

**Groundwater Resource and Capacity Evaluation
of the Saginaw Formation Bedrock Aquifer
for the
City of Mason Source Water Supply**



January 2026

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Introduction

The purpose of this report is to provide a groundwater resource capacity analysis of the bedrock aquifer – the Saginaw Formation - used as the source water for the City of Mason water supply system. This report also addresses the practical reserve capacity available to accommodate the City’s projected 20-year growth - either by utilizing its existing production well capacities or augmenting its current baseline capacity. The City’s source water supply is derived from a regional bedrock aquifer with seven production wells; all are distributed along the southeast and southwest areas of the City. To collect the necessary information for this analysis, this report relies on water use patterns combined with regional mapping and several aquifer tests that were performed on production wells in accordance with the EGLE Policy/Procedure DWRP-03-003¹ during their construction.

The need for this evaluation is driven by the steadily increasing water demands on the water system, which when projected over the next 20 years, is expected to reach about 2.0 MGD which at face value will not exceed 80% of the current wellfield firm capacity². The concept of firm capacity, however, implies each well will be pumping continuously (24-hours per day) and long enough to satisfy the max day demand period(s). These max day demand periods can last anywhere from a few days to a few weeks and during these periods tend to put the greatest amount of pumping stress on the local aquifer. The local aquifer – particularly the bedrock aquifer utilized by the City – requires careful management and should never be pumped continuously over these long periods. Therefore, the practical firm capacity of the City’s source water supply is essentially less than the sum of all well capacities (minus the “largest well”). As a general guideline – particularly given the nature of the local bedrock aquifer – at minimum all run times for any production well should be followed by an equal rest period before being pumped again. Albeit, this is not universally applicable to every groundwater system in Michigan, but it always allows the aquifer to fully recover before being stressed again. In certain cases, a repetitive pumping schedule without equal (or greater) recovery periods will steadily lower aquifer water levels over time leading to storage removal and/or groundwater mining. In the case of the Saginaw Formation bedrock aquifer, there is little or no recharge to the aquifer which will balance this scenario of “over pumping.” Indeed, there are many exceptions to this in other areas of Michigan, but the aquifer within the Saginaw Formation around the City of Mason resides as a confined aquifer and cannot withstand an imbalanced pumping schedule.

If needed, there are two options for upsizing wellfield capacity; i) increase the existing individual production well capacities, or, construct a new production well. Both options have their own set of challenges, but the City’s options are limited only to adding additional source capacity since each City production well is already rated at its maximum capacity. Adding a new production well will also have its own set of challenges particularly with regard to the Water Withdrawal Legislation under Part 327 – under this regulation,

¹ Aquifer Test Requirements for Public Water Supply Wells, 1997, Michigan Department of Environmental Quality – Water Division (now Michigan Department of Environment, Great Lakes and Energy), Policy/Procedure DWRP-03-003.

² It is EGLE's policy that when Type I water supply max day demands meet or exceed 80% of the source water firm capacity, EGLE will require the community to add additional source capacity. When community water supplies are under this condition, the community’s ability to grow or expand their water system may be stalled until additional source capacity is attained.

any attempt to register a new withdrawal within the City limits will be met with a Site Specific Review because at face value, the web-facing Water Withdrawal Assessment Tool (WWAT) indicates the Sycamore Creek Basin withdrawal allowance has already been depleted.

All the conclusions and opinions presented in this report purposely ignore the City's storage capacity which provides wide latitude to modulate system demands under many scenarios. Nevertheless, any demands – either transient or long term – will ultimately be derived from the aquifer regardless of water system storage capacity.

The goals of this study, therefore, had several objectives; i) summarize the bedrock aquifer hydraulic parameters and pumping behavior – we have several local aquifer tests from which we base our conclusions, ii) establish the “practical firm capacity” of the City source water supply, iii) examine the feasibility of constructing of a new production well, iv) determine the long-term pumping behavior of the local aquifer under the projected 20-year max day demand benchmark, and from these, v) provide a practical deduction regarding the reserve capacity of the City's groundwater resources.

The discussion presented in this report demonstrates that the City of Mason can confidently provide its water customers the necessary source water capacity to meet the projected 20-year water use demands. Any additional demands above the 20-year projected demands will likely require construction of an additional well which must be located carefully to avoid negatively impacting the City's existing production well array. However, given the limitations of the Water Withdrawal Legislation under Part 327, adding additional baseline capacity could be challenging for the City, therefore, the City will need to rely on “grandfathered” capacity from its abandoned wells to facilitate the approval process of a new well.

These conclusions are presented below.

Background

The City of Mason water system currently operates with seven (7) production wells, each installed within the bedrock aquifer system of the Saginaw Formation, and each have an average rated capacity of about 350 gpm (see Figure 1). The most recently constructed production wells - Well Nos. 9 and 10 - are quite close to each other and cannot be operated simultaneously for long time periods. The wells are generally operated simultaneously in various combinations depending on the need to meet the demands throughout a typical year. All production wells are pumped directly to the water treatment facility located at the southeast part of the City. When five wells are pumping simultaneously (which would imply at its firm capacity without Well Nos. 6 and 9), the continuous instantaneous pumpage output of the wellfield could be as high as 1800 gpm or about 2.6 MGD, but as will be discussed further below, this is not a sustainable rate for long periods of time (see Figure 1).

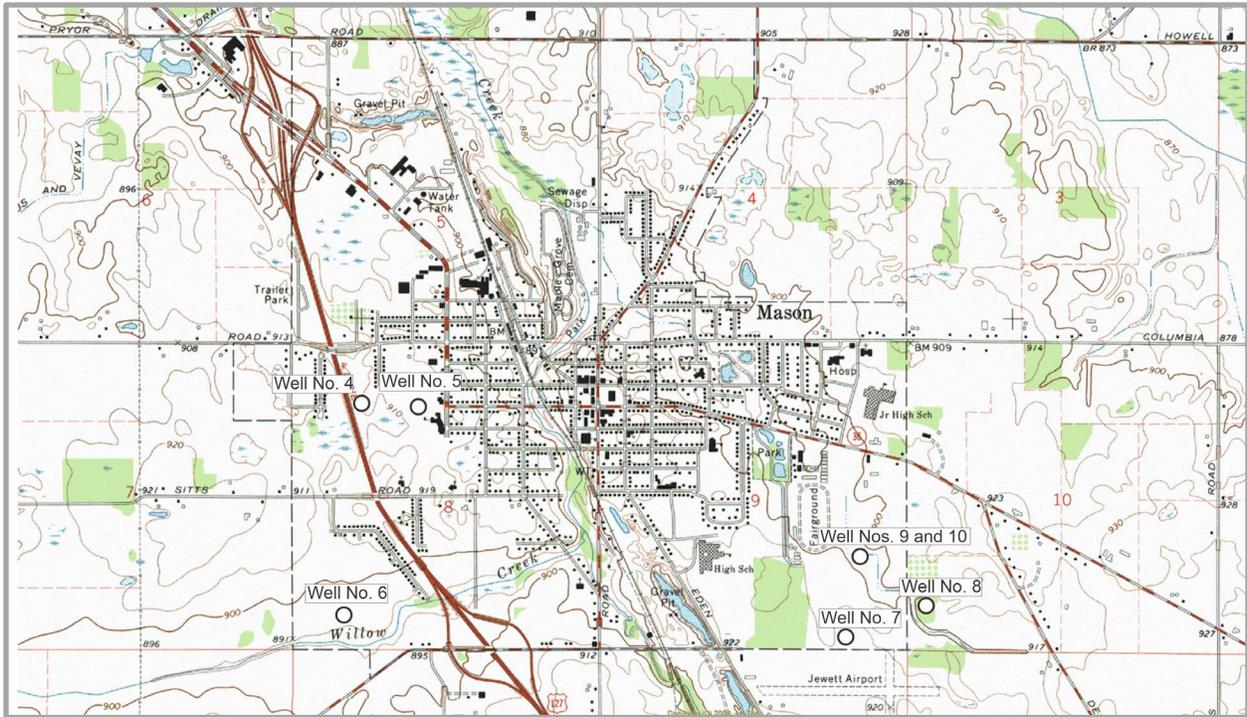


Figure 1. Location Map of the City of Mason Production Wells

A summary of the City production wells and their permitted capacities is as follows. Note here; we are aware that the firm capacity as shown in the table does not agree with the latest Water Reliability Study³ – Well No. 3 has been abandoned since the report was published, and Well No. 10 was chosen over Well No. 9 since these two wells cannot be operated together⁴;

| Well No. | Permitted Well Capacity (gpm) | Actual Capacity (gpm) | Well Depth (ft below grade) | Casing Depth (ft below grade) | Status |
|-----------------|-------------------------------|-----------------------|-----------------------------|-------------------------------|---------|
| Well No. 4 | 300 | 350 | 255 | 102 | on-line |
| Well No. 5 | 250 | 250 | 272 | 65 | on-line |
| * Well No. 6 | 500 | 400 | 346 | 56 | on-line |
| Well No. 7 | 350 | 350 | 358 | 57 | on-line |
| Well No. 8 | 391 | 391 | 400 | 74 | on-line |
| *** Well No. 9 | 250 | 228 | 400 | 90 | on-line |
| *** Well No. 10 | 290 | 300 | 416 | 296 | on-line |

** firm capacity **1581**

* largest capacity well

** firm capacity does not include Well No. 6

*** These wells are too close to each other to be operated simultaneously

Examination of the production well table reveals that Well Nos. 4, 5, 6 and 7 are conspicuously shallower – this is due to the presence or absence of a deeper “clean”

³ Wolverine Engineers and Surveyors, 2022, City of Mason Water Reliability Study, December 2022

⁴ This is the author’s opinion based on the hydraulic behavior of the bedrock aquifer and the probable interference that occurs between these two wells, and may not reflect the manner in which these two wells are operated.

interval of sandstone in the bedrock in those areas of the City. The casing depths of these wells, including Well Nos. 7, 8 and 9, were installed shallower to take advantage of the production potential of the upper bedrock and an attempt to increase their withdrawal capacities at those locations. Empirical evidence has shown however, the upper part of the Saginaw Formation is composed of loose and/or friable sandstones and shales that over time have caved into the open borehole at some of the wells, effectively shutting off the lower section of the well. This has historically occurred on several of the City production wells causing lengthy downtimes and costly rehabilitation work. Conversely, Well No. 10 which is the most recently constructed production well, was purposefully designed with a deeper casing setting to seal-off the upper friable formation. As a consequential observation, the uppermost friable sandstones of the Saginaw Formation appear to produce an insignificant quantity of water to justify leaving these intervals open to the well and risk eventual failure and damage of the well.

Regional Geology and Basinal Setting

The City of Mason lies along the uppermost reaches of the Sycamore Creek Sub-Basin at the confluence of several smaller creek sub-basins - Willow and Talmadge Creeks and their smaller tributaries. The Sycamore Creek basin lies within the Grand River Basin and drains northwesterly where it converges with the Grand River at Lansing (see Figure 2).

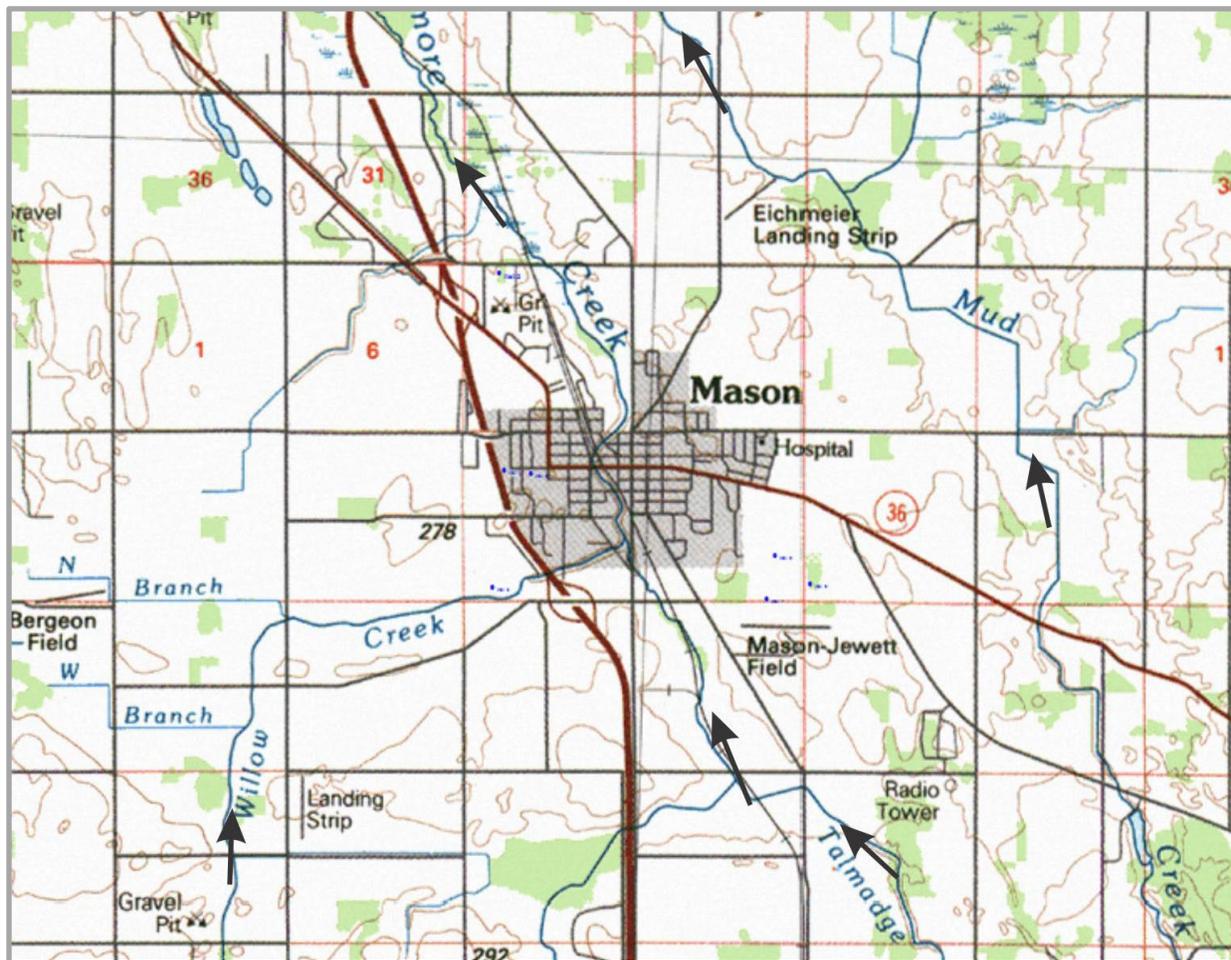


Figure 2: Map of the City of Mason and its Regional Drainage Patterns

The moderately flat topography in this area ranges between 890 feet at Sycamore Creek to 920 feet east of the City at the divide between the Sycamore and Mud Creek Basins. Shallow aquifers that reside within the glacial drift in this area of the basin are influenced by the drainage strength of the Sycamore Creek, but on a larger scale the Grand River Drainageway has the greatest hydraulic strength on the groundwater flow patterns of the Saginaw Formation aquifer.

The City lies within a thin regional glacial till plain which typically consists of poorly sorted loams and silts, with occasional cobbles and boulders. To the north and south of the City lie isolated end morainal complexes which are revealed as elongated hilly areas in the south-central part of Vevay Township and in the north part of Alameda Township. This glacial setting is typical of most of Ingham County (see Figure 3).

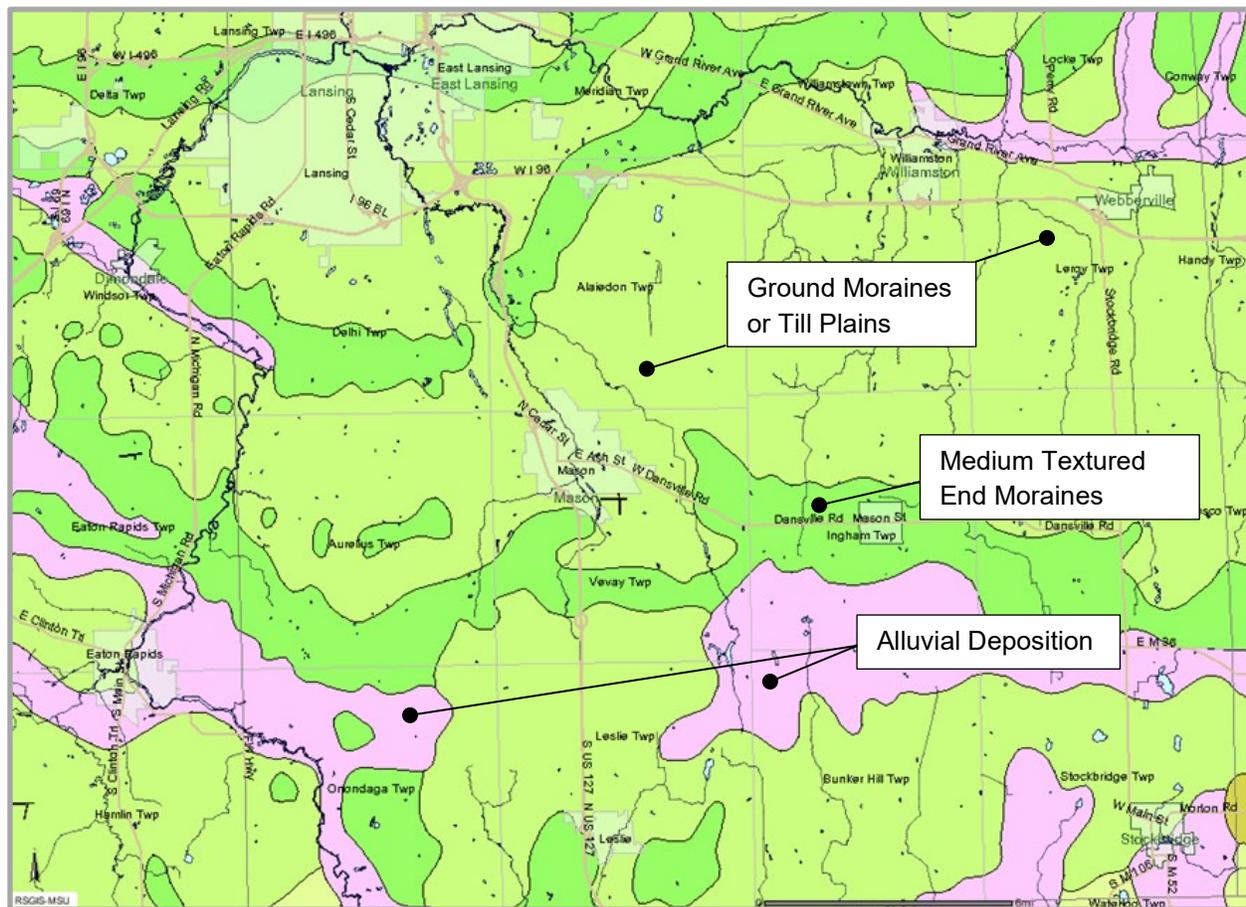


Figure 3. Quaternary Deposits in Central Ingham County

Due to the thin nature of the glacial drift in this area, groundwater occurrence within the glacial materials is scarce and highly unpredictable, and tends to be associated with the alluvial deposits along streams and tributaries. Most private and public wells in this region are, therefore, installed in the local bedrock. In this area, the top of bedrock is the Saginaw Formation which lies less than 50 feet below grade in most areas and contains highly interbedded sandstones, shales and some limestones.

The Saginaw Formation hosts an aquifer which is utilized by nearly all of the public water systems within the central Michigan area – the larger withdrawals are in Eaton, Clinton

and Ingham Counties where the bedrock characteristics can host reasonably significant withdrawals. The Saginaw Formation bedrock aquifer is, therefore, one of the most important sources of drinking water for many central Michigan water supply systems.

Local Area Hydrogeologic Setting

The generalized geology at most of the production well sites consist of surficial clayey soils within the upper 20 feet of drift, sometimes with a sandy and gravelly interval below the surficial clays. The top of the bedrock lies usually less than 50 feet below grade in this area. The Saginaw Formation itself consists mainly of a highly laminated assemblage of sandstones, shales, and occasional limestones from its surface to the thickness of about 400 feet. Throughout this interval, the Saginaw Formation exhibits thick slabs of “clean” sandstone in the upper part of the formation as seen at Well Nos. 4, 5 and 6, and in the location of Well Nos. 7, 8, 9 and 10, a lower thick interval of more competent sandstone is also present. This lower interval does not appear to be present (or was not explored) in the southwest area of the City at Well Nos. 4, 5 and 6. The bedrock aquifer exists under confined conditions with an average static water level approximately 25 feet below grade depending on location and surface elevation.

A local map of the Well No. 9 and 10 wellsite, which is a typical depiction of the complex bedrock assemblage in the area, is shown in Figure 4. A localized cross-sectional illustration of the drift and bedrock package across the City limits is shown below in Figure 5, 6 and 7.

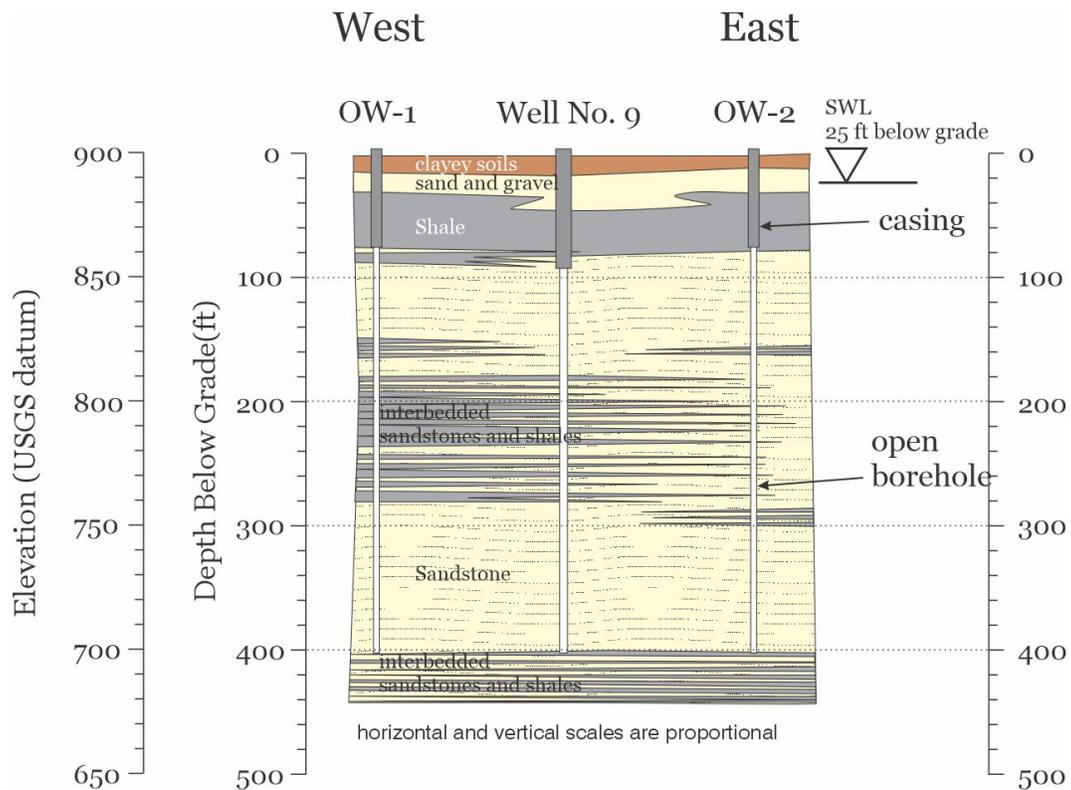


Figure 4. Typical Geologic Cross-Section of the Saginaw Formation at the City of Mason (shown here is the Well No. 9 Wellsite) View Looking North

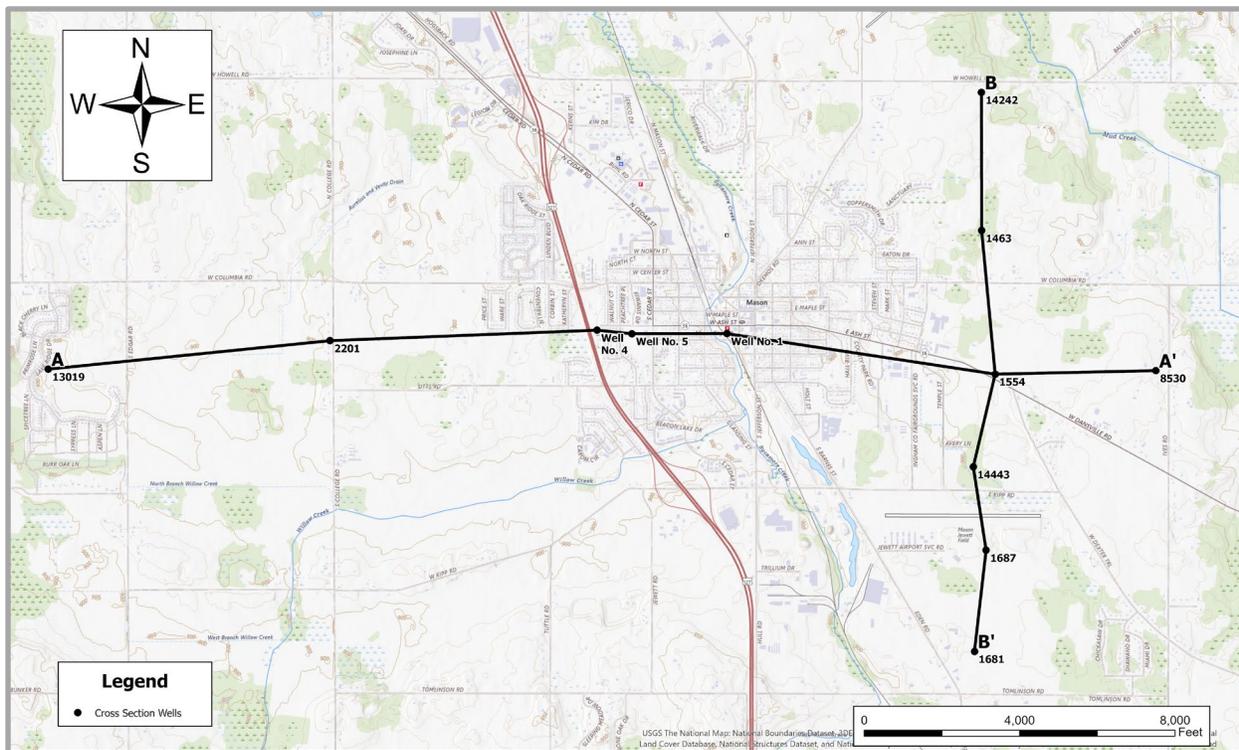


Figure 5. Location Map of Geologic Cross-Section Lines

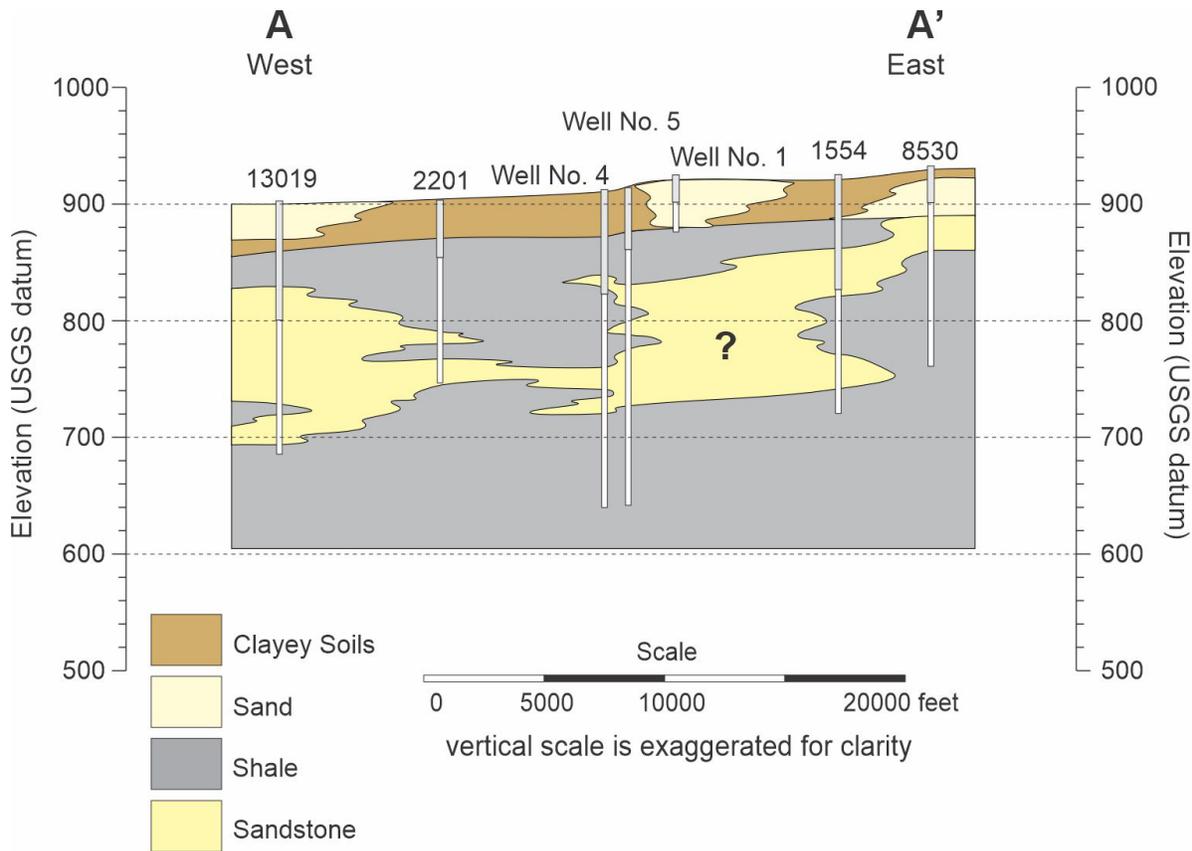


Figure 6 Geologic Cross-Section A-A' – View Looking North

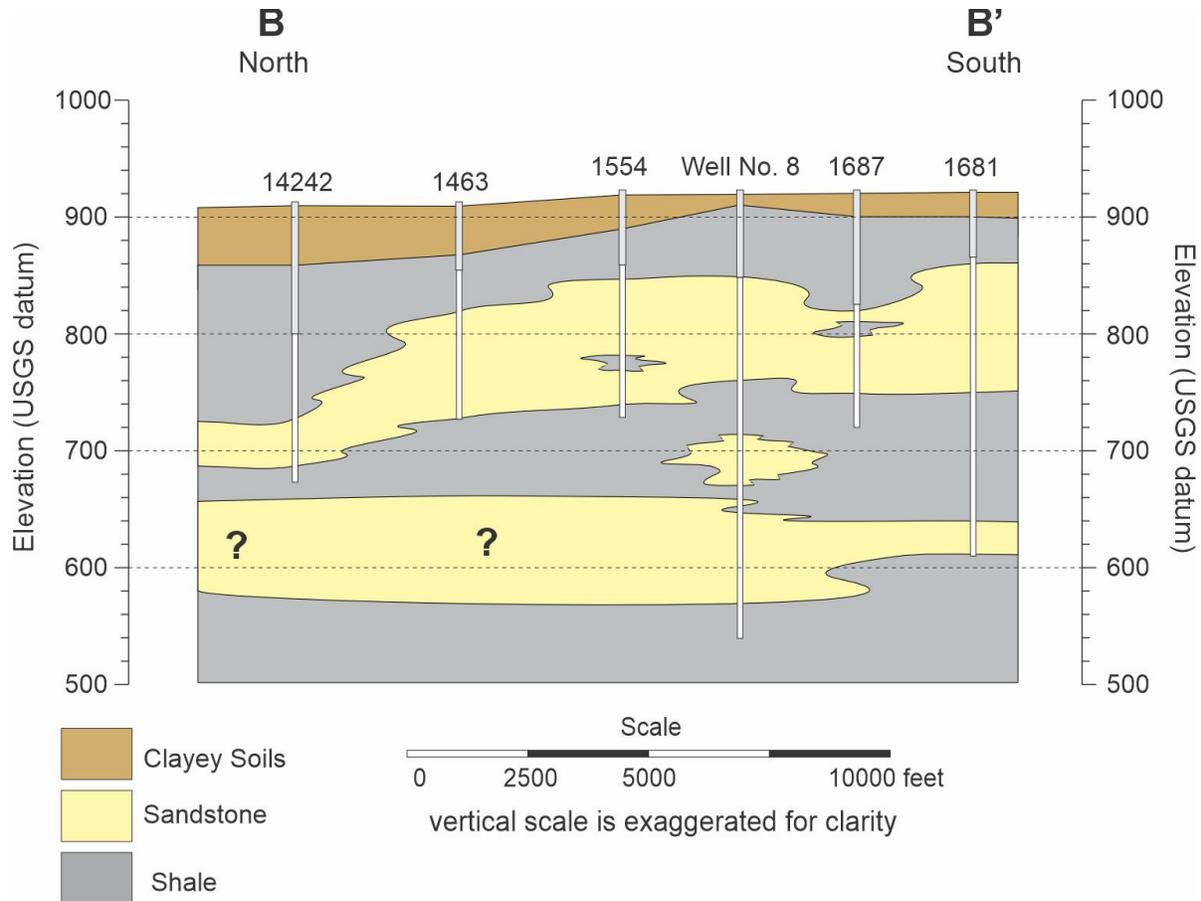


Figure 7. Geologic Cross-Section B-B' – View Looking East

Note here; there are very few wells in this area as deep as the City production wells, therefore, there are large data gaps that limit our mapping resolution along the cross-section lines in Figure Nos. 6 and 7. We can, however, infer from this mapping that the extent of “clean” sandstone packages might be limited toward the west which could imply a lateral boundary within the deeper part of the bedrock aquifer.

Groundwater Flow Mapping. To better understand the regional groundwater flow patterns in this area, water level elevations from the Michigan GIS database were mapped over a wide area using static water levels from the Michigan Wellogic data base using only wells completed in the bedrock. The Wellogic data was visually inspected to remove any obvious outlying data with respect to neighboring datapoints, and interpolated onto a regular grid using an ordinary Kriging method of interpolation – in certain areas, large data gaps and dubious static water levels have contributed to contour anomalies. The resulting grid was further refined using a sliding averaging gate filter to remove “noise” in the data and smooth the groundwater elevation contours. The resulting groundwater elevation map is shown below in Figure 8.

Examination of the groundwater elevations in Figure 8 reveals that the hydraulic strength of the Grand River controls groundwater flow within the Saginaw Formation in this region.

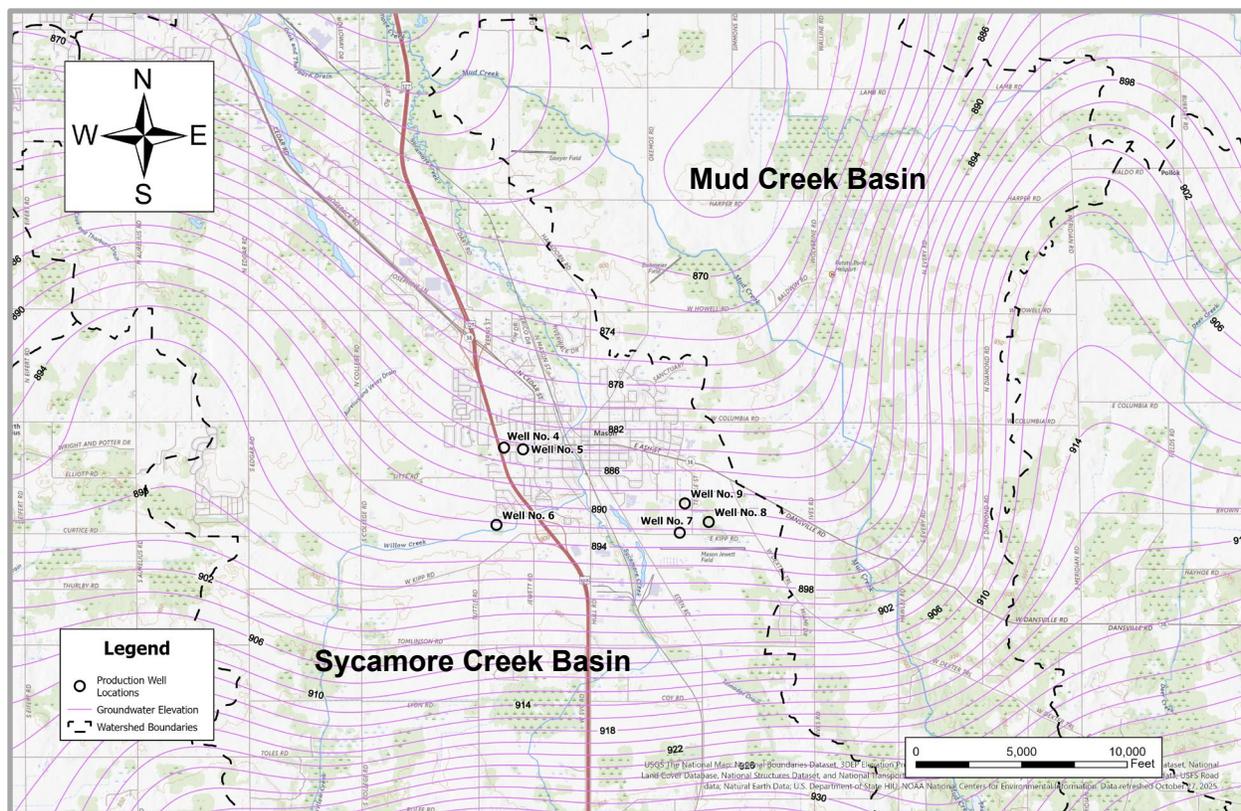


Figure 8. Groundwater Elevations in Central Ingham County

Historical Aquifer Testing and Bedrock Aquifer Characterization

The basis of any basin-wide groundwater resource evaluation relies on two main aquifer hydraulic properties – aquifer transmissivity and storage – which can only be derived from aquifer testing. The aquifer testing data collection and analyses fulfill the requirements of EGLE Policy/Procedure DWRP-03-003⁵, which is reviewed and approved by the EGLE Source Water Unit, and ultimately incorporated into the groundwater inventory and groundwater use process for that basin under Part 327⁶ (this reference has several related documents). The aquifer transmissivity and storage values can be used to predict aquifer behavior and drawdowns at various distances for various pumping scenarios from any pumping well within the same basin. When used for predicting aquifer behavior, the predictive confidence level increases whenever multiple aquifer test results are available within the same groundwater basin, particularly when the results are consistent. In the case of the City of Mason, there have been four aquifer tests performed associated with the City’s most recent constructed Well Nos. 7, 8, 9 and 10.

Summary of Aquifer Tests on the Saginaw Formation Aquifer.

⁵ Aquifer Test Requirements for Public Water Supply Wells, 1997, Michigan Department of Environmental Quality (now EGLE) – Water Division, Policy/Procedure DWRP-03-003.

⁶ Hamilton, D.A., Seelbach, P.W., May 2011, Michigan Department of Natural Resources Fisheries Division, Michigan’s Water Withdrawal Assessment Process and Internet Screening Tool, Fisheries Special Report 55.

Aquifer tests are customarily performed using a production well as the pumping center, with a minimum of two observation wells located at various distances from the pumping well to record aquifer behavior. The production well is pumped for a minimum of 24-hours for confined aquifers as is applicable for the Saginaw Formation bedrock aquifer. There are several analytical methods for the analysis of aquifer behavior to derive aquifer transmissivity and storage (these are main goals). The simplest approach is to plot the drawdown and recovery data in semi-log form and calculate the predictor set based on what is commonly known as the “straight line method” after Cooper and Jacob, 1946⁷. This method has its nuances, and cannot be depended on by itself for every aquifer situation, but the method was originally based on unsteady state confined behavior which is directly applicable to the Saginaw Formation bedrock aquifer. Each of the four, formally conducted aquifer tests on the City production wells reached the same or very similar conclusions. With few exceptions, these results are also consistent with aquifer testing results throughout the Saginaw Formation at many other locations in Ingham and Eaton Counties. The average values for transmissivity and storage are; transmissivity (T) 0.53 ft²/min, and storage coefficient (S) 0.0002, which is shown below in Figure 9 as a classic example of aquifer behavior in this part of the groundwater basin. The example shown in Figure 9 is the aquifer test analysis from Well No. 9. This test was one of the few aquifer tests where nearby City production wells were shut down for a short period allowing most of the test to be performed without the interference from nearby production wells.

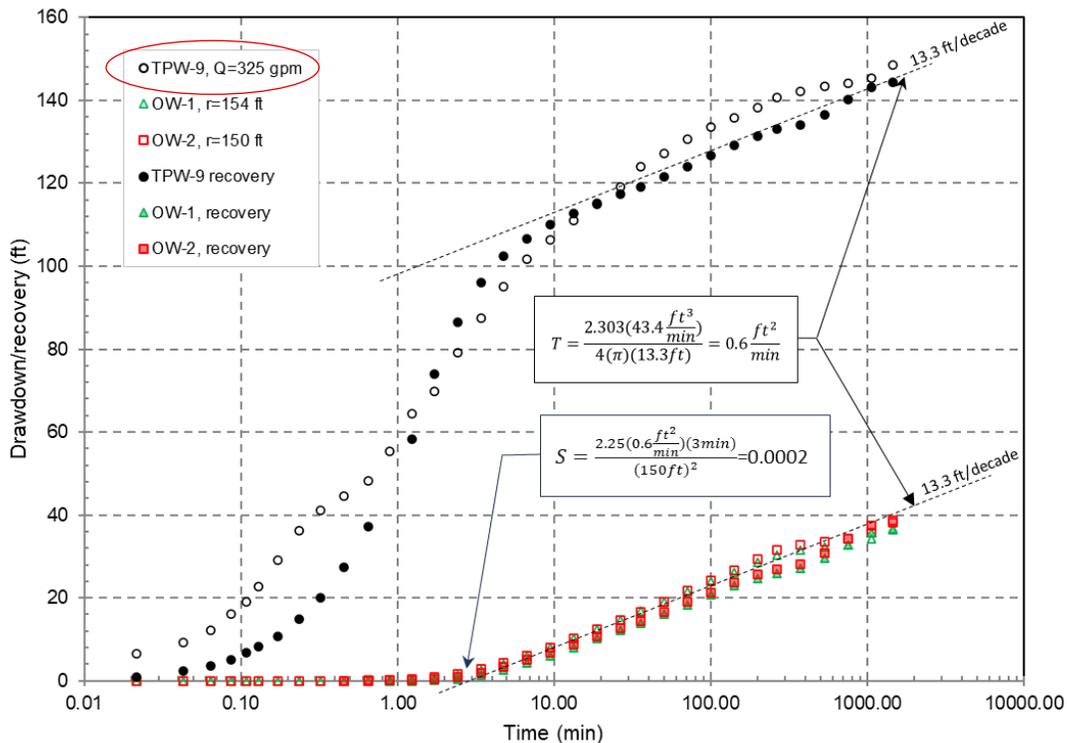


Figure 9. Characteristic Straight-Line Solution (Q=325 gpm)

For additional supporting characterization, most groundwater hydrologists prefer the “curve matching method” of aquifer analysis, and one of the simplest is the analytical

⁷ Cooper, H.H., and C.E. Jacob, 1946, A generalized Graphic Method for Evaluating Formation Constants and Summarizing Well-Field History, Transactions of American Geophysical Union, Vol 27, No.4

method for confined aquifers after Theis, 1935⁸ - this model is the fundamental basis for all other analytical methods used for various other aquifer types and scenarios. In this case, it is directly applicable because the local bedrock aquifer reasonably meets all of model's criteria⁹. This method provides a second valid check for bulk transmissivity ($T=0.53 \text{ ft}^2/\text{min}$) and bulk storage ($S=0.0002$) for the bedrock aquifer (see Figure 10).

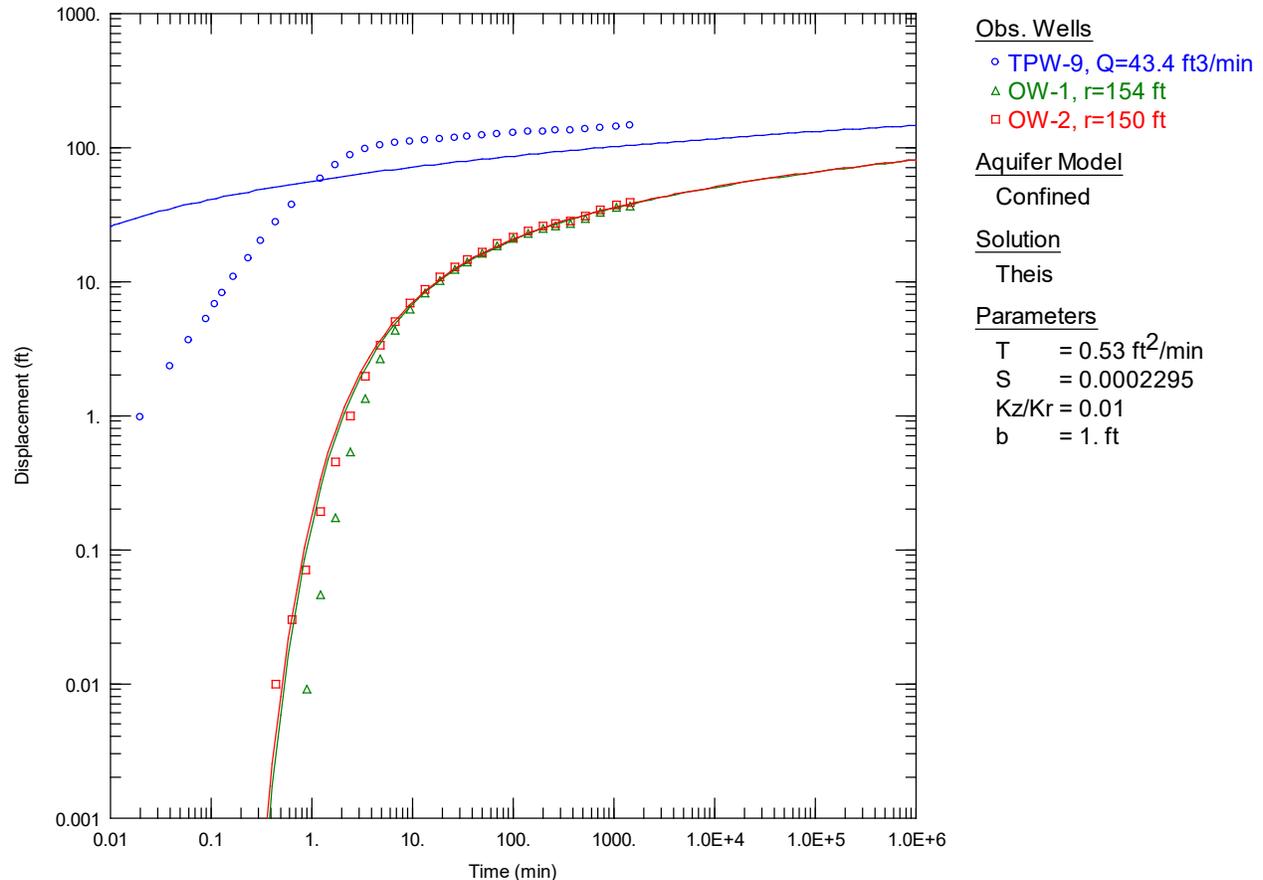


Figure 10 Characteristic Confined Aquifer Solution for the Saginaw Formation (after Theis, 1935). Pumping Well No. 9, Q=325 gpm

The simplest hydrogeologic model for this part of the groundwater basin, therefore, consists of a slab bedrock aquifer (the Saginaw Formation) that is highly interbedded with sandstones and shales, bounded above and below by shales or interlaminated shales and sandstones. The overall bedrock aquifer thickness is about 320 feet, but its effective

⁸ Theis, C.V., 1935, The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage, Transactions, American Geophysical Union, Vol 16, pp 519-524

⁹ There is one caveat regarding this analysis; the confined aquifer analytical approach (after Theis) is based on porous media, i.e., sand and gravel aquifers. In this analysis, the bedrock is assumed to behave as an equivalent porous media and therefore, no attempts are made to differentiate between the hydraulic characteristics of the matrix and(or) localized fracturing. With this method of analysis, the hydraulic behavior of the bedrock aquifer is complex and is controlled by fracturing combined with the permeable nature of the bedrock. The application of this model is appropriate, and, the hydraulic effects from fracturing can generally be ignored, only at "late" times and at larger distances from the pumping well.

thickness is much less due to the shaley partings throughout the section. The overall package is further complicated by the fact that there are at least two “clean” sandstone intervals which contribute water to the pumping well, but both intervals are not always present everywhere within the City limits¹⁰. Drawdowns at each production well tend to be large and propagate rapidly at far distances away from each pumping well, and readily interfere with other production wells when multiple wells are pumping simultaneously.

As a common practice, EGLE requires for every aquifer analysis the expected drawdowns that will occur if the well were pumped continuously for a period of 100 day – this is considered the worst-case benchmark scenario and is ultimately used to support the capacity rating of a Type I water well. In this case, Figure 11 shows this standard method which consists of extrapolating actual drawdown data to 100 days to empirically show the projected 100-day drawdown. This pumping well performance is typical for each City production well, and shows the degree of drawdowns that occur within the Saginaw Formation in this location. This also indicates how deep pump intake settings need to be to avoid a break in pump suction, and deep enough to accommodate the interfering drawdowns from other simultaneously pumping wells (more on this further below).

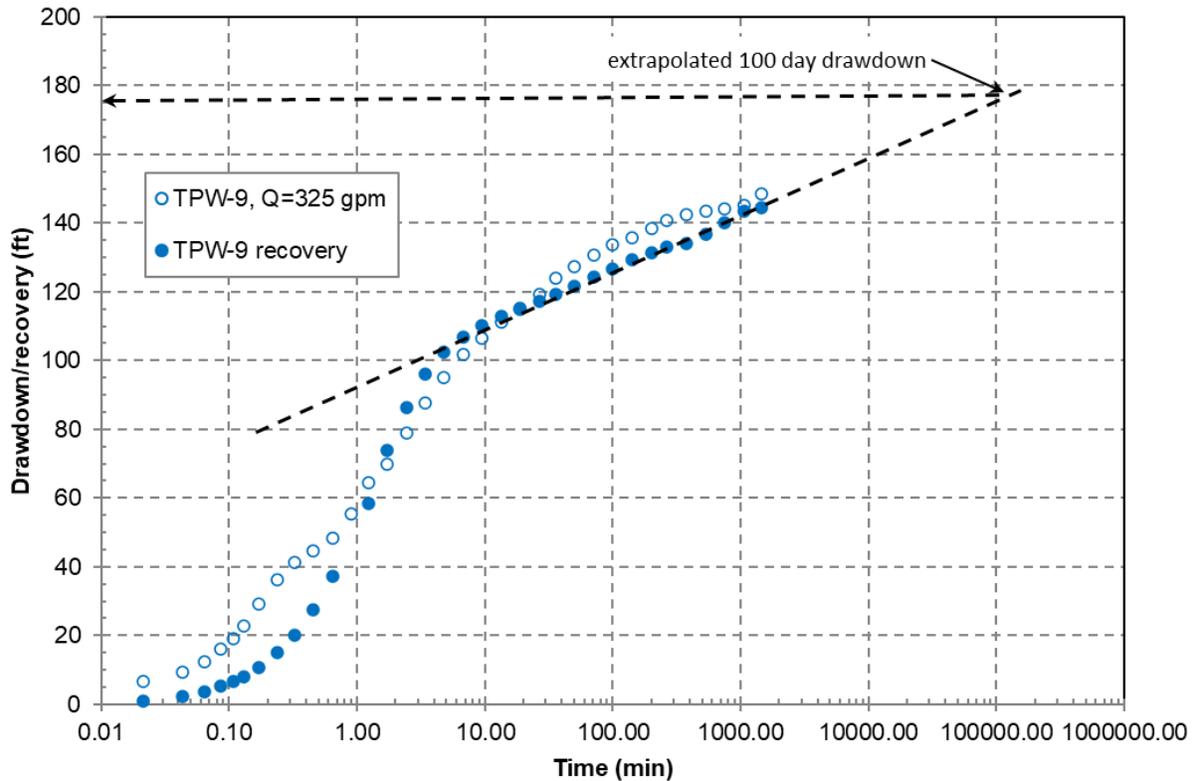


Figure 11 Drawdowns at Test Production Well No. 9, Q=325 gpm.

A final depiction of the drawdowns that occur from each pumping well is shown in Figure 12, below. Figure 12 shows the distance-drawdown relationship of the bedrock aquifer under the 100-day benchmark using an average pumping rate of 350 gpm. The plot shows the large distances drawdowns will propagate when production wells are pumped

¹⁰ Although the actual aquifer boundary geometry is surely more complex, these are the main features that have the most dramatic effect on the pumping behavior of the bedrock aquifer.

continuously for long periods – nearly 20 feet of drawdown will propagate roughly 10,000 feet from the pumping well at long pumping times. The pumping water level at each production well is indicated at the one-foot distance, but this plot shows theoretical drawdowns and does not include entrance losses which add to the pumping water level. Entrance losses are typically stated as the “well efficiency” of a particular production well, and typically entrance losses in this area add an additional 30 to 40 percent to the pumping level, corresponding to a “well efficiency” of about 60 to 70 percent, or an average of 65 percent. Conservatively, the actual pumping water level after 100 days in Well No. 9 will be about 200 feet if the theoretical 100-day drawdown at one foot distance from the well is about 130 feet. This plot is used to calculate the interfering drawdowns between simultaneous pumping wells. For example, with a 100-day pumping water level in Well No. 3, the simultaneous operation of Well No. 7 or 8 will cause an additional interfering drawdown of about 40 feet. Both wells, therefore, will have a resultant pumping water level of about 240 feet under this scenario. Well pump settings must account for this. Using the distance drawdown relationship in Figure 12, we can appreciate that any combination of multiple pumping wells will cause significant interference between each other.

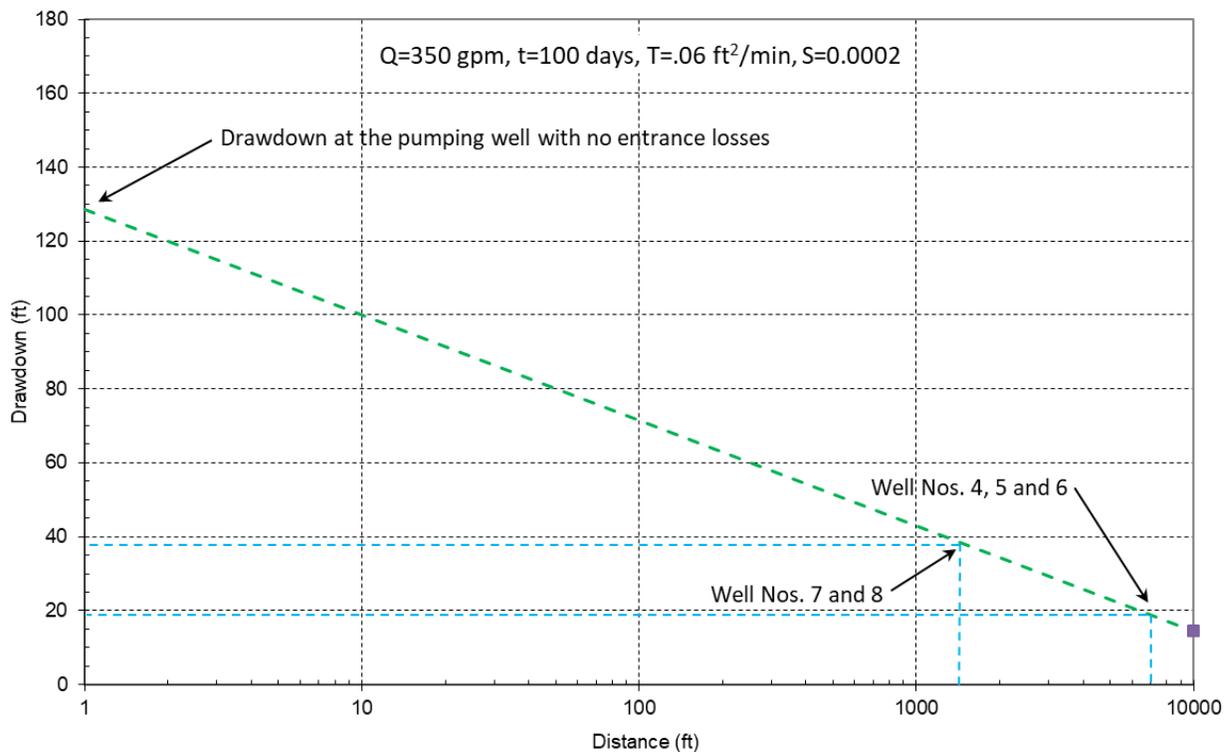


Figure 12 Distance-Drawdown Relationship of the Saginaw Formation Bedrock Aquifer – Q=350 gpm, T=0.6 ft²/min, S=0.0002, Pumping Duration (t) =100 days

Although this discussion may seem extraordinarily conservative, it is worth noting that any new wells added to the City water supply will be required to analyze interfering drawdowns in exactly this manner. Each City production well was originally rated with the same 100-day pumping prediction as the basis for permitting their capacities, and

ultimately each of these existing production wells have little or no ability to increase their capacity.

The only means to increase the City source capacity, therefore, will be to add an additional production well. This is discussed further below.

Firm Capacity and its Implications with Confined Aquifers

The official definition of a water system's firm capacity is the sum of all permitted well capacities minus the largest capacity well. The firm capacity is often considered when evaluating a water system's ultimate supply capacity, and is used as a benchmark to gauge the ability for growth and/or the need for additional source capacity. This is particularly important for water supplies since EGLE's policy is to recommend additional source capacity whenever the present max day demands reaches 80% of the firm capacity (this is only for systems with elevated or ground storage). However, the firm capacity in gallons per minute is typically reported as gallons per day implying all the wells (minus the largest well) can be pumped continuously for 24-hours, or more realistically throughout the max day period which could last several weeks. Some aquifers in Michigan can tolerate this pumping stress, but most cannot. The Saginaw Formation bedrock aquifer is a confined aquifer and if pumped for lengthy periods the aquifer and pumping water levels will continuously lower (see again Figure 11). Proper management of the groundwater resource - particularly for the confined aquifer case – must observe balanced pumping and recovery periods so the drawdowns that occur during operation can recover to their "static water levels" before the pumping cycle can begin again. Excessively long pumping periods with shorter rest periods will never fully recover resulting in progressive lowering of groundwater elevations in the area. This implies a loss of aquifer storage or groundwater mining.

The simplest and most conservative approach, therefore, is to balance pumping and recovery equally at each production well, and preferably allow each production well to rest longer than the preceding pumping period (for example, 8 hours of pumping followed by 16 hours of recovery). This is being accomplished presently without difficulty given the available source capacity versus the current max day demands. However, a balanced pumping schedule of 12-hour run times and 12-hours rest periods will likely accomplish the same management goal. This will be critical if the system demands meet or exceed 80% of the firm capacity during peak demand periods.

Regarding the City of Mason, the firm capacity of the City's water system at face value will accommodate growth for the next 20-years and beyond (assuming the firm capacity is 1580). However, a firm capacity of 1580 gpm "implies" a continuous withdrawal capacity of about 2,270,000 gallons per day (2.27 MGD), which is not sustainable for the reasons given earlier. Conservatively, the "practical" firm capacity would be half of this value – about 1,138,320 gallons per day - to accommodate full recovery after each pump cycling. Indeed, this is a conservative opinion, and a great deal of flexibility is available to the City to modulate pump cycling during max day demands, especially since the City has roughly two million gallons of storage. Nevertheless, these demands must eventually be met from the groundwater resource. **We could argue that the projected 20-year max day period may perhaps "over pump" the aquifer for a short period of time, and as demands subside the pump cycling will be shorter and allow the aquifer to eventually recover during the subsequent low demand periods.** The goal here is to avoid managing

groundwater levels on an annual basis versus managing the groundwater resource on a daily basis which is appropriate. **Nevertheless, it is the authors opinion that the City has sufficient firm capacity to meet its projected 20-year max day demands – assuming pumpage is balanced on a short-term period through the max day period**

Implications of Adding Baseline Capacity or an Additional Well

The main goal of this report is to provide the City with a practical statement regarding the capacity of the local aquifer, and by extension, address its reserve capacity. If groundwater management is approached conservatively as discussed above, the conclusion might be that there is no reserve groundwater capacity. The fact that projected max day demands are highly unpredictable further complicates this matter.

The easiest solution is to add additional production capacity – each new well would be about 350 gpm, or about 252,000 gallons per day if it were operated in a balanced manner as discussed above. The addition of a new production well within the Sycamore Creek Basin, however, is not without its challenges. For this, there are several factors to consider;

- The ability to construct a production well in a location that satisfies the standard isolation areas, and is located where it will not adversely affect the pumping water levels, or aquifer water levels at existing production wells
- Receiving EGLE approval of a new production well within the Sycamore Creek Basin that is contingent on receiving a passing score under the Part 327 Water Withdrawal legislation.

Constructing a production well that satisfies the standard isolation areas and will not adversely affect the existing production wells.

At minimum there are two main isolation areas that must be met for EGLE approval for every Type I production well; 1) The property must have enough area to accommodate the standard isolation area of a 200-foot radius around each well. The property must be owned or under the full control of the water utility. This implies at minimum a 400 by 400 foot parcel with the well at its center (basically a 4 acre square), and 2) All production wells must be at least 2000 feet from any source of potential contamination. There are other criteria that must be met, but these are the most important and are highly scrutinized by EGLE. Other restrictions include; i) no well can be located within the 100-year floodplain of any drainageway, ii) wetlands or surface waters cannot be within 200 feet of any Type I production well, iii) stormwater basins or related facilities, including sanitary collection facilities cannot be within 200 feet of any Type I production well.

With these to consider, the City owns or has access to several properties within its City limits. These are shown in Figure 13 below along with all the potential or existing sources of contamination as mapped from the EGLE RIDE Mapper website. The map only shows the 2000-foot isolation distances, and certain City-owned properties do not meet the 200-foot isolation radius requirement, but as shown on the map, the available options are limited.

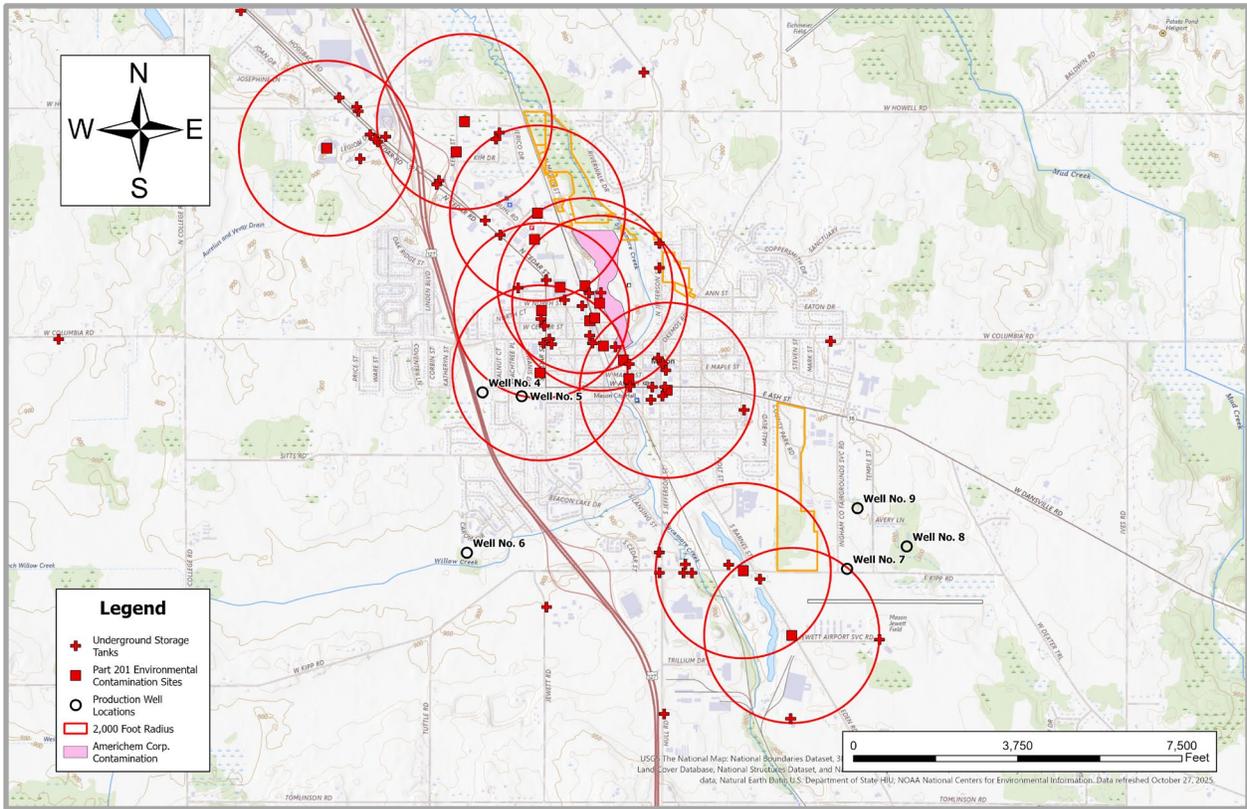


Figure 13 EGLE RIDE Mapper Results with Available City Properties

A cursory examination of Figure 13 reveals a new wellsite could potentially be located northwest of Well Nos. 9 and 10. A secondary location could potentially be located east of Well No. 6 and/or east of US-127, however, further investigation into this area is necessary since these appear to be private properties.

Anything east and north of Well Nos. 4 and 5 will be challenging to receive EGLE approval based on the quantity and proximity of potential sites of contamination. Wells located in the northeast part of the City could also be an option, however, constructing a raw water watermain from this area to the water treatment plant may be cost prohibitive.

Receiving a passing score under the Part 327 Water Withdrawal legislation.

Under Part 327 – Water Withdrawal legislation, groundwater withdrawals are regulated in each stream basin, and each stream basin is assigned an allowable depletion. The basic premise is that every groundwater withdrawal will eventually impact streamflow in the respective basin, and further; the summer low flow period is one of the most important, biologically stressful periods in the annual streamflow cycle. In the approach developed for Michigan, the environmental impact of any proposed withdrawal is assessed against this low flow period. An Index Flow was chosen for every stream basin to represent this period. This is the reference flow from which each new water withdrawal is subtracted and an assessment is made of the environmental impacts caused by that withdrawal (using the web-facing Water Withdrawal Assessment Tool to determine if an Adverse Resource Impact will occur). The maximum amount of water that can be withdrawn from each stream is calculated as a percentage of the Index Flow, and when the risk approaches an Adverse Resource Impact (ARI) is assigned a score of either “C” or “D”

which effectively indicates the basin is either near or at depletion. In those instances, the withdrawal request is normally denied. There are mechanisms, however, which allow the community to demonstrate that an ARI will *not* occur, this is called the Site-Specific Review (SSR) and this process is intensive and the outcome is uncertain.

Note here; every withdrawal we simulated using the web-facing Water Withdrawal Assessment Tool within the Sycamore Creek Basin resulted in a “D” score. The author has since communicated this to the EGLE Water Use Unit to investigate reasons for the “D” score, but in order to explore this further, we would need to formally request a “Site Specific Review” with the EGLE Water Use Unit to explore the ramifications. Meanwhile, the addition of a new well seems uncertain given this preliminary result.

Conversely, the abandonment of Well Nos. 1, 2, and 3 and their withdrawals from the basin may technically still be artificially debiting the basin. In many instances, the permitted withdrawals from abandoned production wells can be reallocated to the basin so that their former debits are available for a new withdrawal – this is not necessarily on a “one for one” basis but is usually very close.

This latter possibility has not yet been explored but offers the real possibility that a new well could be added to the City water system with less regulatory aggravation.

Conclusions

In all cases, groundwater sourced community water supply systems use historical water use data and population trends to forecast their future water use demands and system requirements. These predictions are fundamental to community water-supply planning, and provide the basis for decisions related to infrastructure planning and groundwater supply requirements. The practice of forecasting future water-use demands involves both objective analysis and subjective judgment, and the resulting estimates are typically conservative. Indeed, growth of water use demand coupled with infrastructure deterioration are difficult to predict, and these estimates will change with time. In addition, most groundwater sourced community water systems have a finite source supply which is also a difficult metric to quantify.

The discussion presented in this report addresses two main factors related to the groundwater resources available to the City of Mason; 1) The hydraulic characteristics and behavior of the bedrock aquifer, and the manner in which the City production wells interact with each other, and, 2) the implications associated with increasing the City’s source supply – both related to locating a new production well, and the challenges of regulatory approval.

The City’s source water supply is derived from a regional bedrock aquifer with seven production wells; all are distributed along the southeast and southwest areas of the City. The bedrock aquifer is confined, and multiple aquifer tests performed over the years has demonstrated that pumping stresses on the aquifer cause large drawdowns which propagate quickly and at large distances radially away from every production well. The simultaneous operation of multiple production wells will hydraulically interact with each other and have an additive effect (incremental lowering) on their pumping water levels - this has effectively biased the permitted withdrawal capacities for each City production well. The typical bedrock production well capacity for this area is about 350 gpm, however, pump run times for each well should never exceed pump rest times which effectively

mutes the definition of firm capacity. Nevertheless, this operational philosophy will ultimately add a layer of caution to the overall operation of the City wellfield and will preserve its source capacity for the future.

The City may consider adding additional source capacity with one or more new production wells. The logistics of locating new wells, however, will be challenging given that few areas can host a wellsite that comply with EGLE's Type I water well location vetting process. Albeit, there *are* several locations that would comply with basic siting requirements, but the withdrawal(s) will ultimately need to comply with the Water Withdrawal Legislation under Part 327. Under these restrictions, any simulated attempt to register a new 350 gpm withdrawal within the City limits (using the web-facing WWAT) results in a failing score, which at face value indicates the proposed withdrawal will be denied. The WWAT appears to indicate the Sycamore Creek Basin withdrawal allowance is already depleted. We note here; the web-facing WWAT is not the "last word" on the scoring of proposed groundwater withdrawals - every proposed withdrawal is always analyzed and confirmed by the EGLE Water Use Unit to provide an official score. The fact that the web-facing WWAT produces a failing score for every proposed withdrawal is a good indication that the Water Use Unit will come to the same conclusion – when this happens the Site-Specific Review (SSR) process is available (only if the community wishes to do so) to demand EGLE perform a deeper analysis of the proposed withdrawal. The SSR process is not only time consuming, but can be an expensive process for the City since it will involve the collection of additional data – the outcome is always uncertain.

Finally, with regard to the City's reserve groundwater source capacity;

The City should protect its permitted baseline capacity to ensure its long-term security for future water demands. If an unanticipated end user were to approach the City with a specific "substantial" request for water service, the City should evaluate these on a case-by-case basis and respond consistent with its current water use demands and groundwater supply conditions

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