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

- Cap
- Pollutants, Bacteria
- Seal
SURFACE WATER IMPACT (Cont’d)

Groundwater under influence of surface water

Stream

NO$_3$

20 ft
35 ft
55 ft

10 ft

\[\text{NO$_3$}\]
Depths to tops of gravel pack and screen

Non-point or point source pollutant

NO₃, VOCs
SEPARATION FROM SHALLOW STRATA

Depths to tops of gravel pack and screen

- High conductivity: 130 ft
- Low conductivity: 285 ft, 305 ft
- Migration through gravel pack: 40 ft
- NO3

Diagram showing separation from shallow strata with different conductivity layers and migration through gravel pack.
CONTRIBUTION FROM IMPAIRED STRATA

Gravel pack and screen placement and length

Water quality associated with the high flow contribution will be reflected at the wellhead.

High K  Naturally occurring (As)
Gravel pack and screen placement and length

Different distributions of water quality and strata types result in different wellhead concentrations.

Low K

As

\( Q, WQ \)
WELL SCREEN CONDITIONS

Screen clogging over time changes water quality

Different distributions of water quality and strata types result in different wellhead concentrations

Low K  As
CONDUIT WELLS

Single well effect of conduit flow and transport

Pump Off

Lower head at depth from other pumping in area results in migration of shallow, poor quality water down the well casing.

Displacement of cleaner water

NO$_3$

>100 ft

Well contaminates itself
CONDUIT WELLS

Proximity to conduit wells

Emplacement of contaminants at depth

Migration over 1,000’s of feet

Pump Off

NO$_3$

NO$_3$
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
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IDENTIFYING AREAS OF CONCERN FOR NONPOINT SOURCE POLLUTANT MIGRATION THROUGH INACTIVE SUPPLY WELLS: A POTENTIAL SCREENING APPROACH FOR SGMA

September 26, 2018
Natural groundwater systems produce vertical hydraulic gradients

(Gailey, 2017, Hydrogeology Journal)
FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS

Discharge Area

Recharge Area

Clay

Sand

Pumping often induces or enhances downward gradients

(Gailey, 2017, Hydrogeology Journal)
**FLOW AND TRANSPORT THROUGH INACTIVE WATER WELLS**

<table>
<thead>
<tr>
<th>Properly sealed well</th>
<th>Hole in gravel fill tube</th>
<th>Shallower seal</th>
<th>Shallower screen</th>
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Well structures can create pathways for flow across low-conductivity strata

(Gailey, 2017, Hydrogeology Journal)
Effective hydraulic conductivities of well casings are orders of magnitude greater than layered sediments.
Transport can occur when water quality varies with depth.
Seasonal operation creates periods of inactivity when transport will occur.

(Gailey, 2017, Hydrogeology Journal)
Pumping during the demand season often does not counteract the transport

(Gailey, 2017, Hydrogeology Journal)
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
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

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

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<th></th>
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<th>NO$_3$</th>
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<td>MCL exceeded nearby</td>
<td>27%</td>
<td>36%</td>
<td>17%</td>
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<tr>
<td>Migration through well</td>
<td>5%</td>
<td>3%</td>
<td>1%</td>
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• 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.
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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
MITIGATION OPTION

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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