County of Summit, Ohio

Department of Sanitary Sewer Services

HUDSON WATER SYSTEM EXTENSION: WATER SUPPLY EVALUATION

Technical Memorandum

DRAFT – FOR REVIEW

November 2022

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Acronyms and Abbreviations

City	City of Hudson
gpm	Gallons Per Minute
gpd	Gallons Per Day
MGD	Million Gallons Per Day
PRV	Pressure Reducing Valve
psi	Pounds per Square Inch
Village	Village of Peninsula
WTP	Water Treatment Plant

1 Background

The feasibility of extending municipal water and wastewater services to portions of the Village of Peninsula (Village) is currently being evaluated by the County of Summit (County). To support that evaluation, Arcadis was retained to perform an evaluation of extending potable water supply from the nearby City of Hudson (City) public water system to a proposed water service area.

This evaluation consists of multiple tasks, or phases, contingent on the outcome of the previous tasks, as summarized below:

- Task 1 – Water Distribution Evaluation – Evaluate the technical feasibility of extending water to the proposed service area, including summarizing residential, commercial, and fire protection water demands.
- Task 2 – Water Supply Evaluation – If deemed feasible in Task 1, this task will proceed to evaluate the City of Hudson's raw water supply (well field) and treatment process capacity to meet the additional demands.
- Task 3 – If deemed necessary from Task 2, this task will support well field performance testing to confirm current capacity

This Technical Memorandum presents a summary of Task 2 and Task 3 evaluations, findings, and recommendations. The focus of this feasibility evaluation includes evaluating the capacity of the well field and the water treatment plant, storage, and pumping gap analysis to determine water supply system capacity to meet anticipated additional demands from the City and Village water users.

Note that this document builds off previous evaluations of the distribution system that are documented within the "Water System Extension: Peninsula Water Service Evaluation" technical memorandum(TM) dated March 2022. From this TM, water use estimates are an important piece of information that must be considered for this supply evaluation. The exact flow rate necessary for the Village to be supplied by the City is unknown; for distribution system evaluations, an initial Phase 1 service area and associated water flow rate was considered while the maximum distribution capacity was also evaluated. Table 1 from the Peninsula Water Service Evaluation TM, re-presented on the next page, notes that annual maximum day demands for the City of Hudson was 1,180 gpm (1.699 MGD) in 2020 and additional demands for Phase 1 of the Village would total 17.2 gpm. The evaluation also considered a potential expanded service flow rate of around 200 gpm for the Village; this was used as a placeholder since around this flow rate, fire service may be impacted, and additional storage may need to be considered. This expansion may result in City supply during a maximum day to increase from 1,197 gpm (1.724 MGD) to 1,380 gpm (1.987 MGD).

Table 1 Water Use Estimates for Village of Peninsula Service Extension

Land Use Type	Number of Properties	Average Day Demand (gpm)	Average Day Demand (gpd)	Maximum Day Demand (gpm)	Maximum Day Demand (gpd)	Peak Hour Demand (gpm)
Residential	26	4.8	6,912	7.1	10,224	9.9
Commercial	16	6.8	9,792	10.1	14,544	14.1
Other (National Park and Vacant Lot)	29	0	0	0	0	0
Total Village Estimate	**71**	**11.6**	**16,704**	**17.2**	**24,768**	**24.0**
Current City of Hudson System Usage (2020)		*826*	*1,189,440*	*1,180*	*1,699,200*	*1,596*
Estimated City Usage with Village Expansion		*838*	*1,206,144*	*1,197*	*1,723,968*	*1,620*

2 Well Field

The City of Hudson's primary water source is a ground water well field that is further described in the subsequent subsections.

2.1 Well Field Description

The City's well field is located off W Streetsboro Street adjacent to the water treatment plant. The well field currently consists of 4 production wells designated as wells 1, 3, 4, and 5 (**Figure 1**). Well 3 has a pump capacity of 350 gallons per minute (gpm). Wells 1, 2, and 5 have larger pump capacities of approximately 700 gpm each. The original pump installed in Well 5 had a capacity of approximately 2,100 gpm, but the pump was downsized to approximately 700 gpm to better serve the limited capacity of the water treatment plant, which is rated at 2 million gallons per day (MGD) or approximately 1,400 gpm. Well 5 has a variable frequency drive (VFD) that allows the flow from the well to be reduced to even lower pumping rates (typically around 350 gpm) when lower rates are needed to meet the needs of the water system. Well 5 was brought into operation in November 2021. Well 5 replaced former production Well 2, which is no longer operated due to its age and excessive performance losses.

The well field is typically operated to provide an instantaneous flow rate near or slightly above 1,400 gpm. This flow rate is typically achieved by operating two of the higher capacity wells together (Well 1, 4, or 5 with the VFD set to produce maximum flow) or by operating one higher capacity well with two lower capacity wells (Well 3 or 5 with the VFD set to produce around 350 gpm). The total daily flow to the plant is controlled by adjusting the daily run time of the active combination of wells. The wells become active when water levels in system storage tanks fall to a pre-programmed minimum level. The production wells are typically only operated for a portion of the day, except under very high demand situations.

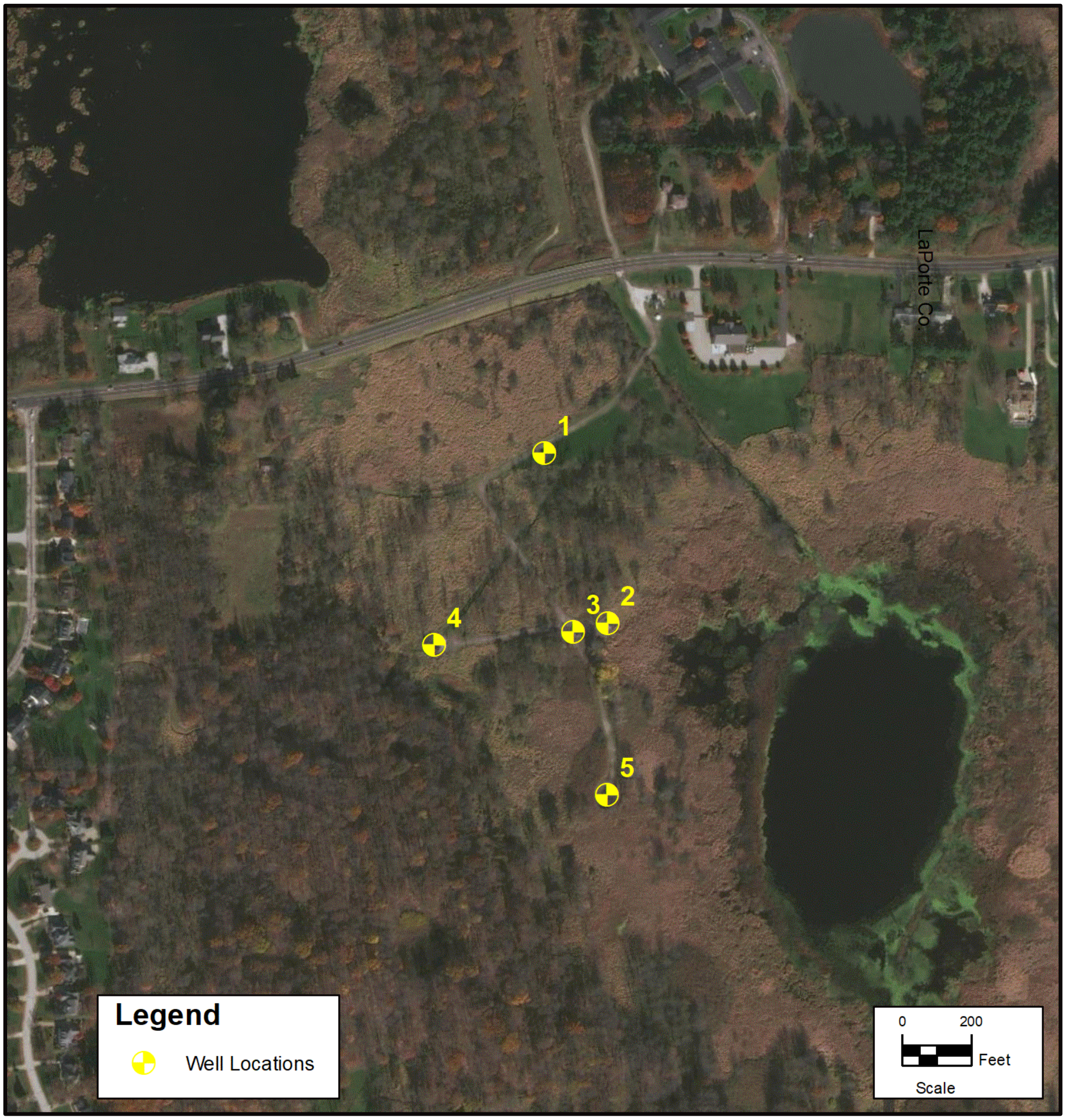

Figure 1 City of Hudson Well Field Layout Map

2.2 Well Field Approved Capacity

Per Ohio Environmental Protection Agency's (OEPA) guidance documents, the Approved Capacity for a groundwater source is defined as the sum of the capacities of the wells with the largest producing well pump out of service ("firm capacity") or the safe yield of aquifer; whichever is the least. Given that the largest wells (Wells 1, 4, and 5) each have the same pump capacity, the firm capacity can be determined by assuming that any one of these wells would be out of service at a given time. Therefore, the firm capacity of the well field is 1,750 gpm, or approximately 2.5 MGD. If it is assumed that the safe yield of the aquifer does not limit the capacity of the well field (discussed below), the Approved Capacity of the well field is also 1,750 gpm. The water system cannot currently be operated at the full 1,750 gpm Approved Capacity of the well field because of the more limited capacity of the water treatment plant (1,400 gpm). According to the guidance documents, the Approved Capacity of the well field and water system must be greater than the system's maximum day water demand.

2.3 Well Field Operating Capacity Estimate

The Approved Capacity of the well field is a theoretical number utilized by OEPA. The actual capacity that can be provided by the well field (operating capacity) is often different than the Approved Capacity because the quantity of water that each well can provide under a multi-well operating scenario can be limited by the mechanical capacity of the well itself, interference drawdowns from other active wells, and hydraulic limitations in the raw water piping. For example, running multiple wells together could cause water levels in a well to decline to the pump setting, thereby causing the pump to cavitate and no longer be functional. Similarly, running multiple wells together can substantially increase friction losses in the raw water piping, thereby causing each pump to operate below its design capacity due to the increased back-pressure. Direct observation of the firm operating capacity of the well field has not previously been possible because the smaller capacity of the water treatment plant prevents the well field from being operated at its firm operating capacity.

Because direct observation of the firm operating capacity of the well field is currently not possible, the firm operating capacity of the well field was estimated using a two-phased approach. For the first phase, operational data from the well field was reviewed to establish operating conditions at current flow rates and then the effect of running the well field at its full firm operating capacity was estimated through a series of calculations (Section 2.7). For the second phase, field testing was performed with various combinations of wells running with one of the wells being pumped to waste (Section 2.10).

2.4 Operational Data Review

Recent operational data for the well field was obtained from the City's water plant staff and included design and construction configurations, flow rates, water levels, and maintenance records. The operational data were reviewed to assess where water levels reside in the production wells at current flow rates and whether a sufficient water column remains above the pump settings and well screens to be able to sustain additional drawdowns resulting from increases in production. Given that several of the wells are relatively old, well maintenance and testing records were also reviewed to assess whether future performance declines in the production wells could impact the production from the well field in the foreseeable future. The construction configurations for each of the production wells are summarized in **Table 2**.

Table 2. Well Construction and Pump Details

	Well 1	Well 3	Well 4	Well 5
Year Installed	1966	1970	1988	1995
Diameter (inches)	12	12	16	16
Depth (feet)	137	143	123	148
Screen Interval (feet below grade)	115-137	123-143	102-123	128-148
Screen Length (feet below grade)	22	20	21	20
Screen Slot Size (inches)	0.100	0.060-0.080	0.125	0.250
Pump Capacity (gpm)	700	350	700	700[2]
Pump Setting (feet below grade)[1]	100.9	108.6	78.2	68.3

[1]Top of Pump Bowls. Depth below grade estimated by subtracting height of pump base plate in the field.
[2]Pump capacity was originally 2,100 gpm, but pump capacity was reduced to 700 gpm to meet the needs of the water treatment plant. Flow rate controlled by a variable frequency drive.

2.5 Current Flow Rates

The annual average flow produced by the well field in 2021 was 1,010 gpm (1.46 mgd). Maximum day flows have reached up to approximately 1,400 gpm (2 MGD) over the past few years, which is approximately equal to the capacity of the water treatment plant. Flow rates from individual production wells cannot be measured because they are not equipped with flow meters. However, total instantaneous flow rates from the well field are recorded by the plant's influent flow meter. Since Well 5 was brought on-line, the City has run Wells 1 and 4 together and Wells 1, 3, and 5 together with the flow from Well 5 set to approximately 350 gpm. The Well 1 and 4 combination was producing approximately 1,460 to 1,530 gpm (2.1 to 2.2 mgd), indicating that the wells run slightly above their design capacity when operating together. For the Well 1, 3 and 5 combination, the flow rate from Well 5 was set so that the total instantaneous flow would also be approximately 1,460 to 1,530 gpm.

2.6 Water Levels

The City periodically measures groundwater levels in its production wells. Over the past several years, water levels have typically been measured every few months, though there are some longer time intervals between measurement events in some years. Water levels have been measured both when the wells are active (pumping water level) and when the wells are inactive (non-pumping water level). The water level measurements from the wells are plotted on **Figures 2 through 5**. The tops of the well screens and the pump settings for each of the wells are also plotted on the figures to assess the remaining available water column in each well when the wells are active. The range in non-pumping and pumping water level measurements, pump settings, and remaining available water columns for each well are summarized in **Table 3**.

Non-pumping water levels for the wells varied seasonally, but were relatively shallow, ranging from approximately 13 to 24 feet below grade. Pumping water levels for Wells 1, 3, and 4 were relatively similar ranging from 31 to 47 feet below grade. Pumping water levels for Well 5 were shallower (24 to 26 feet below grade) due to the greater productivity of this well.

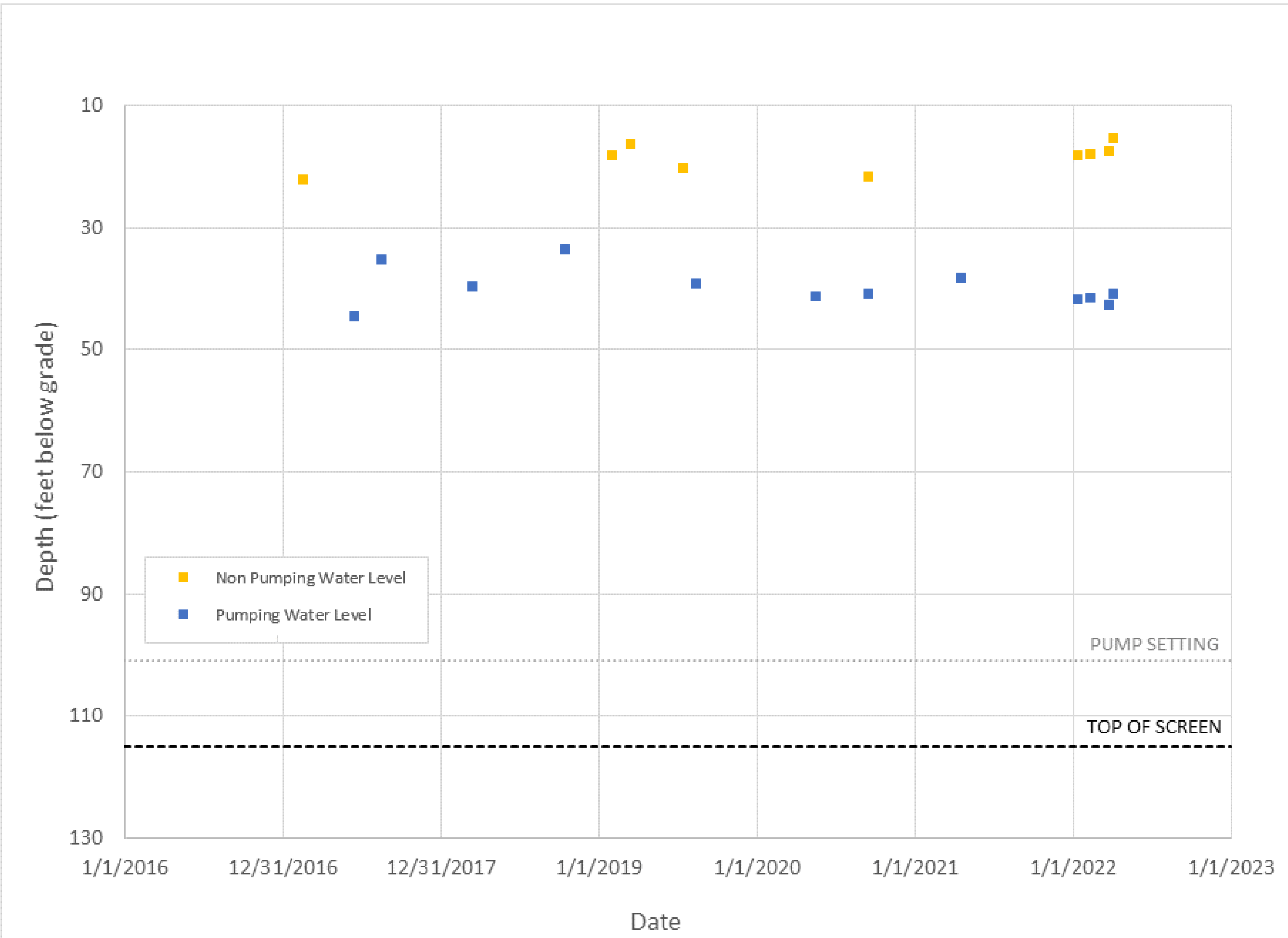

Figure 2. Water Level Measurement Summary: Well 1

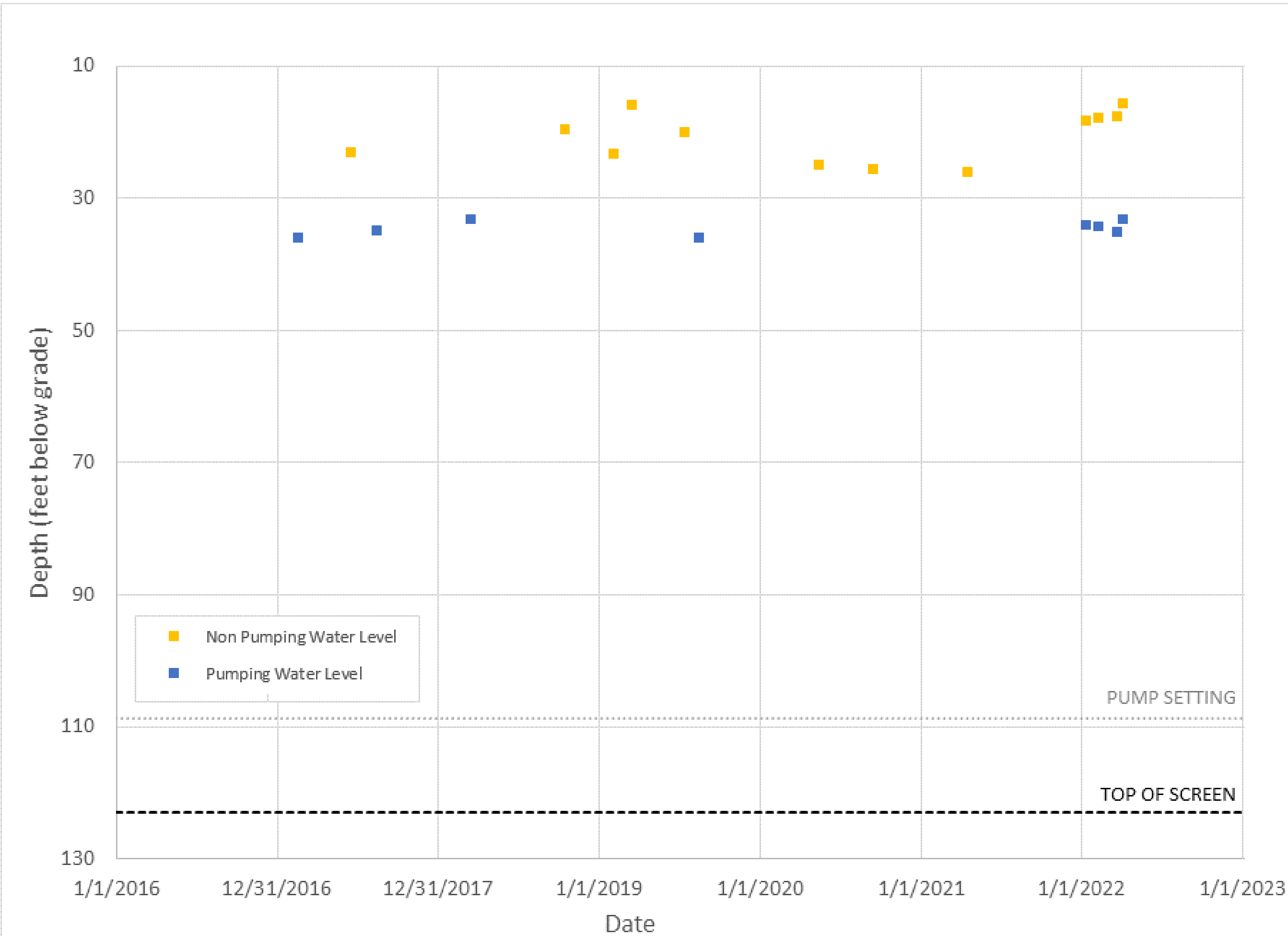

Figure 3. Water Level Measurement Summary: Well 3

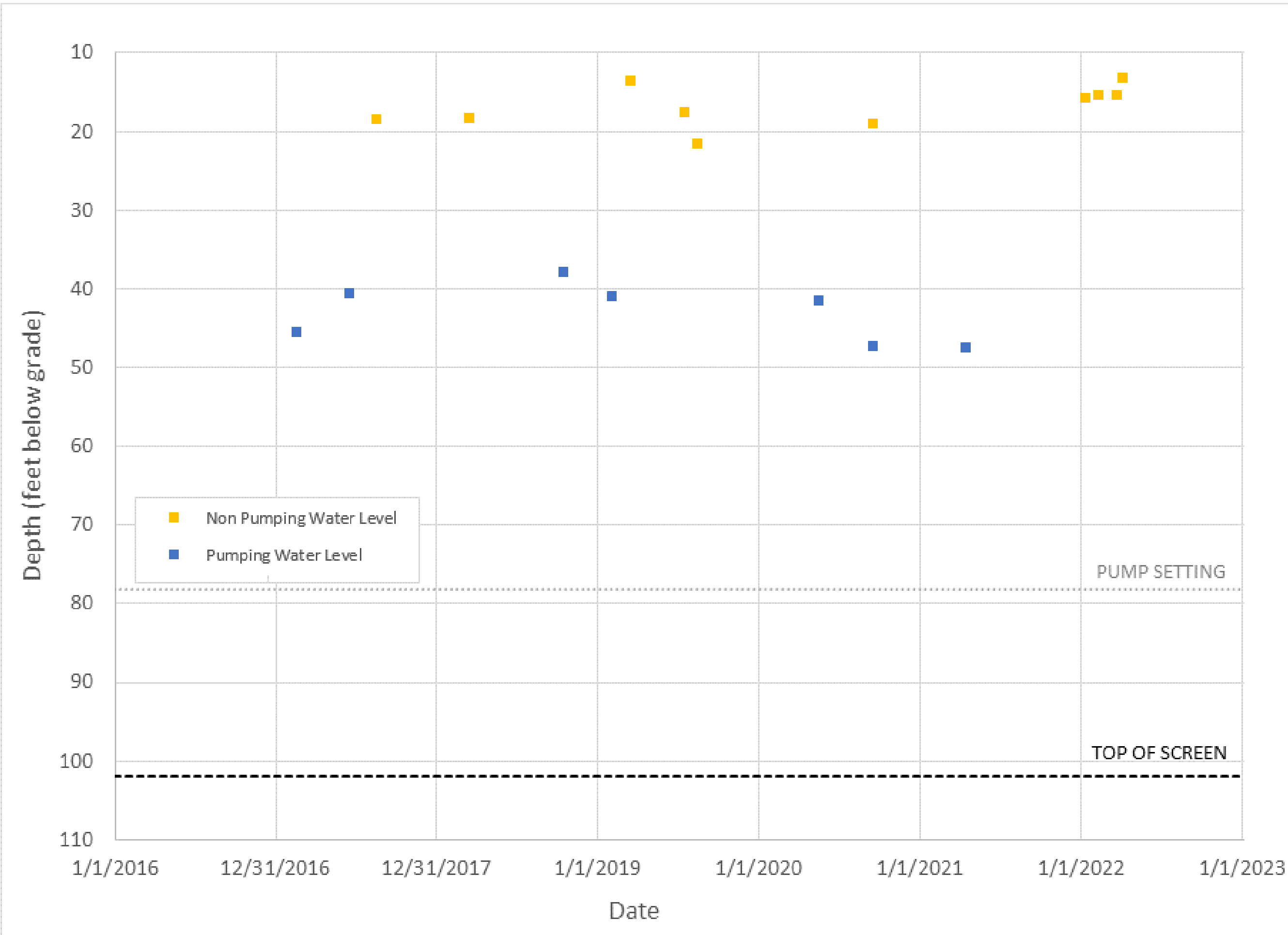

Figure 4. Water Level Measurement Summary: Well 4

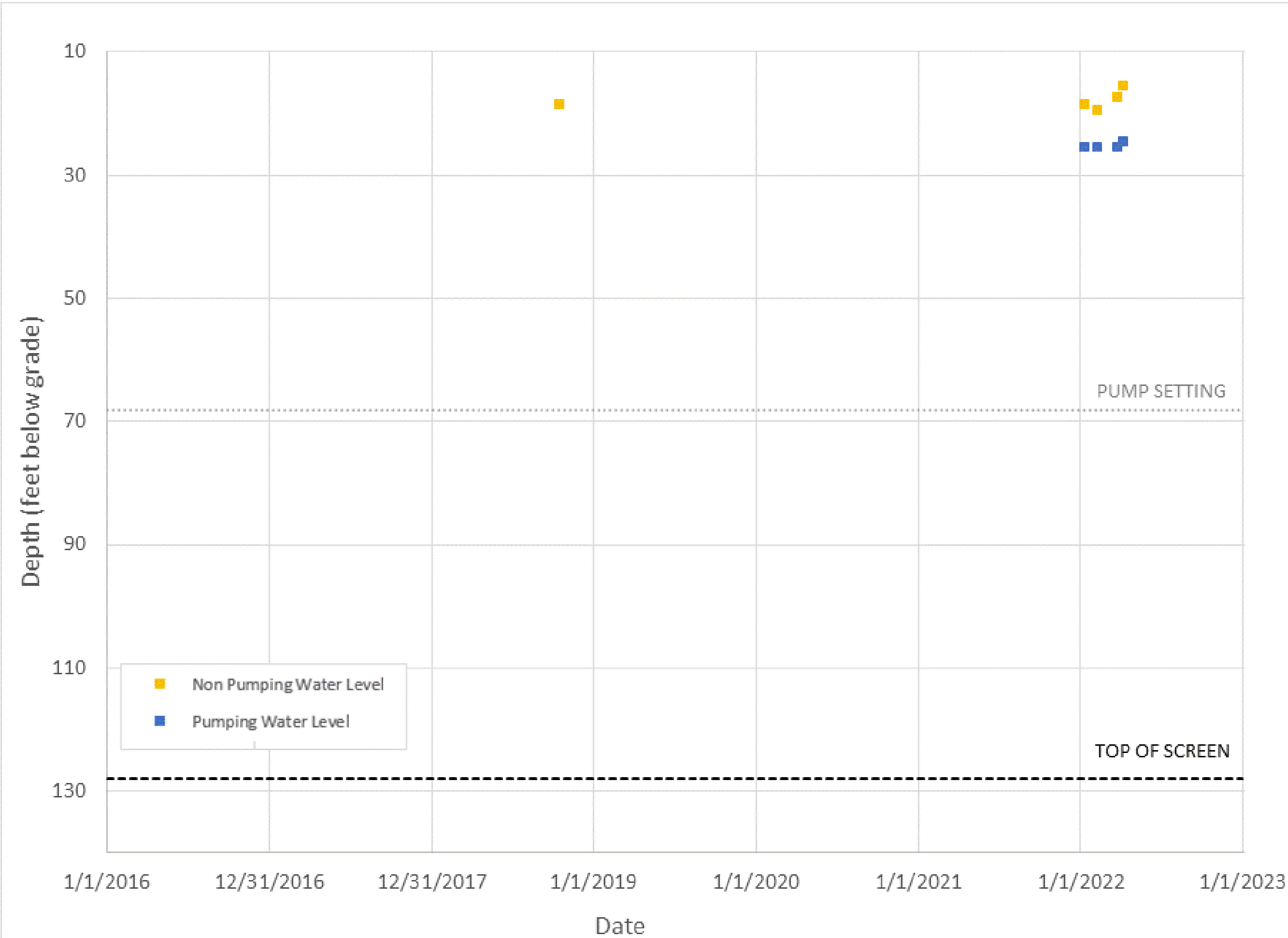

Figure 5. Water Level Measurement Summary: Well 5

The minimum remaining water column (above the pump settings) in each of the wells under the maximum demand condition can be estimated by subtracting the lowest measured pumping water level depth from the pump setting depth. The minimum remaining water columns estimated for Wells 1 and 2 are more than 55 feet. The minimum remaining water columns for Wells 4 and 5 are smaller but are still relatively large at 31 and 43 feet, respectively. It is typically desirable to allow some minimum water column to remain above the pump settings as a safety factor to allow for future increases in drawdown resulting from future well performance declines. If it is assumed that one-third of the non-pumping water column is left above the pump in reserve as a safety factor, there is still 12 to 46 feet of water column remaining above the safety level in each of the wells. In addition, the pump settings in wells 4 and 5 are set well above the top of the well screens (24 feet above the screen in Well 4 and 60 feet above the screen in Well 5) and could be lowered to increase the available water column in these wells if necessary. These data indicate that the wells can easily sustain current pumping rates and there is potential for increased production.

Table 3. Water Level and Remaining Water Column Measurement Summary

	Well 1	Well 3	Well 4	Well 5
Non-Pumping Water Level Range (feet below grade)	15.4 – 22.2	13.9 – 24.2	13.2 – 21.5	15.4 – 19.4
Pumping Water Level Range (feet below grade)	33.5 – 44.5	31.3 – 34.2	37.9 – 47.5	24.4 – 25.4
Pump Setting (feet below grade)	100.9	108.6	78.2	68.3
Minimum Water Column Above Pump (feet below grade)	56.4	74.4	30.7	42.9
Minimum Water Column Above Safety Level Assuming 1/3 of Column Left in Reserve.	30.2	46.3	11.8	26.7

2.7 Firm Operating Capacity Calculations

As discussed above, the firm Approved Capacity of the well field is approximately 1,750 gpm (2.5 mgd). The full firm capacity could be achieved by operating two of the larger wells (Well 1, Well 4, or Well 5 at its maximum capacity) along with one of the smaller wells (Well 3 or Well 5 at a reduced capacity). Operating the well field at its full firm capacity would increase production from the well field by up to 350 gpm (0.5 mgd) above current maximum operating rates. A series of calculations were performed to estimate the additional water level drawdowns that would occur if an additional 350 gpm were produced by the well field.

The additional drawdowns that would result were estimated using the Theis (1935)[1] equation. To utilize the Theis equation, the transmissivity and storage coefficient of the aquifer that the well field draws water from must be known. According to the City's drilling consultant, the average transmissivity of the aquifer near the well field was estimated to be approximately 90,000 gallons per day per foot based on pumping tests completed on Wells 1, 3, and 5 (ACRT, 1996)[2]. The aquifer is overlain by a relatively thick sequence of clays and fine-grained glacial sediments that confine the aquifer near the well field. A typical storage coefficient of 0.0001 for confined aquifers was assumed for the calculations.

The additional drawdowns were estimated assuming a continuous pumping period of 120 days. This corresponds to a long summer drought period over which it assumed that no recharge occurs. The estimated additional drawdowns ranged from approximately 5 to 6 feet across the well field depending on which combination of wells were assumed to be pumping. The 5 to 6 feet of additional drawdown is a small fraction of the remaining minimum water columns above the pump settings of the wells under current conditions and did not exceed the safety levels described above, which indicates that the well field can support this additional pumping.

[1] 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. Transaction of the American Geophysical Union, v. 16, p. 519-524.
[2] ARCT, Inc. (1996). Wellhead Protection Plan Phase I, City of Hudson, Summit County, Ohio. Consultant Report prepared for the City of Hudson.

2.8 Aquifer Recharge

The aquifer that well field draws water from is a linear channel-like feature that is overlain by a relatively thick sequence of clays and fine-grained glacial sediments that likely limits the quantities of recharge entering the aquifer. The long-term sustainable flow rate that well field can support is ultimately dependent on the quantity of water recharging the aquifer. Groundwater levels in the well field have been stable, indicating that the maximum sustainable yield of the aquifer is currently not being exceeded. An assessment of the maximum recharge potential of the aquifer is beyond the scope of this study, but regional planning documents suggest that the well field would be capable of supplying at least 2,100 gpm (3.0 mgd) with further expansion (ODNR, 1988)[3].

2.9 Well Performance

Because of the age of several of the production wells (particularly Well 1 and Well 3), available maintenance and cleaning records for the wells were reviewed to evaluate whether the wells have experiencing significant performance declines over time that might limit production from the well field in the future. The performance of the wells was assessed by evaluating changes in specific capacity (flow rate per unit drawdown) measured in the wells over time as recorded during well performance tests periodically performed during routine well inspection, maintenance, or cleaning activities. Specific capacity measurements are an indirect measure of well performance in that well performance declines will result in corresponding declines in specific capacity.

The specific capacities measured in each of the wells over time are depicted on **Figures 5 through 8**. The plots illustrate that the specific capacities measured in the wells have remained relatively consistent over time, which indicates that there has been relatively little loss in well performance since the wells were installed (**Table 4**). The exception to this trend was for Well 1. The specific capacity of Well 1 declined from approximately 41 gallons per minute per foot of drawdown (gpm/ft) at the time it was installed (1966) to as low as 12.5 gpm/ft in the late 1990s just prior to a cleaning performed on this well. Though this represents a substantial decline in performance, recent well cleanings have brought the specific capacity back in line with the original specific capacity measured at the time of its installation. The specific capacity measurements indicate that the well field should be able to provide both current and the full firm capacity production rates into the foreseeable future provided that routine well maintenance and cleanings are continued.

[3] Ohio Department of Natural Resources. (1988). Northeast Ohio Water Plan: Public Water Supply, 1988.

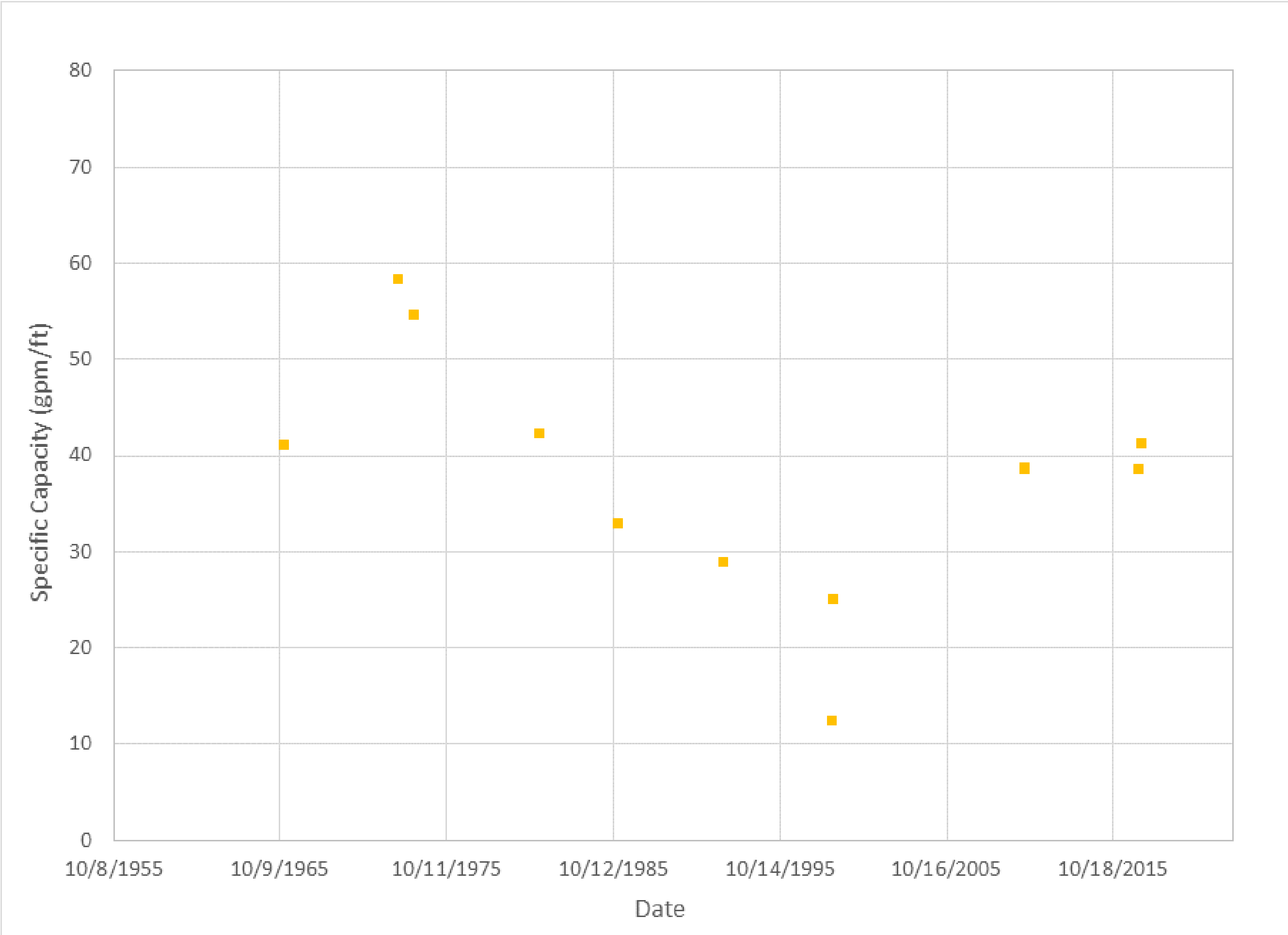

Figure 6. Specific Capacity Summary: Well 1

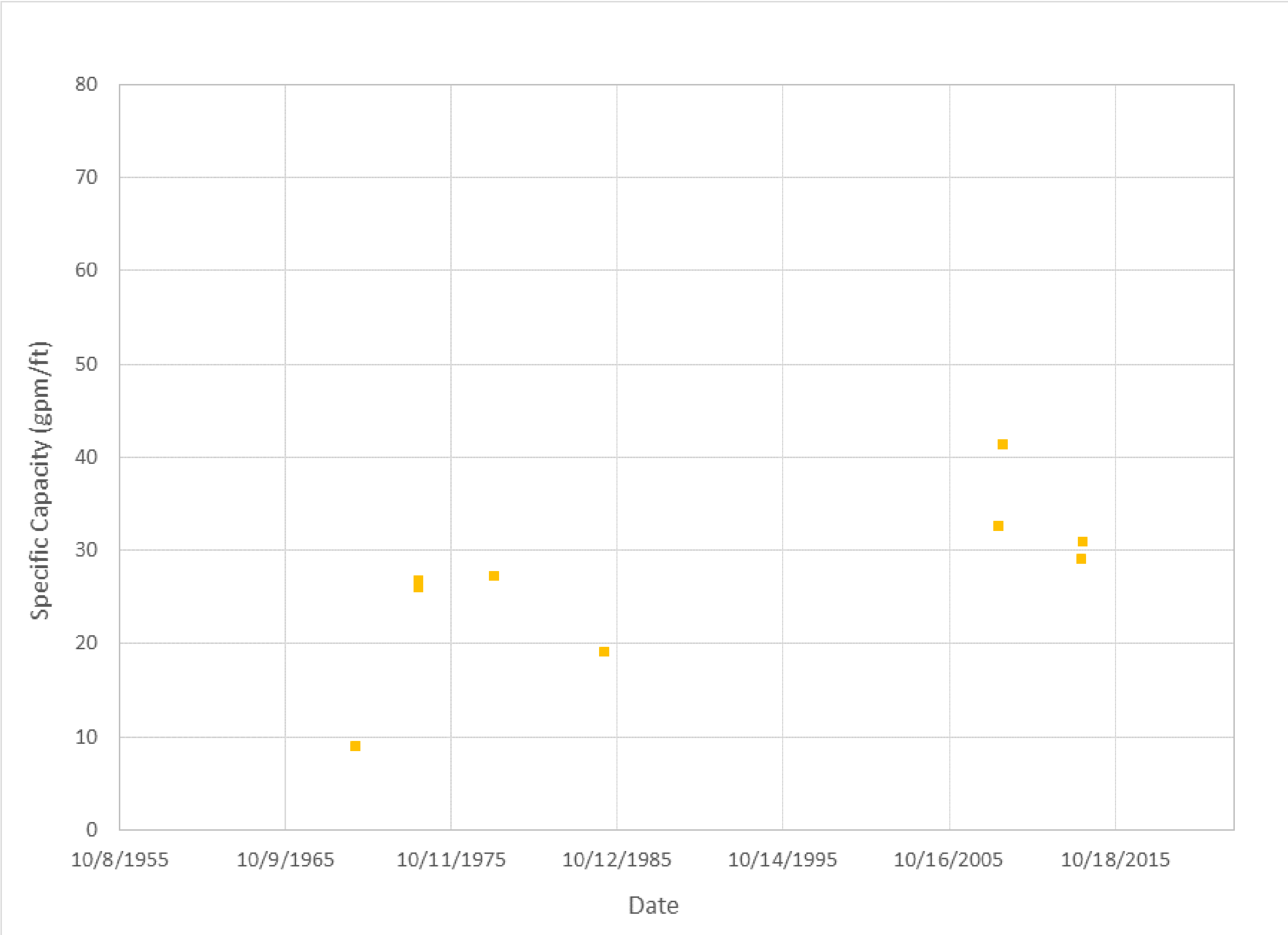

Figure 7. Specific Capacity Summary: Well 3

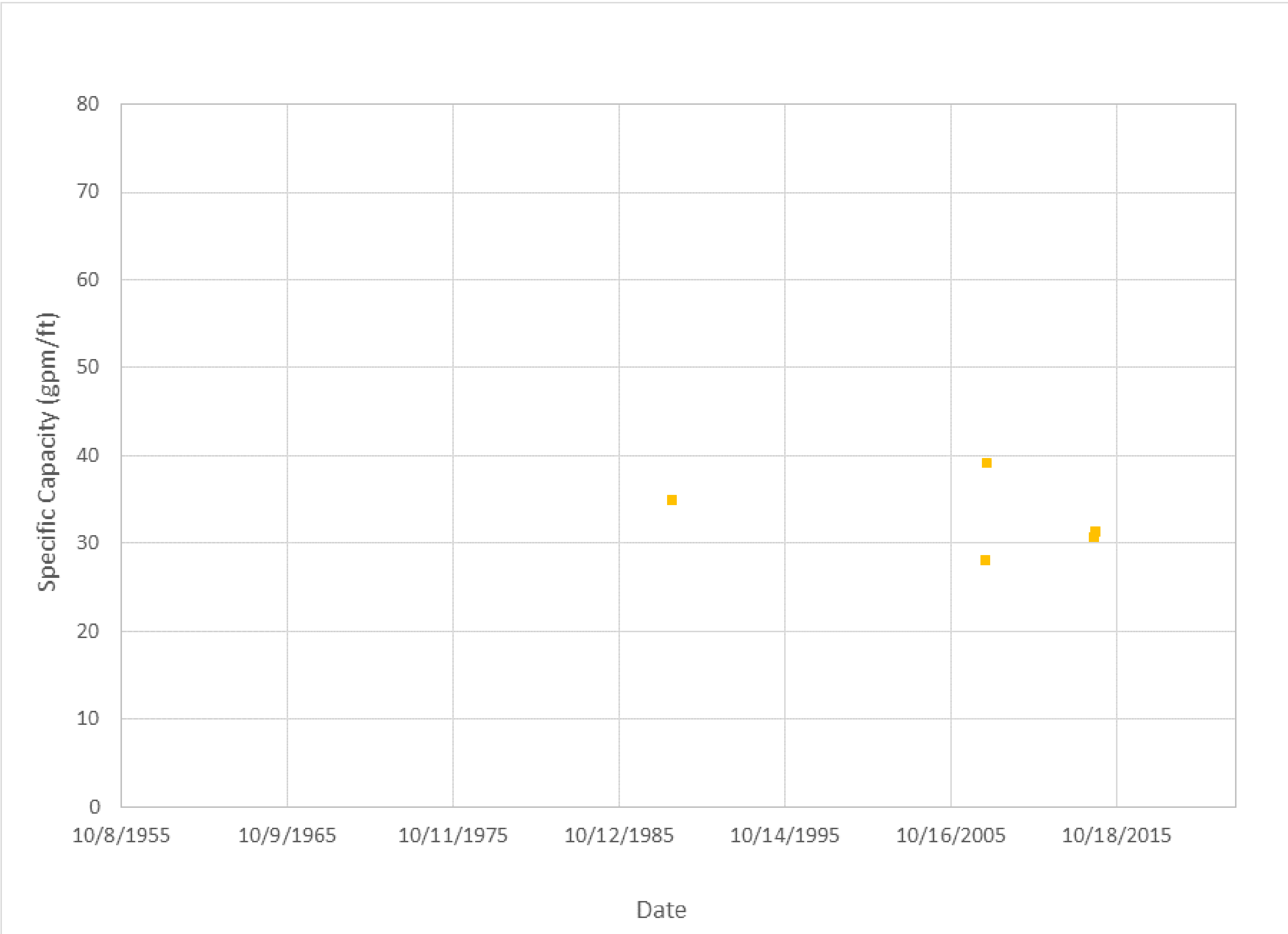

Figure 8. Specific Capacity Summary: Well 4

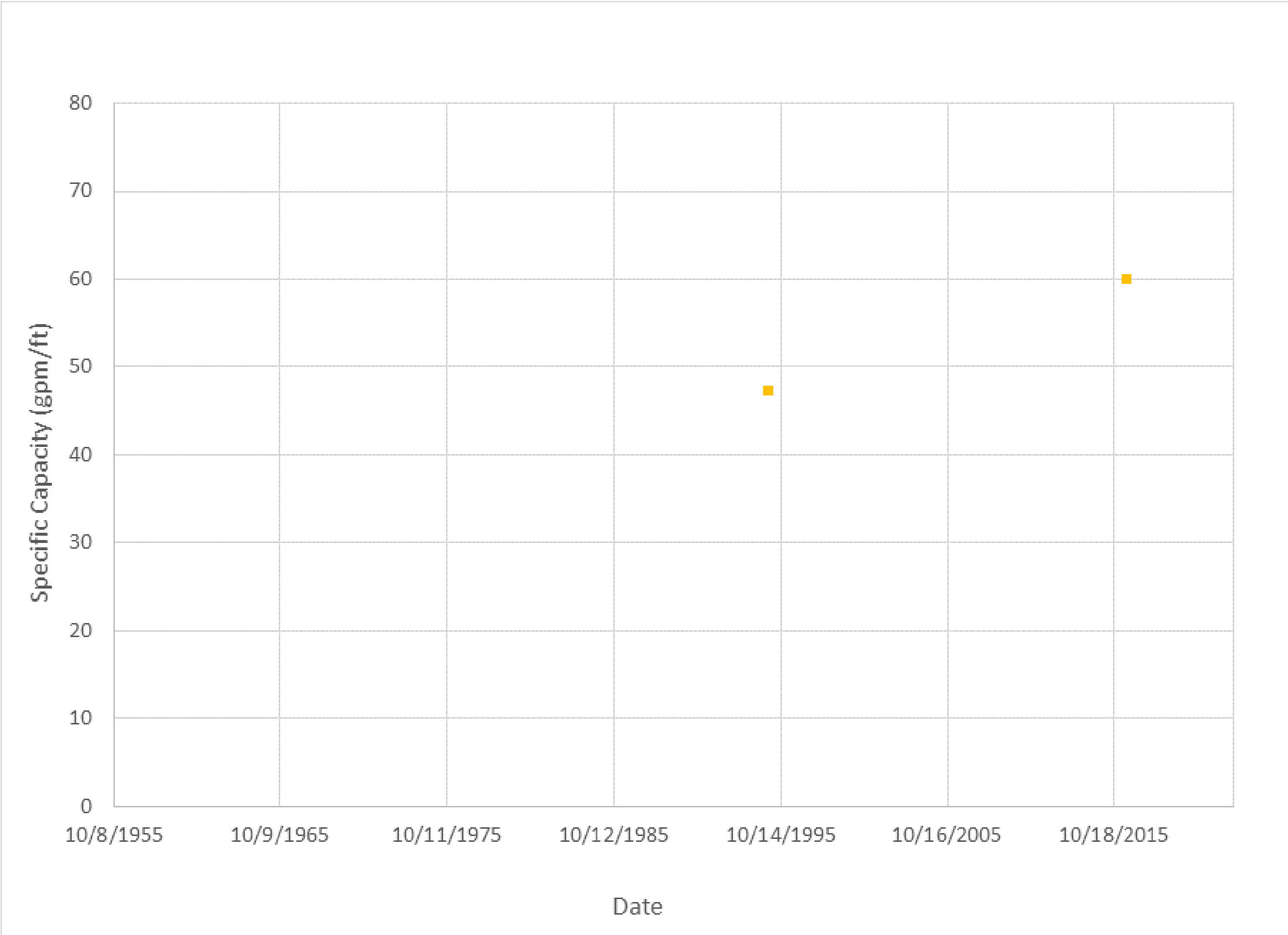

Figure 9. Specific Capacity Summary: Well 5

Table 4. Summary of Specific Capacities Over Time

	Well 1	Well 3	Well 4	Well 5
Original Specific Capacity (gpm/ft)	41.2 (1966)	9.0 (1970)[1]	35.0 (1989)	47.3 (1994)
Most Recent Measured Specific Capacity (gpm/ft)	41.3 (2017)	31.0 (2013)	31.3 (2014)	60.0 (2016)

[1]Well 3 may have been incompletely developed during the original testing. The first specific capacity measured from the well during a test in 1973 was 26.8 gpm/ft.

2.10 Field Testing

Field testing of the well field (Task 3) was performed to further evaluate the firm operating capacity of the well field. The field testing involved operating the well field at its full firm capacity and measuring water levels in the production wells to ascertain whether the wells could operate together without exceeding available drawdowns. Because the water treatment plant could not accept all of the water pumped during the test, water from one of the wells (Well 3) was pumped to waste (to the ground). Though pumping a well to waste neglects to account for the affect of increased back-pressures in the raw water main that would result from pumping that well, the increase in back-pressure is not anticipated to be large, and the field test is the closest approximation to an operating condition that could be achieved without expansion of the water treatment plant capacity.

Because the three larger production wells (Wells 1, 4, and 5) each have the same pump capacity (700 gpm), removing any of these three wells from service would result in a similar firm operating capacity. Therefore, three combinations of wells (1+3+4, 1+3+5, and 3+4+5) were run together to test the firm capacity. the combination of wells with the lowest total combined capacity would be defined as the firm operating capacity of the well field.

Because Well 3 is active in each tested combination of wells, Well 3 was selected as the well to be pumped to waste. The discharge piping from Well 3 was disconnected from the system, and temporary piping was added to convey the pumped water to Mud Lake. Flow from the well was measured using an orifice meter attached to the end of the discharge pipe, which was set to the wells normal operating rate of approximately 350 gpm.

The testing was completed during the week of October 10, 2022. The City was conducting hydrant flushing during this week, which increased the demand on the well field and allowed the two wells supplying the plant to be operated for most of the day (the wells automatically become active when dictated by tank levels and system demands). The testing was completed over three days, with a given combination of wells being testing on a single day. The test for a given combination of wells was initiated by turning on Well 3 at the start of the day. Well 3 was run for approximately 8 hours each day and then shut off at the end of the day. The other two active wells supplying the plant were programmed the night before to become active when called upon based on system demands. Due to the hydrant flushing, the two wells supplying the plant became active each day prior to the startup of Well 3 and remained active until after Well 3 was shut off for the day. In this manner, each combination of wells was able to be run together for a period of approximately 8 hours.

The water levels measured in the wells during the testing are summarized on **Figures 10 through 13**. The pump settings and tops of screens for each well are also depicted on the figures. The figures show the water levels measured for each of the three well combinations along with static water level measurements collected when the well field was off entirely. Similar to the evaluation presented above, the water levels were compared to the pump settings to assess the remaining available water column in each well when the wells are active with the well field operating at its firm capacity.

The lowest pumping water level measurements observed during the testing (lowest observed for any combination of wells) are summarized in **Table 5** along with the pump settings and remaining available water columns for each well. The water levels in each of the wells remained above the pump settings in all of the wells for each combination of wells that was tested. The lowest remaining water column was in Well 4, which still had 21 feet above the pump setting with the lowest pumping level. Wells 1, 3, and 5 all had more than 30 feet of remaining water column. If it is assumed that one-third of the non-pumping water column is left above the pump in reserve as a safety factor, the lowest pumping water levels for all of the wells were above the safety level. The safety level was approached in Well 4 but was not exceeded.

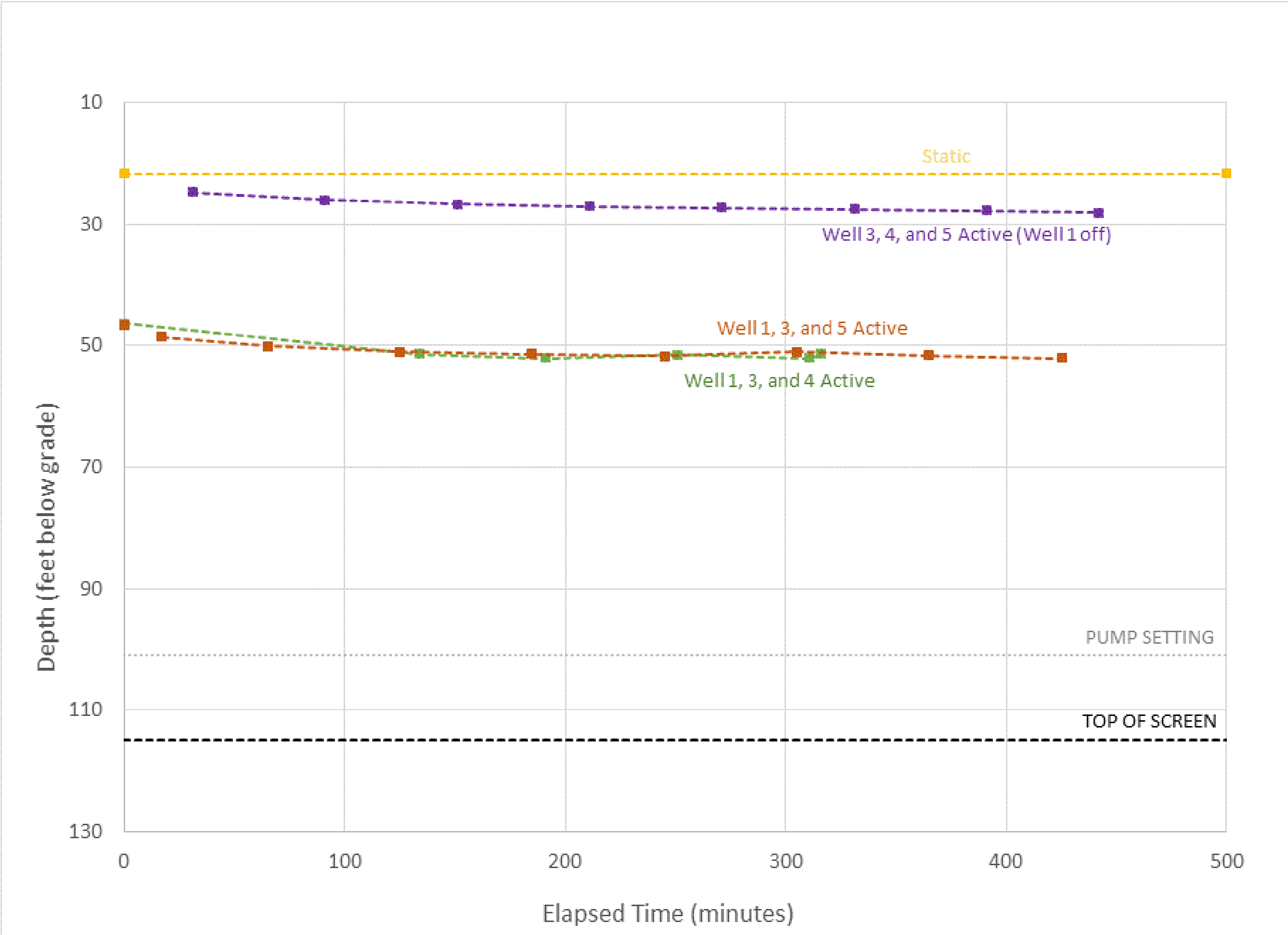

Figure 10. Field Testing Water Level Measurement Summary: Well 1

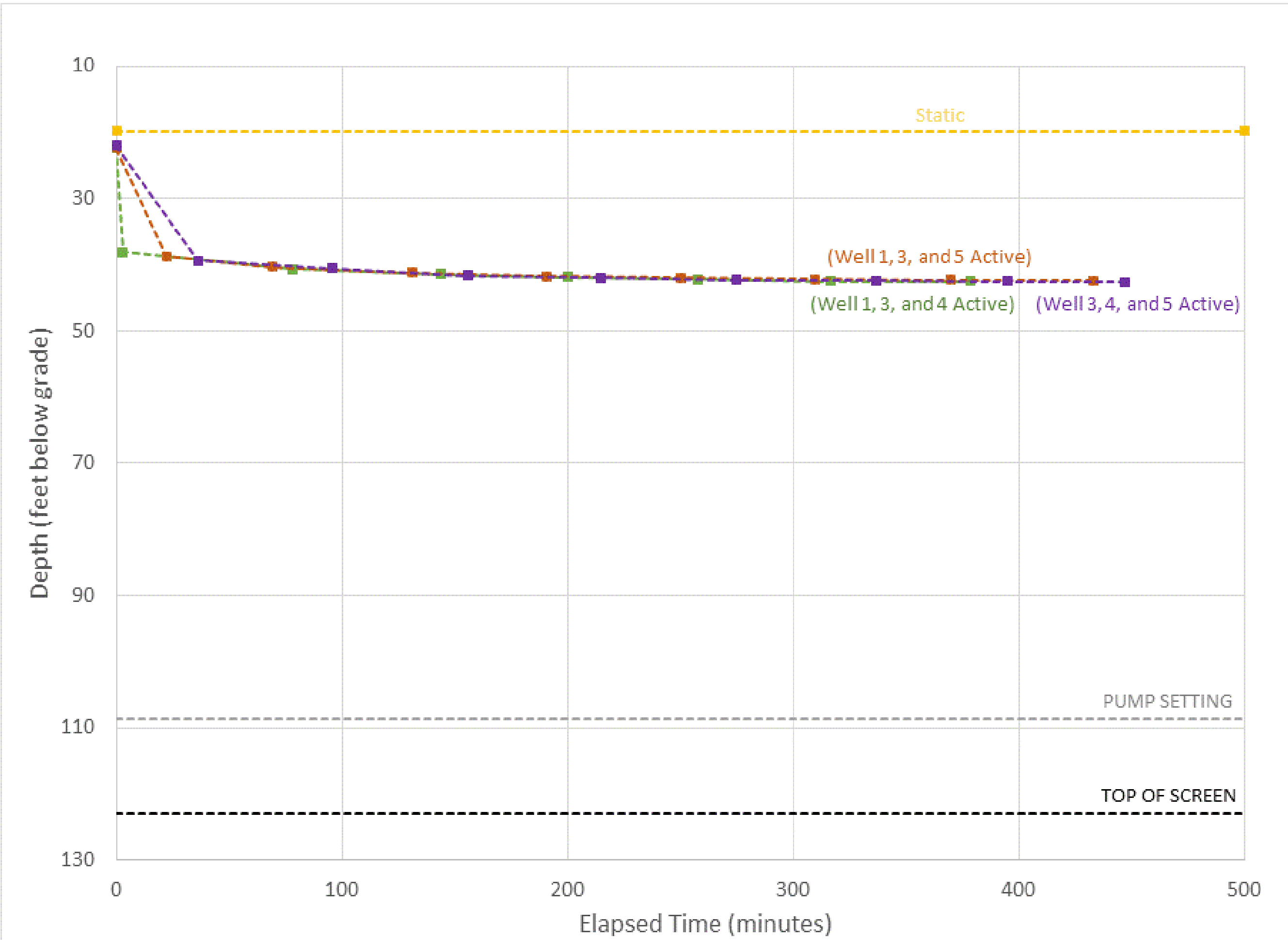

Figure 11. Field Testing Water Level Measurement Summary: Well 3

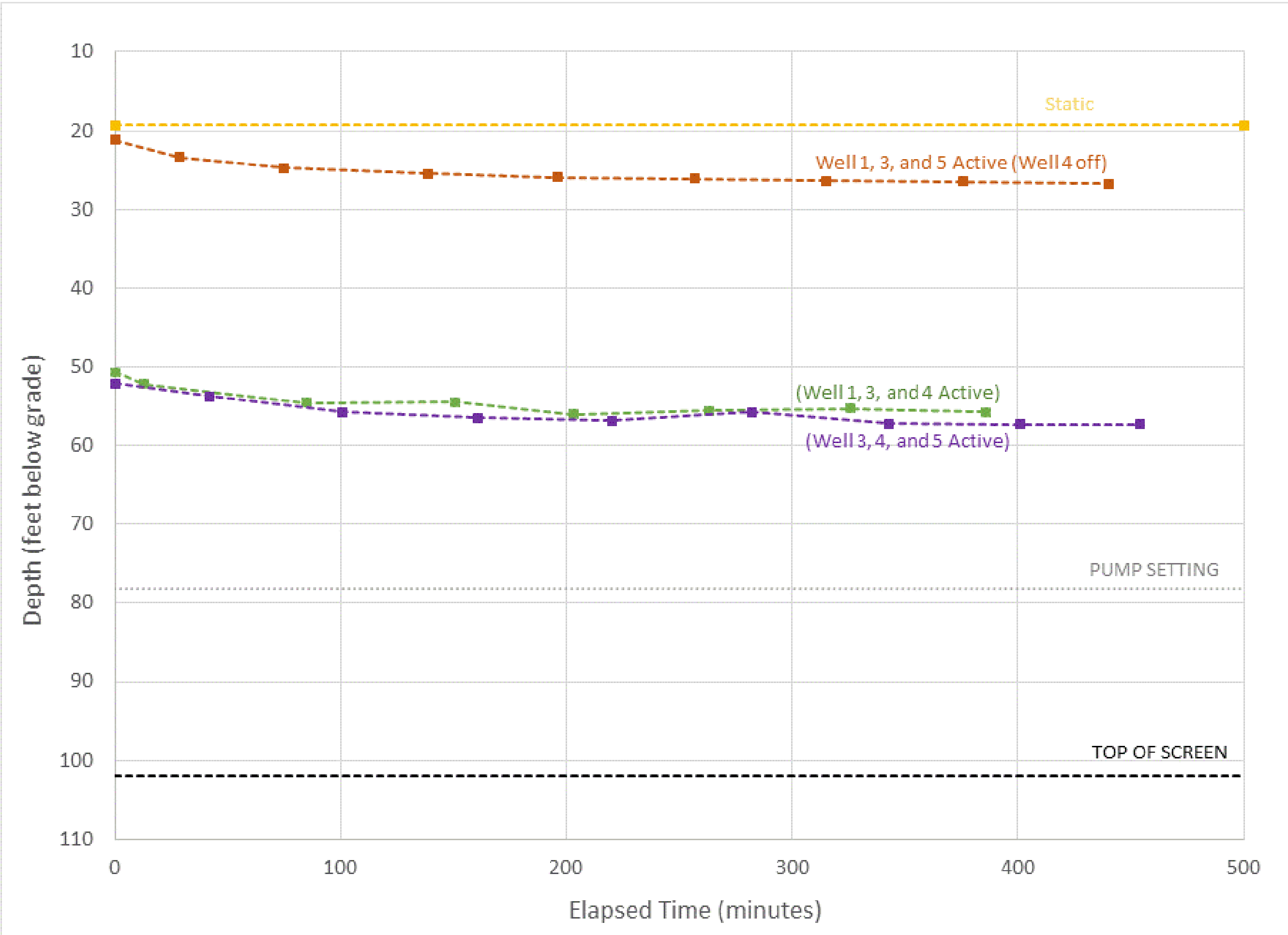

Figure 12. Field Testing Water Level Measurement Summary: Well 4

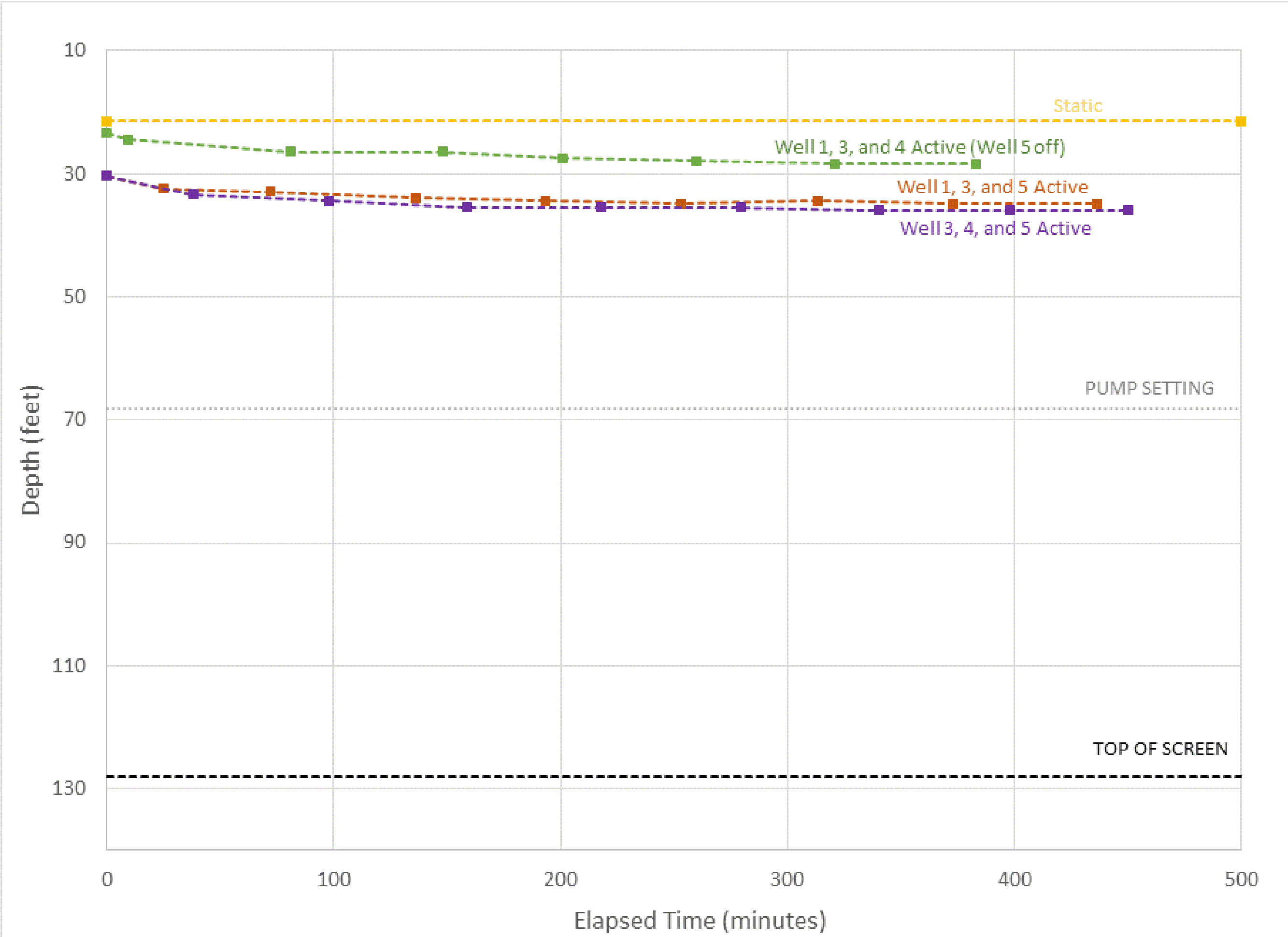

Figure 13. Field Testing Water Level Measurement Summary: Well 5

The well field is typically run for as long as needed during the day and the well field is allowed to rest during the night. However, during a maximum demand condition, the well field may need to run continuously for several days or potentially even longer. The water levels measured during the testing did not stabilize by the end of each day's test, indicating that water levels would continue to draw down under longer periods of pumping. If it were conservatively assumed that the wells would need to run for an extended period of 120 days continuously, it is estimated that an additional 7 to 8 feet of drawdown would occur in the wells relative to those listed in **Table 5**. The estimated additional drawdown would not reach the pump settings in any of the wells, but the safety level would be exceeded in **Well 4** by approximately 6 to 7 feet. The water column remaining above the pump would still be 12 feet above the pump setting, and the well could still be operated without issues, but monitoring the performance of the well would be recommended to ensure specific capacity declines would not cause the pumping level to be lowered further. Alternatively, the pump in this well could be lowered closer to the top of the screen to increase the available drawdown.

The measurements collected during the testing indicate that the well field could be run at its full firm capacity without issues. The average flow measured at the plant's influent flow meter during the testing ranged from 1,492 to 1,526 gpm depending on the which combination of wells was active. Including the flow from Well 3 that was being pumped to waste (350 gpm), the well field was pumped at 1,842 to 1,876 gpm during the testing. The lowest flow measured was for the day during which Wells 3, 4, and 5 were active. The flow measured during this day is considered to be most representative of the firm operating capacity of the well field. Therefore, the firm operating capacity of the well field is approximately 1,842 gpm, or 2.65 mgd.

Table 5. Water Level and Remaining Water Column Measurement Summary for Field Testing

	Well 1	Well 3	Well 4	Well 5
Static Water Level (feet below grade)	21.7	19.9	19.3	21.4
Lowest Pumping Water Level (feet below grade)	52.0	42.7	57.3	35.9
Pump Setting (feet below grade)	100.9	108.6	78.2	68.3
Minimum Water Column Above Pump (feet below grade)	48.9	65.9	20.9	32.4
Minimum Water Column Above Pump Assuming 1/3 of Column Left in Reserve (Safety Factor)	22.5	36.3	1.3	16.8

3 Water Treatment Plant

City of Hudson Water Treatment Plant (Plant) is the primary water supplier to the Hudson system and has a rated capacity of 2 MGD by the EPA. The treatment plant includes the following components:

1. Pretreatment
2. Filtration
3. Water Softening
4. Clearwell
5. High Service Pumps

To determine the capacity of the treatment plant, Arcadis reviewed City of Hudson's submittals to Ohio EPA which includes a capacity assessment. The reviewed documents included the regulatory approvals by Ohio EPA issued in 2018 for piping and monitoring wells around the new Brine well at the Water treatment Plant. Though this document mentioned that the City's groundwater treatment plant has a capacity of 2 MGD, it did not contain a detailed assessment of how the plant capacity was calculated. Arcadis staff performed a walkthrough of Hudson Water Treatment Plant on May 24th, 2022 with the City's plant operations staff to understand and document process flow and operations. The observations from the walkthrough are documented and presented throughout this section of the report.

The raw water influent from the well field enters the treatment building on the lower level of the plant and is immediately dosed with chlorine gas and potassium permanganate solution. The pre-treated water is then sent to the filters on the main building floor, which houses all six green sand filters as shown in Figure 14 below. The filters are in two groups of 3 each shown in two photos as part of Figure 14.

Figure 14. Photo of six filters at the Hudson Water Treatment Plant

Each of these six filters are capable of treating water at a flow rate of 220–260 gpm depending on filter uptime which is displayed on the main display panel in the same room and is shown in Figure 15. As the filters treat water, they slowly begin to experience particle buildup, hereby reducing the flow capacity through them. Each filter is backwashed approximately every 24 hours such that 3 of the 6 filters are backwashed on any given day under normal operating conditions. Filters are backwashed using water from the clearwell supplied by dedicated backwash pumps located in the lower level of the plant. Backwash for each filter takes approximately 35 minutes. This equates to 97.5% runtime availability for each filter, resulting in total filtration capacity of approximately 2 MGD assuming an average flow rate of 240 gpm through each filter.

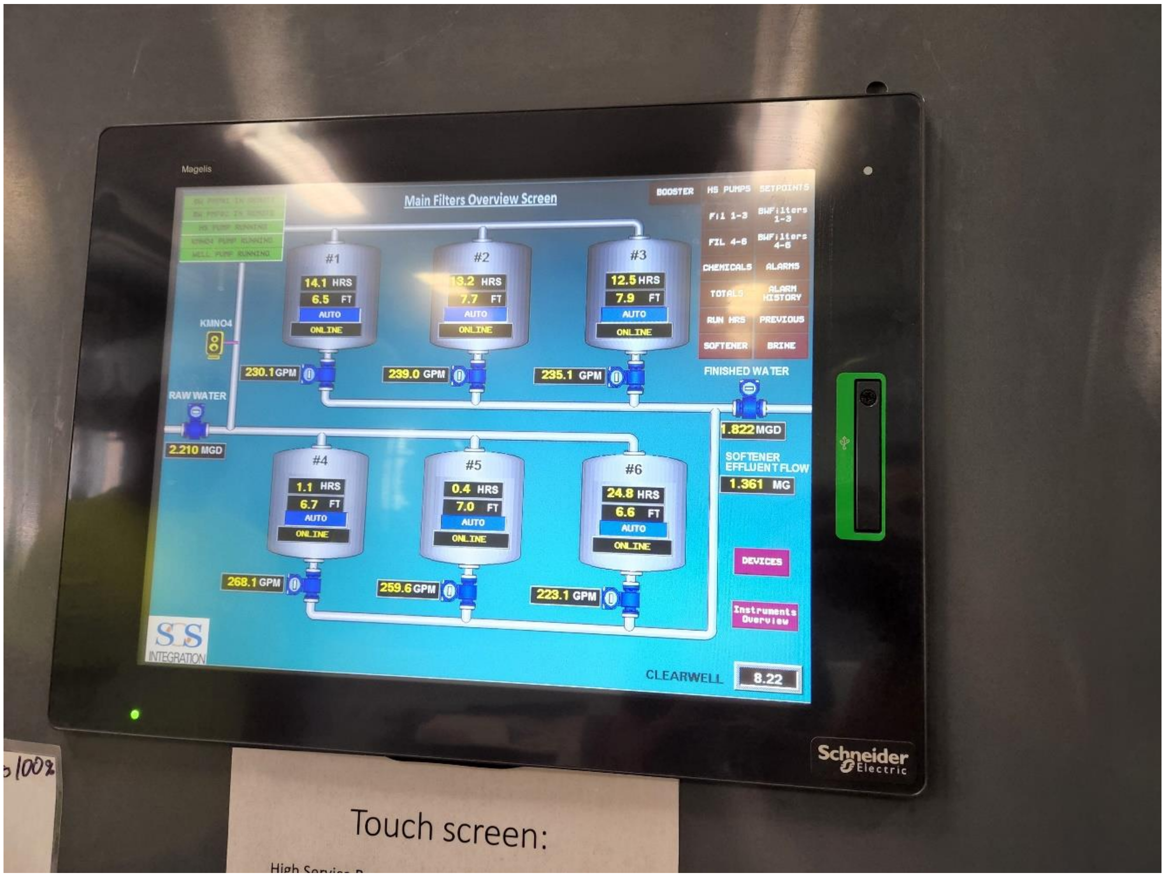

Figure 15. Photo of main overview display panel for the water filters

The influent lines are pressurized by the well field pumps which push the water through the filters and softeners in the plant. If more than one filter is offline for backwash, the well pumps are not currently setup to adjust output; this results in pressure build up in the influent line upstream of the filters which subsequently can result in chlorination difficulties. Therefore, current operations dictate that no more than one filter is backwashed at any given time.

The filtered water is then sent to four ion exchange softeners in the main level of the plant as shown in Figure 16 below. Only 66% of the filter effluent is treated through the softeners and the remaining 34% is bypassed. Flow through each softener is maintained within a 220 – 230 gpm range to yield desired water quality results.

Figure 16. Photo of four ion-exchange water softeners at Hudson Water Treatment Plant

Softeners 1 and 2 have the capacity to treat up to 200,000 gallons and softeners 3 and 4 have the capacity to treat up to 150,000 gallons before they need to be regenerated. The softeners are regenerated using the brine from the brine well located at the Plant. The regeneration cycle for each softener differs slightly because of underlying brine feed hydraulics but typically takes a maximum of 1.5 hours to complete. This gives operational availability of 94% for softeners 1 and 2 assuming one regeneration cycle per day and 87.5% for softeners 3 and 4 assuming two regeneration cycles per day. This equates to a total softening capacity of 1.15 MGD. Maintaining the ratio of softened water to filtered water at the City's desired level of 0.66 would result in total softening capacity of 1.74 MGD. It should be noted that water softening is not a regulatory requirement but is desired by the City due to elevated hardness found in the raw ground water. For flow rates higher than the softening capacity, the ration of softened water to filtered water may be reduced.

Discussion with City's treatment plant operators identified that maximum production of 1.8 MGD has resulted in very rigid operational schedule and a loss of flexibility with filter backwash cycles and lower fraction of water being softened. The softened water is chlorinated and is sent to the 125,000-gallon clearwell which feeds three high service pumps located in the Plant's lower level. Operators at the treatment plant did not express any concerns with the clearwell capacity and implications of contact time with increased production.

The treatment plant capacities for each of the treatment process described above are summarized in Table 6. While the filtration capacity is a hard capacity limit, the other capacity numbers are not as rigid but do provide guidance and what to reasonable expect at the treatment plant. Following treatment, water is pumped out of the clearwell into the distribution system. The Plant’s high service pumps have a pumping capacity as described in the following section.

Table 6 Water Treatment Plant Capacities by Treatment Process

Treatment Process	Capacity Limit (gpm)	Capacity Limit (MGD)
Filtration (w/ Backwashing)	1,404	2.0
Water Softening	799	1.15
Softening with Target Ratio (0.66)	1,208	1.74
Operator Flexibility (Backwash & Softening)	1,250	1.8

4 Pumping Gap Analysis

A pumping gap analysis was conducted to evaluate the capacity of pumps within the system necessary to meet the City's water distribution needs. Pumping facilities within a distribution system serve the primary purpose of pressurizing the system by pumping water into the distribution system. In some cases, pumps can be used to boost the water pressure from one zone to the next. For the City of Hudson, three high service pumps located at the Plant are the primary source of water. Additional pumps at the Cleveland Water connection were not considered as this location is primarily for emergency use and not regularly operated to provide water service to the City.

This pumping evaluation considered the total pumping capacity and the firm capacity of the high service pumping station (HSPS) and how that matches up the required pumping capacity based on system demands. Firm capacity is defined as the amount of water that can be pumped by the station with its largest pump out of service (whether due to scheduled maintenance or emergency repairs). The detailed breakdown of pumping capacity is shown in Table 7 along with Average Day and Maximum Day Demands for both existing conditions and with additional demands anticipated from the future service area expansion into the Village. Total required pumping volume is calculated as the maximum day demand flow rate for the system. Note that this table only includes future demands for Phase 1 of the system expansion as described in Section 1.

Table 7. Total Minimum Pumping Capacity Requirements

Service Area	Existing Conditions (Hudson)	With Service Extension (Hudson + Peninsula)
Existing Average Day Demand (mgd)	1.19	1.206
Maximum Day Demand (mgd)	1.70	1.724
Pump Station	HSPS	HSPS
Number of Pumps	3	3
Total Rated Capacity (mgd)	6.19	6.19
Firm Capacity (mgd)	3.17	3.17
Total Required Volume (mgd)	1.70	1.72
Pumping Gap[1] (mgd)	**-1.47**	**-1.44**

[1] *A positive pumping gap indicates pumping capacity deficiency*

Based on these numbers, the City has access pumping capacity at the high service pumping station now and following the Phase 1 service extension.

5 Storage Gap Analysis

A storage gap analysis was conducted to evaluate the amount of storage that is necessary to meet the City's water distribution needs and to determine if this storage is still adequate with additional demands following system expansion. Storage facilities within a distribution system serve many purposes. These include providing adequate volume of water for fire protection, water supply during an emergency such as a power outage or main break, maintaining system hydraulic grade, and allowing treatment and pumping facilities to deliver at a more consistent flow rate while storage supplies are utilized during peaks in diurnal demands. The gap analysis was performed to determine the appropriate total storage volume for current and future system demands.

Finished water storage volume were analyzed to understand existing conditions. Existing information from the Water Emergency Contingency Plan was used to determine the available storage capacity in the distribution system as well as the water treatment plant and are shown in Table 8.

Table 8. Summary of existing finished water storage

Tank #	Tank Name	Type	Location	Storage Capacity (MG)
1	Milford Water Tower	Elevated	Distribution	0.75
2	JoAnn Fabrics Tank	Elevated	Distribution	0.5
3	WTP Clearwell	Ground	Plant	0.125

Once the total available storage was established, the required storage was determined using the following relationships. Typical required total water storage volume is comprised of three components: (1) equalization storage, (2) emergency storage and (3) fire storage. Equalization storage is a storage allocation that provides water supply during peak hourly demand times that occur because of the variation in water usage during a 24-hour period. Emergency storage is water that is allocated to satisfy system demand during an event that disrupts supply. Such events would include temporary source contamination, equipment failure, power supply interruption, and main breaks. Fire storage is water that is allocated to mitigate facility fires. The fire flow rating within the service area and fire flow duration period are considered when calculating this volume.

The minimum required storage volume for the Hudson system under existing and proposed conditions was calculated using components described above and are presented in Table 9. Note that this table only includes future demands for Phase 1 of the system expansion as described in Section 1.

Table 9. Total Minimum Required Finished Water Storage Volume

Storage Criteria	Existing Conditions (Hudson)	With Service Extension (Hudson + Peninsula)
Existing Average Day Demand (MGD)	1.19	1.21
Maximum Day Demand (MGD)	1.70	1.72
Total Required Storage Volume (MG)	1.14	1.15
Equalization - based on diurnal usage on modeled maximum day demand	0.22	0.23
Fire Volume - 3,500 gpm at 3 hours (MG)	0.63	0.63
Emergency Volume - Max Day Demand for 4 hours (MG)	0.28	0.29
Available Storage in the system including WTP (MG)	1.38	1.38
Available Storage in the distribution system alone (MG)	1.25	1.25
Storage Gap[1] [2] (MG)	**-0.11**	**-0.10**

[1] A positive pumping gap indicates pumping capacity deficiency

[2] This storage gap number includes distribution system storage only since it is a more conservative number

Once all existing finished water storage was summarized and minimum required storage volumes evaluated, a comparison was made with other distribution systems based on other Arcadis projects; from these comparisons, the existing storage volume relative to system demands for both the existing and proposed Hudson systems are similar to these other systems and no increases in storage volume are necessary. The results of this storage gap analysis have identified that Hudson system does not currently have any storage shortfall and that additional demands from Phase 1 of the system expansion and supply to the Village do not have any significant detrimental impact to effective water distribution system storage. When considering the required storage volumes as described above, the City has storage capacity to support up to 2.09 MGD of demand during a maximum day (only considering distribution system storage).

6 Findings and Recommendations

Based on the evaluations presented above, the extension of water service from the City of Hudson to supply an area within the Village of Peninsula was determined to be feasible. This evaluation was based on four metrics:

1. Well Field Capacity
2. Water Treatment Plant Capacity
3. Pumping Capacity
4. Storage Capacity

During these evaluations, some of these metrics had different limiting factors that led to different overall capacity results (especially for the treatment plan and storage volumes). Table 10 summarizes the capacity results for each of these metrics and factors. The table also includes the current maximum daily flow or demand values along with the additional available flow beyond current values based on the individual capacities. This represents the City's system expansion capabilities based on each of these categories.

Table 10 Capacity Evaluation Results and Additional Flow Availability

	Daily Capacity (gpm)	Current Max Day Flow / Demand (gpm)	Additional Available Daily Flow (gpm)
Well Field	1,842	1,400	442
Treatment Plant (Filters)	1,404	1,180	224
Treatment Plant (Softening)	1,208	1,180	28
Pumping	2,200	1,180	1,020
Storage Volume (Distribution)	1,451	1,180	271
Storage Volume (Distribution + WTP clearwell)	1,744	1,180	564

Based on these results, the City's source, treatment, pumping, and storage capacity is sufficient for the additional demands anticipated for Phase 1 of the Village system expansion (approximately 17 gpm for a max day). Beyond the first phase of development, the City may encounter some capacity limitations. The lowest availability is the softening capacity which was estimated by considering a 0.66 softening ratio. It should be noted that this ratio is not a hard limit and there may be flexibility to increase flow beyond this limit with a reduced softening ratio.

At around 200 gpm above current maximum day demands, the filters (considering backwash downtime) and storage volume (distribution only) capacity limits would be reached. This flow also represents the rated capacity of the plant per OEPA (2 MGD), and system infrastructure changes would be required to support additional flow beyond this number. Note that City operators also commented that flows above 1.8 MGD often caused logistical challenges with softening and backwash at the plant. This is only 70 gpm above current max demands, and constituents less availability for system expansion.

Based on these findings, key recommendations were developed for each of the criteria:

1. **Well Field Capacity**
    a. No changes are necessary to support the Phase 1 Peninsula expansion, and no changes are necessary even at larger system expansions.
    b. Additional well drilling may be necessary if additional customers are added beyond 442 gpm max day demands (approximately equivalent to 1,500 new residential customers).
2. **Water Treatment Plant Capacity**
    a. No changes are necessary to support the Phase 1 Peninsula expansion.
    b. The City should continue tracking system growth and demand forecasts to determine if treatment plant capacity changes may be needed in the future. Softening has very limited flexibility for growth at the current mixing ratio, and the filters have capacity for an additional 224 gpm max day demands (approximately 800 new residential customers).
3. **Pumping Capacity**
    a. No changes are necessary to support the Phase 1 Peninsula expansion, and no changes are necessary even at larger system expansions.
    b. Pumping capacity is well above any other metric considered here, and the City will not need any additional pumping unless significant growth is observed (an additional 1,020 gpm max day demands or over 3,000 new residential customers).
4. **Storage Capacity**
    a. No changes are necessary to support the Phase 1 Peninsula expansion.
    b. Additional distribution storage may be necessary if additional customers are added beyond 271 gpm max day demands (approximately equivalent to 1,000 new residential customers).
    c. The City should evaluate current and future chlorine contact time to determine if additional clearwell storage may be needed in parallel or instead of additional distribution storage.
    d. New ground or elevated storage options in the Peninsula service area should be considered and evaluated if future growth beyond the current evaluation area requires additional fire protection or support for diurnal variability.

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