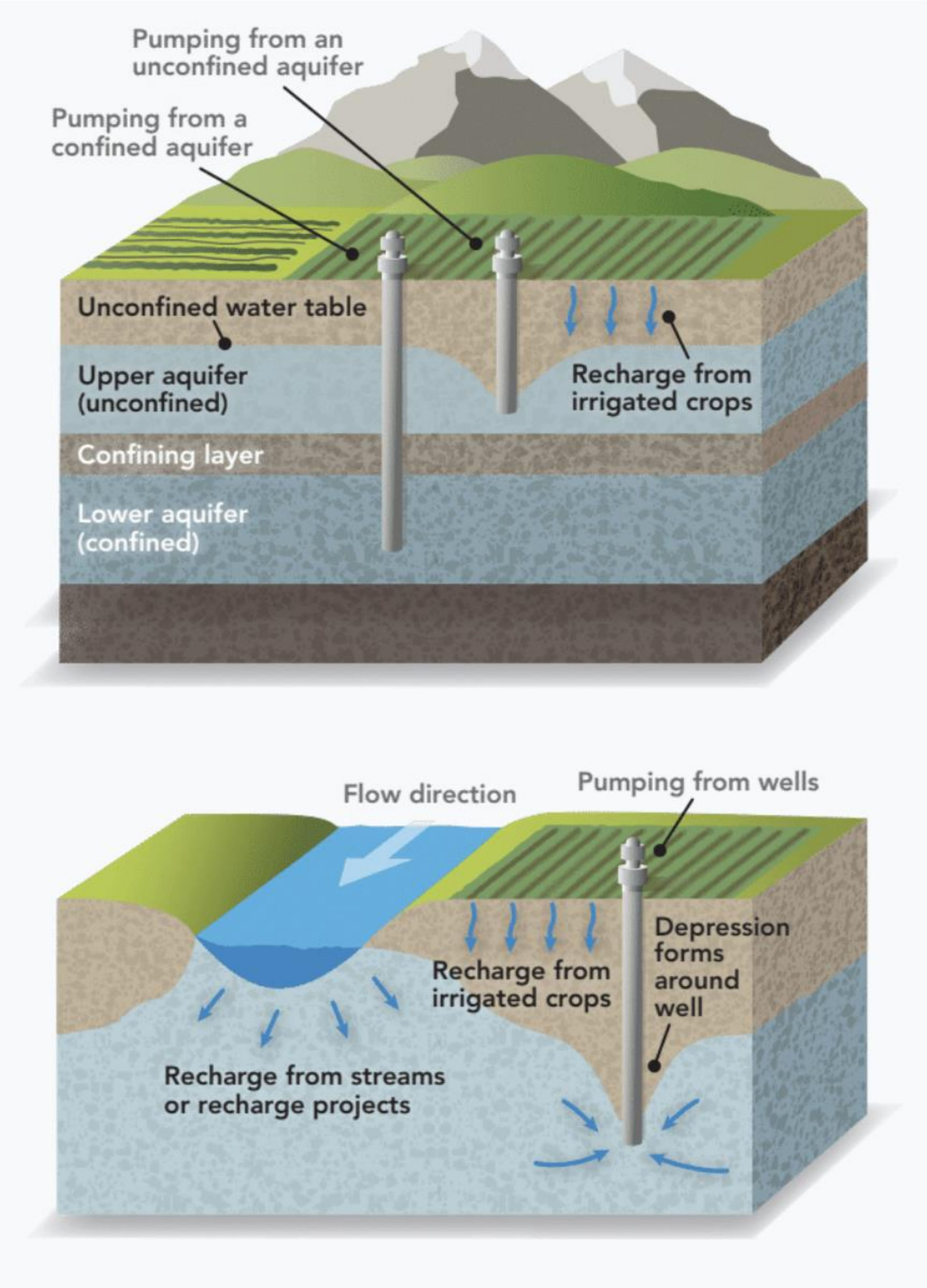
Sierra Valley Groundwater Sustainability Plan Development

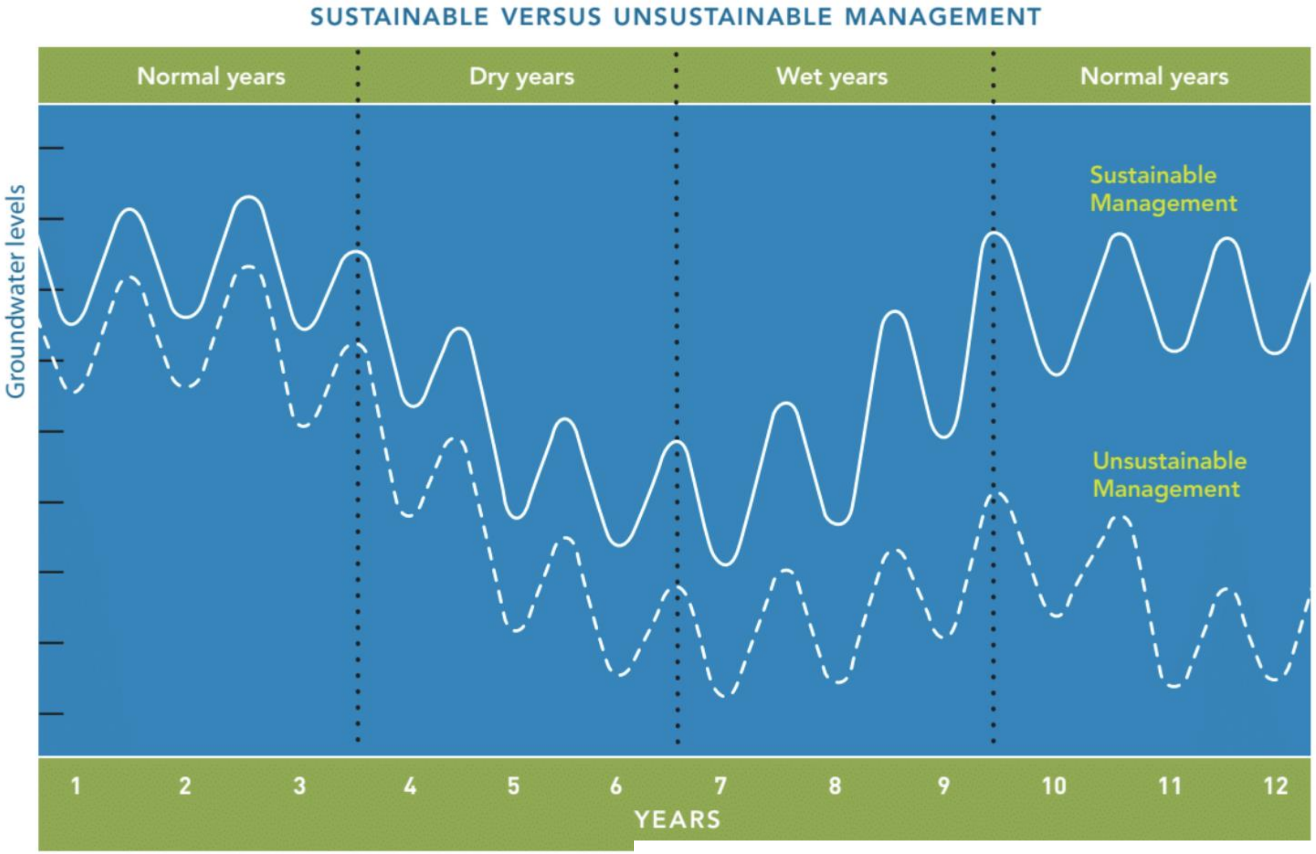
GROUNDWATER LEVEL DECLINE IN SIERRA VALLEY AND DOMESTIC WELL PROTECTION

Approaches to quantify Undesirable Results, SMCs, and IMs

March 8, 2021

Agenda


Pumping from an unconfined aquifer
Pumping from a confined aquifer
Unconfined water table
Upper aquifer (unconfined)
Recharge from irrigated crops
Confining layer
Lower aquifer (confined)
Flow direction
Pumping from wells
Depression forms around well
Recharge from irrigated crops
Recharge from streams or recharge projects

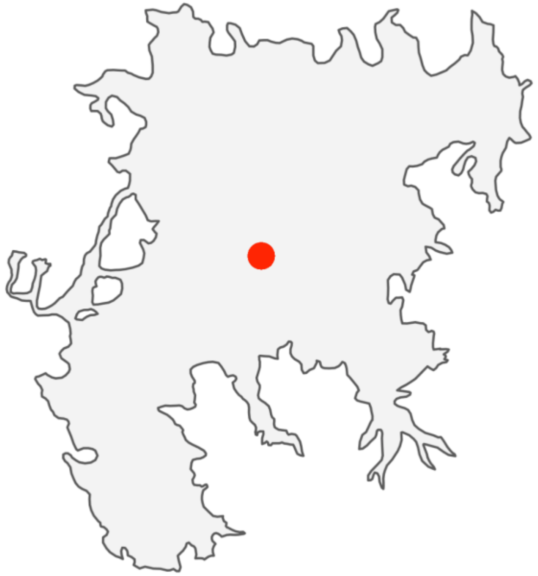

SUSTAINABLE VERSUS UNSUSTAINABLE MANAGEMENT
Normal years
Dry years
Wet years
Normal years
Groundwater levels
Sustainable Management
Unsustainable Management
1
2
3
4
5
6
7
8
9
10
11
12
YEARS

Groundwater elevation trends

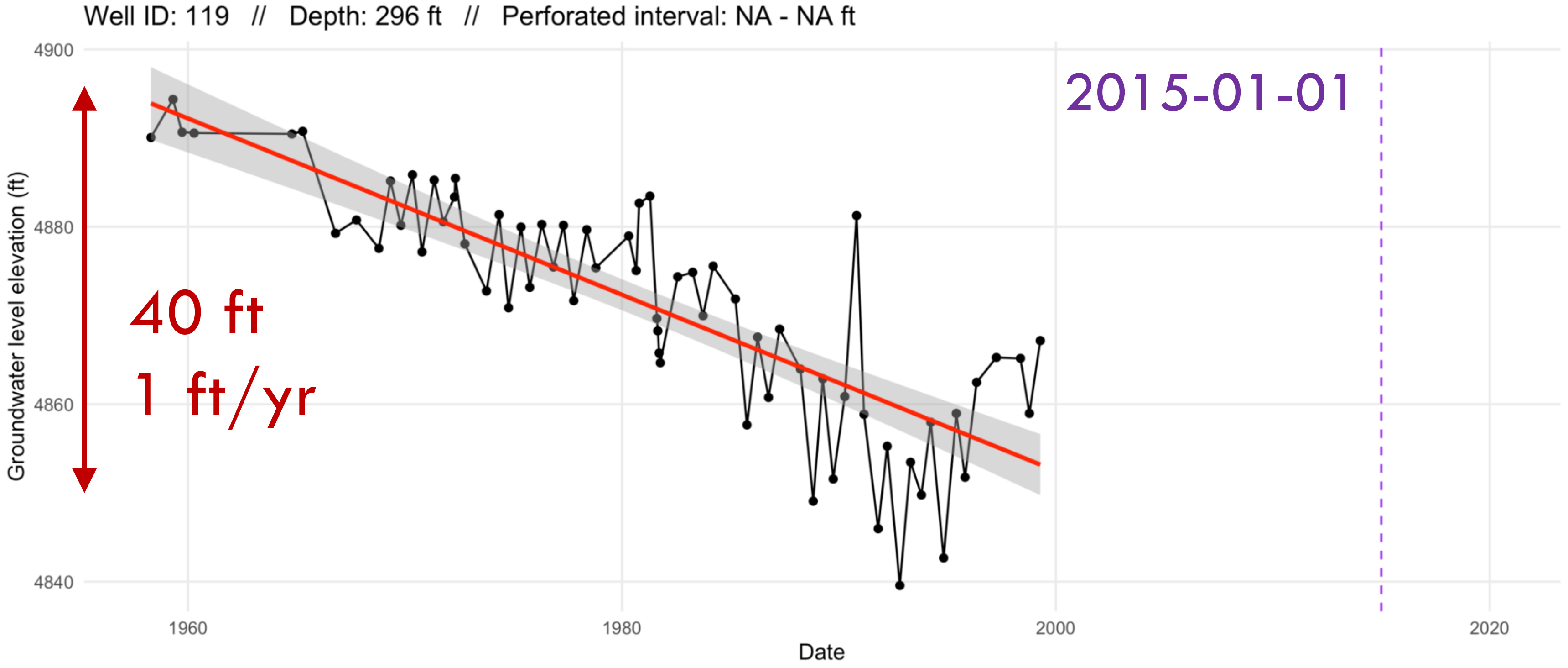
decreasing

stable (flat)

increasing

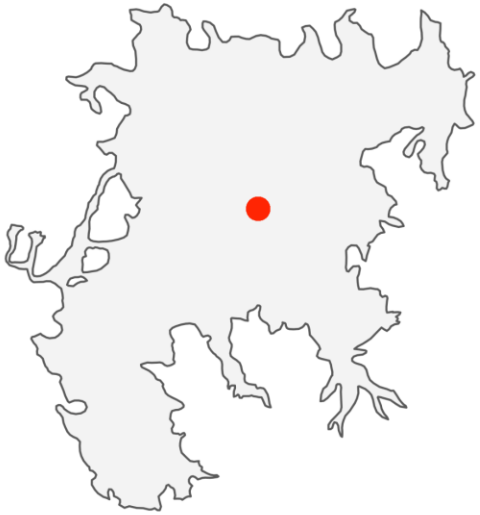


(39.7282, -120.3065)



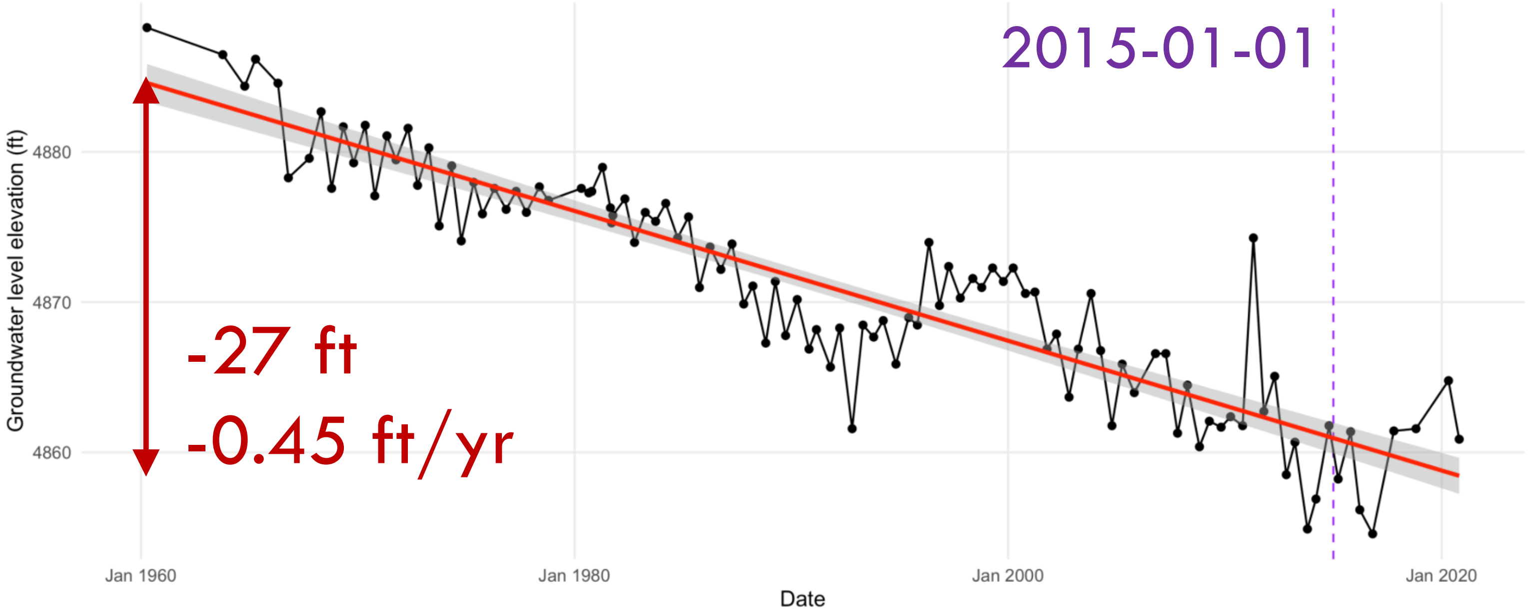
40 ft
1 ft/yr

2015-01-01



(39.7403, -120.287)

Well ID: 112 // Depth: 600 ft // Perforated interval: NA - NA ft

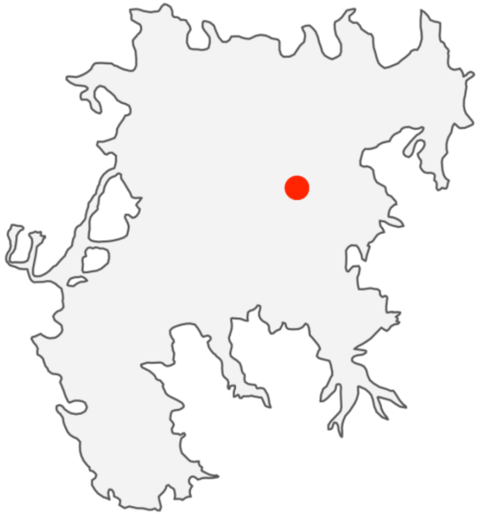


2015-01-01

-27 ft

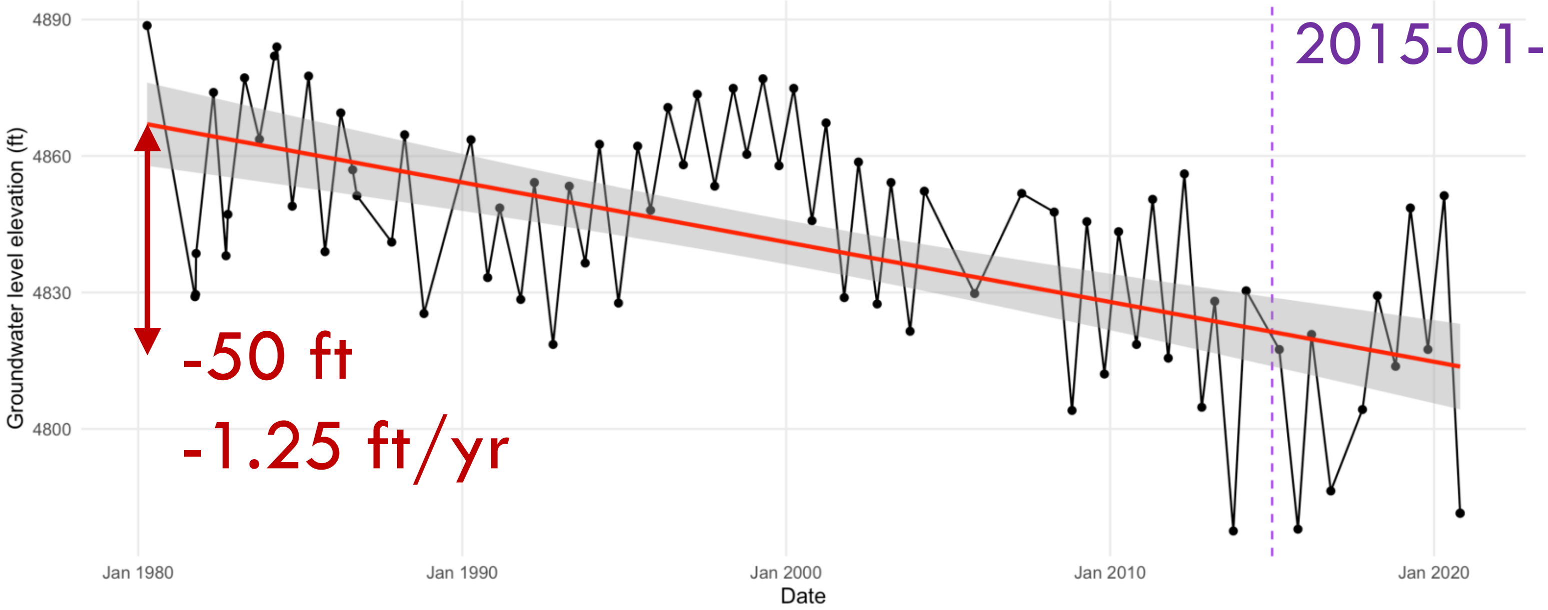
-0.45 ft/yr

decreasing



(39.7527403, -120.2566675)

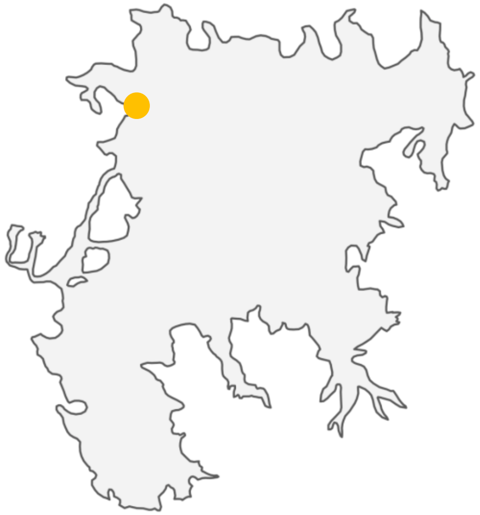
Well ID: 100 // Depth: 800 ft // Perforated interval: 435 - 740 ft



2015-01-01

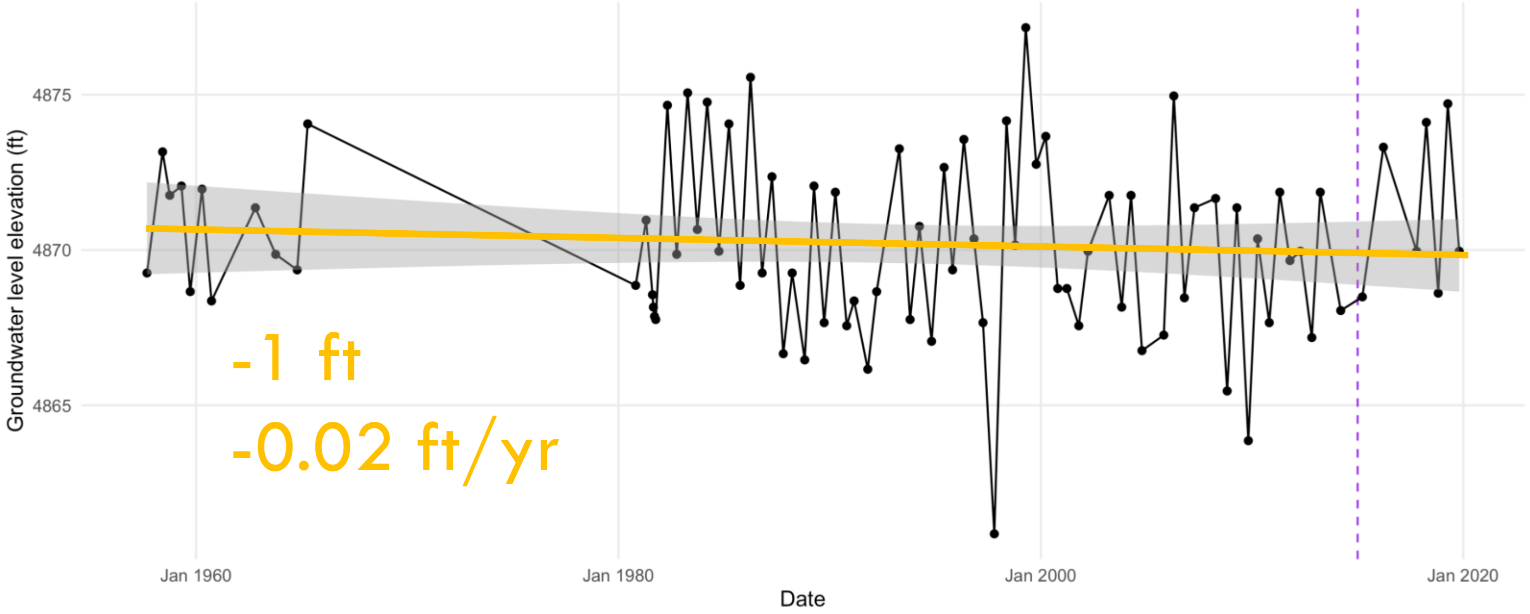
-50 ft

-1.25 ft/yr



(39.802017, -120.381727)

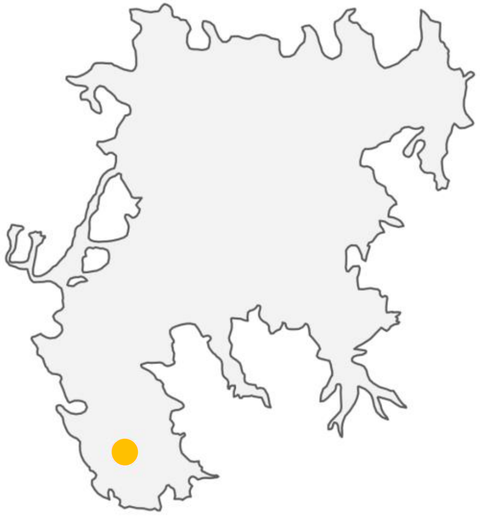
Well ID: 161 // Depth: 18 ft // Perforated interval: NA - NA ft



-1 ft

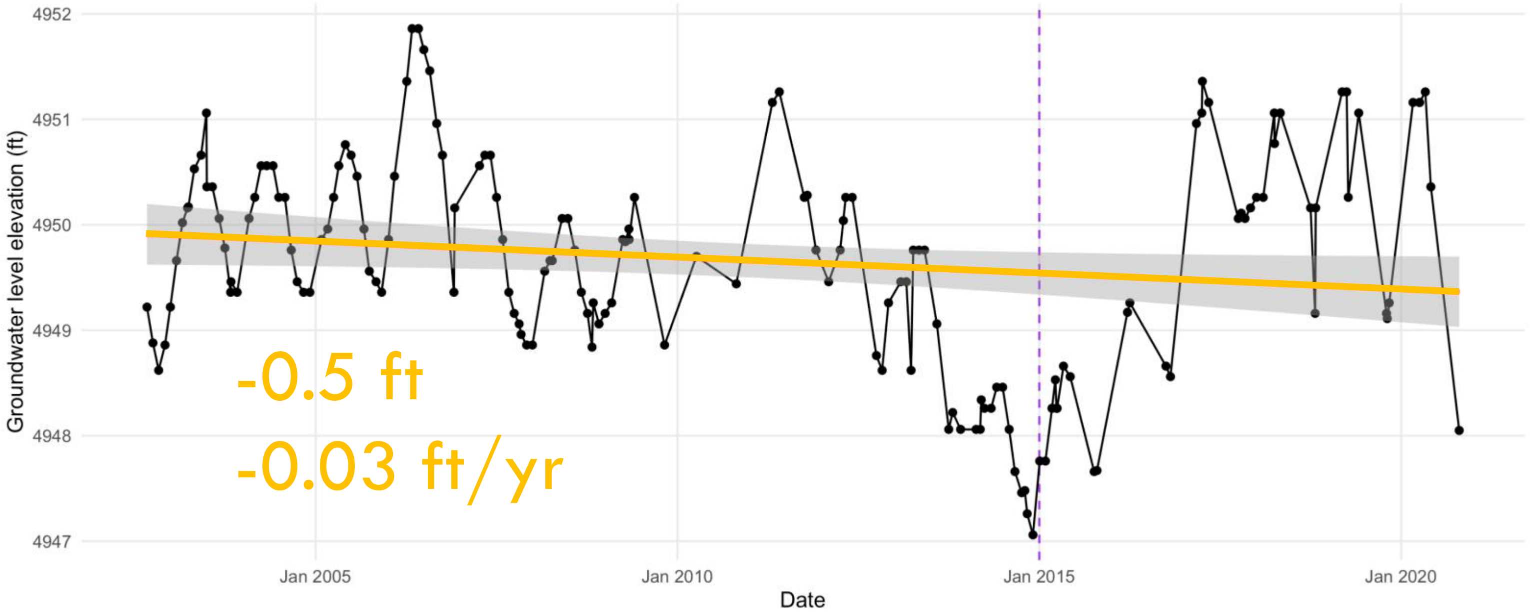
-0.02 ft/yr

stable (flat)



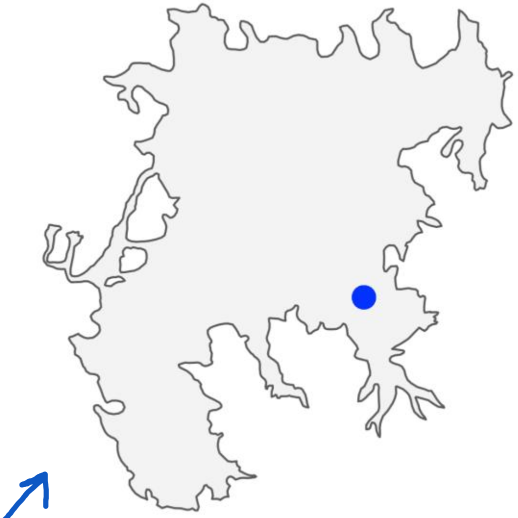
(39.595064, -120.3910121)

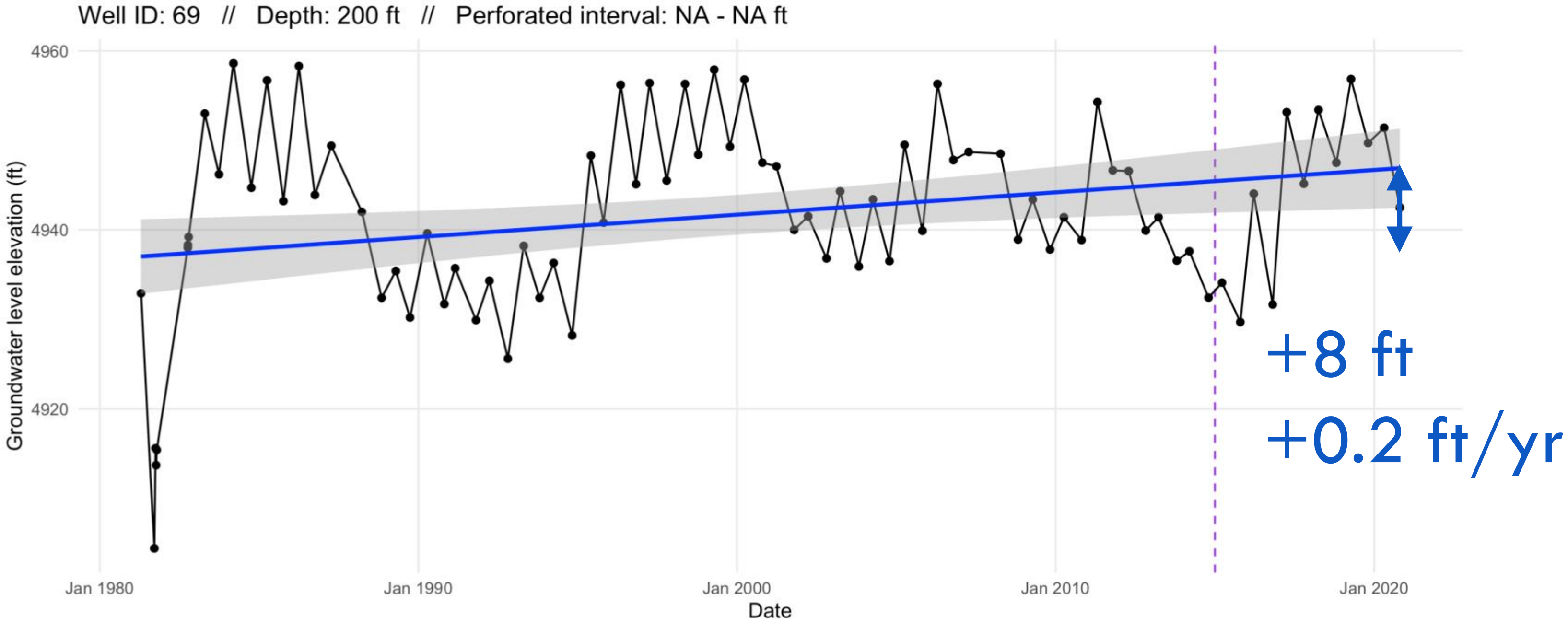
Well ID: 290 // Depth: 670 ft // Perforated interval: 220 - 250 ft



-0.5 ft

-0.03 ft/yr





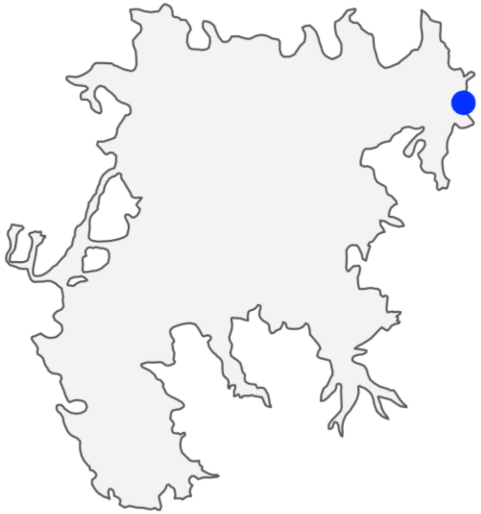
Well ID: 69 // Depth: 200 ft // Perforated interval: NA - NA ft

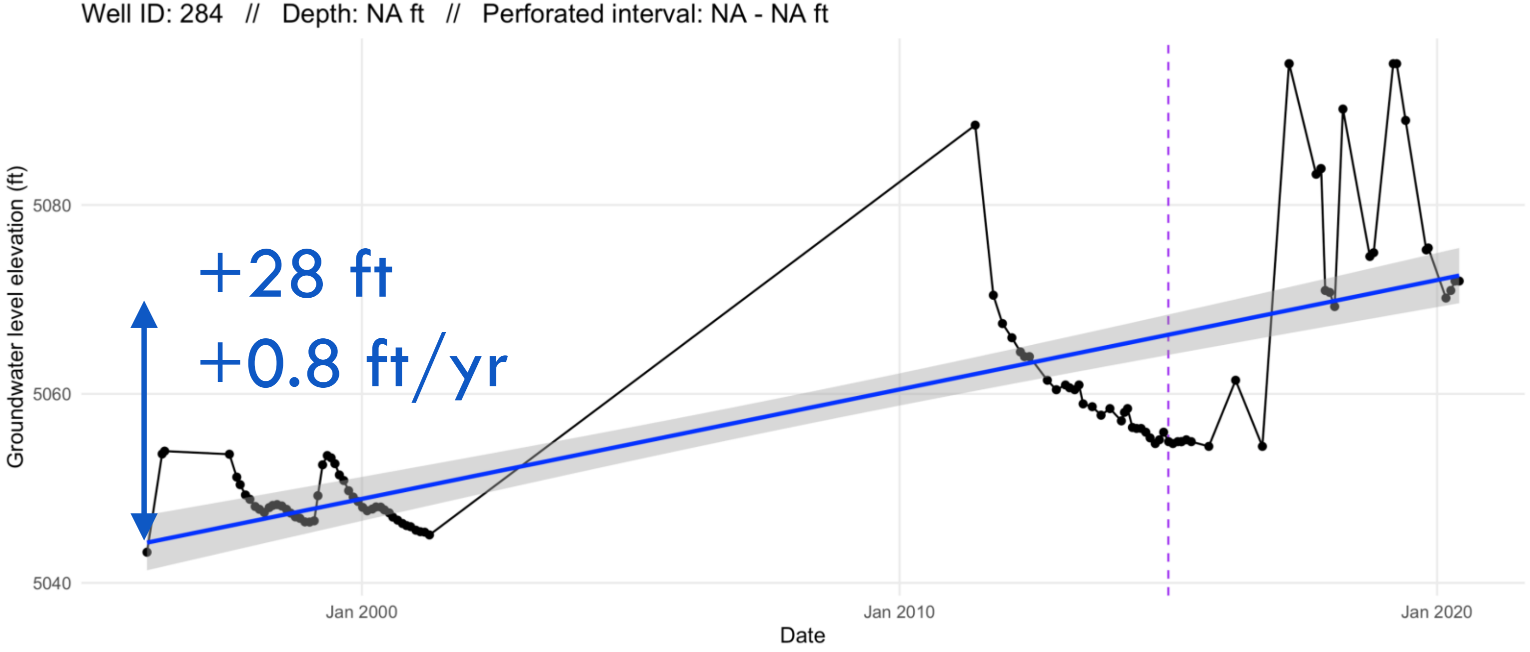
+8 ft

+0.2 ft/yr

(39.687371, -120.234103)

increasing





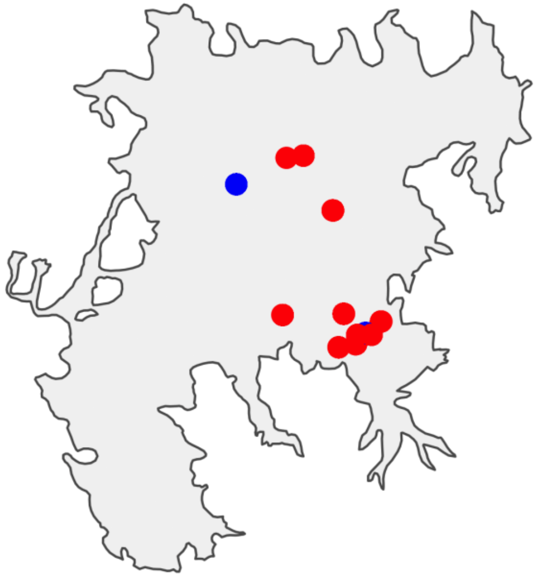
Well ID: 284 // Depth: NA ft // Perforated interval: NA - NA ft

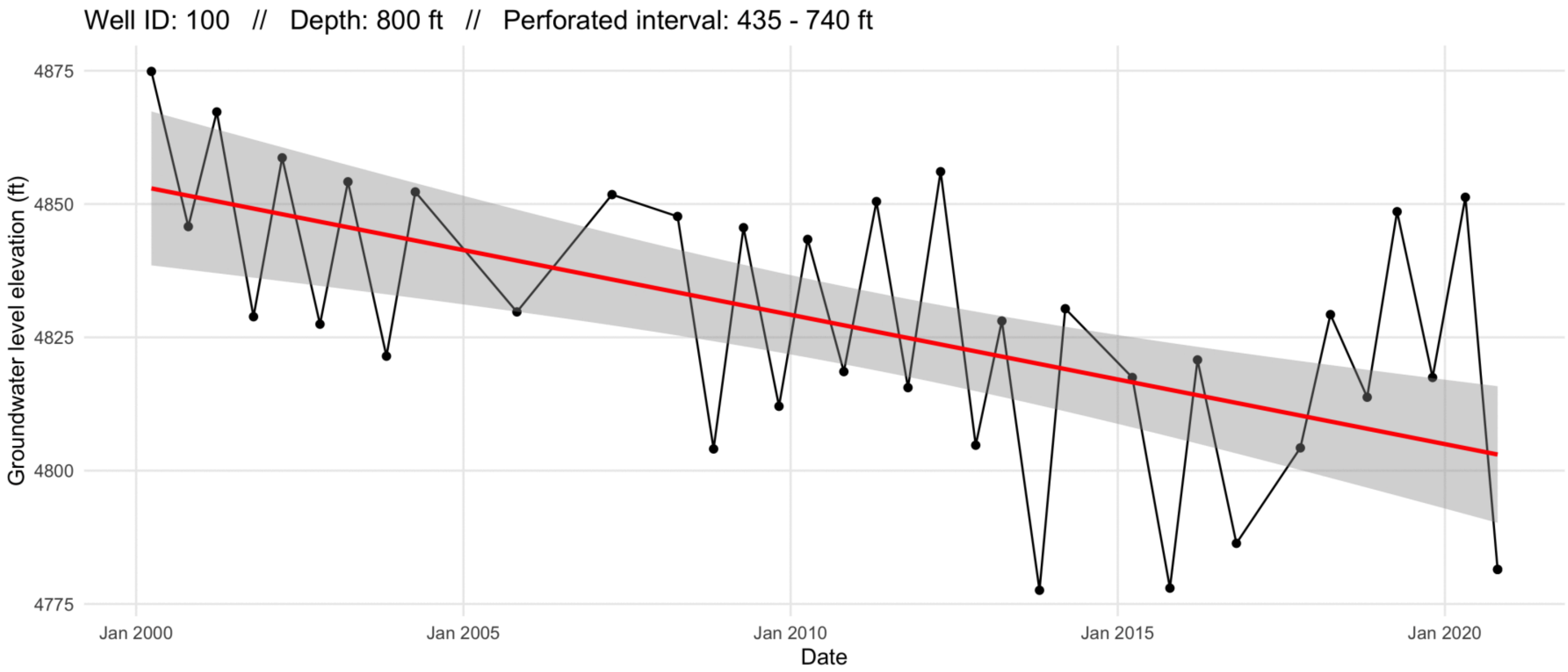
+28 ft

+0.8 ft/yr

(39.8035742, -120.1276009)

Most groundwater elevations are decreasing (2000-2020)





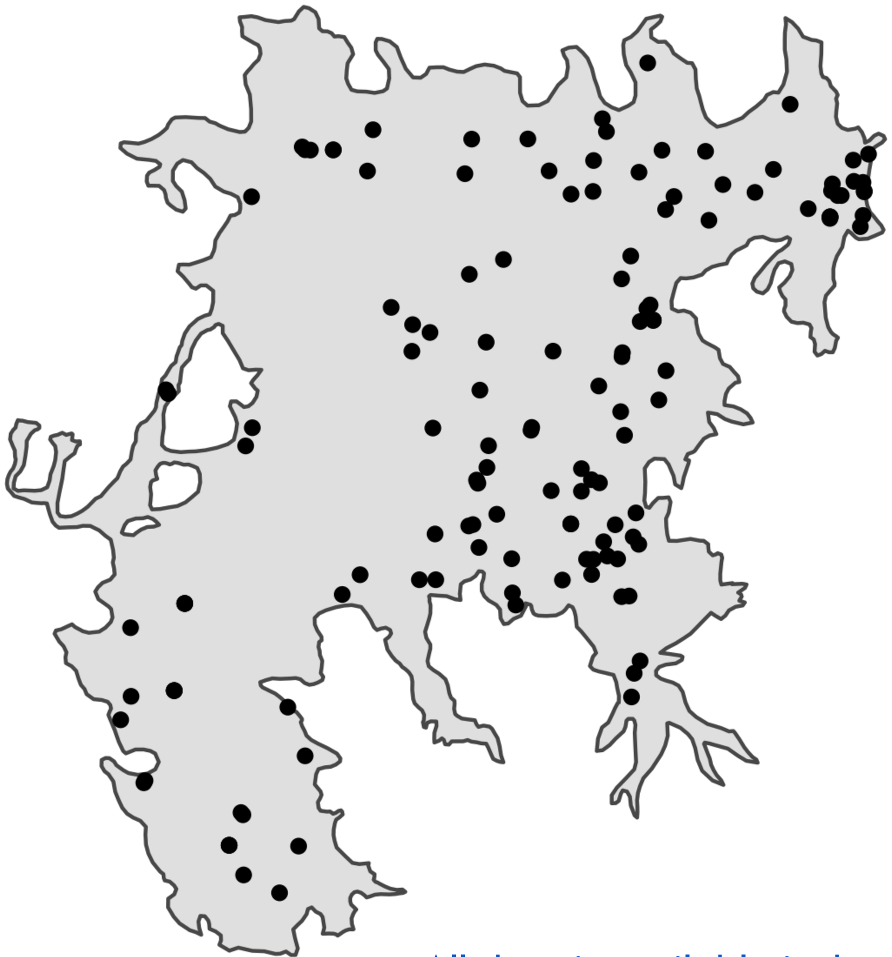
(39.7527403, -120.2566675)

● increasing

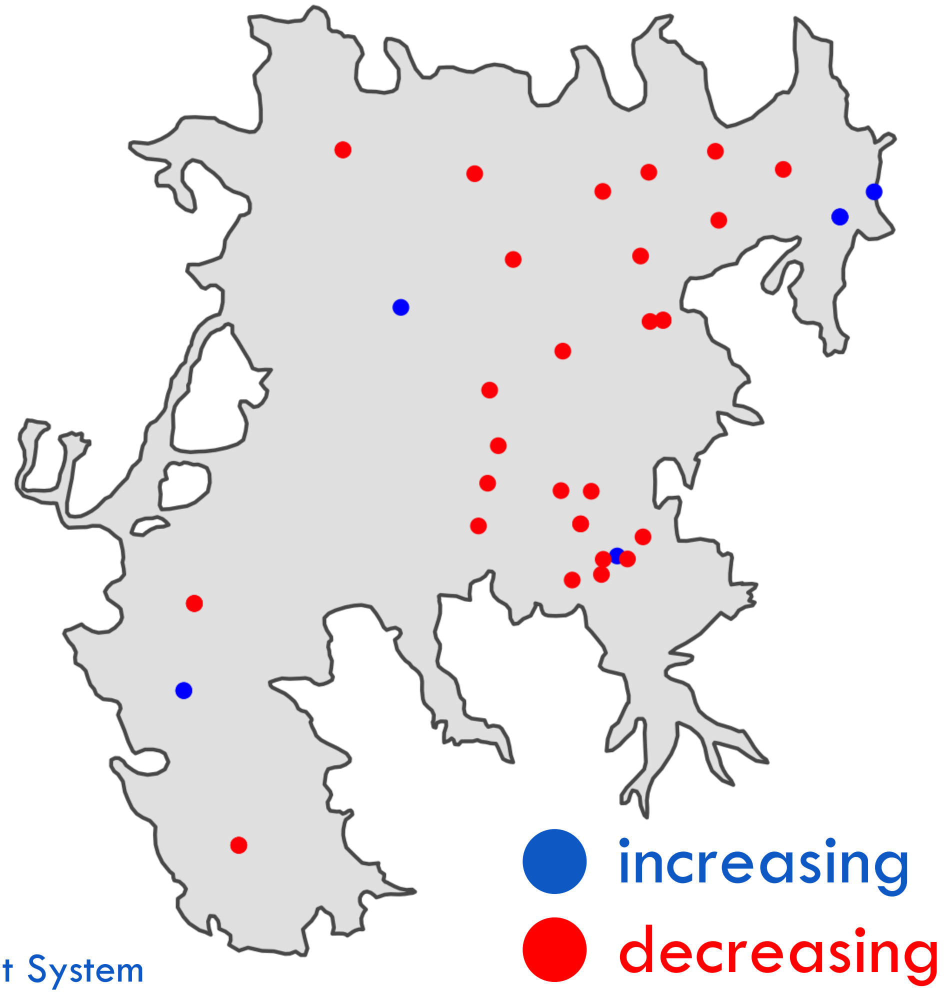
● decreasing

Groundwater level monitoring locations

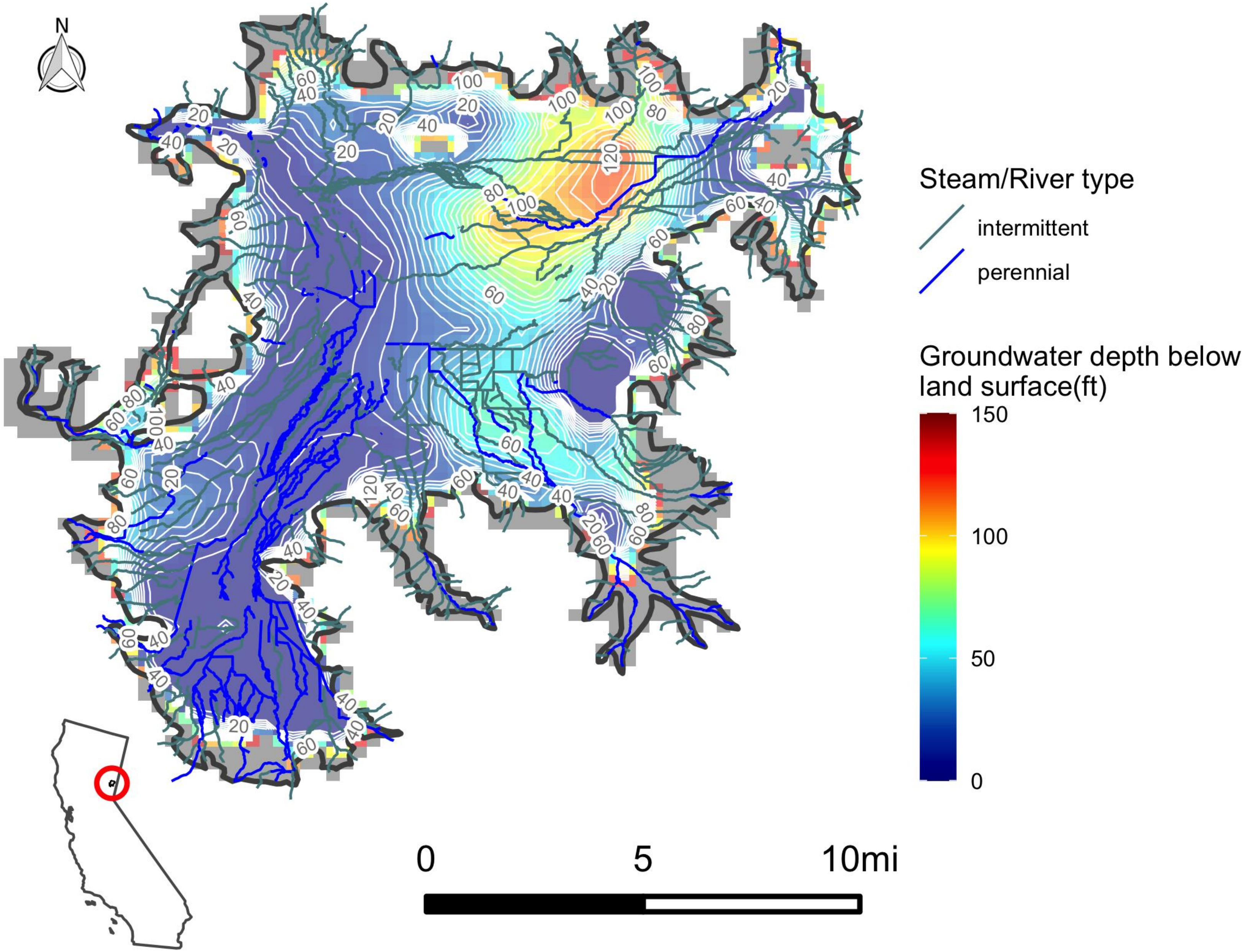
pre-2000 (historical)



through-2020 (present-day)

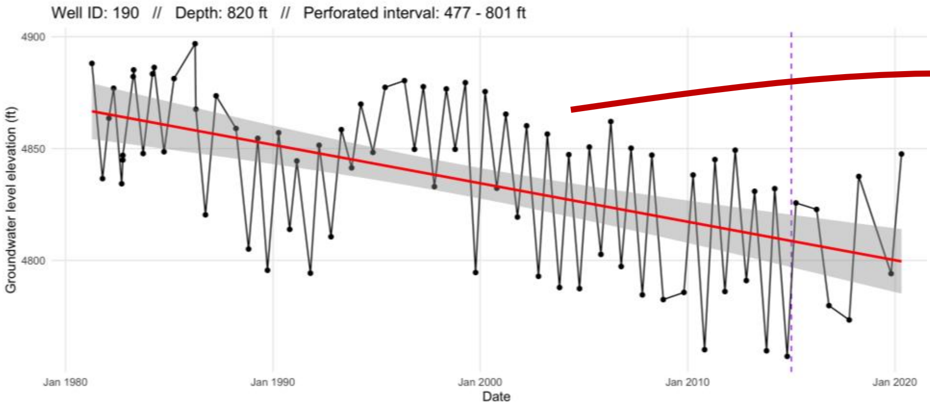


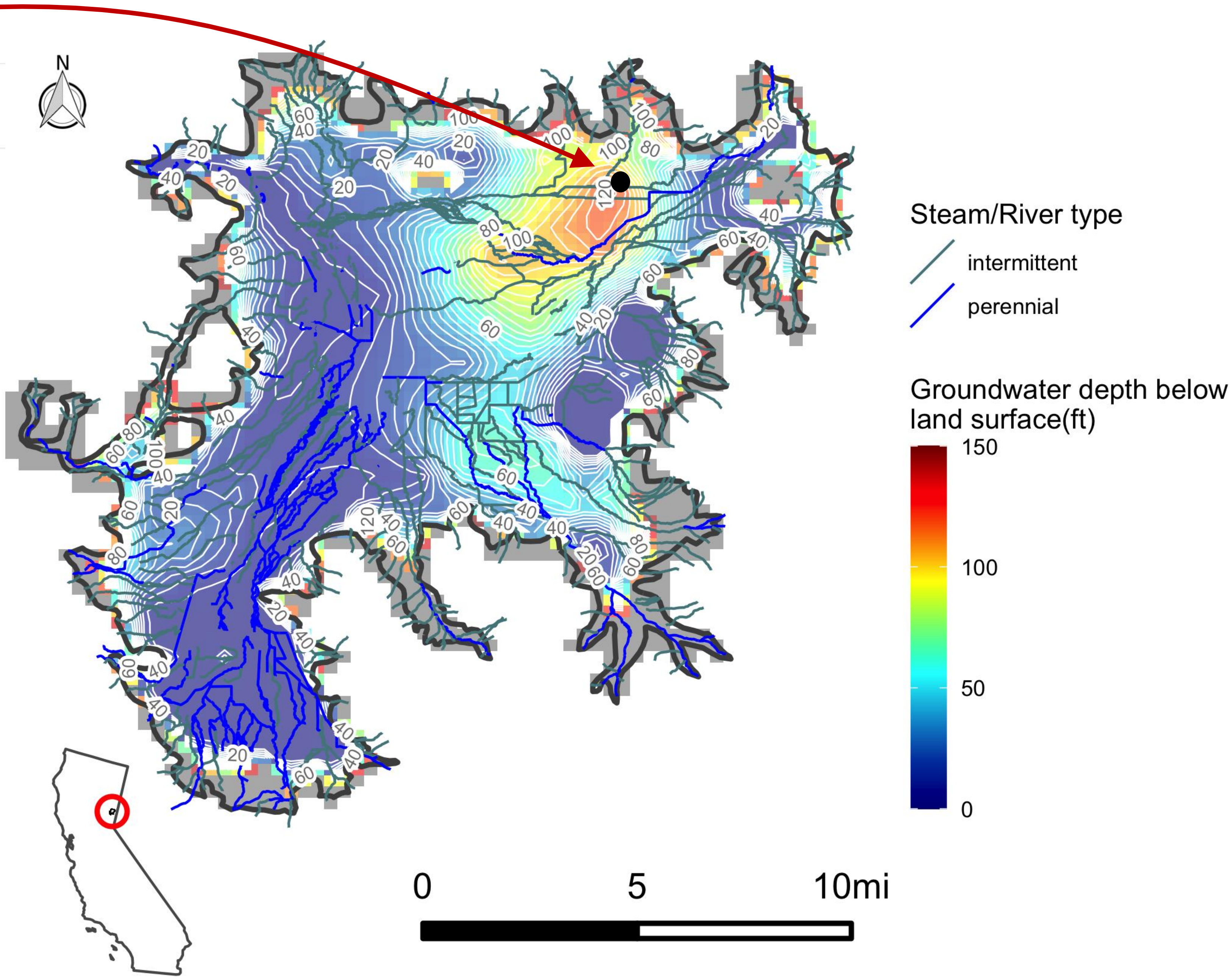
All data is available in the online Data Management System



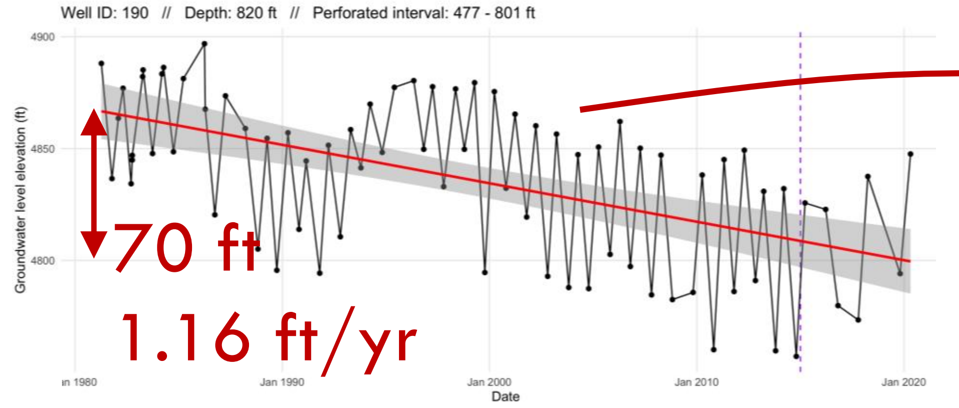
Average fall groundwater depth below land surface, 2000-2019

Average fall groundwater depth below land surface, 2000-2019



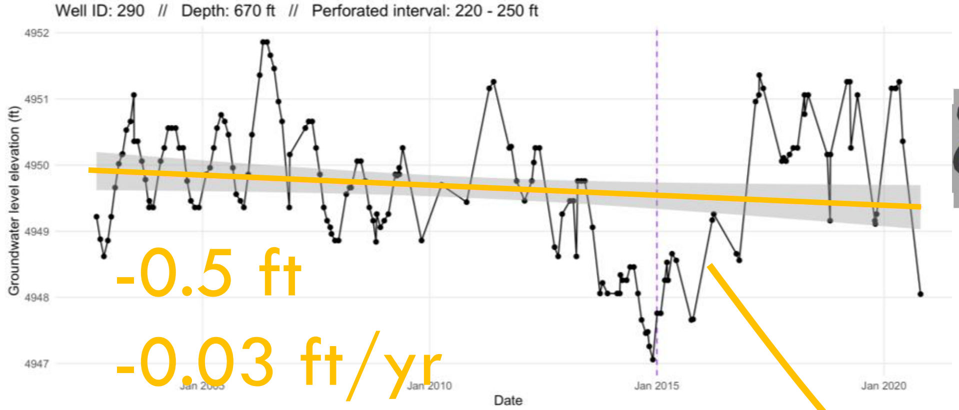


Average fall groundwater depth below land surface, 2000-2019


Well ID: 190 // Depth: 820 ft // Perforated interval: 477 - 801 ft

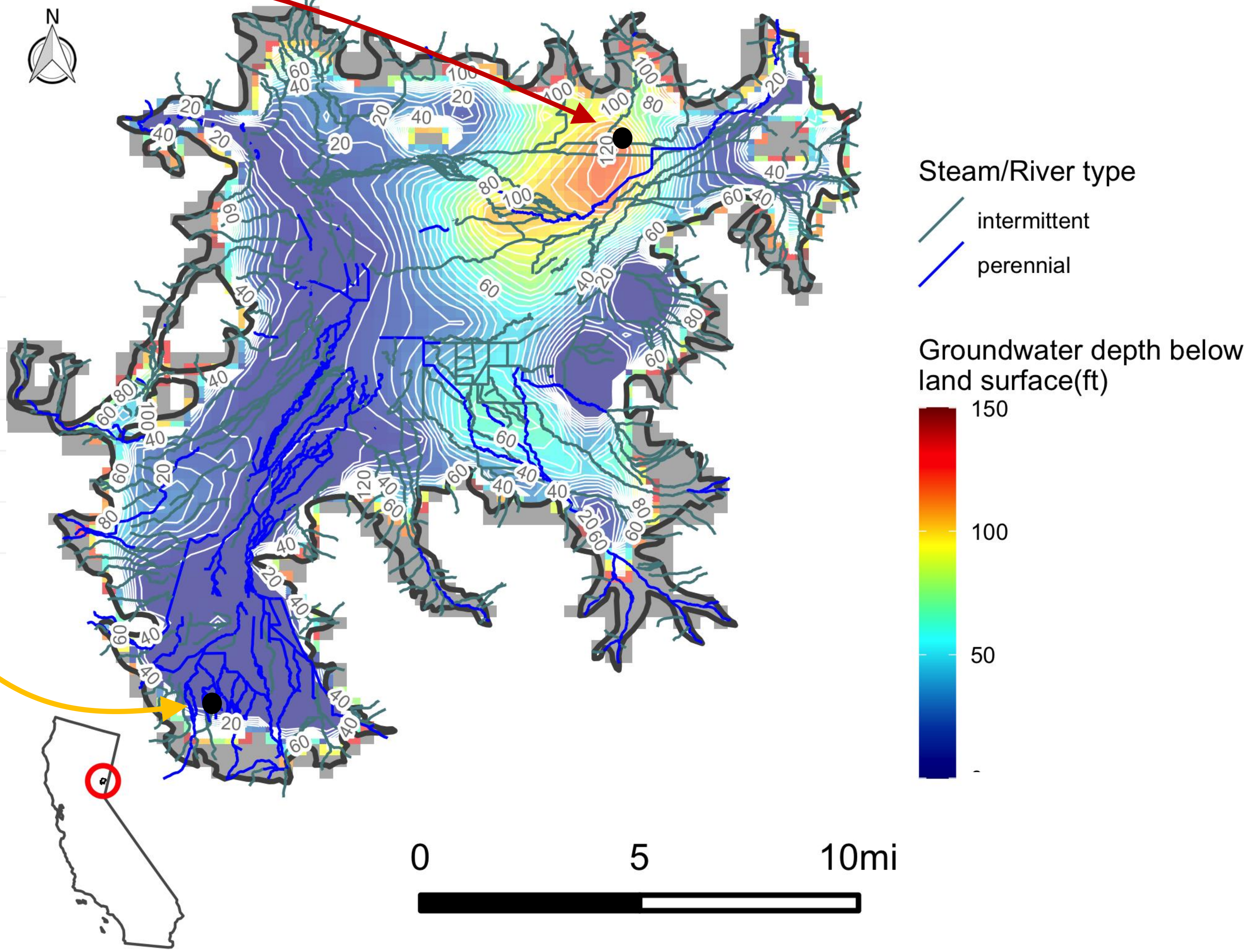
70 ft

1.16 ft/yr

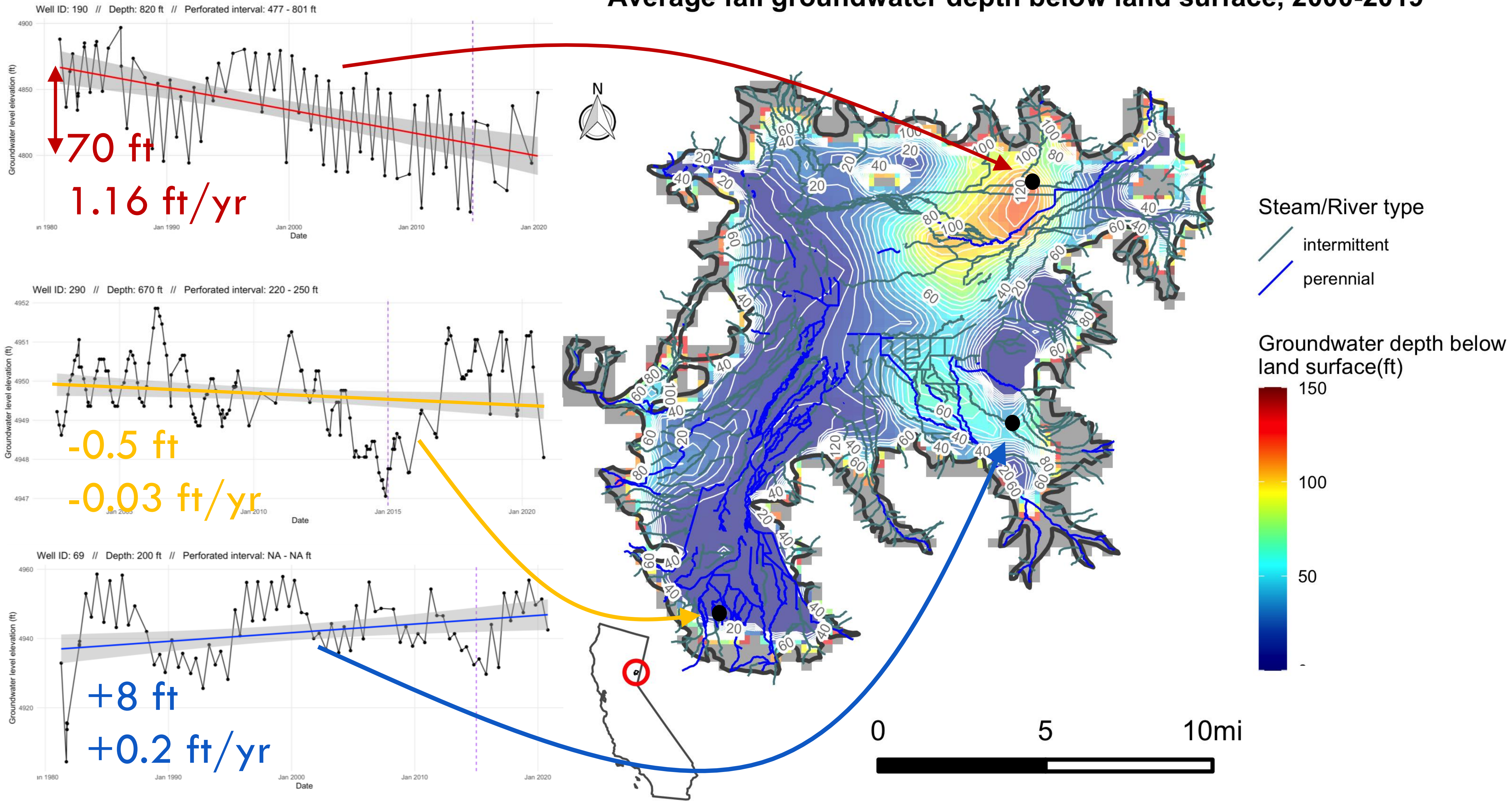

Well ID: 290 // Depth: 670 ft // Perforated interval: 220 - 250 ft

-0.5 ft

-0.03 ft/yr



Average fall groundwater depth below land surface, 2000-2019



70 ft

1.16 ft/yr

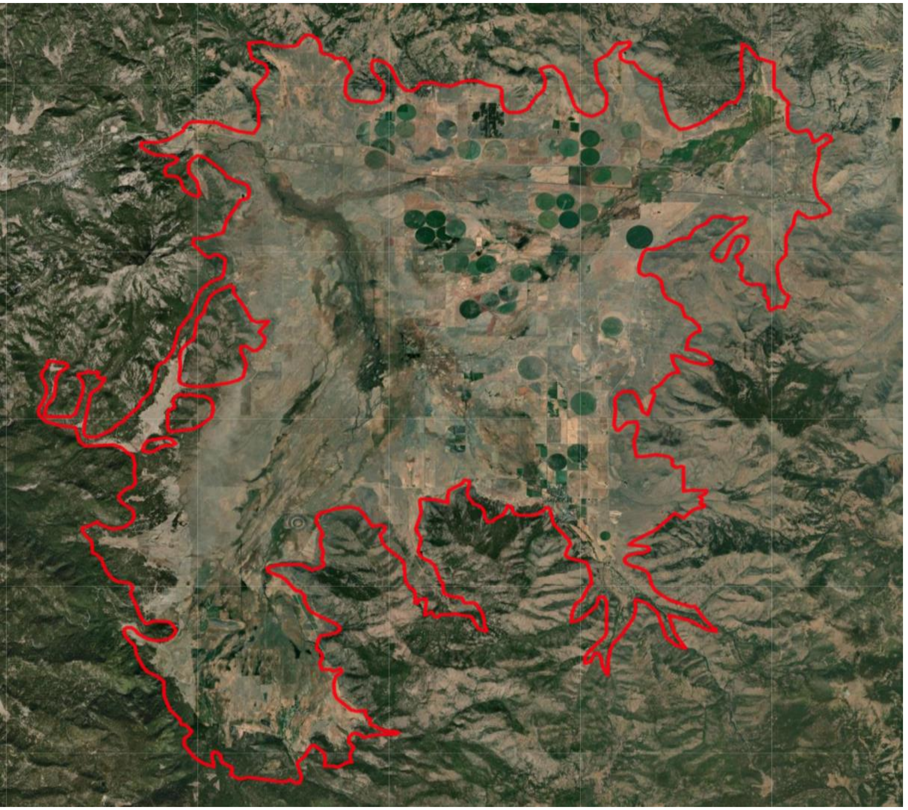
-0.5 ft

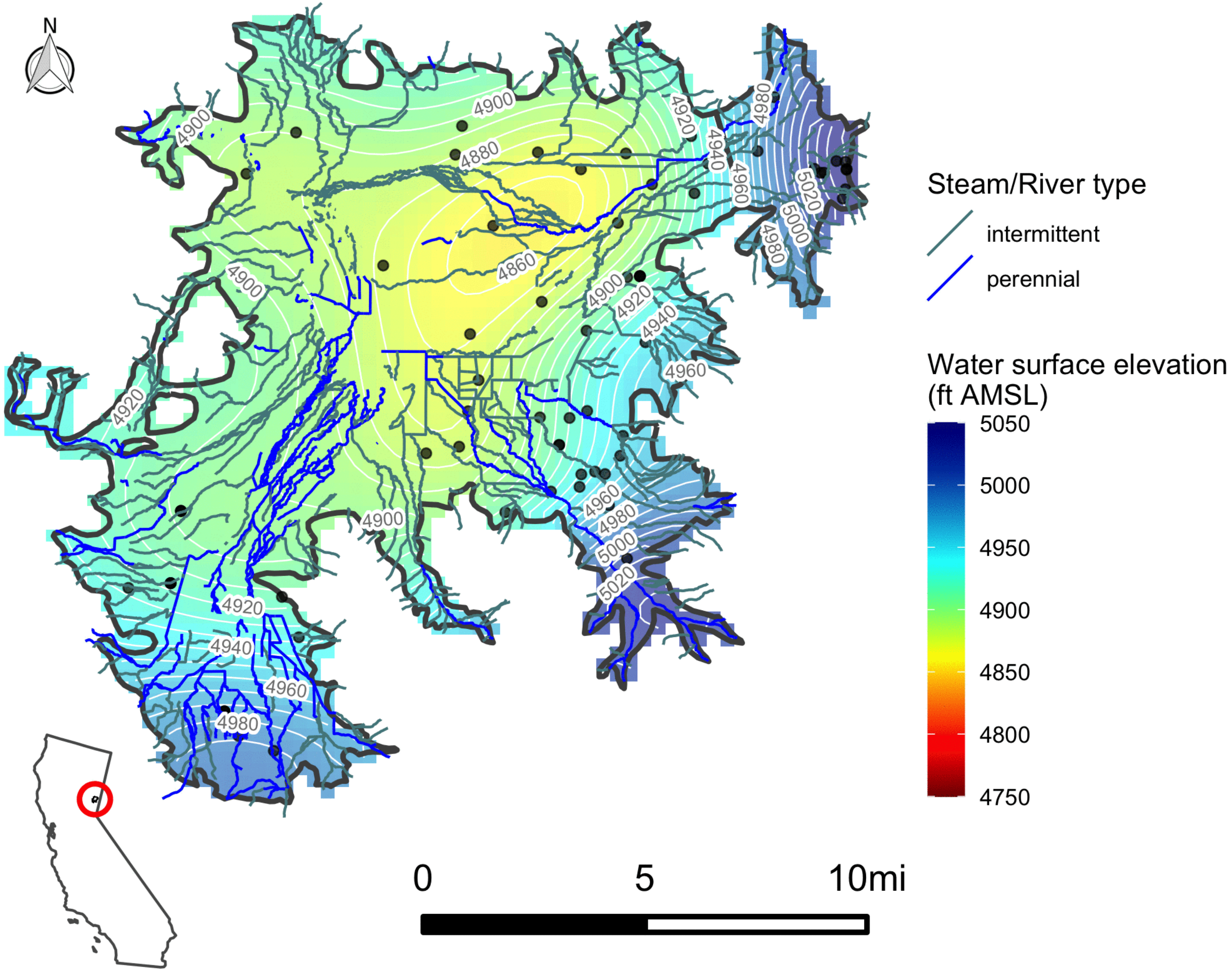
-0.03 ft/yr

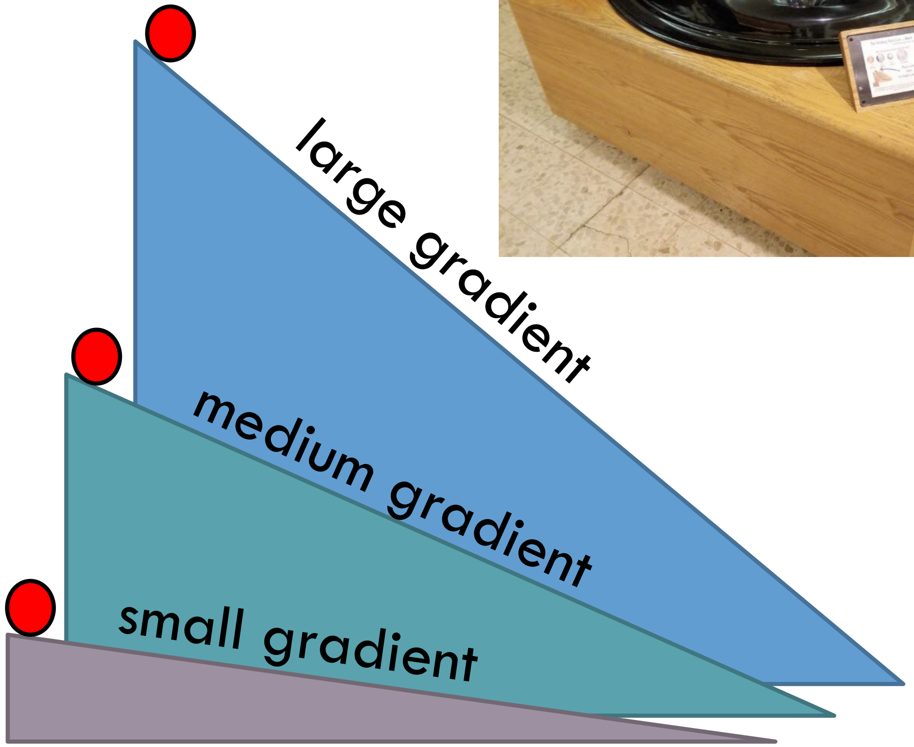
+8 ft

+0.2 ft/yr

Average groundwater elevation, spring 2000 - 2003



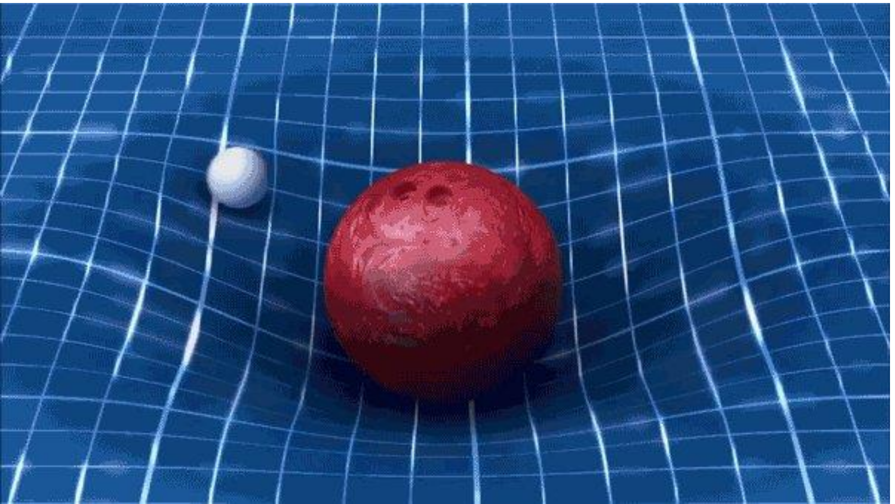




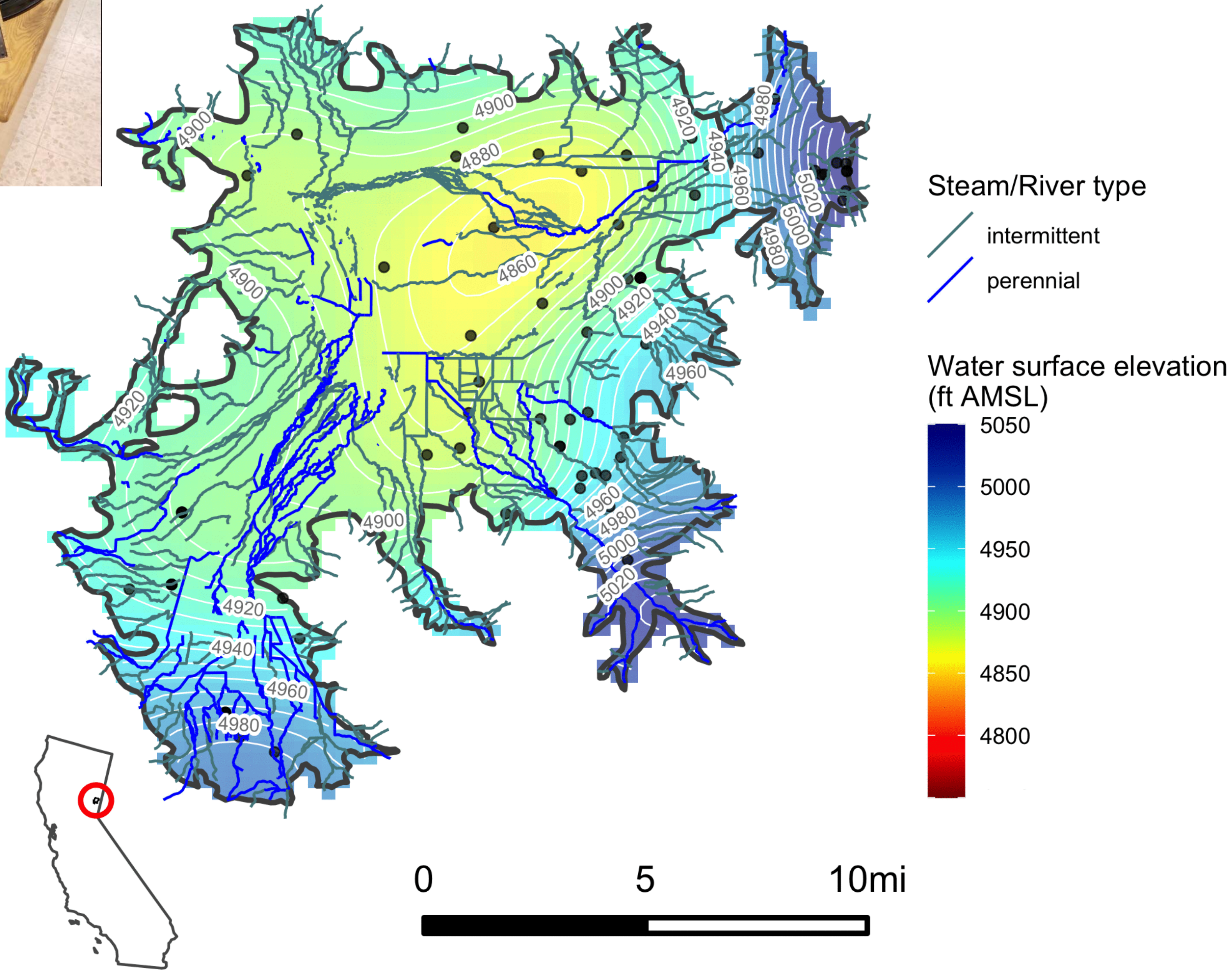
large gradient

medium gradient

small gradient

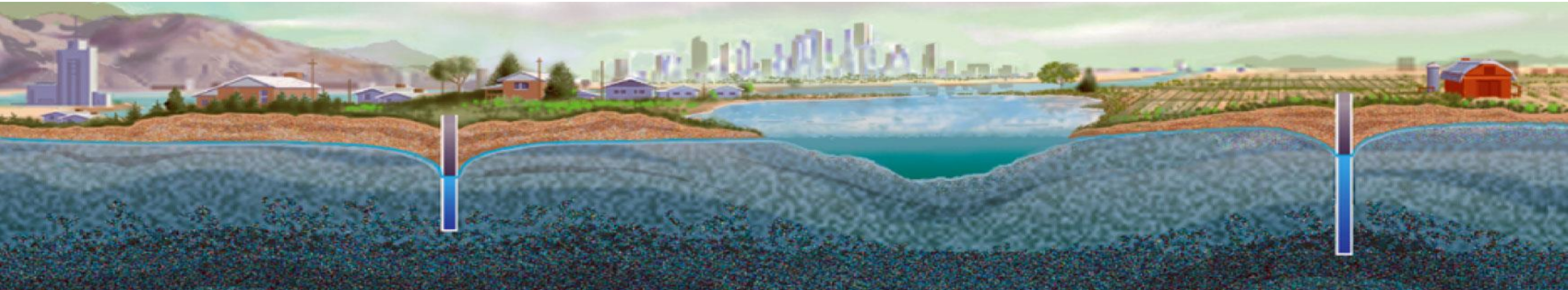


Average groundwater elevation, spring 2000 - 2003

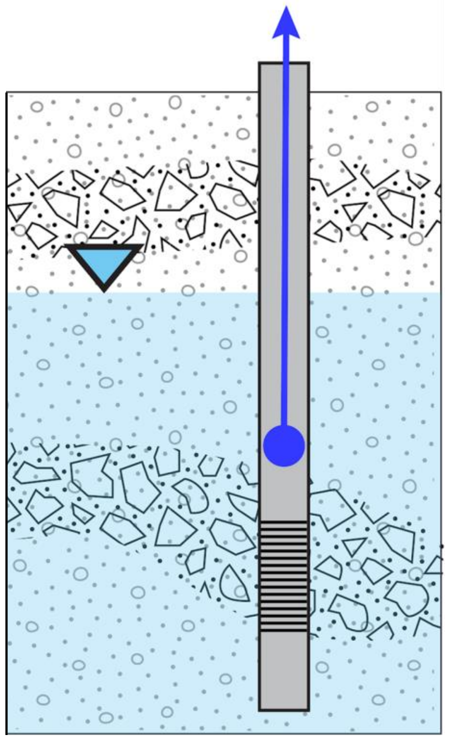


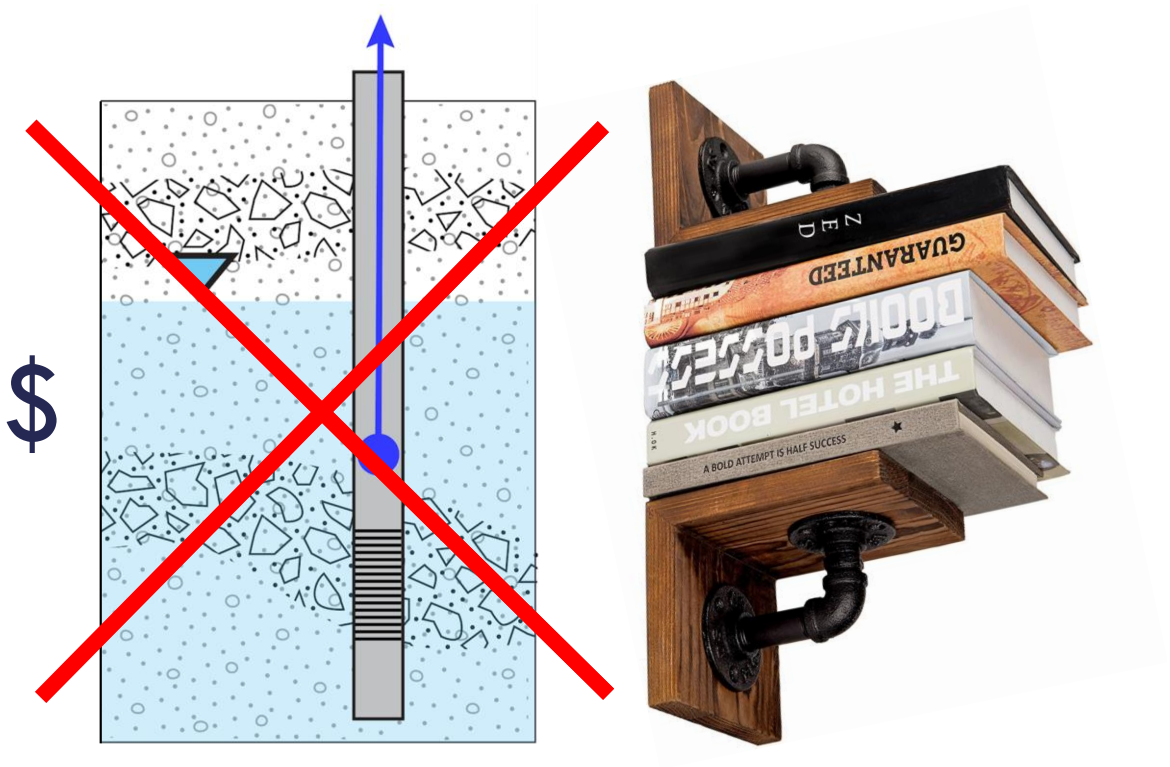
Are you concerned about
long-term declining trends in groundwater level?
(please prepare1-2 reasons to share if answering yes or no)

What beneficial users/uses of groundwater may be impacted by declining groundwater level?



Part 2: Bookend well protection analysis for agricultural and domestic beneficial users



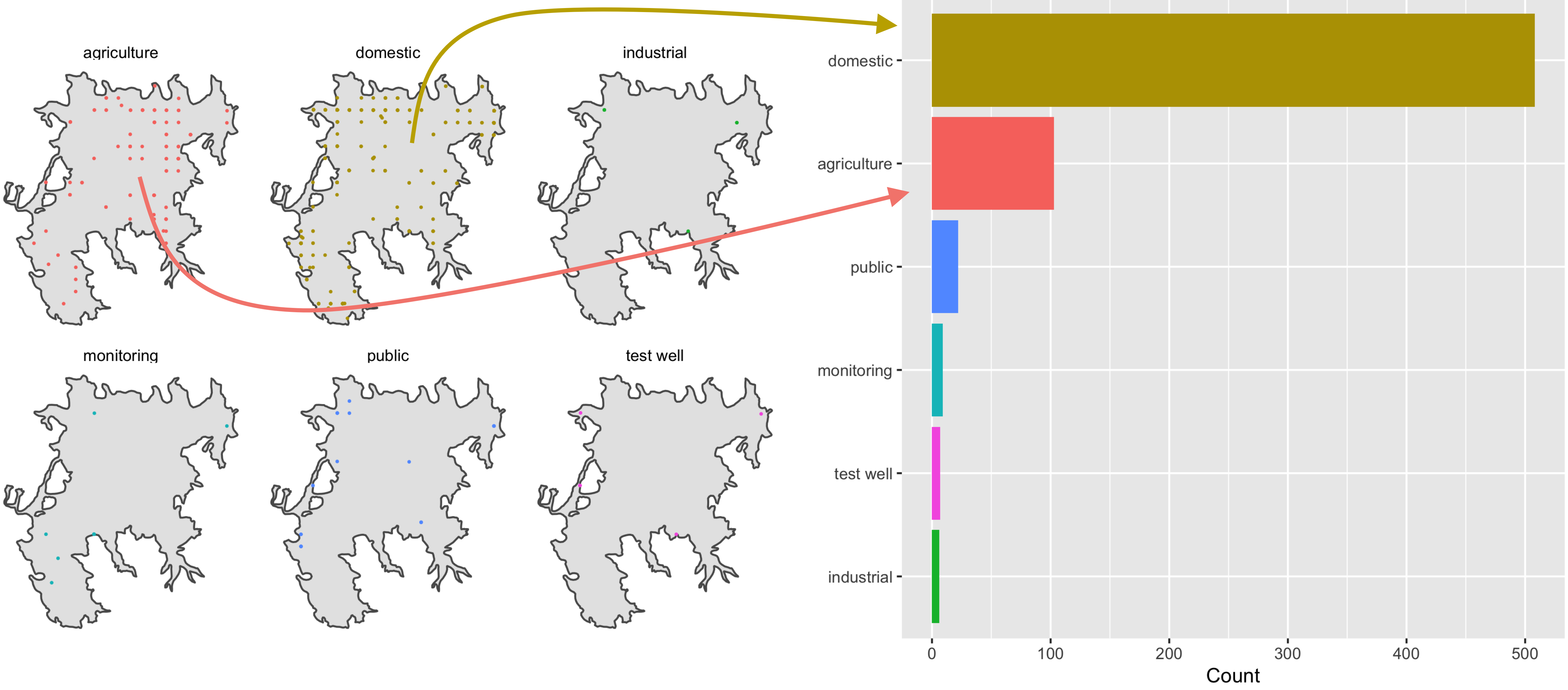


Sustainable management criteria (SMCs)

Significant and unreasonable (S & UR)

Domestic & agricultural wells are colocated

Domestic wells outnumber all other well types

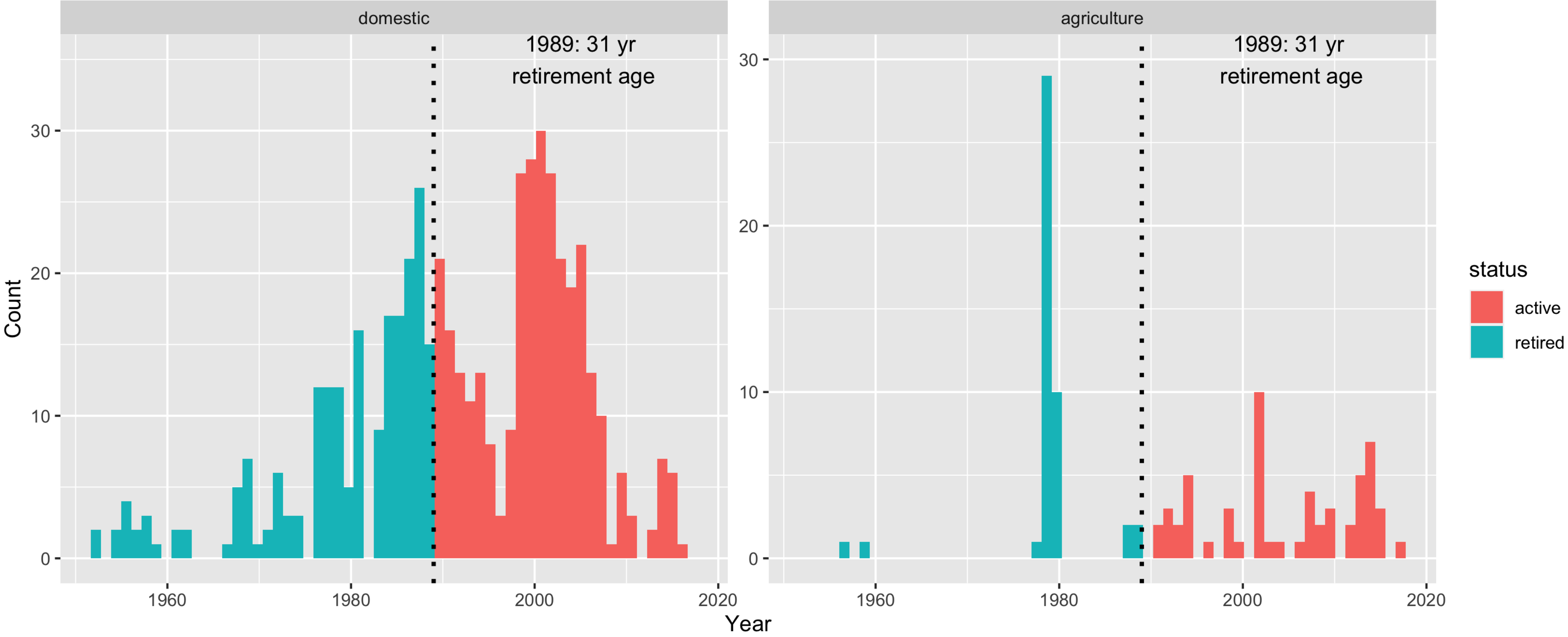


DWR Well Completion Report Database, https://data.cnra.ca.gov/dataset/well-completion-reports

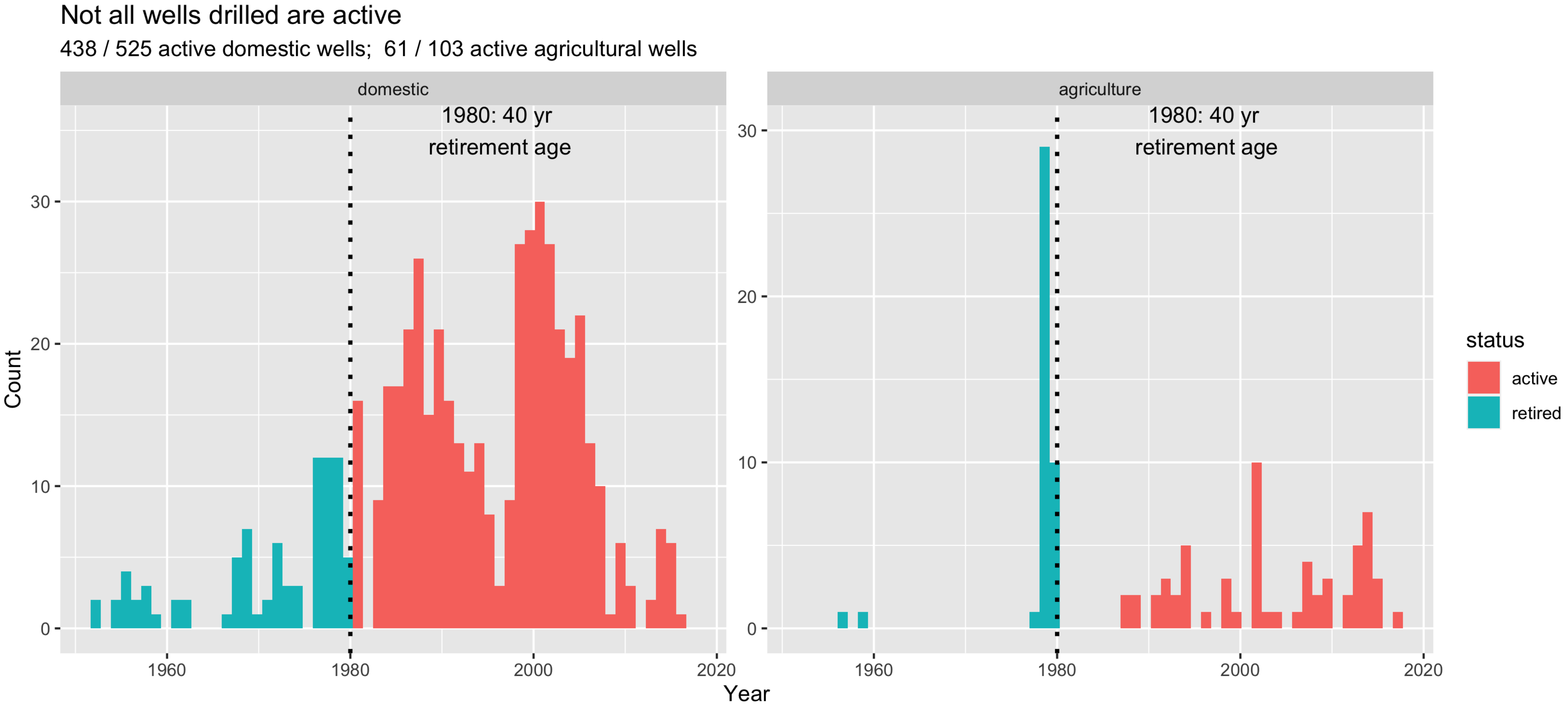
Many wells are old (likely retired) and hence not a liability…

Not all wells drilled are active

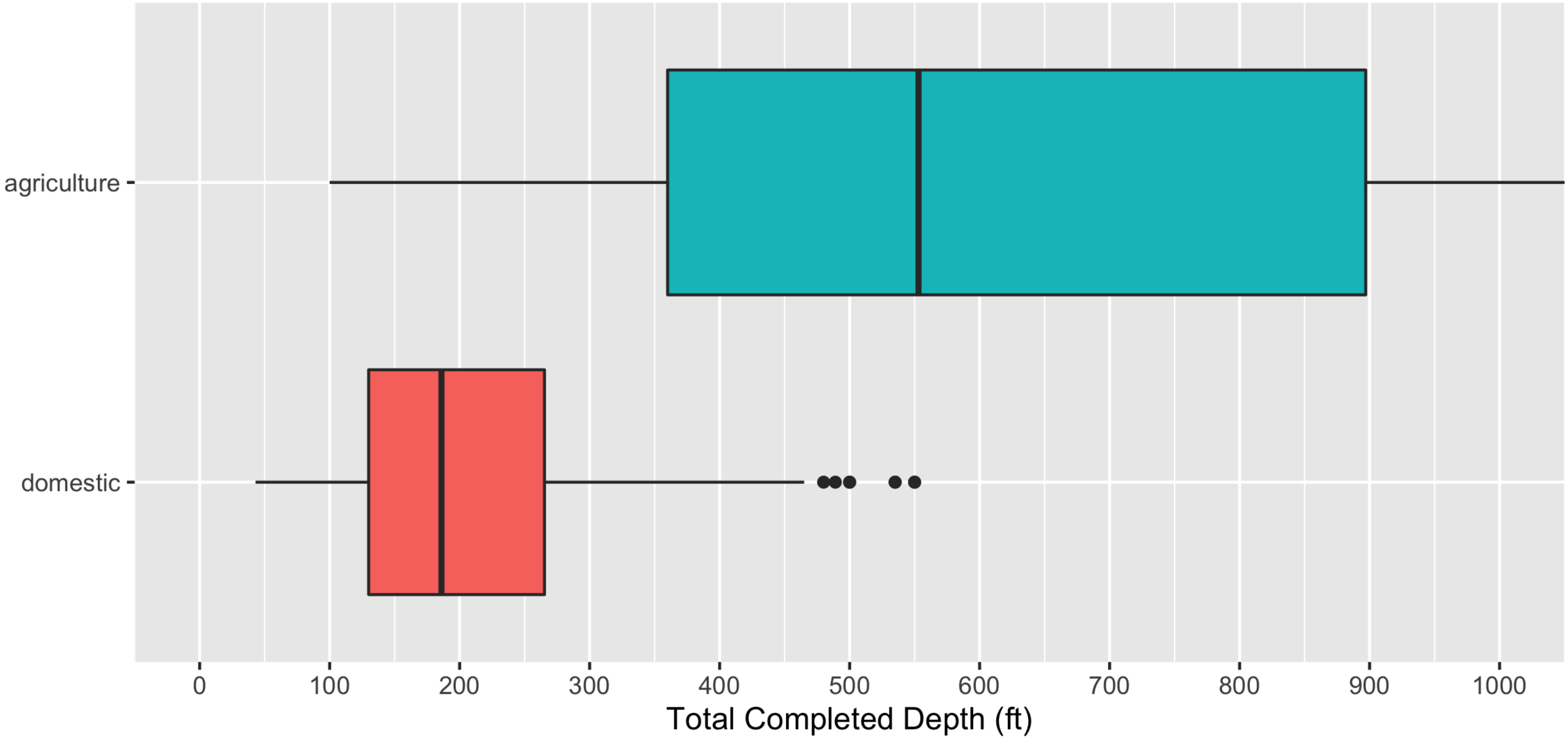
317 / 525 active domestic wells; 57 / 103 active agricultural wells

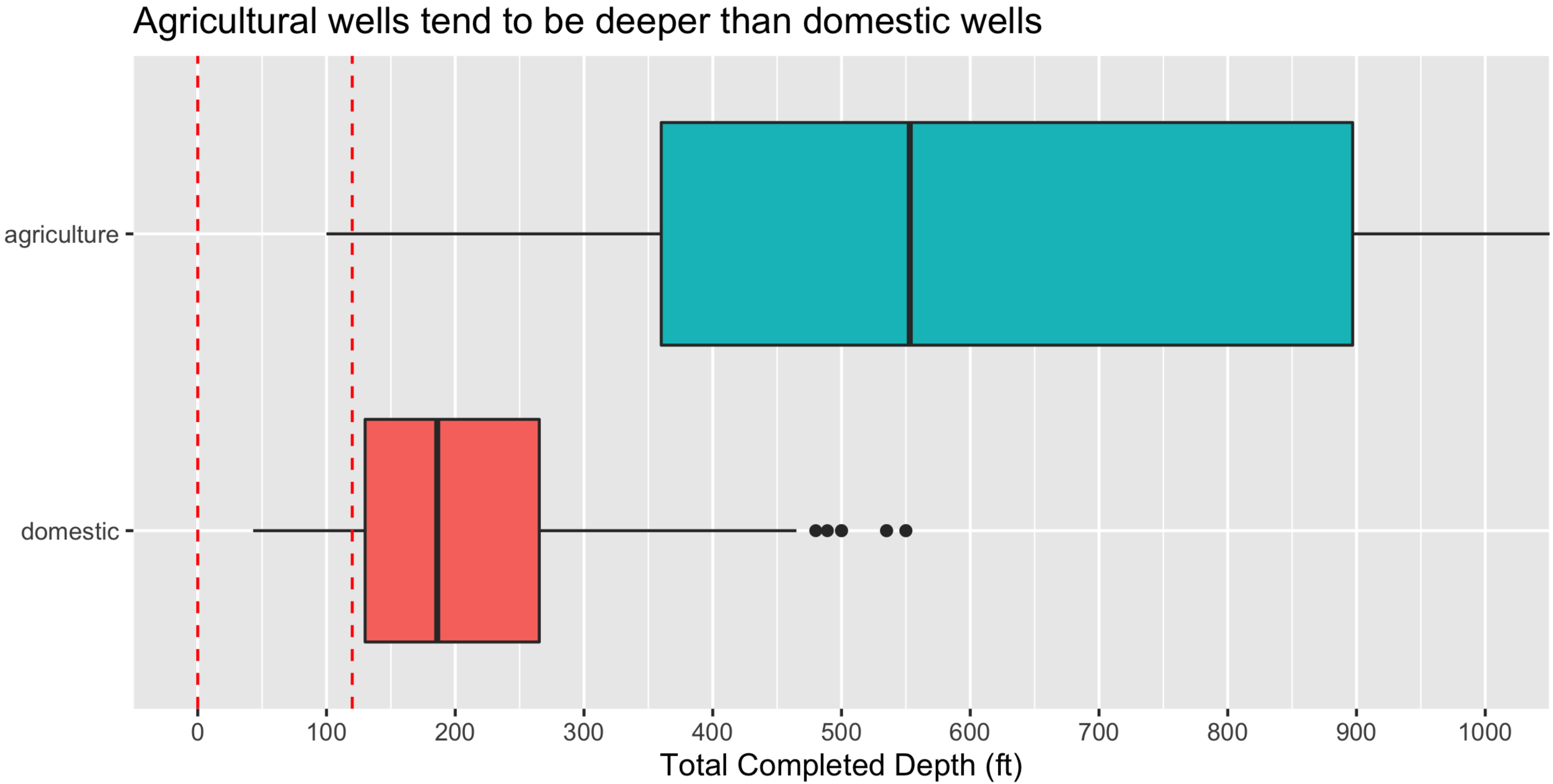


… but there is uncertainty in retirement age



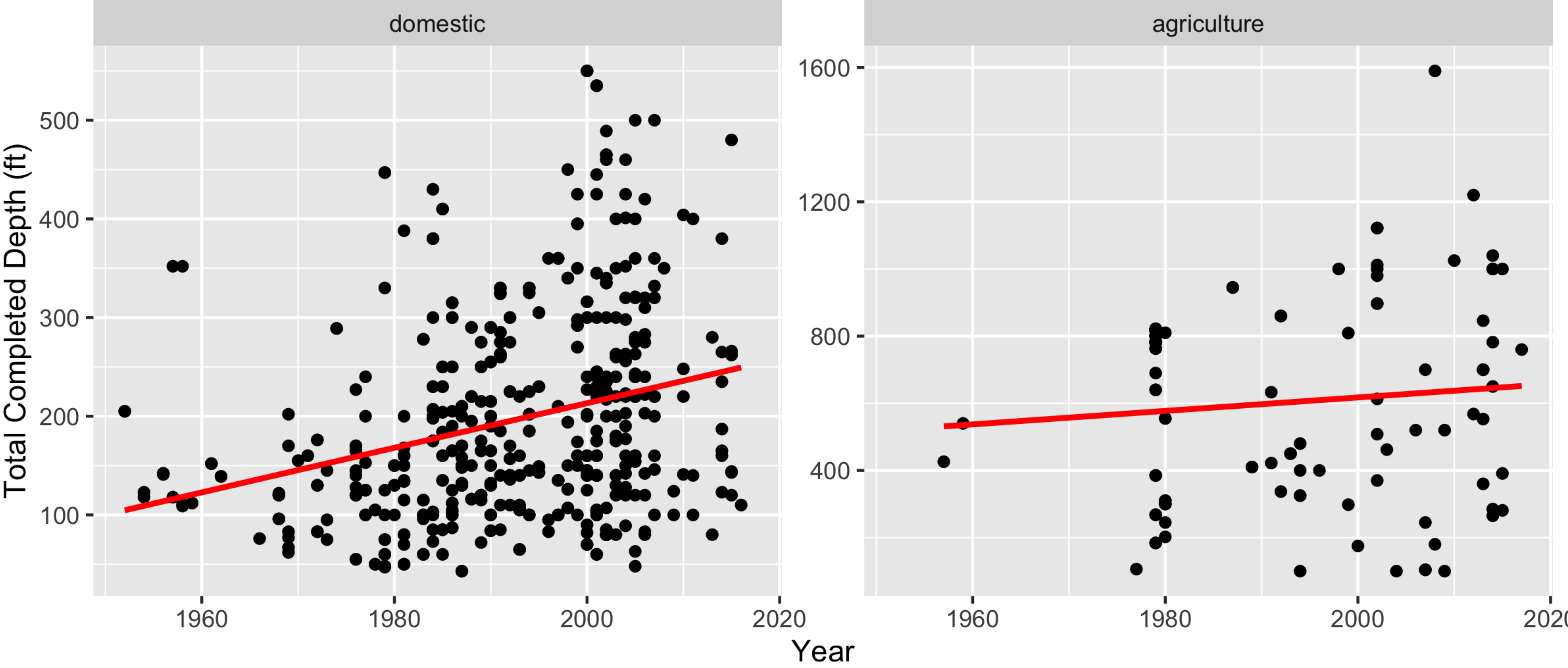
Agricultural wells tend to be deeper than domestic wells




Agricultural wells tend to be deeper than domestic wells
agriculture
domestic
0
100
200
300
400
500
600
700
800
900
1000
Total Completed Depth (ft)

Since 1950, average domestic well depth increases by around 2.5x

agricultural well depths increase by around 1.3x



Define undesirable results

Set SMCs (MOs/MTs)

Set Interim Milestones

Chronic lowering of groundwater level (Merced GSP)

Undesirable Results: *Greater than 25% of representative wells fall below MT in 2 consecutive wet, above normal, or below normal years*

Measurable Objective: *Projected average future groundwater level under sustainable yield modeling simulation*

Minimum threshold: *Depth of shallowest well in a 2-mile radius of each representative well or minimum pre-January 1, 2015, elevation*

- Define undesirable results
- Set SMCs (MOs/MTs)
- Set Interim Milestones

Chronic lowering of groundwater level (Yuba GSP)

Undesirable Results: *A result that causes significant and unreasonable reduction in the long-term viability of domestic, agricultural, municipal, or environmental uses over the planning and implementation horizon of this GSP.*

Identification of Undesirable Results: *More than 25% of representative monitoring wells fall below minimum thresholds for two consecutive years at each location.*

Measurable Objective: *The measurable objective was defined for each representative monitoring well based on the minimum March groundwater level at that well within the 2014-2015 time period.*

Minimum threshold: *The deeper of either 1) the bottom of the shallowest domestic well near a monitoring well, adjusted for March measurements or 2) the historical low March groundwater level from 1985 to present at the monitoring well. A 75- foot minimum value was applied to the threshold.*

Define undesirable results

Set SMCs (MOs/MTs)

Set Interim Milestones

Chronic lowering of groundwater level (Delta Mendota GSP)

Undesirable Results: *significant and unreasonable chronic change in water levels, as defined by each GSP Group, that has an impact on the beneficial users of groundwater in the Subbasin through intra- and/or inter-basin actions*

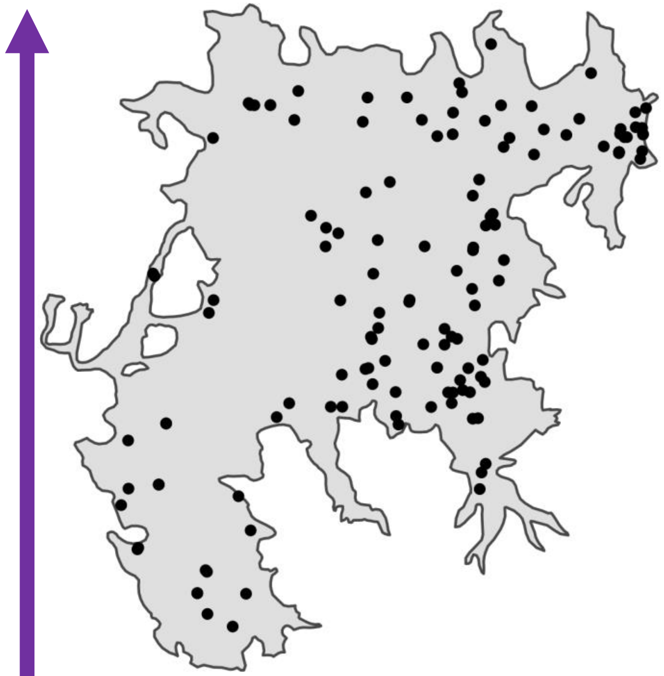
Identification of Undesirable Results: *groundwater elevations drop below the site-specific minimum threshold at 25 percent of representative monitoring wells in a principal aquifer in the Northern and Central Delta-Mendota Regions concurrently over a given year*

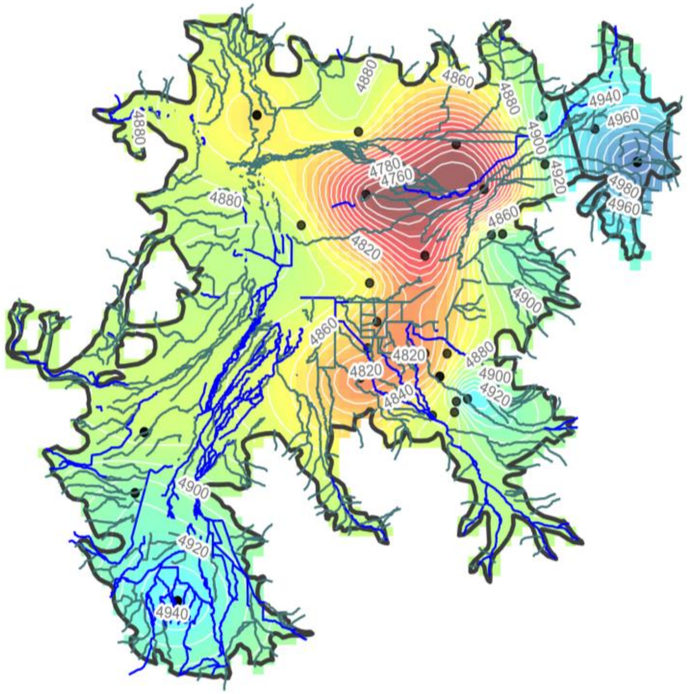
Measurable Objective: *the lowest value of three possible parameters – the average of historic seasonal highs over the available hydrograph, Spring 2012 seasonal high, or Spring 2017 seasonal high (where seasonal high and Spring are synonymous and defined as measurements taken between February and April)*

Minimum threshold: *hydrologic low for wells perforated in the Upper Aquifer (above the Corcoran Clay) and 95 percent of the hydrologic low for wells perforated in the Lower Aquifer (below the Corcoran Clay) over the available hydrographs on record*

Well protection analysis informs "Undesirable Results" for chronic lowering of groundwater levels

Set MTs at RMPS in monitoring network → *Calculate the MT surface* → *Calculate the count and cost of well protection*





X wells fail if MTs are reached and cost $Y dollars

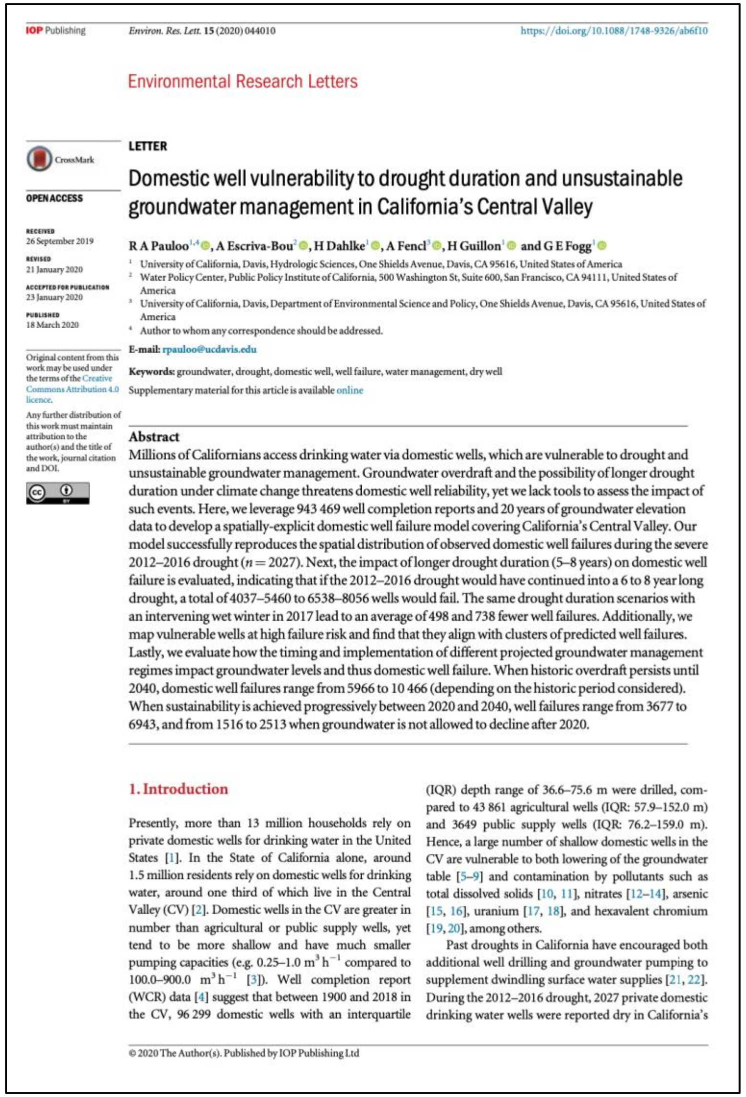
Significant and unreasonable?

NO

YES

Stop. SMC reached.

Previous approaches abound and are recent



IOP Publishing Environ. Res. Lett. 15 (2020) 044010 https://doi.org/10.1088/1748-9326/ab6f10

Environmental Research Letters

LETTER

CrossMark

OPEN ACCESS

RECEIVED
26 September 2019

REVISED
21 January 2020

ACCEPTED FOR PUBLICATION
23 January 2020

PUBLISHED
18 March 2020

Domestic well vulnerability to drought duration and unsustainable groundwater management in California's Central Valley

R A Pauloo[1,4], A Escriva-Bou[2], H Dahlke[1], A Fencl[3], H Guillon[1] and G E Fogg[1]

[1] University of California, Davis, Hydrologic Sciences, One Shields Avenue, Davis, CA 95616, United States of America
[2] Water Policy Center, Public Policy Institute of California, 500 Washington St, Suite 600, San Francisco, CA 94111, United States of America
[3] University of California, Davis, Department of Environmental Science and Policy, One Shields Avenue, Davis, CA 95616, United States of America
[4] Author to whom any correspondence should be addressed.

E-mail: rpauloo@ucdavis.edu

Keywords: groundwater, drought, domestic well, well failure, water management, dry well

Supplementary material for this article is available online

Abstract

Millions of Californians access drinking water via domestic wells, which are vulnerable to drought and unsustainable groundwater management. Groundwater overdraft and the possibility of longer drought duration under climate change threatens domestic well reliability, yet we lack tools to assess the impact of such events. Here, we leverage 943 469 well completion reports and 20 years of groundwater elevation data to develop a spatially-explicit domestic well failure model covering California's Central Valley. Our model successfully reproduces the spatial distribution of observed domestic well failures during the severe 2012–2016 drought ($n = 2027$). Next, the impact of longer drought duration (5–8 years) on domestic well failure is evaluated, indicating that if the 2012–2016 drought would have continued into a 6 to 8 year long drought, a total of 4037–5460 to 6538–8056 wells would fail. The same drought duration scenarios with an intervening wet winter in 2017 lead to an average of 498 and 738 fewer well failures. Additionally, we map vulnerable wells at high failure risk and find that they align with clusters of predicted well failures. Lastly, we evaluate how the timing and implementation of different projected groundwater management regimes impact groundwater levels and thus domestic well failure. When historic overdraft persists until 2040, domestic well failures range from 5966 to 10 466 (depending on the historic period considered). When sustainability is achieved progressively between 2020 and 2040, well failures range from 3677 to 6943, and from 1516 to 2513 when groundwater is not allowed to decline after 2020.

1. Introduction

Presently, more than 13 million households rely on private domestic wells for drinking water in the United States [1]. In the State of California alone, around 1.5 million residents rely on domestic wells for drinking water, around one third of which live in the Central Valley (CV) [2]. Domestic wells in the CV are greater in number than agricultural or public supply wells, yet tend to be more shallow and have much smaller pumping capacities (e.g. 0.25–1.0 $m^3 h^{-1}$ compared to 100.0–900.0 $m^3 h^{-1}$ [3]). Well completion report (WCR) data [4] suggest that between 1900 and 2018 in the CV, 96 299 domestic wells with an interquartile (IQR) depth range of 36.6–75.6 m were drilled, compared to 43 861 agricultural wells (IQR: 57.9–152.0 m) and 3649 public supply wells (IQR: 76.2–159.0 m). Hence, a large number of shallow domestic wells in the CV are vulnerable to both lowering of the groundwater table [5–9] and contamination by pollutants such as total dissolved solids [10, 11], nitrates [12–14], arsenic [15, 16], uranium [17, 18], and hexavalent chromium [19, 20], among others.

Past droughts in California have encouraged both additional well drilling and groundwater pumping to supplement dwindling surface water supplies [21, 22]. During the 2012–2016 drought, 2027 private domestic drinking water wells were reported dry in California's

Gailey et al., 2019 – Tulare County

Pauloo et al., 2020 – Central Valley (CV)

Bostic et al., 2020 – CV critical priority GSPs

EKI, 2020 – CV critical priority GSPs

gspdrywells.com – CV critical priority GSPs

Models are 1-2 years old because digitized well completion data recently became public

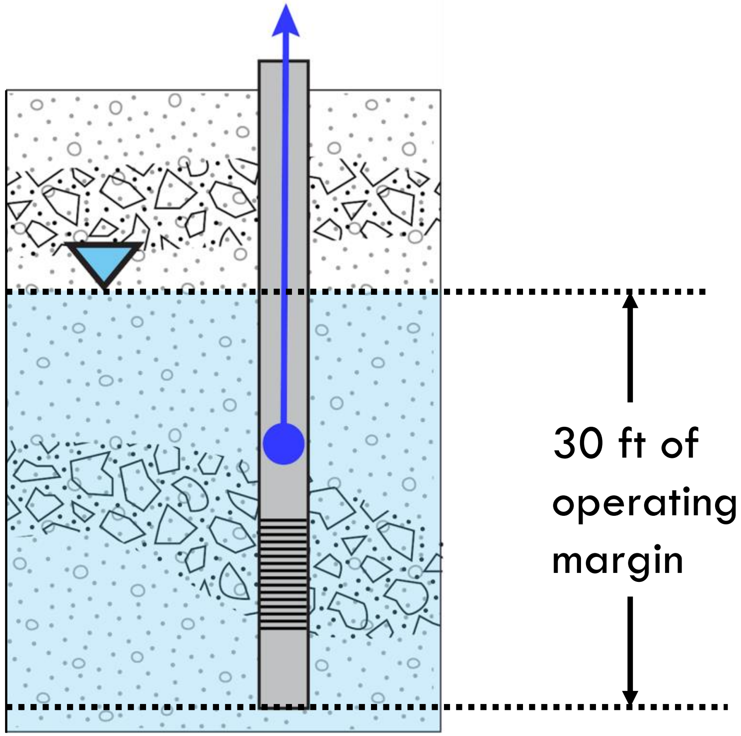
Models are validated on well failures observed during the 2012-2016 drought

Key questions and Approach

1. How many wells need protection if Sierra Valley returns to 2015 low groundwater levels?

2. What are the relative costs borne by agricultural and domestic users along this trajectory?

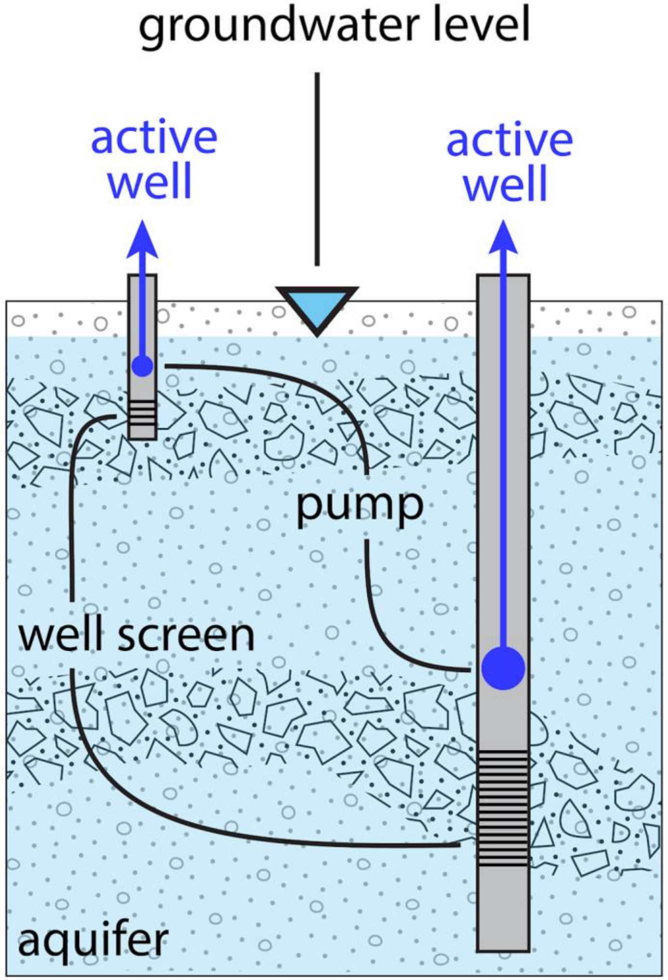
- Approach:
  - Use 31- and 40-year retirement ages to select initial wells
  - Remove wells dry at initial condition (present day groundwater level)
  - Wells “fail” if the 2015 level falls lower than a 30 ft operating margin above the bottom of the well
  - Evaluate groundwater level bookends



Thought experiment

Question: How can we protect the vast majority of future well failure in Sierra Valley?

Thought experiment



Answer: Hold the present-day groundwater level constant.

Thought experiment: groundwater level **bookends**

Present day groundwater level (post-drought)

What’s the other bookend?

Thought experiment: groundwater level **bookends**

Present day groundwater level (post-drought)

2012-2016 groundwater level

Cost to keep present day (post-drought) groundwater levels?

Cost to return to 2012-2016 groundwater levels?

Cost to keep present day (post-drought) groundwater levels?

Cost to return to 2012-2016 groundwater levels?

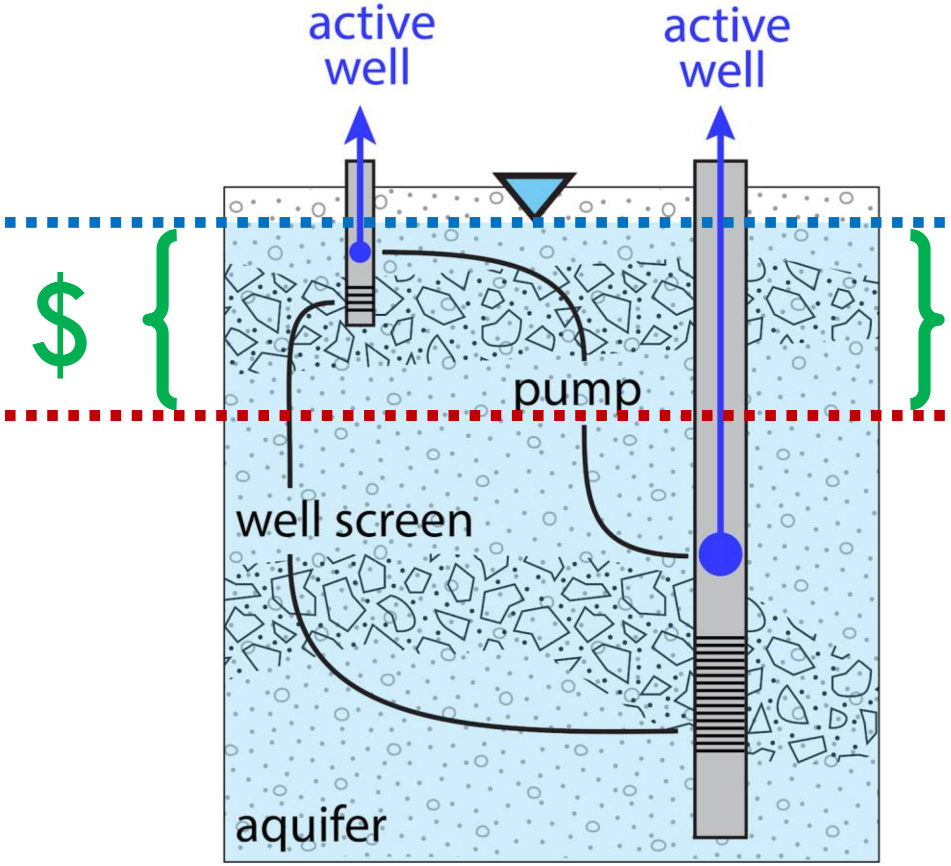
Cost to keep present day (post-drought) groundwater levels?

Cost to return to 2012-2016 groundwater levels?

Cost to keep present day (post-drought) groundwater levels?

Cost to return to 2012-2016 groundwater levels?

Thought experiment: maintain present day post-drought level



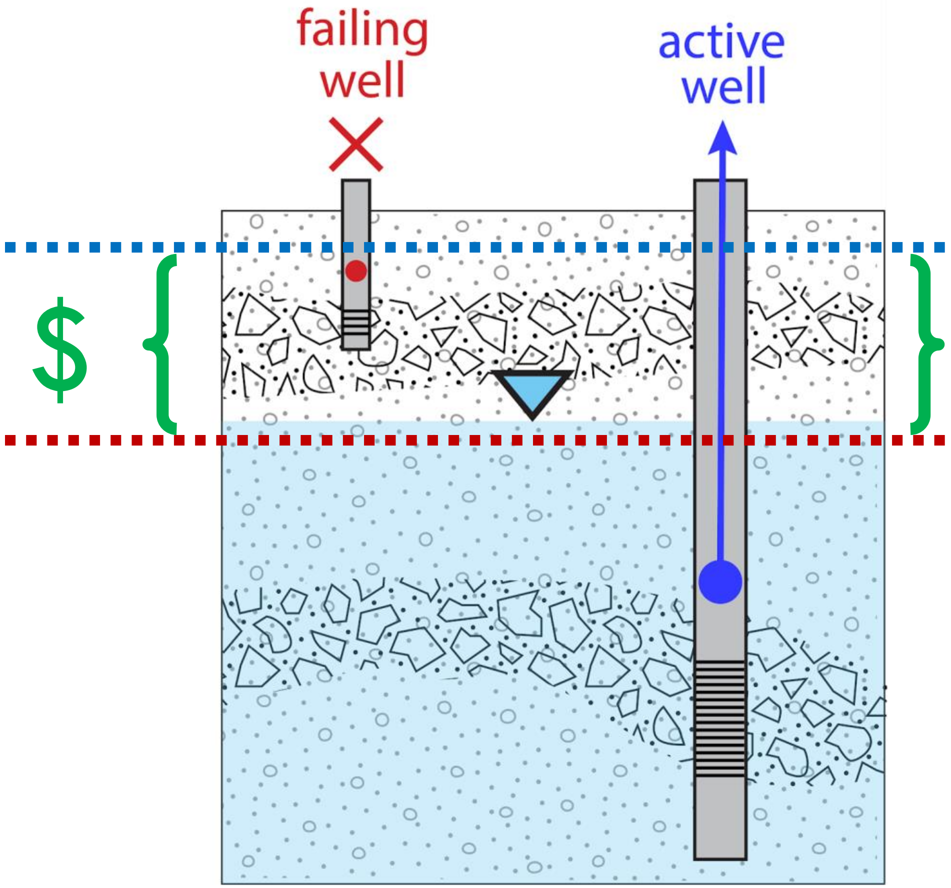
Present day groundwater level

2012-2016 groundwater level

Zero cost to protect wells

Non-zero cost of lost revenue from agriculture

Thought experiment: return to 2012-2016 drought level



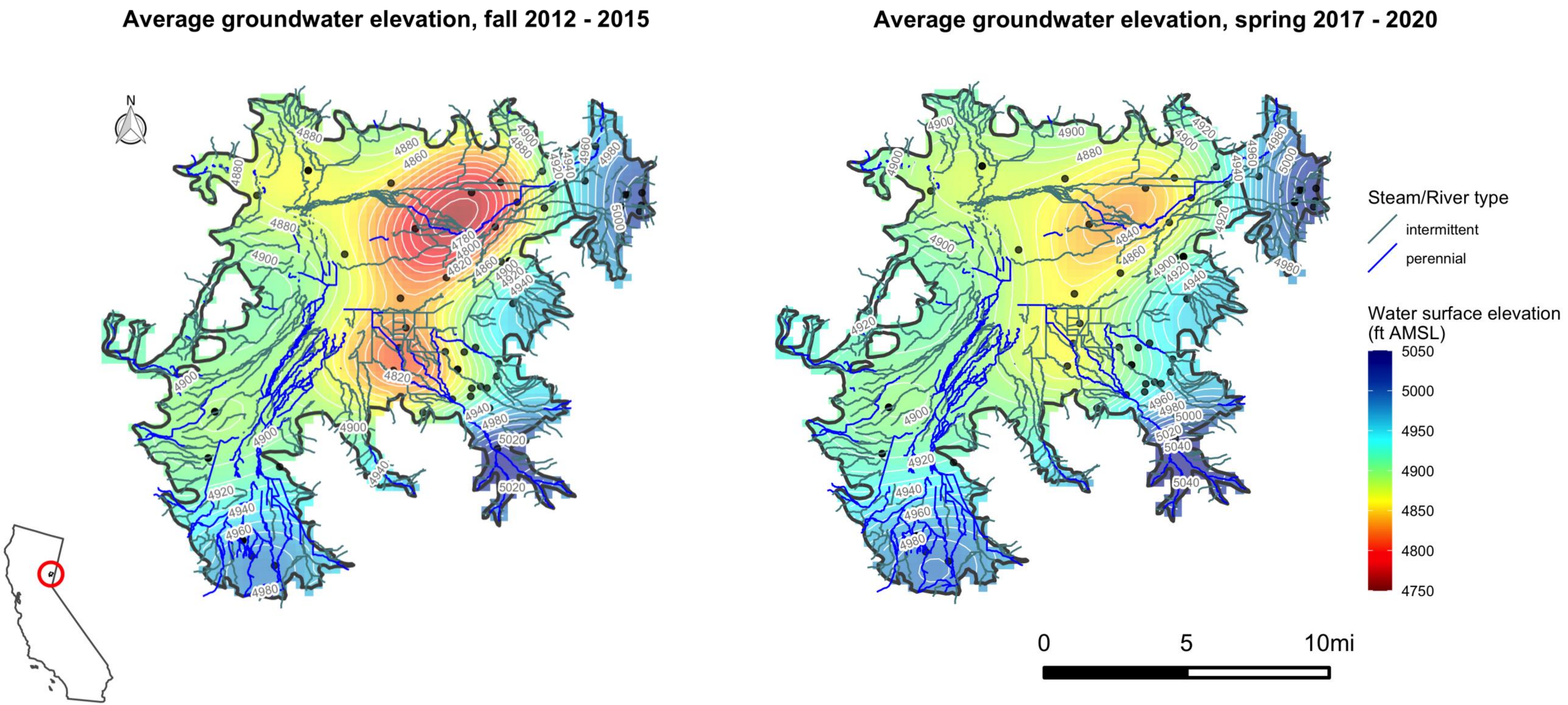
Present day groundwater level

2012-2016 groundwater level

Non- zero cost to protect wells

Zero cost of lost revenue from agriculture

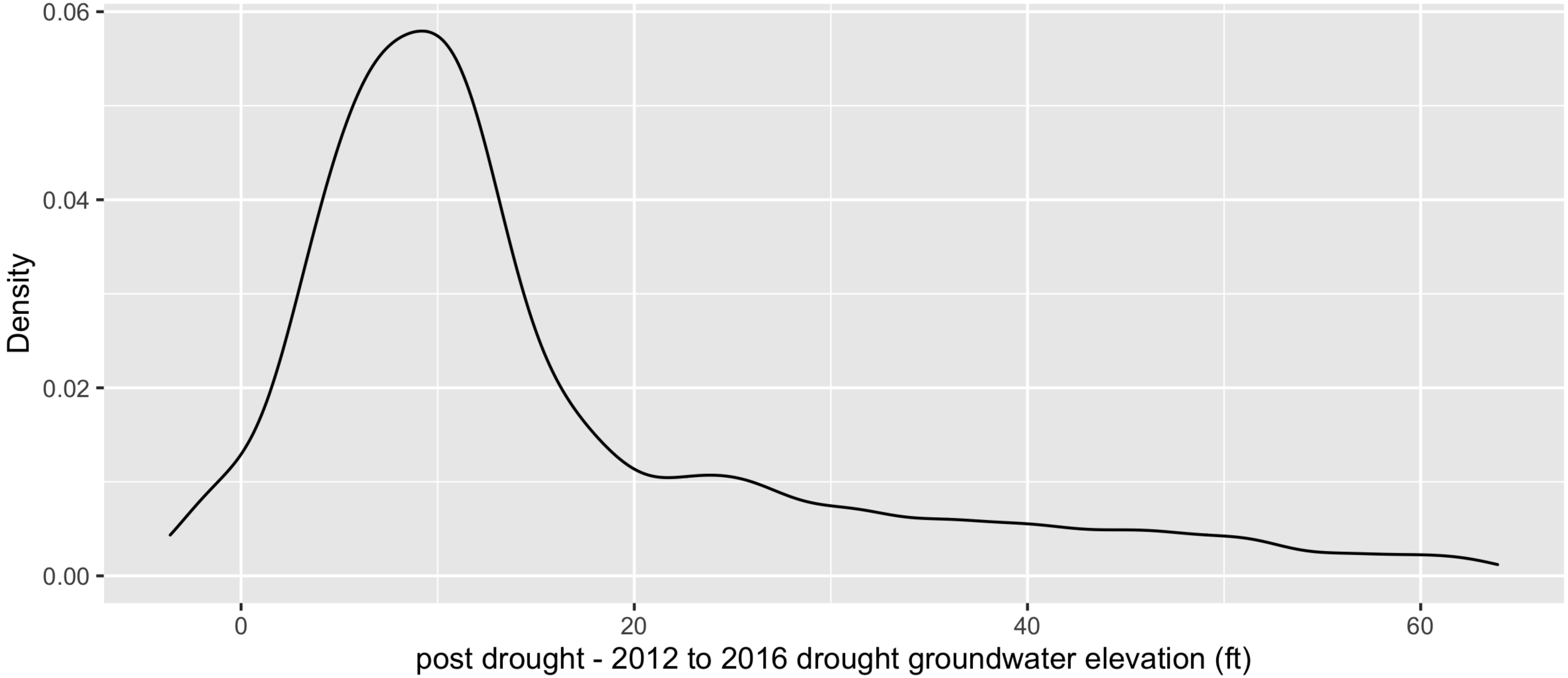
Groundwater level bookends



Average groundwater elevation, fall 2012 - 2015

Average groundwater elevation, spring 2017 - 2020

Groundwater level bookends



Data suggest shallow groundwater levels were about 10 ft lower

when comparing average post drought levels to the 2012-2016 drought fall lows*

Forecasted well failure under a return to 2012-2016 fall lows are minimal

31-year retirement age

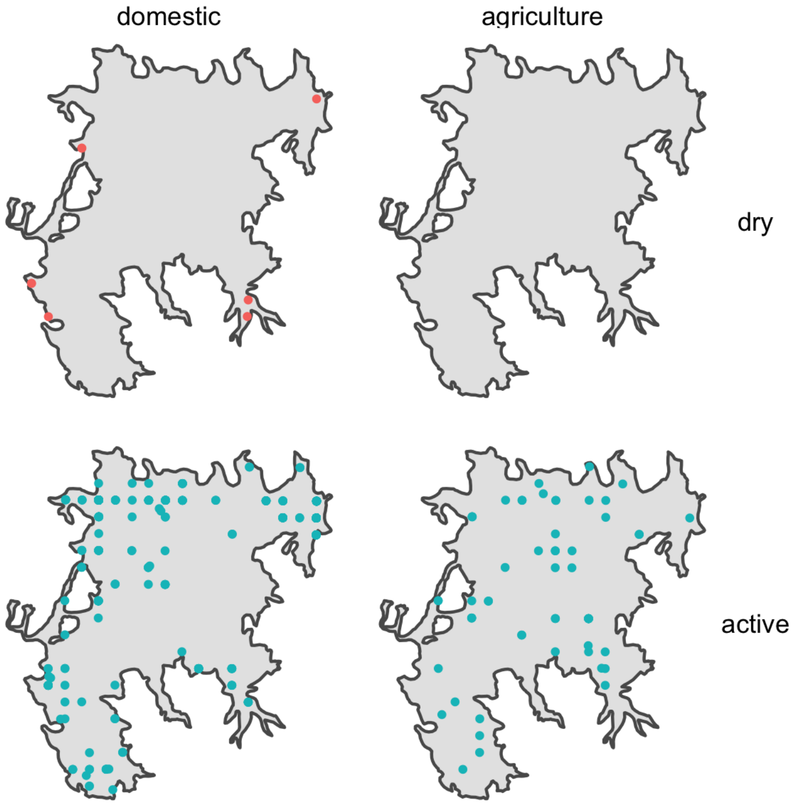
well type	n active	n dry
domestic	309	8
agricultural	57	0

~2%

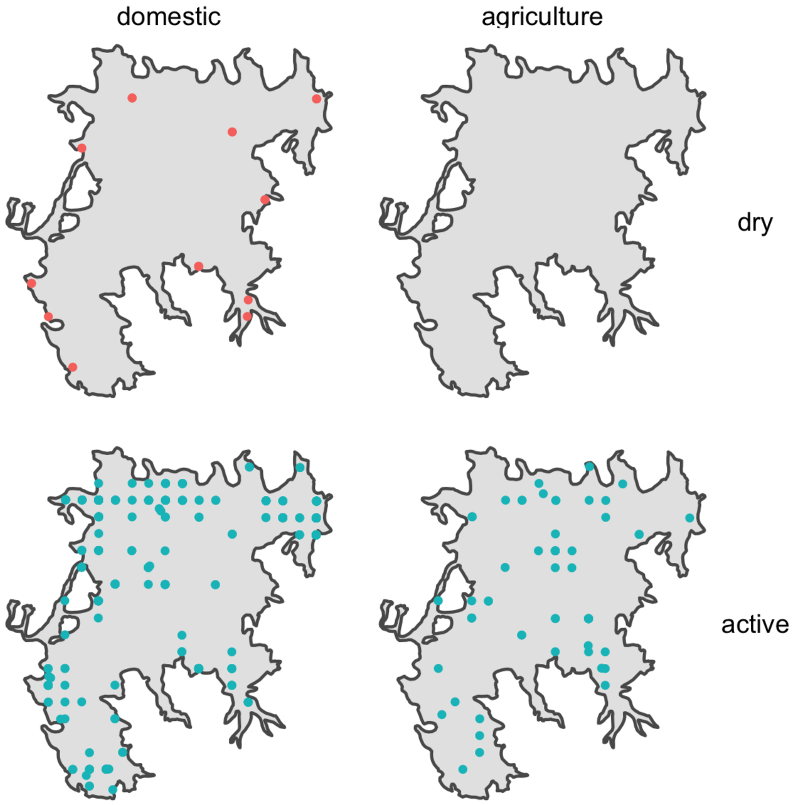
40-year retirement age

well type	n active	n dry
domestic	418	20
agricultural	61	0

~4%

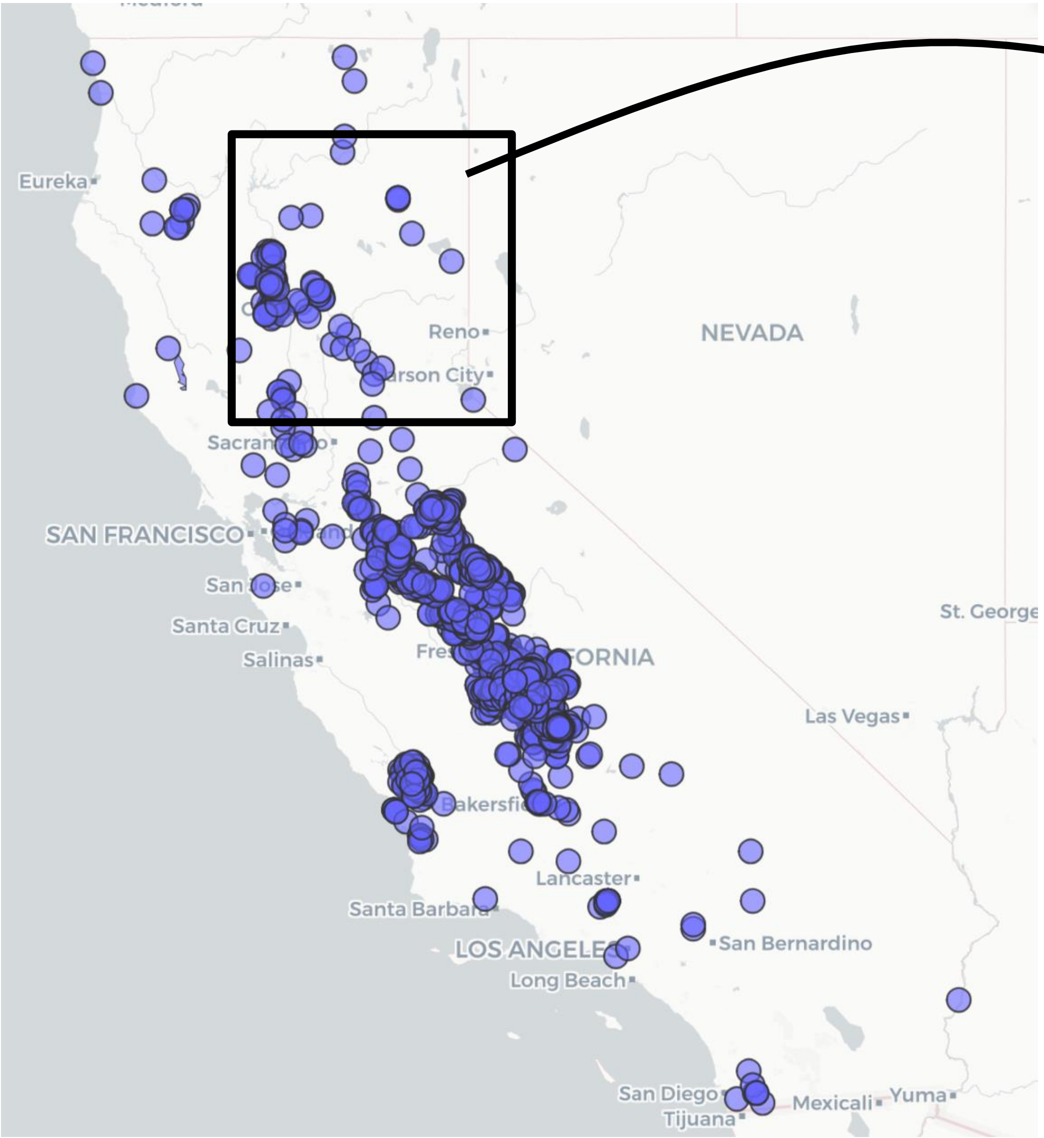


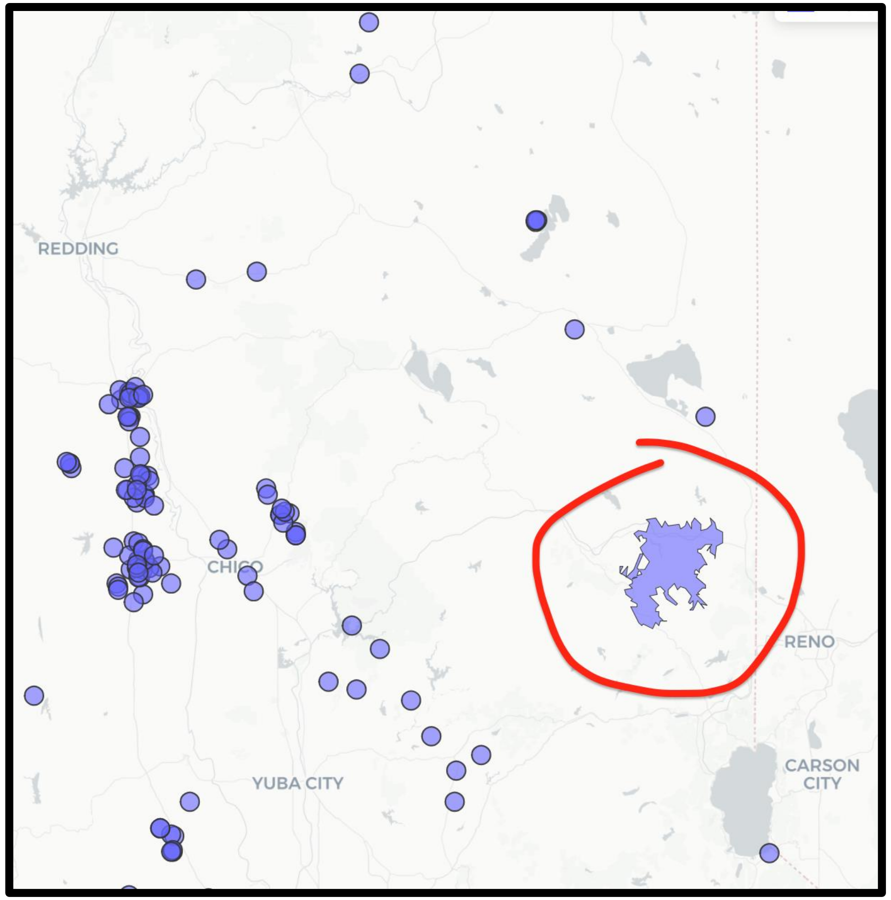
assuming a 31 year retirement age



assuming a 40 year retirement age

Results agree with observed well failure





Each blue dot is a *reported* dry well during 2012-2016, according to data collected by the California Governor's Office of Planning and Research (Cal-OPR)

Implications for well protection measures

Results agree with reported well outages during the last drought: 0 wells were reported dry in Sierra Valley.

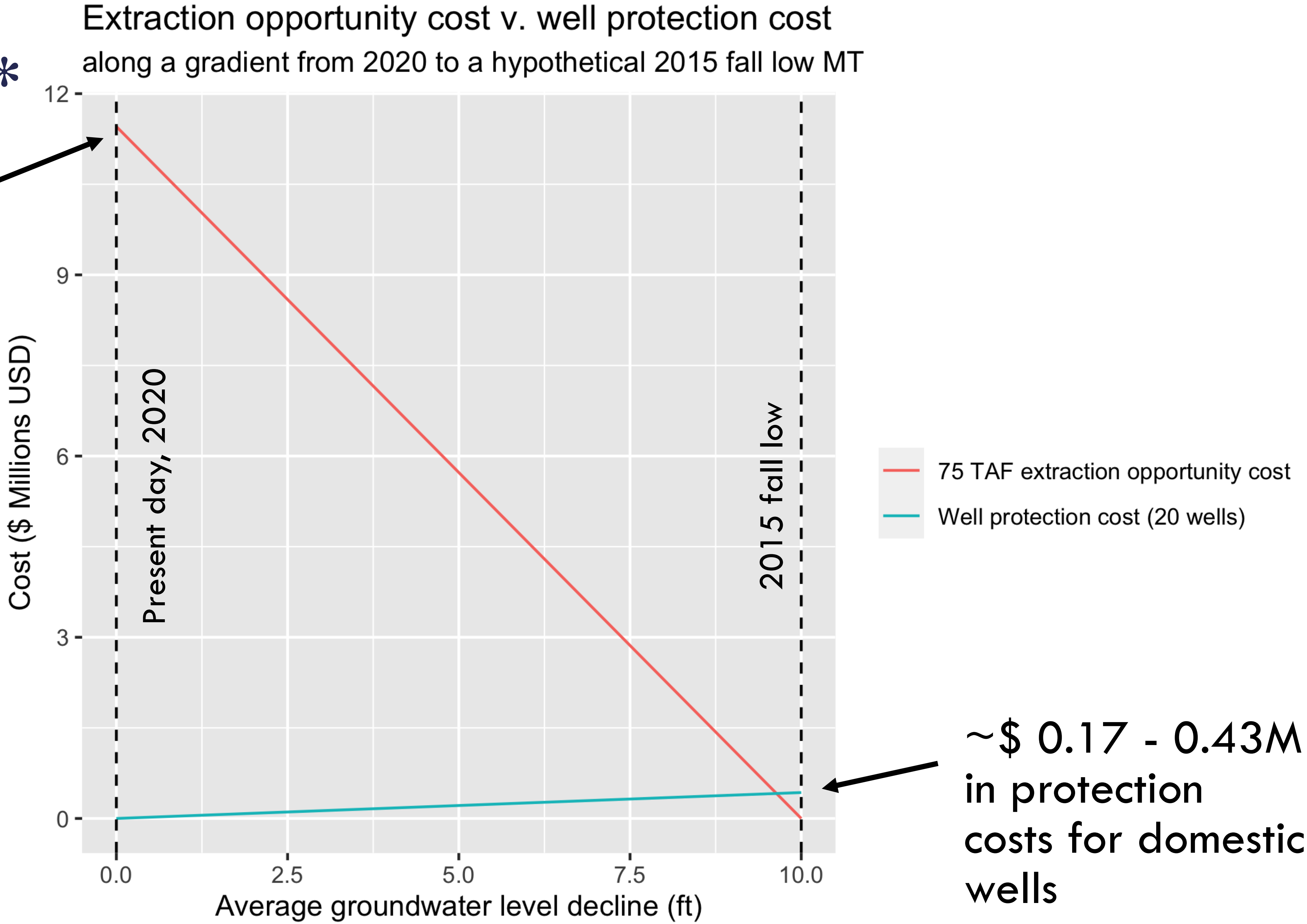
Results suggest that a return to the 2012-2016 drought groundwater levels would not significantly threaten wells, i.e., 2 – 4% failure. Most failures occur at basin boundaries which are less likely to be influenced by pumping, and may be model artifacts

Hence, protection measures are necessary, but modest.

- $0.17 - 0.43M domestic well replacement costs (https://www.gspdrywells.com/#methodology)
- ~ $11.5M agricultural value of groundwater back of the envelope assumes:
  - 15 TAF/yr of depletion for 5 years, or an MT at the 2012-2016 average level
  - $550/acre yr (2017 CDFA Agricultural statistics review)
  - 3 ft of applied water per year
  - Energy and pump assumptions from Section 6.3 of this hydrogeologic technical study

Tradeoffs*

~$11.5M in ag value, minus unavoided lift cost increases & replacement costs

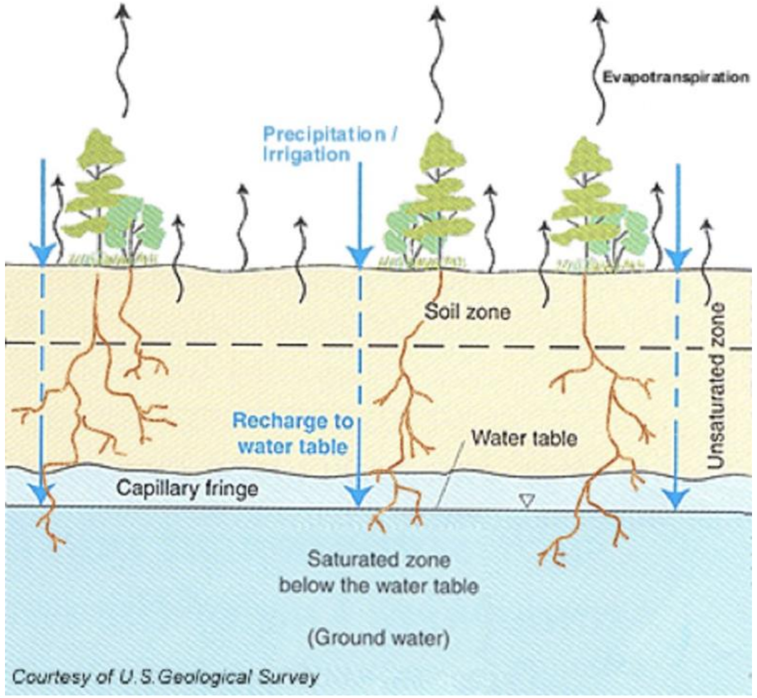


~$ 0.17 - 0.43M in protection costs for domestic wells

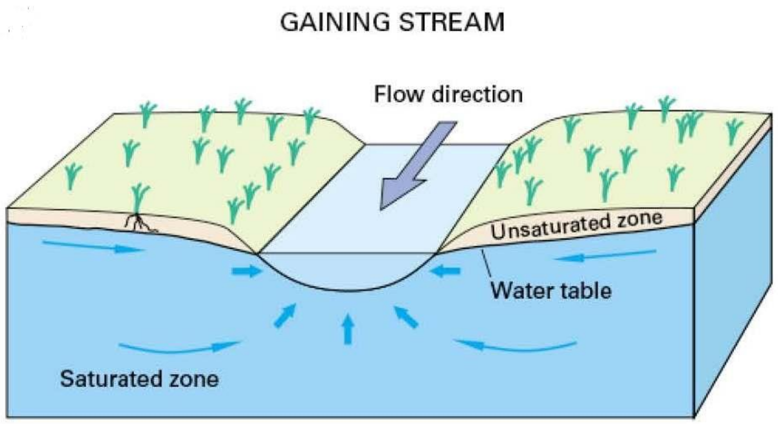
*back of envelope

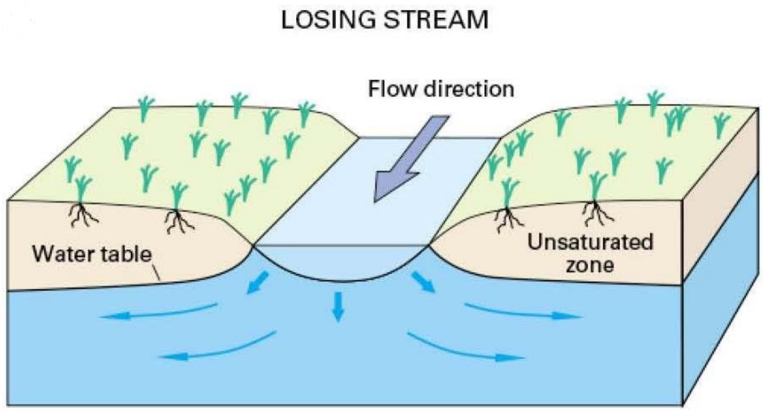
The ISW/GDE elephant in the room

Global-scale groundwater declines will negatively impact local-scale GDEs and ISW



Courtesy of U.S. Geological Survey





Take away messages

- Detective work on wells in Sierra Valley
- Analyzed groundwater level bookends
- Back of the envelope suggests that that widespread, catastrophic failure is unlikely. Estimated well protection costs are likely 1.7-3.5% of agricultural value obtained if we return to 2015 groundwater levels (assuming 75 TAF of extraction).
- Results enable informed creation of SMCs

Define undesirable results

Set SMCs (MOs/MTs)

Set Interim Milestones

Domestic wells are vulnerable due to their relatively shallow depth. What % of well failure do you consider to be the threshold for SIGNIFICANT and UNREASONABLE? For reference, 10% of well failure is about 30-40 wells, 20% is about 60-80 wells, and so on.

Do you think a minimum threshold (MT) for groundwater level should be allowed to fall below the observed 2012-2016 drought? Please prepare 1-2 reasons to share if answering yes or no.