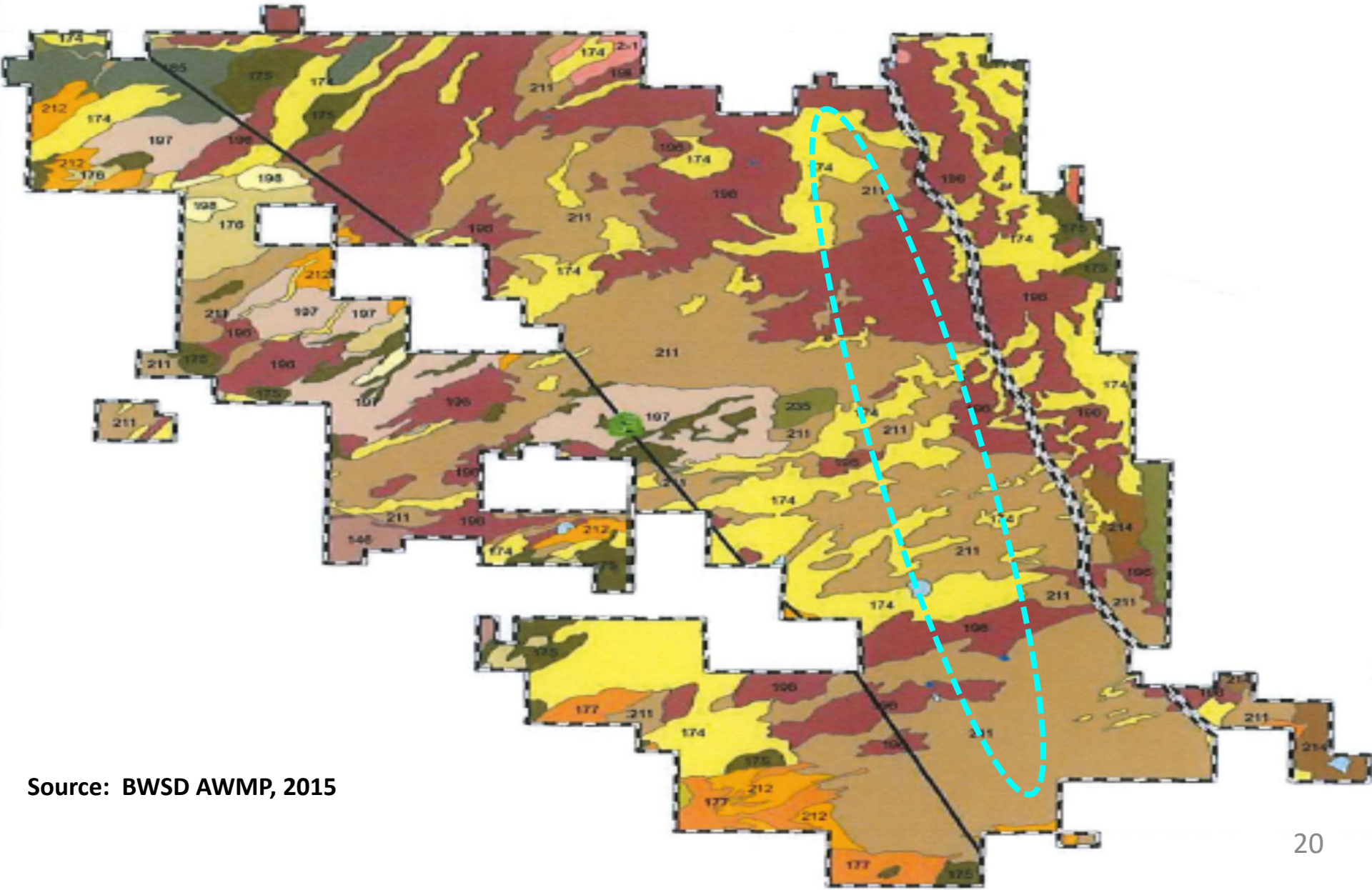
Source: LHWD AWMP, 2015

Lost Hills Water District

Soils Series in Proximity of the Aqueduct

- Garces silt loam (#157)
- Kimberlina fine sandy loam (#174)
- Panoche clay loam (#211,215)
- Twisselman sandy loam (#233, 234,235)

Belridge Water Storage District Surface Soils



Source: BWSD AWMP, 2015

Belridge Water Storage District

Soil Series in Proximity to the Aqueduct

- Kimberlina fine sandy loam (# 174)
- Milham sandy loam (#196)
- Panoche clay loam (# 211)

Perched Water Occurrence

- Pre-drought: perched water occurred east of the Aqueduct in localized places
- Sourced by row crop return flows and precipitation
- Post-drought: shift to permanent crops, micro-irrigation, climate change have minimized perched water occurrence

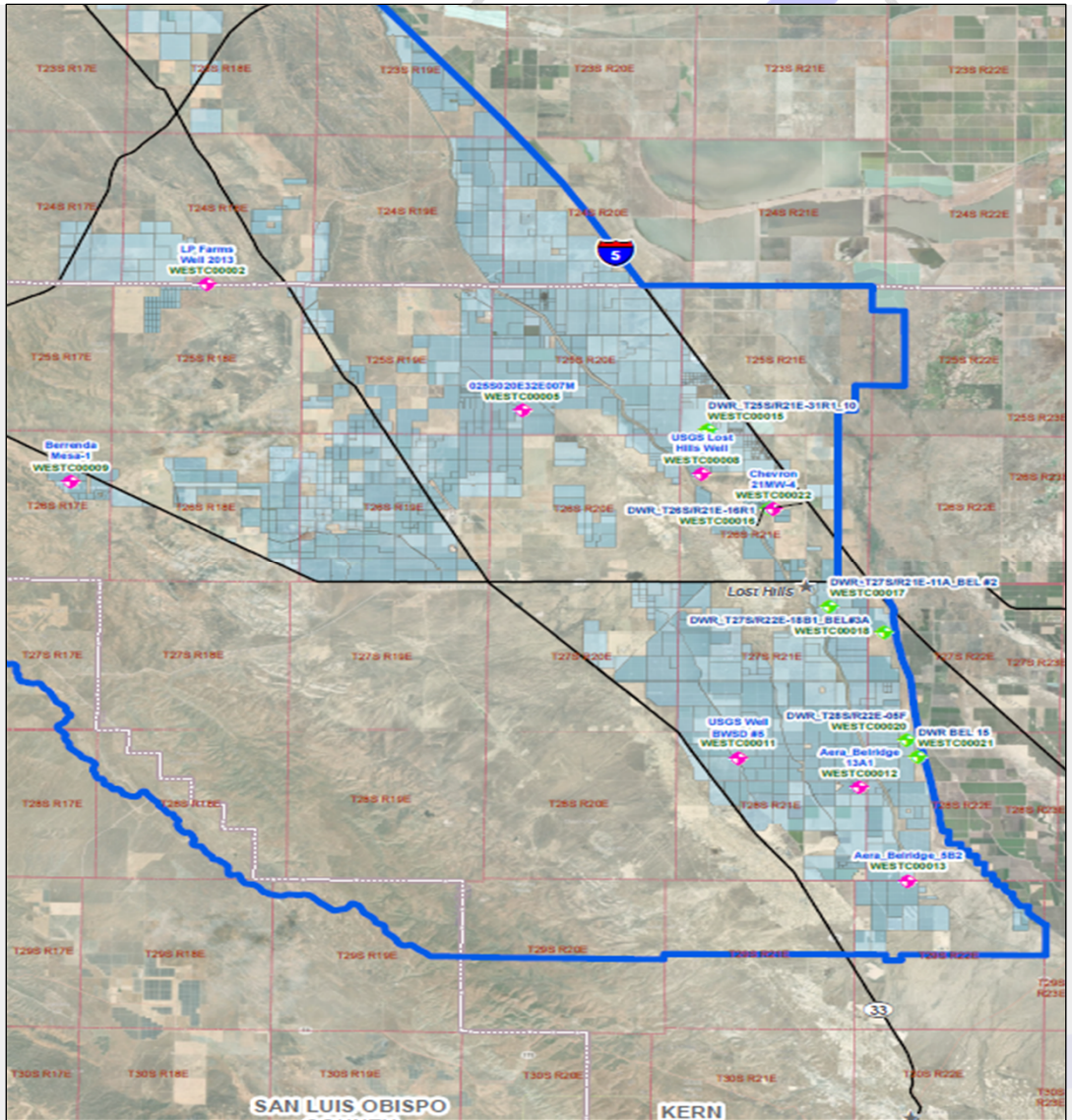


Figure Source: WWQC / Wood Environmental, 2019.

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Concrete Durability

- Typical life span (durability) of concrete structures is ~30-60 years
- Aqueduct is ~53 years old
- Chemical attack on concrete is common in desert soils (Aridisols)
- Aqueduct was likely constructed with Type II concrete/moderate resistance to alkali/sulfate soils

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Summary: Slides # 15 - 23

- Perched water occurrence is minimal in WDWA due to micro-irrigation and climate change
- Aridisols are common in arid climates and are found within the WDWA and adjacent to the Aqueduct
- Alkalinity/sulfate concentration is typically high
- Susceptible to solubilization of salts/Hydrocollapse
- Chemical attack on concrete by desert soils is common
- Sulfate damage is most often associated with partially buried structures

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Conclusions and Recommendations

- 2015-2017 InSAR: 2 – 4 inches of subsidence concomitant with Aqueduct, Lost Hills Oil Field (LHOF) and Agriculture
- LHOF activities appear to influence subsidence
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- Import/ Surface water is primary source of supply
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Conclusions and Recommendations (Cont.)

- Shift to permanent crops and drip/micro-irrigation in ~1996
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Conclusions and Recommendations (Cont.)

- Subsidence in AOI 2 is complex and has multiple potential causes
  - Geology/Soils/Aqueduct
  - Produced Water/Deep Well Pumping
- Coordination between all stakeholders (DWR,GSA/GSP, CalGEM (DOGGR), Agriculture and Oil) is necessary to comprehensively assess causes and solutions
- Recommend additional monitoring (InSAR, pumping and geodetic) in coordination with GSA/GSP, CalGEM, Oil and DWR

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Questions

Subsidence Review Part I Materials

- The following reference materials are key slides from the Draft WDWA Subsidence Review Part I Area of Interest (AOI) 2 Aqueduct Mileposts 195 – 215, presented to DWR on 2/7/20.

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Background

- Inelastic land subsidence identified as undesirable result
- Area of Interest (AOI) 2 – Aqueduct Mileposts (MP) 195 – 215
- 2011 Embankment failure MP 208
- DWR concludes geology and groundwater pumping as cause of subsidence
- Data indicates alternative interpretations should be considered

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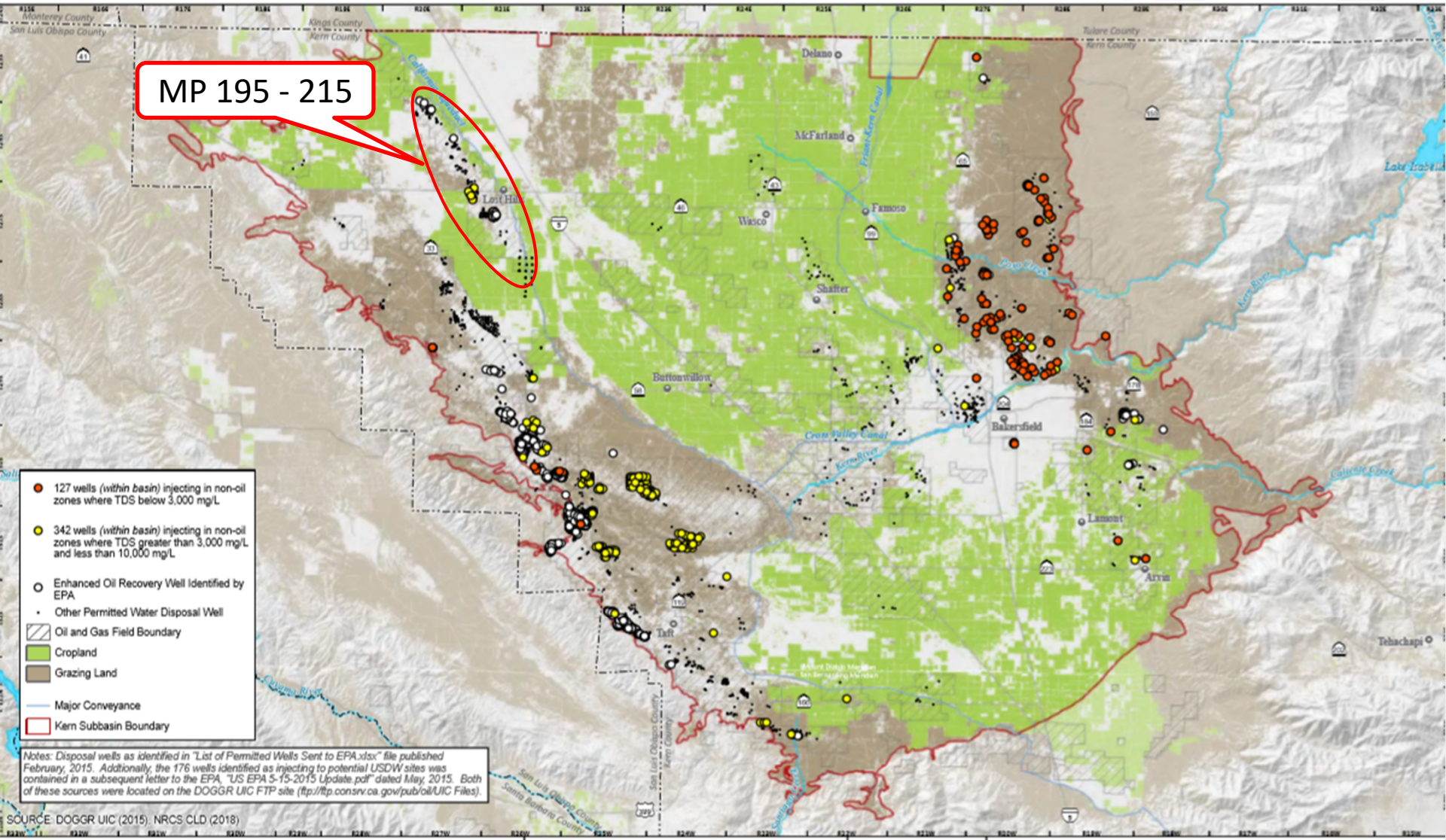
AOI 2 UIC Wells



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Basin Setting

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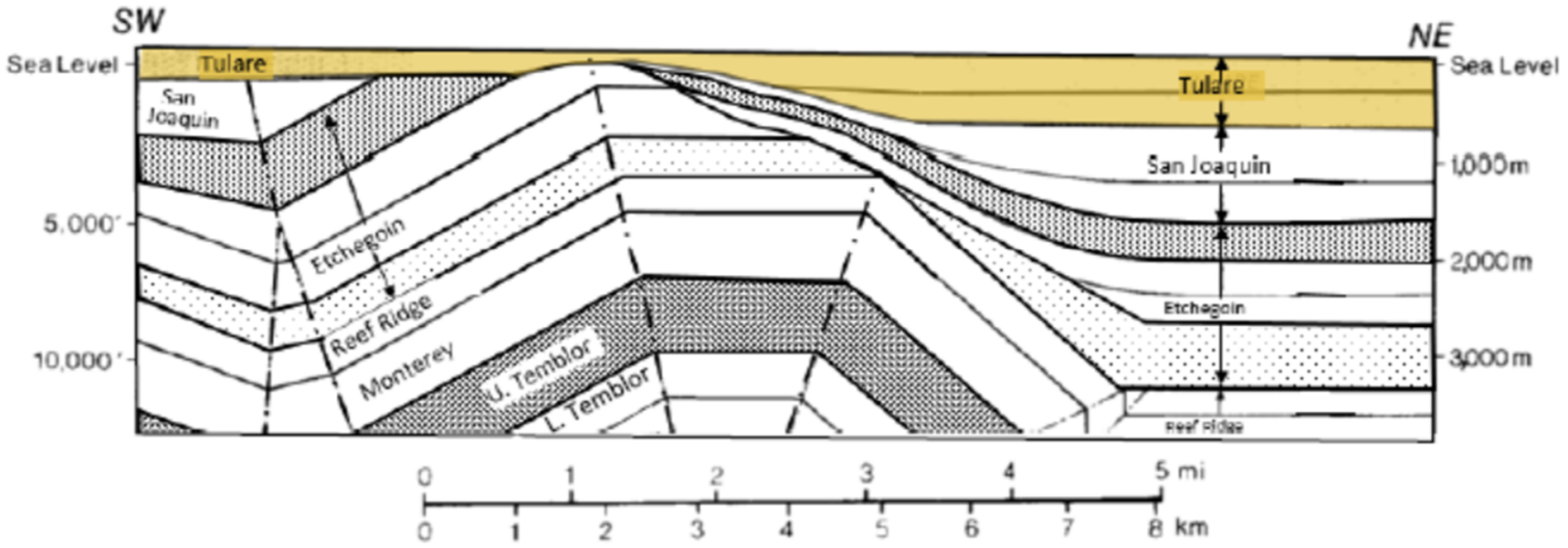
OIL AND GAS WELLS IN THE
UNDERGROUND INJECTION CONTROL PROGRAM

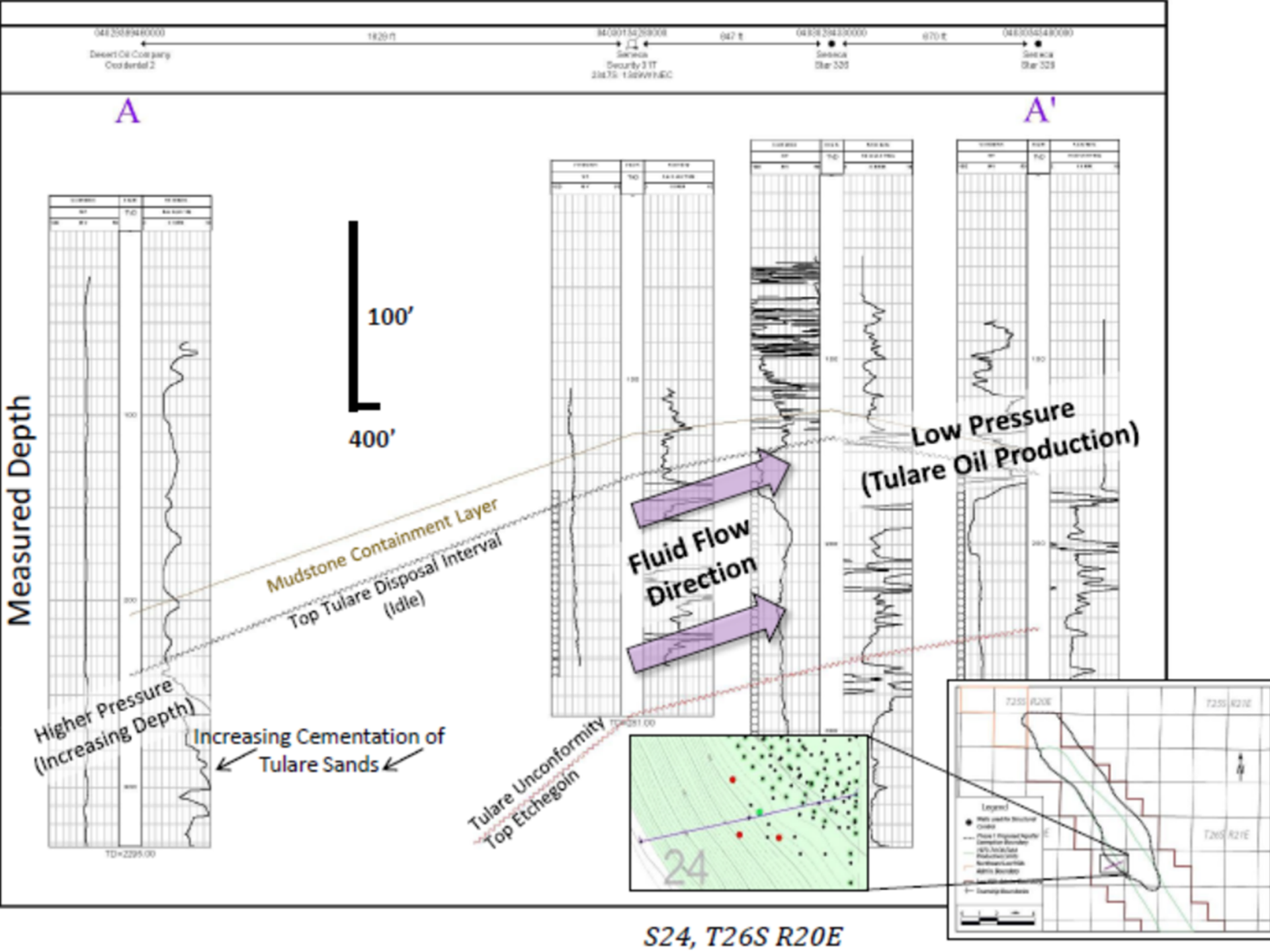
AUGUST 2019

FIGURE 2-39

Figure 8 : Structural cross section over Lost Hills anticline from Medwedeff (1989)

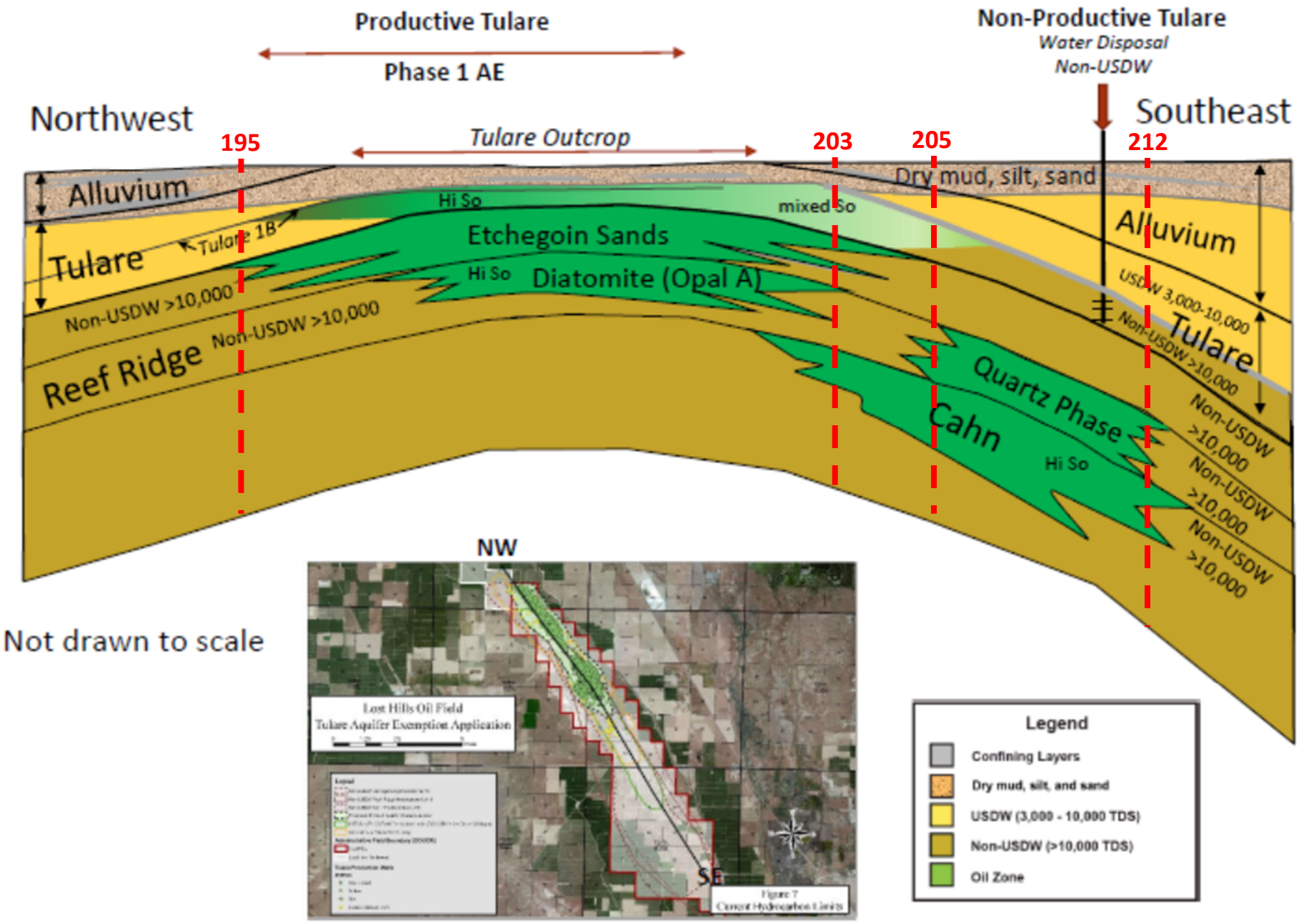


Structural cross section over Lost Hills anticline modified after Medwedeff (1989) showing asymmetric fold with erosion of Etchegoin and San Joaquin Formations with eastward deposition of Tulare Formation thinning onto the structure and thickening to the east.



S24, T26S R20E

Figure 10: Conceptual strike cross section; Lost Hills Oil Field



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LHOF Distribution of Oil Production Intervals

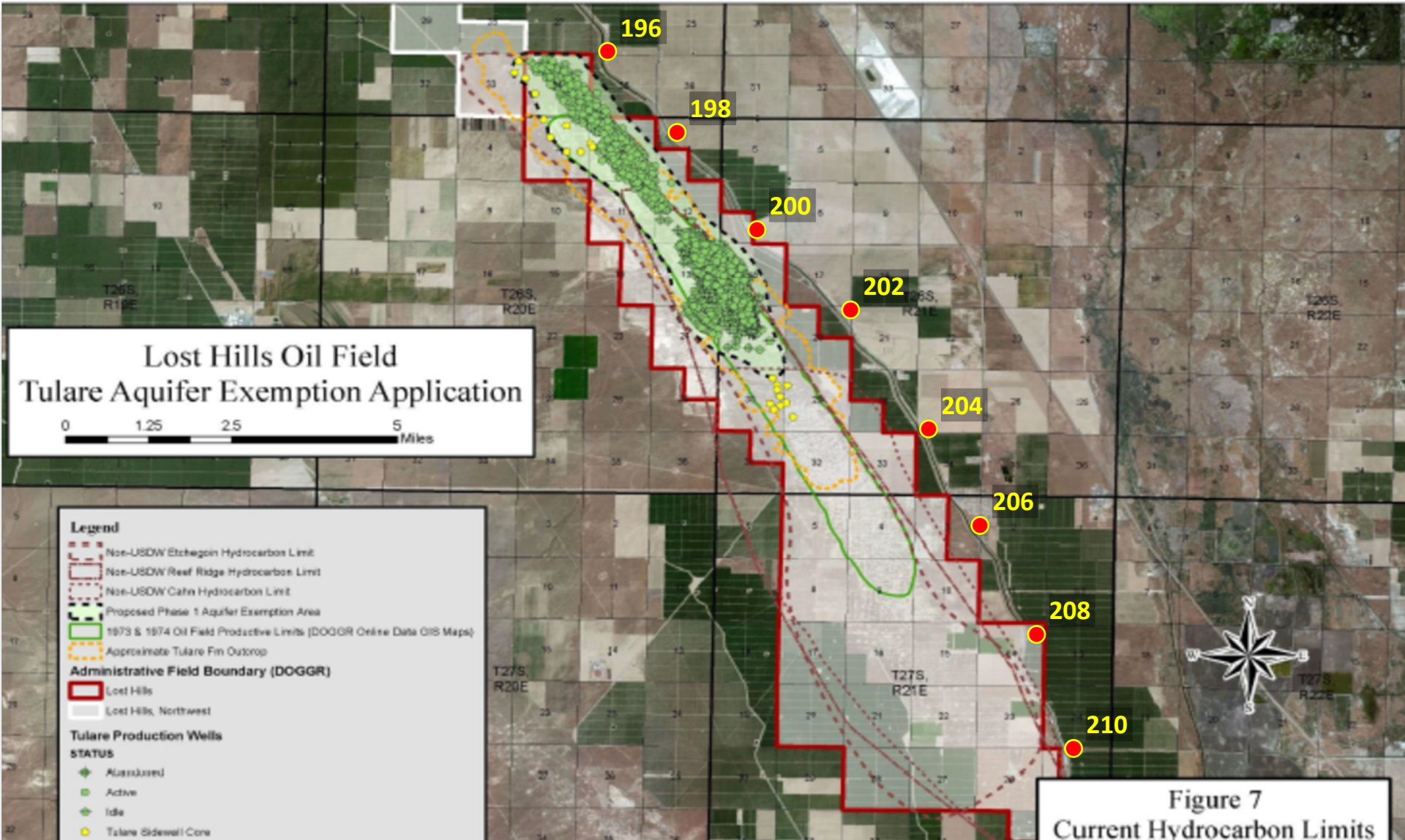
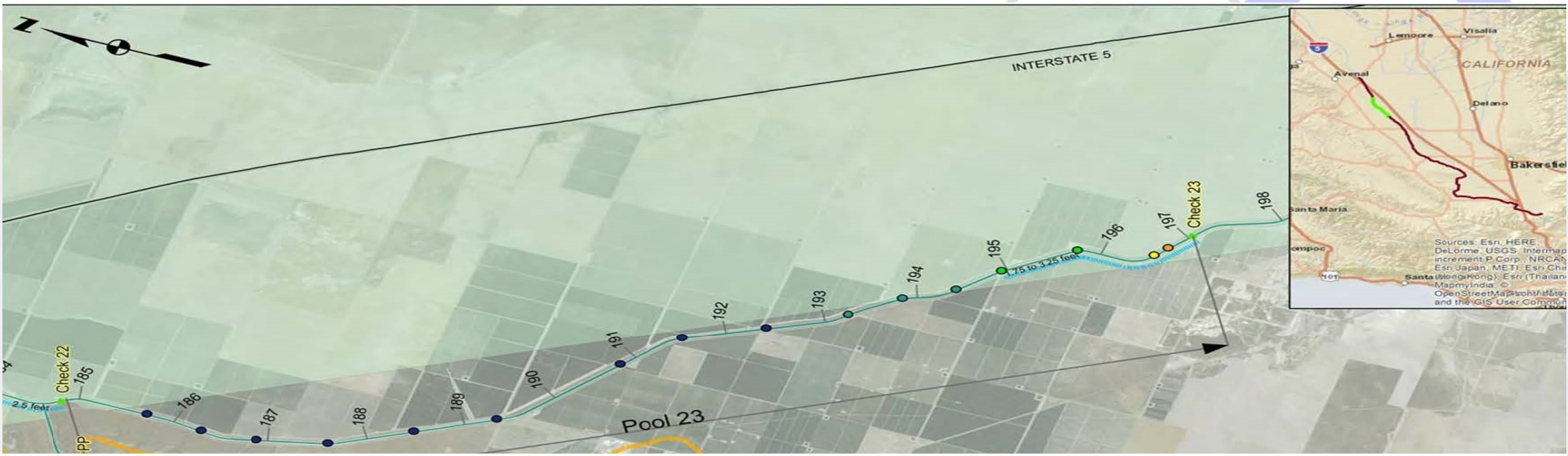
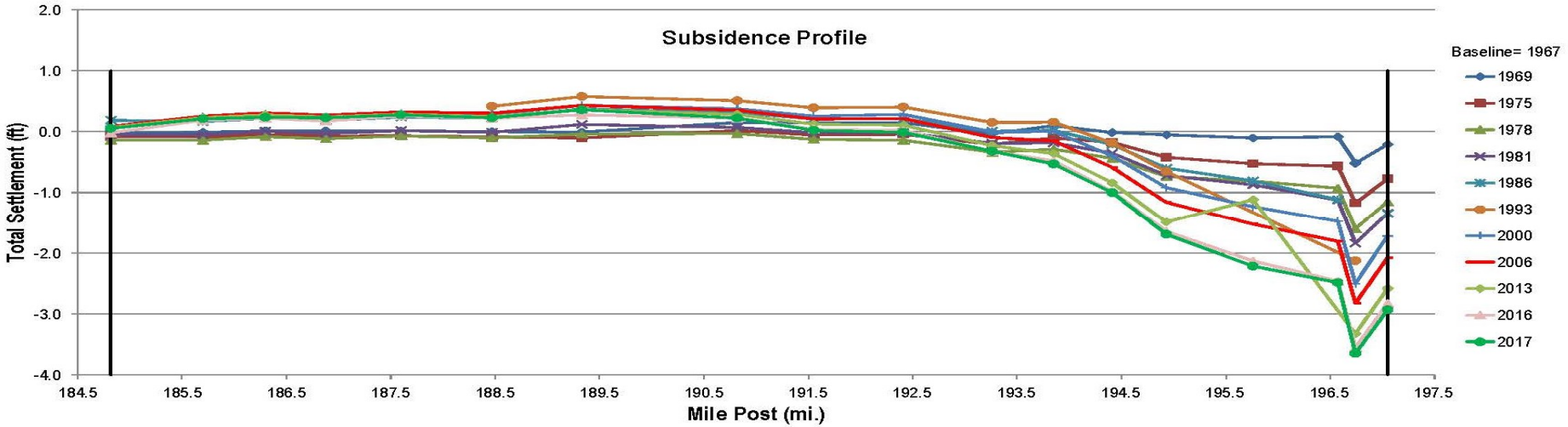


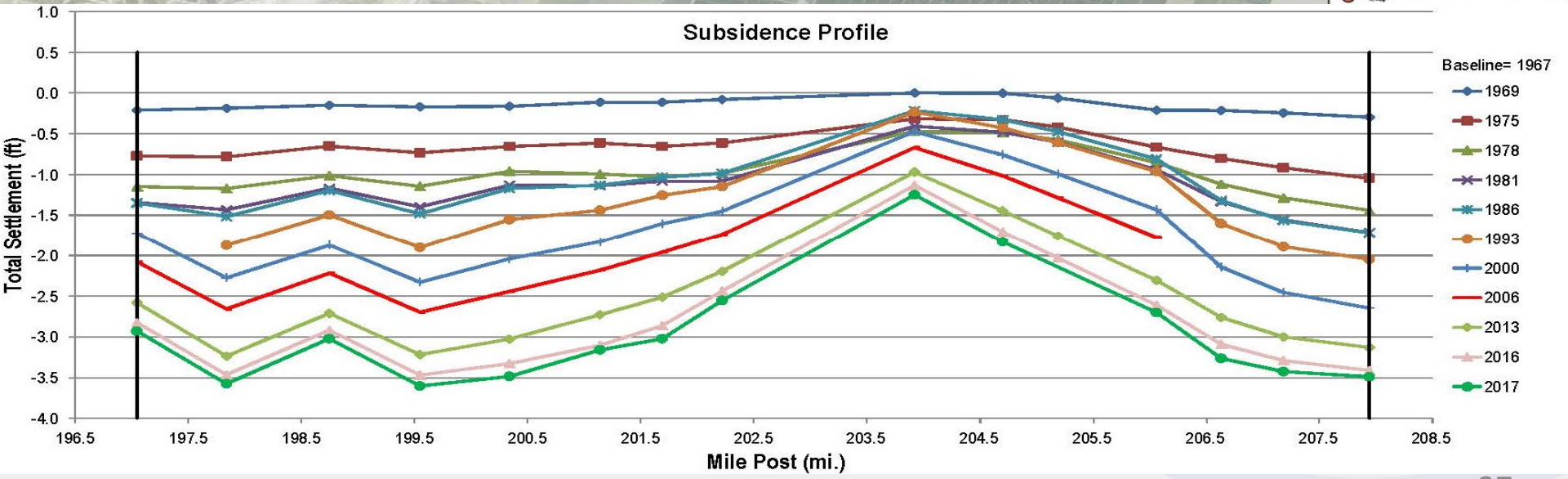
Figure 7
Current Hydrocarbon Limits

2019 DWR Report Plate: 12 MP 185-197

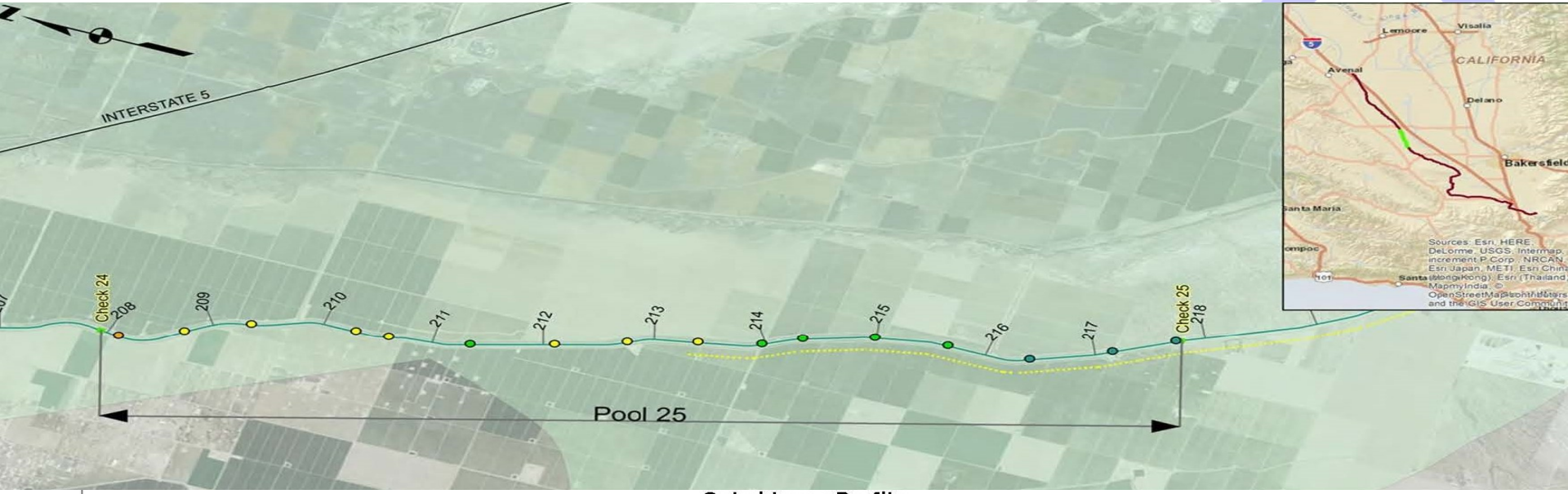


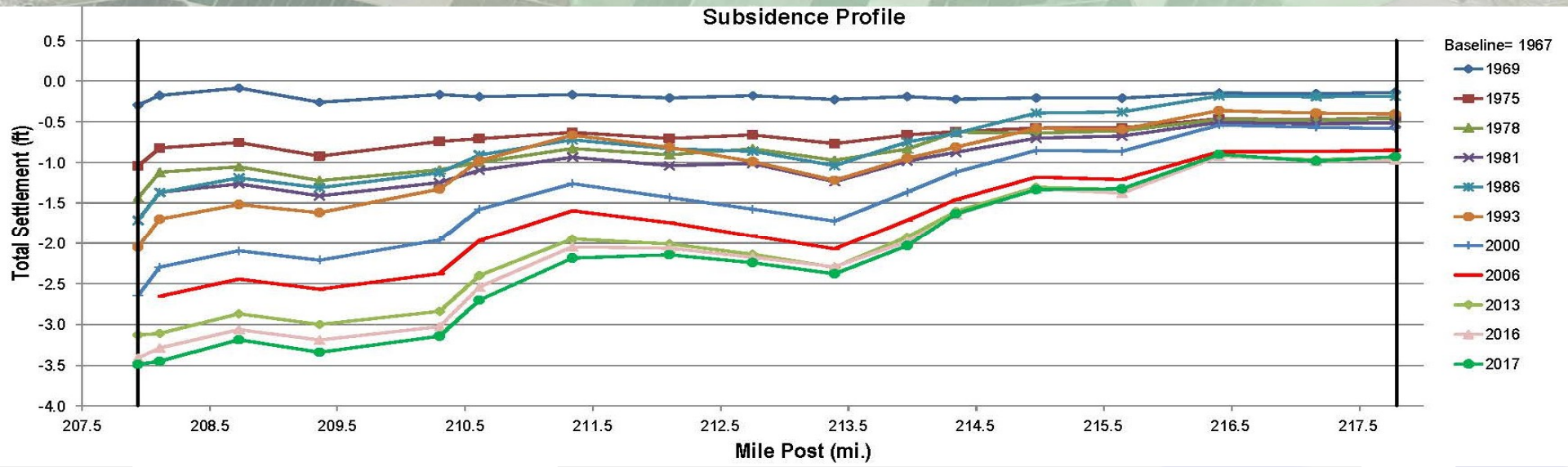


2019 DWR Report: Plate 13 MP 197-208



2019 DWR Report: Plate 14 MP 208-218





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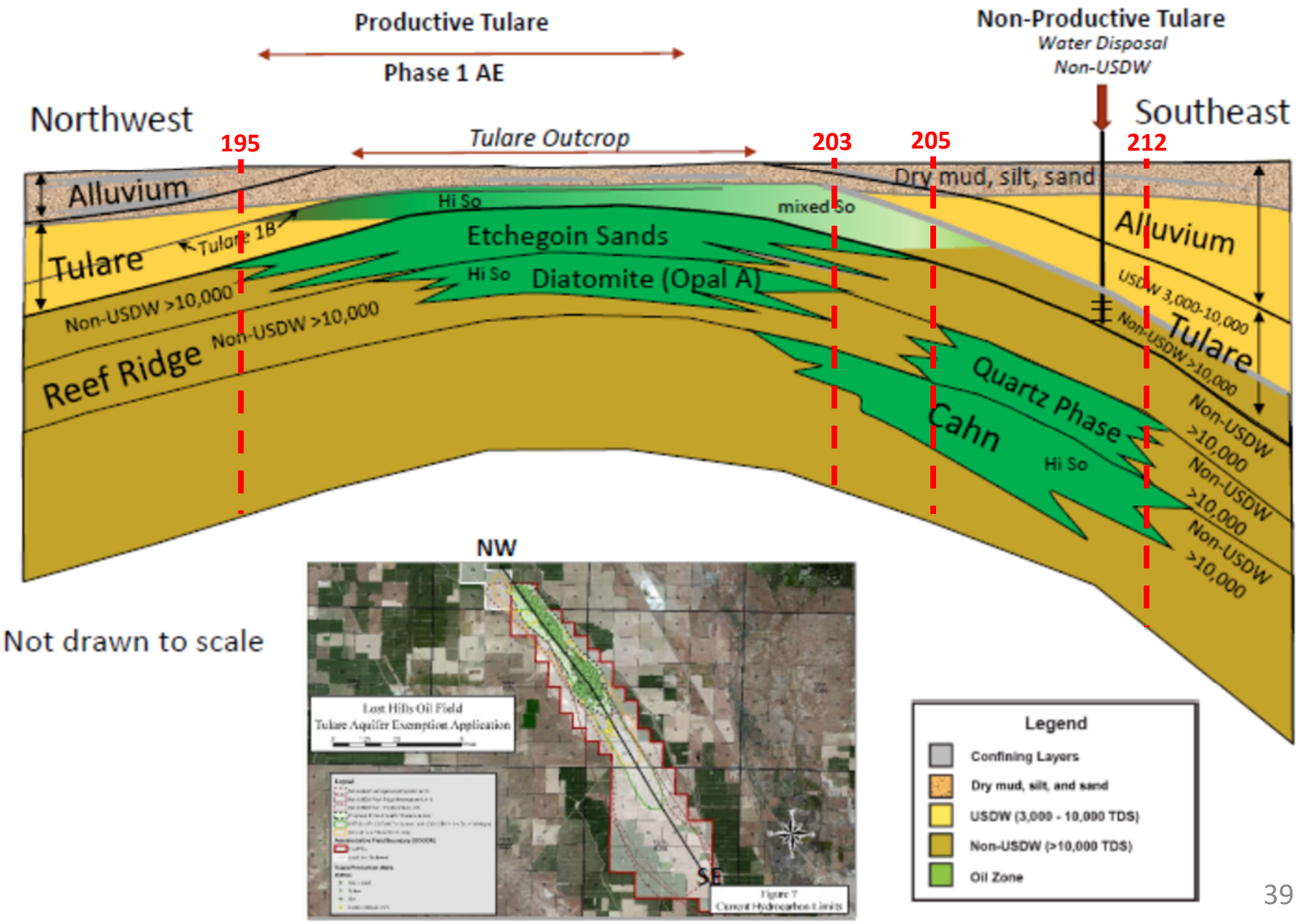

Summary: Slides # 26 - 35

- LHOF Aquifer Exemption Application (AEA): shows up-flank migration of groundwater towards crest of the geologic structure due to pressure gradient
- LHOF Administrative Area and flanks of the geologic structure extend to the east beyond the Aqueduct in places (e.g. MP 208)
- AEA: Tulare oil zone extends from~ MP 195 - MP 204
  - DWR data shows land surface “high point”:MP202.5-MP 205.5
  - High Point concomitant with pinchout of Tulare zone production