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Analysis of Risk to Sandstone Supply in the Southwest Suburbs

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A Report to the Southwest Water Planning Group (SWPG),
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Table of Contents

List of Figures

List of Tables

Abstract

In 2018, the City of Joliet assessed its long-term water supply and found that the city should change its water supply source, the deep Cambrian-Ordovician Sandstone aquifer, by 2030. A three-year follow-up study has been initiated with a collaboration among scientists from the Illinois State Water Survey and multiple communities and industries in the southwest suburbs of Chicago. This contract report summarizes the Year 1 findings.

Withdrawals from the deep Cambrian-Ordovician aquifer system in northeastern Illinois have been unsustainable since the early 1900s. The sandstone aquifer system that supplies water to Will County contains the uppermost St. Peter Sandstone and the Ironton-Galesville Sandstone; this study frequently uses the terms "Cambrian-Ordovician Sandstone aquifers," "sandstone aquifers," or "sandstone" when referring to the St. Peter and Ironton-Galesville collectively. In the study area, sustainable withdrawals are estimated to range from 2 to 7 million gallons per day (mgd), while recent sandstone demands range from 35 to 38 mgd. As a result, sandstone water levels have been declining for over a century. In some areas, the uppermost St. Peter Sandstone is currently dewatered, while the lowermost freshwater aquifer, the Ironton-Galesville Sandstone, is at-risk of dewatering in localized areas. Further declines will increase the risk to both aquifers.

With Joliet planning to switch off the sandstone aquifers by 2030 and communities in Kendall County considering leaving the aquifer shortly after, updated groundwater flow models have assessed the regional impact of this reduction on sandstone water use. This report focuses on a single model scenario, referred to as the Current Trend, and outlines its underlying assumptions. A sensitivity analysis was conducted to demonstrate the impact of pumping assumptions in different portions of the region.

Joliet and Kendall County communities switching from the sandstone aquifer will not alleviate the regional risk to the sandstone supply. The impact of alternate demands from new and existing industries, which were assumed to remain unchanged in the future, may still pose a risk to the regional sandstone supply. Regional action is needed to ensure a sustainable future water supply and to preserve the sandstone aquifer as an option for future back-up supply needs.

Acknowledgments

This work was funded by several communities in the southwest suburbs: 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.

In addition to funding the work of the Illinois State Water Survey, members of the Southwest Water Planning Group (SWPG) have held monthly meetings over the past year to discuss the future demand scenarios for the model and the inputs and uncertainties involved. This participatory effort remains critical to building confidence in the modeling results, and the feedback received is greatly appreciated by the principal investigators of this project.

We also thank Devin Mannix, Allan Jones, and Walton Kelly at the Illinois State Water Survey (ISWS) for their constructive peer reviews of the technical content of this report. Finally, we thank Lisa Sheppard (ISWS), who edited the text.

Introduction

Residents in the southwest suburbs of Chicago rely on multiple water sources to meet their demands. One important source is the deep Cambrian-Ordovician Sandstone aquifer system, from which regional withdrawals have been unsustainable for nearly a century. As a result, water levels have declined and wells in the region are at risk of not meeting current demand in localized areas and regional demand in at least some future scenarios.

In 2018, the City of Joliet initiated Phase 1 to investigate the status of their regional water supply and found that the sandstone aquifer, specifically water from the two major sandstone units (the uppermost St. Peter and the lower Ironton-Galesville), would no longer meet their needs by 2030. As the city plans to transition away from the aquifer, the surrounding communities and industries formed the Southwest Water Planning Group (SWPG) to assess risk to their own sandstone supplies. This group is made up of entities that rely on the sandstone aquifer for some or all of their primary water supply (communities of Elwood, Channahon, Joliet, Lemont, Lockport, Minooka, Romeoville, and Shorewood and Exxon Mobile, INEOS-Flint Hills, and LyondellBasell). The SWPG also includes some communities that currently rely solely on shallow dolomite aquifers in the region (Crest Hill and Frankfort), as well as two Lake Michigan users (New Lenox and Plainfield).

The SWPG contracted with the Illinois State Water Survey (ISWS) to update the groundwater flow models developed in the 2018 study with additional local feedback. This report details:

1) the unsustainability of withdrawals in the sandstone aquifer,
2) assumptions used to develop model scenarios and assign at-risk regions,
3) the impact of uncertainty in these assumptions, and
4) conclusions from the first year of this investigation.

This report focuses on the status of the regional sandstone aquifer system in the southwest suburb region of Chicago. Per request of the SWPG, a community-by-community assessment for existing sandstone users was developed. Each assessment has been reviewed by the respective community. Industries also received personalized assessments of their water supply.

Background

Geologic and Hydrogeologic Setting

The deep sandstone aquifers are an important source of water in the northern half of Illinois. Sandstone is a sedimentary rock composed of sand-sized grains with significant primary intergranular porosity. In other words, the pore spaces between grains in sandstone are comparatively large and generally interconnected. Sandstone can also develop secondary fractures that can further increase permeability. Well treatment often attempts to enhance these fractures to boost local permeability and reduce drawdown in an actively pumping well.

The sandstone aquifers are contained within a sequence of bedrock layers in Illinois. The intervening layers, referred to as aquitards, are generally composed of shale, siltstone, and unweathered carbonates. The aquitards separating the individual sandstone aquifers generally have lower permeability and impede the vertical flow of groundwater. Recent studies at the ISWS hypothesized that some of these layers may provide considerable water from storage, although this is still under investigation (Mannix et al. 2018). A generalized cutaway of the geology is depicted in Figure 1. The cutaway runs through McHenry, Kane, and Kendall Counties on the left (west) and Kendall, Will, and Cook Counties on the right (south). Note that this diagram refers to hydrostratigraphic units, each lumping similar geologic material into a single layer. This is primarily done to simplify the geologic framework of groundwater flow models.

Since the major sandstone aquifers in northern Illinois are Cambrian or Ordovician in age, they are collectively referred to as the Cambrian-Ordovician Sandstone aquifers. For simplicity, this report often refers to this collective aquifer simply as the "sandstone" or "sandstone aquifers." Two Cambrian-Ordovician Sandstone aquifers are of interest in the SWPG region, the uppermost St. Peter and the lower Ironton-Galesville.

The St. Peter Sandstone consists mostly of well-sorted and well-rounded quartz sand and is at the bedrock surface in portions of north-central Illinois (Figure 2). Where it is not overlain by shale units, the sustainable yield of the sandstone aquifer is much higher because of increased vertical leakage. In most of the SWPG region, shale layers (mostly the Maquoketa Formation) overly the sandstone (Figure 1), greatly impeding vertical infiltration to the St. Peter Sandstone.

The Ironton-Galesville Sandstone consists of well-rounded quartz sand grains like the St. Peter. In the study area, the Ironton-Galesville is separated from the St. Peter Sandstone by two predominantly (unweathered) carbonate units, the Prairie du Chien-Eminence and Potosi-Franconia. Under natural conditions, these units greatly impede flow between the St. Peter and Ironton-Galesville. However, the increasing prevalence of artificial connections from multi-aquifer wells (MAWs) promote rapid flow between the St. Peter and Ironton-Galesville. The Ironton-Galesville does not approach the bedrock surface in Illinois. As a result, vertical leakage is limited everywhere in the state, so high-capacity wells open to only the Ironton-Galesville generally pump in excess of the sustainable yield, regardless of location in the state.

A third, deeper sandstone, the Mt. Simon, is present in the southwest suburbs, but is highly saline. The Mt. Simon has been used as a water supply as far south as Aurora, but issues with salinity in Will, Kendall, and Grundy Counties have resulted in modern wells being drilled no farther than the Ironton-Galesville. Paper records at the ISWS indicate that previous attempts at drilling wells into the Mt. Simon aquifer in Will County failed; the flowing water was highly saline and formed salt crystals around the base of the well.

The Sandwich Fault Zone is an important geologic feature that affects flow in northeastern and north-central Illinois, vertically displacing the Cambrian-Ordovician Sandstone aquifers in Kendall and Will Counties. The Sandwich Fault Zone appears to limit horizontal flow because of the potential development of deformation bands, increased cementation, and the offset of high permeability zones (Kolata et al. 1978; Abrams et al. 2015). Hadley et al. (2019) conceptualized that the fault zone has the lowest permeability along the linear feature in Figure 1 and Figure 2, but also noted that it has substantial width, potentially as wide as 2 miles. The most at-risk wells in the southwest suburbs have been observed to occur within this 2-mile faulted area.

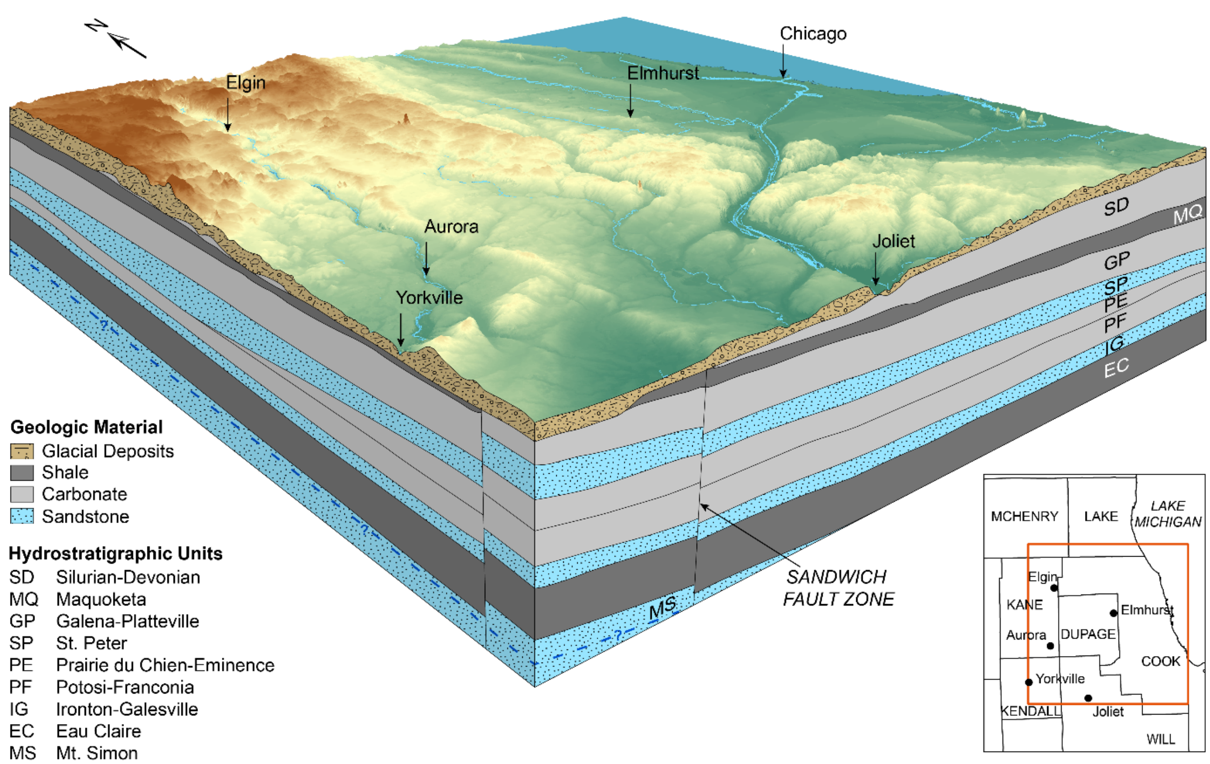

Figure 1: Generalized cutaway of the geology in the southwest suburbs of Chicago. Image modified from Abrams et al. (2015).

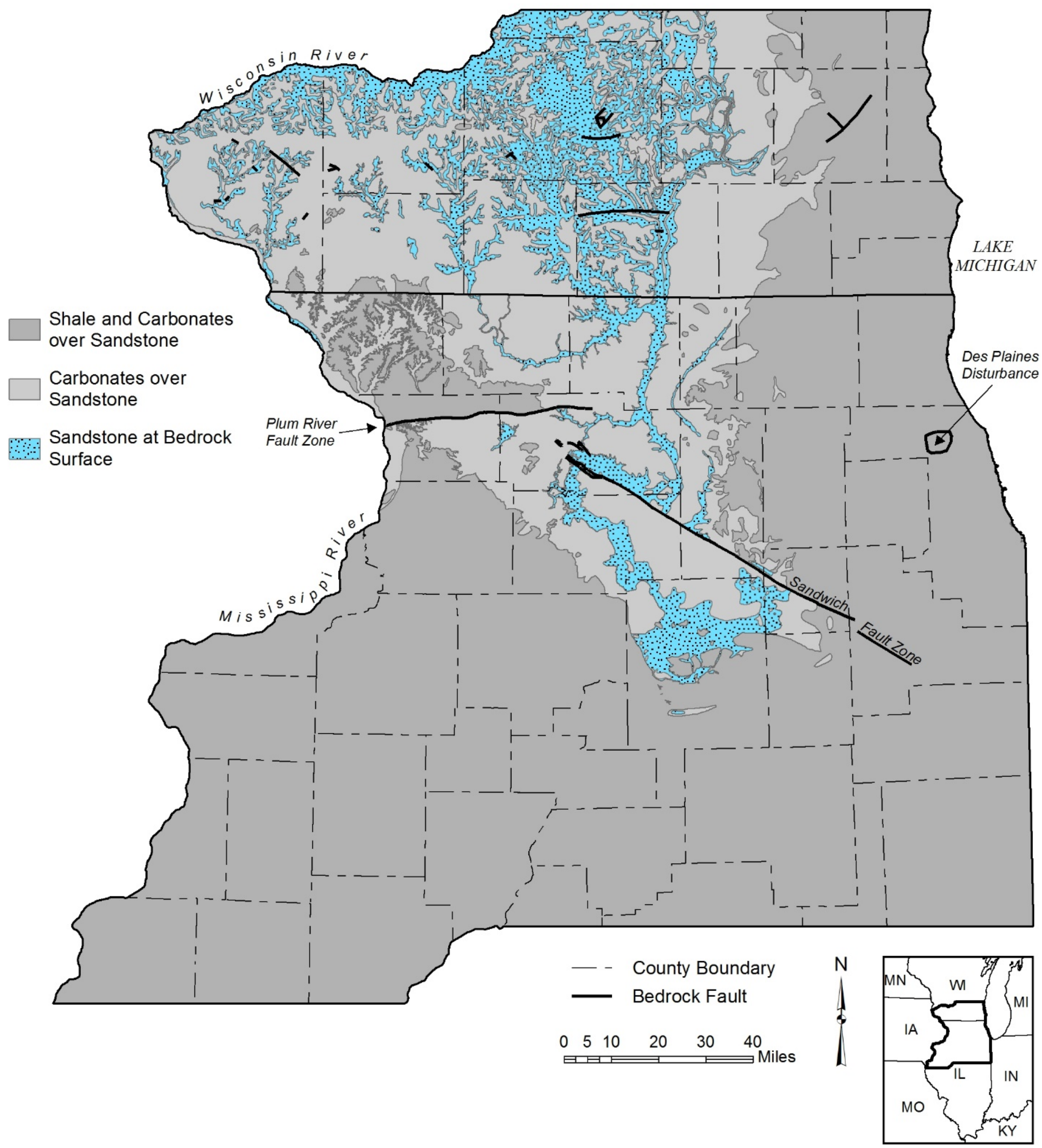

Figure 2: Lithology of bedrock material overlying the Cambrian-Ordovician Sandstone aquifers. Image from Abrams et al. (2015).

Leakage and Sustainability

Sustainability of the sandstone is defined as the maximum leakage that can occur vertically over an area. The ISWS has been investigating approaches to determine this leakage rate, with current approximations shown in an interactive web map: https://univofillinois.maps.arcgis.com/apps/webappviewer/index.html?id=0e2da1792bc64d3284a7b6b435d25efe. Details on the analysis and resulting estimates can be found in Mannix et al. (2018).

The current best estimates for wells open to both the St. Peter and Ironton-Galesville are that sustainable withdrawals are generally less than 0.001 million gallons per day () per square mile (mgd/mi^2) for most of the southwest suburbs. Leakage rates increase in central Grundy County, around Morris, IL, to approximately 0.1 mgd for each square mile. The sandstone is not overlain by shale for a considerable area in Grundy County, enabling greater leakage rates (Figure 2).

Most new wells in the southwest suburbs are open only to the deeper Ironton-Galesville Sandstone, so the above sustainable withdrawal metric does not apply. For these wells, in areas of new development where multi-aquifer wells are absent, the sustainable withdrawal rate is generally less than 0.0001 mgd/mi^2. Recent modeling at the ISWS indicates that the transition in well installation practice from wells open to multiple sandstone layers to only the Ironton-Galesville has had an important role in the accelerated decline in water levels in the region (Abrams et al. 2018; Mannix et al. 2018).

In Will County, where the preponderance of demands are located, the current best estimate of sustainable yield from the sandstone is 2.5 mgd if the St. Peter and Ironton-Galesville are both used, and less than 0.1 mgd if only the Ironton-Galesville is used (which is currently the most common situation). When considering both aquifers, Grundy (12.0 mgd) and Kendall (9.2 mgd) Counties experience increased sustainable yields. However, these yields may be misleading. Most demands are in the eastern portion of the counties where the sandstone is overlain by shale (i.e., small local leakage and sustainable yield), while the greatest aquifer sustainable yields are in the western, less populated, portions of those counties. Furthermore, these sustainable yields characterize the combined yield of both aquifers; however, most newly constructed wells are open only to the Ironton-Galesville Sandstone, which alone has a sustainable yield of < 0.1 mgd in both Grundy and Kendall Counties.

Unpublished work by the ISWS has attempted to define a range of realistic, sustainable yield estimates for the southwest suburbs, modifying both the parameters and methodology for calculating the metric. The latest results of this study indicate a worst-case estimate of 2 mgd and best-case of 7 mgd. Regardless of the approach, the calculated sustainable withdrawals are clearly less than current withdrawals in the region.

It is important to understand how sustainability is defined here. Pumping in excess of sustainable withdrawals will result in an overall regional decline in water levels, but the value does not necessarily consider **when** the needed supply will no longer be available. In Will County, withdrawals have been unsustainable for approximately a century, but supply issues for high-capacity wells are only now manifesting.

Water Use in the Southwest Suburbs

Communities withdrawing from the deep aquifers in the southwest suburbs include Aurora, Channahon, Elwood, Joliet, Lemont, Lockport, Manhattan, Minooka, Montgomery, Morris, Oswego, Rockdale, Romeoville, Shorewood, and Yorkville. Several industries also use the sandstone aquifer in the region, particularly where the Des Plaines River passes underneath I-55 (Figure 3). Total sandstone demands in the southwest suburbs were 51.5 mgd in 2018.

Total demands in the southwest suburbs in 1990 (55.5 mgd) were similar to current pumping from the sandstone. However, the distribution of pumping has changed considerably, as shown in Figure 4. In 1990, demands in Aurora and Naperville were much greater, while Joliet's demands were more focused on the eastern part of the city. Industrial demands along the Des Plaines River were also much smaller along I-55, but greater between I-355 and I-80 in 1990, while Kendall County had virtually no demands at all, with only one well exceeding 0.25 mgd. The most important difference between the 1990 and current demands is the growth and increased withdrawals along I-80 in western Will County, southeastern Kendall County, and northeastern Grundy County. This area anticipates future growth that is particularly problematic due to the proximity to the geologically complex Sandwich Fault Zone.

This study specifically addresses the SWPG region, whose demands are focused along the Des Plaines and Illinois Rivers. Total sandstone demands in the SWPG region, not accounting for shallow aquifer usage, were 36.7 mgd in 2018. Joliet, which plans to switch off the sandstone in 2030, accounts for 15.3 mgd. Industries account for 12.8 mgd. The current combined demand in the remaining communities (Channahon, Elwood, Lemont, Lockport, Manhattan, Minooka, Morris, Rockdale, Romeoville, and Shorewood) is 8.6 mgd.

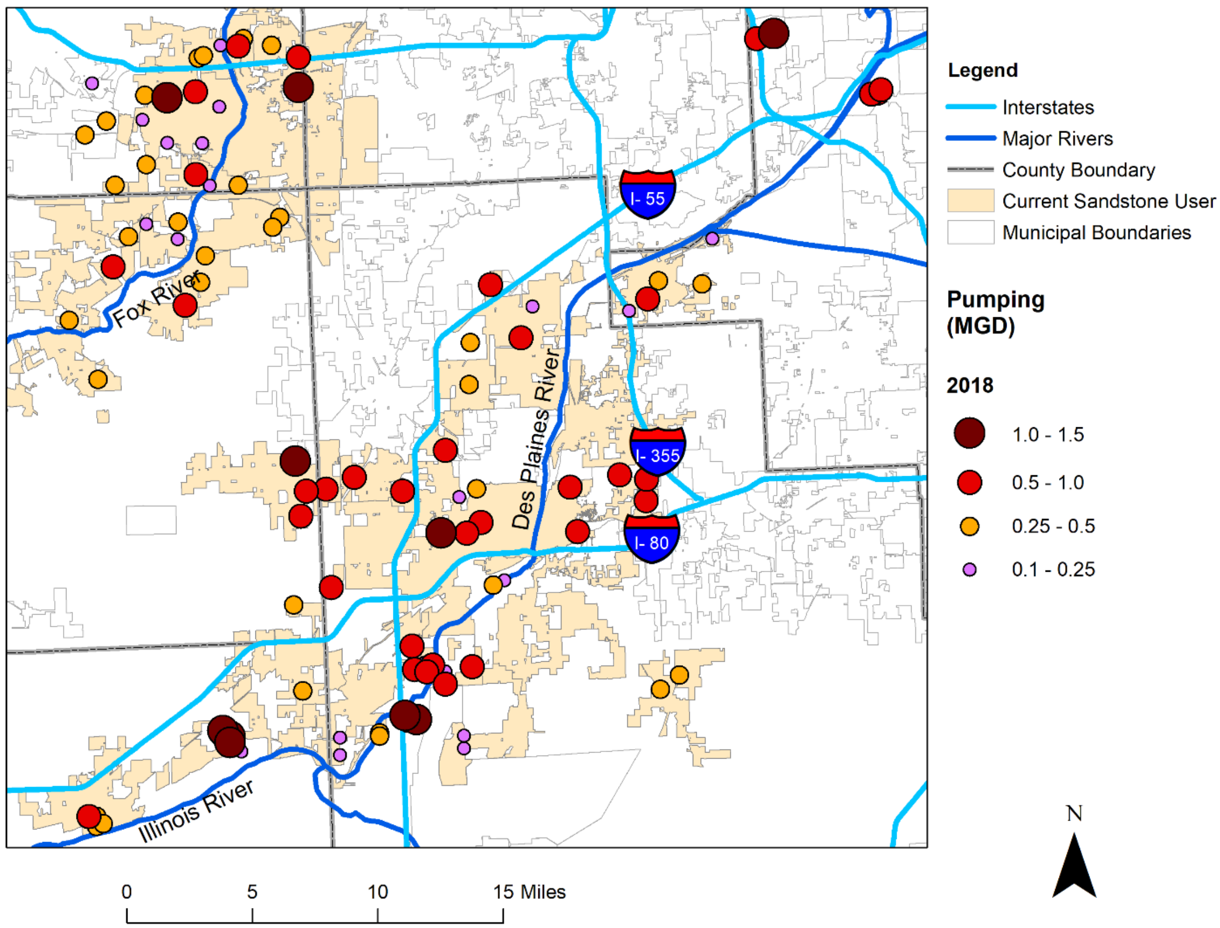

Figure 3: Current demands (2018) from the Cambrian-Ordovician Sandstone aquifer system in the southwest suburbs

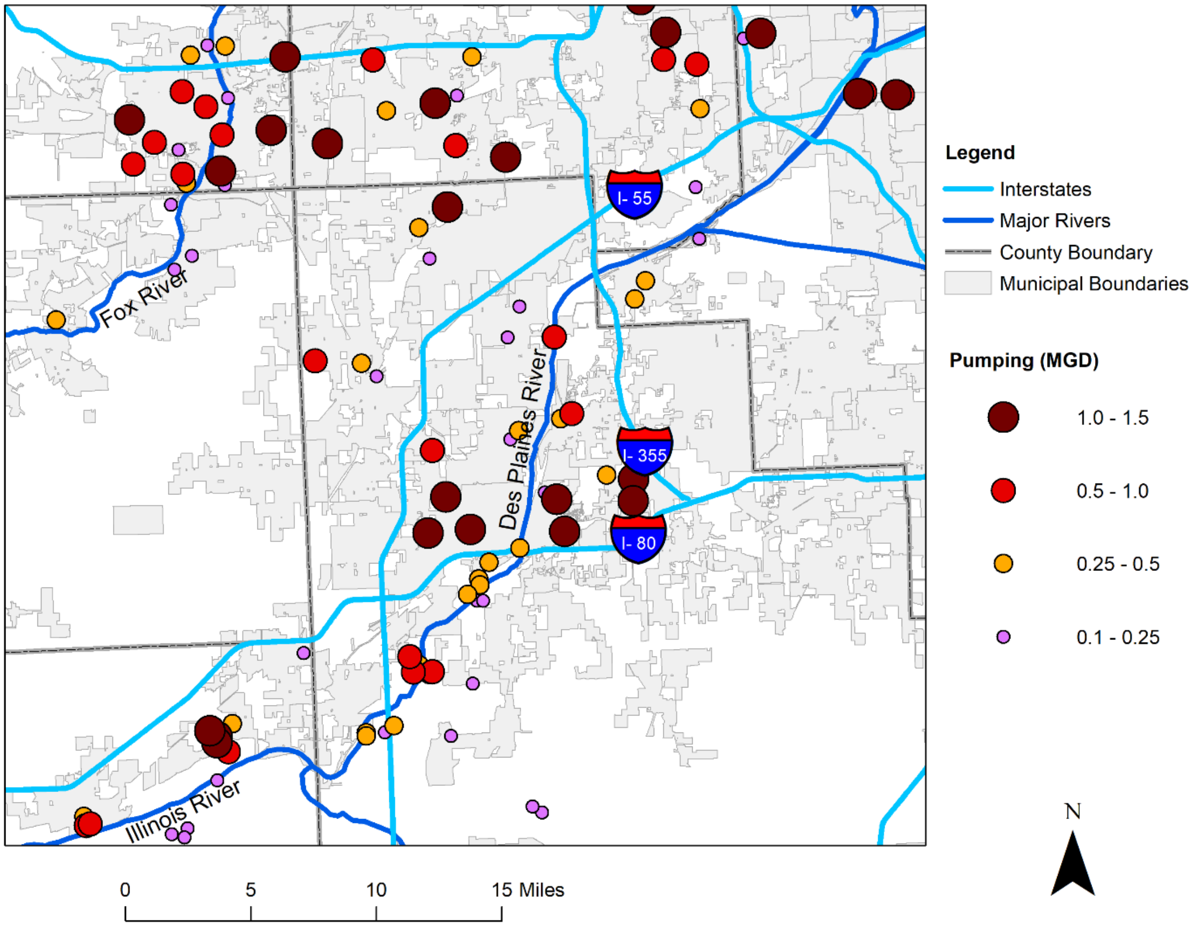

Figure 4: 1990 demands from the Cambrian-Ordovician Sandstone aquifer system in the southwest suburbs

Demands in the SWPG region began increasing before 1900 (Figure 5). Before the year 2000, the peak of reported pumping occurred in the mid-1970s with a sharp decrease following the peak, primarily from a decrease in reported industrial pumping. Water use reporting was more approximate before the Illinois Water Inventory Program (IWIP) was established in 1978. Pumping increased slightly from the mid-1980s to late 1990s. An almost 10 mgd increase occurred in the early 2000s, driven both by increased population and additional industrial demands. Those increased industrial demands appear to be due to process changes requiring improved water quality at existing facilities. This increase would have been larger if not for the departure of some industrial demands over the same period. Demands stopped increasing around 2008, coincident with the housing market crash, and remained flat for the next decade.

Any additional demands from the sandstone will result in unprecedented withdrawals in the region. Furthermore, with Joliet expected to leave the sandstone aquifer in 2030, the remaining water users, which total 58 percent of the current sandstone demands in the SWPG region, are still evaluating their future water supply. The major question being asked by communities and industries is whether the decrease in regional demands when Joliet no longer uses the aquifer will be enough to offset an increase in local demands as other communities grow in the coming decades.

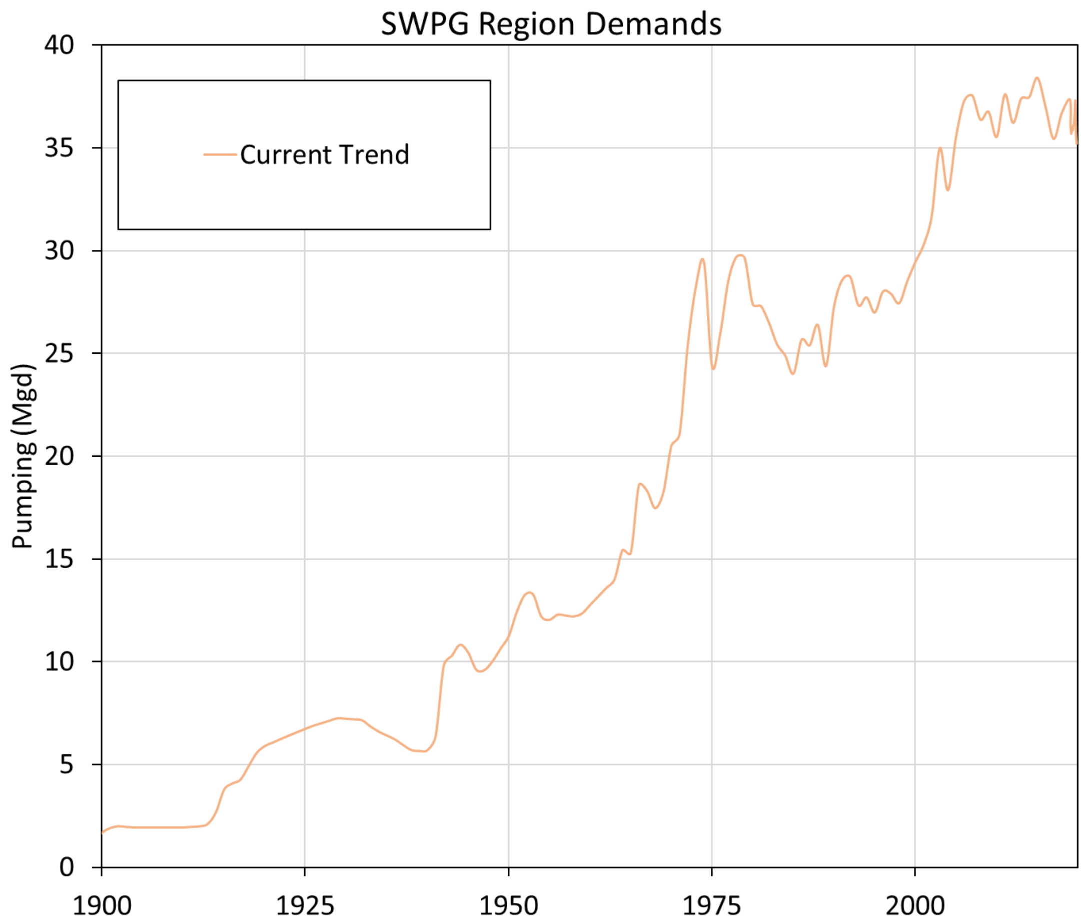

Figure 5: Changes in sandstone demands in the SWPG region

Groundwater Flow Model: Methods and Assumptions

The Illinois Groundwater Flow Model

The Illinois State Water Survey has developed a groundwater flow model that extends over the northern half of Illinois. The initial focus of this model was to assess sandstone supply throughout the state, and the model was used in the Phase 1 assessment of water supply for the City of Joliet (Crawford et al. 2019). The technical details of this model are documented in Abrams et al. (2018), covering information pertaining to the conceptualization, parameterization, inputs, and calibration of the model. This report briefly details the most important of the assumptions that go into this model and the implications of the uncertainty underlying those assumptions.

The model discretizes the geology in a 3-dimensional gridded network using the finite-difference code MODFLOW (McDonald and Harbaugh 1988). Each cell covers a 2500 ft by 2500 ft area, and has a thickness based on the hydrostratigraphic unit that it represents, resulting in layers coinciding with those shown in Figure 1. For example, the 18th layer in the model depicts the Ironton-Galesville, broken up into grid cells that are 2500 ft on each side and approximately 150–200 ft thick. Most layers have a uniform value assigned to each cell that determines how much flow moves through the aquifer (referred to as a hydraulic conductivity). Exceptions include complex hydrologic features such as the Sandwich Fault Zone, which consists of four to five cells of lowered hydraulic conductivity in the sandstone layers.

Model inputs also include boundary conditions in the form of rivers, lakes, recharge, and wells. Stages are assigned to the river and lake boundary conditions and are relatively unimportant to the model in northeastern Illinois. These surface water boundary conditions are more influential in the central part of Illinois where the sandstone is near the bedrock surface. Similarly, the sandstone model is highly insensitive to recharge rates assigned to the model, primarily because very little precipitation infiltrates to the deeper sandstone.

Wells, on the other hand, are much more important in the southwest suburbs. The time-domain of the model is broken up into annual stress periods, and wells are assigned to each stress period based on inferred or reported data. Before 1980, withdrawals are more speculative, but with the advent of the IWIP in 1978, reporting on a by-well basis has improved. Data gaps still exist, and those are generally linearly interpolated unless additional data are available. Both the rate of pumping and the open interval of wells matter, as will be further discussed in subsections titled *Assumption 1* and *Assumption 2*.

Historic Calibration

The ISWS has collected both water usage and water level data from communities and industries since the early 1900s. Abrams et al. (2018) discussed the calibration process in more depth, but briefly, both spatial and temporal calibrations are important for building confidence that the model can capture the large changes in demands that are anticipated in the coming decade in the sandstone aquifer. In general, the water levels used for calibration are taken during non-pumping (static) conditions, consistent with what is simulated by the groundwater flow model.

Figure 6 shows the model calibration to data collected during and since the 2014 synoptic measurement of the sandstone aquifer (Abrams et al. 2015). This includes monthly data collected since the start of the SWPG project in summer 2019. The plot shows model residuals, calculated as the observed value minus the simulated value. Where the simulated value is positive, model water levels are too low, shown with red arrows. Where the simulated value is negative, model water levels are too high, shown with blue arrows.

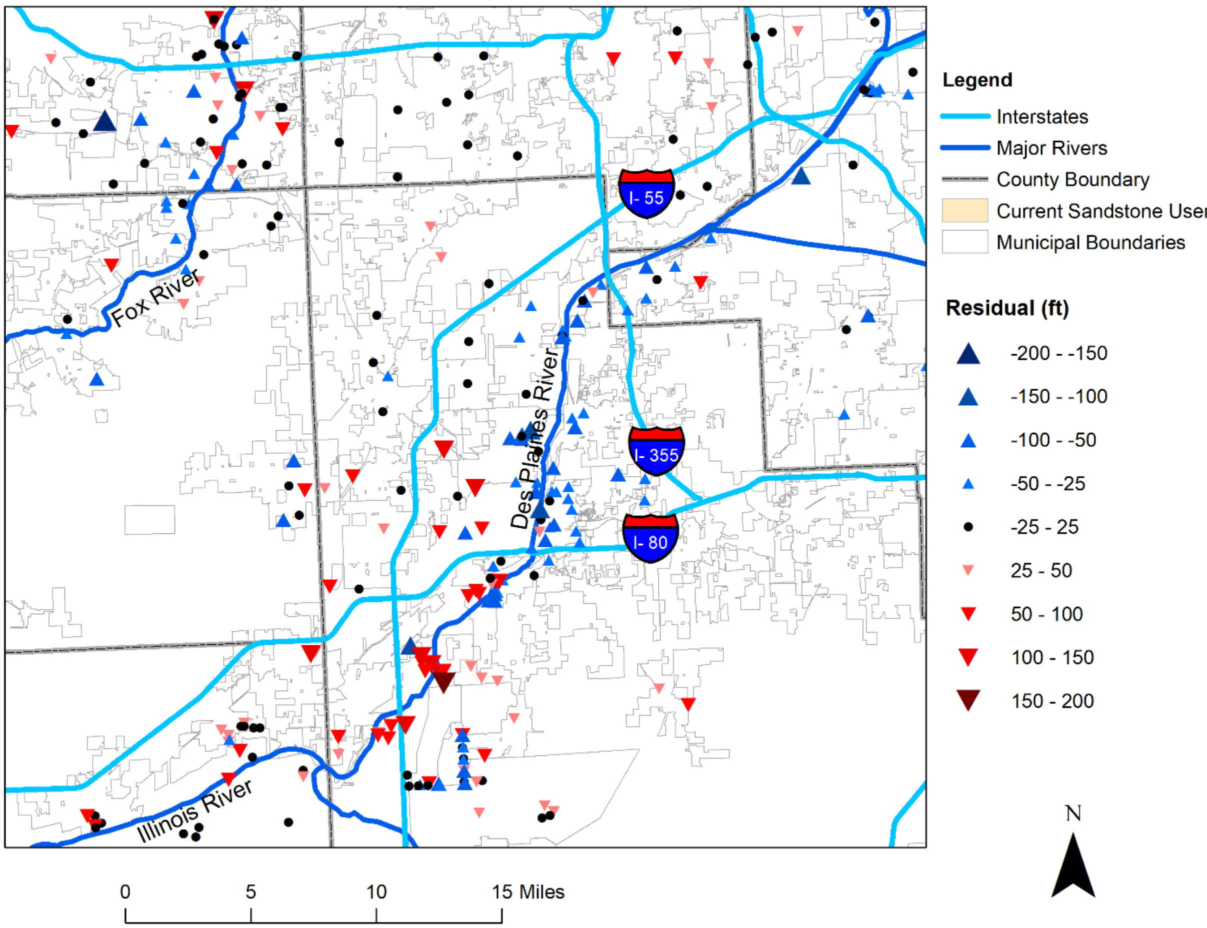

Figure 6: Calibration to water levels in the Cambrian-Ordovician Sandstone aquifer system. Blue indicates that model water levels are too high and red indicates they are too low.

Although ideally the model would have a minimal (< 25 feet) error in the water level for all observation points, there is too much noise in the data for this to be realistic. This is primarily because the model simulates annually averaged conditions, while seasonal fluctuations are present in the observed data. Recognizing this, the SWPG group has begun collecting monthly water level data to improve modeling of seasonal variability. This fine-tuned calibration is ongoing and will be discussed in more depth in a future report (2022).

Given the noise in the data, how should Figure 6 be interpreted? An area that contains a combination of red arrows, blue arrows, and black dots constitutes a "good" calibration, while an area with a disproportionate number of red or blue arrows has a bias. For example, simulated water levels along the Des Plaines River between I-355 and I-80 are generally biased too high, and the reason for this bias is currently not well understood. Water levels in the vicinity of where the Des Plaines River crosses underneath I-55 are biased too low, likely due to the presence of the Sandwich Fault Zone.

Areas with a spatial bias can still provide useful information if the trend is captured, which is the case for almost all wells. This trend in water levels through time is determined by evaluating each well's hydrograph. The simulated static water level is adjusted by offsetting all values through time by a single amount to match observations, as shown in Figure 7. The hydrograph in Figure 7 is from an industrial well with a long data history where unadjusted, simulated static water levels are biased too low by about 70 ft.

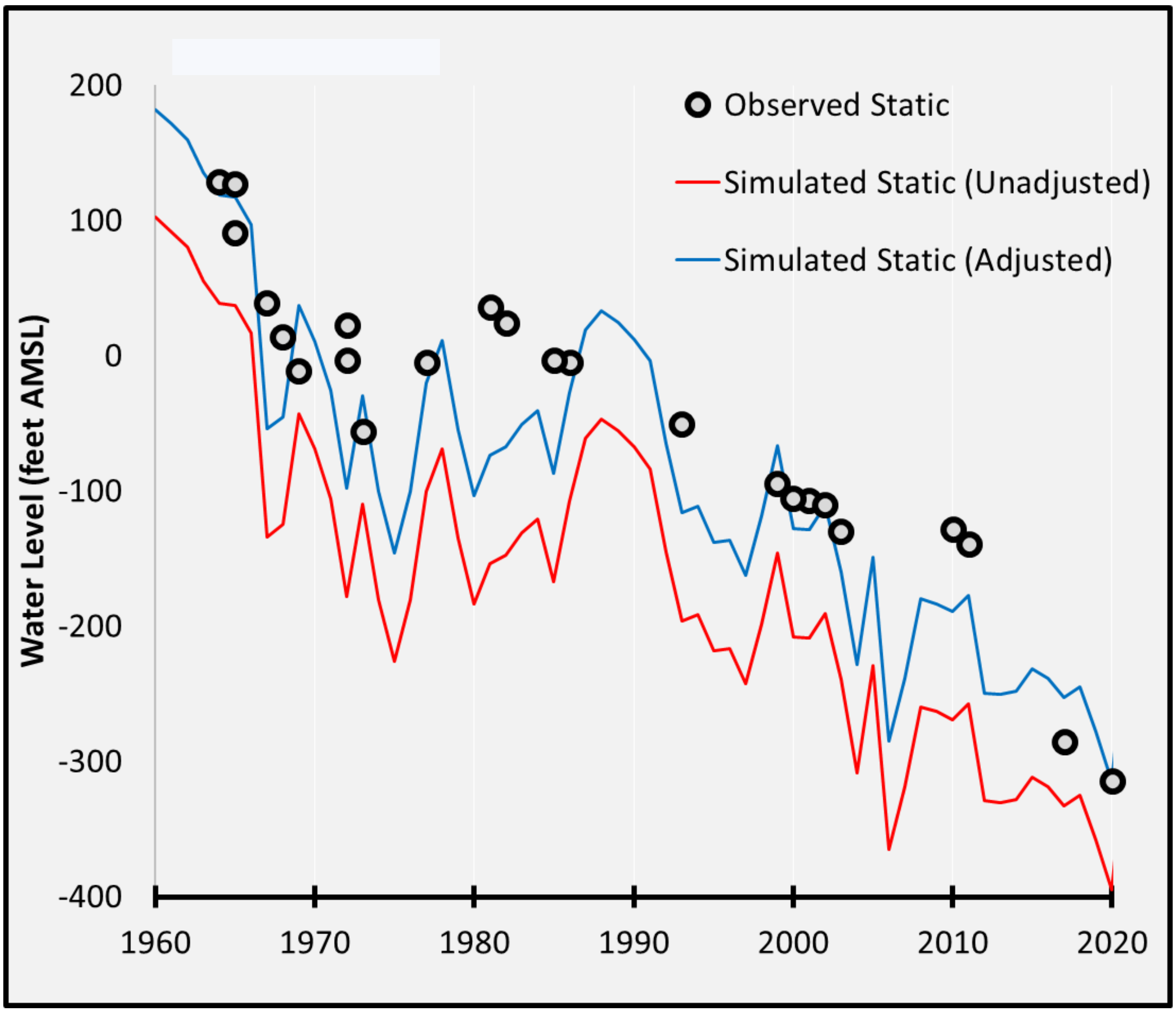

Figure 7: Adjustment of simulated static water levels to account for bias and improve assessment of risk

Due to the seasonal variability in water levels, hydrographs do not necessarily capture every observation, just the overall trend. In Figure 7, most observations are greater than the simulated value, while other monitoring locations may experience points greater and/or less than the simulated values. The monthly data collection ongoing with the SWPG effort seeks to improve this aspect of calibration and an understand of the variability during average and peak demand conditions, which plays a major role in assessing future risk to the deep sandstone aquifer. Please refer to Abrams et al. (2018) for additional details on calibration.

Assumption 1: Current Trend Future Demand Scenario

The model results detailed in this report are based on the Current Trend future demand scenario (Figure 8). This scenario assumes growth per Chicago Metropolitan Agency for Planning's projected population, discussed in the Joliet Phase 1 report (Crawford et al. 2019). The Current Trend assumes "business as usual," while an alternative scenario, "Less Resource Intensive," assumes water conservation goals and strategies are implemented to reduce water use per capita. This report focuses on the more conservative Current Trend scenario, while the lower demand scenario is considered in the sensitivity analysis at the end of this report.

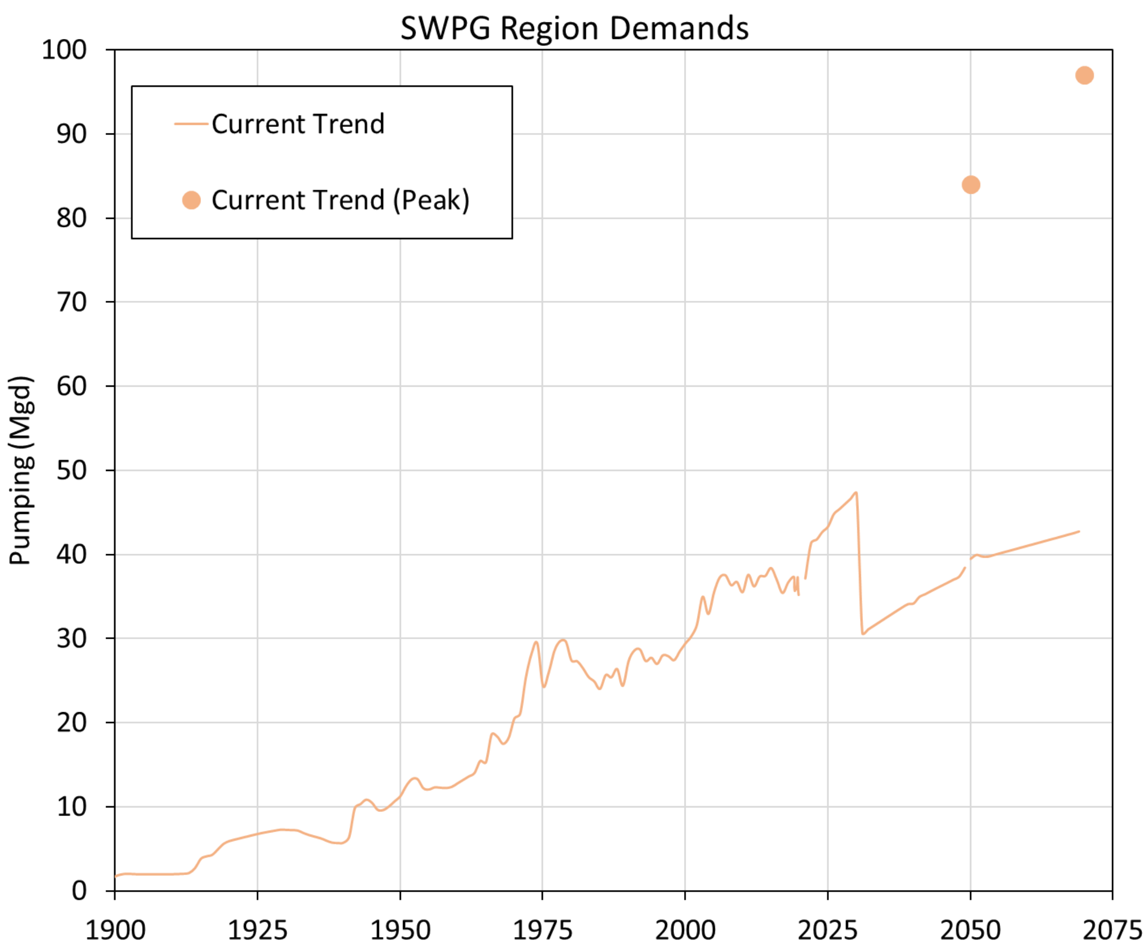

Figure 8: The Current Trend scenario analyzed in this study with the maximum daily demand shown in 2050 and 2070

The Current Trend scenario for SWPG communities, summarized in Table 1, underwent months of vetting at monthly SWPG meetings. Total sandstone water use demands of this trend for most communities remained unchanged from the Phase 1 Joliet study. Note that these pumping values are exclusively from the deep sandstone units, the St. Peter and the Ironton-Galesville, and do not include shallow aquifer pumping. Channahon and Minooka's sandstone demands grew because of previously unaccounted for growth in Grundy County compared to the Phase 1 study.

Table 1: Future sandstone demands (Current Trend) for communities participating in or falling within the SWPG study area. Industries within the SWPG region and communities in Kendall and Kane Counties are also included for comparison. Average and peak demands for 2050 are shown as mgd.

	2018	*2050 (Average)*	*2050 (Peak)*
Channahon	0.5	4.4	10.0
Elwood	0.3	1.3	3.9
Joliet	15.3	0.0	20.0
Lemont	1.6	1.8	3.8
Lockport	0.0	1.5	3.6
Manhattan	0.6	0.9	1.4
Minooka	0.8	2.5	5.0
*Morris**	1.8	2.7	4.1
Rockdale	0.1	0.8	1.0
Romeoville	2.1	3.9	5.1
Shorewood	0.8	2.5	2.8
Industries	12.8	15.0	21.8
Kendall/Kane	11.6	6.8	23.8

**Demand estimates did not exist for Morris, so average percent increases in Northeastern Illinois were applied.*

Another change from the Phase 1 Joliet study was the future proportioning of shallow aquifer versus deep sandstone demands. Some communities, such as Shorewood, Minooka, and Channahon, requested that a larger proportion of their communities' total demands be shifted from the shallow dolomite aquifers to the deep sandstone. The primary reason was the increasing chloride concentration in the shallow dolomite aquifer wells due to road salt contamination (Kelly 2020). Similarly, Lockport provided additional information about a newly drilled deep well and a potential future deep well. These prospective deep well installations are largely driven by potential impacts to the habitat of the endangered Hines Emerald Dragonfly. Previous demands added during the Phase 1 Joliet study in Crest Hill and Romeoville were removed for the same reason after receiving community feedback.

There are four distinct regions in the SWPG study area to consider. First, Joliet-proper has an approximate 15 mgd reduction in demand between the current conditions and 2050, save for a 14-day period when the sandstone wells at Joliet are used during a hypothetical service interruption from Lake Michigan. Second, demand from the combined area of Shorewood, Minooka, and Channahon increases from 2.1 mgd in 2018 to 9.4 mgd in 2050; this large increase, combined with the proximity to the Sandwich Fault Zone, has a major influence on the model results as will be discussed later in this report. Third, the demand from the combined area of Romeoville, Lockport, and Lemont experiences an increase of 3.6 to 7.3 mgd. Finally, the area of Elwood and Manhattan experienced a more modest growth from 0.9 to 2.2 mgd, although some industrial growth was also simulated in the model in the region. A map of the 2050 demands with Joliet's switch from the aquifer is shown in Figure 9.

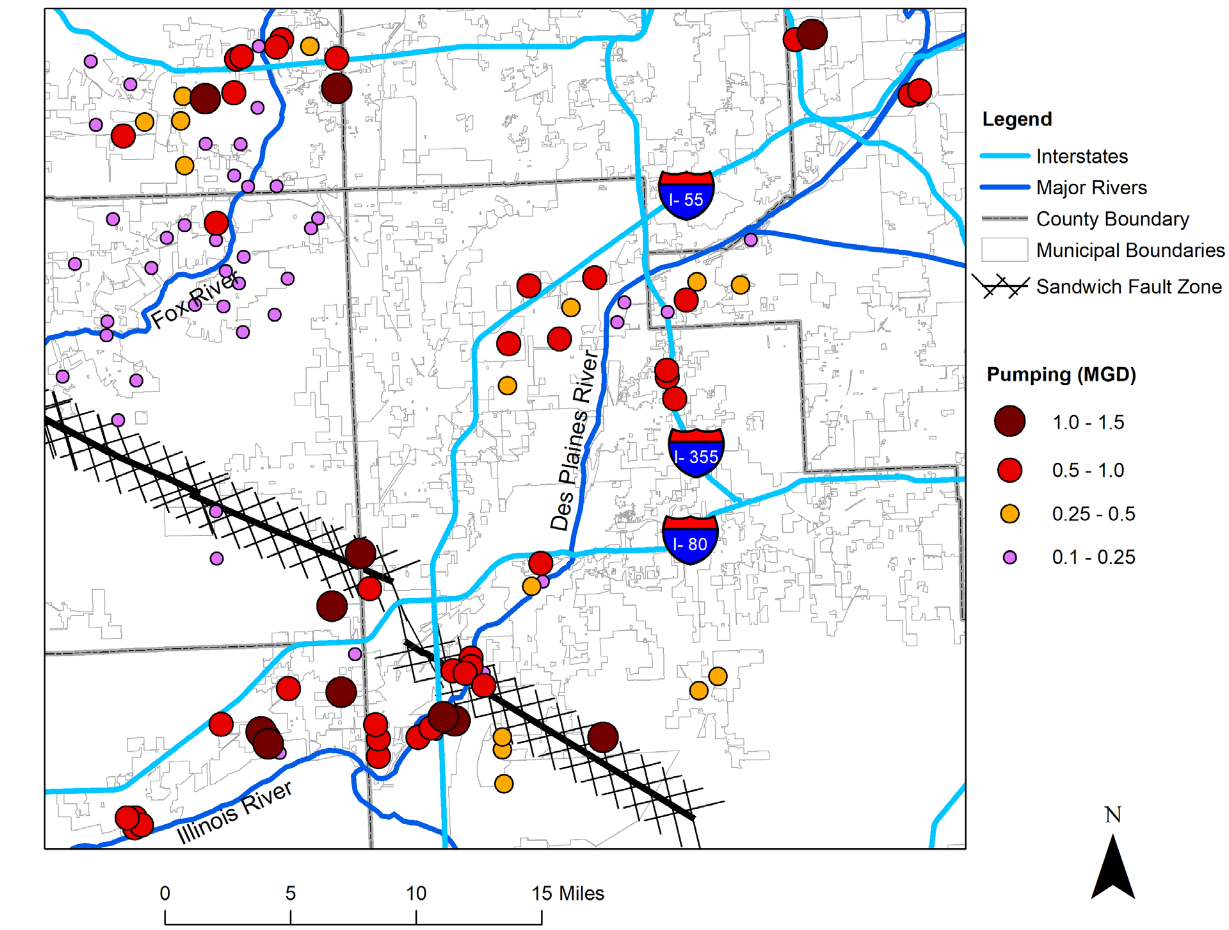

Figure 9: 2050 demands in the Current Trend simulation

A few points should be clarified about the demands in Table 1. Joliet is assumed to leave the aquifer in 2030, hence 2050 average daily demands are zero except for a 14-day period in the model, indicative of a service interruption. Average conditions are used for Joliet during this 14-day span, which coincides with peak demand for all other communities, as listed in the Table 1 2050 peak conditions column. The same treatment was applied to Oswego, Yorkville, and Montgomery (summed with Aurora and categorized as "Kendall/Kane"), which leave the aquifer but return for this 14-day period. These communities are assumed to leave the aquifer in 2035. This 14-day period of combined peak pumping/service interruption was assumed to occur in 2050 and 2070 in the groundwater flow model, although, in reality, this could occur at any point.

An advantage of the ongoing work in the SWPG region is that potential new wells can be identified and incorporated into the model based on local feedback, preventing the model from stacking demand growth in existing wells unequipped for additional pumping. Not all wells represent additional new sandstone demands, such as the newly drilled Romeoville 14, but instead are intended to replace old or poorly performing wells. Other wells, such as the newly drilled well in Lockport, are intended to reduce demands from the shallow aquifer.

The following wells were added to the model:

- Channahon (3 wells in 2020, 2025, 2035)
- Minooka (2 wells in 2025 and 2035)
- Shorewood (2 wells in 2030 and 2050)
- Romeoville 14 (1 well to be online in 2020)
- Lockport (2 wells added in 2020 and 2030)
- Joliet (2 wells to be online in 2021 and 2025)
- One new industrial well (2020), no net increase at facility totals
- One new industrial well (2025), increase in facility totals

This report does not attempt to address the most likely year that the aquifer will be at risk, an effort that would require a suite of model simulations and a more advanced uncertainty analysis. Also, an analysis attempting to identify this answer may be misleading since the aquifer is highly responsive to changes in demands, both locally and regionally.

Assumption 2: Multi-Aquifer Wells

The open interval of wells has changed dramatically through time, particularly in the southwest suburbs. Originally, most wells constructed were open to all sandstone aquifers, but problems occurred as water levels fell. For example, the St. Peter Sandstone has had issues with caving, resulting in the need to install liners that tend to fail after a couple of decades. If the water level in a well falls below the bottom of the St. Peter Sandstone, water can cascade down, introducing oxygen and potentially biologically fouling the well bore. As a result, since the 1960s, there has been a trend to install wells open only to the deeper Ironton-Galesville Sandstone. Similarly, wells open to all sandstone aquifers have been sealed, resulting in a decline in connections.

The groundwater flow model indicates that the addition and removal of those connections, multi-aquifer wells (MAWs), play an important role in calibrating the groundwater model to observed water levels in the SWPG region. The ISWS has considered several possible explanations for the need to remove MAWs in the model:

- Unreported well sealings to the ISWS.
- Mineral-scale formation and biological fouling along the well bore due to changing chemistry with dewatering in the St. Peter, including the introduction of oxygen, resulting in a loss of productivity. This is particularly likely in the common scenario in which only the Ironton-Galesville is rehabilitated, while the St. Peter is not.
- Local dewatering of the St. Peter that is not captured in a 2500 ft by 2500 ft grid cell.

As a result, MAWs are removed from the historic and future model simulation. A common point of discussion at the SWPG meetings was that a well in a specific location in Figure 10 had either not been sealed or had no immediate plans to be sealed. Indeed, not all wells removed were sealed by a driller. However, the St. Peter could lose connection with the Ironton-Galesville if the St. Peter is dewatered or not rehabilitated frequently. Historically, the selection of well removal was largely driven by changes in observed water levels that could not be explained by changes in pumping. Modeled multi-aquifer well locations are based on sparse open interval data in the ISWS database, which may not fully represent the extent of all connections between the St. Peter and the Ironton-Galesville aquifers.

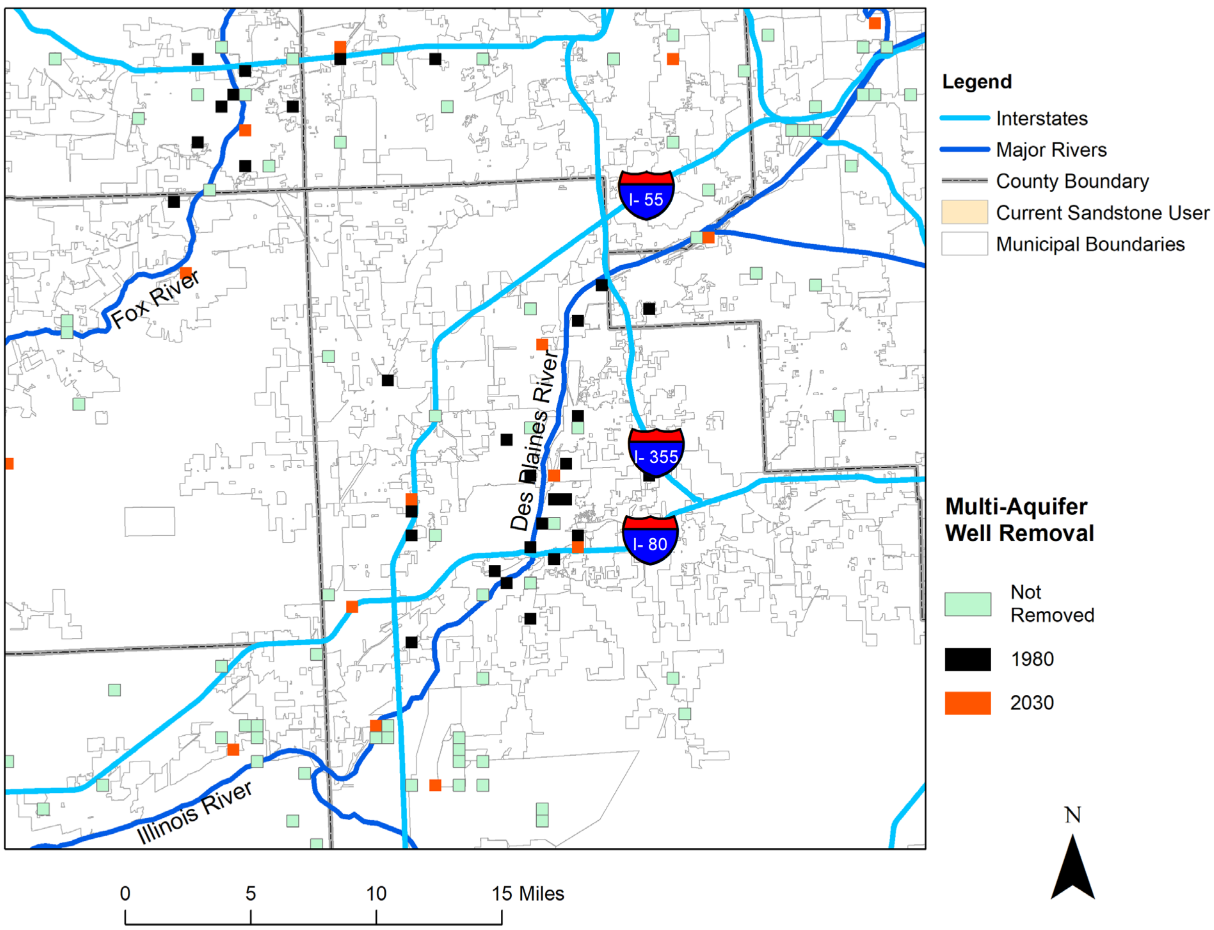

Figure 10: Location of cells simulating multi-aquifer well flow between the St. Peter and Ironton-Galesville. Green cells indicate wells that are never removed in the simulation, black represents wells that were removed in 1980 in the simulation, and orange indicates wells that are removed in the future simulation (with removal being phased from 2030 to 2050).

Defining Risk

The maps and hydrographs developed for this report determine risk by comparing simulated static water levels to the top of the Ironton-Galesville Sandstone aquifer. Static water levels that are less than 400 ft above the top of the Ironton-Galesville are referred to as having a "risk of well inoperability." Static water levels between 400 and 600 ft above the top of the Ironton-Galesville are defined as having a "risk of declining well performance." A summary of specific risks in the two zones is provided in Table 2. Specific details of how this risk is determined and should be interpreted are outlined in this section.

Perhaps the biggest uncertainty in the southwest suburbs is related to how deep a pump can be lowered, which in turn defines when a well will no longer be able to meet demands. After talking with drillers, the current hypothesis is that a pump cannot be lowered below the top of the Ironton-Galesville Sandstone, especially for existing wells. Currently, most static water levels are between 400 and 600 ft above the top of the Ironton-Galesville Sandstone with an additional 200 ft of drawdown when pumping. However, for the most at-risk wells in the region, static water levels are approaching 400 ft above the top of the Ironton-Galesville, in some cases with 400 ft of additional drawdown when pumping. In other words, the theoretical limit on how far a pump can be lowered is quickly being reached.

These most at-risk wells have shown demonstrable decreases in specific capacity through time. Specific capacity is defined as the ratio of pumping to drawdown and is generally reported in units of gallons per minute per foot (gpm/ft). Extensive datasets for specific capacity are rare, but very insightful. For example, one at-risk well had a linear decline in specific capacity from 4.5 gpm/ft in 2000 to 2.0 gpm/ft in 2020. Also, this well is in the geologically complicated Sandwich Fault Zone. As a result, an important question must be raised: is the at-risk nature of these wells purely a function of being in the fault zone or are their low water levels occurring at the center of a cone of depression? In other words, will wells currently with a 200 ft decline in water levels lose specific capacity (and experience more drawdown) as a result of water levels falling or wells getting older? With the consideration that a 200 ft decline is not enough to assess risk, we chose to use 400 ft as a conservative threshold to define the zone of risk of well inoperability.

Future demands assume a linear increase in communities' demands but no growth in industrial demands except for immediate plans shared by the SWPG group. An unsimulated demand could be due to a new industry moving in or an existing industry changing processes to require different water quality. Other possible unsimulated sources include sandstone communities having new demands from unexpected growth or shallow aquifer communities forced to use the sandstone because of water quality or quantity issues in the shallow aquifer. The aquifer is highly responsive to new demands, and these must be considered when determining risk. The proximity of a new well to a community and the pumping and actual rate of withdrawal of a new well are critical components in determining the actual risk (Figure 11, see Appendix I for details of how this graphic was developed). For example, 200 ft of drawdown could result from a new source pumping 3 mgd located 1 mile away from an existing well or a new source withdrawing 4 mgd spaced 2 miles away from an existing well. This water level sensitivity is the primary reason to define an additional risk zone from 400 to 600 ft above the top of the Ironton-Galesville, referred to as the risk of declining well performance. In addition to the risk of unsimulated demands, there are additional risks in this zone, outlined in Table 2, including increased cost to operate the well and the potential to pump sand in multi-aquifer wells open to the St. Peter, which is prone to caving.

Table 2: Summary of risks associated with different zones. IG - Ironton-Galesville.

Risk of declining well performance (400–600 ft above the IG)	**Risk of well inoperability (< 400 ft above the IG)**
Risk of dry wells (domestic and industrial)	Severe risk of well inoperability
Lost well performance	Reaching a limit that pump can be dropped
Potential for pumping sand	Uncharted territory
Interference from neighboring wells	Exacerbated risks associated with declining well performance
Increased well maintenance costs	
Increased cost of lifting water	
Vulnerable to new sandstone demands	

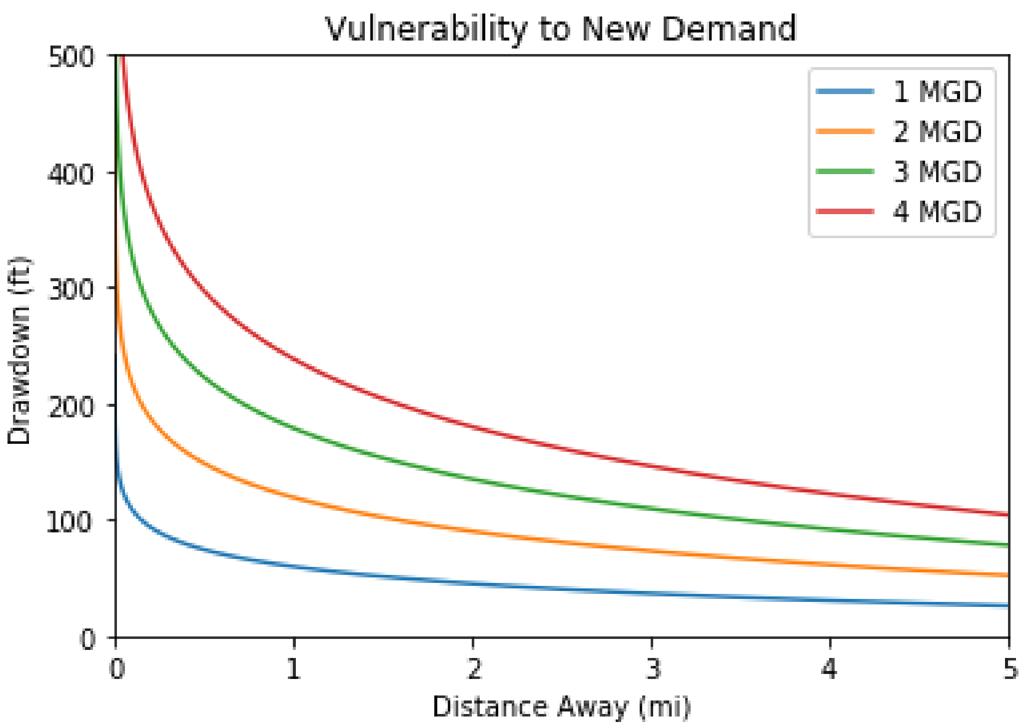

Figure 11: Drawdown in response to new demands at different pumping rates. The x-axis indicates the distance the new demand is from the current source.

This study considers risk only to high-capacity wells that can or already have sealed off the uppermost St. Peter for the preservation of the lower Ironton-Galesville (although at the possible cost of specific capacity). However, some industries and domestic wells rely exclusively on the St. Peter Sandstone aquifer in areas of Will County. These supplies are particularly vulnerable to withdrawals from MAWs open to the St. Peter and Ironton-Galesville. The management strategy of constructing connections through new MAWs to extend the life of the aquifer would exacerbate the risk for shallower industrial and domestic St. Peter Sandstone users.

Results/Discussion

Risk Maps

A series of maps developed from the groundwater flow model show the changing risk through time (see Figure 12 through Figure 20). Figure 12 indicates risk in 1990, with peak use of the sandstone immediately outside of the SWPG region. Groundwater use in southern DuPage and southeastern Kane Counties was at a maximum, primarily because of Naperville's and Aurora's heavy use of the sandstone aquifer. The Ironton-Galesville static water levels were within 400–600 ft above the top of the Ironton-Galesville, resulting in the risk of declining well performance in Central Joliet (between I-55 and the Des Plaines River) and extending north into DuPage County. In the early 1990s, Naperville switched away from the sandstone aquifer, and Aurora switched partially to the Fox River. In contrast, demands along the eastern Kendall/western Will County borders were starting to grow.

Demands in the SWPG region grew considerably over the next three decades, mostly driven by municipal and industrial growth in the early 2000s (Figure 5). In particular, demand increases were prominent in western Joliet and Shorewood and from industries along I-55/the Des Plaines River (Figure 13). Outside of the SWPG region, the communities of Oswego, Yorkville, and Montgomery in Kendall County also grew rapidly. As a result, the risk of declining well performance extended west into Kendall County, although the risk zone was no longer present in DuPage County because of the large number of communities that left the sandstone aquifer in the 1990s. For the first time in the region, a small patch of static water levels neared 400 ft above the top of the Ironton-Galesville Sandstone aquifer, located where the Des Plaines River passes over the Sandwich Fault Zone. This indicated an increased risk of well inoperability.

The Current Trend model scenario assumes an increase in regional (SWPG) pumping rates of 10.7 mgd between 2018 (most recent data at the time of this report) and 2030. The increase in demand decreases static water levels in a large area of the region below 400 ft above the Ironton-Galesville, resulting in the risk of well inoperability for multiple communities and industries (Figure 14). Communities and industries falling into the zone of risk of well inoperability are in uncharted territory, and careful monitoring of both pumping and static water levels will be necessary to manage sustainable pumping. Demands considered in the base Current Trend scenario are greater than those of the Joliet Phase 1 water supply investigation, which found that the city should switch off the sandstone aquifer by 2030 (Crawford et al. 2019). However, the Phase 1 assessment was based on several scenarios, including one higher growth scenario (Current Trend + 2 mgd) that had very similar results to the Current Trend scenario depicted in this report. As a result, this single scenario does not change the conclusion of that analysis but does indicate that the status of the aquifer should be monitored, and the 2030 timeframe should be fully reassessed in 2022 at the end of the ISWS study or sooner if growth happens faster than anticipated.

After Joliet switches off the sandstone aquifer, modeled to occur in 2030, water levels do recover. In some communities, particularly south of the Sandwich Fault Zone, recovery from Joliet departing the sandstone aquifer is effectively offset by new demands. In other communities with a lower growth rate, such as Romeoville, only ~100 ft of recovery is observed, similar to the recovery observed when Naperville and Aurora transitioned away from the sandstone aquifer in the early 1990s. In general, the gain in water level from Joliet leaving the aquifer, while considerable, is relatively small compared to the overall drawdown of water lost from predevelopment conditions in the late 1800s when water levels were near land surface. As a result, risk zones persist. The zone of risk of well inoperability diminishes greatly after Joliet leaves the aquifer, but does not disappear (Figure 15), persisting in the same location as in 2020, along the Sandwich Fault Zone. The risk of declining well performance area after Joliet leaves the aquifer is very similar to the 2020 risk zone. This indicates that the increase in demands outside of Joliet is enough to offset the rebound in water levels from Joliet's departure. Since demands on the Cambrian-Ordovician Sandstone aquifer system are unsustainable, any reasonable projection of future demand increases will also be unsustainable. Water removed will not be replaced on a sustainable time horizon (the groundwater flow model estimates that centuries are needed to replenish the aquifer).

Modeled recovery is simulated again in 2035 when Oswego, Yorkville, and Montgomery are assumed to switch off the sandstone aquifer (Figure 16). Visually, the risk appears smaller, but the actual recovery in water level is relatively muted, and water levels are still hovering around 600 ft above the top of the Ironton-Galesville in much of the region. The risk of well inoperability remains along the Sandwich Fault Zone.

In 2050, the risk of declining well performance expands again, with the risk of well inoperability also expanding along the fault zone and in southeastern Kendall County (Figure 17). This risk is compounded when considering peak demands (Figure 18), shown as spikes in the time series plot of pumping in Figure 9. During peak demands, risk of well inoperability also appears along I-355, the first appearance of this higher risk zone in this area of Will County. This model simulation assumes that peak demands coincide with Joliet requiring the sandstone aquifer for a period of 14 days due to a hypothetical Lake Michigan service interruption.

The model scenario was simulated through 2070, where both average (Figure 19) and peak (Figure 20) conditions were simulated again. Risk continued to expand throughout this model scenario. Almost every community in the SWPG region suffers the risk of declining well performance, with many also experiencing risk of well inoperability, especially within the fault zone. Also, by 2070, more prominent areas with a risk of well inoperability occur in northern Will County.

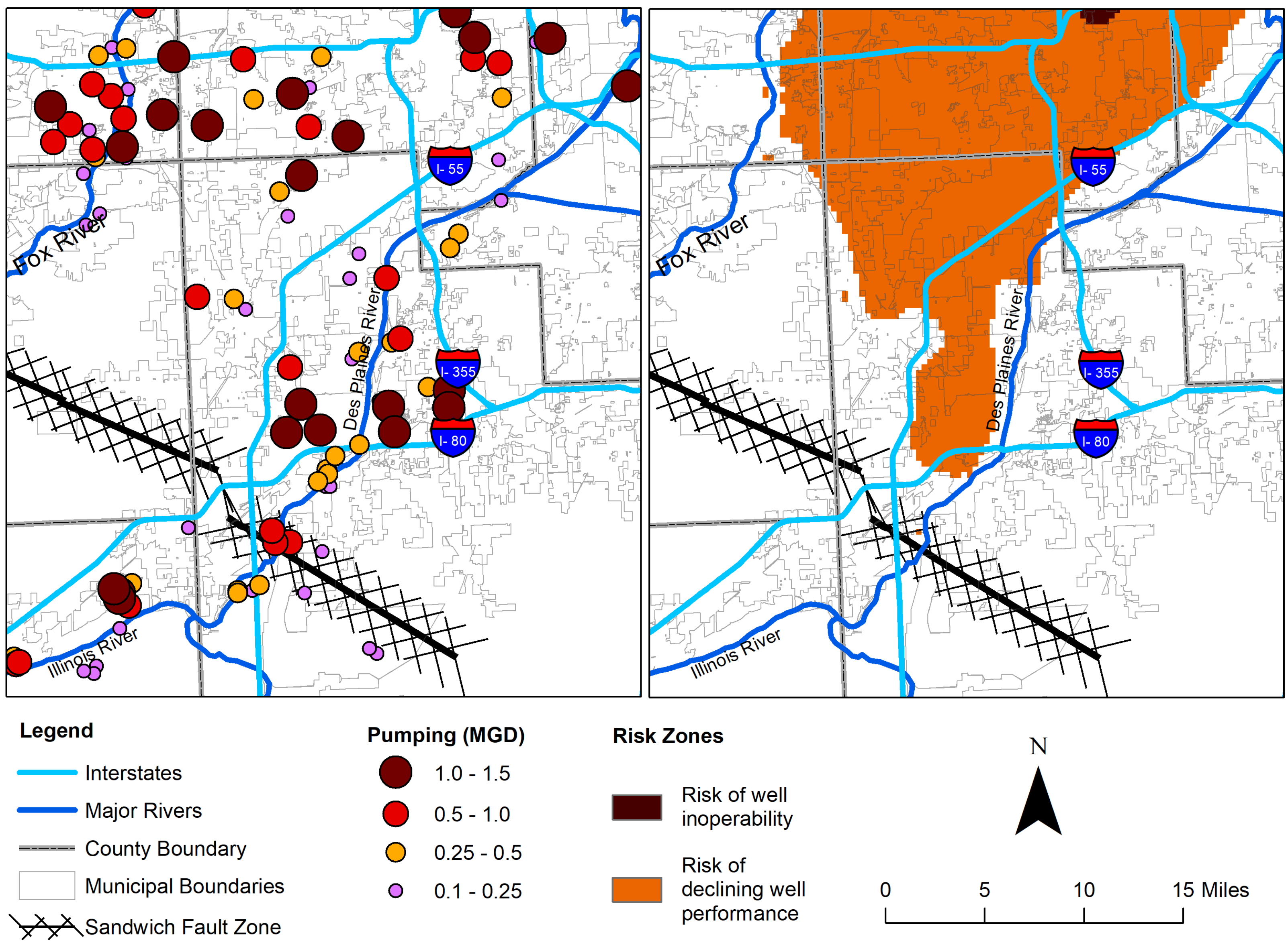

Figure 12: 1990 pumping and risk in the Ironton-Galesville Sandstone aquifer

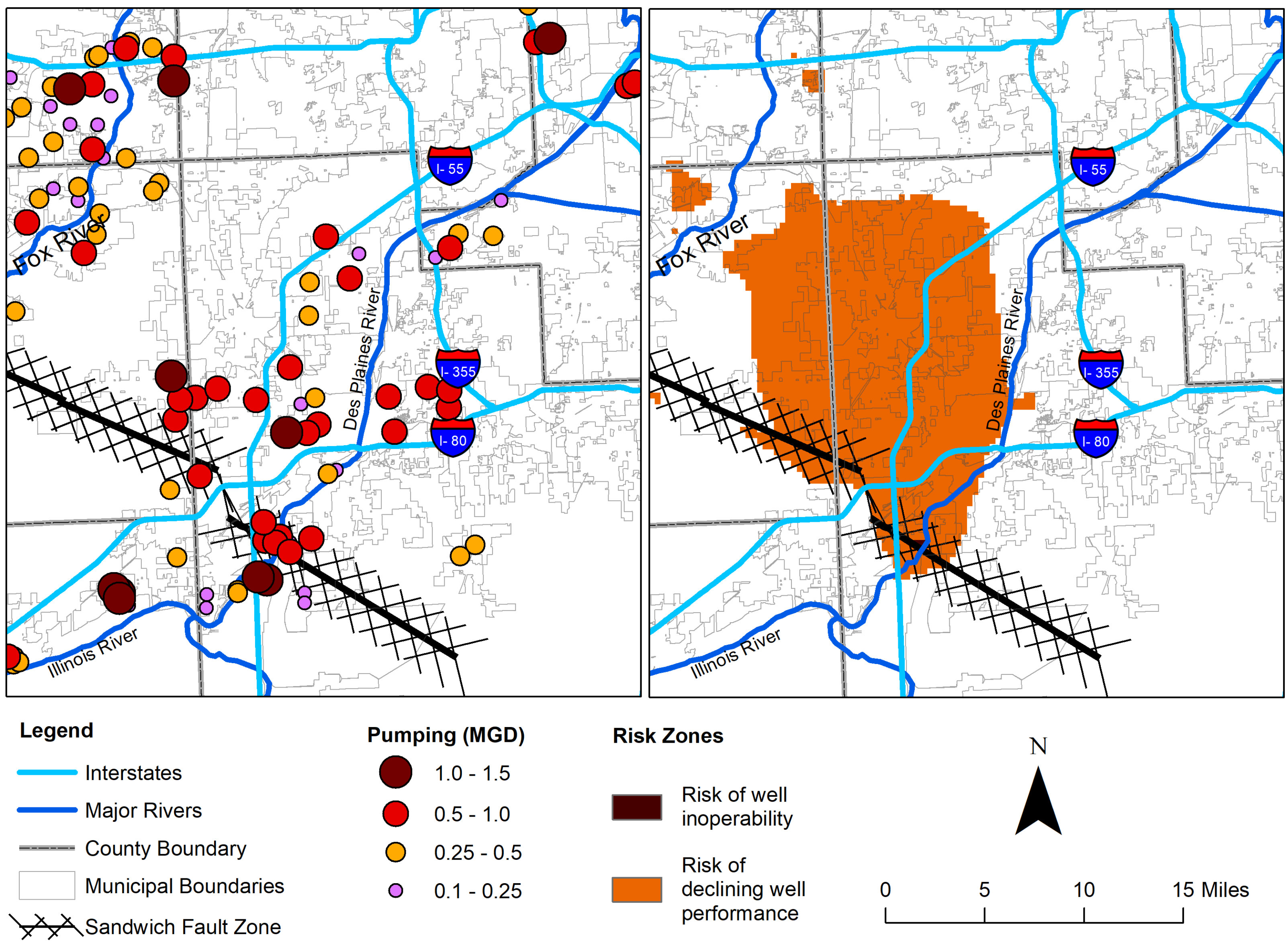

Figure 13: 2020 pumping and risk in the Ironton-Galesville Sandstone aquifer

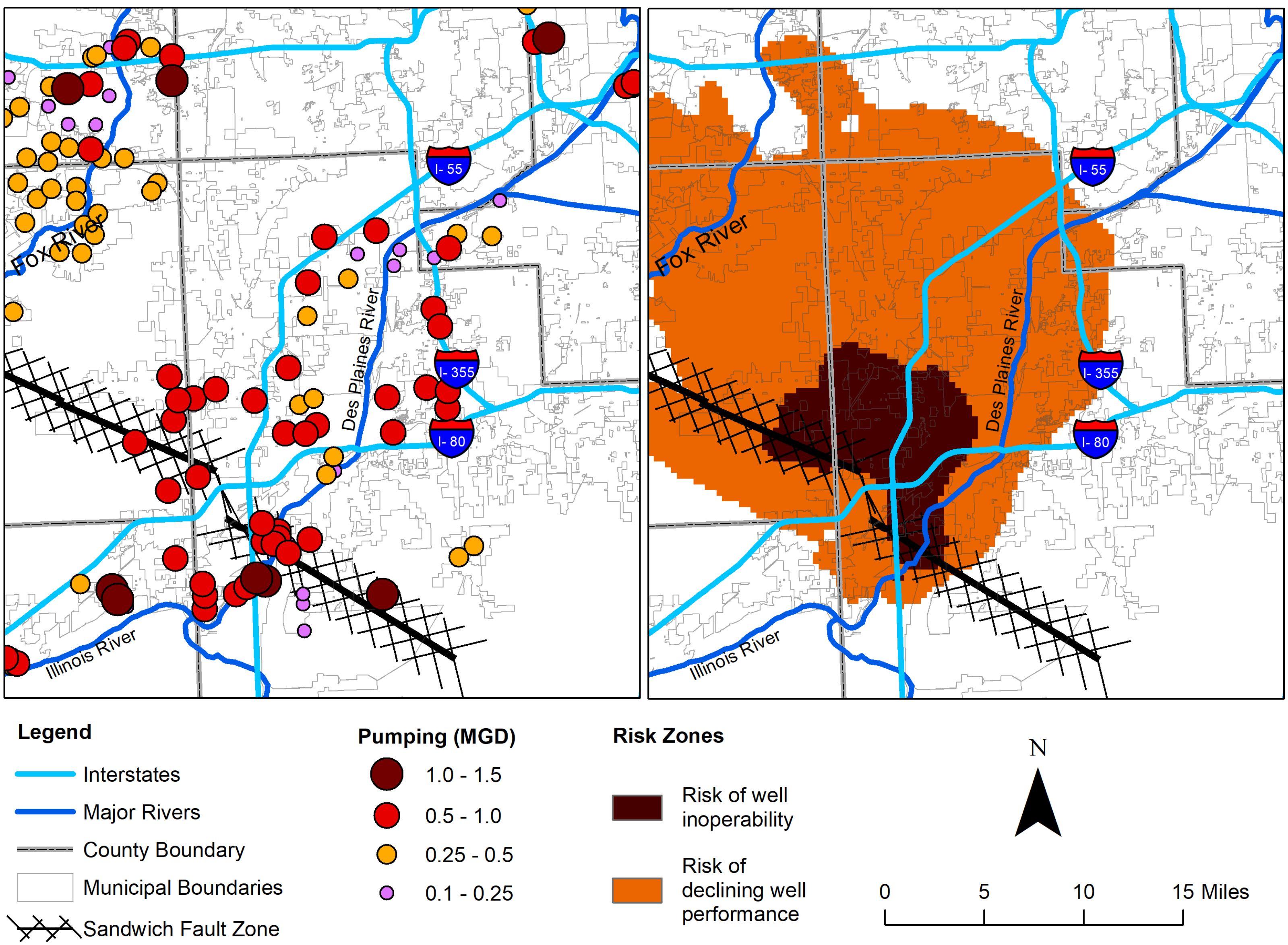

Figure 14: 2029 pumping and risk in the Ironton-Galesville Sandstone aquifer (before Joliet switches from the aquifer)

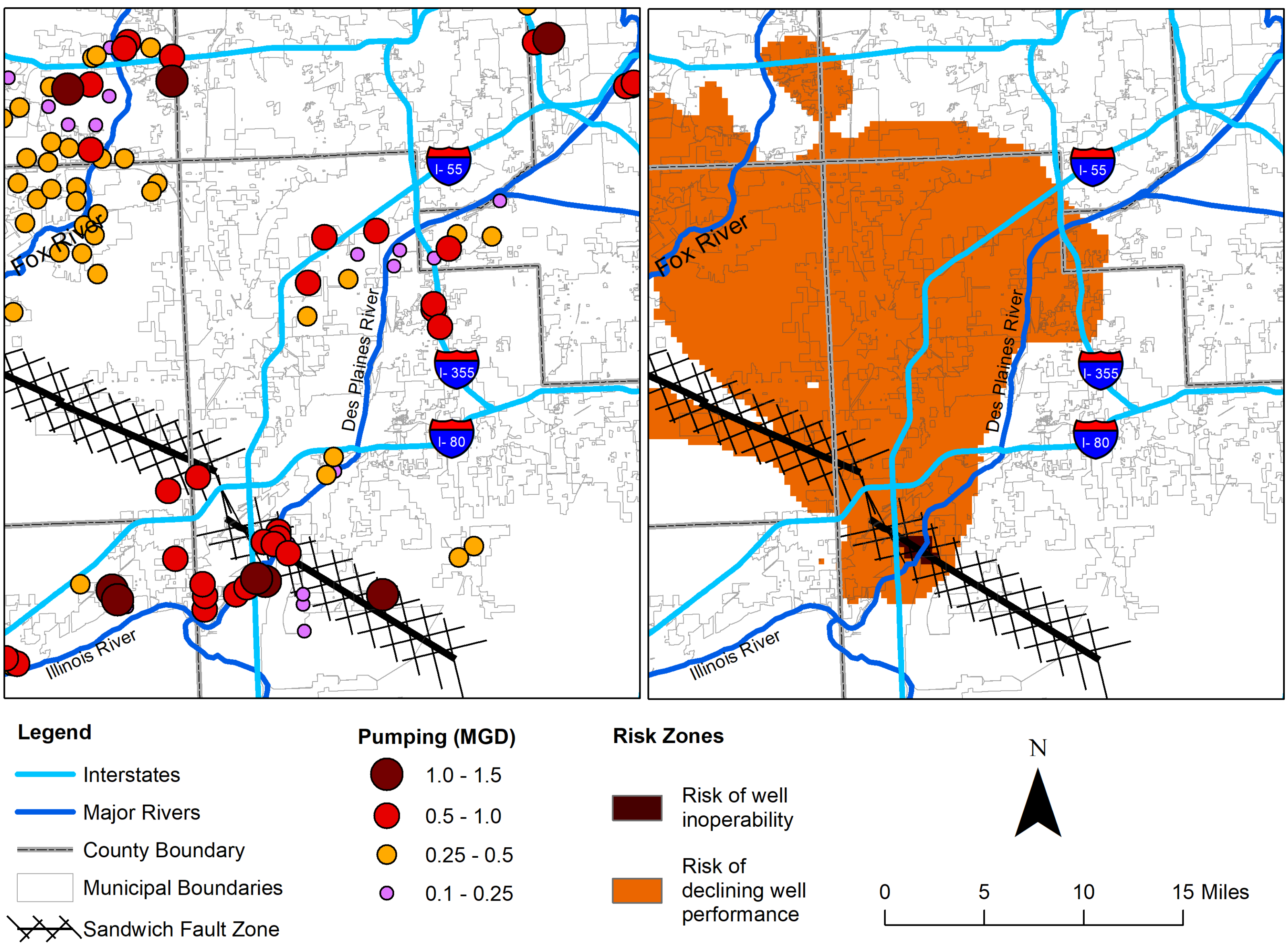

Figure 15: 2030 pumping and risk in the Ironton-Galesville Sandstone aquifer (immediately after Joliet switches from the aquifer)

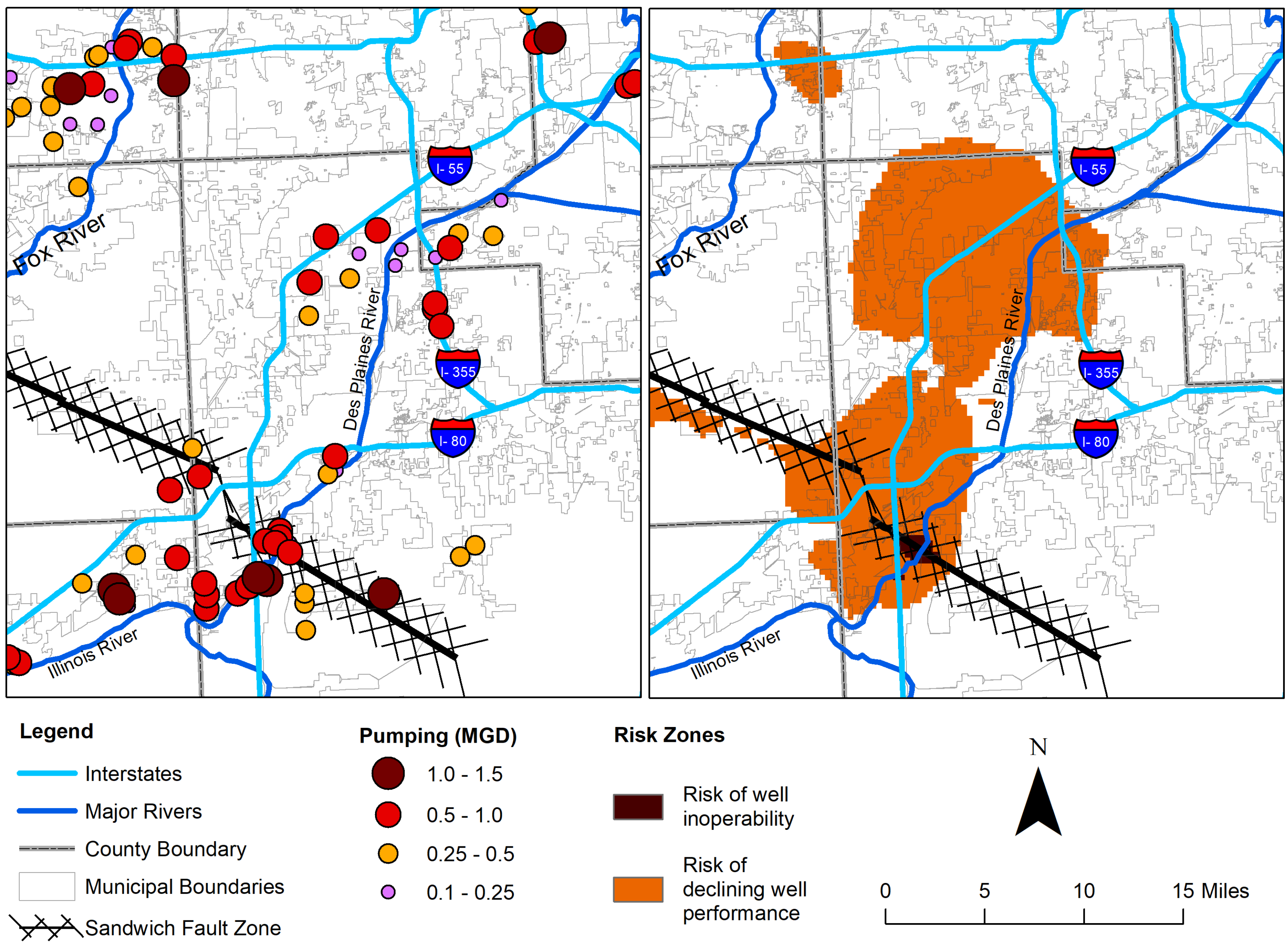

Figure 16: 2035 pumping and risk in the Ironton-Galesville Sandstone aquifer

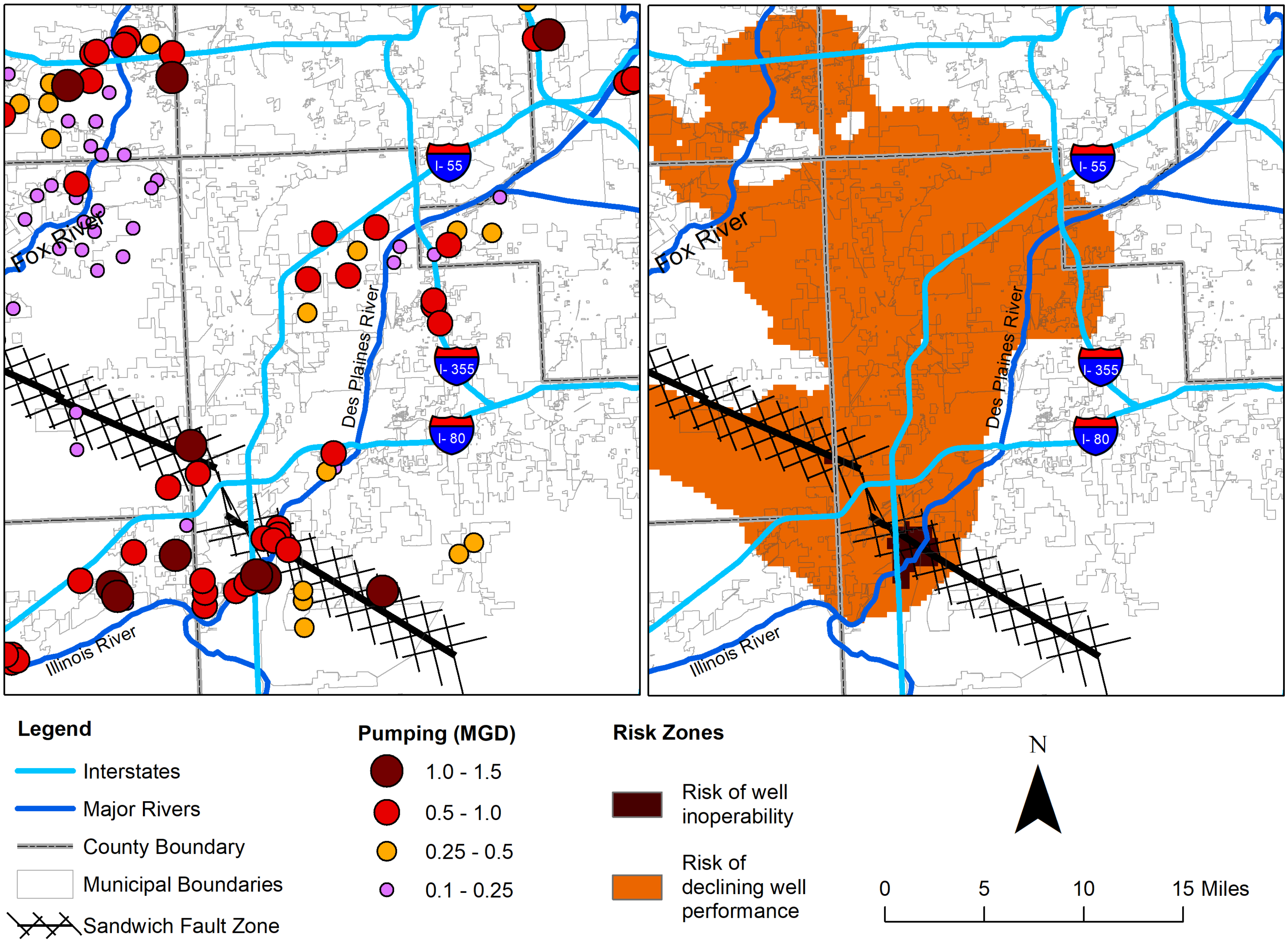

Figure 17: 2050 pumping and risk in the Ironton-Galesville Sandstone aquifer

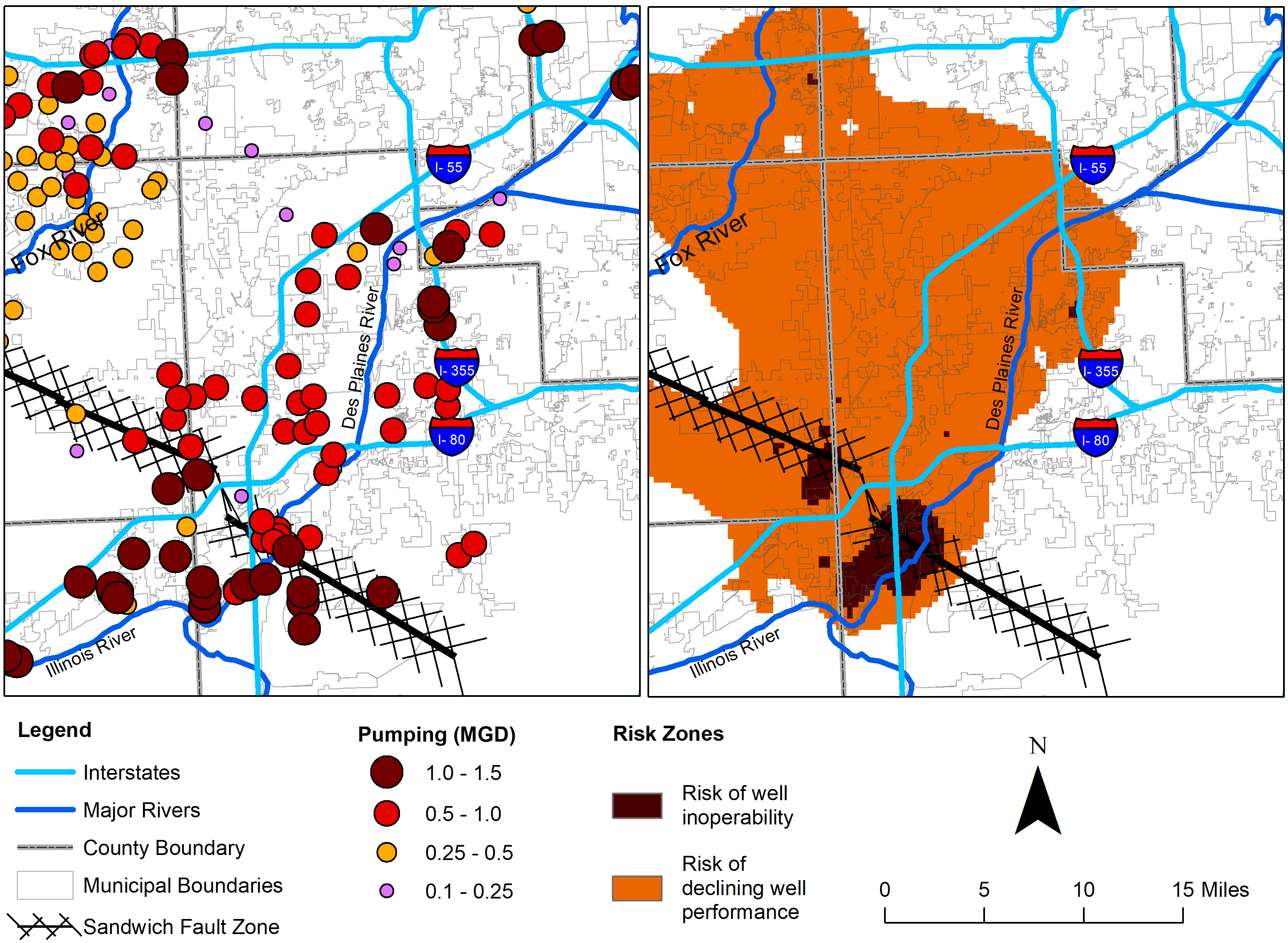

Figure 18: 2050 (peak) pumping and risk in the Ironton-Galesville Sandstone aquifer

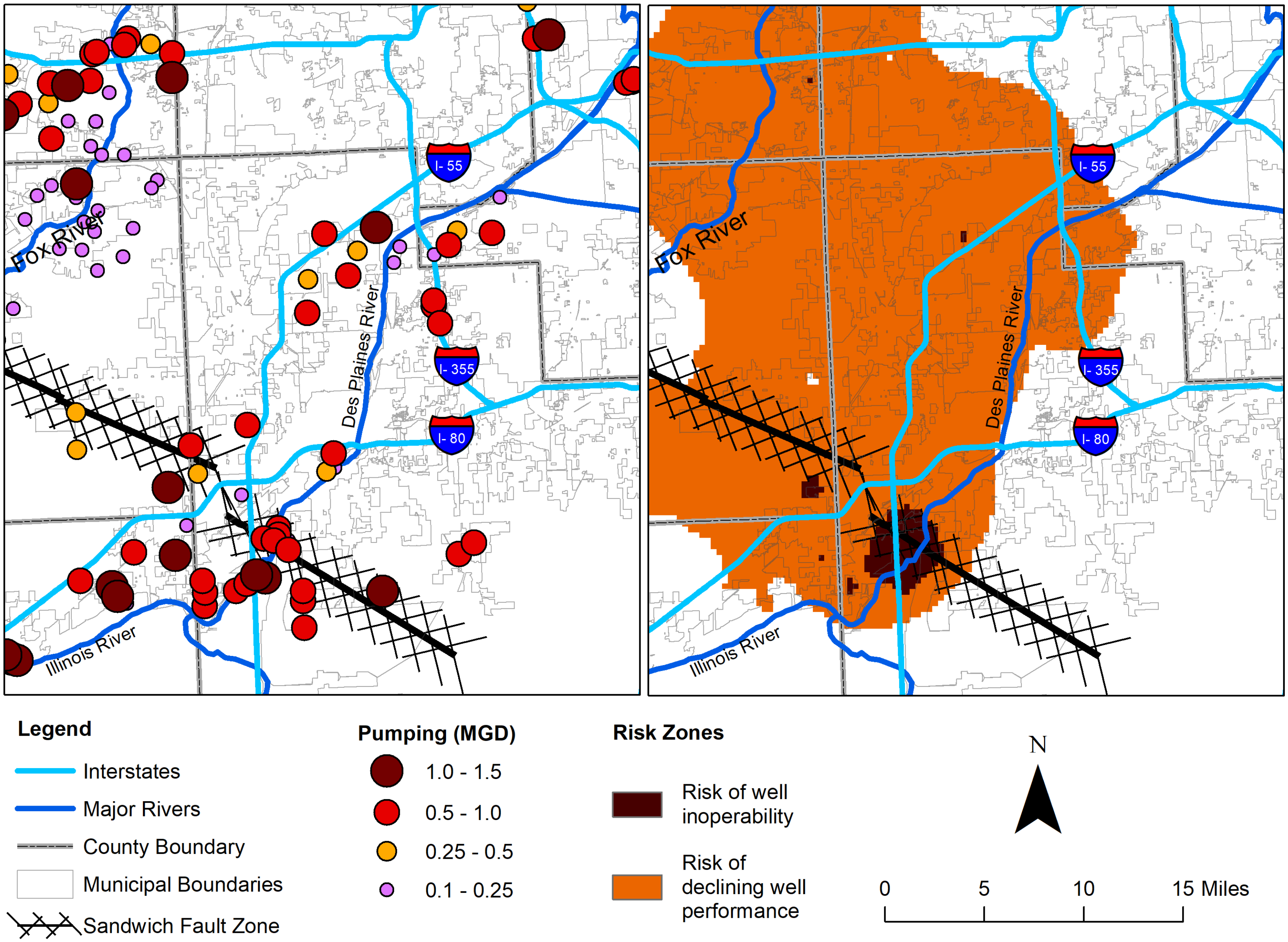

Figure 19: 2070 pumping and risk in the Ironton-Galesville Sandstone aquifer

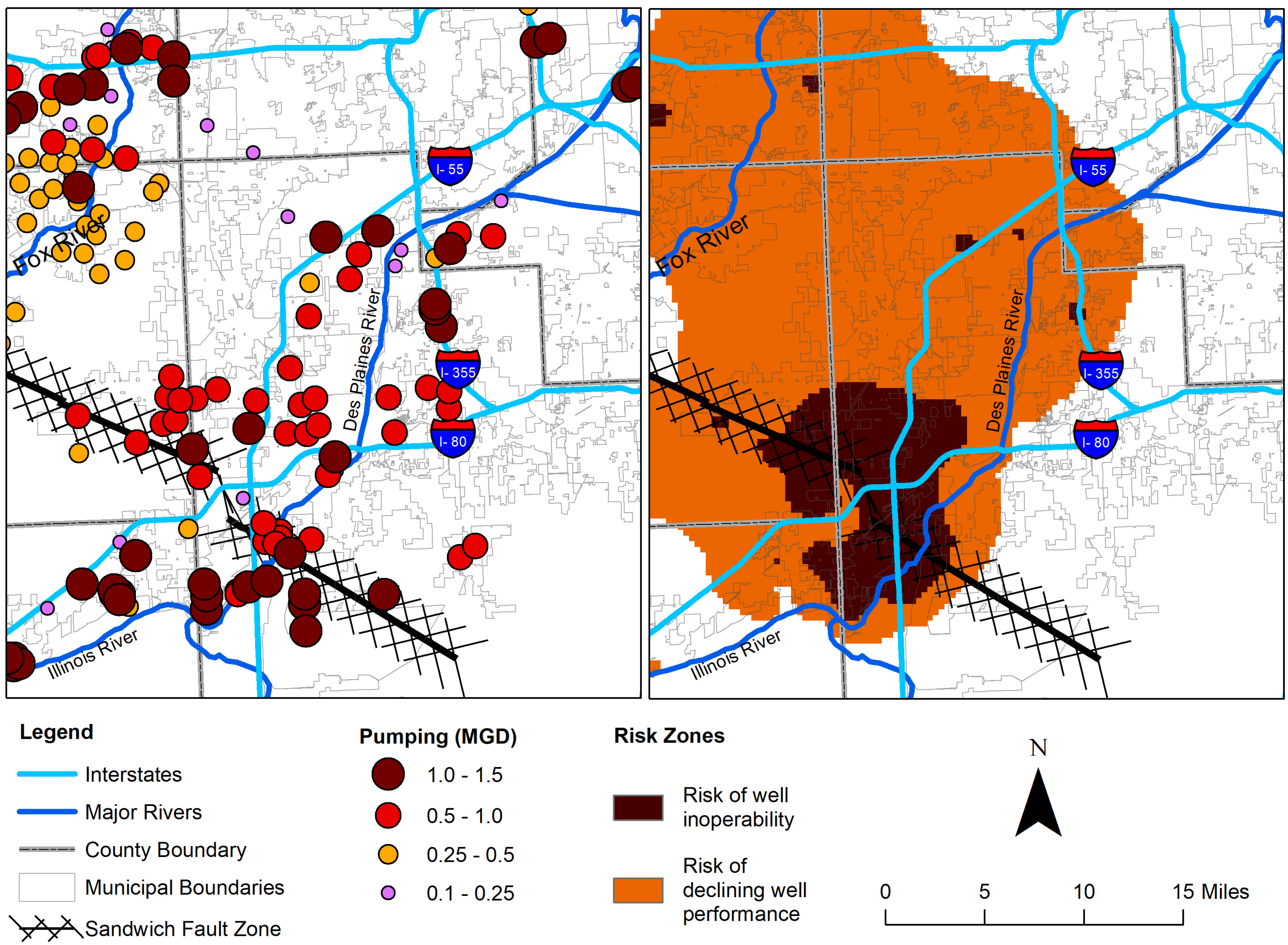

Figure 20: 2070 (peak) pumping and risk in the Ironton-Galesville Sandstone aquifer

Hydrographs (Static Water Levels)

Another way to examine risk is to plot the water level of a well through time. This plot is referred to as a "hydrograph" and is very useful for indicating when water levels reach certain risk thresholds. In this discussion, we consider four hydrographs with relatively different responses: Joliet 22, Romeoville 10, Channahon 4, and Elwood 10 (Figure 21). Here, we only consider static water levels, which are used to determine risk due to the ability to calibrate to long-term static water level records not available for pumping water levels. In addition, the current model design only allows for the simulation of static water levels.

The four wells selected for Figure 21 are intended to be representative of the region; the locations of these wells are shown in Figure 22. Elwood 10 represents the highest simulated static water levels in the region, while Joliet 22 represents the lowest (at least before the 2030 movement away from the aquifer). Most community wells (including Romeoville 10 and Channahon 4) have static water levels that fall between the two. **As a result, it is important to understand how risk is interpreted for these wells so that the individual risk can be evaluated**.

First, consider Joliet 22, where the current static water level approaches the risk of well inoperability zone and falls into it before 2030 (red shading in Figure 21). However, this well will not necessarily fail immediately when water levels enter this risk zone, and fortunately, Joliet 22's pumping water level is currently 200 ft below the static water level. This leaves an additional 200 ft of available water level above the top of the Ironton-Galesville at this location. A key exercise between now and 2030 will be ensuring that the specific capacity at this well is maintained. Recovery in water levels at Joliet 22 is ~250 ft after Joliet leaves the aquifer in 2030. When the sandstone is used as a 14-day back-up supply in 2050 and 2070, 2030 water levels are approached but not reached. The rapid decline in water levels during this 14-day period is indicative of the highly responsive nature of this aquifer.

Romeoville 10 has experienced more moderate changes in water levels through time. The single largest, short-term change occurred in the early 1990s with a precipitous recovery of approximately 100 ft in water levels as Naperville and Aurora reduced their sandstone demands. This recovery is analogous to the simulated rebound in 2030/2035 when Joliet, Oswego, Yorkville, and Montgomery switch off the sandstone aquifer (50 ft), although this recovery is somewhat muted by the regional demand increases elsewhere, as shown in Table 1. By 2050, during both average and peak demand conditions, static water levels approach the zone of risk of well inoperability and fall into the upper portion of this zone by 2070.

Average demands in the Current Trend model scenario increase by a factor of eight in Channahon. As a result, water levels continue to decline. The increased demands override any recovery in 2030 when Joliet switches off the sandstone aquifer; the lack of recovery in 2030 is further explained by the location of Channahon south of the Sandwich Fault Zone, which restricts flow and minimizes the impact of changes in Joliet on communities to the south of the fault. Peak demands also exceed 10 mgd, resulting in spikes of considerably lowered water levels during these peak conditions. Over time, water levels decline from 200 ft above any risk threshold to falling into the risk of declining well performance during average pumping conditions and the risk of well inoperability during peak pumping conditions.

Finally, water levels at Elwood 10 declined historically to reach the zone of risk of declining well performance in 2070. The recovery from Joliet switching off the sandstone aquifer is minimal in 2030, likely due to the flow buffer provided by the Sandwich Fault Zone and the fact that the Elwood wells are relatively far away from most Joliet wells. An additional consideration for the Elwood wells is that they are currently open to both the St. Peter and Ironton-Galesville; the integrity of the St. Peter should be closely monitored as the future water level decline results in dewatering of this uppermost sandstone unit.

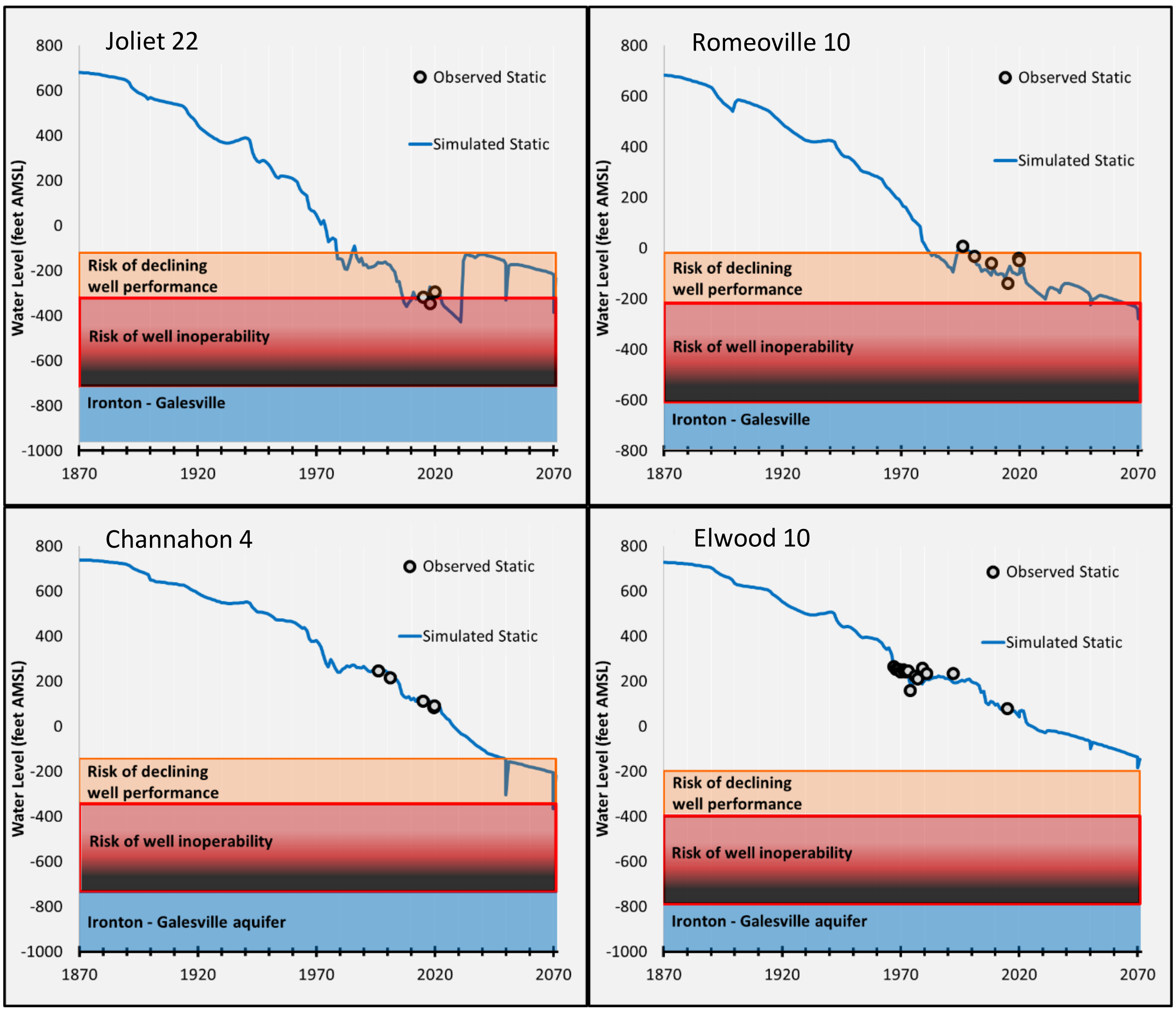

Figure 21: Hydrographs for Joliet 22, Romeoville 10, Channahon 4, and Elwood 10

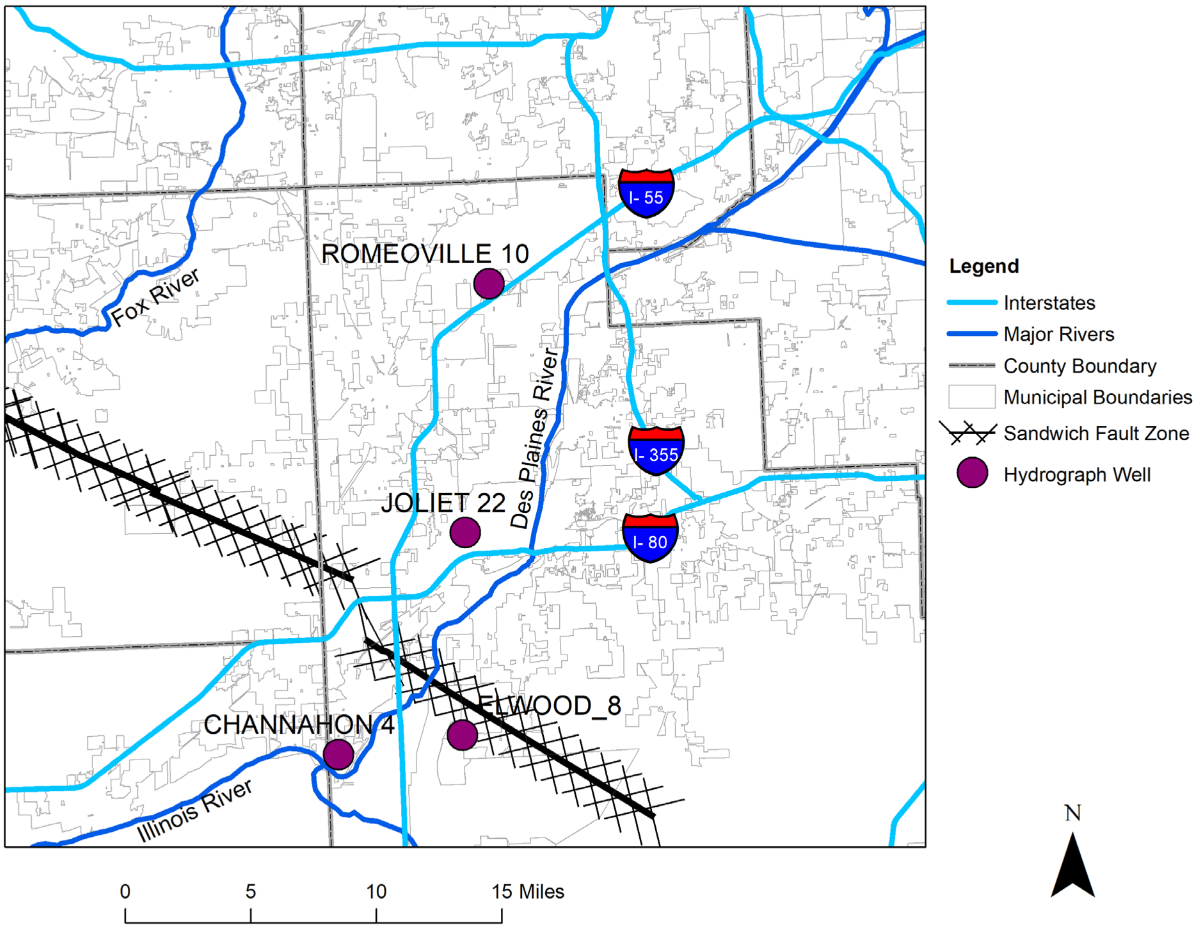

Figure 22: Location of hydrographs shown in Figure 21

Hydrographs (Pumping Water Levels)

Although static water levels are used to categorize risk, actual risk manifests under pumping conditions. Pumping levels would make a better metric for determining risk, but the ISWS has not collected pumping data historically, at least not in a controlled scientific study. In addition to a lack of long-term pumping data, there is considerable uncertainty in how pumping levels will change with respect to static water levels in the future, especially as water levels decline. Refer to the section "Defining Risk" for a discussion on the uncertainty in pumping water levels.

To help visualize where pumping levels are located in relation to the top of the Ironton-Galesville, the hydrographs in Figure 23 depict pumping water levels in addition to static water levels. Each pumping hydrograph depicts future pumping uncertainty (purple shading in Figure 23 and Figure 21) to account for a lack of data and unknown future specific capacity and pumping rates as water levels decline. The bounds are defined as follows:

- The upper bound of this pumping water level uncertainty band is assumed to be 200 ft lower than the static water level, a value observation for newly drilled wells in the region.
- The lower bound defining the uncertainty in pumping water levels is determined by the depth of the static water level.
    - Where the static level is above the risk of declining well performance zone, pumping levels are assumed to be 200 ft lower than the static levels.
    - Where the static level is within the risk of declining well performance zone, pumping levels (linearly) range from 200 to 400 ft lower.
    - Where the static level is below the risk of declining well performance zone, pumping levels are assumed to be 400 ft lower.

A few observations should be noted from the hydrographs in Figure 23. First, the observed pumping water level at Joliet 22 is 200 ft lower than the observed static water level, indicating that the upper threshold of the pumping uncertainty band is currently most accurate, despite the static level having reached the risk of well inoperability zone. This provides a buffer for this well as water levels decline in the Current Trend Scenario out to 2030. Maintaining specific capacity at this well is of utmost importance, particularly since the lower end of the pumping uncertainty band drops into the Ironton-Galesville.

Second, at Romeoville 10, the static water level is currently in the upper half of the risk of declining well performance zone. This indicates that the pumping level is likely within 400 ft of the top of the Ironton-Galesville. In the Current Trend scenario, by 2070, static water levels fall into the risk of well inoperability zone, in which case pumping water levels are at best within 200 ft of the top of the Ironton-Galesville and, depending on how the specific capacity changes as water levels decline, perhaps at the top of the deepest sandstone.

Third, at Channahon 4, the pumping water level under average conditions stays more than 200 ft above the top of the Ironton-Galesville but approaches the top during peak pumping conditions. Because the static water level under average conditions never falls far into the risk of declining well performance zone, the pumping uncertainty band is much narrower than at Joliet and

Romeoville. Although not visible on the hydrograph due to the short time frame over which peak pumping occurs, the uncertainty band widens during peak pumping conditions.

Finally, since static levels at Elwood 10 just reach the top of the zone of risk of declining well performance, there is only ever a single estimated pumping level at 200 ft below the static level. This is not to say that there is no uncertainty in the pumping level, because factors such as specific capacity and pumping rate certainly play a role in determining the actual value.

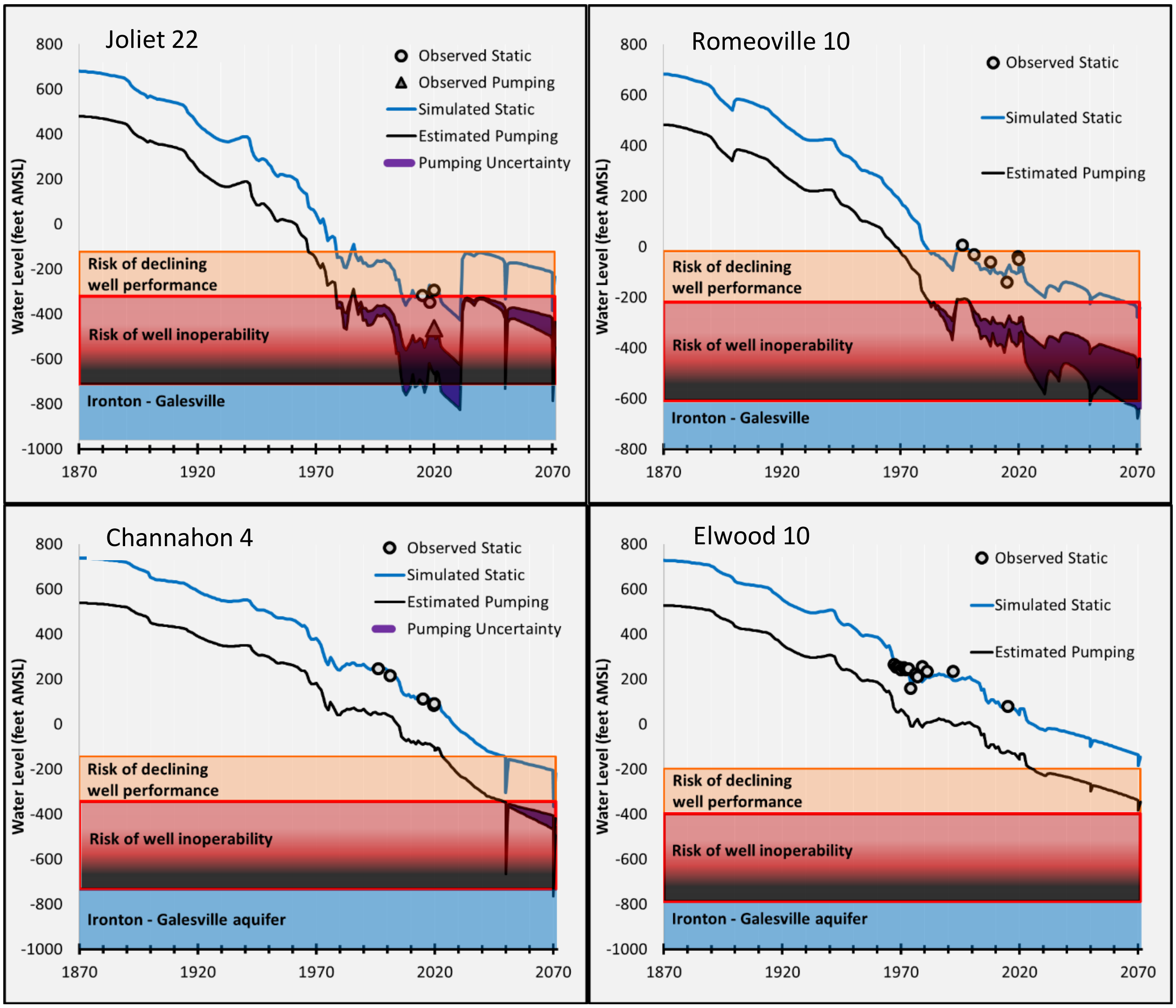

Figure 23: Hydrographs for Joliet 22, Romeoville 10, Channahon 4, and Elwood 10

Unsimulated New Water User

The hydrographs in Figure 23 clearly indicate the risk for wells like Joliet 22 and Romeoville 10, where the static head is already within the risk of declining well performance. The risk at Channahon and Elwood is not as immediately clear, particularly if only considering average conditions. Are pumping water levels that are more than 300 ft above the top of the Ironton-Galesville truly at risk? Two things should be considered. First, the model trends indicate that the aquifer will not reach steady state by 2070, meaning that water levels continue to decline beyond that. Second, the aquifer is extremely vulnerable to unsimulated demands, which could be from industries or unexpected community growth. Recall that Figure 11 depicts additional drawdown resulting from a new demand on the aquifer. Once static water levels are within 600 ft of the top of the Ironton-Galesville, a large new user could rapidly impact supply; static water levels within 400 ft of the top of the Ironton-Galesville would exacerbate this issue.

This situation is demonstrated in Figure 24, which repeats the same hydrographs for Channahon and Elwood from Figure 21, with the exception of adding a new large user (3 mgd demand located 1.5 miles away). In this case, static water levels in Channahon reach the top of the zone of risk of well inoperability; at Elwood, static water levels fall into the risk of declining well performance zone.

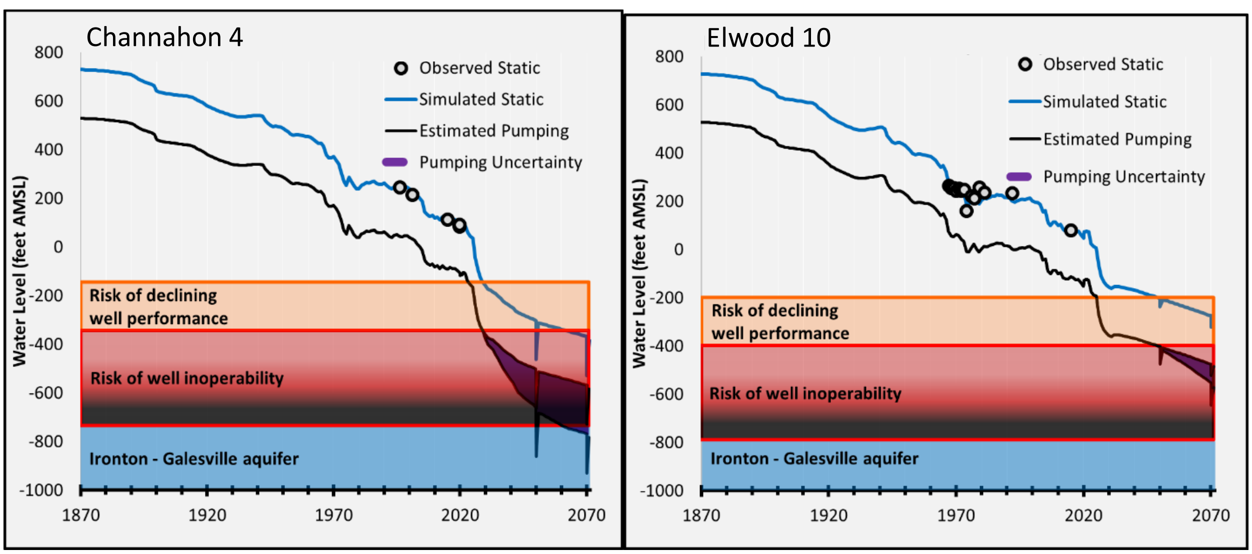

Figure 24: Hydrographs for Channahon 4 and Elwood 10, with a new water user on top of the Current Trend scenario

<u>All communities need to be cognizant of the risk associated with new potential users that may not have been simulated in the groundwater flow model. Although Figure 11 provides an approximate impact of new water users, the ISWS encourages SWPG communities to contact us to run simulations based on potential new water users.</u>

Aquifer Sensitivity

Alternative Demand Scenarios

A common mistake in interpreting model results is to confuse a scenario with a prediction. **The Current Trend scenario is not a prediction of future water use, but a plausible scenario of relatively high-demand growth.** It is not intended as a most likely scenario or a worst-case scenario. The important take away from the model is understanding **how the aquifer responds to changes in demands**. Using demand scenarios vetted by communities, many communities' wells have been determined to be at risk even after Joliet switches from the aquifer. This does not mean that they will fail to meet demand by 2030, 2050, or even 2070. Rather, they are at risk of not meeting demands and are vulnerable to unmodeled demands or other unforeseen circumstances as water levels fall into uncharted territory.

Many variables are incorporated in a groundwater flow model, including rates of pumping, location of pumping, and open interval of wells. To acquire a more comprehensive understanding of model behavior, we consider two additional scenarios. The first, Less Resource Intensive, was developed concurrently with the Current Trend scenario (Table 3). This scenario assumes the same population growth as the Current Trend, but improved water conservation approaches result in reduced water use per capita. The second scenario considered is Alternative Trend, which is the average of the Current Trend and Less Resource Intensive. Like the Current Trend, both additional scenarios assume that Joliet switches from the aquifer in 2030, and Oswego, Yorkville, and Montgomery switch from the aquifer in 2035. Peak demands are simulated in the years 2050 and 2070. All three scenarios are shown in Figure 25.

Table 3: Comparison of 2050 Current Trend (CT) and Less Resource Intensive (LRI) Demands (Mgd). Peak demands shown in parentheses.

	2018	*2050 CT Avg (Peak)*	*2050 LRI Avg (Peak)*
Channahon	0.5	4.4 (10.0)	3.5 (8.0)
Elwood	0.3	1.3 (3.9)	1.0 (3.1)
Joliet	15.3	0.0 (20.0)	0.0 (16.0)
Lemont	1.6	1.8 (3.8)	1.6 (3.0)
Lockport	0.0	1.5 (3.6)	1.2 (2.9)
Manhattan	0.6	0.9 (1.4)	0.7 (1.1)
Minooka	0.8	2.5 (5.0)	2.0 (4.0)
*Morris**	1.8	2.7 (4.1)	2.2 (3.3)
Rockdale	0.1	0.8 (1.0)	0.7 (0.8)
Romeoville	2.1	3.9 (5.1)	3.1 (4.1)
Shorewood	0.8	2.5 (2.8)	2.0 (2.2)
Industries	12.8	15.0 (21.8)	12.2 (17.7)
Kendall/Kane	11.6	6.8 (23.8)	5.4 (19.1)

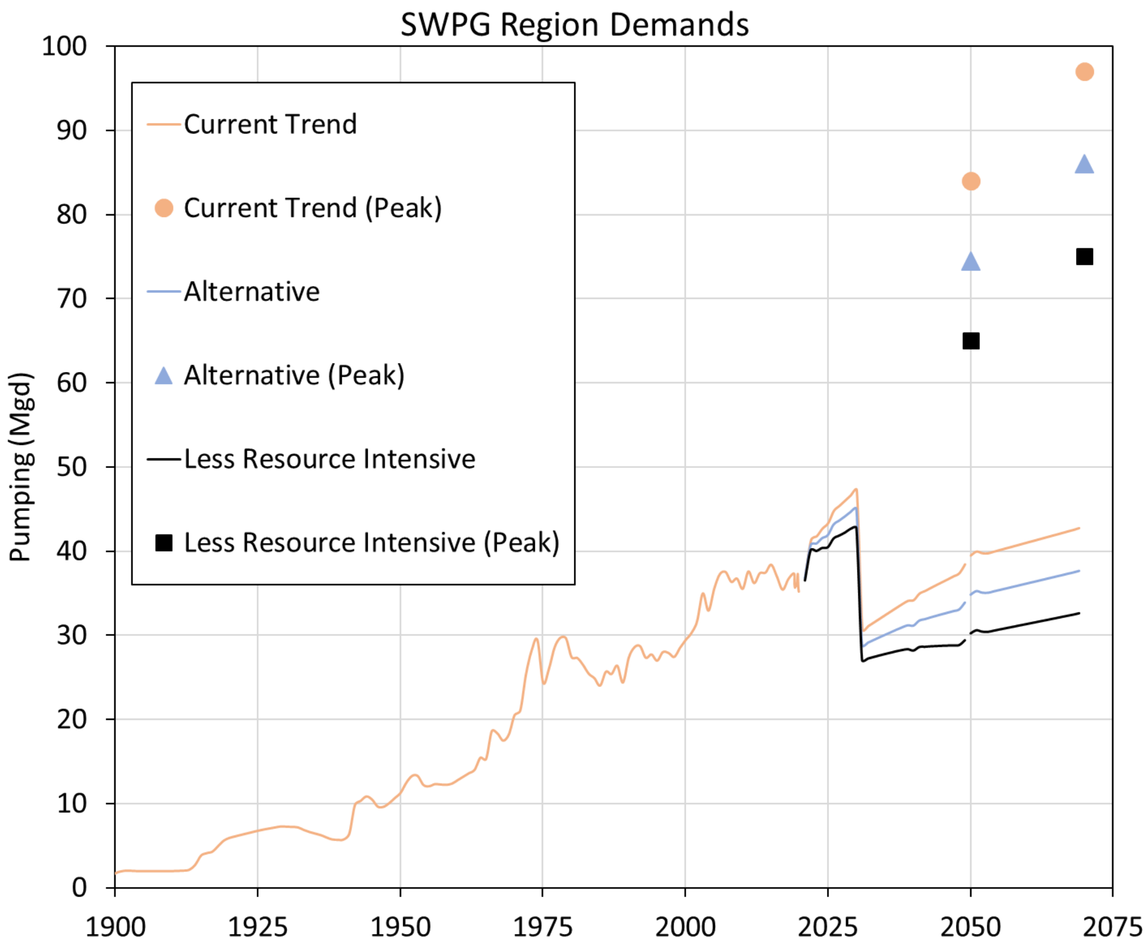

Figure 25: Current Trend, Less Resource Intensive, and Alternative Trend demand scenarios in the SWPG region from 1900 to 2070, assuming Joliet switches off the deep aquifer in 2030 and Oswego, Yorkville, and Montgomery switch off in 2035

As withdrawals in demand scenarios are reduced, future drawdown is lessened. Consequently, the spatial extent of the both risk zones is reduced, but not eliminated, in the LRI and Alternative Trend scenarios. This is true just before Joliet switches off the aquifer (Figure 26) and with 2050 average demands (Figure 27), 2050 peak demands (Figure 28), 2070 average demands (Figure 29), and 2070 peak demands (Figure 30). It is notable that the LRI peak pumping in the year 2070 (Figure 30a) looks remarkably similar to the current risk (Figure 13). However, a key difference is the presence of isolated pockets of risk of well inoperability. It is also important to note that the reduction in future demands means there is an increased probability of an unsimulated future demand in the model.

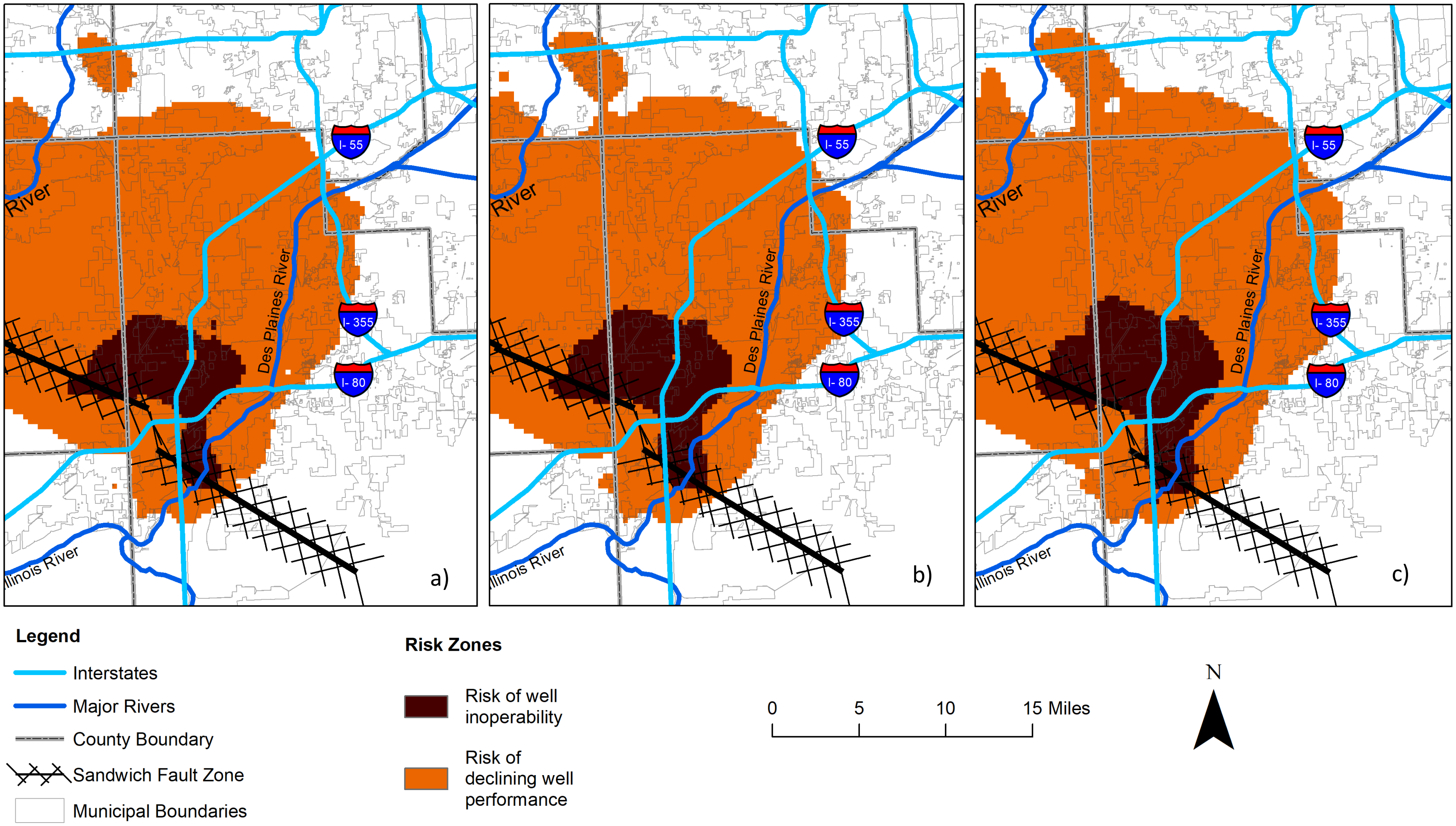

Figure 26: 2030 risk zones based on the a) LRI, b) Alternative, and c) Current Trend scenarios

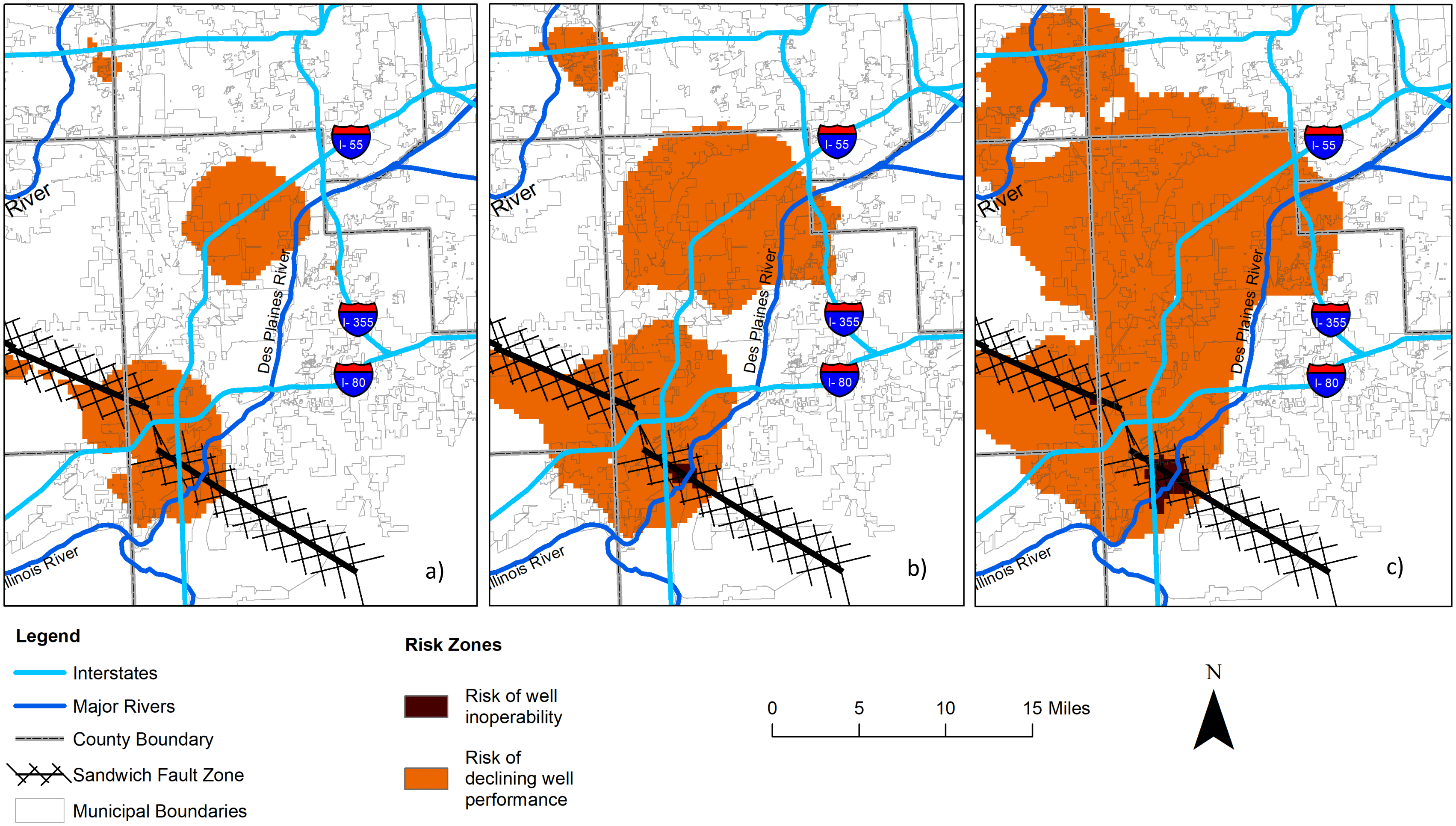

Figure 27: 2050 risk zones based on the a) LRI, b) Alternative, and c) Current Trend scenarios

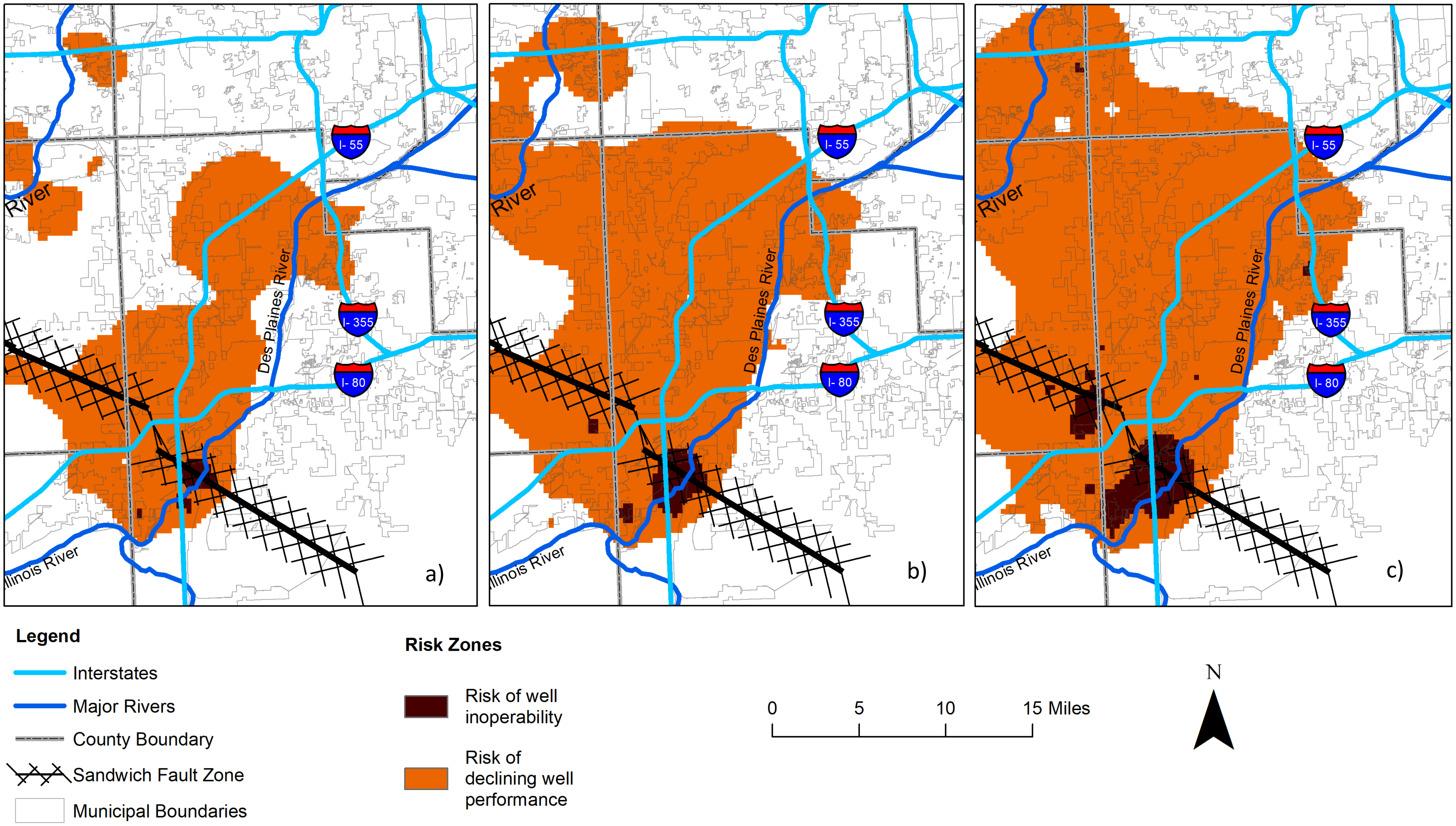

Figure 28: Peak 2050 risk zones based on the a) LRI, b) Alternative, and c) Current Trend scenarios

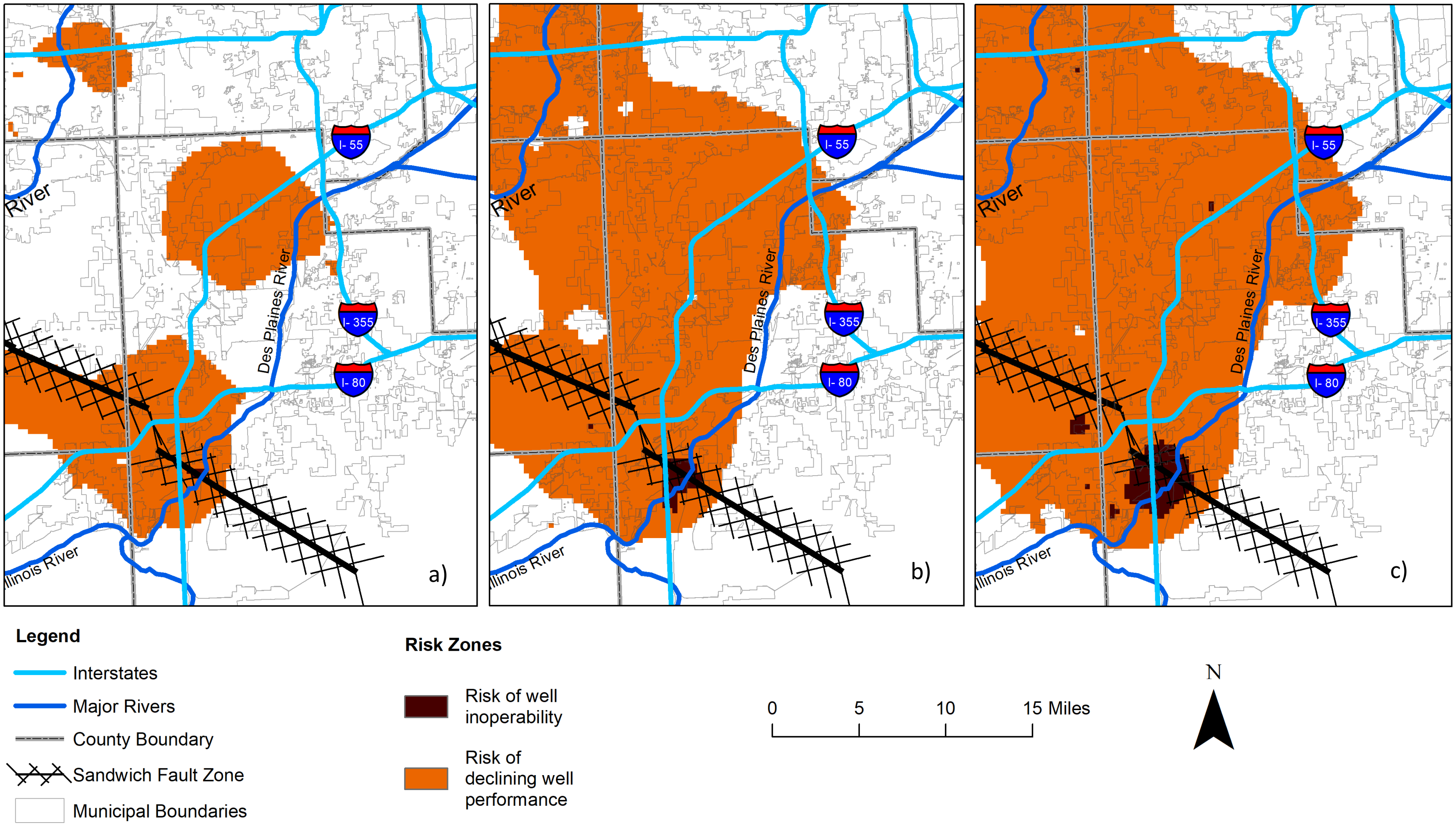

Figure 29: 2070 risk zones based on the a) LRI, b) Alternative, and c) Current Trend scenarios

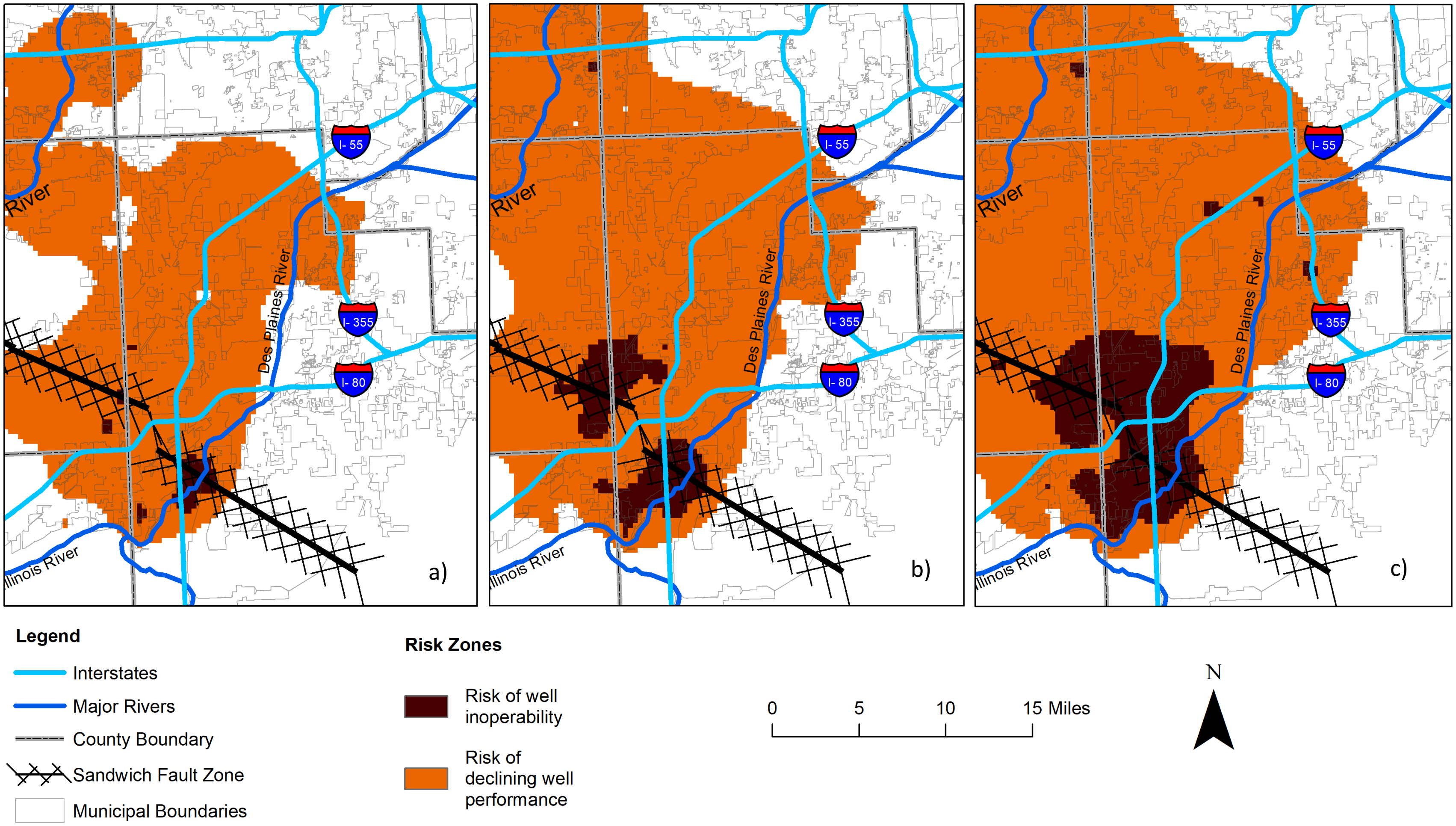

Figure 30: Peak 2070 risk zones based on the a) LRI, b) Alternative, and c) Current Trend scenarios

Hydrograph sensitivity

A very common request regarding the reporting of model simulations in this report is to provide a best-case and worst-case scenario for the region. However, future demands might be less than the LRI or greater than the Current Trend, so this terminology is not appropriate. What can be provided are “less conservative” and “more conservative” scenarios, which are defined as follows:

- *Less conservative*: Less Resource Intensive demand scenario and assumption that all pumping levels fall on the upper bound of pumping uncertainty.
- *More conservative*: Current Trend demand scenario and assumption that all pumping levels fall on the lower bound of pumping uncertainty

The less and more conservative scenarios are shown for the same four wells in hydrograph form: Joliet 22 (Figure 31), Romeoville 10 (Figure 32), Channahon 4 (Figure 33), and Elwood 10 (Figure 34). In all four cases, the static water level in 2070 was approximately 50–100 ft higher in the less conservative scenario. This is the primary reason that the spatial extent of risk zones in the LRI scenario is smaller than that for the Current Trend zones in the preceding maps (Figure 26 through Figure 30). The variability in pumping levels are much greater due to the assumption of declining specific capacity with depth in the “More Conservative” scenario.

In terms of risk, the overarching narrative for the Joliet, Romeoville, and Channahon wells does not change considerably under either scenario, although the degree of risk is certainly lessened as future demands are decreased. For all three communities, 2070 static water levels occur in the mid-range of the risk of declining well performance zone, meaning that pumping water levels are within 400 ft of the top of the Ironton-Galesville. This is an improvement over the “more conservative scenario, in which the Joliet, Romeoville, and Channahon wells have static water levels falling into the risk of well inoperability and pumping water levels into the Ironton-Galesville, effectively reducing or eliminating the ability of this well to meet the required demands.

It should be noted that the authors of this report caution against making decisions exclusively based on a less conservative scenario due to the high degree of unknown factors that can influence a decline in water levels. Historically, factors such as dewatering of sandstone layers, reduced specific capacity, and removal of multi-aquifer wells have led to the more conservative scenarios from previous model simulations to be more accurate, even in cases where pumping is over-estimated. In addition, wells in the less conservative scenario are more vulnerable to unsimulated demands given that, in the LRI scenario, municipal water use grows at a slower rate and industrial demands decrease slightly over the region. This means that the probability that the model is missing future demands is increased compared to the more conservative scenario.

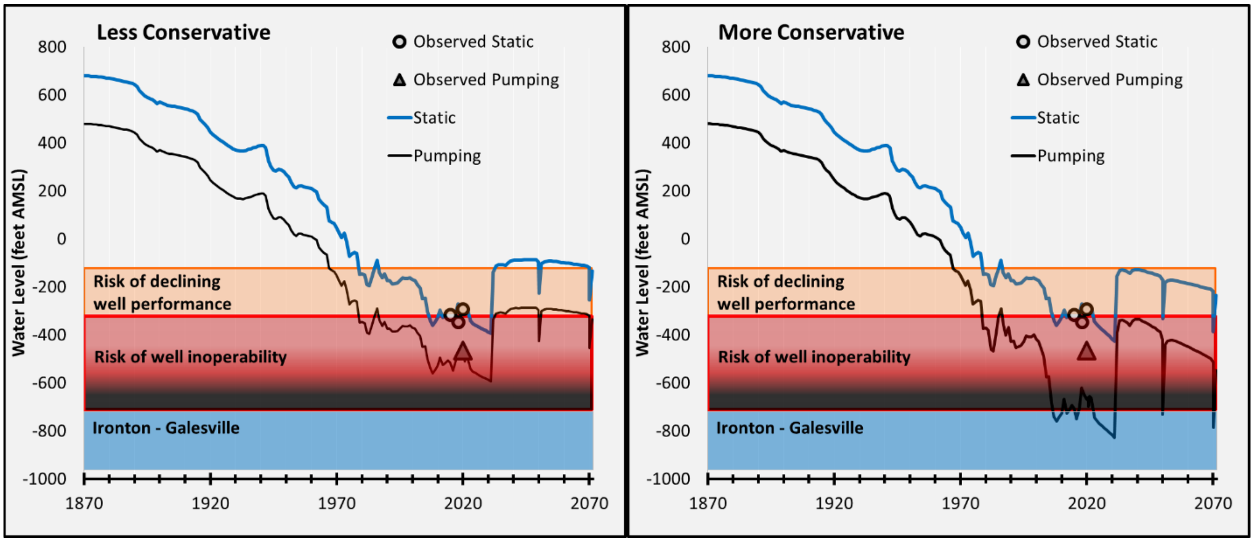

Figure 31: Comparison of the less and more conservative future pumping scenarios at Joliet 22

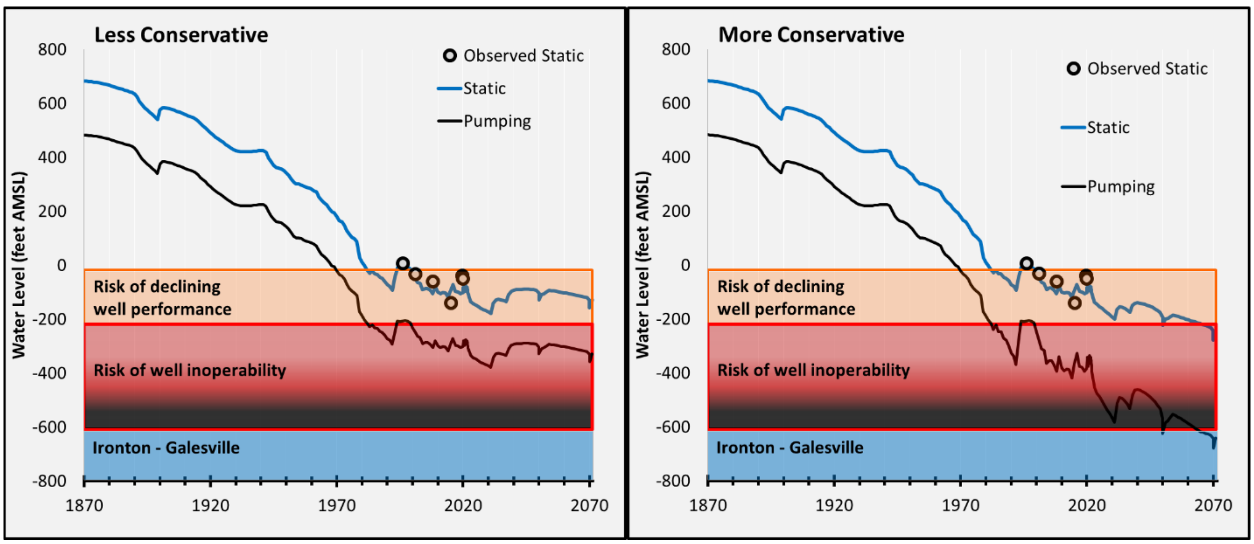

Figure 32: Comparison of the less and more conservative future pumping scenarios at Romeoville 10

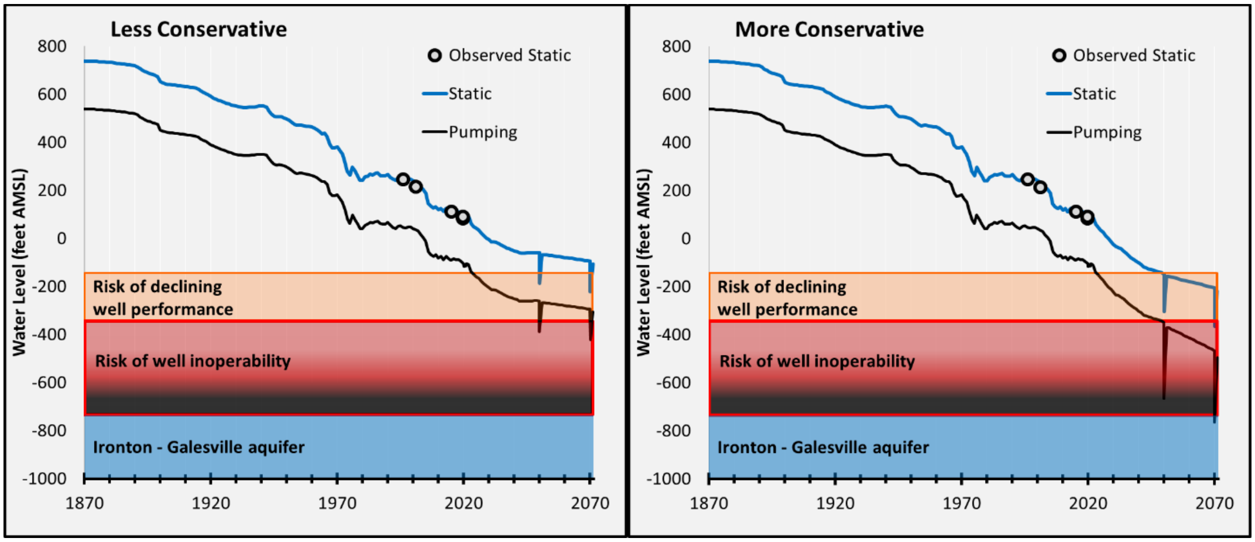

Figure 33: Comparison of the less and more conservative future pumping scenarios at Channahon 4

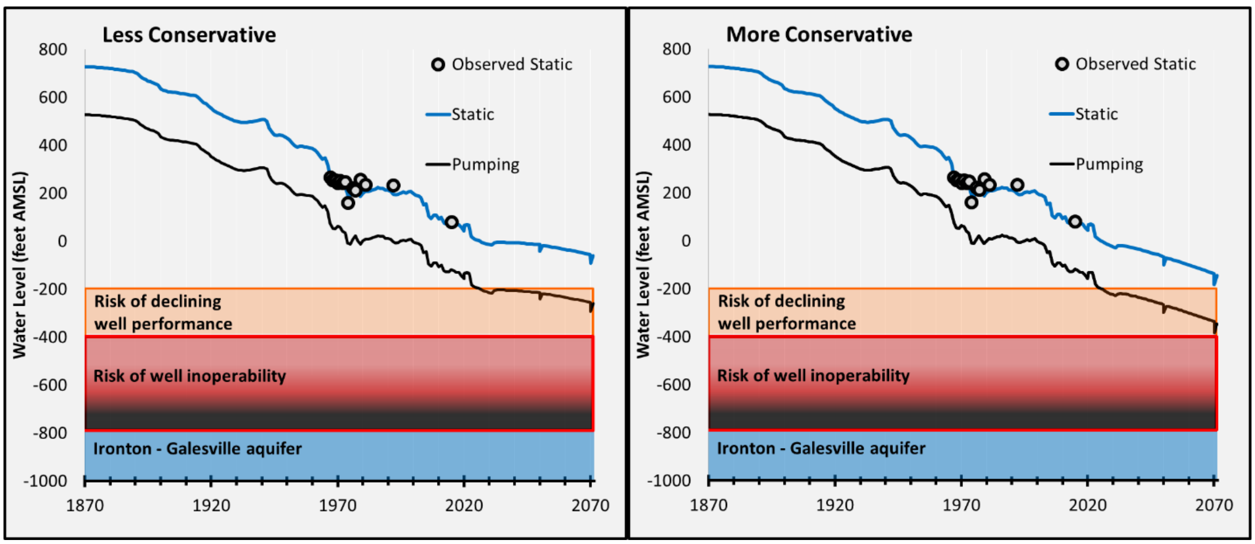

Figure 34: Comparison of the less and more conservative future pumping scenarios at Elwood 10

Sensitivity to Multi-Aquifer Well

Another assumption in the groundwater flow model was the removal of multi-aquifer wells (MAWs) throughout the future simulation. This was evaluated by holding demands constant out to 2050 and running two alternative scenarios: 1) holding MAWs as they currently are positioned and 2) removing a subset of MAWs, as shown in Figure 10. Although this certainly has some influence locally, the water level difference is generally less than 40 ft (Figure 35).

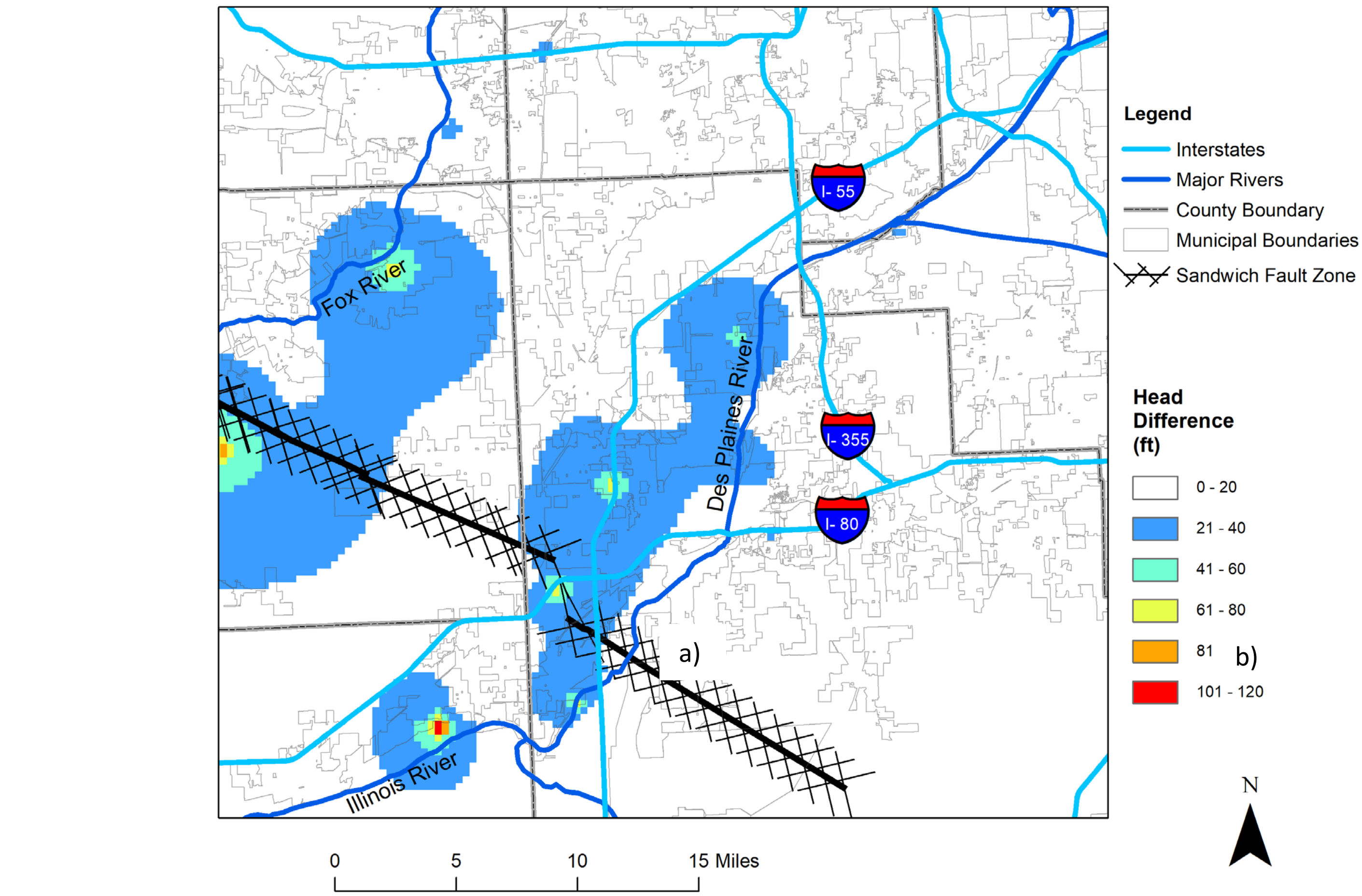

Figure 35: The water level difference map between a 2050 model simulation that included the removal of multi-aquifer wells and a similar run with no removal of multi-aquifer wells

Conclusions, Recommendations, and Future Planned Work

Conclusions: What does all this mean?

The modeling conducted by the Illinois State Water Survey found that, under the Current Trend scenario, the aquifer remains at risk regionally and for most communities/industries within the Southwest Water Planning Group (SWPG) region. A Phase 1 investigation of Joliet's water supply indicated that the city needs to find an alternative source by 2030, and the updated analysis in this report supports that conclusion. Other communities also received an update on their local water supply with individual summaries. **The authors conclude that most sandstone wells in the Southwest Water Planning Group (SWPG) region are at risk of not meeting supply in the future, and as water levels continue to decline, they will become increasingly vulnerable to new demands in the region. Communities must consider the impact of possible new industrial demands, or even growth in neighboring communities that might not have been simulated or that shifts from the growth's current distribution.** The results in these documents are not a **projection** by the ISWS or a definitive statement that the aquifer will run out of water by 2050 or 2070. Not enough information is available to make this assessment, nor is it likely such information will become available due to the uncertainty in future demands.

Another clear conclusion of the model and data analysis is that withdrawals from the Cambrian-Ordovician Sandstone aquifer system are unsustainable and have been for over a century. Unsustainable pumping rates do not mean that wells will immediately cease to function, but rather that water is removed far faster than water can be replenished. Current estimates are that it would take centuries to replenish the aquifer if all pumping were to cease. As a result, when a community as large as Joliet stops pumping, the recovery is relatively small (on the order of 50–100 feet for most communities and around 250 ft at the center of pumping in Joliet) compared to the over 600 ft of static water level decline (800-1200 ft pumping level decline) since the start of the 20th century.

Most communities will likely be forced off the sandstone aquifer, but whether this is by 2030, 2050, 2070, or later is entirely dependent on how fast future demands increase. The aquifer is very responsive to changes in demands, so negative impacts in response to increased demands will manifest almost instantaneously. Questions should not focus on when the aquifer will be depleted, but rather on how much demand the aquifer can withstand. Compounding community and regional demands makes this question particularly difficult to answer. **Thus, this is a regional issue that requires a regional solution with input from many communities and industries.**

Recommendations: What next?

Although the overall conclusion is not likely to change for the region, specific communities should explore additional model scenarios if they require additional information from the single Current Trend scenario developed in this report. Additional model scenarios will help evaluate risk under different conditions and discussing alternative scenarios with ISWS staff will lead to improved understanding of how the model (and aquifer) reacts to specific stresses.

All communities should prioritize the installation of transducers to monitor both static and pumping data. The lack of a long history of pumping data at most facilities is problematic and increases model uncertainty, particularly in relation to the threshold at which risk will manifest. At a minimum, every community in the southwest suburbs should be collecting pumping and static water level data on a monthly basis. Please contact the authors of this report if you would like to share that data with the ISWS for incorporation into the regional groundwater flow model.

Unfortunately, some wells will likely experience supply issues before 2030 if the Current Trend demand scenario occurs. This is likely in very localized areas, even if demands stay constant, especially within the Sandwich Fault Zone. These wells require constant attention to evaluate how they respond to further water level declines. What is learned there could help reduce uncertainty in the risk thresholds assigned in this report throughout the region.

Future ISWS work

Over the next two years, the ISWS will continue to work with the SWPG to improve an understanding of the deep sandstone supply issue. This will involve several making additional modeling improvements, including:

- Conducting a refined, discrete simulation of multi-aquifer wells that accounts more robustly for construction and sealing dates. Advanced modeling packages will be used to perform this simulation.
- Applying different conceptualizations of the aquitard to evaluate whether it may be providing water from storage. This may either slow (due to the added water from aquitards) or accelerate (due to the loss in transmissivity as drawdown increases) the future decline.
- Improving calibration along the fault zone and other areas with a spatial bias.
- Examining monthly calibration results over the complete span of a year, evaluating any seasonal trends and considering consistency with the peak demand scenarios.
- Assessing the age of groundwater within the deep sandstone aquifer system.

In addition to modeling, water quality samples will be collected along the fault zone to help understand this complex feature. This will include collecting isotopic data to understand the age of water and how vertical and horizontal flow along this feature influences water supply.

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Appendix I: Calculation of Data in Figure 11

The Theis solution is a long-standing equation used to assess the impact to groundwater levels due to pumping over a specified period (Theis 1935). Due to the lack of boundary conditions, it is highly applicable for rapid, approximate assessments of groundwater conditions. The equation is defined as:

$$s = \frac{Q}{4\pi T} W\left(\frac{r^2 S}{4Tt}\right)$$

where s is drawdown [ft], Q is pumping [ft^3/d], T is transmissivity of the aquifer [ft^2/d], r is the distance to a new pumping well, S is storage [-], and t is the time that the well has been on [d]. W() is called the well function, also known as the exponential integral and is similar to other functions such as the logarithm or natural logarithm.

The Theis equation was used to develop the data in Figure 11, which shows the impact in terms of drawdown based on the pumping rate and distance to a new pumping source. Parameters used to develop Figure 11 were consistent with parameters in the model developed by Abrams et al. (2018), specifically T = 1000 ft^2/d, S = $5.2x10^{-5}$, and t = 180 days. Time t was determined to be 180 days by evaluating the more detailed groundwater flow model to assess when drawdown stabilized. To develop the lines in Figure 11, four pumping rates were selected (1, 2, 3, and 4 mgd, converted to ft^3/d). The distance from pumping (r) was varied in 1 ft intervals and assigned to the x-axis. Drawdown was then calculated and assigned to the y-axis.

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