UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Prairie Research Institute
Illinois State Water Survey
2204 Griffith Drive, MC-674
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Risk to Sandstone Aquifer Supply
Supplemental Information

1. *Definition of Important Terms*

The Ironton-Galesville Sandstone is the deepest freshwater aquifer in Will County, overlain by hundreds of feet of impermeable material and limits the percolation of water into the aquifer. Most withdrawals are unsustainable from this aquifer, and the aquifer has been subject to hundreds of feet of drawdown throughout Will County. Historical records indicate that water levels in this aquifer will not recover to predevelopment levels when a large community switches off the aquifer; most of the drawdown that has occurred over the last 150 years of pumping from the aquifer will remain.

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 (drawdown) 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.

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.

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2. *Calculation of Risk*

Risk to the deep sandstone aquifer is determined by a groundwater flow model developed by the Illinois State Water Survey (Abrams and Cullen, 2020). To develop the risk table, we utilized the Current Trend scenario for the years 2021, 2050, and 2070. Unlike previous analyses, the simulated risk for a given year was determined based on the comparison of pumping levels and specific elevations above the top of the Ironton-Galesville Sandstone Aquifer:

1) Moderate risk was assigned where pumping levels reached 600 feet to 400 ft above the top of the Ironton-Galesville Sandstone. This is the earliest that the bedrock overlying the Ironton-Galesville sandstone could be dewatered and has been noted at multiple wells to coincide with a decline in specific capacity. However, each well behaves differently. **The primary ISWS recommendation for wells with pumping levels that are at Moderate Risk is to keep frequent (preferably monthly) records of pumping heads in the wells to evaluate whether the specific capacity of a well is declining.**
2) High risk was assigned where pumping levels reached 400 feet to 200 ft above the top of the Ironton-Galesville Sandstone. The risk of dewatering bedrock fractures increases at these deeper depths, with a specific concern of the aquifer losing transmissivity and storage, which in turn accelerates drawdown and exacerbates risk. **The primary ISWS recommendation for wells with pumping levels that are at High Risk is to immediately install pressure transducers to allow for real time monitoring of groundwater conditions. Any well reaching this threshold will be extremely vulnerable to potential new demands in the vicinity of the well. Detailed water supply studies are critical to evaluate how much longer wells can meet demands, including varying scenarios of pumping configurations. Evaluation of alternative supplies is recommended.**
3) Excessive risk was assigned where pumping levels reached 200 feet or less above the top of the Ironton-Galesville Sandstone. Wells that have reached this threshold struggle to meet modern-day demands. However, this relatively rare occurrence in 2021 occurs much more frequently in future simulations. **Previous records indicate that wells with pumping levels reaching this threshold are in immediate danger of not being able to provide adequate supply and will be particularly vulnerable to minor increases in demands, either via new demands or even seasonal fluctuations in water levels. There is not evidence that pumps can be lowered further. Evaluation of alternative supplies is strongly recommended and likely unavoidable.**

To evaluate well vulnerability on the addition of a new well to the community, only risk in the year 2070 was considered. Hydrographs are provided later in this supplemental material to provide more context.

3) *On Uncertainty*

The deep sandstone aquifer, despite years of investigation and scientific research, still has some critical uncertainties. The future of water use in Will County is even more uncertain. Communities in the SWPG study area have stressed that they need to know whether their water supply can be viable beyond their planning horizon. However, this is not the right question in the deep sandstone aquifer. The Illinois State Water Survey strongly recommends communities to consider the unknown, as water levels that fall below their current water levels are reaching uncharted territory. **The single most important thing for all communities and industries impacted by this scientific investigation to understand is that there is no single answer to the question, "*When will this well run dry?*".**

By necessity, the Illinois State Water Survey considers conservative scenarios. This is critical and highlighted by post-audits of the New Chicago Model (Burch, 1991). Two key assumptions were made in this model: 1) Joliet would leave the deep sandstone aquifer in the 1990s, switching to the Kankakee River and 2) Oswego, Yorkville, and Montgomery would have very little growth. In reality, Joliet remained on the aquifer and Oswego, Yorkville, and Montgomery had a boom in population growth; the model results which indicated moderate risk in these regions have actually had such expansive growth that Joliet, Oswego, Yorkville, and Montgomery are now forced to find alternative supplies and are in currently in the process of doing just this. To apply what was learned from the New Chicago Model to your community's water supply decision, please consider the following:

- Is accelerated population growth possible?
- Is the addition of a new data center or major industry, which utilizes a lot of water, possible?
- Are there any neighboring industries where a process change could greatly increase water use in your region?

If the answer is yes to any of these three questions, it is imperative to pay attention to all model scenarios, including the most aggressive scenario in Table 1, which shows the impact of a new demand that is a distance of 1.5 miles away from at least one of your community's wells. The Illinois State Water Survey is unable to determine whether this will become a reality for your community, but historic records indicate that this will be a possibility for multiple communities throughout Northeastern Illinois. It is imperative not to make decisions based on the last 15 years, when water use has been steady, but on the next 15-30 years. Each community will have the best understanding of what plausible future demand scenarios will be for their community and should carefully consider these.

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4) *Specific Capacity and Future Risk Determination*

Most assumptions in this study are chronicled in Abrams and Cullen (2020). In addition, since pumping levels were used to assess risk, specific capacity was also considered. As a result, a few additional assumptions must be made.

Where possible, each well's current specific capacity is utilized to establish current pumping levels in the aquifer through post-processing. Data on how specific capacity changes through time are limited. However, the available data indicate a decreasing trend in over half of the wells investigated. To conduct a comparative analysis, all wells were normalized by dividing all of each well's specific capacities by the that well's earliest record of specific capacity. As a result, normalized specific capacities greater than 1 indicate an increase in specific capacity and less than one indicate a decrease.

Figure 1 shows the trends in normalized specific capacity through time. The wells that lost normalized specific capacity were relatively consistent in their decline with an annual normalized loss of 0.028 per year. To determine what this could mean for your wells, you would multiple 0.028 by your current specific capacity to calculate the annual decline. For example, if your well has a specific capacity of 5 gpm/ft, then the empirically determined potential annual specific capacity decline would be 0.14 gpm/ft.

Given the limited number of wells available for consideration in this study, this decline might be too severe, particularly for wells that have not exhibited such a decline. However, such a decline in the future cannot be discounted, particularly if transmissivity and storage in the aquifer are lost and drawdown accelerates. To avoid being too conservative, we reperformed the analysis and included all wells, including those without a decline, to obtain a normalized specific capacity loss of 0.017 per year. In the case of the well with specific capacity of 5 gpm/ft, the empirically determined potential annual specific capacity decline would be 0.08 gpm/ft.

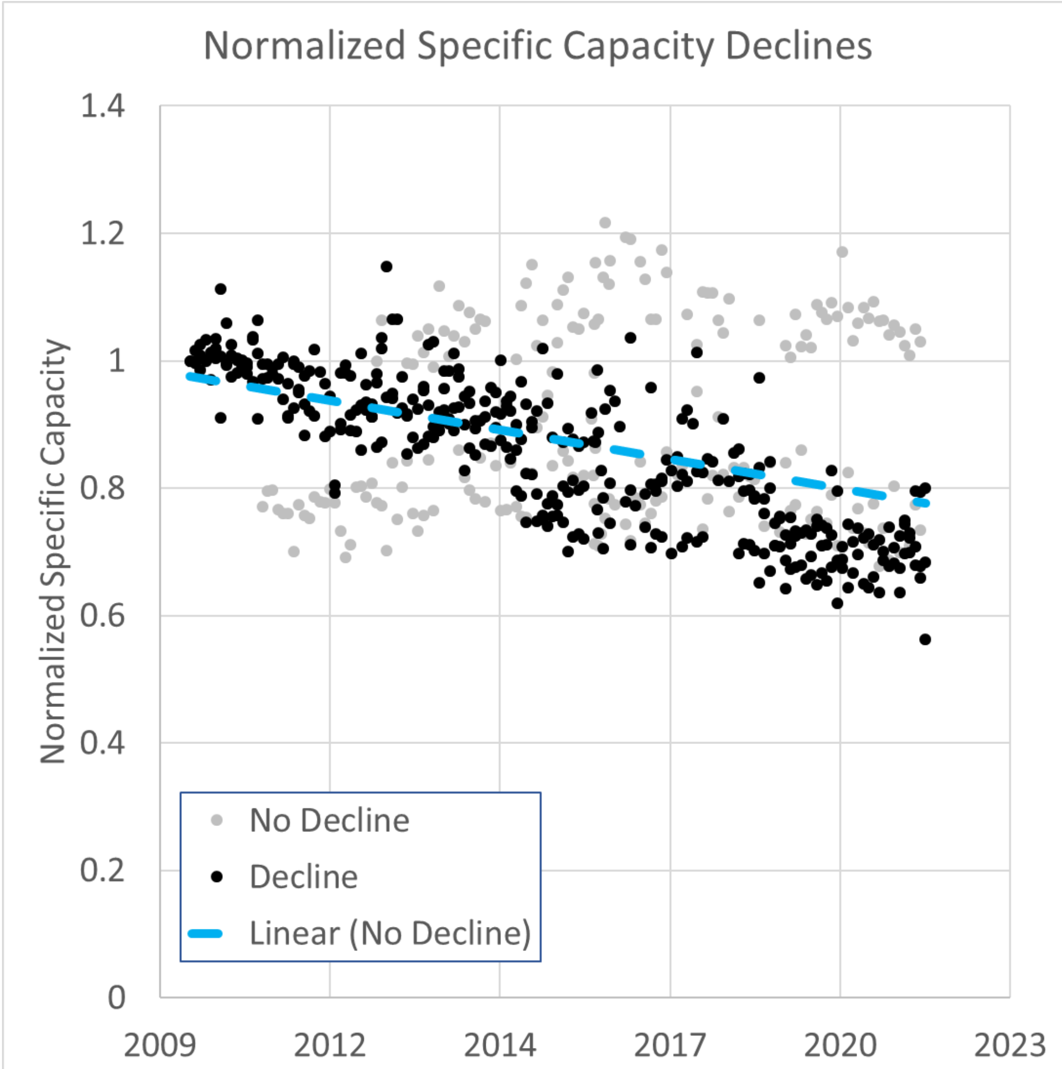
In the hydrographs developed for this investigation, the range of future pumping levels was established by first evaluating the range of current pumping levels and then:

1) Establishing an upper bound representative of the best case (minimum) drawdown when compared to static heads observed in the well's (or from the nearest similarly situated well's) empirical data
2) Establishing a lower bound representative of the worst case (maximum) drawdown when compared to static heads observed in the well's (or from the nearest similarly situated well's) empirical data **plus** any additional drawdown associated with a normalized specific capacity decline of 0.017 gpm/ft per year. For all wells, as specific capacities declined, we assumed a future minimum specific capacity of 0.5 gpm/ft.

For calculation of risk, even this mild specific capacity loss led to severe acceleration in the decline of water levels. Although not conservative, we elected to use the average of the upper and lower bound of drawdown to calculate a well's risk status.

Some specific capacity loss is unavoidable under the influence of regional declines, as loss in transmissivity and specific yield will decrease specific capacity. However, some specific capacity loss can be mitigated by treating wells to avoid mineralization along a well-bore. Where this mineralization is extreme, a new well ***may*** be able to have a superior specific capacity, at least for a time. What remains unclear, and is a subject of ongoing investigation at the ISWS, is whether the introduction of oxygen into the deeper formations as water levels decline is exacerbating the loss in specific capacity and how treatment may have to change in response, either the type of treatment or the frequency. These are discussions that all communities should be having with their drillers.

Any community with moderate or higher risk at their wells should be monitoring their specific capacity to determine if trends are favorable or will lead to water supply issues in the future. This monitoring should be conducted monthly at a minimum, with staff trained in taking airline measurements properly to avoid inaccurate and inconsistent readings.



Normalized specific capacity trends in wells with long-term data records shared with the ISWS. Gray points represent specific capacity at wells lacking statistically significant trend, while black points represent wells with a decline. All points (both gray and black) were used to calculate the expected trend for regional declines in specific capacity.

Reference List

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Burch, S.L. 1991. The New Chicago Model: A Reassessment of the Impacts of Lake Michigan Allocations on the Cambrian-Ordovician Aquifer System in Northeastern Illinois. Illinois State Water Survey Research Report 119, Champaign, IL. Available at: http://hdl.handle.net/2142/75855

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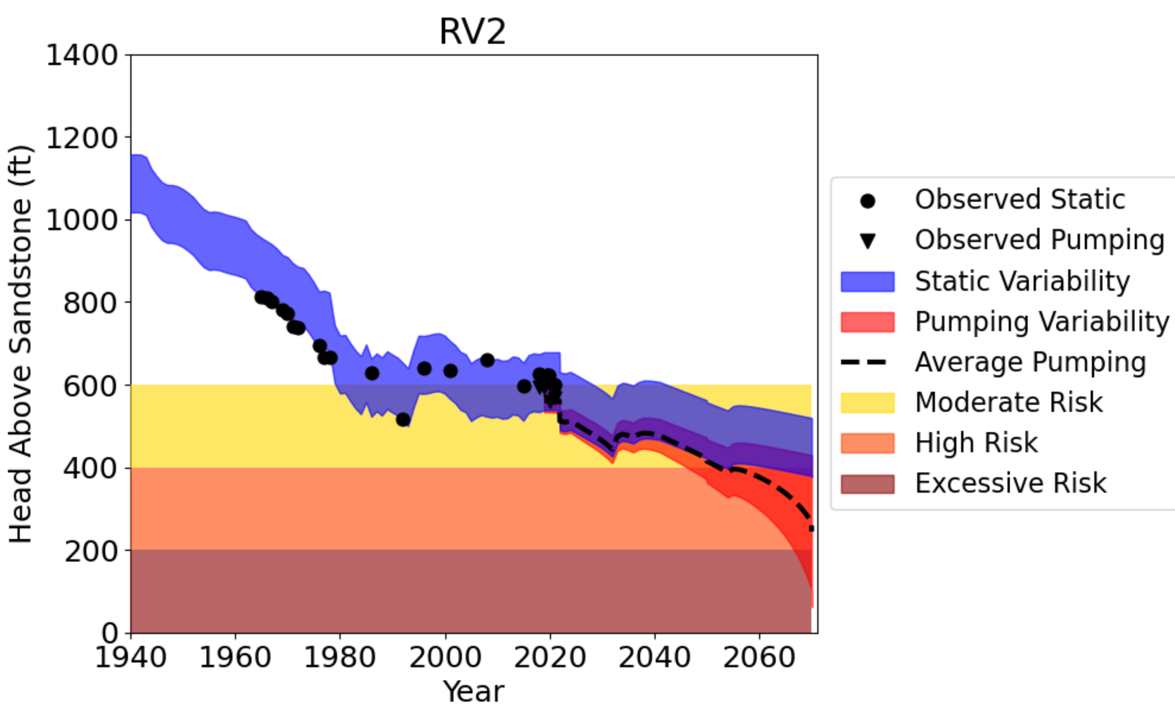
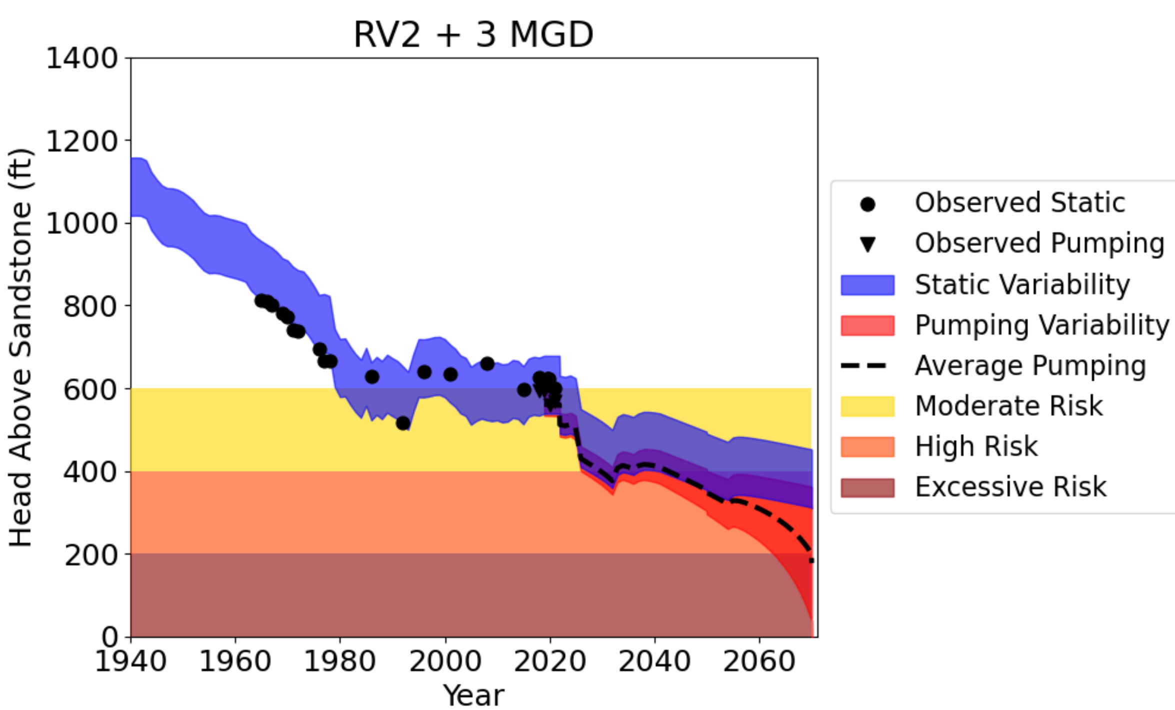
Crawford, Murphy, and Tilly. 2019. City of Joliet Alternative Water Source Study, Phase 1 Final Report. Available at: https://www.rethinkwaterjoliet.org/reports

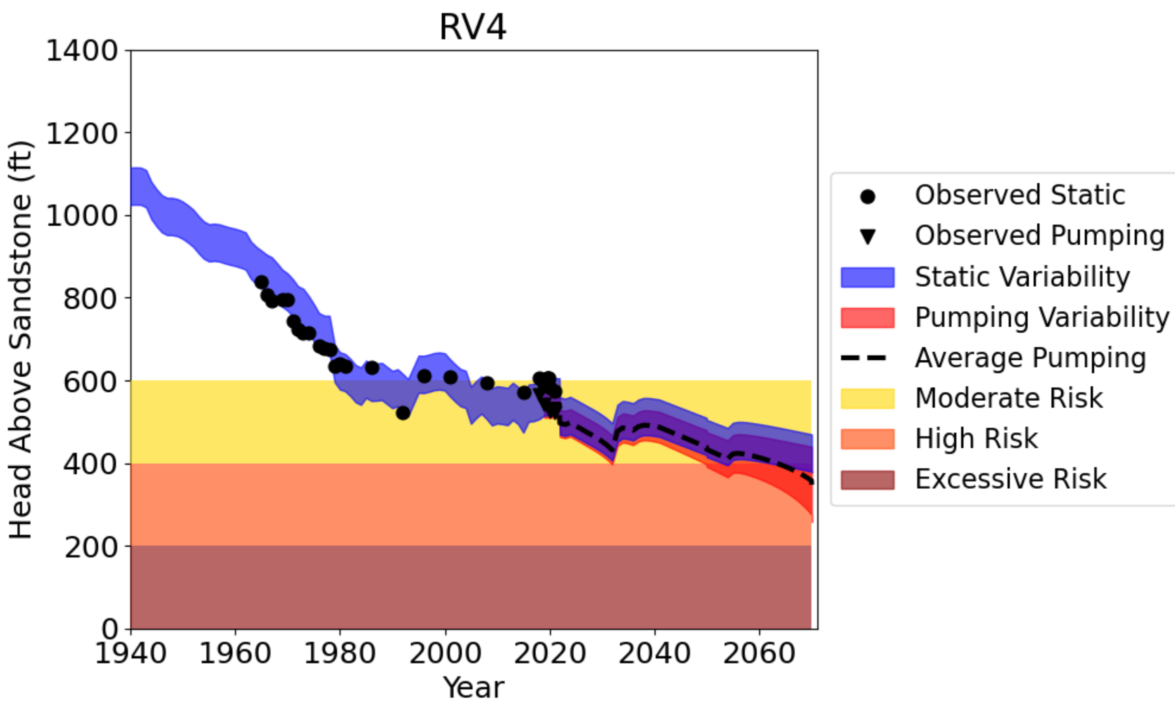
Roadcap, G.S., S.J. Cravens, and E.C. Smith. 1993. Meeting the Growing Demand for Water: An Evaluation of the Shallow Ground- Water Resources in Will and Southern Cook Counties, Illinois. Illinois State Water Survey Research Report 123, Champaign, IL. Available at: http://hdl.handle.net/2142/75859

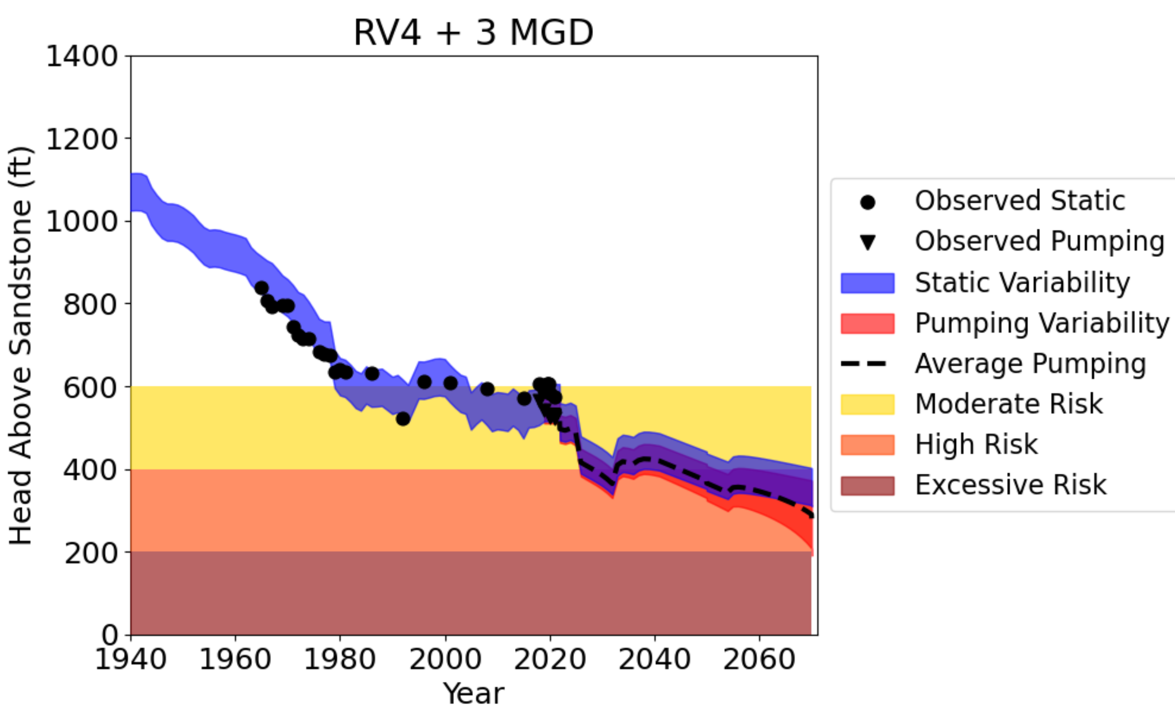
5) Sandstone Hydrographs

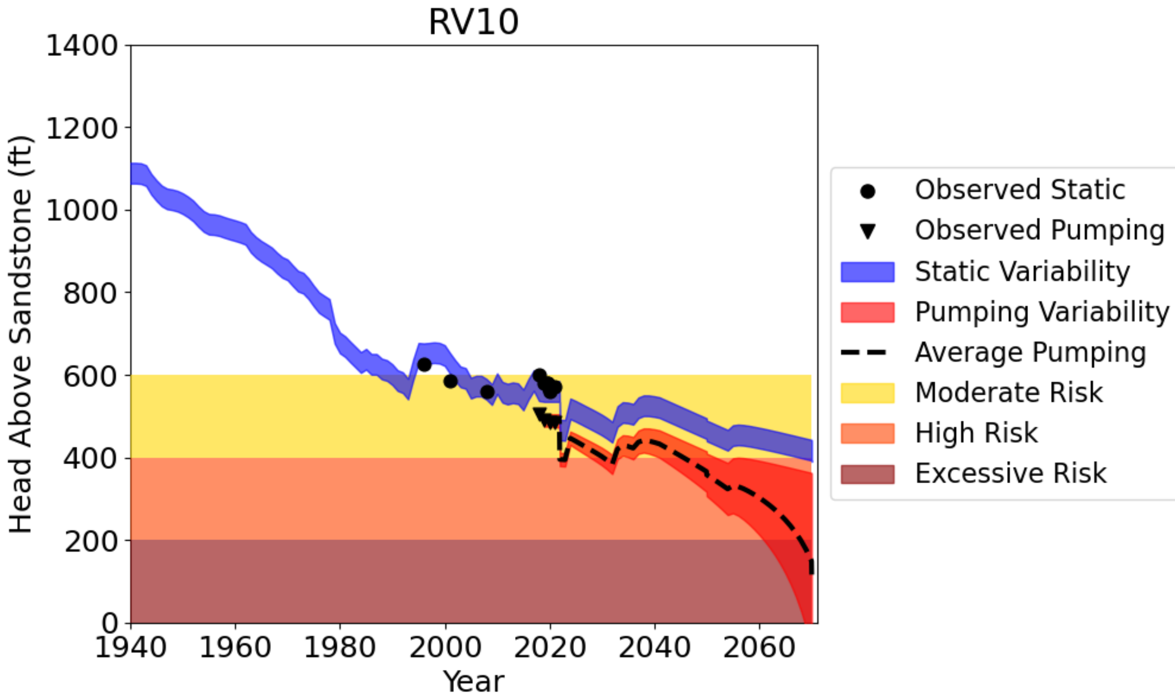
The following pages include the sandstone hydrographs for all current and hypothesized future wells for your community. Average pumping is used to determine when a well moves into at-risk conditions. This is not the most conservative solution, so it is important to consider the impacts of more rapid declines in specific capacity on your wells.

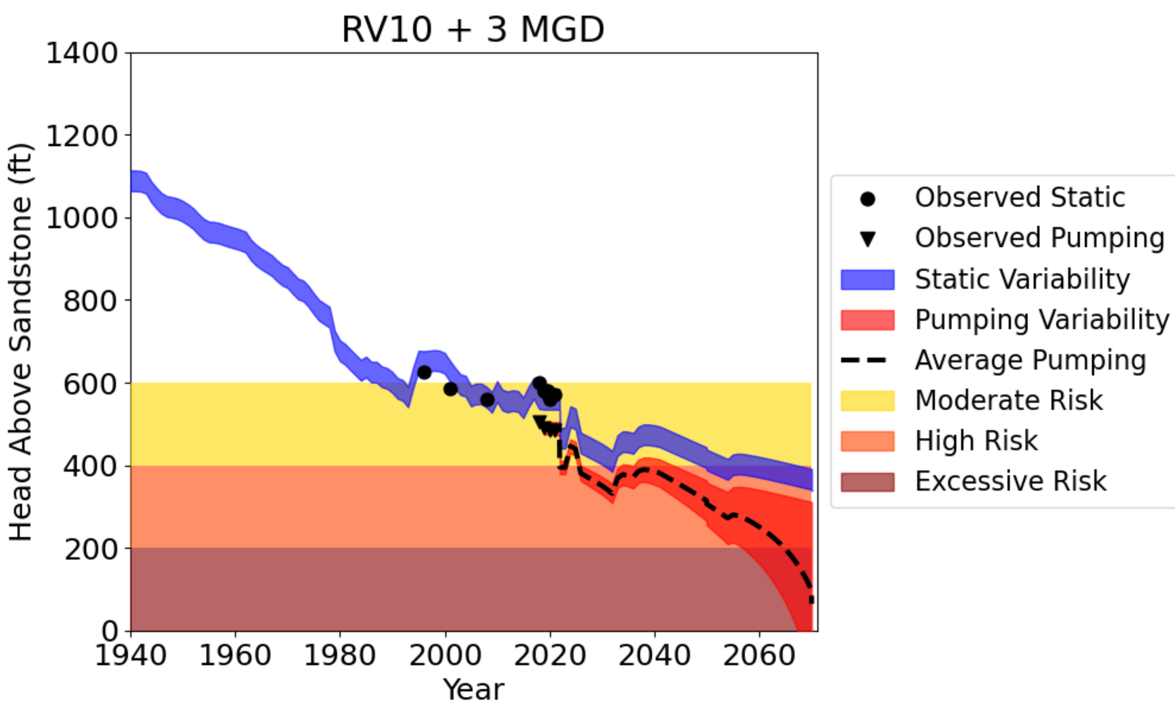


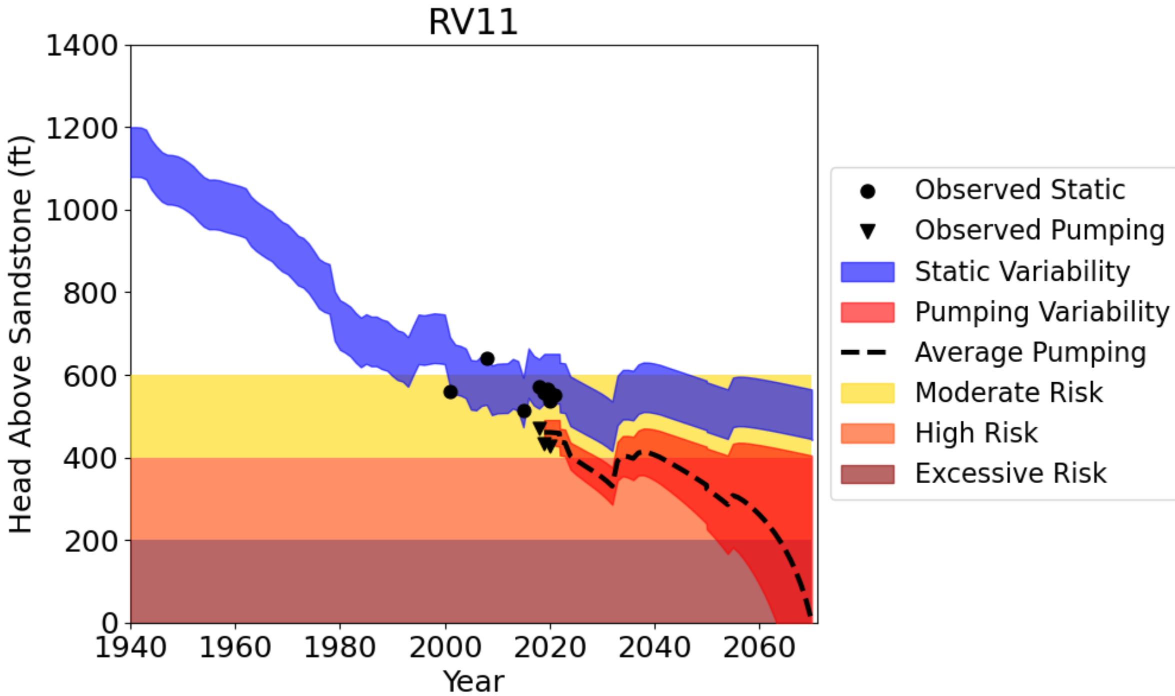


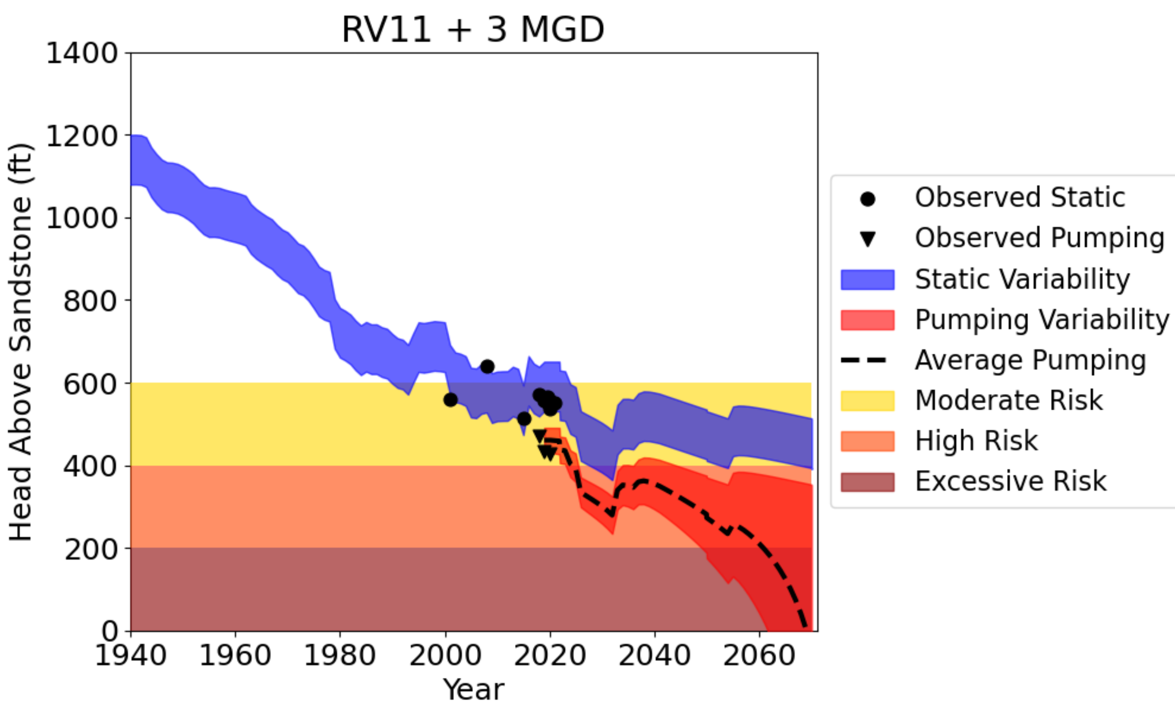

RV4
Head Above Sandstone (ft)
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk

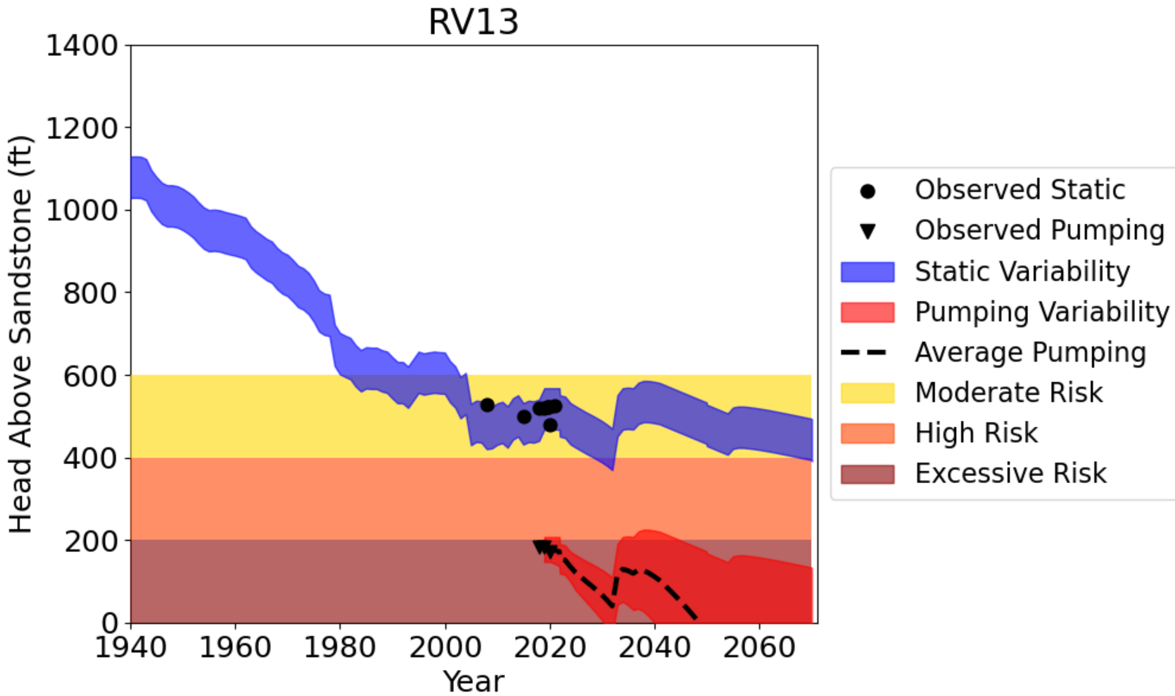

RV4 + 3 MGD
Head Above Sandstone (ft)
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk

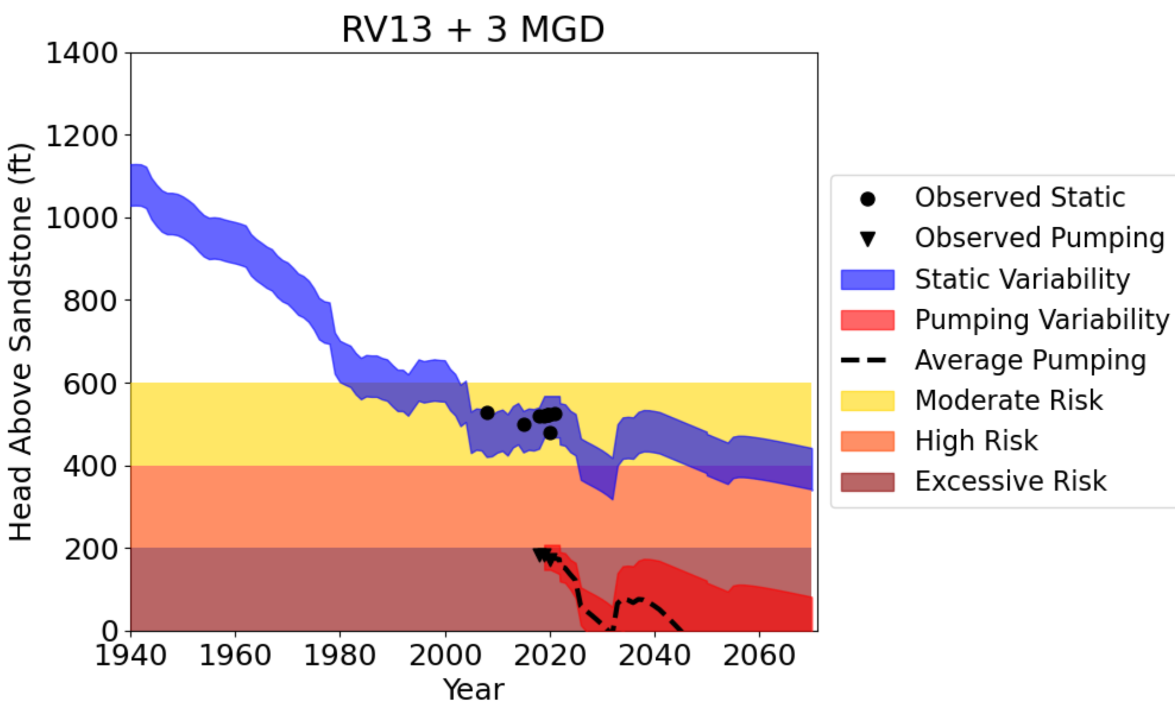

RV10
Head Above Sandstone (ft)
1400
1200
1000
800
600
400
200
0
1940
1960
1980
2000
2020
2040
2060
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk

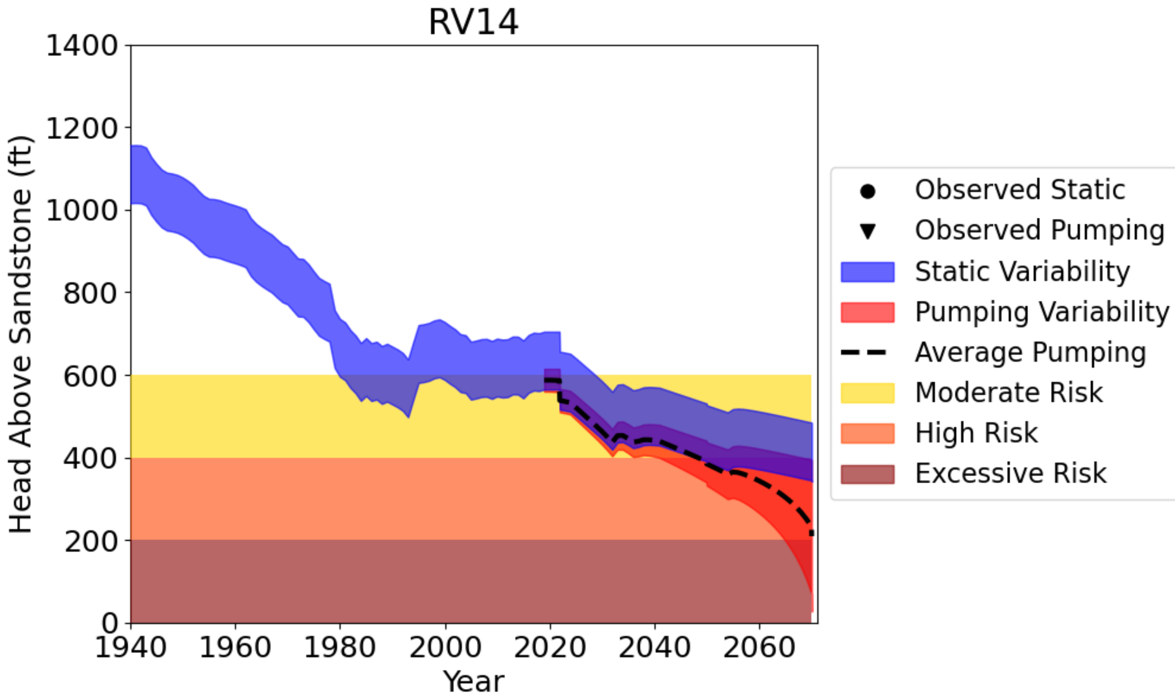

RV10 + 3 MGD
Head Above Sandstone (ft)
1400
1200
1000
800
600
400
200
0
1940
1960
1980
2000
2020
2040
2060
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk

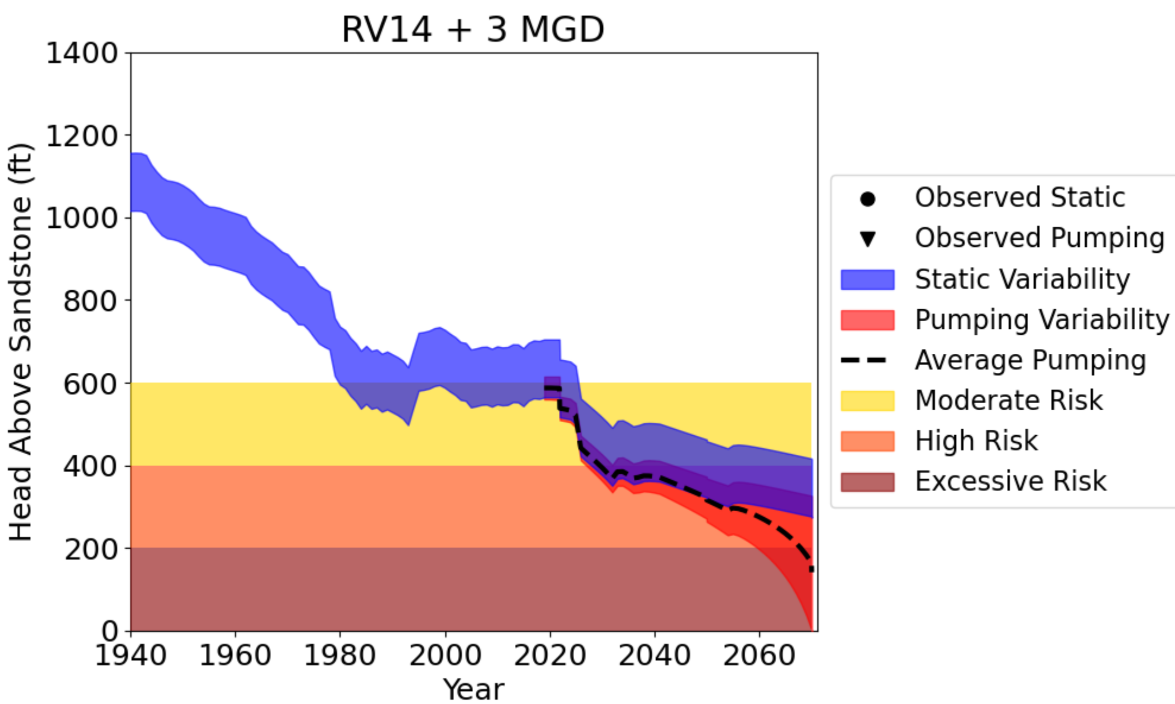

RV11
Head Above Sandstone (ft)
1400
1200
1000
800
600
400
200
0
1940
1960
1980
2000
2020
2040
2060
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk


RV11 + 3 MGD
Head Above Sandstone (ft)
1400
1200
1000
800
600
400
200
0
1940
1960
1980
2000
2020
2040
2060
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk


RV13
1400
1200
1000
800
600
400
200
0
Head Above Sandstone (ft)
1940
1960
1980
2000
2020
2040
2060
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk


RV13 + 3 MGD
1400
1200
1000
800
600
400
200
0
Head Above Sandstone (ft)
1940
1960
1980
2000
2020
2040
2060
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk


RV14
1400
1200
1000
800
600
400
200
0
Head Above Sandstone (ft)
1940
1960
1980
2000
2020
2040
2060
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk


RV14 + 3 MGD
1400
1200
1000
800
600
400
200
0
Head Above Sandstone (ft)
1940
1960
1980
2000
2020
2040
2060
Year
Observed Static
Observed Pumping
Static Variability
Pumping Variability
Average Pumping
Moderate Risk
High Risk
Excessive Risk