UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Prairie Research Institute
Illinois State Water Survey
2204 Griffith Drive, MC-674
Champaign, IL 61820

Risk to Shallow Aquifer Supply
Supplemental Information

1. *Definition of Important Terms*

The Shallow Dolomite Aquifer is the uppermost aquifer system in Will County, comprised of fractured bedrock and overlying spatially variable sand lens. For most communities in Will County, it is an important source of water. This aquifer is generally most productive where fractures in the rock have developed, with most fractures occurring in the upper part of the bedrock. As a result, the transmissivity and storage of the shallow dolomite aquifer decrease with depth. This aquifer is close to land surface and susceptible to surface contamination, thus analyses of water quality and quantity are needed to assess risk.

Heads are the water levels in an aquifer. Observed heads are measured in active production wells or dedicated monitoring wells, and simulated heads are generated from a groundwater flow model or empirical post-processing. **Static heads** are measured when a well is not pumping, and **pumping heads** are measured when a well is in operation.

Drawdown is the difference between the static (non-pumping) head and pumping head.

Groundwater Flow Models are computer simulations of the past, present, and future of aquifer conditions. They utilize available geologic and water use information and are calibrated to historic water levels. The models used in this study are calibrated to static (non-pumping) heads, but empirical post-processing models are assigned to simulate pumping conditions now and into the future. More details on the models can be found in other Illinois State Water Survey publications (Abrams et al. 2018).

Specific Capacity is defined as the pumping rate of a well divided by the drawdown. To avoid inaccurate measurements of specific capacity, a static head should be measured such that it is not visibly changing over a 15 to 20-minute span, and the same is true for pumping levels. Wells with insufficient recovery time will have a static head that is too low, and as a result the difference in static and pumping head will be too small; in turn, specific capacity will be too large.

Transmissivity is the ability of an aquifer to move water through the formation (and thus into and out of wells. The lower the transmissivity of an aquifer, the more drawdown when a well is turned on.

Storage is a quantification of the water that is within a bedrock formation that can be successfully extracted (not all water can be extracted due to surface tension on particles). Removal of water from storage can occur in two ways: 1) by removing pressure from a formation when heads are overlying it and 2) by **dewatering** pore spaces within a formation. Dewatering of the shallow dolomite aquifer is not recommended per a previous study in the region (Roadcap et al. 1993), although the impacts of dewatering are not fully understood and will be subject to local variability in fracture networks of the dolomite.

Southwest Water Planning Group. This work was funded by the Southwest Water Planning Group; which is comprised of several communities in the southwest suburbs of Chicago: Channahon, Crest Hill, Elwood, Frankfort, Joliet, Lemont, Lockport, Minooka, New Lenox, Plainfield, Romeoville, and Shorewood. In addition, the following industries contributed to this study: Exxon Mobile, INEOS (Flint Hills), and LyondellBasell. Will County also contributed funding to make this work possible. The Lower Des Plaines Watershed Group assisted in the management of this project.

2. *Risk to supply: Water Quality*

Risk of contamination of shallow aquifers is contingent on two factors: 1) a given contaminant's source and 2) how that contaminant reaches the shallow aquifer. In Will County, the most prevalent type of contamination with a long history of data is chloride, which originates from winter deicing agents applied on paved surfaces throughout the winter. Other emerging contaminants, such as PFAS/PFOAs (Per- and Polyfluoroalkyl Substances), are also of concern. While these emerging contaminants are not the focus of this study, understanding how chloride reaches and accumulates in the shallow aquifer is useful in studying these newer contaminants of concern.

Chloride poses two risks. First elevated chloride concentrations in water have been linked to reduced health in aquatic species. Chloride in groundwater can transfer to surface water and impact freshwater habitats. Second, the EPA secondary standard for drinking water is 250 mg/L, above this level water will begin to taste salty. High chloride concentrations are also costly to treat via reverse osmosis and have the potential to increase water's corrosivity. Highly corrosive waters can leach heavy metals from infrastructure, causing more severe water contamination issues.

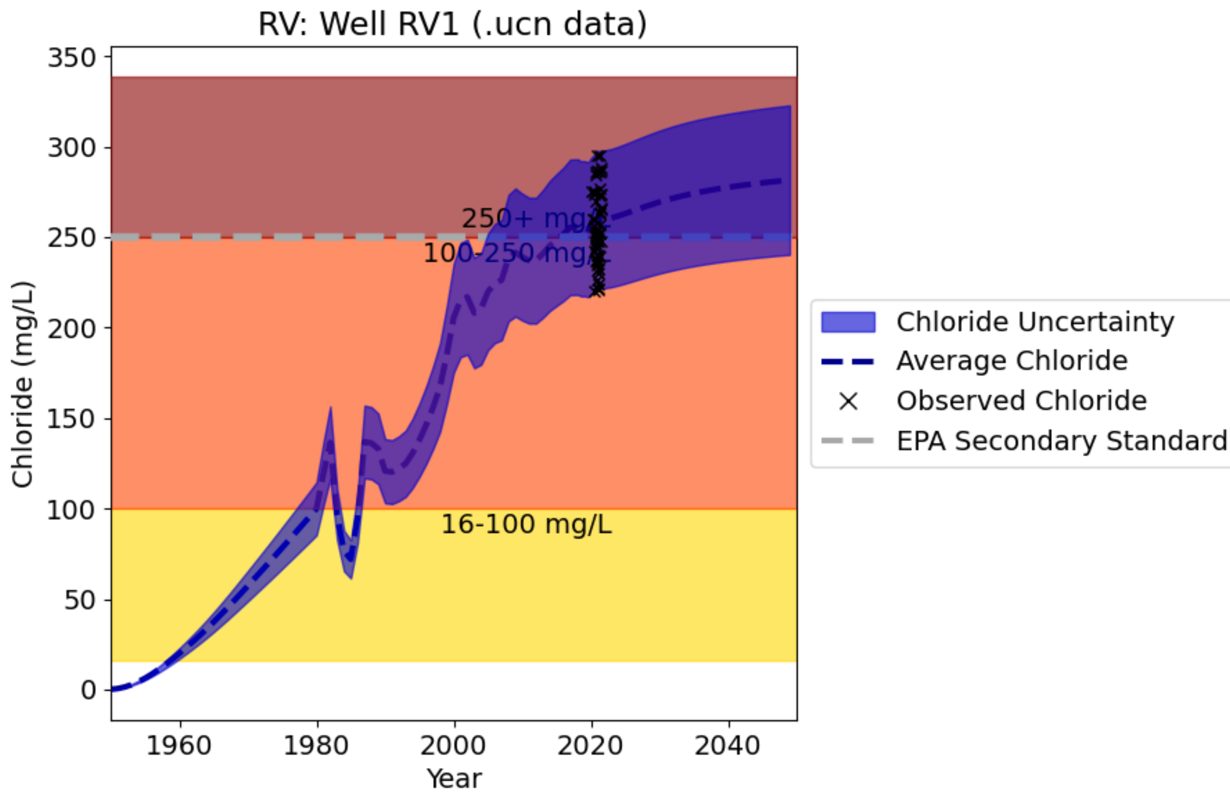
Our groundwater flow model is first calibrated to observed static heads, then it is coupled to a solute transport model that allows the simulation of chloride migration through the subsurface. This solute transport model is calibrated to observed chloride concentrations, where available. Where data are not available, the model results are more uncertain. Risk of chloride to water quality is defined by the following categories:

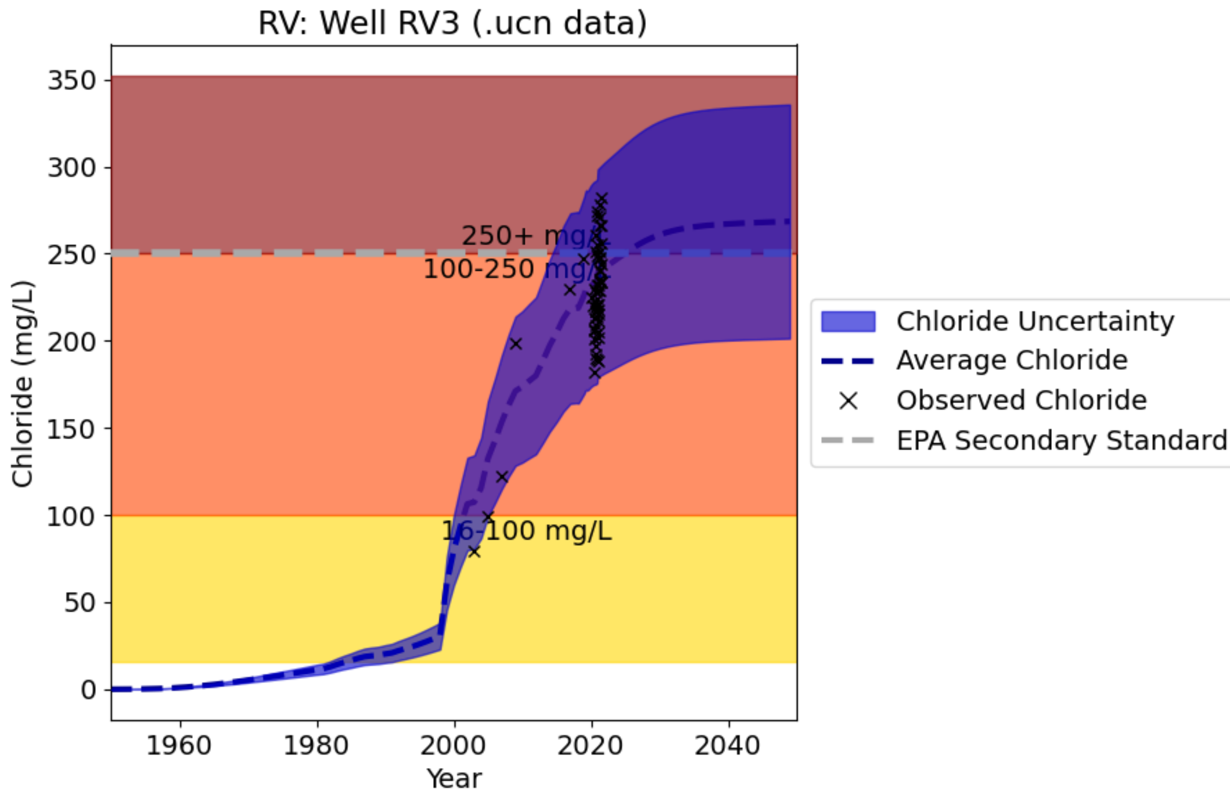
1) Low risk was assigned where chloride concentrations are below the environmental background level of 15 mg/L (what we would expect in natural groundwater of northeast Illinois)
2) Moderate risk was assigned chloride with concentrations for 16 – 100 mg/L. The primary ISWS recommendation for wells with moderate chloride concentrations is to measure chloride annually to ensure no long-term increases. Also, municipalities with urbanization (i.e. land use changing from fields to paved surfaces) have experienced a rapid jump from moderate concentrations to high or excessive within a few years. Understanding the impact of land use changes is also critical.
3) High risk was assigned where chloride concentrations are 100-250 mg/L. These wells have chloride levels elevated well above natural background rates and are approaching the EPA secondary standard. The primary ISWS recommendation for wells with High Chloride Concentrations is to measure chloride monthly. Future land use changes must be carefully considered for their implications on water quality. Blending wells with an alternative source, if possible, has been successful in the region, although the viability of the deep sandstone aquifer (which is often used to blend) is highly questionable.
4) Excessive risk was assigned when chloride concentrations exceeded 250 mg/L. If blending is not available, taste and odor issues are likely. Treatment is possible via reverse osmosis but is expensive and creates highly concentrated wastewater effluent. If blending is not viable in the future and treatment is not economically efficient, then alternative sources of water will likely need to be considered.

The analysis used in this study considered average chloride concentrations exceeding the secondary standard, but risk could result sooner if there is a lot of variability in chloride. Empirical evidence indicates that high variability in chloride concentrations is likely where: 1) clay overlying the bedrock is thin or absent or 2) retention ponds and/or infiltration basins within heavily trafficked areas incise into the clay layer and increase the potential for contaminants to enter the aquifer.

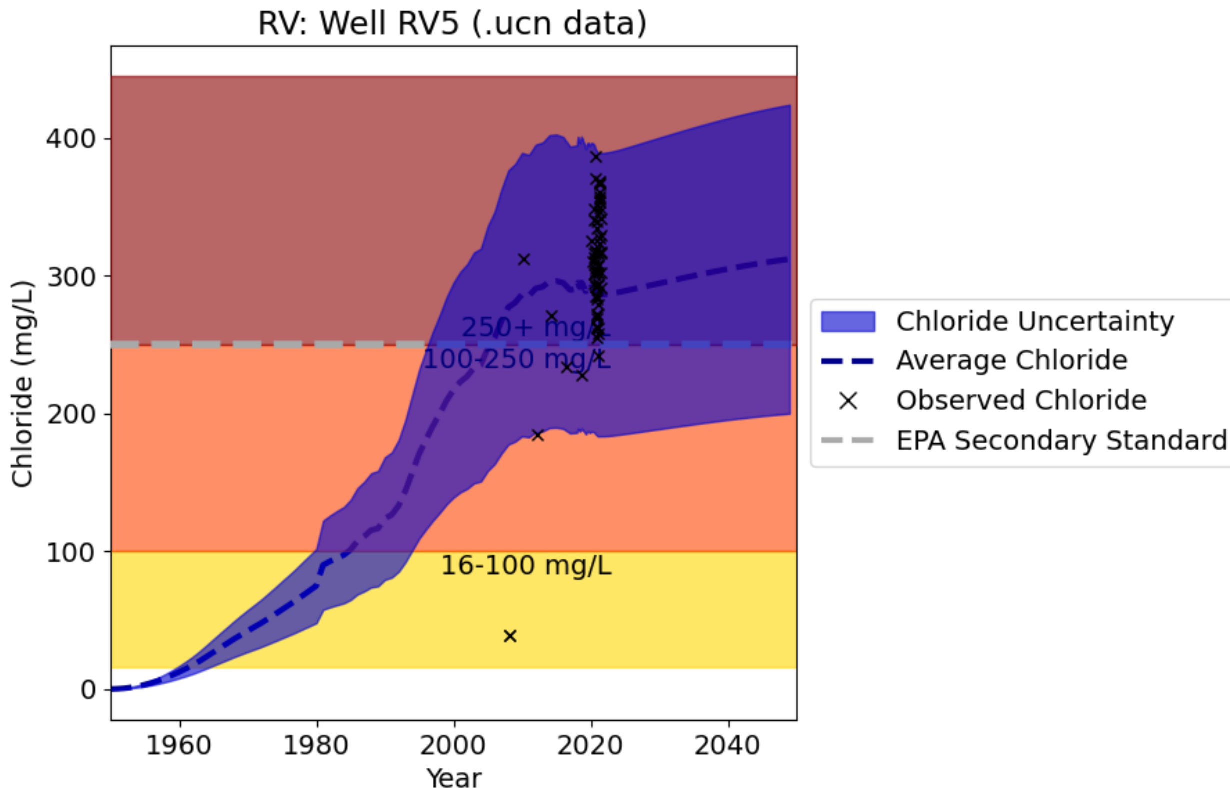
Our models assume that land use after 2020 does not change into the future, and as a result chloride inputs into the aquifer do not increase in the model. Any future increases are a result of a lag time of chloride accumulation due to the slow infiltration of chloride to the shallow aquifer. For a more thorough analysis of risk, other scenarios of future land use should be considered when evaluating chloride's future risk to water supply. In addition, as new research is completed, the potential sources of emerging contaminants such as PFAS/PFOA should also be considered.

Chloride Time Series Plots

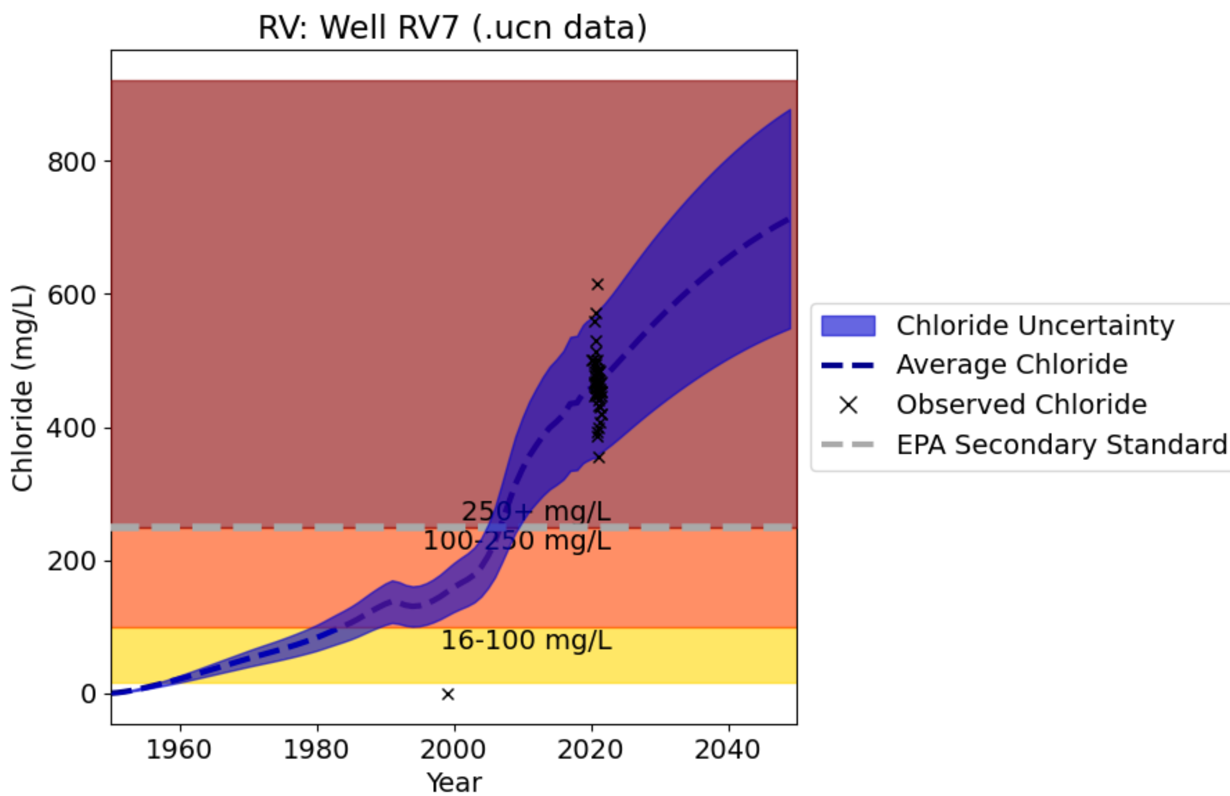


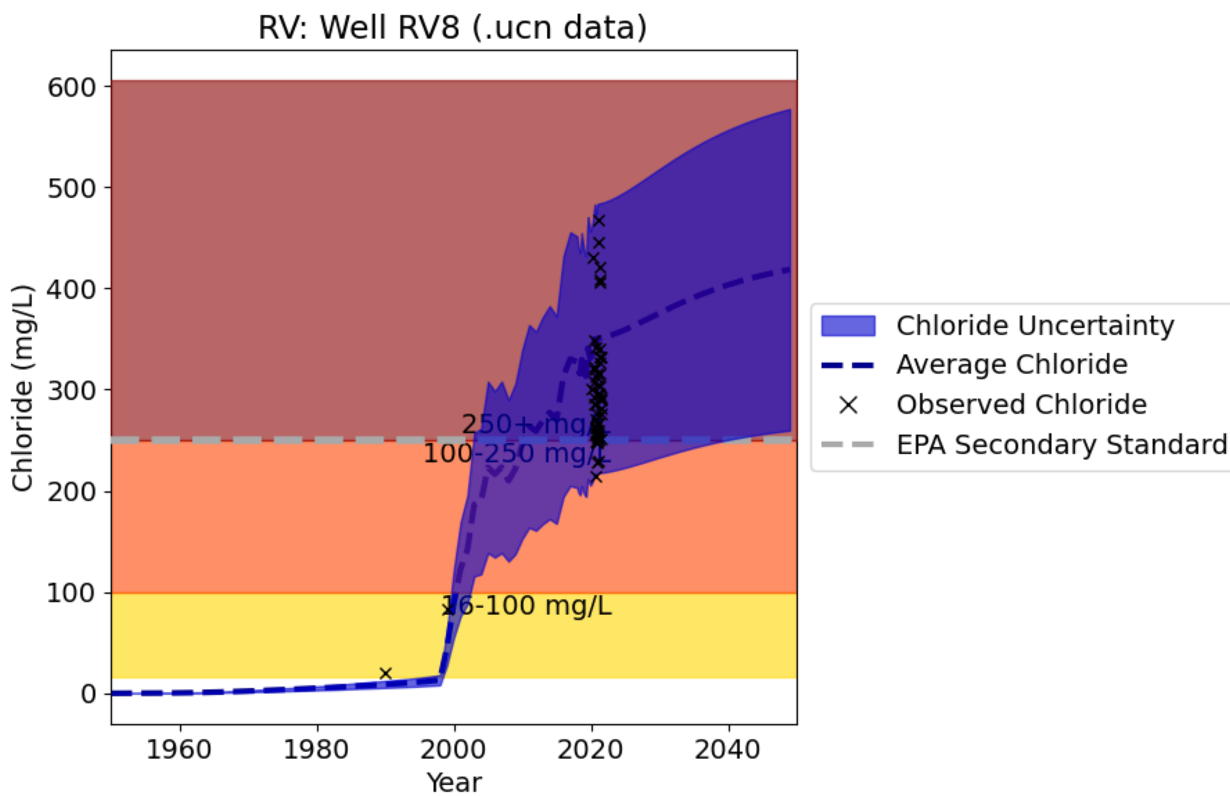


RV: Well RV3 (.ucn data)
Chloride (mg/L)
Year
250+ mg/L
100-250 mg/L
16-100 mg/L
Chloride Uncertainty
Average Chloride
Observed Chloride
EPA Secondary Standard

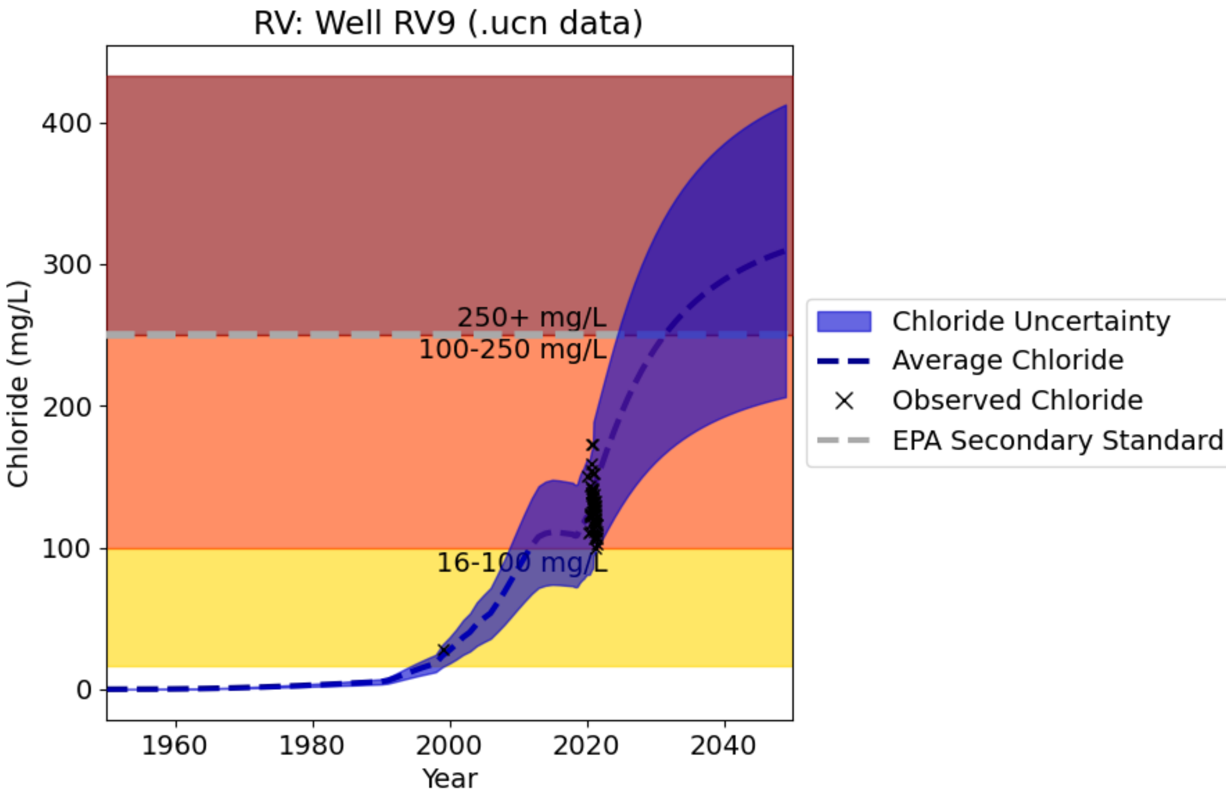


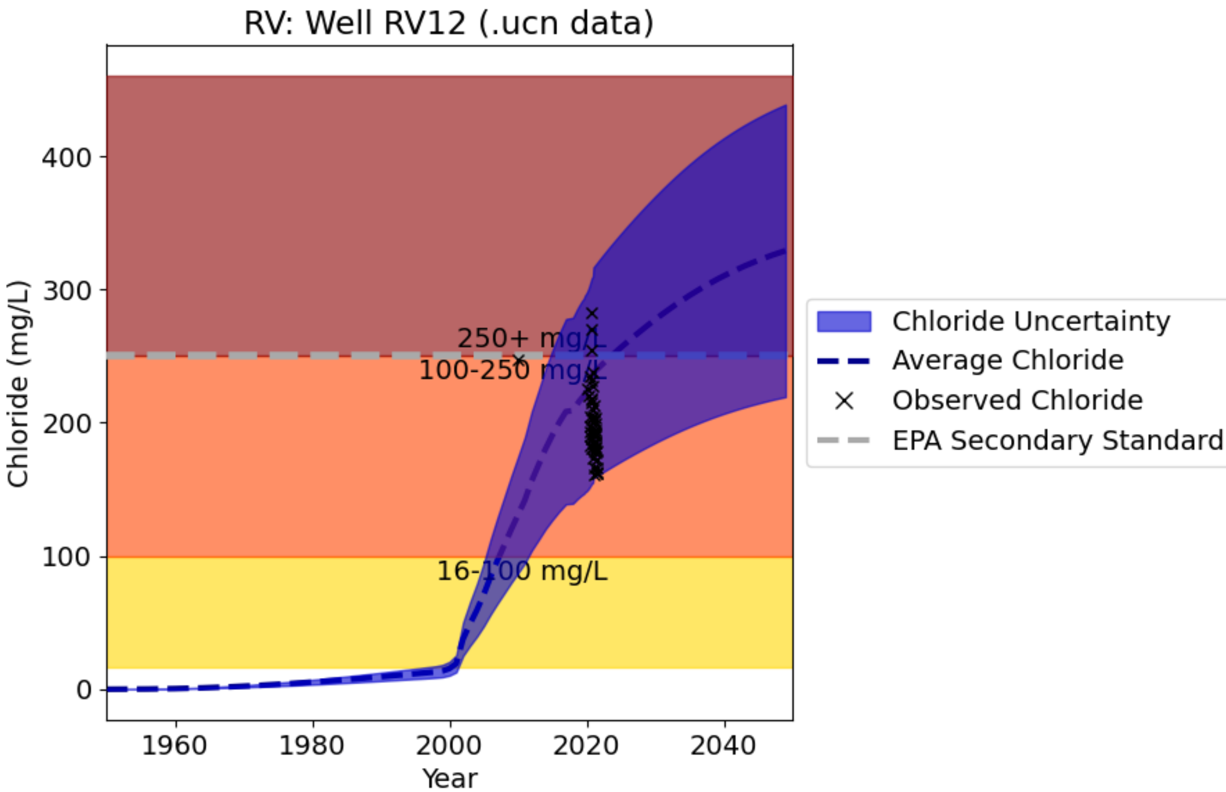
RV: Well RV5 (.ucn data)
Chloride (mg/L)
Year
250+ mg/L
100-250 mg/L
16-100 mg/L
Chloride Uncertainty
Average Chloride
Observed Chloride
EPA Secondary Standard


RV: Well RV7 (.ucn data)
Chloride (mg/L)
800
600
400
200
0
250+ mg/L
100-250 mg/L
16-100 mg/L
1960
1980
2000
2020
2040
Year
Chloride Uncertainty
Average Chloride
Observed Chloride
EPA Secondary Standard



RV: Well RV8 (.ucn data)
Chloride (mg/L)
Year
250+ mg/L
100-250 mg/L
16-100 mg/L
Chloride Uncertainty
Average Chloride
Observed Chloride
EPA Secondary Standard


RV: Well RV9 (.ucn data)
Chloride (mg/L)
400
300
200
100
0
250+ mg/L
100-250 mg/L
16-100 mg/L
1960
1980
2000
2020
2040
Year
Chloride Uncertainty
Average Chloride
Observed Chloride
EPA Secondary Standard



RV: Well RV12 (.ucn data)
Chloride (mg/L)
400
300
200
100
0
1960
1980
2000
2020
2040
Year
250+ mg/L
100-250 mg/L
16-100 mg/L
Chloride Uncertainty
Average Chloride
Observed Chloride
EPA Secondary Standard

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3. *Risk to Supply: Water Quantity*

Unlike the drawdown of the deep sandstone aquifer and shallow aquifer contamination via chloride, which are regional in nature, risk to supply based on water quantity of the shallow dolomite aquifer in Will County is more complicated to define. This is due to heterogeneities in fractures in the dolomite and overlying basal sands, both of which can greatly change the productivity of an aquifer. While certain geologic features, such as clay overlying dolomite, can restrict recharge and limit productivity on a regional scale, well performance remains variable.

In other words, a dolomite well with poor performance may be improved by simply drilling a new well a few blocks away. As such, risk for shallow aquifer quantity is not as well defined as sandstone quantity or shallow aquifer quality, but still important for long-term planning purposes. We define risk by analyzing a series of two types of plots:

1) Plots showing specific capacity changes through time, where available, and a comparison of how specific capacity at a given well compares to the median value in Will County.
2) Hydrographs that show the water level in relation to the top of the dolomite. Previous literature recommends avoiding dewatering the dolomite, although sometimes this is unavoidable based on the geology at a specific site, and enough research has not been completed to assess whether such wells are truly at risk. Rather, we recommend that your community considers the following factors when viewing the hydrograph for your well(s):
    a. Are water levels declining over the period of data records at the well? If so, this likely indicates that more water is being removed than enters via precipitation, an unsustainable condition. This is particularly problematic if the upper portions of the dolomite are being desaturated, which would result in a loss of transmissivity and storage.
    b. If water levels have fallen more than 50 feet below the top of the dolomite, an investigation of the well (such as with a downhole camera) and long-term, monthly data collection of water levels or installation of a pressure transducer is strongly recommended.

Wells with water levels that have lowered into the dolomite and that have lower specific capacities would likely be the wells at greatest risk. This is shown in the last table of the 2-pager by considering three categories:

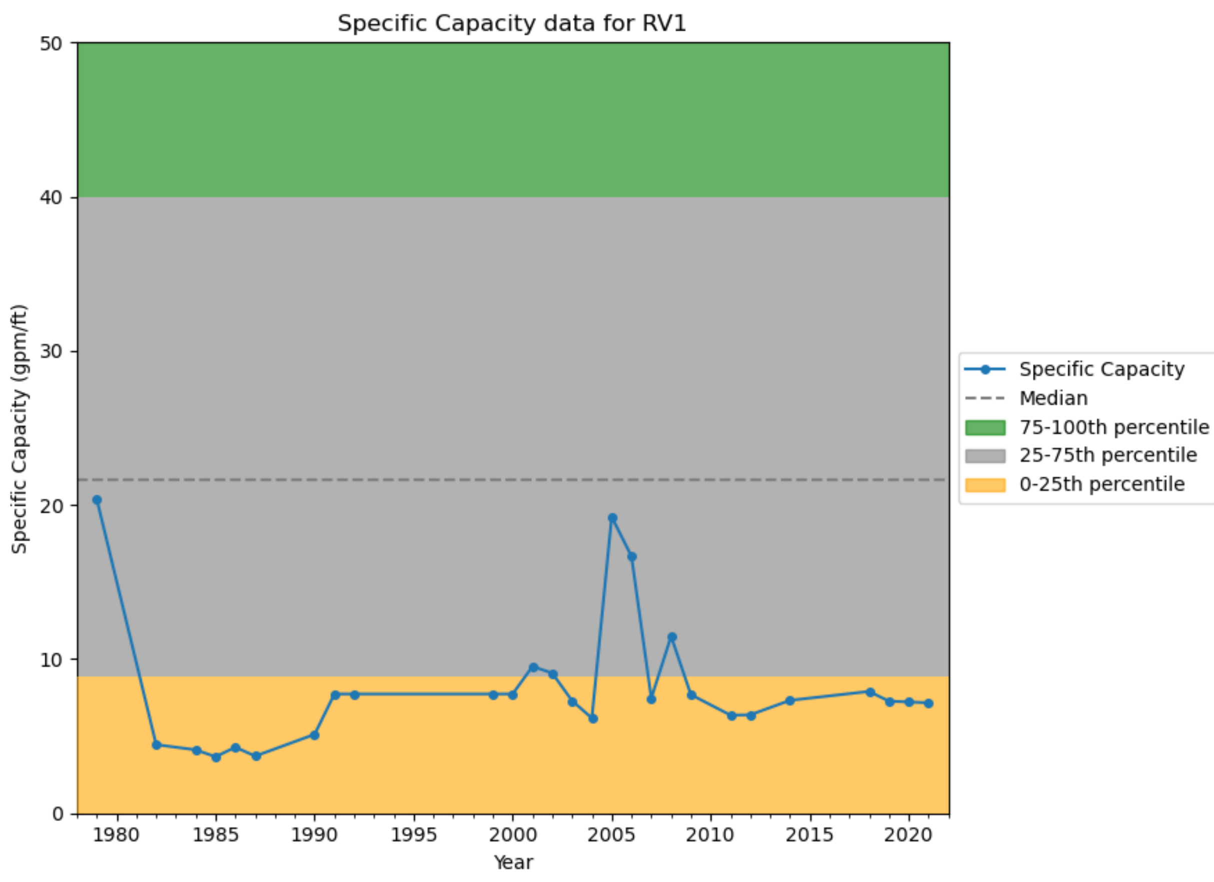
1) **Does the well have poor capacity to increase in demands?**
2) **Has well productivity decreased?**
3) **Is the shallow aquifer dewatering?**

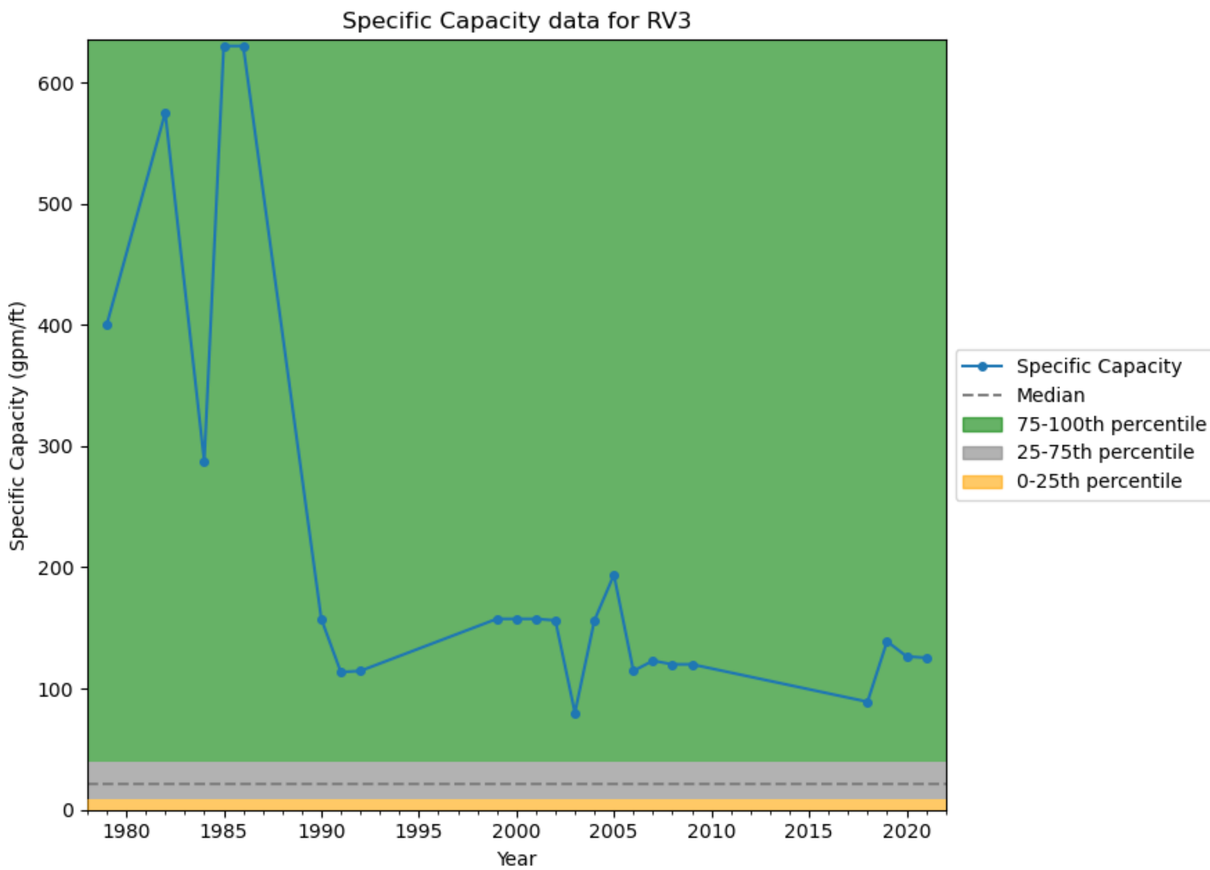
As a rule of thumb, the more categories that a well shows up as a checked mark, the more challenging operation of that well will become moving forward. Discussion with local engineers is recommended if more than one category is classified as yes to determine the best course of action to ensure the future of the well. For cases where two or three categories are classified as yes, a new well will likely be needed in the future. For cases where multiple wells have a "Yes" answer for two or three categories, the decline in the aquifer may indeed be regional and not just local, at which point the viability of this aquifer would need considered with the possibility of an alternative supply investigation becoming necessary.

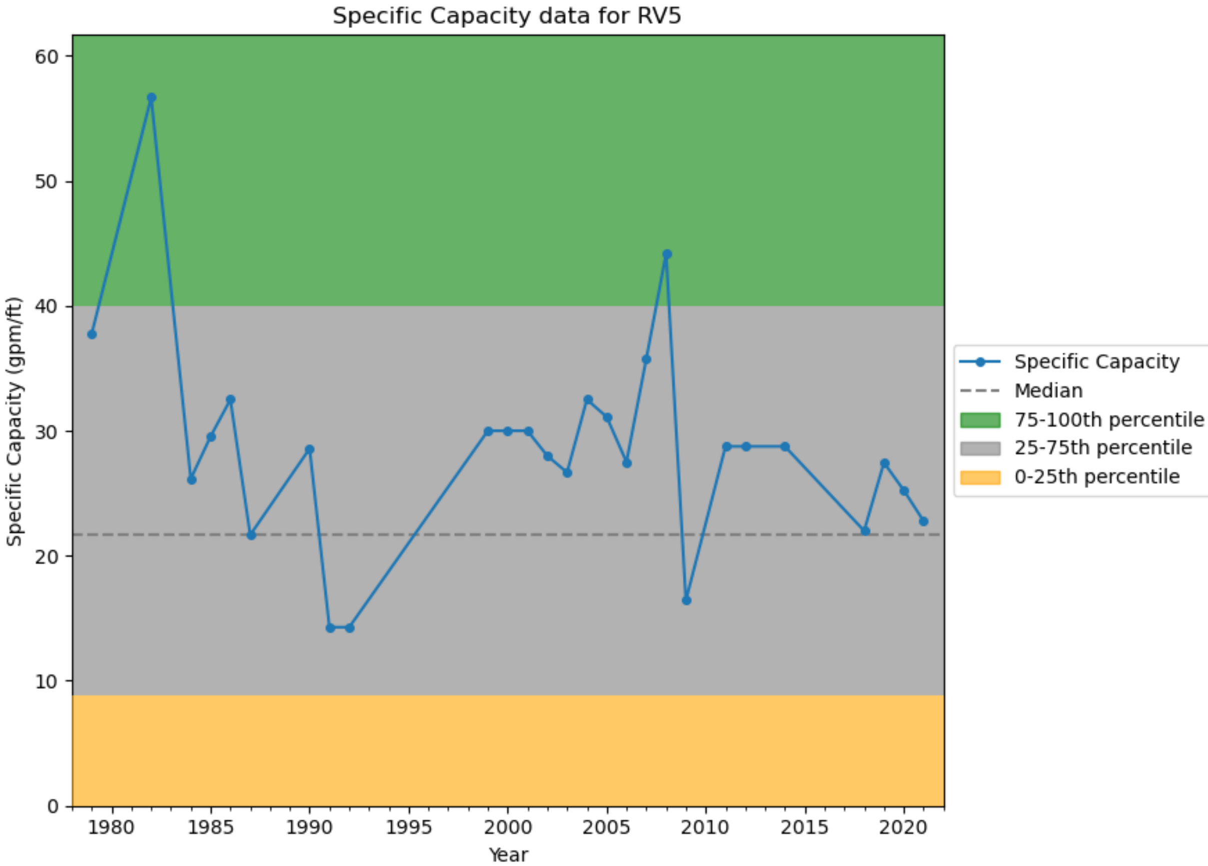
Specific Capacity Plots (“Does the well have poor capacity to increase demands?” and “Has well productivity decreased?”)

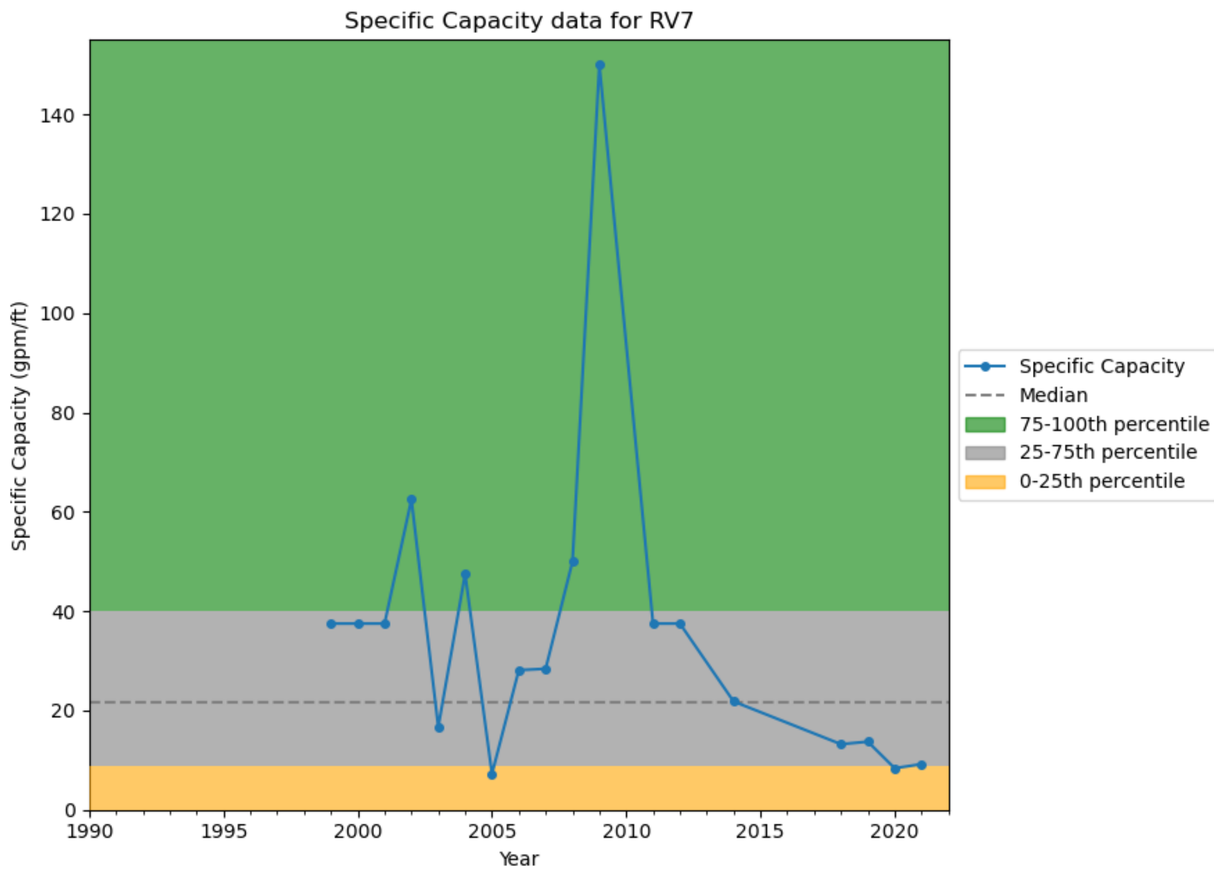
The second and third columns in the ‘Shallow Pumping Risk Table’ relate to specific capacity data at a given well. The ‘**Does the well have poor capacity to increase demands?**’ column asks whether a well’s specific capacity is below the calculated median value for the encompassed study area and has a more limited capacity for new demands. This feature is mainly related to the geology of the well location, but could also be a function of dewatering of an aquifer. Communities with access to the sand lens component of the shallow aquifer, predominantly in northern Will County, will likely have better specific capacity than communities where the aquifer is not overlain by a sand lens. The other specific capacity related column, ‘**Has well productivity decreased?**’, is more straightforward, simply asking whether specific capacity has decreased at the well since installation.

All specific capacity data is from Illinois Water Inventory Program (IWIP) records sent by communities since 1980 or more recent data submitted during the Southwest Water Planning Alliance project period. In some cases, extraneous high or low values may be reported. This can happen when the average pumping head over a year is greater than the average static head over that same year; such as when a well has a static head measured in the summer, during peak demands, and a pumping head measured in the winter, during lighter periods of demand. These also could be due to error in reporting

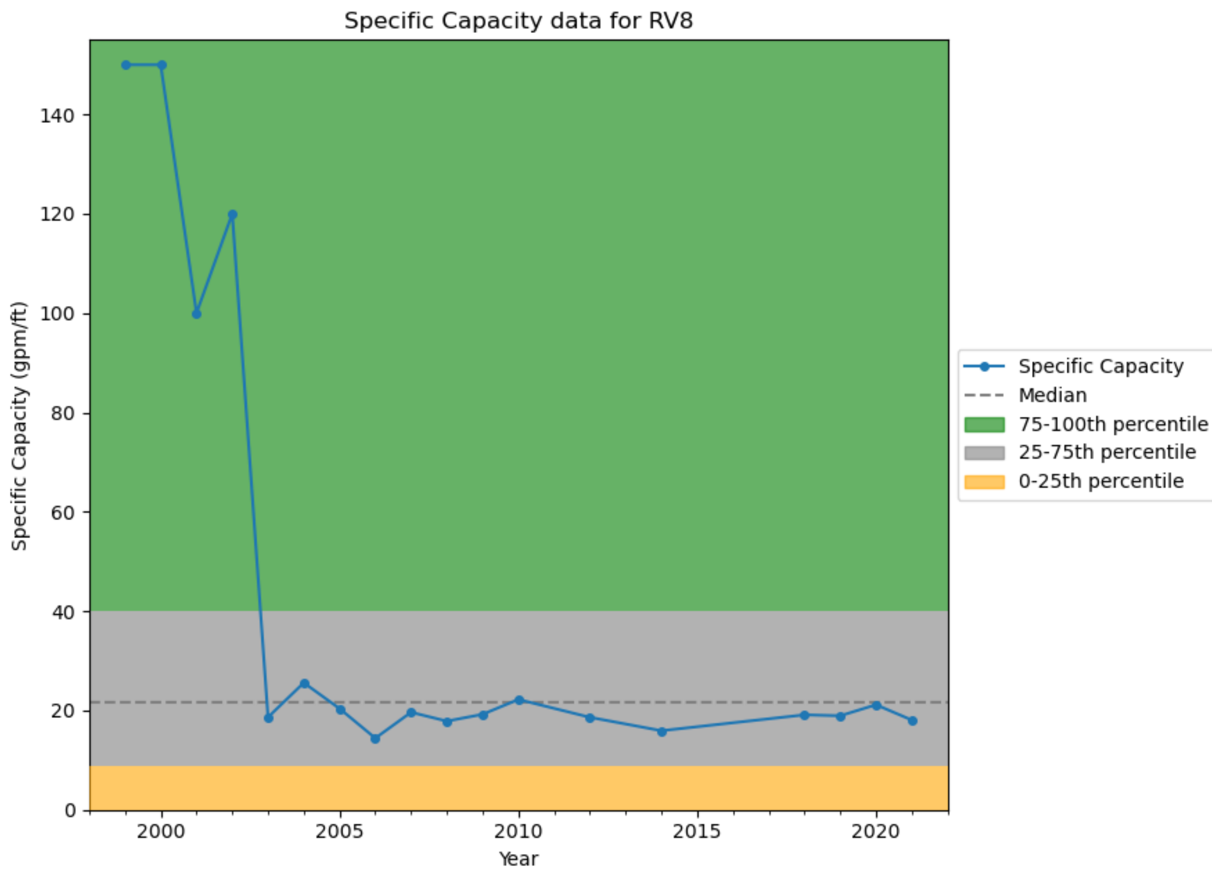


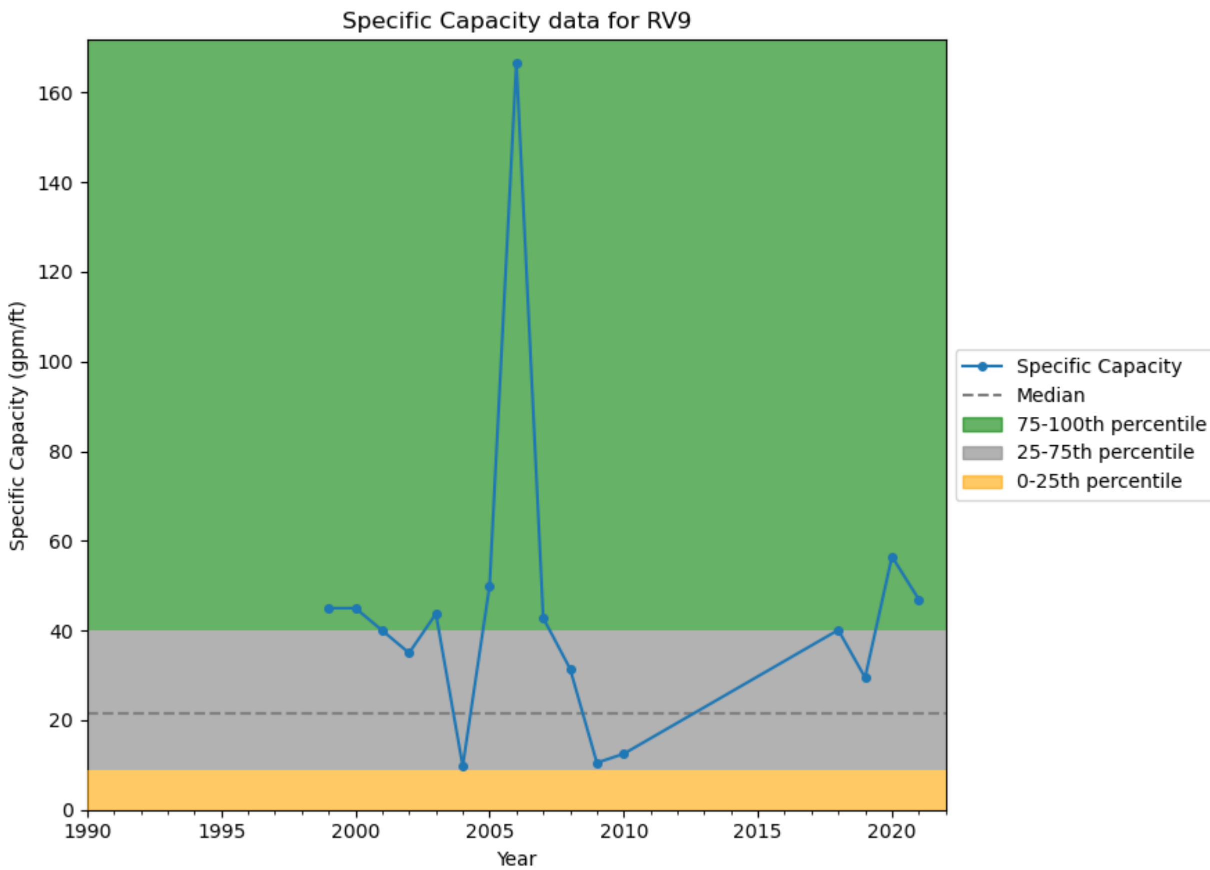

Specific Capacity data for RV3
Specific Capacity (gpm/ft)
Year
0
100
200
300
400
500
600
1980
1985
1990
1995
2000
2005
2010
2015
2020
Specific Capacity
Median
75-100th percentile
25-75th percentile
0-25th percentile


Specific Capacity data for RV5
Specific Capacity (gpm/ft)
Year
0
10
20
30
40
50
60
1980
1985
1990
1995
2000
2005
2010
2015
2020
Specific Capacity
Median
75-100th percentile
25-75th percentile
0-25th percentile

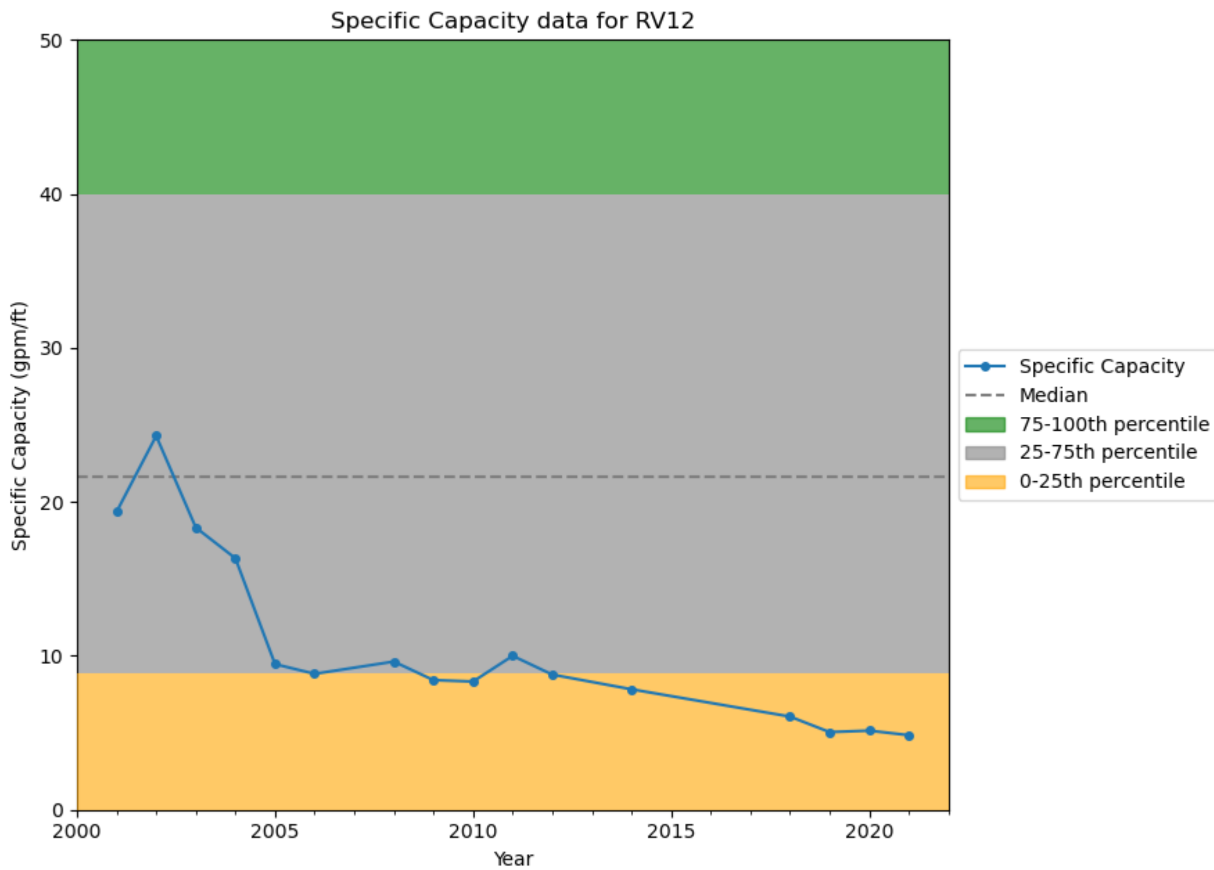


Specific Capacity data for RV7
Specific Capacity (gpm/ft)
0
20
40
60
80
100
120
140
1990
1995
2000
2005
2010
2015
2020
Year
Specific Capacity
Median
75-100th percentile
25-75th percentile
0-25th percentile


Specific Capacity data for RV8
Specific Capacity (gpm/ft)
Year
0
20
40
60
80
100
120
140
2000
2005
2010
2015
2020
Specific Capacity
Median
75-100th percentile
25-75th percentile
0-25th percentile

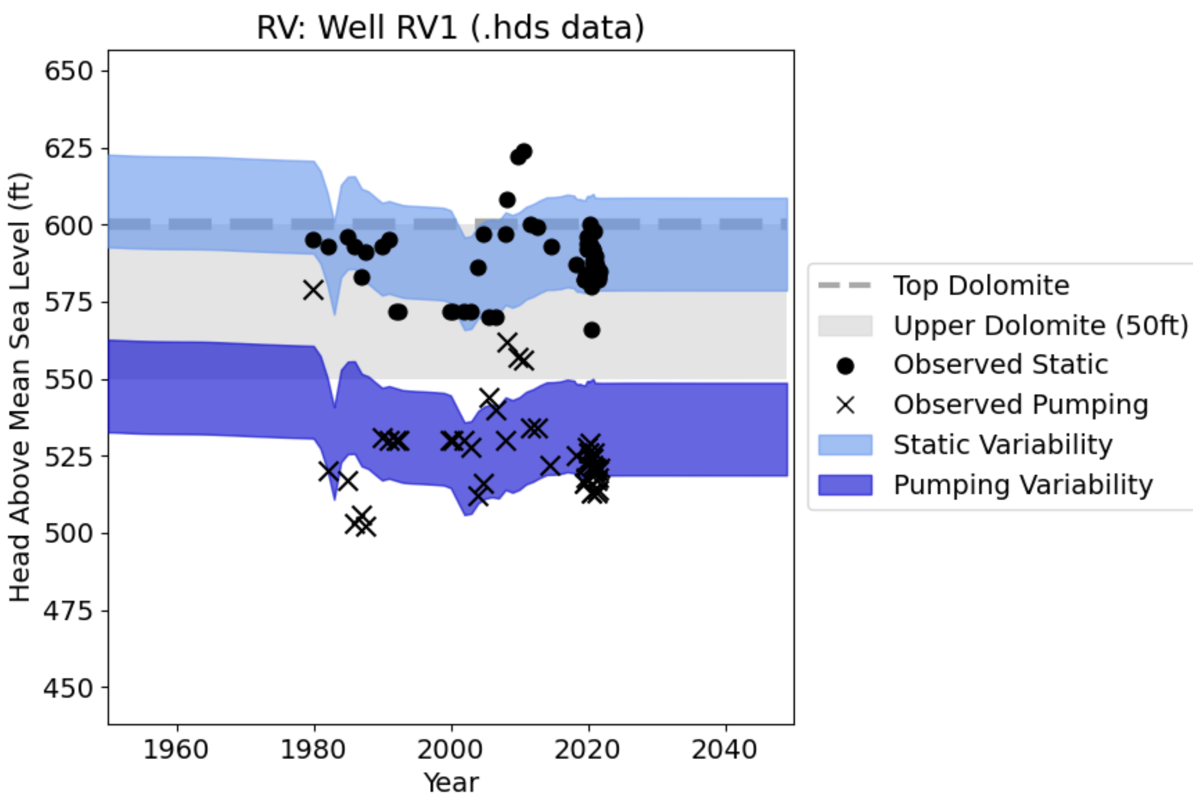


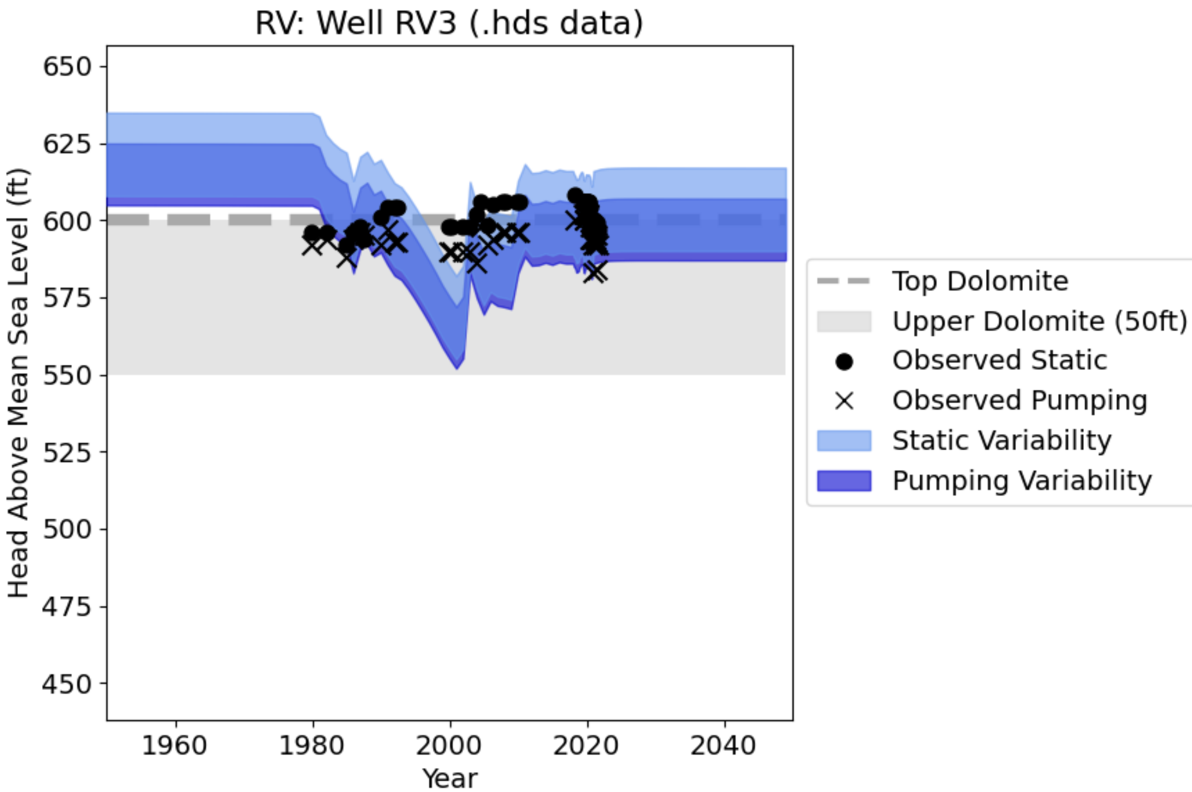
Specific Capacity data for RV9
Specific Capacity (gpm/ft)
0
20
40
60
80
100
120
140
160
1990
1995
2000
2005
2010
2015
2020
Year
Specific Capacity
Median
75-100th percentile
25-75th percentile
0-25th percentile

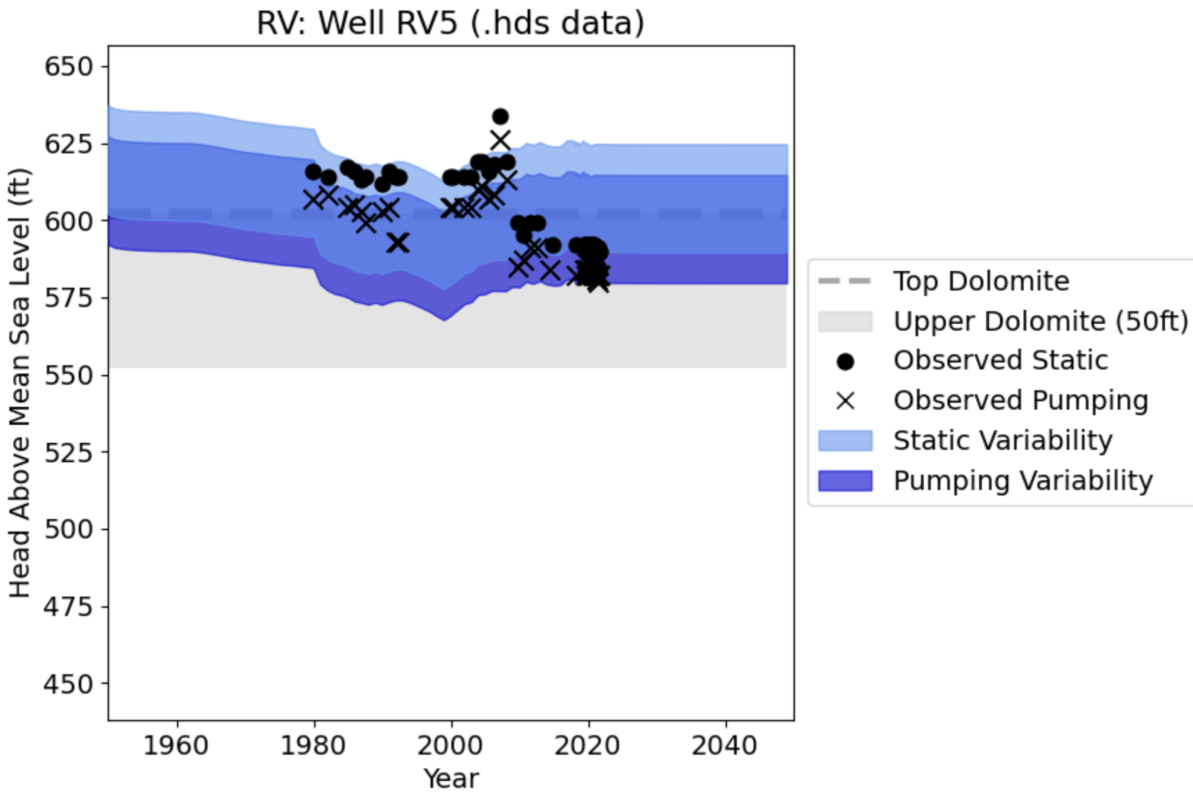

Specific Capacity data for RV12
Specific Capacity (gpm/ft)
Year
0
10
20
30
40
50
2000
2005
2010
2015
2020
Specific Capacity
Median
75-100th percentile
25-75th percentile
0-25th percentile

Shallow Aquifer Hydrographs (‘Is the shallow aquifer dewatering?’)

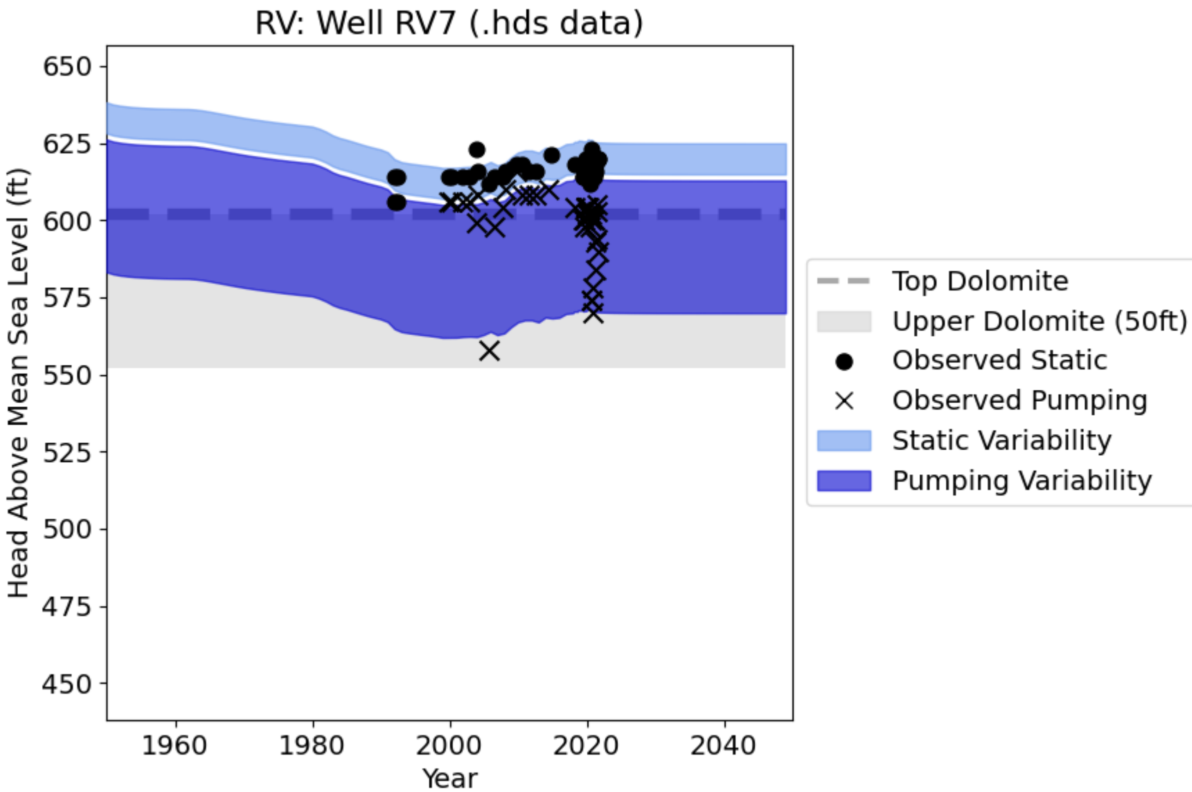
In Shallow Pumping Risk Table has one column that relates to water levels, ‘**Is the shallow aquifer dewatering?**’. A well is checked ‘at risk’ if water levels lower into the dolomite aquifer at any point in time. Dewatering the dolomite is not recommended, if at all avoidable; although we acknowledge that this can occur under natural conditions in some instances. While this table does not differentiate between static and pumping water levels, records at the ISWS indicate that a well with static levels in the dolomite is more likely to experience negative side effects from desaturation, such as mineral precipitation. The hydrographs are meant to better illuminate the risk at each well.



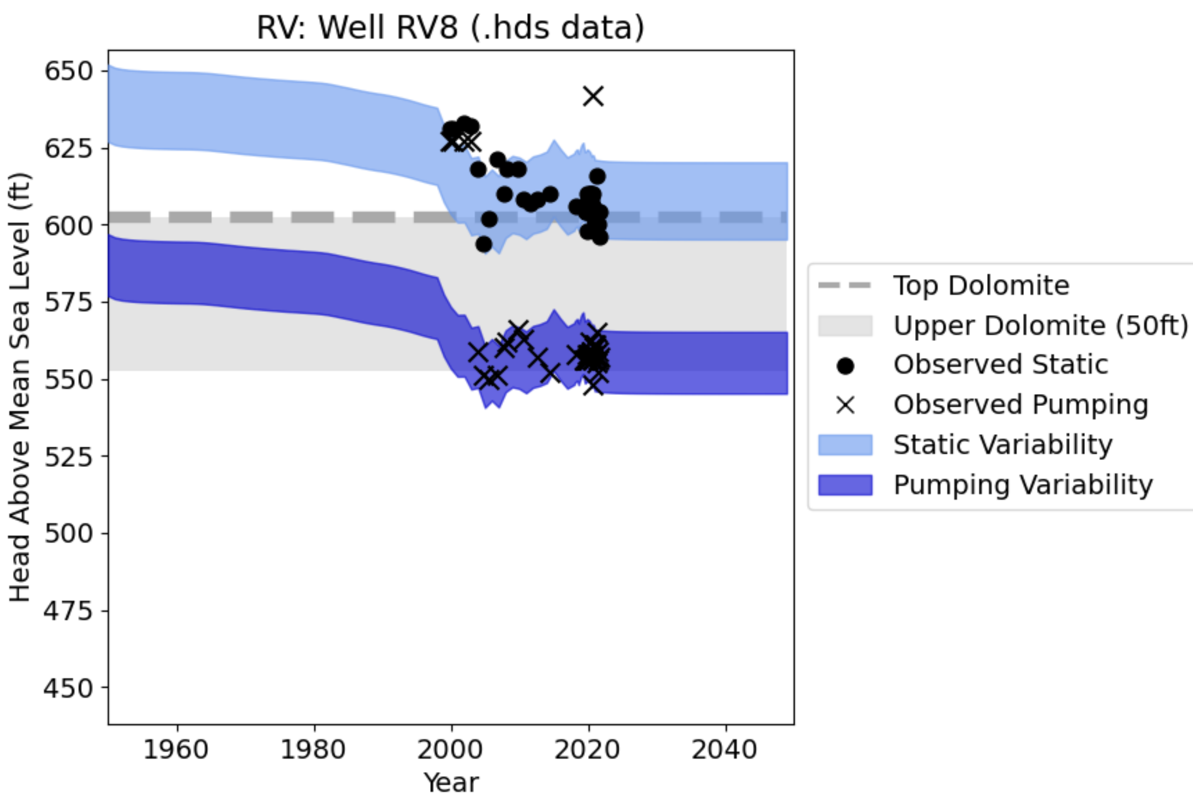

RV: Well RV3 (.hds data)
Head Above Mean Sea Level (ft)
650
625
600
575
550
525
500
475
450
1960
1980
2000
2020
2040
Year
Top Dolomite
Upper Dolomite (50ft)
Observed Static
Observed Pumping
Static Variability
Pumping Variability

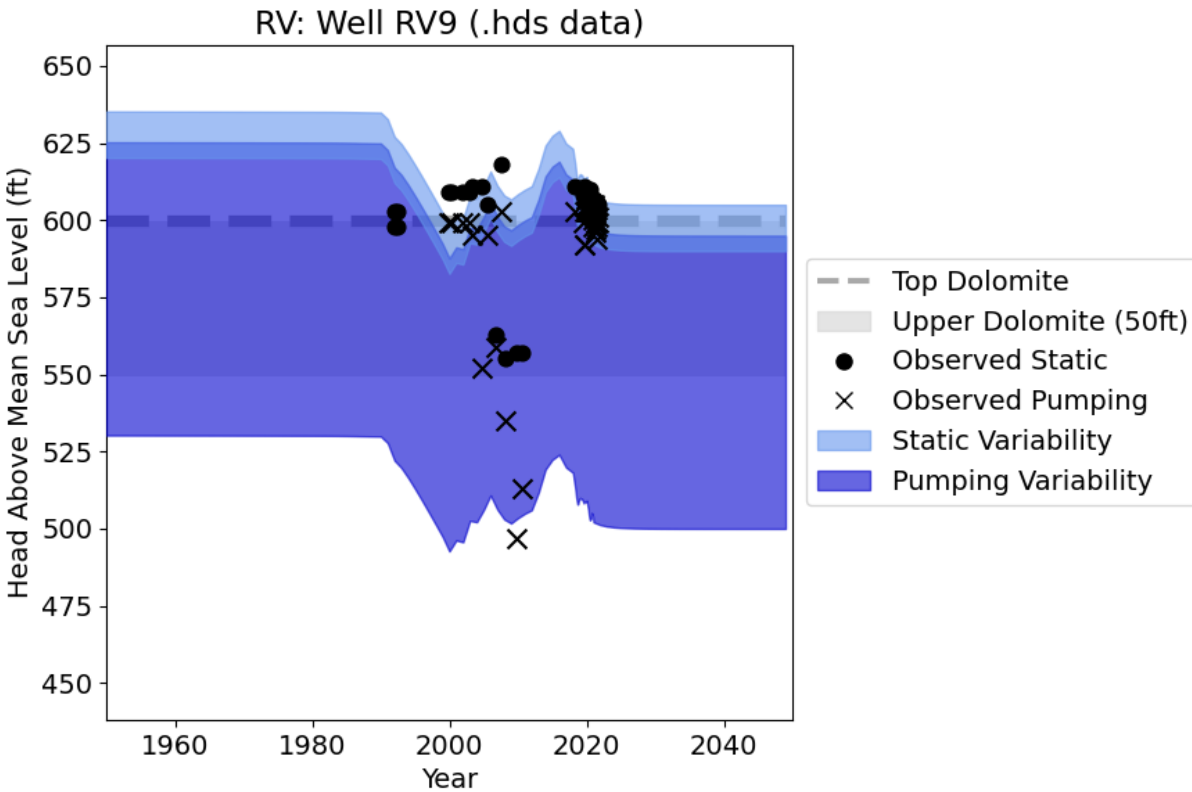


Comment on Well 5: The sharp decrease in the early 2000's may be representative of unsimulated pumping near this well or an inaccurate airline length over a long period of data. Data were not available to isolate the issue and improve the calibration.

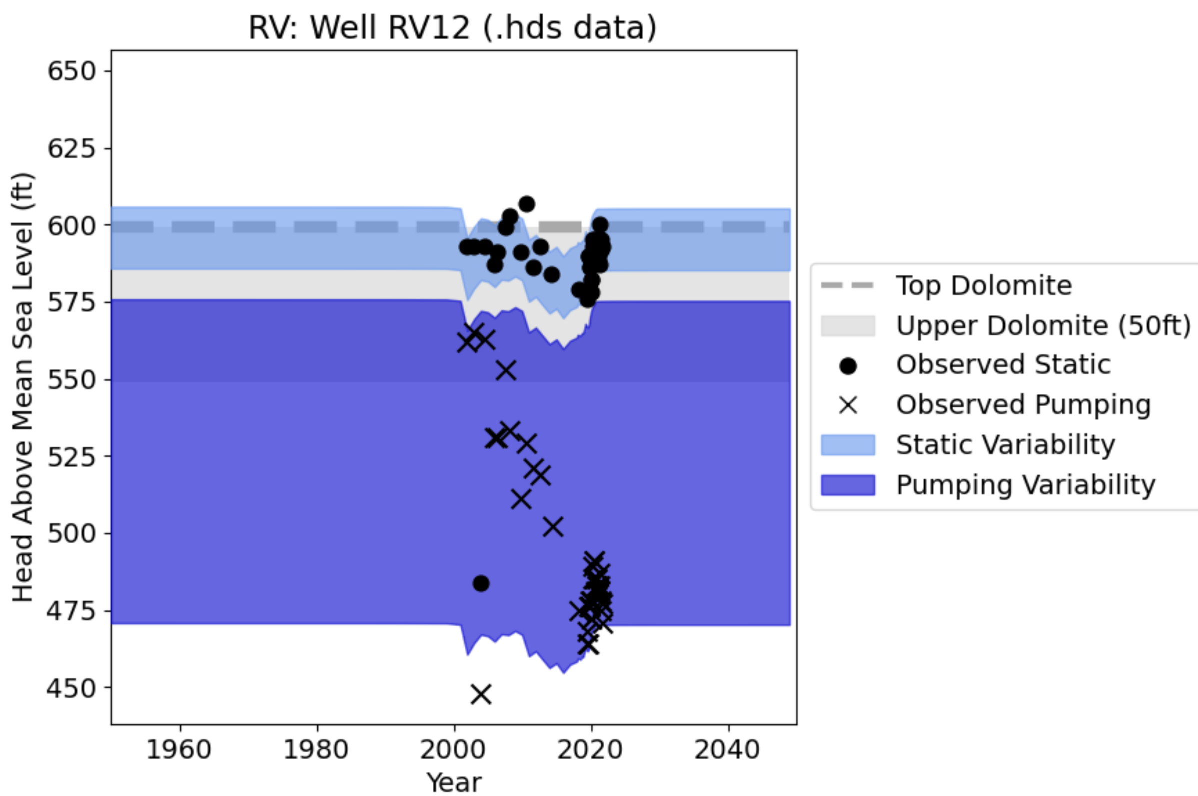


RV: Well RV7 (.hds data)
Head Above Mean Sea Level (ft)
650
625
600
575
550
525
500
475
450
1960
1980
2000
2020
2040
Year
Top Dolomite
Upper Dolomite (50ft)
Observed Static
Observed Pumping
Static Variability
Pumping Variability


RV: Well RV8 (.hds data)
Head Above Mean Sea Level (ft)
650
625
600
575
550
525
500
475
450
1960
1980
2000
2020
2040
Year
Top Dolomite
Upper Dolomite (50ft)
Observed Static
Observed Pumping
Static Variability
Pumping Variability



RV: Well RV9 (.hds data)
Head Above Mean Sea Level (ft)
650
625
600
575
550
525
500
475
450
1960
1980
2000
2020
2040
Year
Top Dolomite
Upper Dolomite (50ft)
Observed Static
Observed Pumping
Static Variability
Pumping Variability


RV: Well RV12 (.hds data)
Head Above Mean Sea Level (ft)
650
625
600
575
550
525
500
475
450
1960
1980
2000
2020
2040
Year
Top Dolomite
Upper Dolomite (50ft)
Observed Static
Observed Pumping
Static Variability
Pumping Variability