Effects of Well and Piezometer Design on Water-Level Monitoring

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Technical Session D:Water Levels and Well Design
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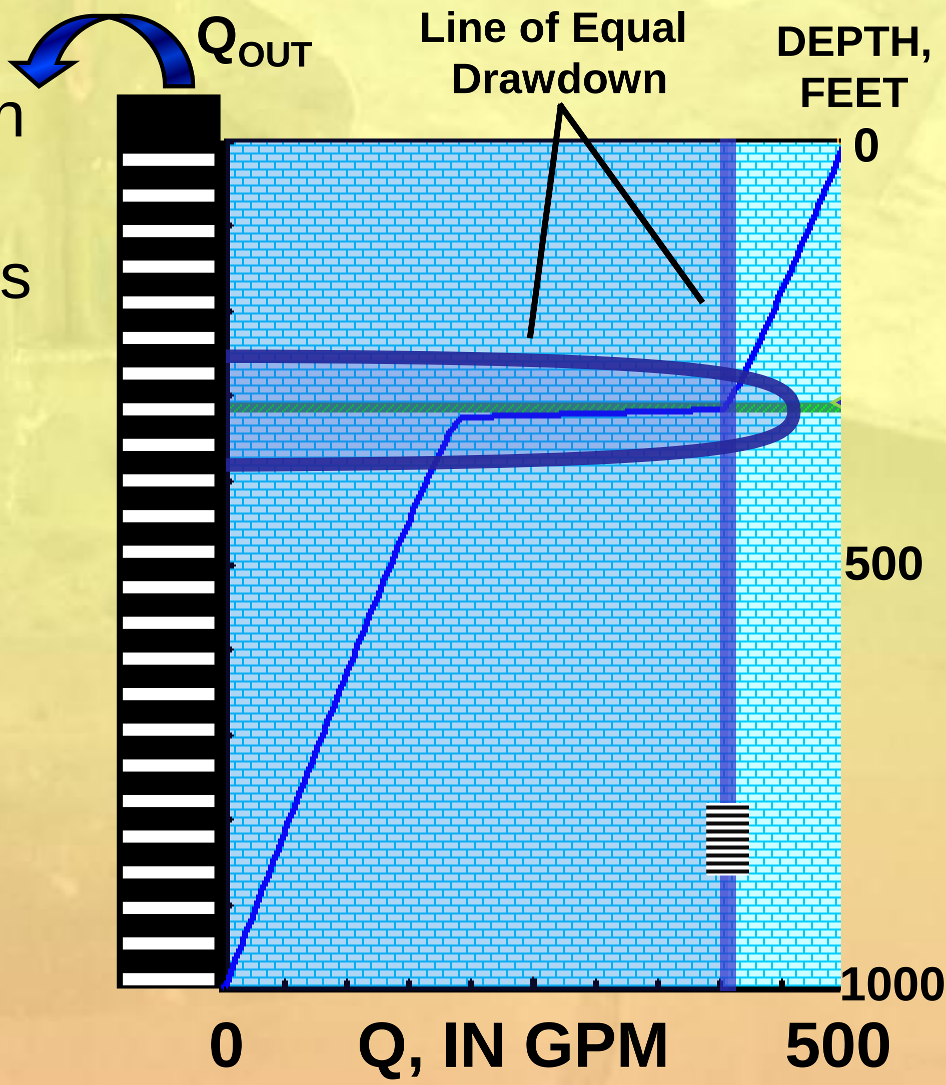
Short / Long Screens

- Short screens <20 ft and piezometers
  - Discrete interval, point
  - Head and QW differences observable
  - Minimally disturbs flow system
- Long screens >100 ft
  - Integrates head and QW
  - Head skewed towards most transmissive interval
  - Well passively induces flow between units
  - QW skewed towards interval with higher head
- Bias towards short screens
  - Reduce apparent risk of contaminant migration
  - Less likely to observe water-level changes

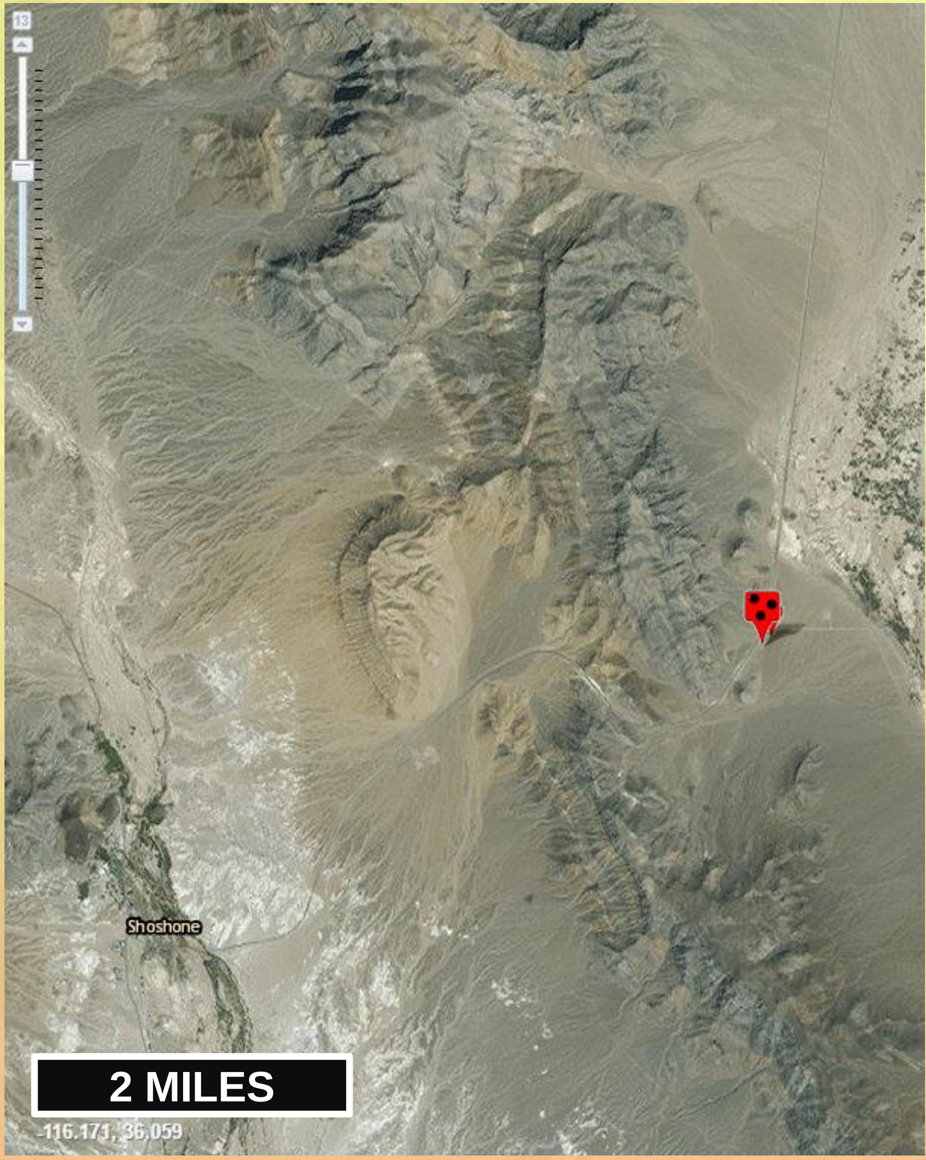
Heterogeneity Effects

- Homogeneous aquifer
  - Drawdown similar with depth
  - Screen position & length minimally affect observations
- Heterogeneous aquifer
  - Discrete fracture
  - Proximity to transmissive feature controls drawdown
  - Screen position & length greatly affect observations
- Completion approach
  - Prior knowledge
  - Honest assessment of need



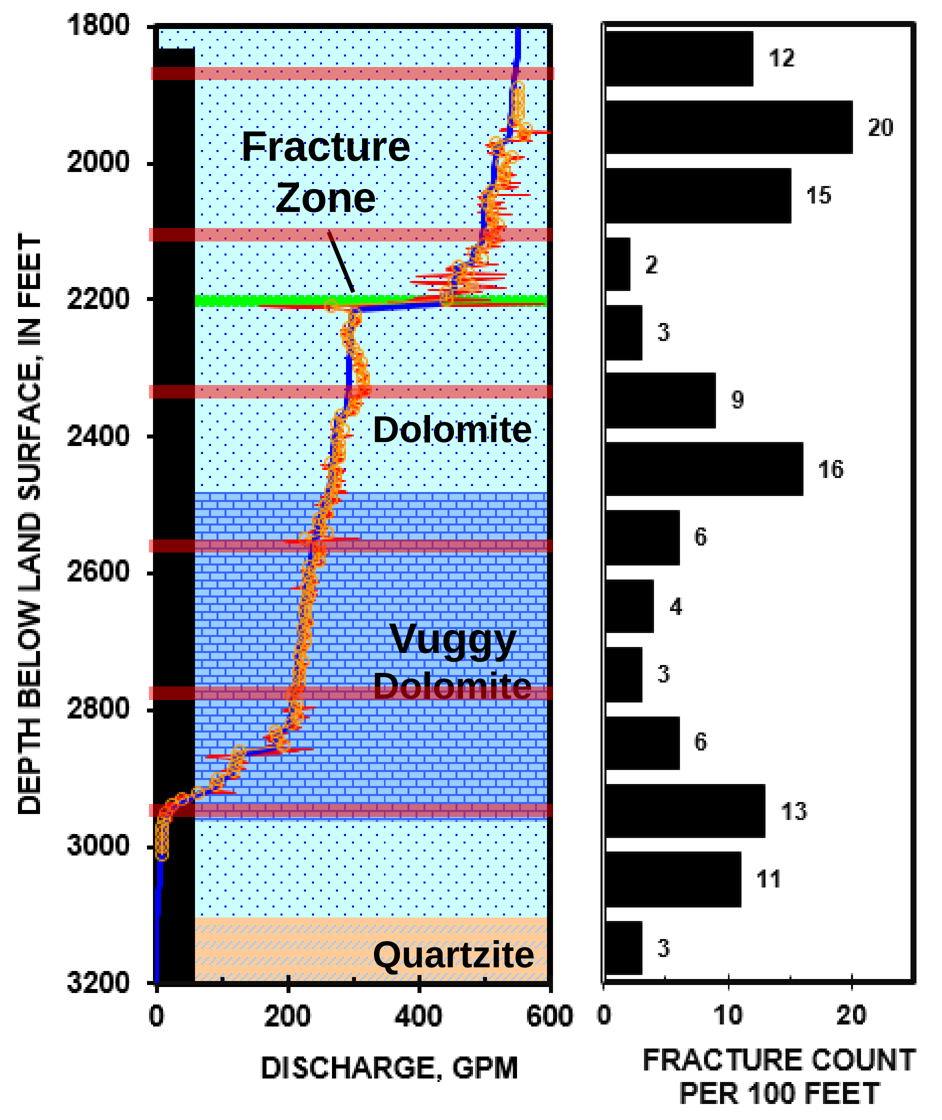
Prior Knowledge

- Surficial geology offers some clue
  - Basin fill more predictable, than hard rocks
  - Significant variability all units
- Wells provide real knowledge
  - Developed basin, Short screens can work
  - Undeveloped basin, Hedge bets with long screen Embrace your ignorance



Hard Rock

- ER-6-1 #2, Yucca Flat, NV
  - Open to 1,300 ft carbonate
  - >90% of transmissivity, in 2% of open hole
  - Determined with flow logs & aquifer testing
- Other indicators of T
  - Not rock type
  - Not fracture count
- More likely to miss permeable interval with short screen



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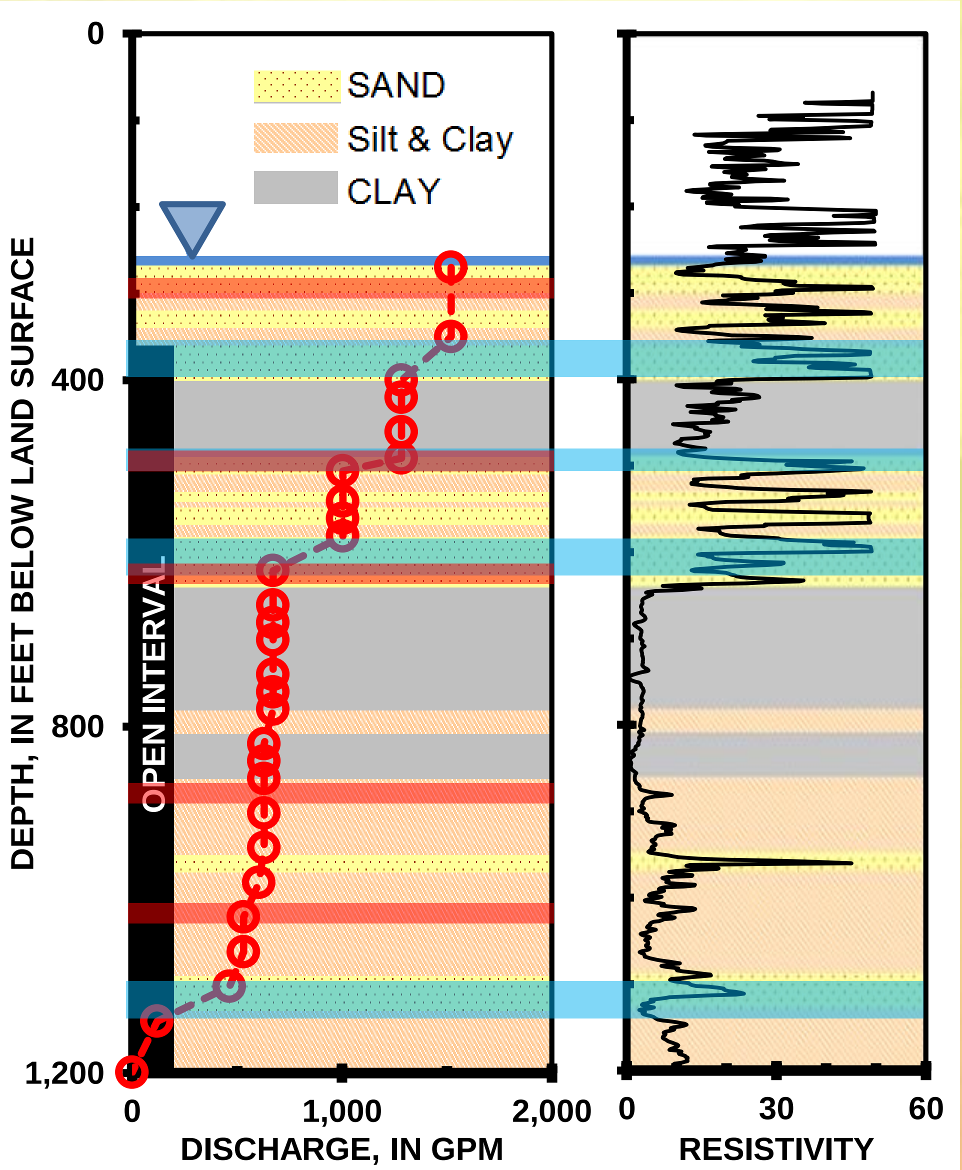
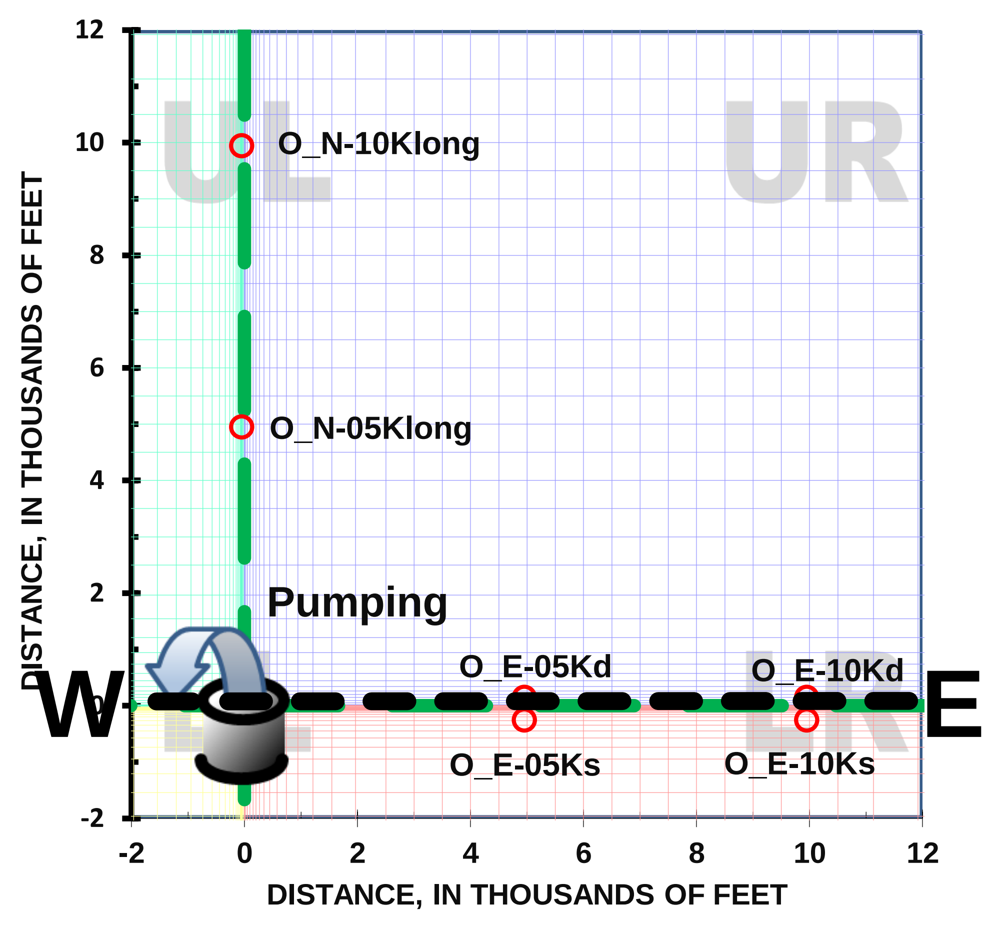
Basin Fill

- W4-54, Antelope V., CA
  - Open to 900 ft basin fill
  - 80% of transmissivity, in 16% of open hole
  - Determined with flow logs
- Lithology & resistivity
  - Clay & sand distinct
  - Permeable sands similar to low-K sands
- Short screen
  - Better odds than hard rock
  - Can still miss target



Test Tradeoffs

- Compare responses in hypothetical system
  - Two distinct aquifers
  - 90% of transmissivity in shallow aquifer
- Aquifer test
  - Pump 500 gpm, 10 d
  - Recovery observed, 40 d
- Hydraulic properties
  - T = 8,800 ft²/d
  - Sy = 0.1; Ss = 2.E-6 1/ft
  - Kh/Kv = 10:1



Lithology	K, ft/d	T, ft²/d
Lava	200	8,000
Partially-welded tuff	10	800
Ash-Fall Tuff	0.03	11

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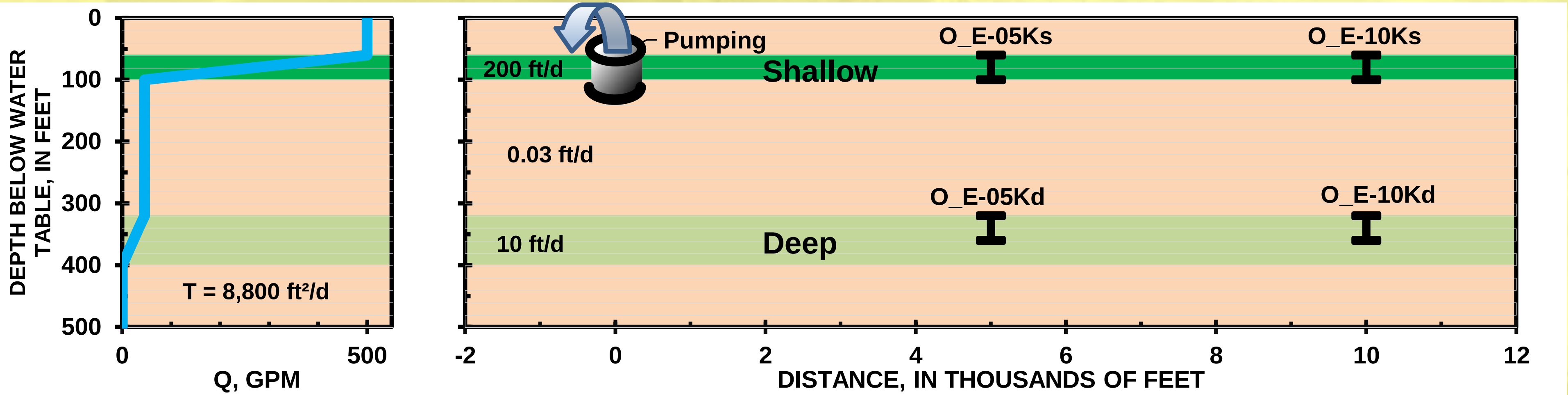
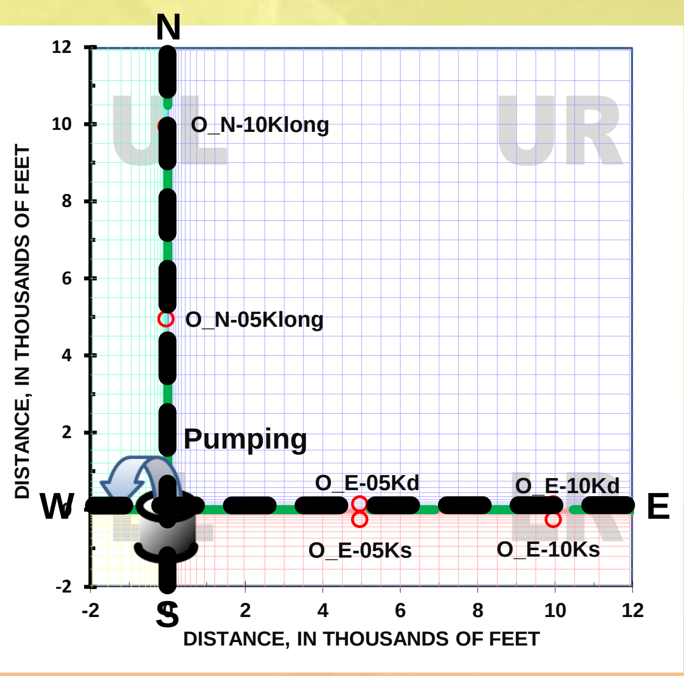
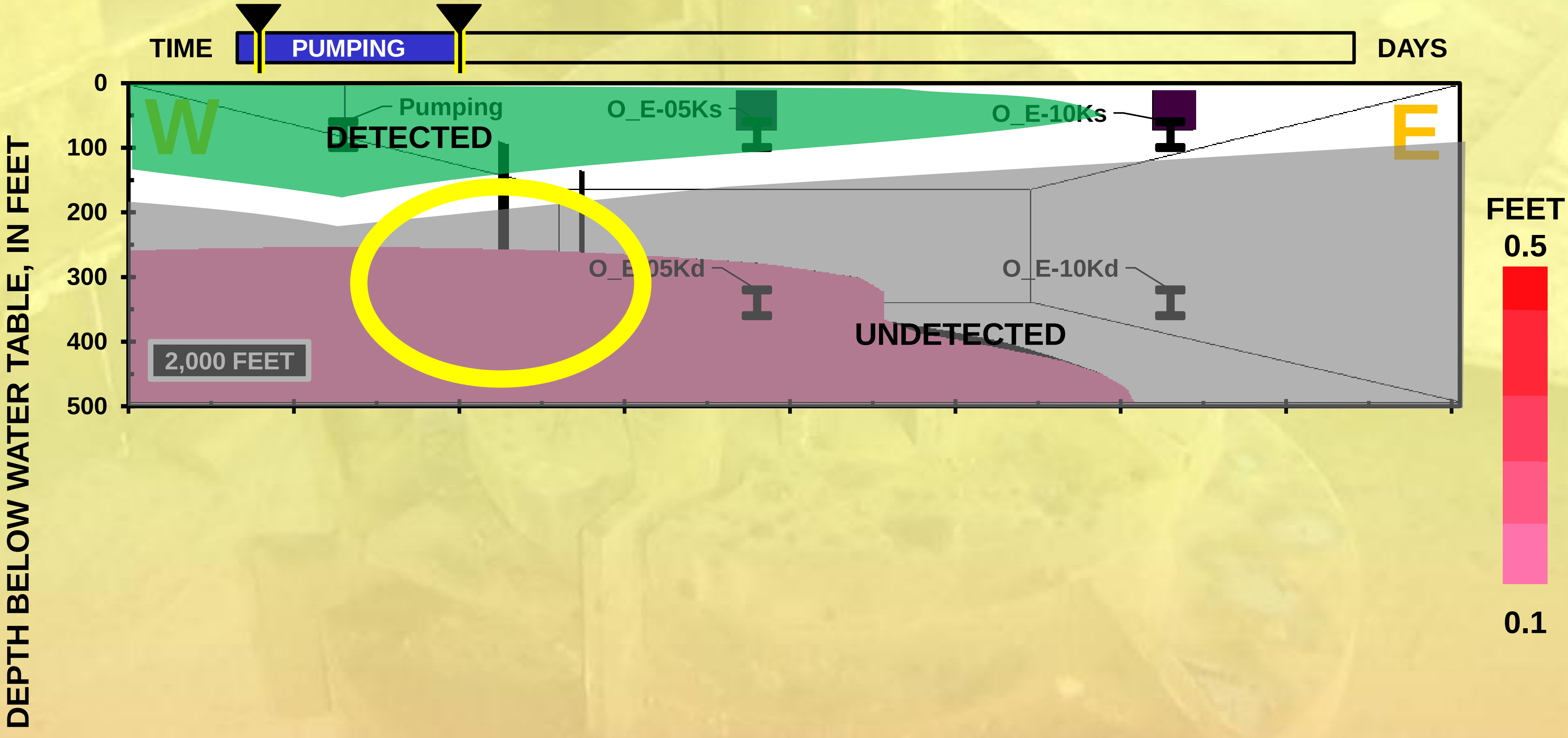
Lithology & Completions



- Distribution from Pahute Mesa
  – 90% of T in <4% of >50,000 ft
- Pump permeable interval
- Observation wells
  – 1 and 2 miles from pumping well
  – E-W short screens, shallow & deep
  – N-S long screens, intersect all

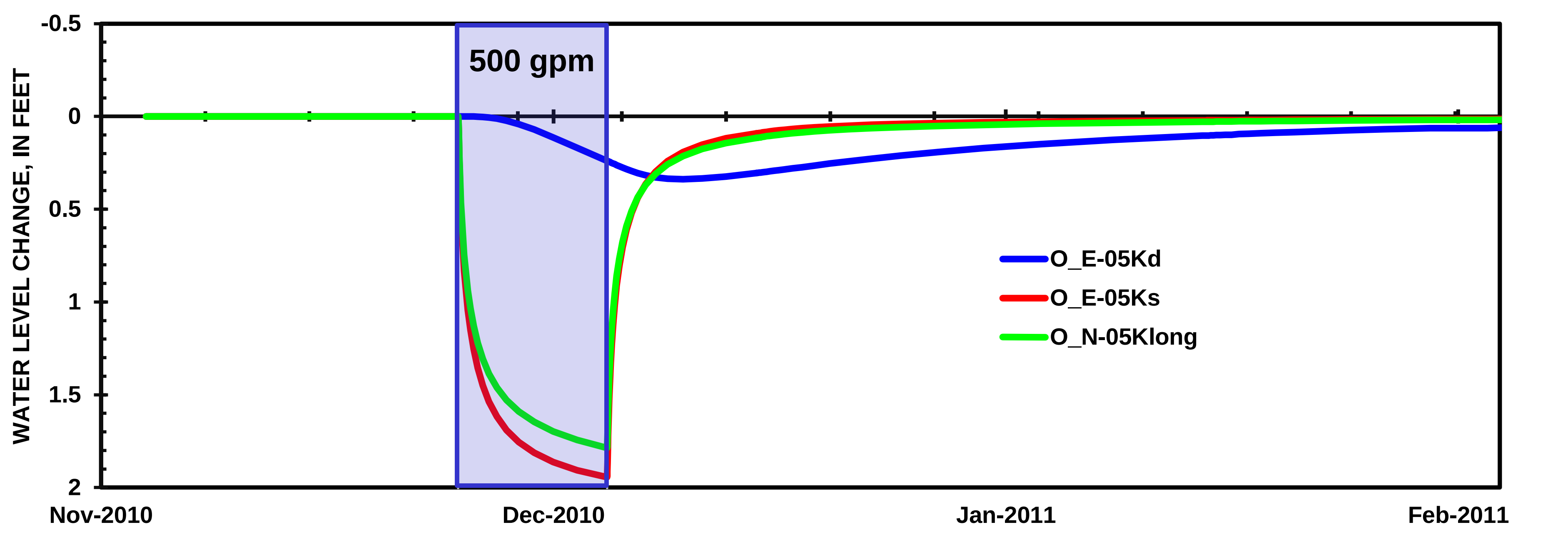


Drawdown in Sections



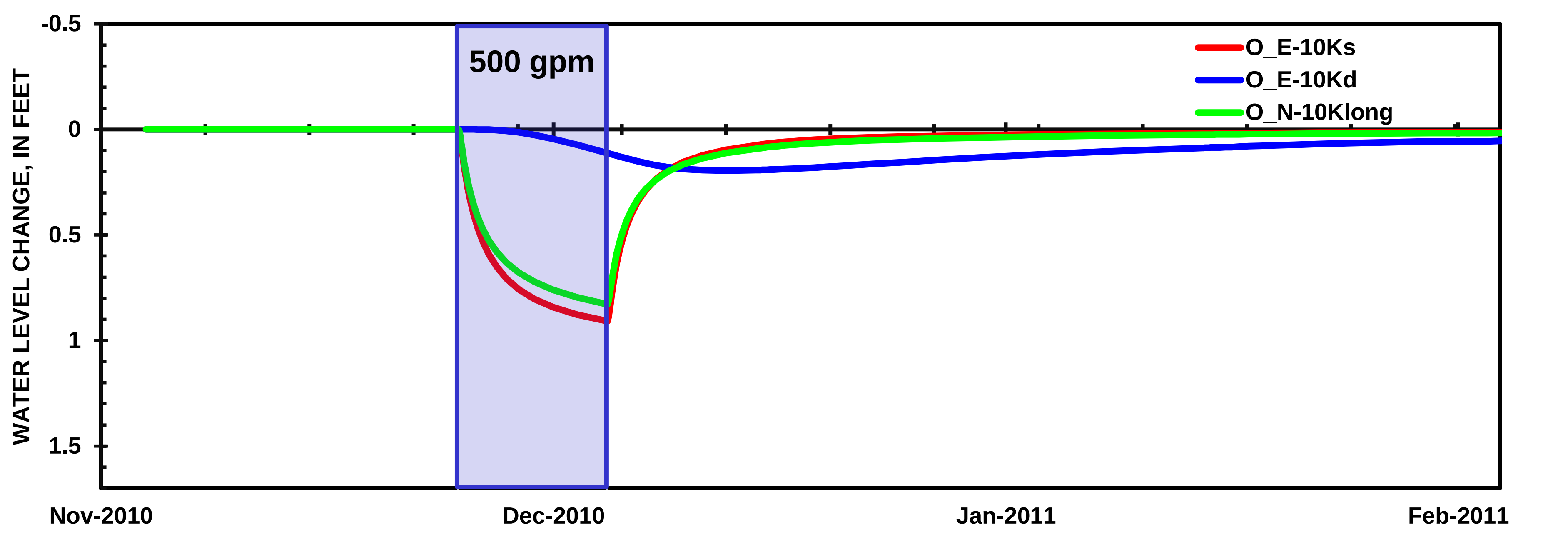
- Long screens affect drawdown, less so during recovery
  - Increase likelihood of drawdown detection, Reduces detection limit

1 Mile Away



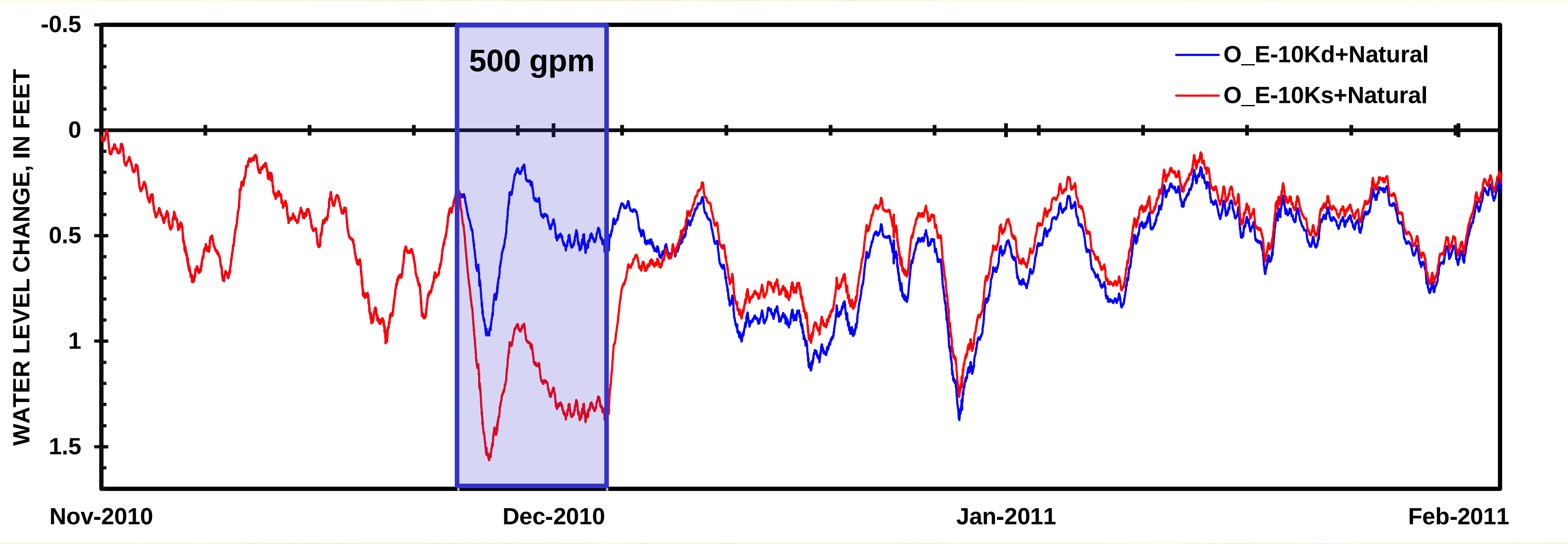
- Sharp response in pumped, shallow unit
- Attenuated & delayed in unpumped, deep unit
- Long screen change similar to shallow, short screen
  - Weighted towards unit with greater transmissivity
- Maximum induced Q is 4 gpm in long well

2 Miles Away



- Responses similar to 1 mi, Except half the change
- Maximum induced Q <2 gpm in long well
  - Minor effect on QW, long-term QW greater consideration
- True detectability less clear than advertised
  - Risk of non-detection greater than apparent

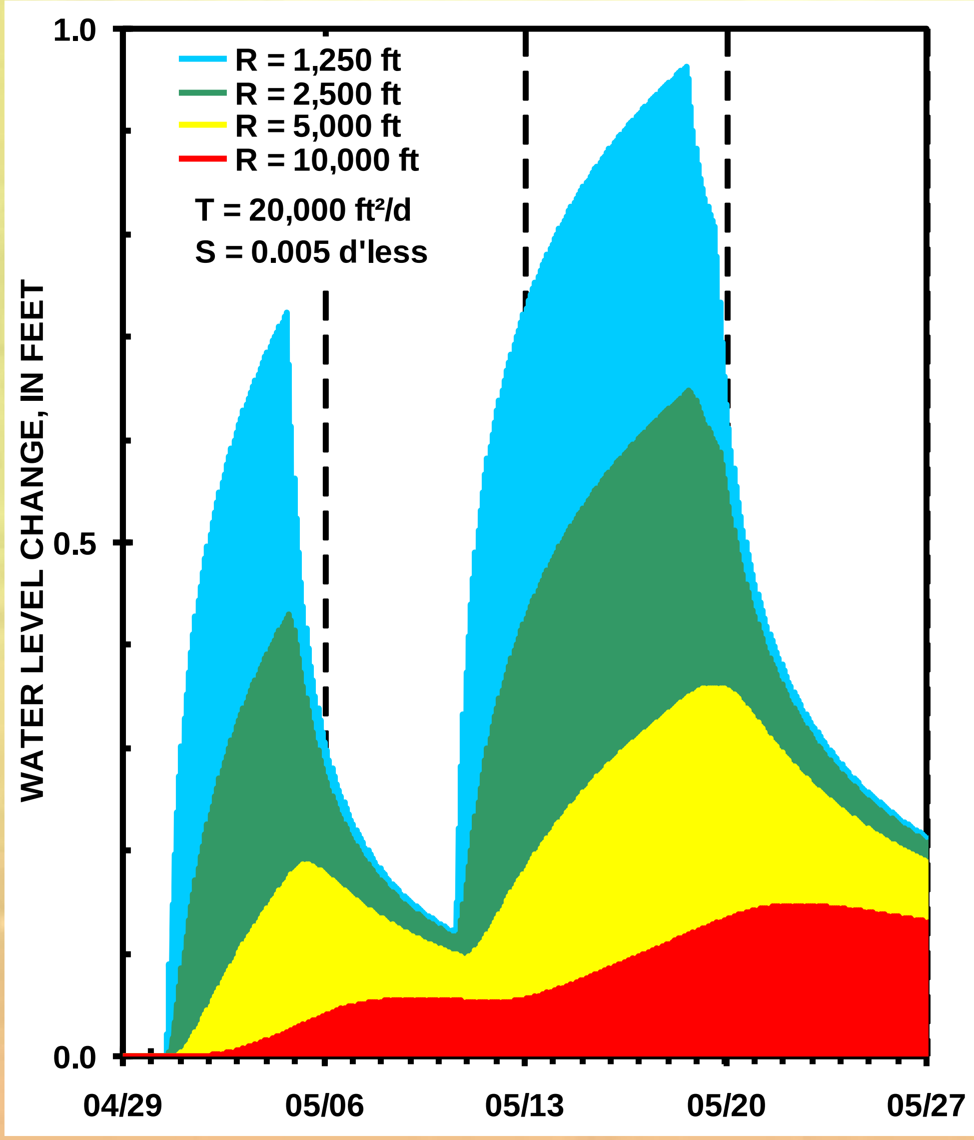
Natural Fluctuations



- Ideal drawdowns, natural fluctuations absent
- Responses less clear combined with barometric change, tidal signals, & long-term trends
- Drawdown recoverable with water-level modeling

Water-Level Modeling

- Sum possible sources
- Natural signals
  - Tides
  - Barometer
  - Background water levels
- Natural components can be correlated
- Pumping
  - Superimpose Theis
  - Transform function
  - T & S limited to no value
- Theis Transform
- Synthetic water levels



Synthetic Water Levels

Estimated

$$SWL(t) = C_0 + \sum_{i=1}^{n} a_i V_i(t + \phi_i)$$

C_0 is a constant, L

n is the number of time series components

V_i is the time series component

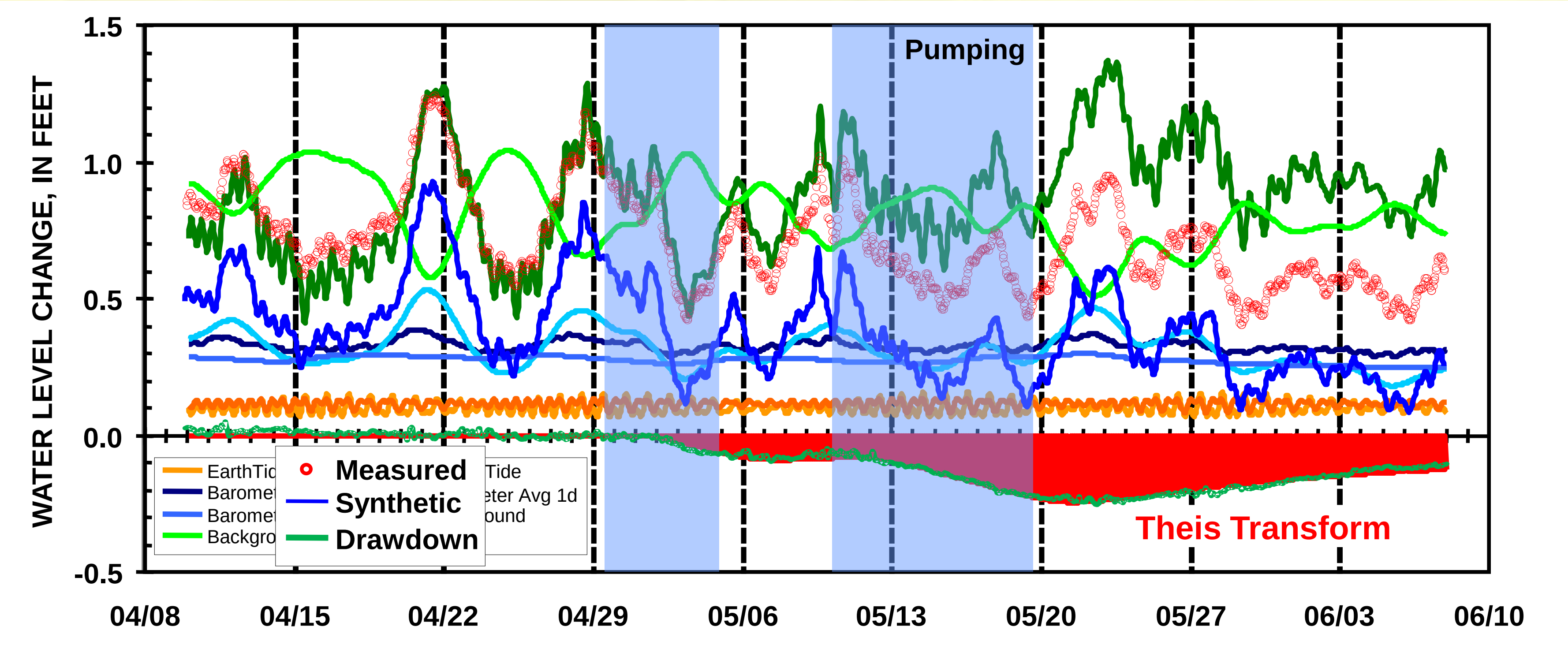
a_i is the amplitude multiplier of the i^{th} component, L

ϕ_i is the phase shift of the i^{th} component, T

$V_i(t + \phi_i)$ is the value of the i^{th} component at time $t + \phi_i$

All series interpolated ► Functions are smooth

WLM Example



- Fit measured water levels
- Adjust amplitude and phase each series
- Drawdown = Theis Transform – Residuals
- SeriesSEE, an Excel Add-IN, USGS TM4-F4

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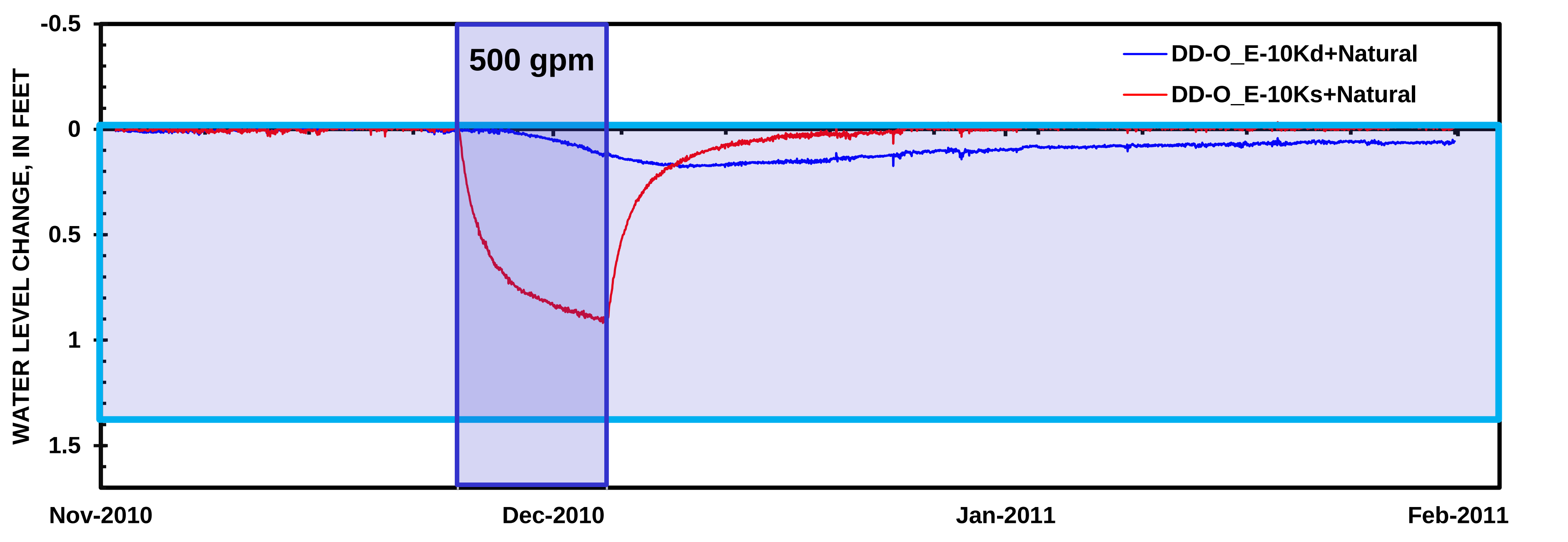
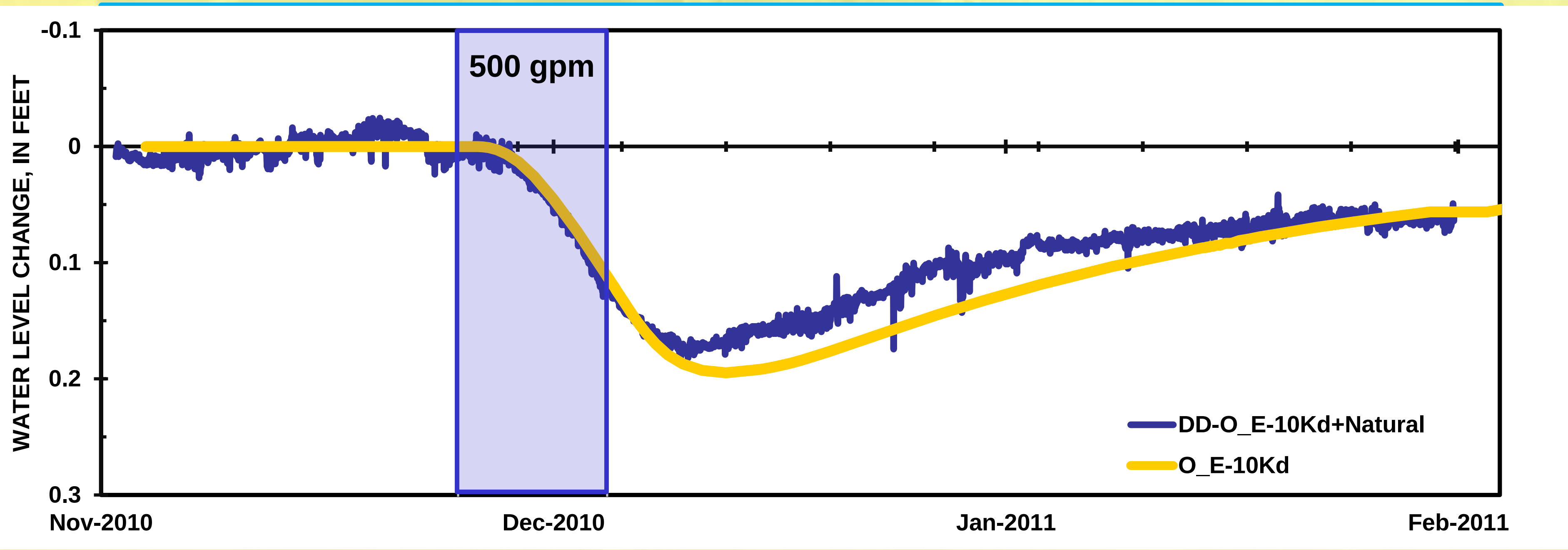
Estimated with WLM



- Drawdown recoverable with water-level modeling
  - Sensitive to measurement resolution
- Vibrating wire installations—Grouted in-place or Avoiding thermal effects in pumping wells
  - Greater pressures, Lower resolution

Measurement Resolution



- Drawdown estimable with water-level modeling
  - Inherent noise remains in estimated drawdowns
  - Low resolution reduces detection
- Further explanation in upcoming SeriesSEE classes
  - March 1, Las Vegas; June 19, 2017, Reno

CONCLUSIONS

- Hydraulic conductivity variable in most wellbores
  – Transmissive intervals small fraction, <10% in carbonate & volcanic rocks
  – Flow only definitive identifier of permeable intervals
- Adapt wells to intended observations
  – Short screens appropriately add detail,
    - Developed basins with nearby stresses
  – Long screens better in the absence of data
    - Undeveloped basins with distant stresses
- Monitor distant drawdowns with long screens
  – More effective than multiple short screens
  – Consistent with how smart we actually are