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POTENTIAL IMPACT OF LEGACY WELL CONSTRUCTIONS ON WATER QUALITY IN SUPPLY WELLS

Robert M. Gailey

California State Water Resources Control Board

Drinking Water Needs Assessment Domestic Well Workshop

January 18, 2019

OUTLINE

- Overview of factors affecting water quality in supply wells
- Potential impact of legacy well constructions
- Possible path forward

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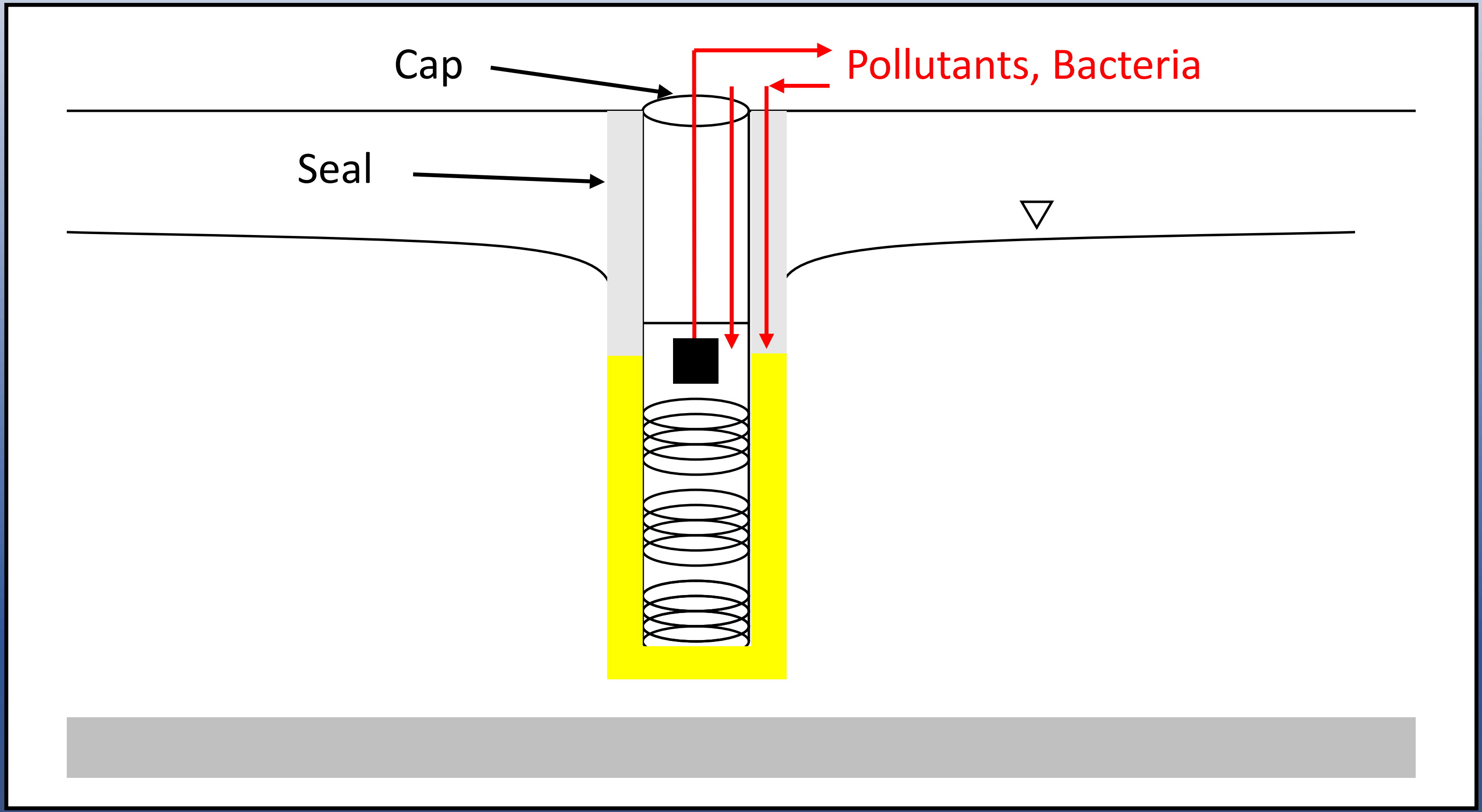
FACTORS AFFECTING WELL WATER QUALITY

- Surface water impact
- Separation from shallow strata
- Contribution from impaired strata
- Well screen condition
- Conduit wells

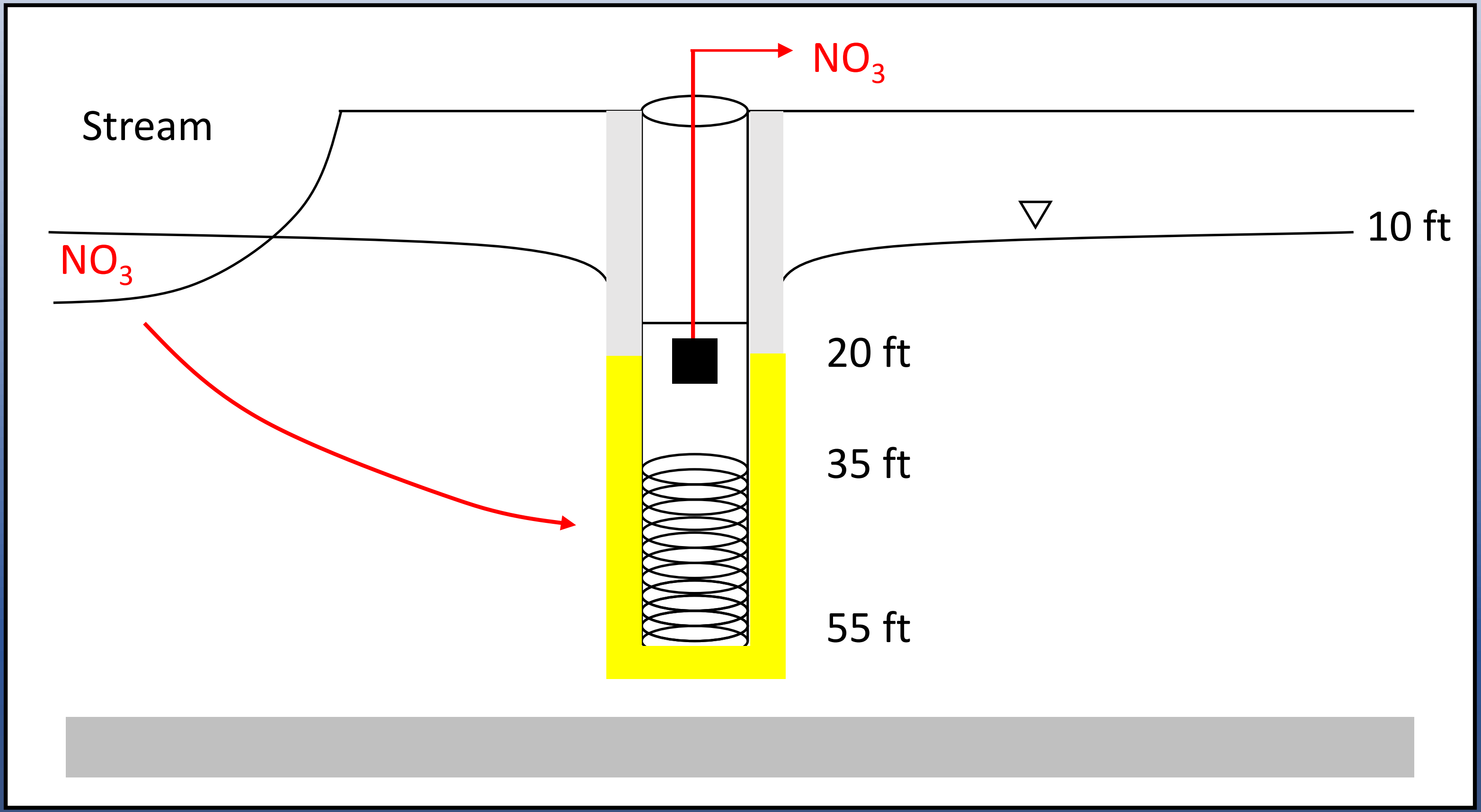
SURFACEWATER IMPACT

Cap integrity and annular seal performance



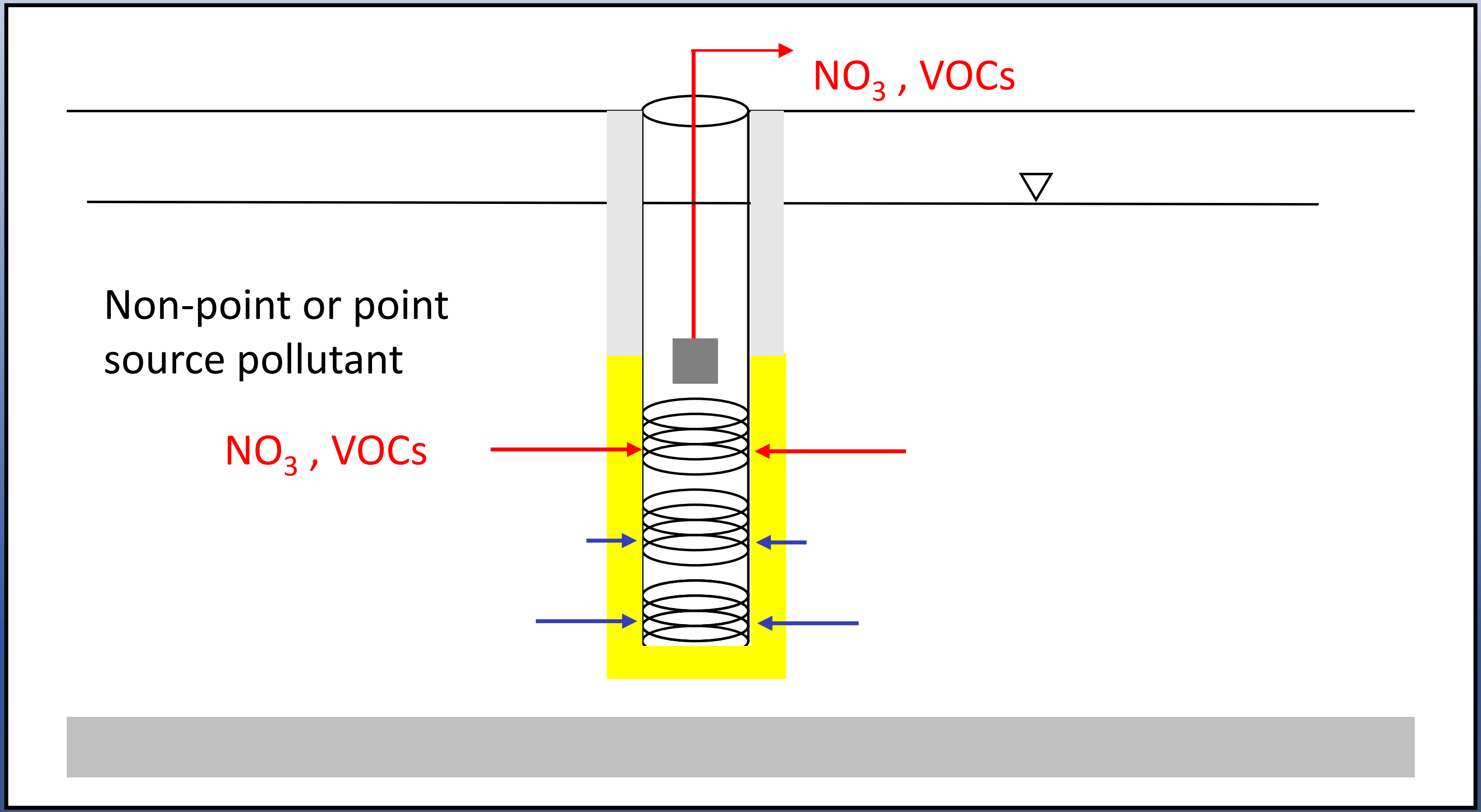
SURFACE WATER IMPACT (Cont'd)

Groundwater under influence of surface water



SEPARATION FROM SHALLOW STRATA (Cont'd)

Depths to tops of gravel pack and screen



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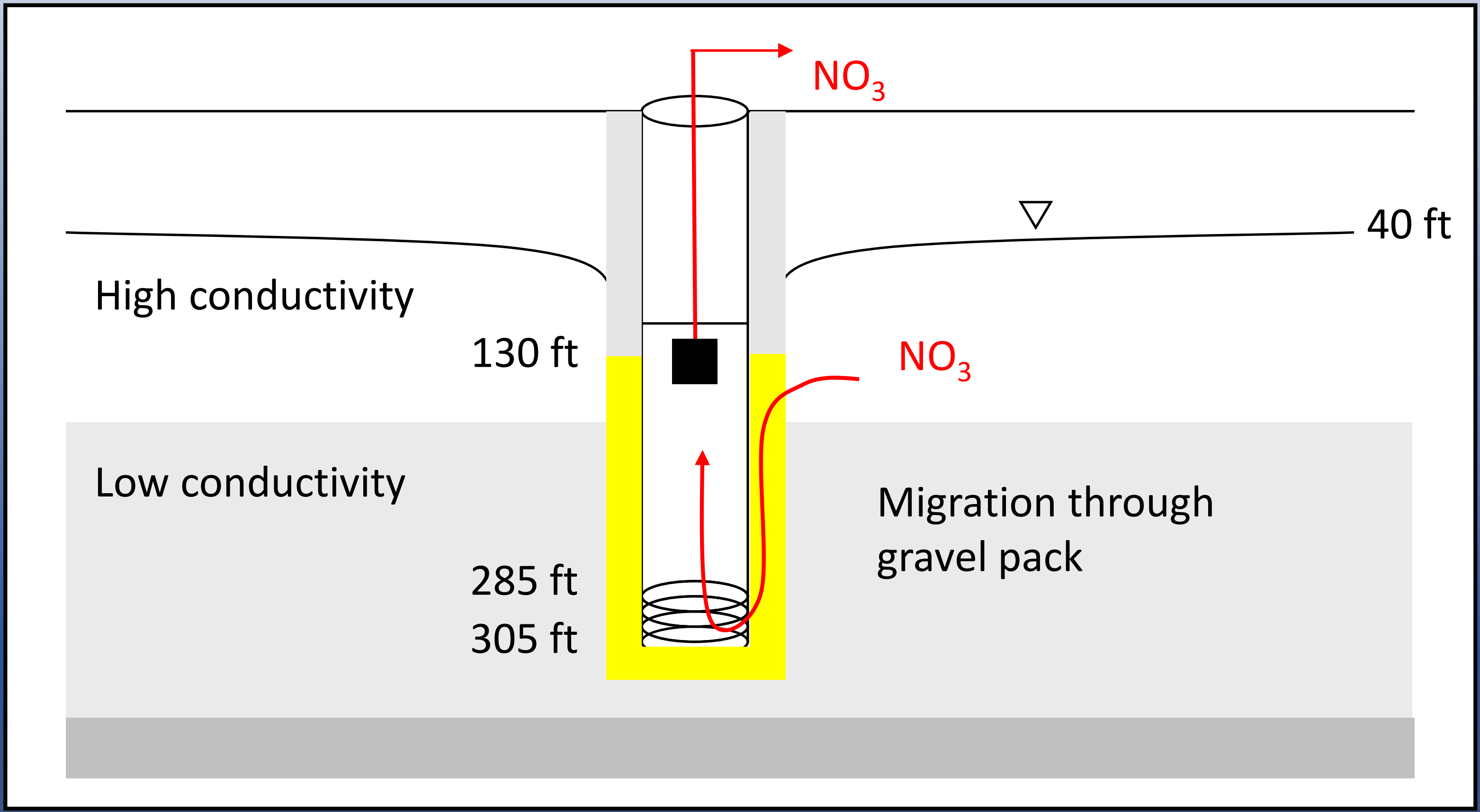
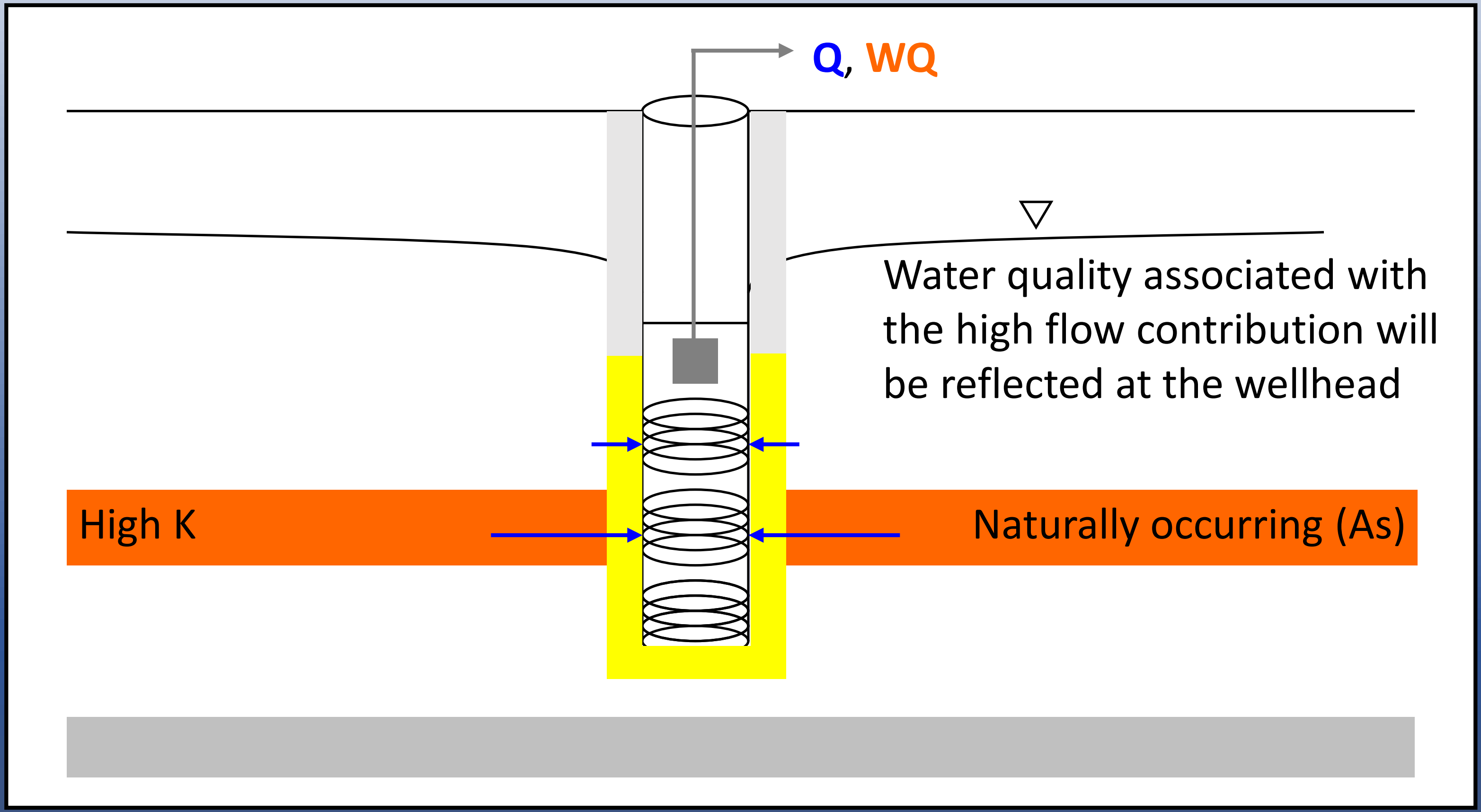


CONTRIBUTION FROM IMPAIRED STRATA

Gravel pack and screen placement and length



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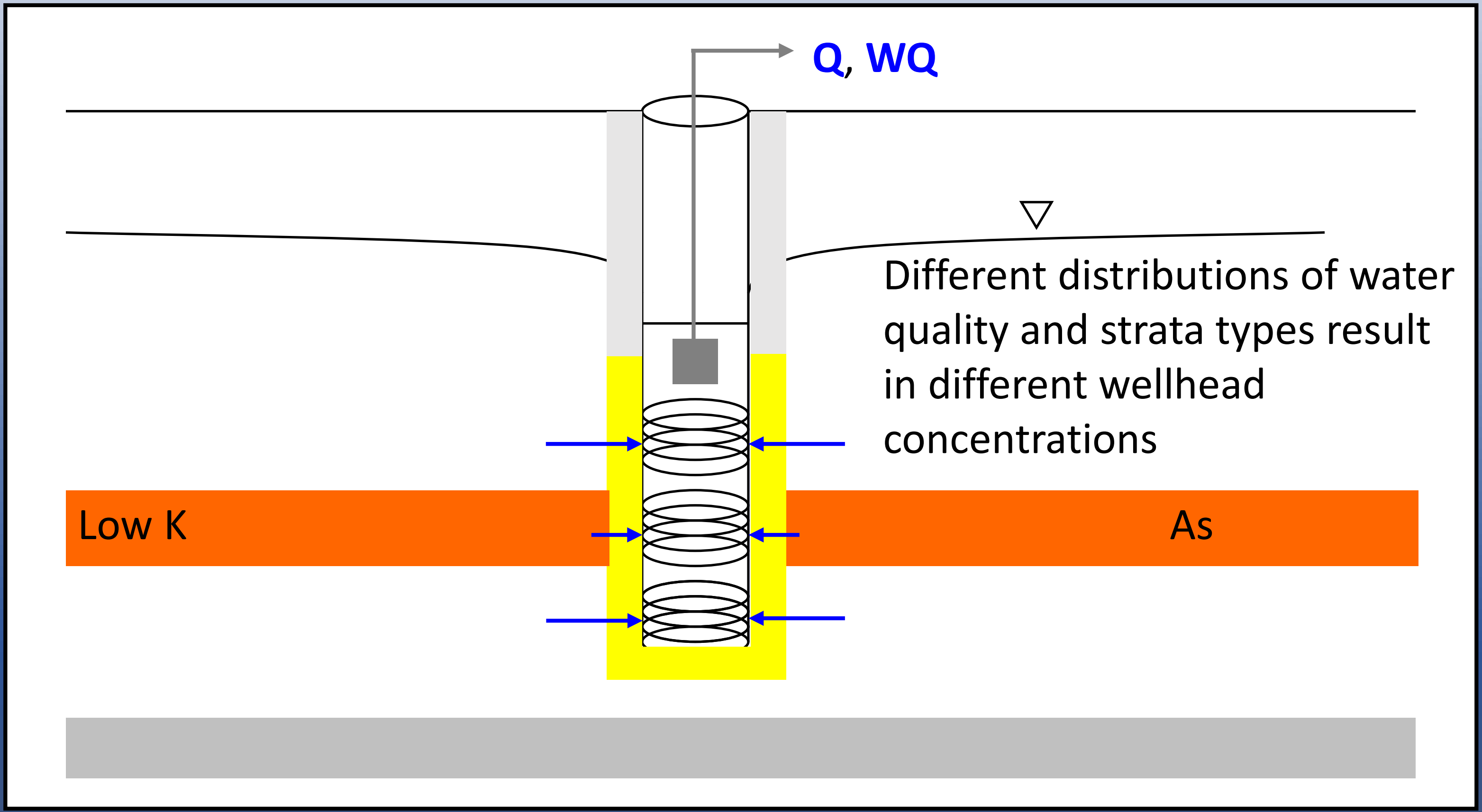
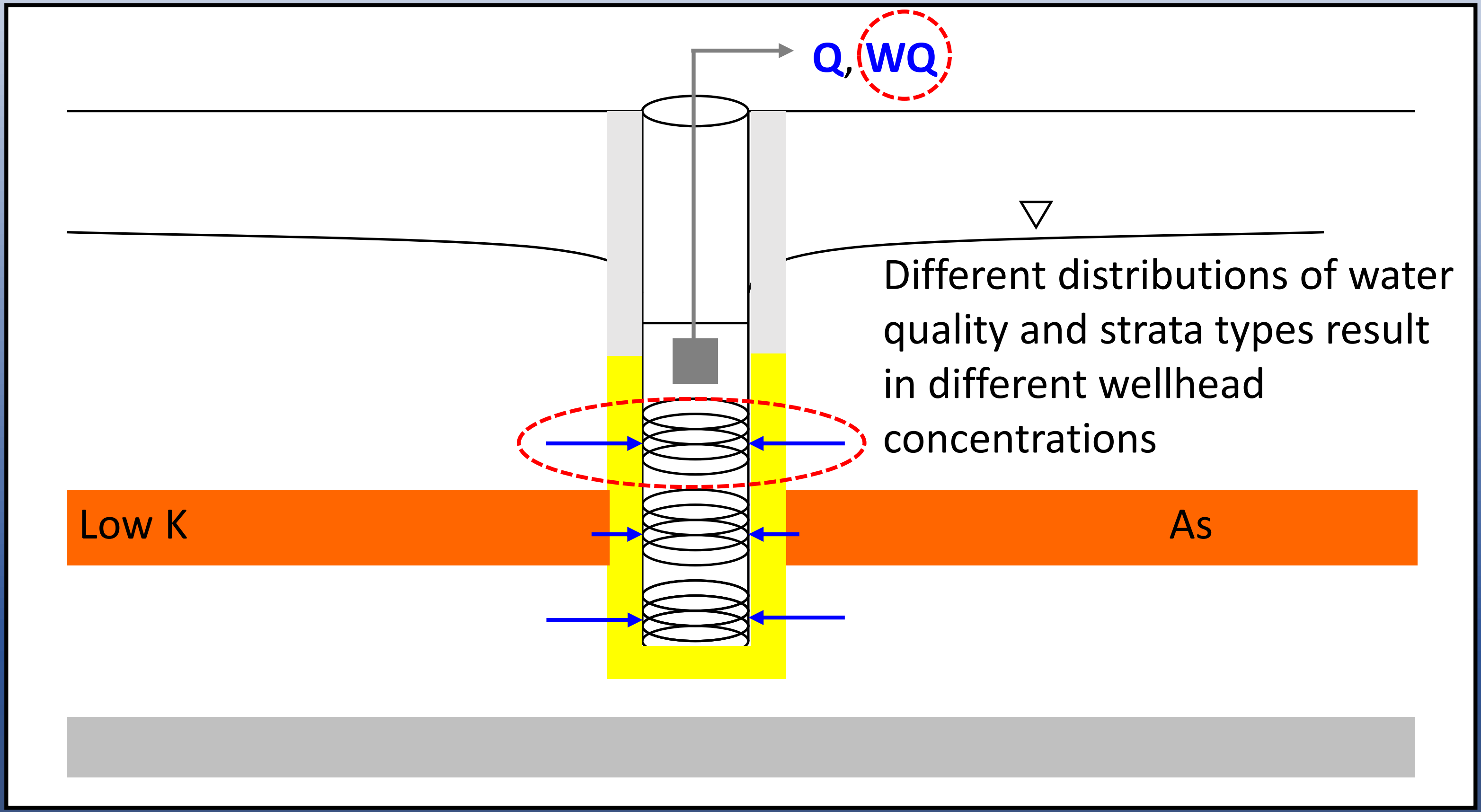


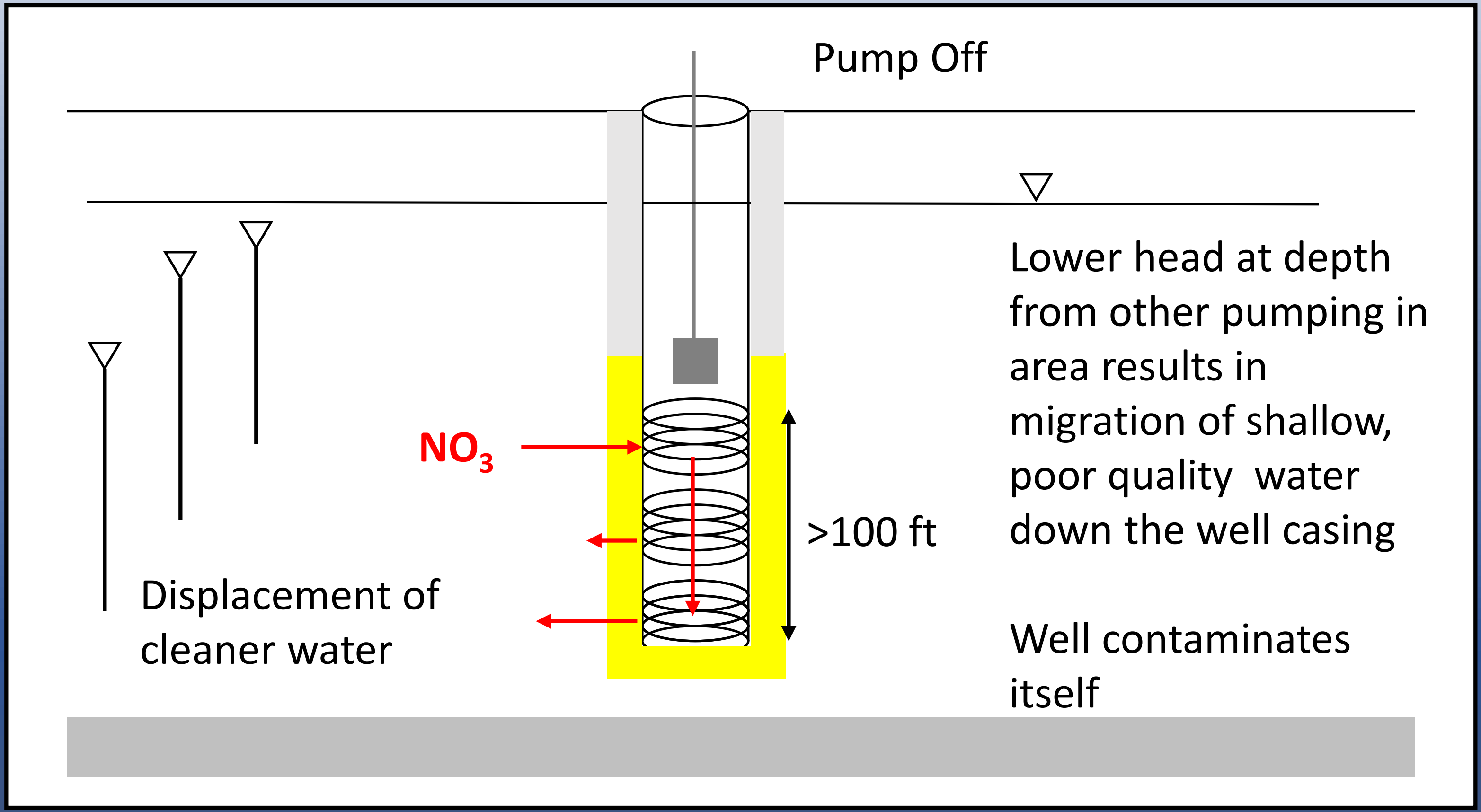
WELL SCREEN CONDITIONS

Screen clogging over time changes water quality



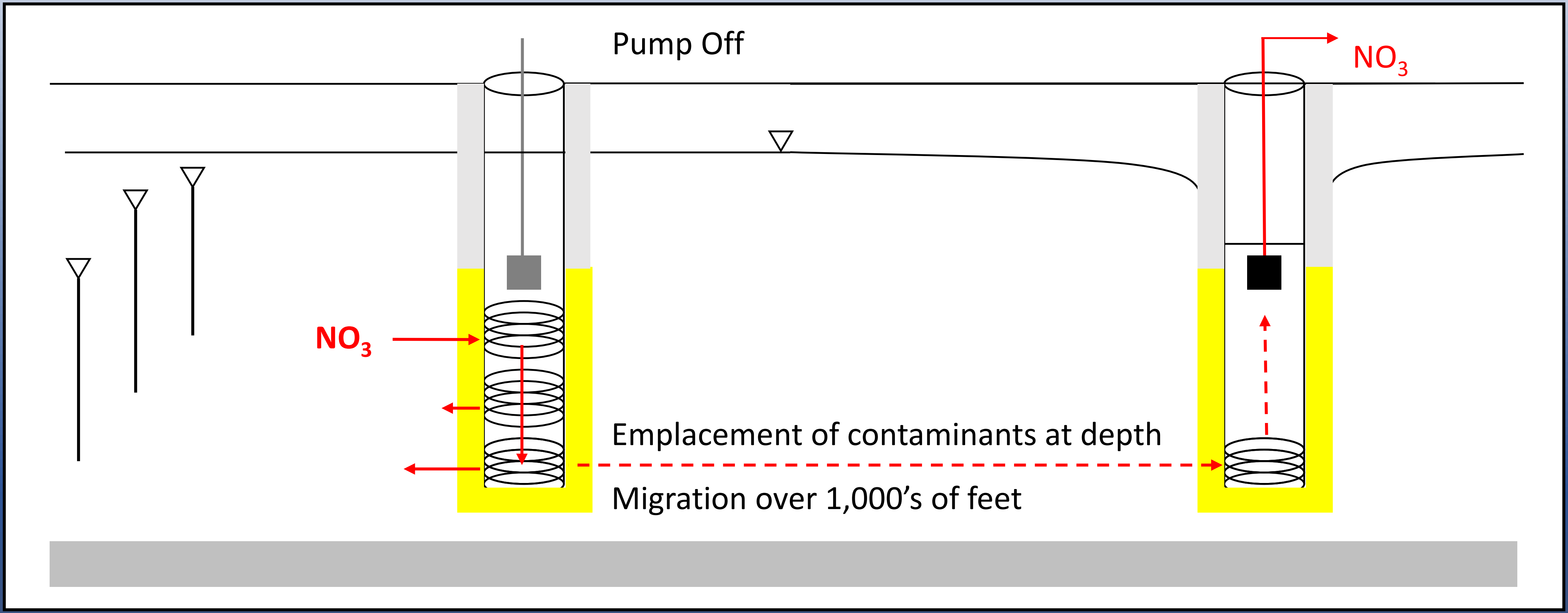
CONDUIT WELLS

Single well effect of conduit flow and transport



CONDUIT WELLS

Proximity to conduit wells



COMMON THREADS

- Construction details and well condition relative to
  - Water quality stratification
  - Hydrogeology
- Certainly must consider for new well constructions
- Challenge is what to do about large population of existing wells

OUTLINE

- Overview of factors affecting water quality in supply wells
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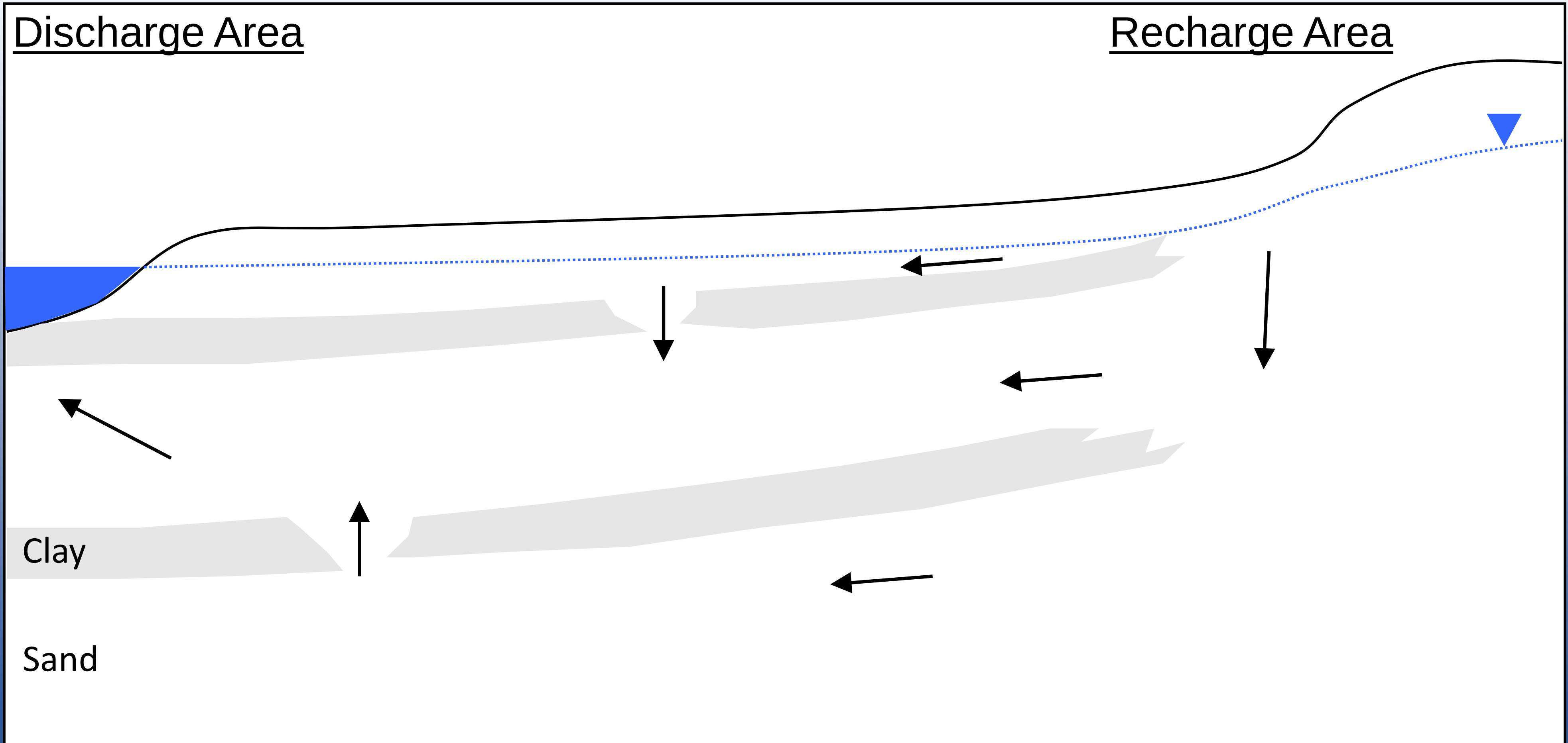
GRA ANNUAL CONFERENCE PRESENTATION

IDENTIFYING AREAS OF CONCERN FOR NONPOINT SOURCE POLLUTANT MIGRATION THROUGH INACTIVE SUPPLY WELLS: A POTENTIAL SCREENING APPROACH FOR SGMA

September 26, 2018

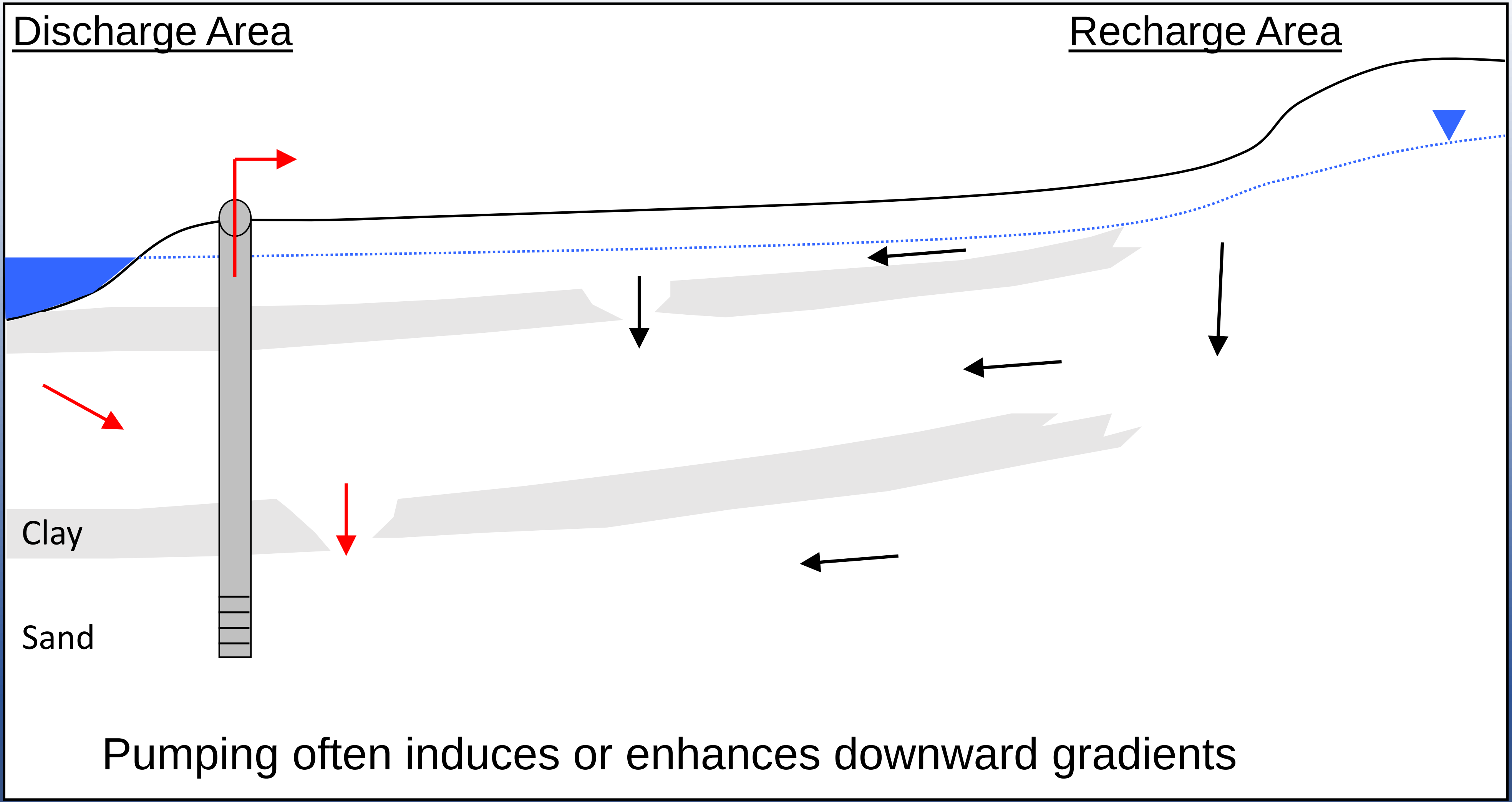
FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS



Natural groundwater systems produce vertical hydraulic gradients

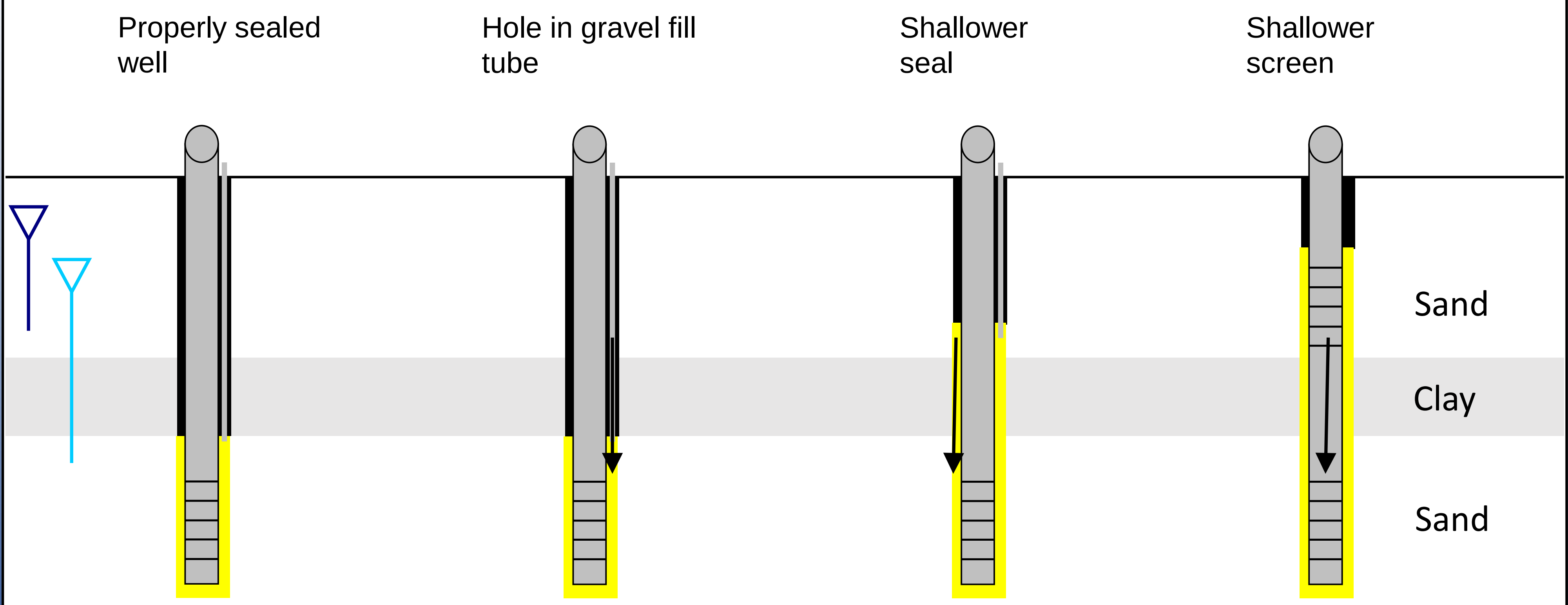
(Gailey, 2017, Hydrogeology Journal)

FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS



(Gailey, 2017, Hydrogeology Journal)

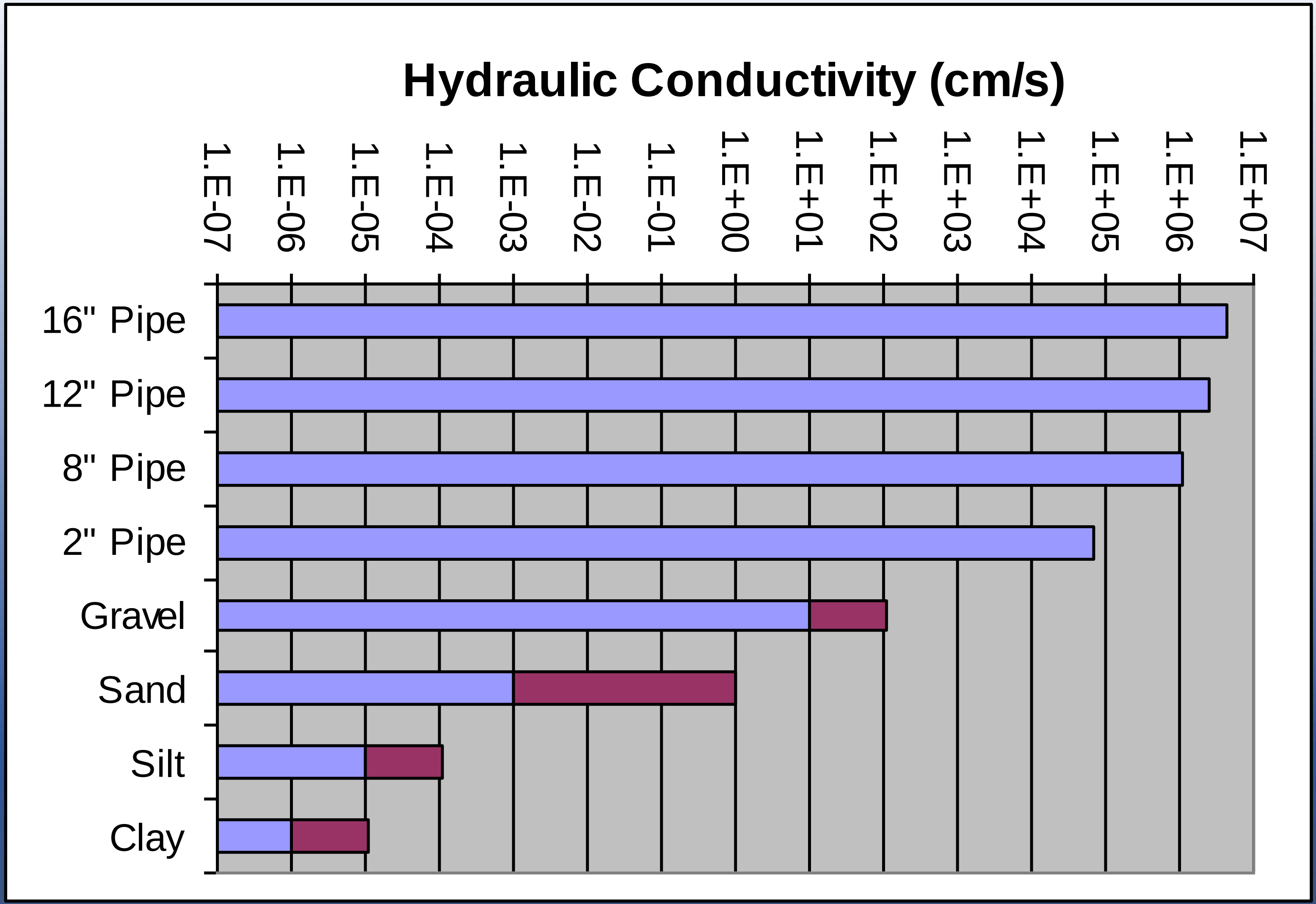
FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS



Well structures can create pathways for flow across low-conductivity strata

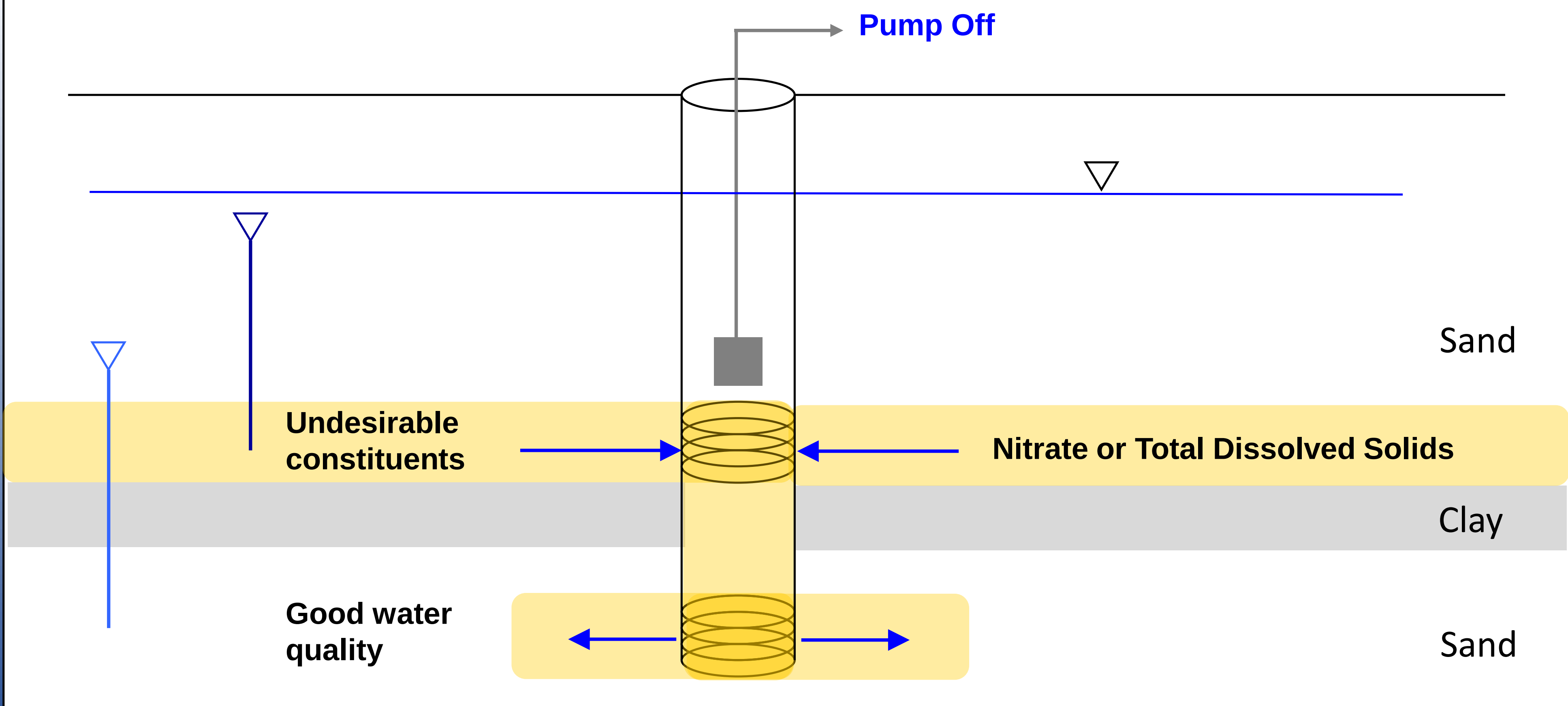
(Gailey, 2017, Hydrogeology Journal)

FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS



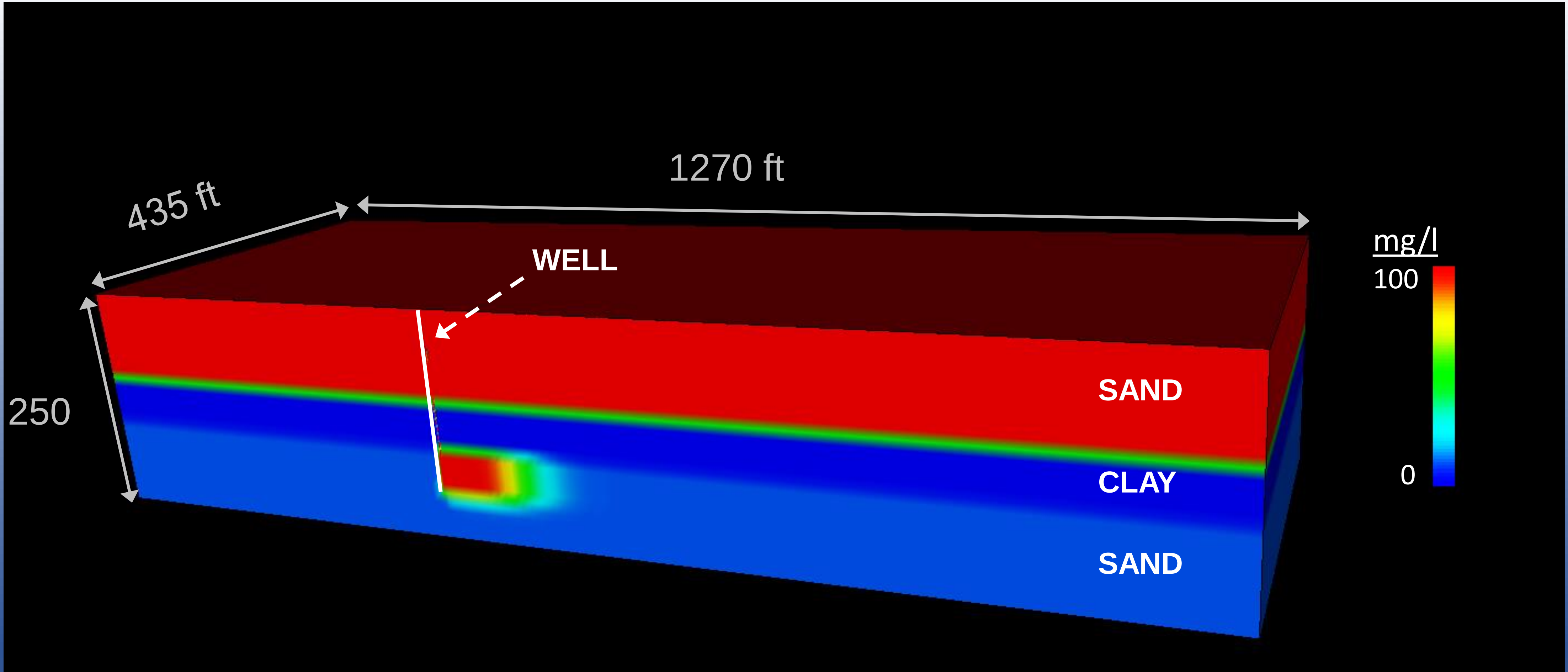
Effective hydraulic conductivities of well casings are orders of magnitude greater than layered sediments

FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS



Transport can occur when water quality varies with depth

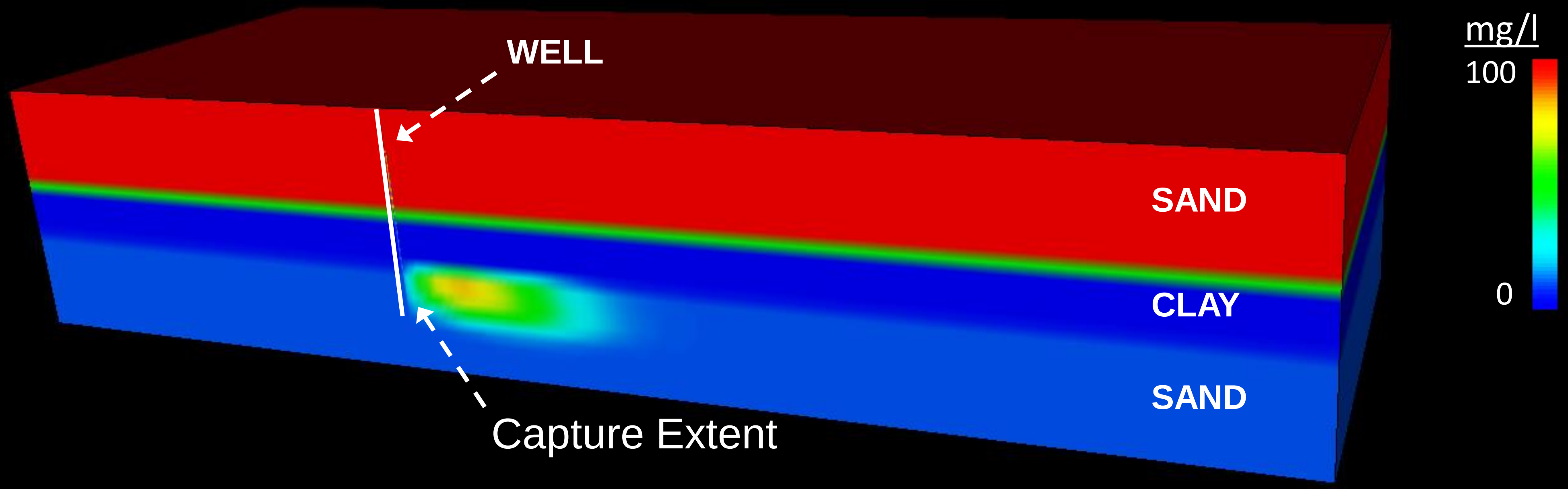
FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS



Seasonal operation creates periods of inactivity when transport will occur

(Gailey, 2017, Hydrogeology Journal)

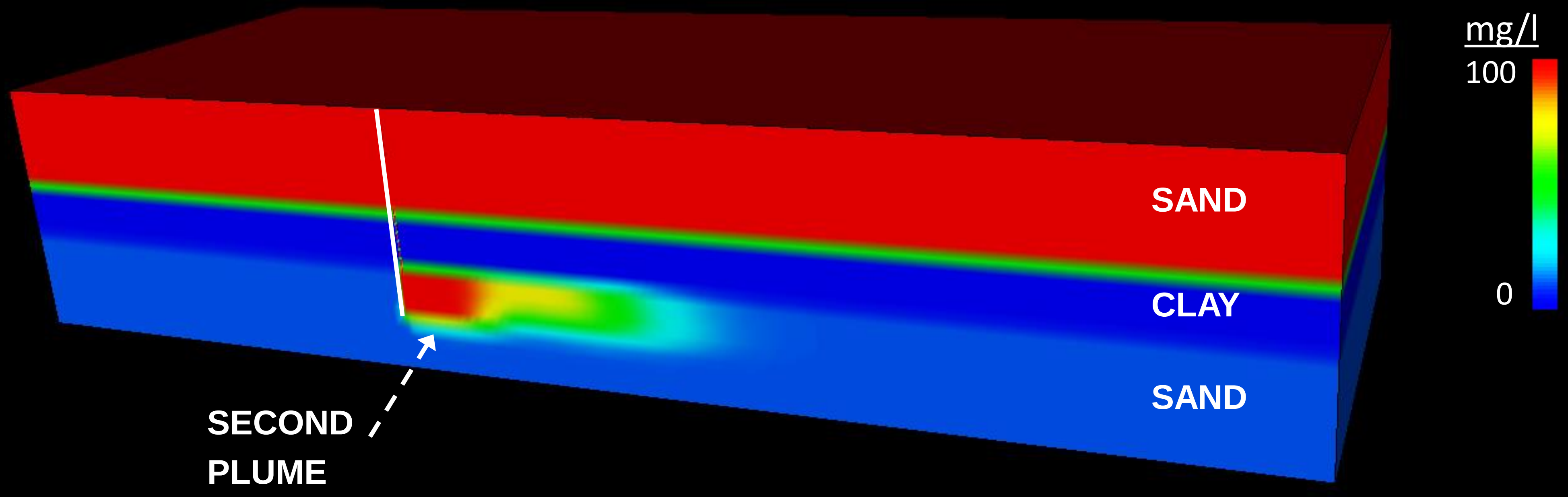
FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS



Pumping during the demand season often does not counteract the transport

(Gailey, 2017, Hydrogeology Journal)

FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS



Tens of millions of gallon can be contaminated by a single well

(Gailey, 2017, Hydrogeology Journal)

POTENTIAL PREVALENCE IN CALIFORNIA

- Central Valley (20,000 sq mi)
- Pronounced agricultural activity
- Significant groundwater pumping
- Flow and transport through inactive wells evident around the valley (Gailey, 2017)
- Particularly notable in southern part of valley
- Potential contributing factor for nonpoint source contamination (total dissolved solids, nitrate, etc.)

ASSESSMENT APPROACH

- Apply methods to southern part of Central Valley
- Survey-level investigation as a first step
- Use wealth of newly available information
- Search for conditions that lead to wells acting as conduits

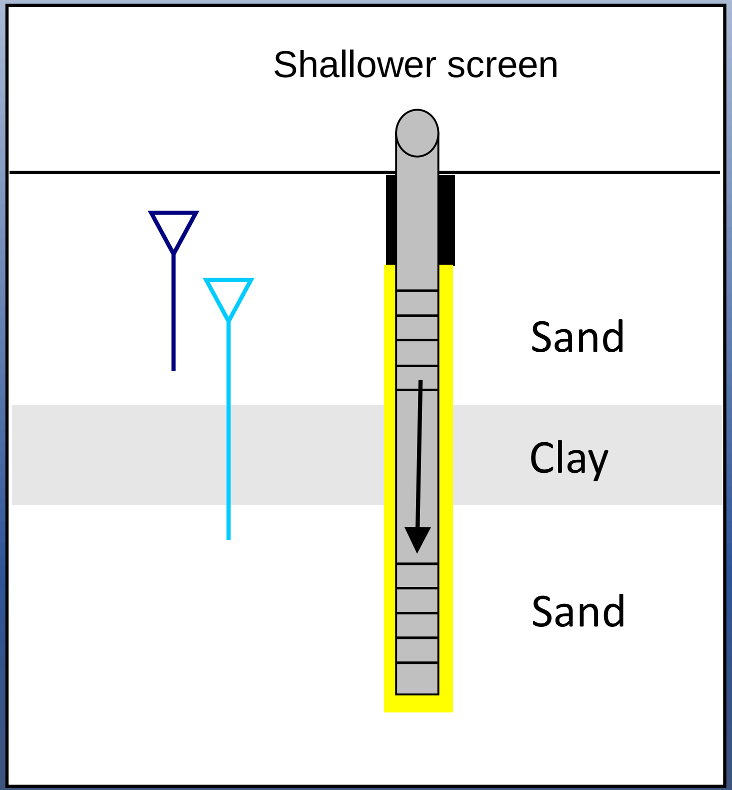
ASSESSMENT APPROACH

- Conditions when wells act as conduits
  - Vertical head differences (often from pumping at depth)
  - Shallow water quality impacts
  - Stratigraphy that impedes vertical flow and transport
  - Wells that short-circuit stratigraphy

AVAILABLE INFORMATION

- Well construction report data from CA Department of Water Resources
  - Locations accurate to the level of Public Land Survey System sections
  - Construction details including
    - Depth to top of screen
    - Depth to bottom of screen

Scenario Considered



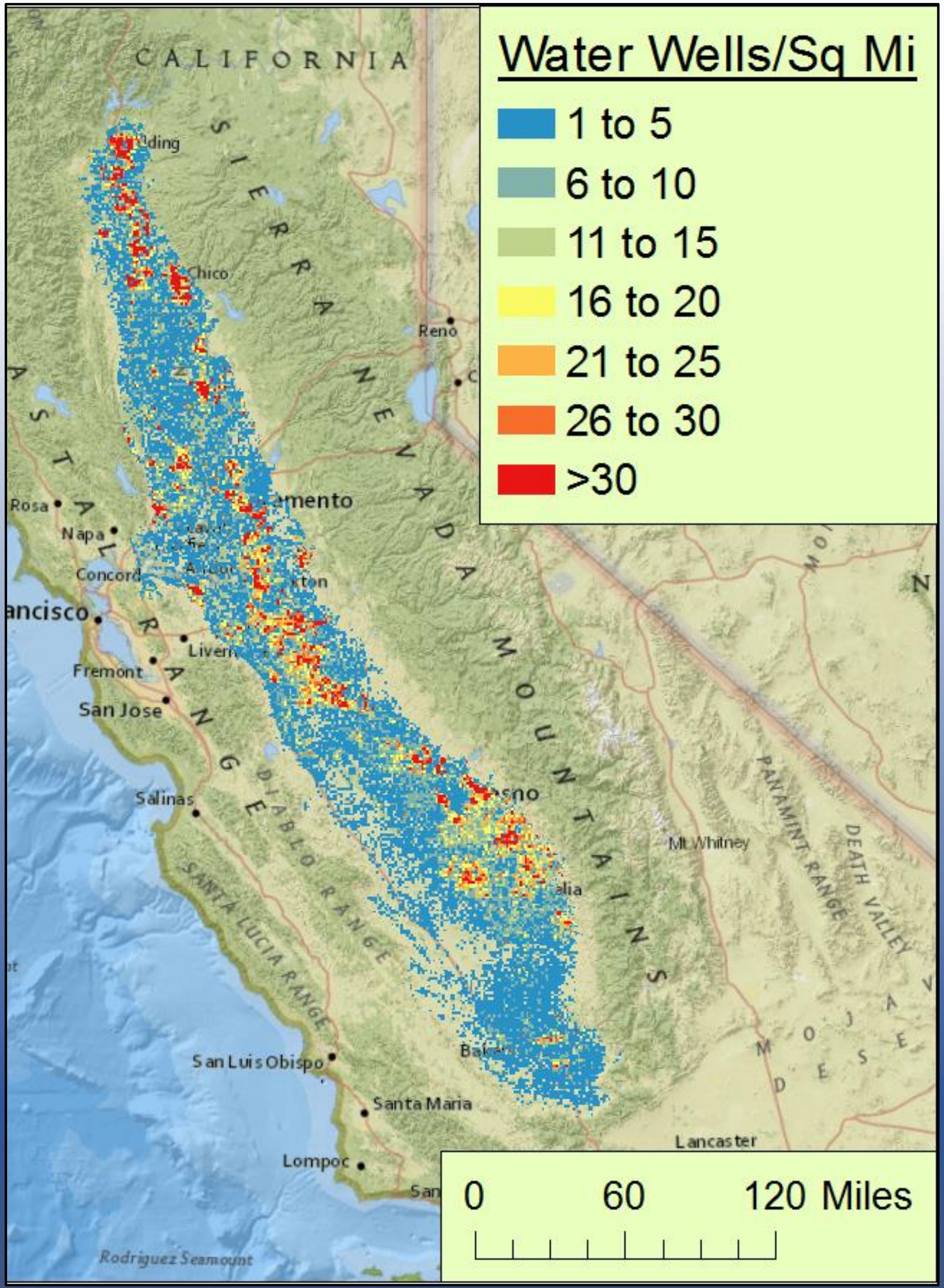
AVAILABLE INFORMATION

- Shallow water quality from CV-SALTS
    - Total dissolved solids
    - Nitrate as nitrogen
- Large-scale stratigraphy (Corcoran Clay) from USGS
    - Spatial extent
    - Depth to top
    - Thickness

AVAILABLE INFORMATION

- Well counts aggregated to PLSS sections from DWR data

	Number	% of State
• Total water wells:	145,098	(37%)
• Domestic:	95,688	(30%)
• Irrigation:	44,064	(71%)
• Public:	3,574	(27%)
• Industrial:	1,772	(41%)



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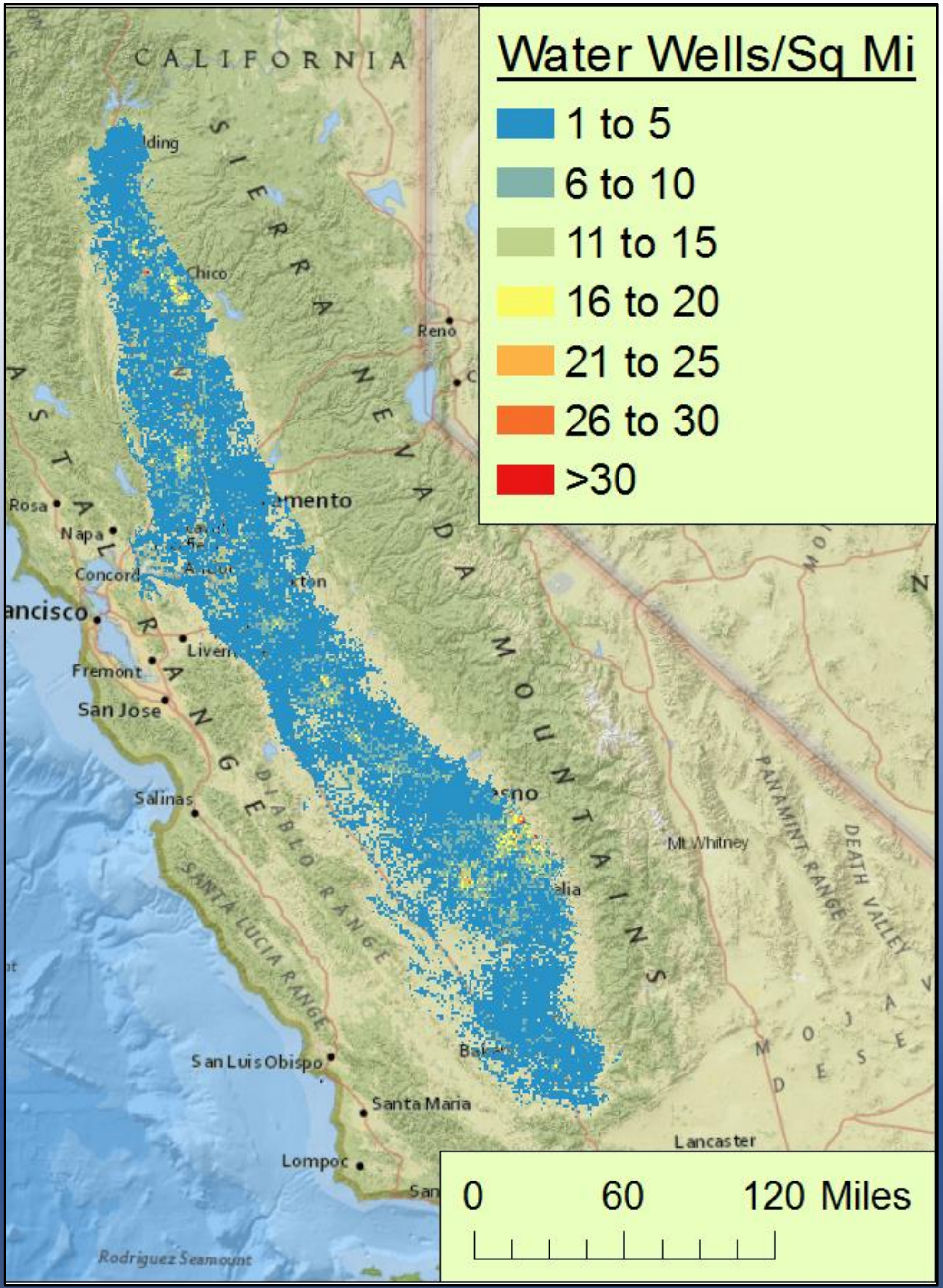
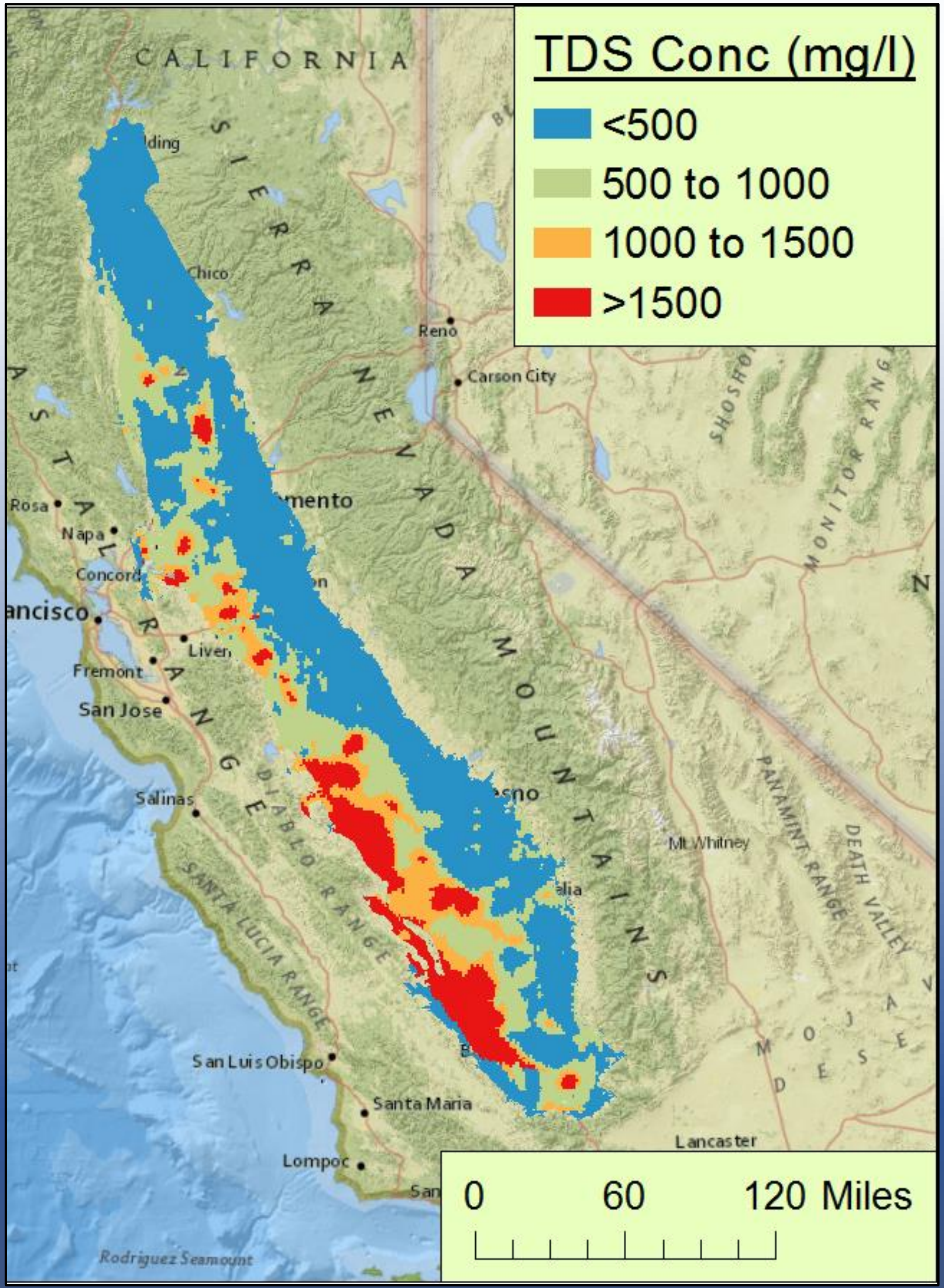
- Irrigation wells tend to be deeper



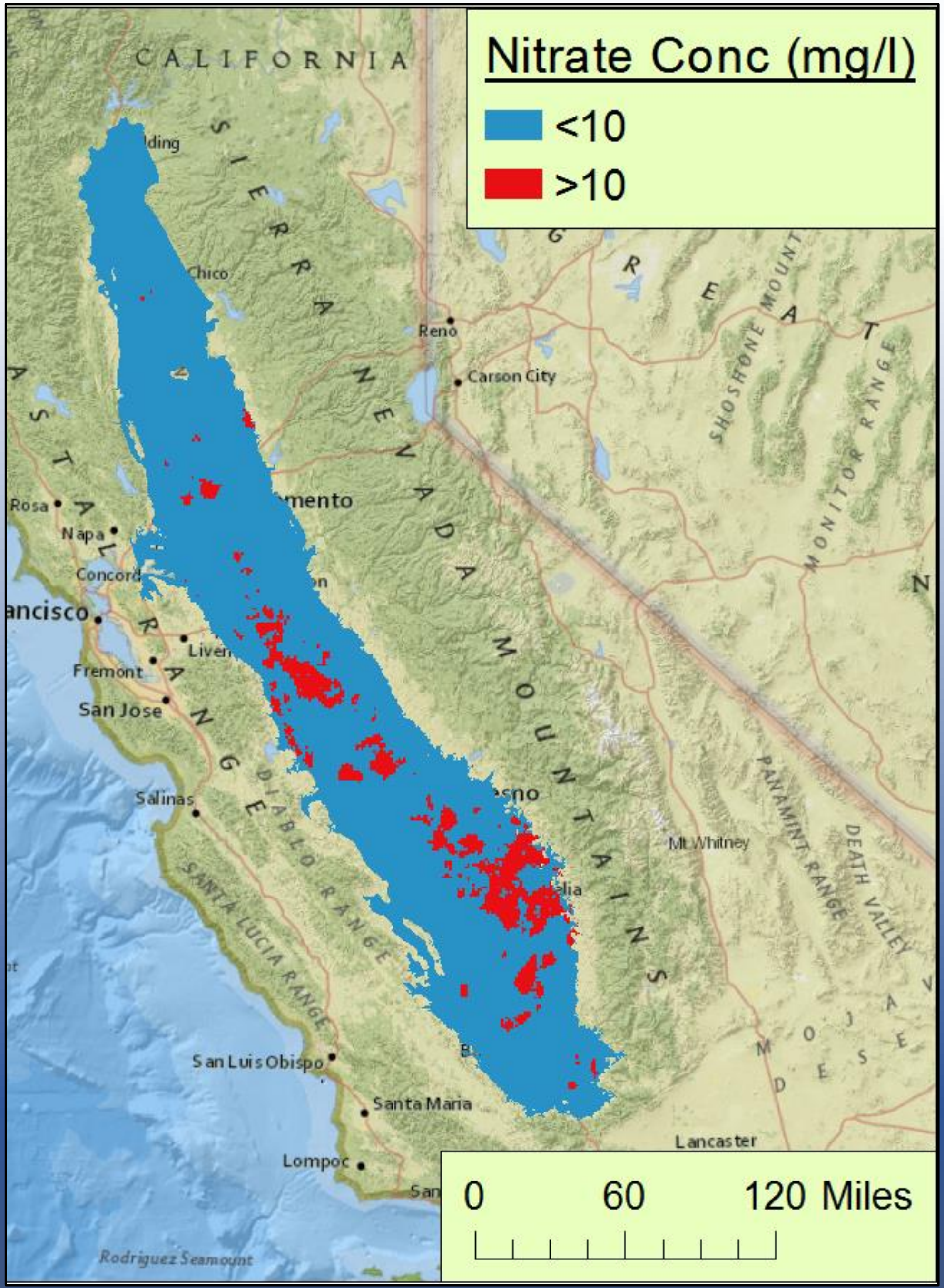
AVAILABLE INFORMATION

- Mapped to PLSS sections from CV-SALTS (2016)
- Secondary MCL for total dissolved solids
  - Recommended: 500 mg/l
  - Upper: 1,000 mg/l
  - Short-term: 1,500 mg/l
- Shallower water quality mapped
- Impacts often related to activities at ground surface



AVAILABLE INFORMATION

- Mapped to PLSS sections from CV-SALTS (2016)
- Maximum Contaminant Level (MCL) for nitrate as nitrogen is 10 mg/l
- Shallower water quality mapped
- Impacts often related to activities at ground surface



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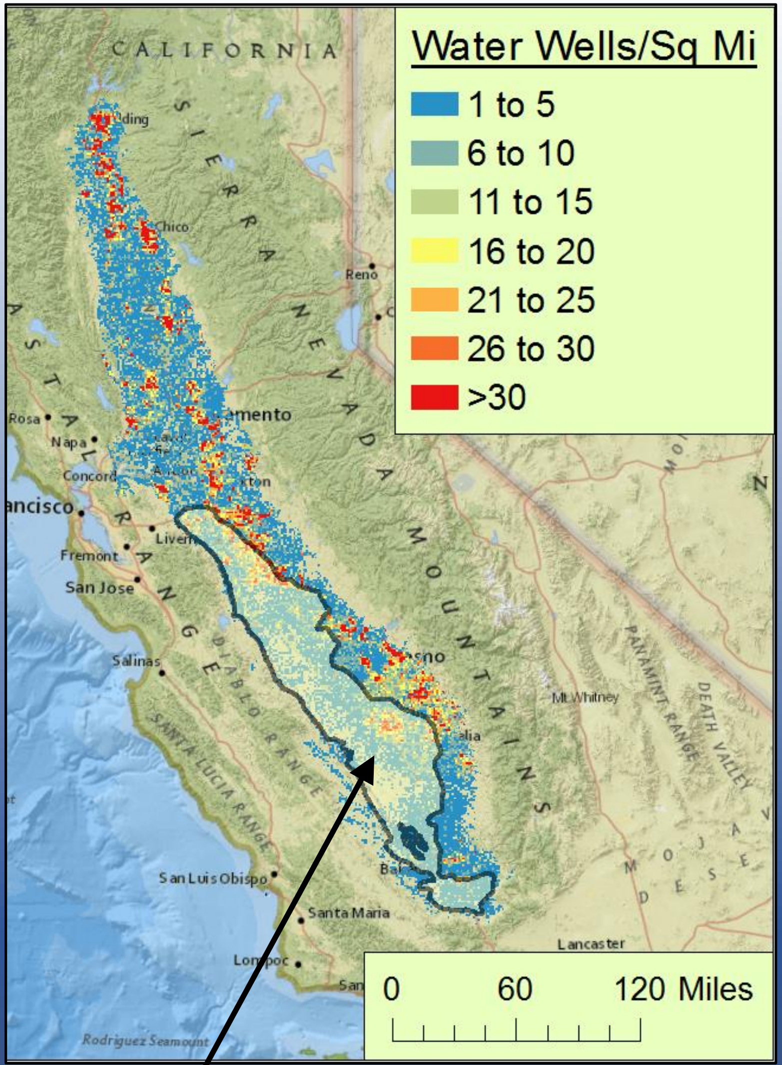
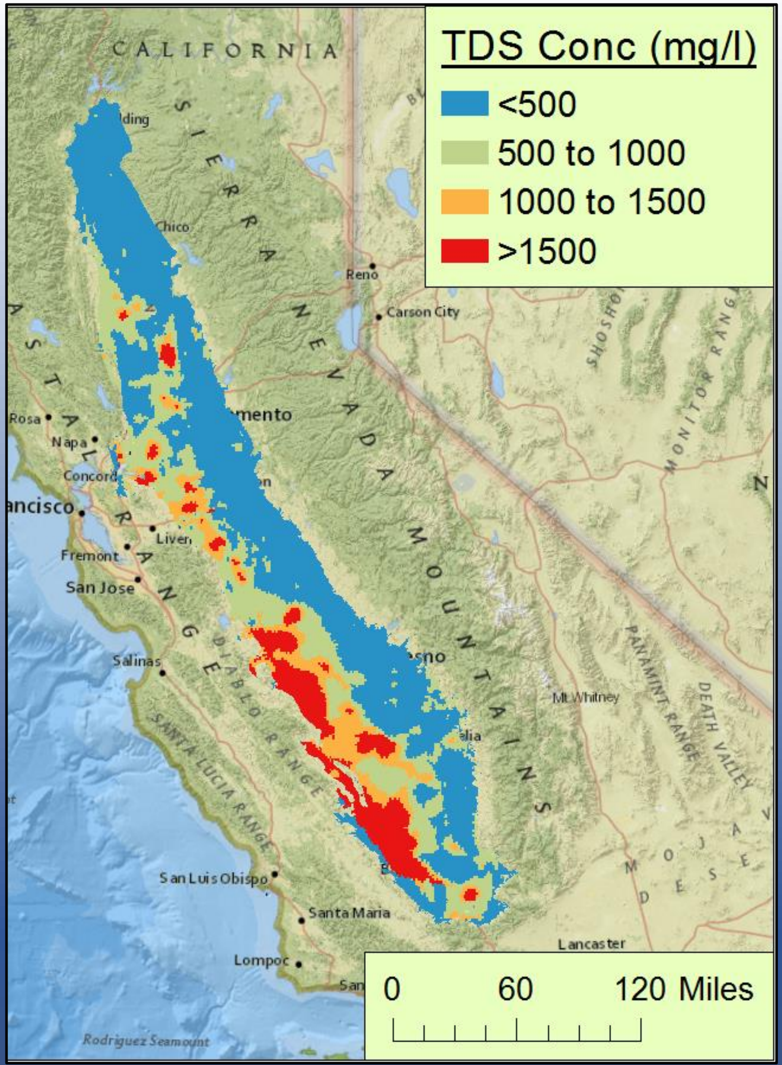
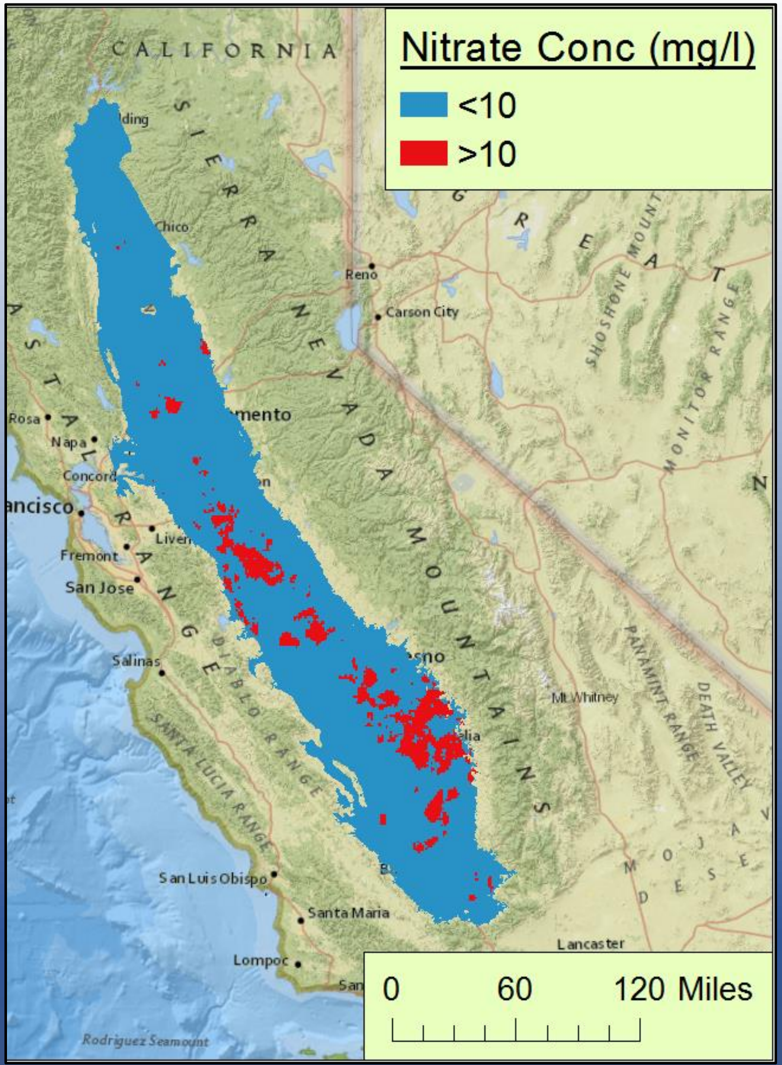
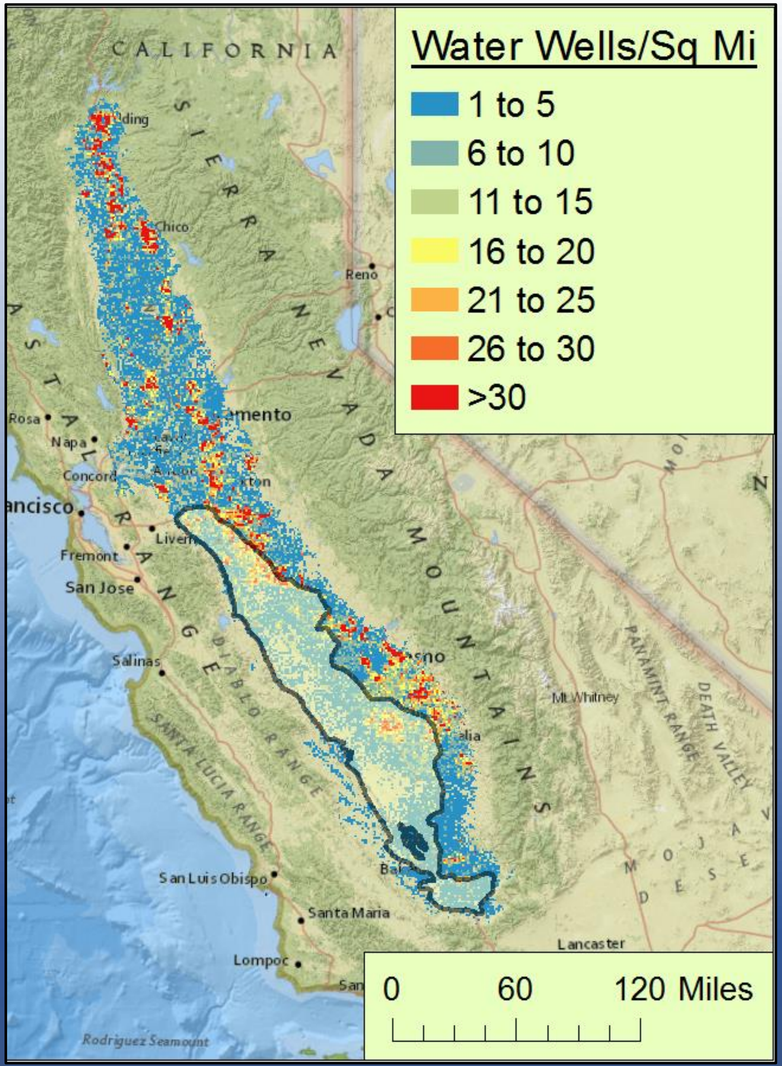






Corcoran Clay impedes migration of contaminants to depth unless compromised by conduit wells

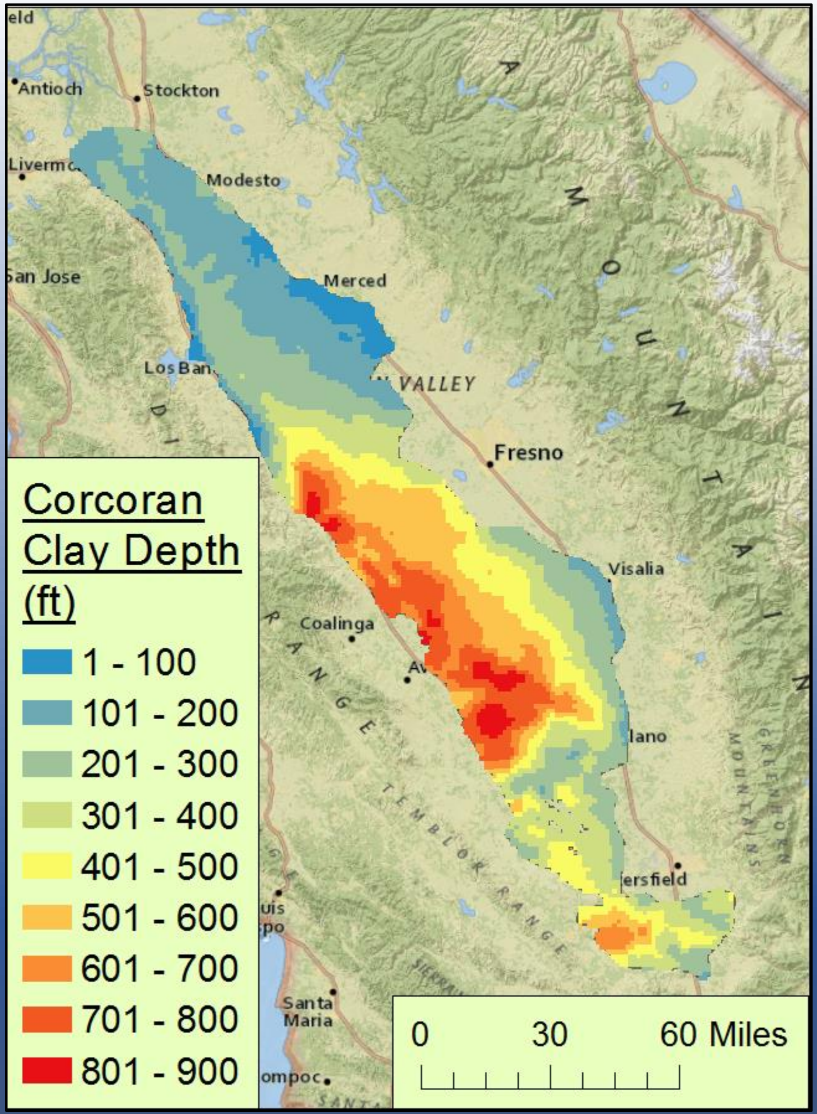
AVAILABLE INFORMATION



Wells within Corcoran Clay extent

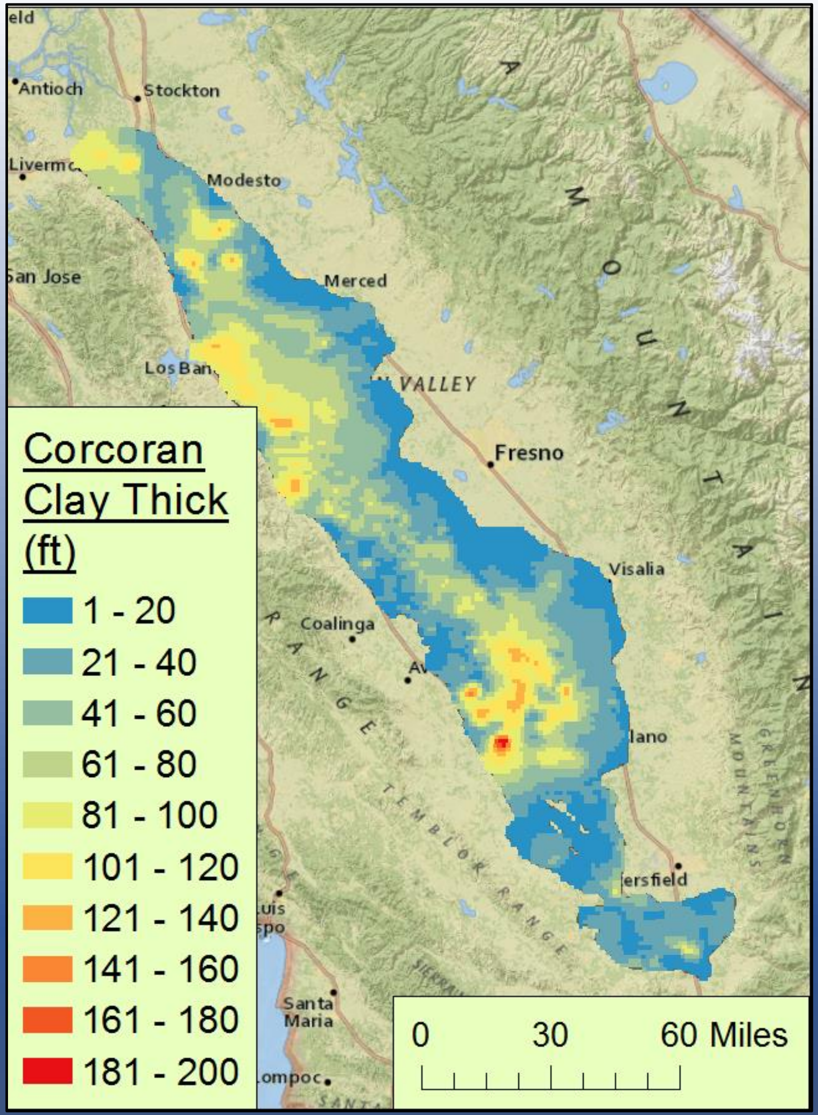
Total water wells:	33,579
• Domestic:	17,323
• Irrigation:	15,024
• Public:	804
• Industrial:	428

AVAILABLE INFORMATION



6,600 sq mi area within Central Valley

Mapped to PLS sections from USGS (2009)



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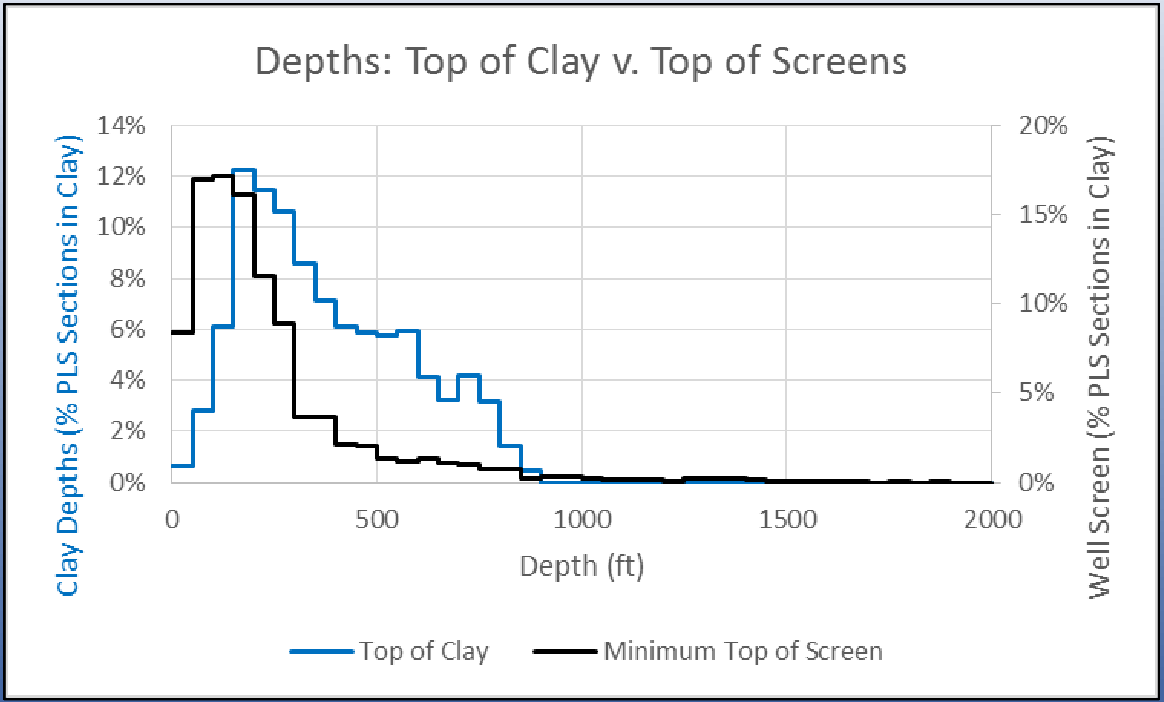
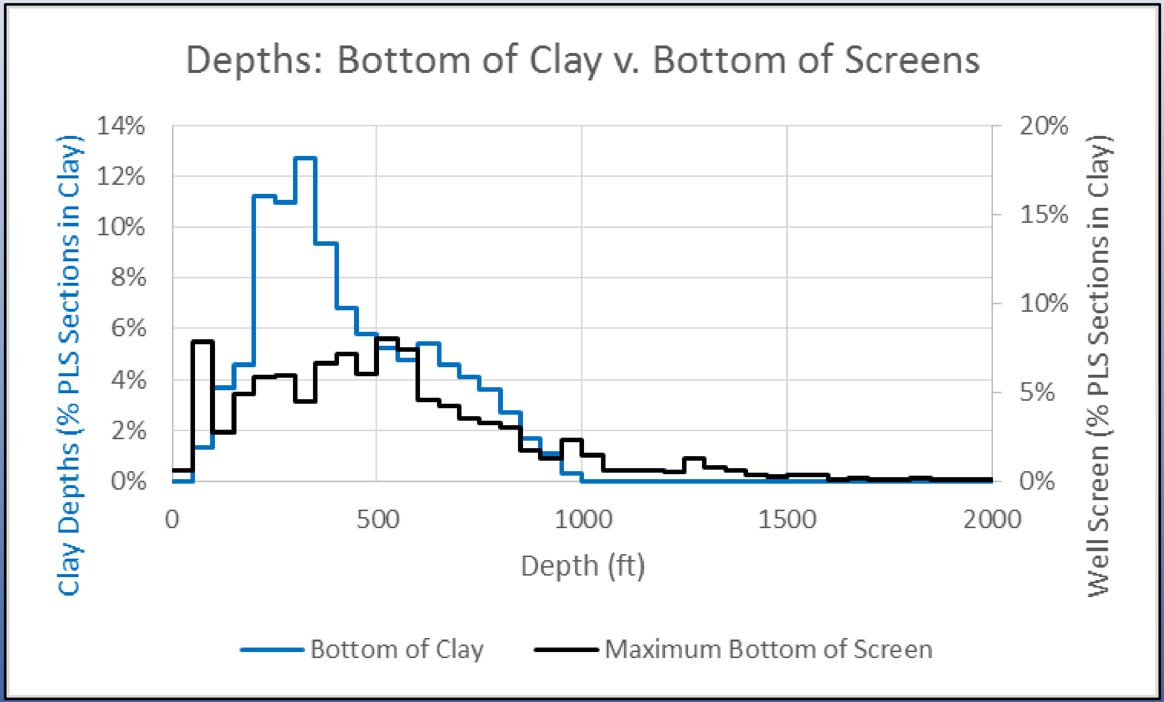




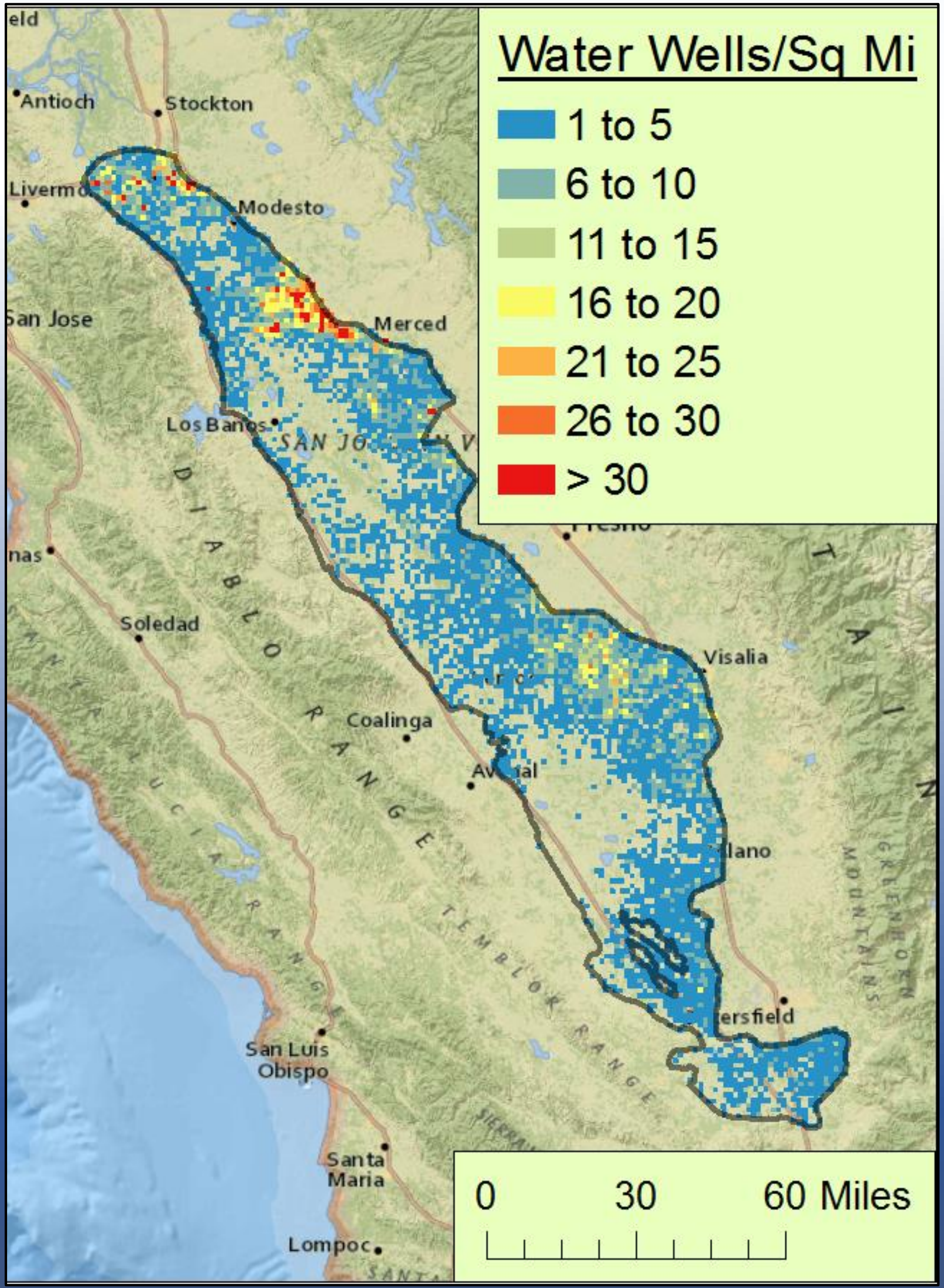
Summary of well screen depths within the extent of the Corcoran Clay from individual well completion reports. Analysis for each PLS section required to identify conduits.

RESULTS

WELL CONSTRUCTIONS BY PLS SECTION

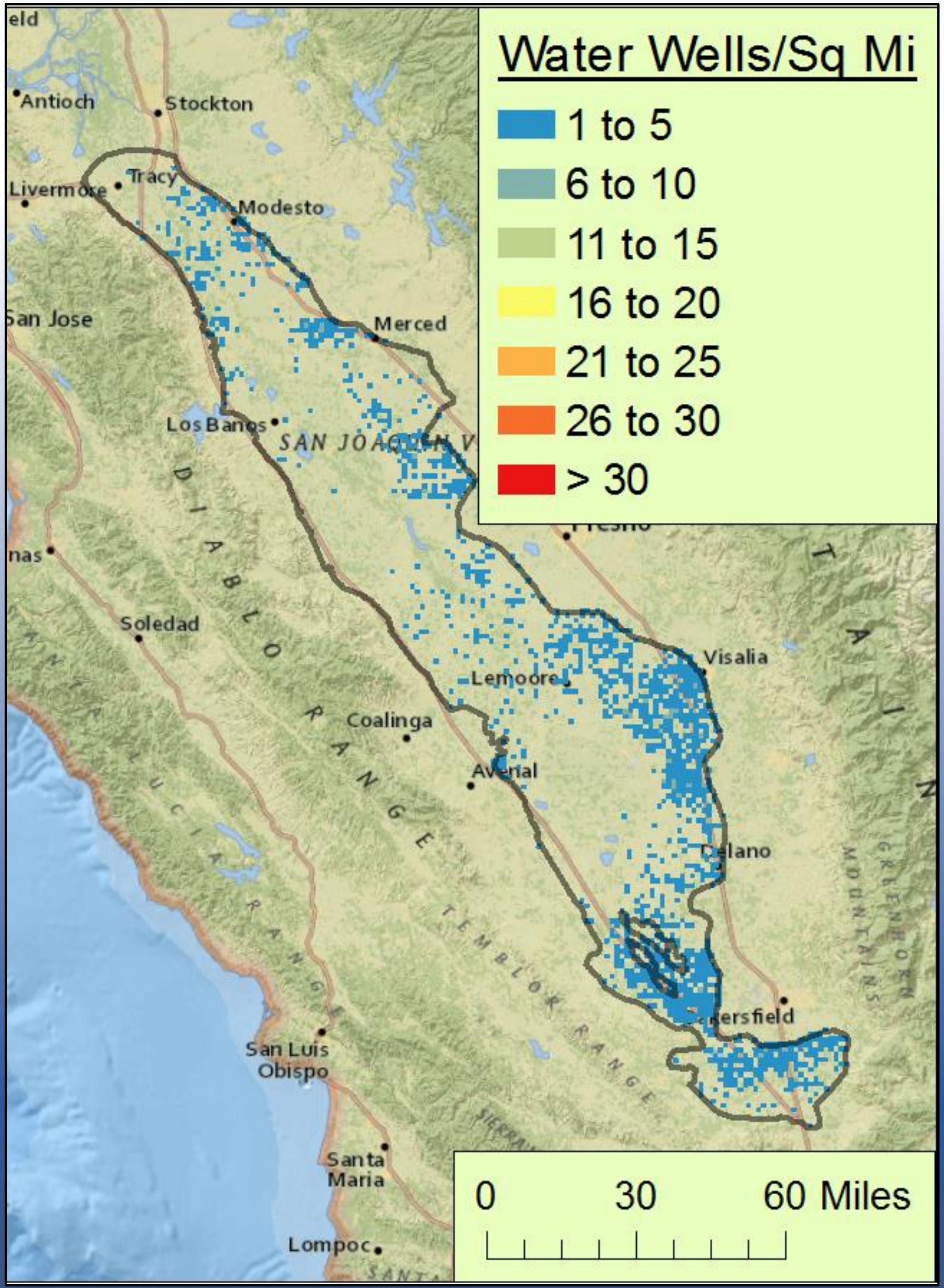
- Wells with bottom of screen beneath Corcoran Clay

- Subset of these wells with top of screens above clay can act as flow conduits

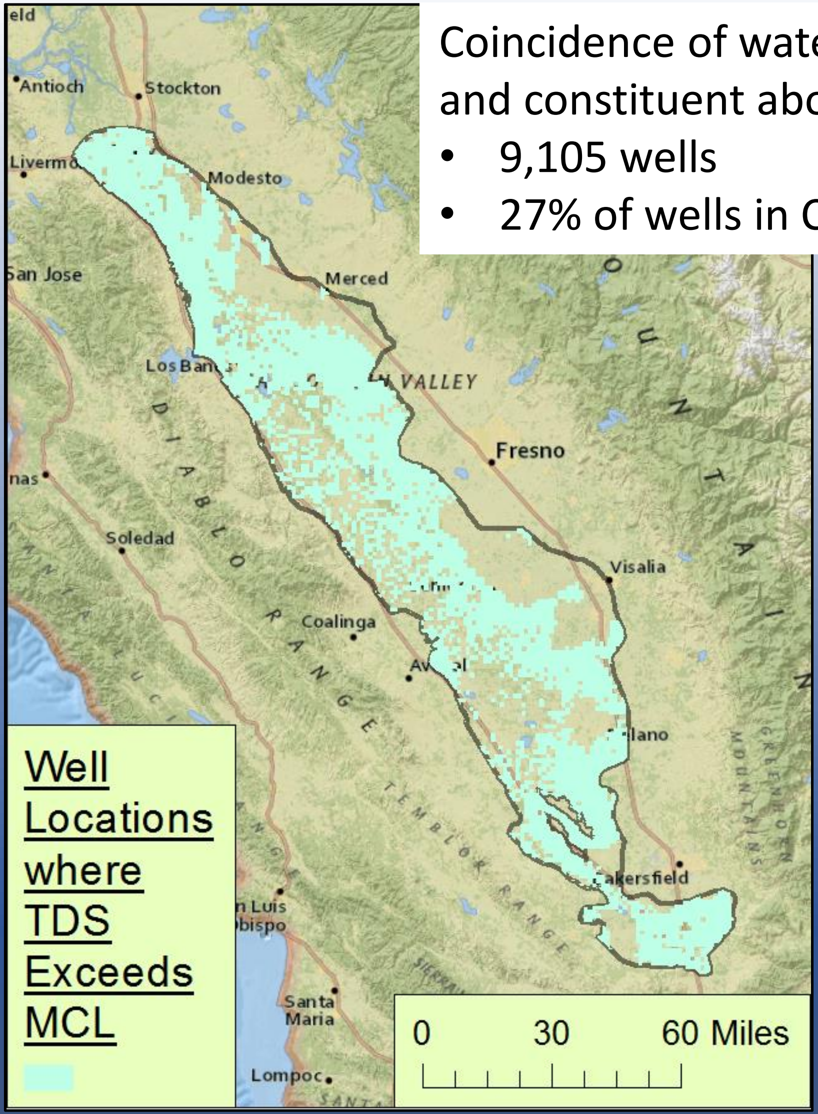


WELL CONSTRUCTIONS BY PLS SECTION

- Wells with screens that span Corcoran Clay (potential flow conduits)
- Subset of these wells located within areas of groundwater contamination can act as <u>migration</u> conduits

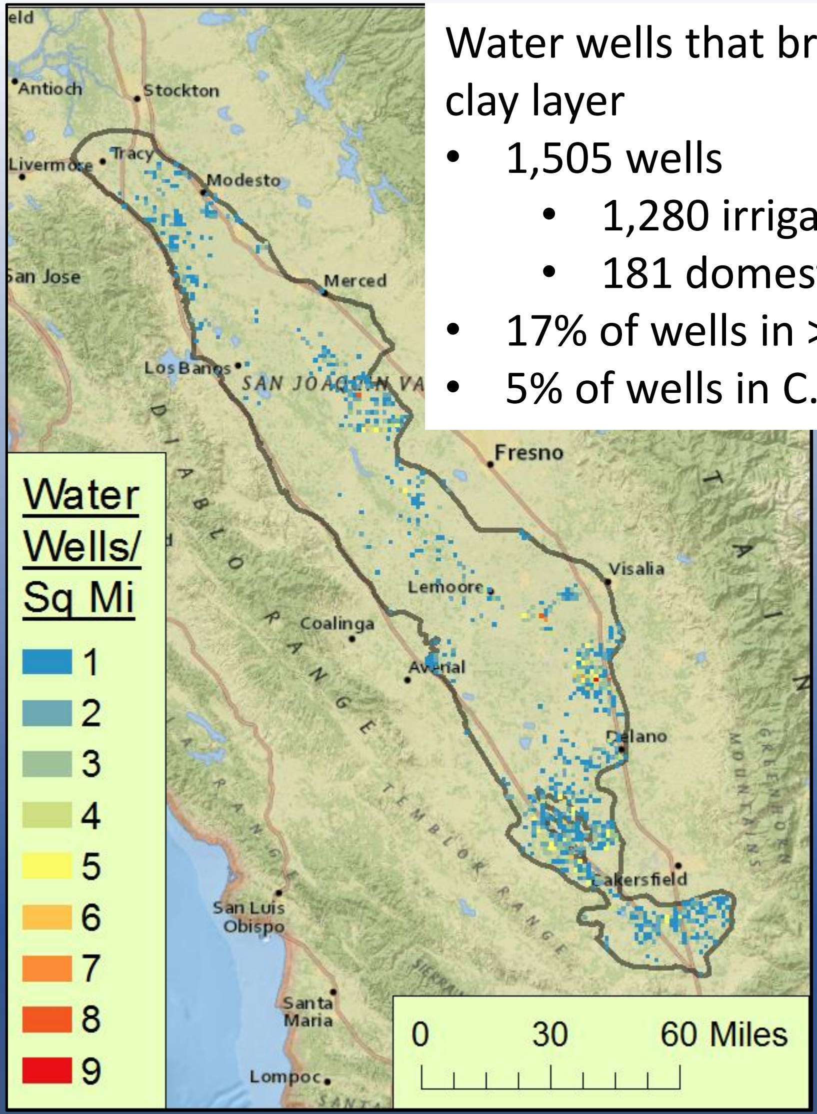


TOTAL DISSOLVED SOLIDS



Coincidence of water wells and constituent above MCL

- 9,105 wells
- 27% of wells in C. Clay

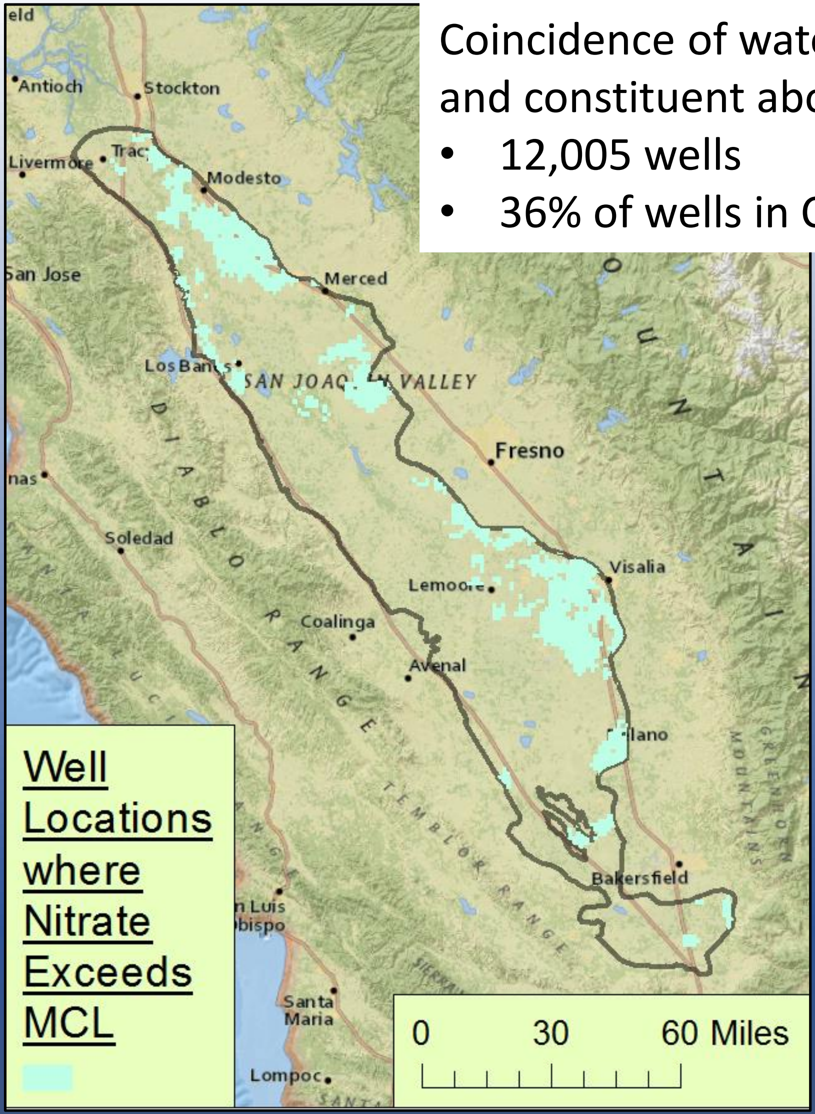


Water wells that breach clay layer

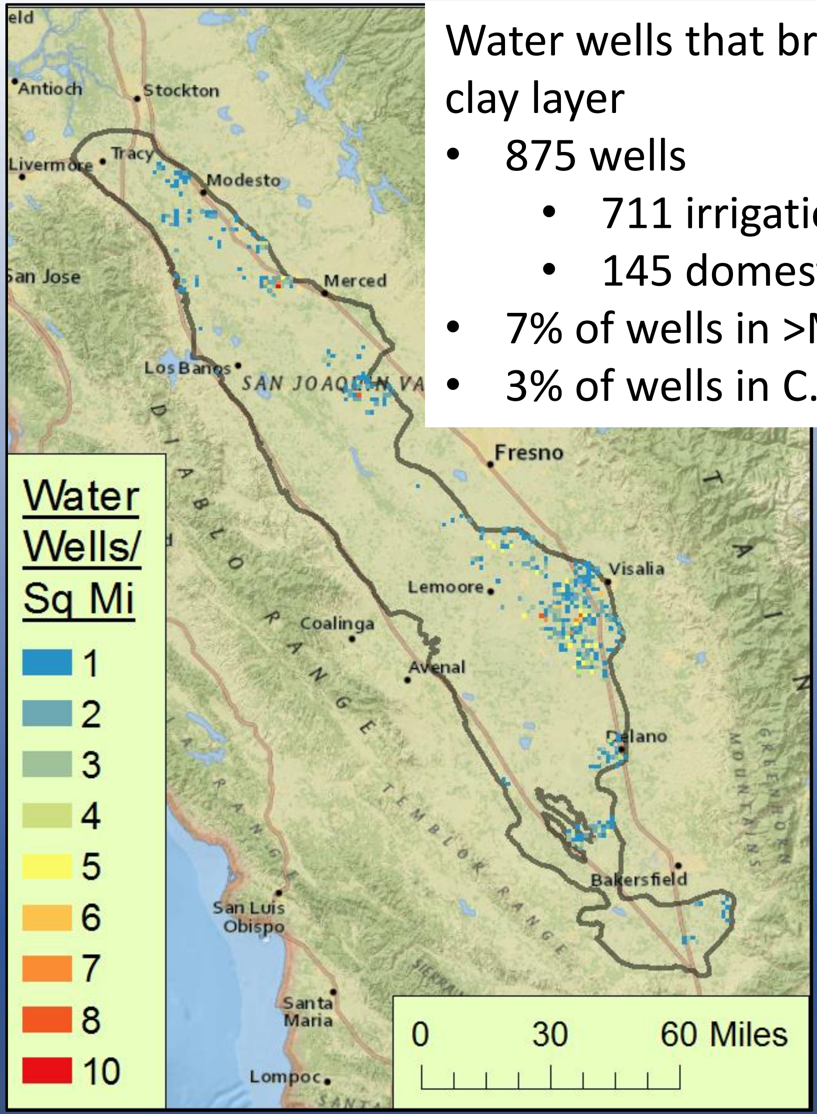
- 1,505 wells
    - 1,280 irrigation
    - 181 domestic
- 17% of wells in >MCL
- 5% of wells in C. Clay

NITRATE

Coincidence of water wells and constituent above MCL
- 12,005 wells
- 36% of wells in C. Clay



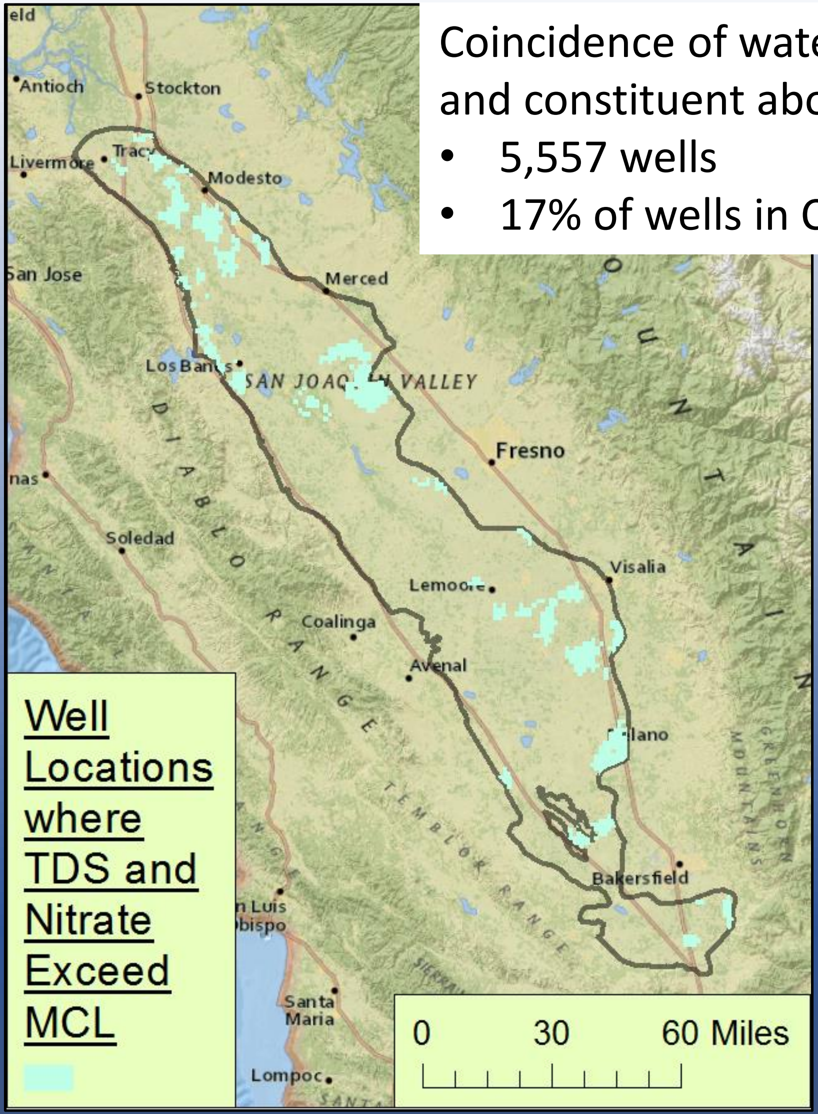
Water wells that breach clay layer
- 875 wells
  - 711 irrigation
  - 145 domestic
- 7% of wells in >MCL
- 3% of wells in C. Clay



TOTAL DISSOLVED SOLIDS AND NITRATE

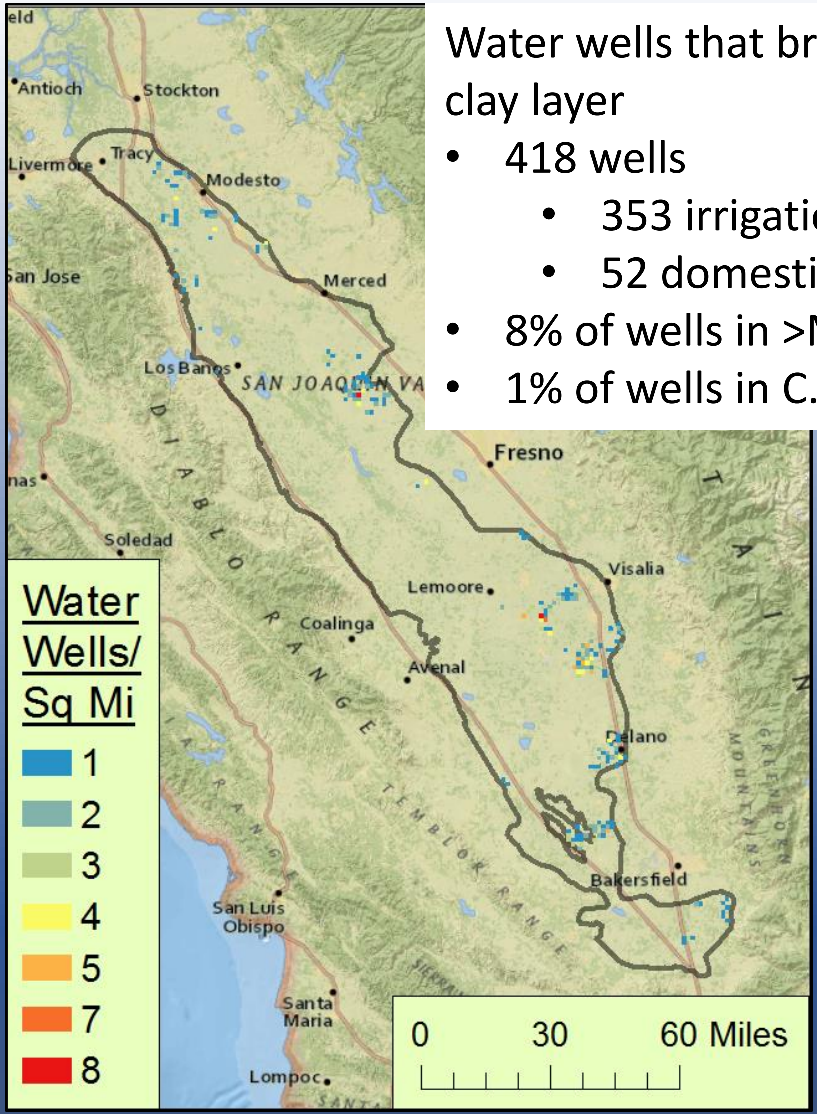
Coincidence of water wells and constituent above MCL

- 5,557 wells
- 17% of wells in C. Clay



Water wells that breach clay layer

- 418 wells
  - 353 irrigation
  - 52 domestic
- 8% of wells in >MCL
- 1% of wells in C. Clay



TAKEAWAY POINTS

- Wealth of information available to conduct survey-level evaluations
- Survey results for conduit wells
  - Within context of Corcoran Clay
    - Horizontal extent
    - Vertical migration across through long well screens
  - Considered two constituents
    - Total dissolved solids
    - Nitrate

TAKEAWAY POINTS

- Well conditions revealed (percent of wells within clay extent):

	TDS	NO_3	Both
MCL exceeded nearby	*27%*	*36%*	*17%*
Migration through well	*5%*	*3%*	*1%*

- Results could be used to plan site-specific evaluations as appropriate
- Investigating and addressing a small portion of the highest transport rate wells could be the most beneficial
- Vertical transport could also occur for other constituents and at shallower depths. Study not designed to address these possibilities.

OUTLINE

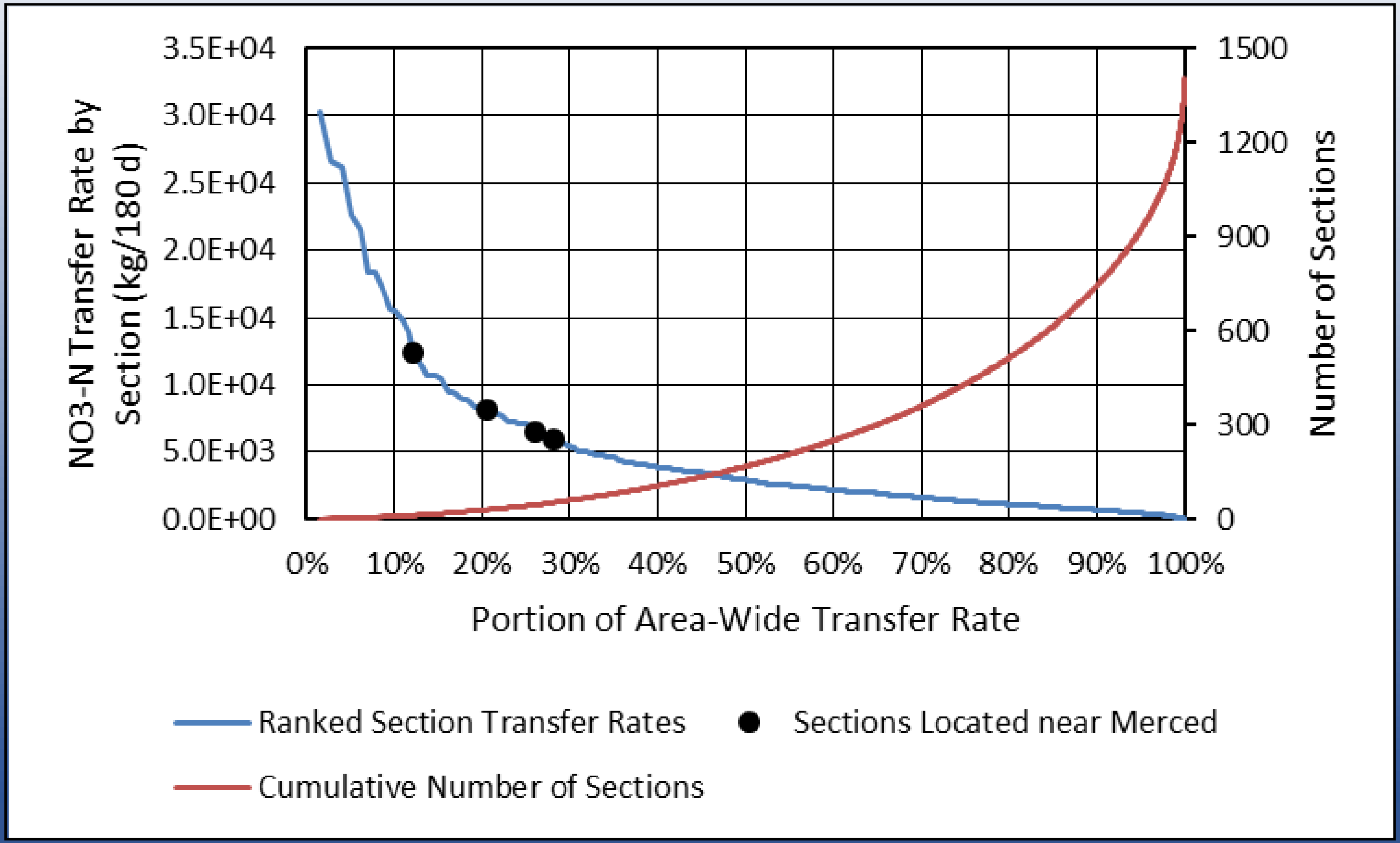
- Overview of factors affecting water quality in supply wells
- Potential impact of legacy well constructions
- Possible path forward

POSSIBLE PATH FORWARD

- Great number of existing wells creates impediments for extensive remedial program
- Must look for means of achieving high marginal impacts
- Additional study results may suggest elements of an approach

MITIGATION OPTION

- Cannot address all wells
  - Logistics and time
  - Expense
- Target highest transfer rates
- 10% of transfer
  - 10 sections
  - 21 wells
- 30% of transfer
  - 61 sections
  - 225 wells



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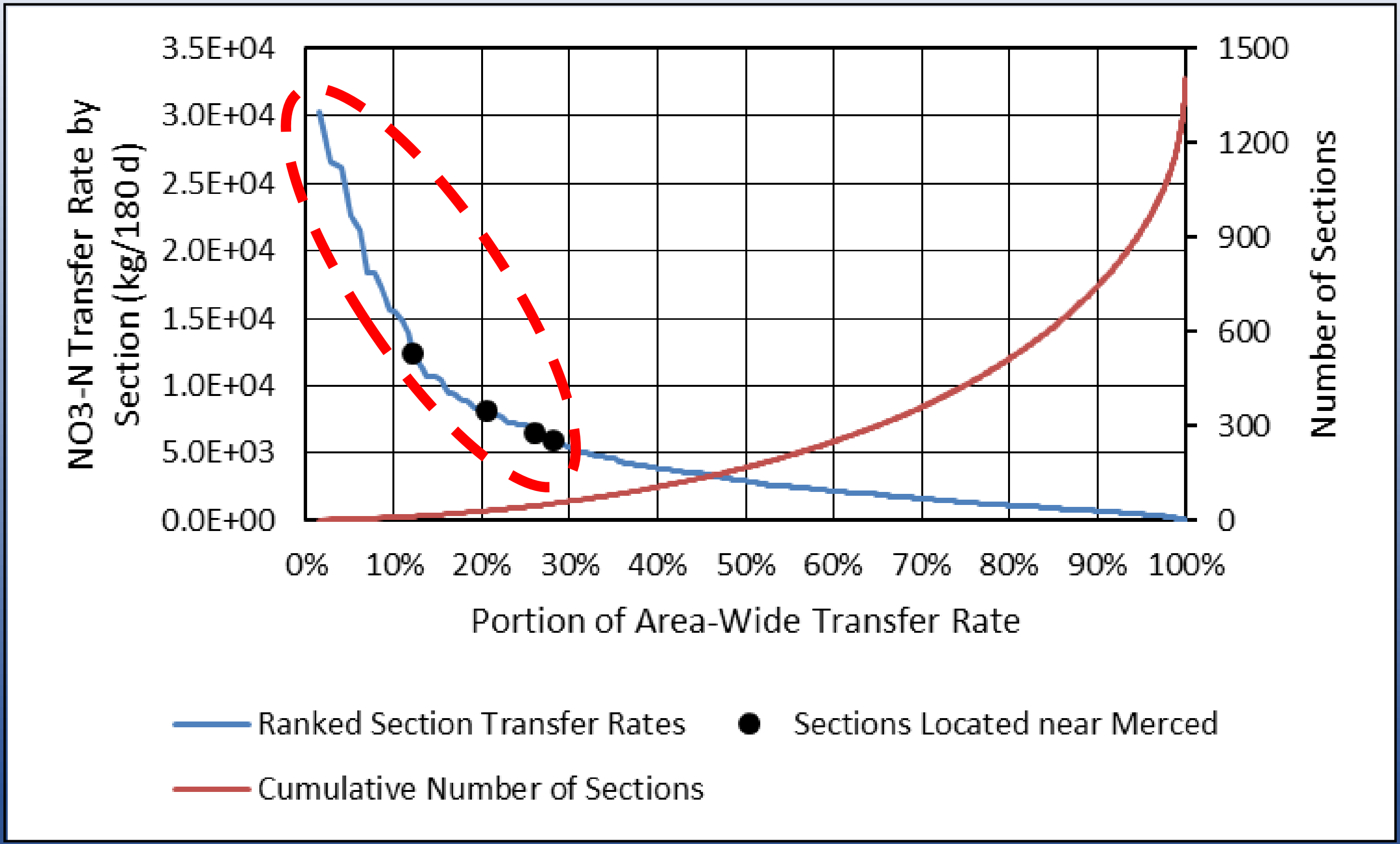

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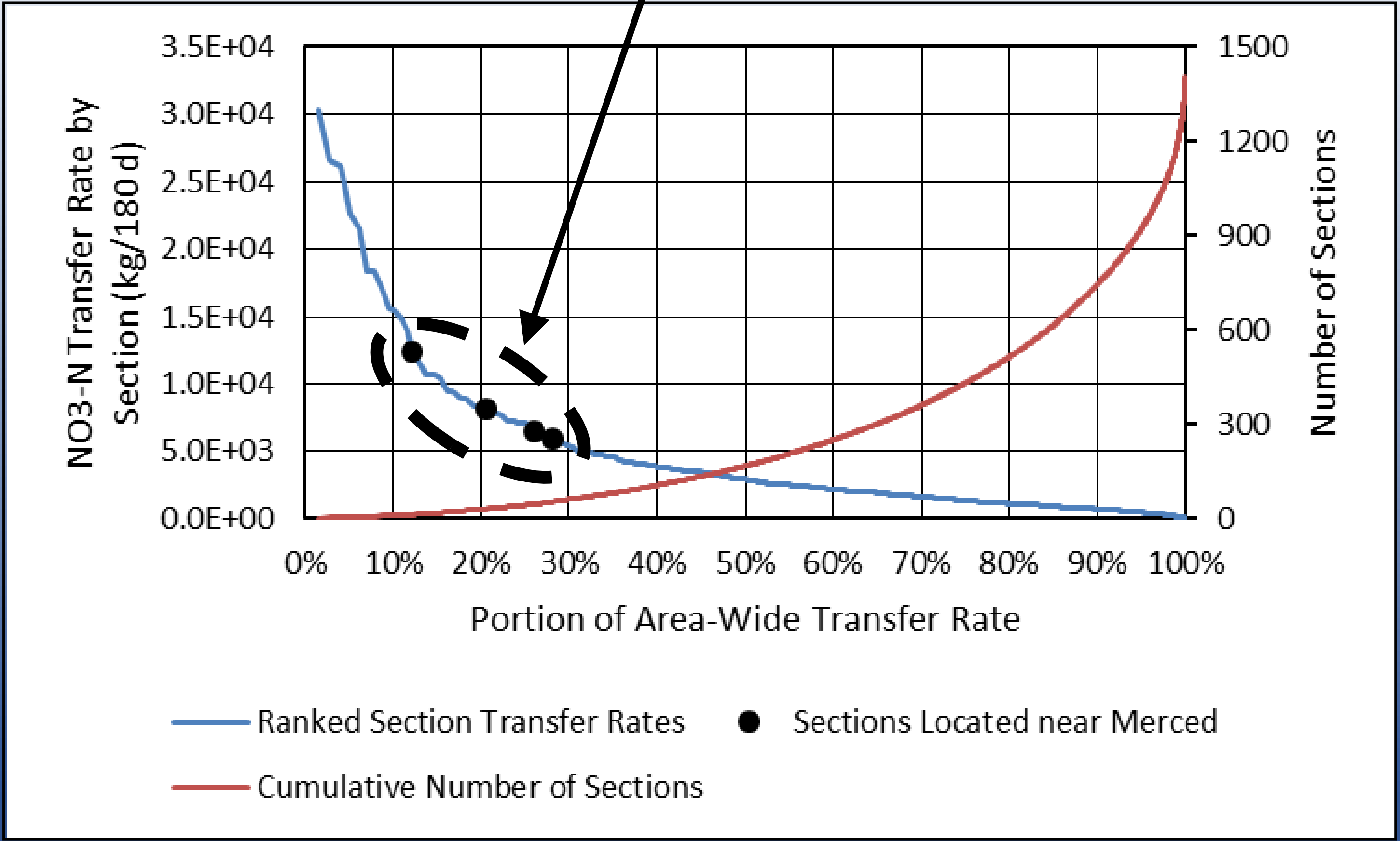
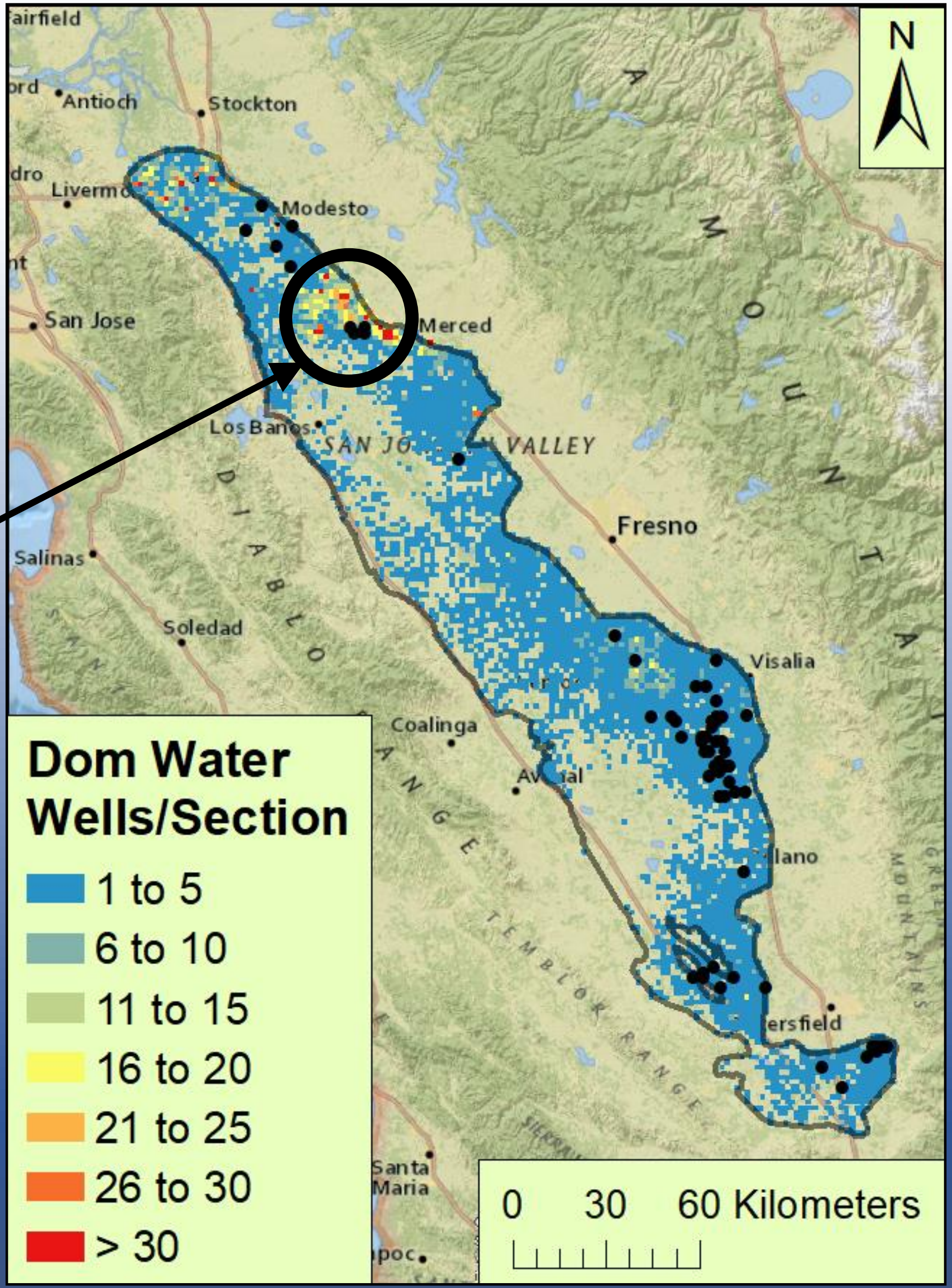
Only four sections are located near obvious sensitive receptors



MITIGATION OPTION

Four sections

28 wells



WANT MORE INFORMATION?

- Hydrogeology Journal
    - Two open-access papers (2017 and 2018)
    - Search “Gailey” in the journal
- Contact: rob@rmgailey.com