County of Summit, Ohio

Department of Sanitary Sewer Services

HUDSON WATER SYSTEM EXTENSION: PHASE 2 EVALUATION

Technical Memorandum

FINAL

May 2023

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Acronyms and Abbreviations

City	City of Hudson
County	County of Summit
gpm	Gallons Per Minute
gpd	Gallons Per Day
MG	Million Gallons
MGD	Million Gallons Per Day
OEPA	Ohio Environmental Protection Agency
PRV	Pressure Reducing Valve
psi	Pounds per Square Inch
SR	State Route
TM	Technical Memorandum
VFD	Variable Frequency Drive
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 (Phase 1), 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.
- Tasks 3 and 4 – If deemed necessary from Task 2, these tasks will support well field performance testing to confirm current capacity.
- Task 5 – An expanded service area (Phase 2) will be evaluated similar to previous tasks but with considerations and recommendations focused on the larger area with substantially different ground topography.

This Technical Memorandum presents a summary of Task 5 evaluations, findings, and recommendations. The focus of this feasibility evaluation includes estimating the water demand for the Phase 2 service area, evaluating the distribution system capabilities to support the larger service area, and evaluating system supply capabilities to serve the 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, and previous evaluations of the supply that are documented within the *Water System Extension: Water Supply Evaluation* TM dated February 2023. Details from both TMs are expanded in this document as it relates to the Phase 2 service area, but additional details and discussion are still valid and contained within those original TMs.

2 Service Area Evaluation

The technical feasibility of extending water service from the existing City distribution system to the proposed service area was evaluated previously in the *Water System Extension: Peninsula Water Service Evaluation* TM. However, a potential Phase 2 of the expansion is being considered which includes a larger service area and additional water use. Therefore, the expanded service area was identified, and anticipated water use was estimated compared with the original Phase 1 service area.

2.1 Peninsula Service Area

The Village of Peninsula, Ohio (Village) is located in the Cuyahoga Valley National Park and is about six miles west of the City of Hudson, Ohio (City). The Village has a population of approximately 554 people (2020 Census) and local commercial and residential properties currently receive potable water from individual, private ground water wells. The Phase 2 water service area was defined and provided to Arcadis for evaluation. This area represents a larger portion of the Village that extends west of the Cuyahoga River in areas with higher ground elevations.

Based on this proposed service area, the City's existing water distribution main that runs along Streetsboro Road (SR 303) and ends at the Boy Scouts Camp would need to be extended west into Peninsula. Additional expansion of the water line west on Streetsboro Road is necessary to support the Phase 2 service area. Figure 1 shows the proposed Phase 1 and 2 service area extensions and approximate water line location along Streetsboro Road along with select distribution mains on side streets to allow anticipated customer tie-ins.

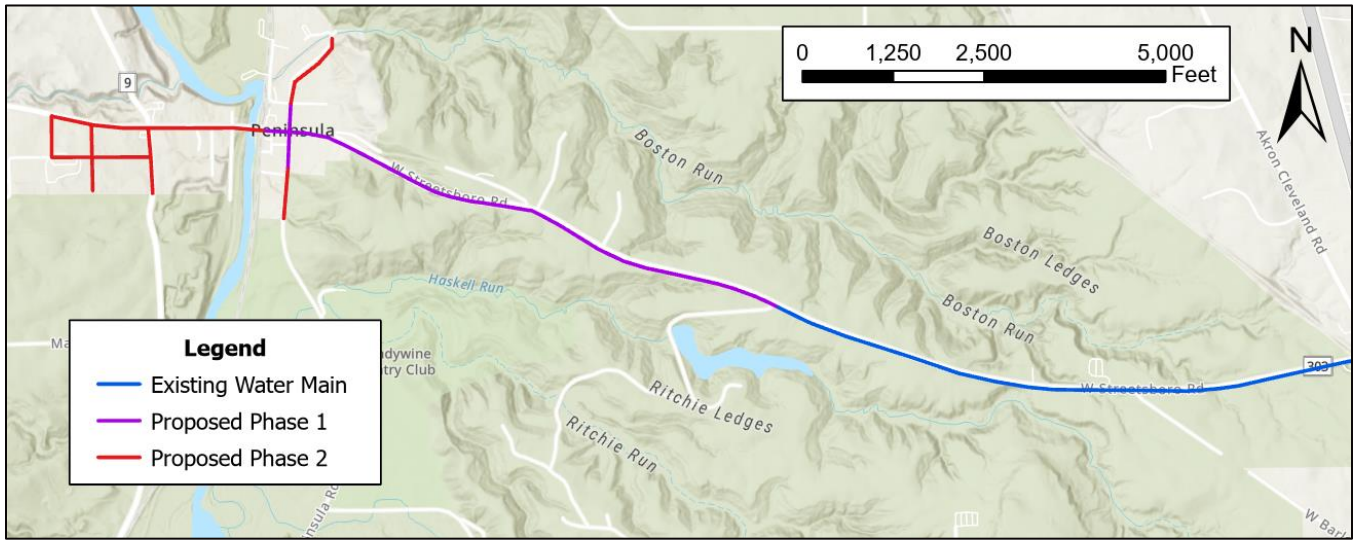

Figure 1. Service Area Expansion Phases from City of Hudson to Village of Peninsula

2.2 Water Use Estimates

Through local GIS data and coordination with the City and County, the proposed Phase 2 water service properties were identified and classified by land use into categories for residential, commercial, industrial, and other properties. Anticipated water service connections were categorized by land use type to develop water use

estimates for each property. Water use observed in the City based on 2018 billing data was used to estimate average baseline water use, but additional estimates were necessary for the industrial users in the service area. The following summarizes the per capita water use estimates per category:

- Residential users from City historic averages: 0.19 gpm (273.6 gpd) per user
- Commercial users from City historic averages: 0.57 gpm (820.8 gpd) per user
- Heritage Classical Academy (school):
    - Assumed 40 gpd per student ("Water Consumptions in Public Schools" December 2011)
    - Estimated average of 11.11 gpm (based on 400 students at Heritage Classical Academy)
- General Die Casters (Industrial/manufacturing):
    - Die casting water use varies by process and exact information was not available for this location.
    - Assumed 25 gpd per employee (Ohio Revised Code for industrial users without showers and assuming one working shift).
    - Estimated average of 2.78 gpm (based on 160 employees at General Die Casters)
- Annual average to maximum day peaking factor from City historic data: 1.47
- Peak hour factor based on City's hydraulic model: 1.4

This technical feasibility evaluation assumes that all customers within the proposed service areas will connect to the water distribution system. Further, uncertainty in the demands for the school and the die caster have minimal impact on this feasibility analysis. This is because the available capacity for normal demands (e.g. excluding fire flow) is much larger than the estimated system demand. Table 1 provides a summary of consumption per user type and final estimates for the entire proposed service area that includes both Phase 1 and Phase 2 (not that this estimate does not include any other potential expansion of service for the City of Hudson beyond the Village).

Table 1. Water Use Estimates for Village of Peninsula Service Extension

Land Use Type	Quantity 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 Phase 1 Estimate	**71**	**11.6**	**16,704**	**17.2**	**24,768**	**24.0**
Residential	101	19.2	27,634	28.2	40,621	39.5
Commercial	21	12.0	17,237	17.6	25,338	24.6
Industrial (School)	1	11.1	15,998	16.3	23,518	22.9
Industrial (Manufacturing)	1	2.8	4,003	4.1	5,885	5.7
Total Village Phase 2 Estimate	**124**	**45.1**	**64,872**	**66.2**	**95,362**	**92.7**
Total Phase 1 & 2 Estimate	**195**	**56.7**	**81,576**	**83.4**	**120,130**	**116.7**
Current City of Hudson System Usage (2020)		*826*	*1,189,440*	*1,180*	*1,699,200*	*1,596*
Estimated City Usage with Village Phase 1 & 2 Expansion		*883*	*1,271,016*	*1,263*	*1,819,330*	*1,713*

3 Distribution System

The proposed 8,500-foot long, 8-inch diameter water main from the City's existing water distribution system extent at the boy scout camp on SR 303 to Phase 1 of the Peninsula expansion was evaluated previously, and results summarized in other referenced documents. The Phase 2 expansion builds off those results because some infrastructure options may change in order to effectively serve the potentially expanded service area.

In general, the ground elevation (e.g. topography) presents challenges in serving the area within level of service goals for system pressure and fire flow. As a result, a simple extension of the water main is not sufficient to provide service to either Phase 1 or Phase 2 proposed service areas.

3.1 Infrastructure Options

Various water infrastructure options were identified during the Phase 1 feasibility evaluation. The options considered include: Water Main Sizing, Distribution Pressure Reducing Valves, and a Hydropneumatic Tank.

Ultimately, a pressure reducing valve was recommended for the Phase 1 service area with the option to consider a hydropneumatic or ground storage tank to better support both high and low flow extremes if demand increases. A pressure reducing valve (PRV) reduces higher upstream pressures to a constant lower downstream pressure by inducing head loss across the valve. This downstream pressure is set to a desired pressure, and the valve automatically adjusts as upstream pressure or flow conditions change. If a PRV is installed along the proposed distribution main, pressures can be controlled such that downstream pressure in the Village (e.g., at Streetsboro Road and Locust Street) are reduced.

With the inclusion of additional Phase 2 demands described in Section 2, the recommended solution of an 8-inch diameter service line, pressure reducing valve, and optional hydropneumatic tank are still valid and recommended. During previous evaluations of future system capacity, it was noted that flows of up to 200 gpm could be supported while still maintaining approximately 1,000 gpm Available Fire Flow Rate at a 20 psi residual pressure. The total system expansion water use, including Phase 2, is projected to be less than 100 gpm, and therefore this distribution infrastructure recommended in Phase 1 is still suitable. A downstream pressure relief valve is also recommended to help with pressure control and to reduce risk of pressure surges. Following this planning level feasibility analysis, engineering design will be necessary to confirm infrastructure details, costs, any property necessary, and validate the feasibility of the selected approach with valve equipment vendors.

3.2 Pressure Evaluation

The Village is located near the low point of the Cuyahoga Valley and thus there is a substantial ground elevation difference in the area. For example, the difference in ground elevation from the City's Water Treatment Plant (WTP) at 1,008 feet above mean sea level to the Village at 706 feet is approximately 300 feet. Assuming a relatively consistent hydraulic grade line in the water distribution system, the pressure is directly impacted by ground elevation (e.g., a decrease in 2.3 feet of ground elevation represents 1 psi increase in pressure). This presents challenges with providing water service across large elevation differences. The ground elevation changes from 883 feet above mean sea level at the existing end point of the City's water main at the Boy Scouts Camp on SR 303, to 706 feet near the Cuyahoga River. This roughly 180-foot elevation change equates to an approximate 75 psi pressure increase at SR 303 and Locust Street in the valley. This pressure is in addition to the high pressure that exists at the current end of the City's water distribution system near the Boy Scouts Camp.

As noted previously, a PRV was recommended to help control high pressure in the Valley. With the Phase 2 service expansion, the water mains continue west past the river and begin to rise on the other side of the Valley. Therefore, service pressure will be lower on the West side and proposed pressure regulation settings from Phase 1 were reviewed to confirm feasibility while also achieving the minimum the level of service criteria. The hydraulic model was used to balance the PRV setting with the downstream minimum and maximum pressures and is described further in Section 3.3.

Based on this modeling, a PRV pressure setting of 50 psi was selected. Using this PRV setting, the ground elevations were analyzed across the Phase 2 service area to create a profile of anticipated pressures. Figure 2 illustrates ground elevation changes in the area by color coding contours such that each band would be a change in pressure of 10 psi. This identifies areas with high or low anticipated pressures, and it identifies service area limitations. For example, based on the current PRV location and pressure, the bottom of the valley will experience pressures over 100 psi (blue color banded area) while the school in the west is at a high ground elevation point and approximately 40 psi pressure is anticipated at ground level. While this shows that the entire Phase 2 service remains close to service level criteria (identified as 40 to 100 psi during previous evaluations), higher ground elevation areas further to the west would produce too low of pressure for normal service and may not be easily served without additional adjustments or infrastructure changes.

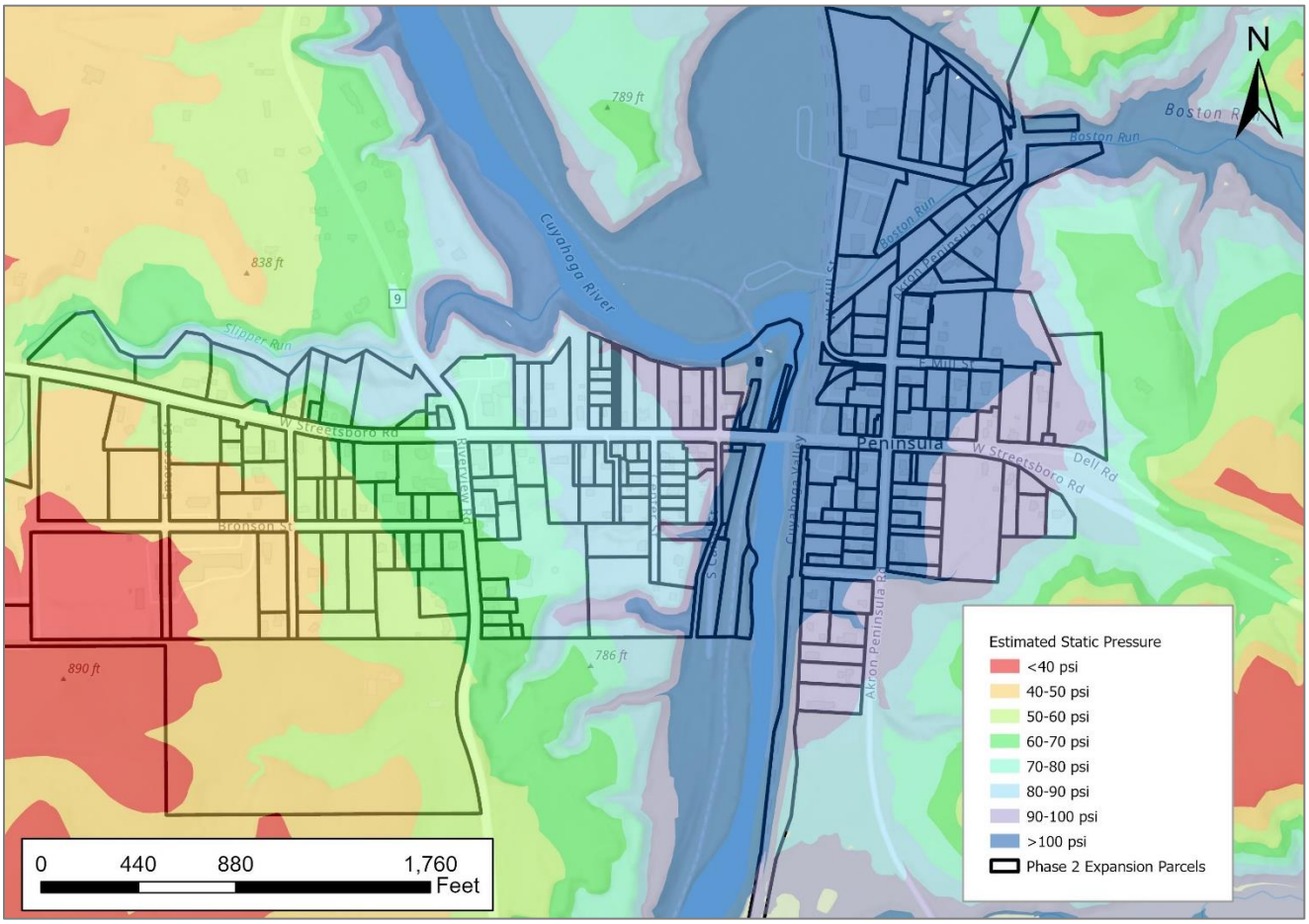

Figure 2. Ground Elevation Changes with Color Bands Equivalent to Anticipated Pressure Ranges

3.3 Hydraulic Model Results

The City's 2021 updated and calibrated water distribution system hydraulic model was used to evaluate the feasibility of various options to provide municipal water supply to the proposed Phase 2 service area. The primary infrastructure evaluated was a new 8-inch diameter water main along Streetsboro Road with a PRV to mitigate high pressures in the proposed service area. The estimated annual maximum day demands were used to evaluate the system.

While the PRV location was left at the location identified during Phase 1 evaluations, the pressure setting was adjusted to balance downstream pressure across the larger Phase 2 service area. Initial evaluations revealed the relationship of PRV settings versus static pressures at Peninsula, but the pressure setting of 30 psi that best supported Phase 1 was adjusted to 50 psi to support Phase 2. While this allowed a minimum pressure of 40 psi at the high point of the Phase 2 service area, it also increased pressures at the bottom of the Valley to over 100 psi. While higher than originally recommended, and outside the City's 100 psi service goal, this was deemed as acceptable since other areas of the City's existing distribution system are above 100 psi. Additionally, individual home PRVs were already recommended based on previous pressures to protect customer interior plumbing, so a slight increase in distribution pressures should not negatively impact customer service. Note that if the PRV location is moved, the pressure setting would subsequently need to be adjusted. These values are provided as part of this feasibility evaluation and will need to be reviewed and validated for the exact location and elevation of the PRV.

Figure 3. Model Results Showing Pipe Diameter and Minimum Pressures for Phase 2 Expansion

The model was also used to evaluate Available Fire Flow Rate along the proposed water mains. This was also evaluated during the annual maximum day demand scenario which is the industry standard practice to evaluate fire suppression capacity. Model results indicate the system is still able to provide approximately 1,100 gpm Available Fire Flow Rate at Streetsboro Road and Locust Street. While this does achieve the primary goal of

1,000 gpm for residential fire protection, the model also indicated that the system is only able to provide approximately 600 gpm for fire protection at the school on Bronson Avenue. While this is an improvement over existing conditions where no fire suppression capacity is available from a public water system, the City and Village will need to determine if this is sufficient fire protection for this location. Significant additional infrastructure would be required if additional fire suppression capacity is required for the school, therefore this technical feasibility proceeds with a limited capacity at the school for fire suppression.

4 Water Supply

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.

4.1 Well Field

The City's well field is located off West Streetsboro Road adjacent to the City's WTP. The well field currently consists of 4 production wells designated as Wells 1, 3, 4, and 5. Well 3 has a pump capacity of 350 gallons per minute (gpm). Wells 1, 3, and 5 have larger pump capacities of approximately 700 gpm each, and Well 5 has a variable frequency drive (VFD) that allows the flow rate from the well to be reduced to lower pumping rates (typically around 350 gpm) when needed to meet the varying demands of the water system.

The well field is typically operated to provide an instantaneous flow rate near or slightly above 1,400 gpm, and the total daily flow to the plant is controlled by adjusting the daily run time of the active combination of wells. 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. This was further validated with well field testing in October of 2022. The measurements collected during testing indicate that the well field could be run at its full firm capacity without issues, and that the firm operating capacity of the well field is approximately 1,842 gpm, or 2.65 mgd.

If it is assumed that the safe yield of the aquifer does not limit the capacity of the well field, the Approved Capacity of the well field is also 1,842 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. Even at the larger Phase 2 demands estimated in Section 2.2, the total system maximum day demands do not reach the capacity of the well field.

Table 2. Well Field Capacity Estimates

Estimate Method	Capacity Limit (gpm)	Projected Max Day Demand (gpm)	Capacity Limited?
Desktop Estimate	1,750	1,263	No
Well Testing Results	1,842	1,263	No

4.2 Water Treatment Plant

The 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: Pretreatment, Filtration, Water Softening, Clearwell, and High Service Pumps.

To determine the capacity of the treatment plant, a review of the City of Hudson's submittals to Ohio EPA documented that the City's groundwater treatment plant has a capacity of 2 MGD. Following a site visit, the capacity limitations were broken down by treatment process as summarized in Table 3. 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. Limitations are observed similar between Phase 1 and 2 were water softening is over capacity with the service expansion while filtration is within capacity at maximum day flows.

Table 3. Water Treatment Plant Capacities by Treatment Process

Treatment Process	Capacity Limit (gpm)	Projected Max Day Demand (gpm)	Capacity Limited?
Filtration (w/ Backwashing)	1,404	1,263	No
Water Softening	799	1,263	Yes
Softening with Target Ratio (0.66)	1,208	1,263	Yes
Operator Flexibility (Backwash & Softening)	1,250	1,263	Yes

4.3 Pumping and Storage 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. 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. The 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. The total required pumping volume is calculated as the maximum day demand flow rate projected for the City and expansion. Based on these numbers, the City has access pumping capacity at the high service pumping station now and following either the Phase 1 and Phase 2 service extension.

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 including providing adequate volume of water for fire protection (fire storage), supplying water during an emergency such as a power outage or main break (emergency storage), and allowing treatment and pumping facilities to deliver at a more consistent flow rate while storage supplies are utilized during peaks in diurnal demands (equalization storage). The gap analysis was performed to determine the appropriate total storage volume for current and future system demands while comparing to existing finished water storage. The City current has two elevated storage tanks (totaling 1.25 MG) and ground storage at the WTP (at 0.125 MG). The minimum required storage volume for the Hudson system under existing and proposed conditions was calculated using individual storage components. The results of this storage gap analysis identified that Hudson system does not currently have any storage shortfall and that additional demands from Phase 1 or Phase 2 of the system expansion and supply to the Village do not have any significant detrimental impact to effective water distribution system storage. Table 4 shows a summary of results

for the Phase 2 expansion for both pumping and storage volumes (Note that this table only includes future demands for Phase 1 and 2 of the system expansion as described in Section 2).

Table 4. Total Minimum Required Finished Water Storage Volume

Treatment Process	Available Capacity	Required	Capacity Limited?
Pumping Capacity (MGD)	3.17	1.82	No
Storage Capacity (MG)	1.25	1.16	No

5 Findings and Recommendations

Based on the evaluations presented above, the extension of water service from the City of Hudson to supply the Phase 2 area within the Village of Peninsula is determined to be technically feasible for both the distribution system and for the water supply.

Based on Phase 1 and 2 service extents, and available per-capita water use information for the area, a maximum daily supply flow of 120,130 gallons per day (peak hour of 116.7 gpm). This represents the maximum anticipated flow for the service area and any flows beyond this or service area expansions beyond the Phase 2 boundaries should be re-evaluated for engineering feasibility. Based on these water use estimates, the anticipated flow rate for Phase 2 is comparatively low to the City system and could be supplied with an extension of the City's existing main to Peninsula along Streetsboro Road. The ground elevations in the area produce pressure challenges that can be overcome with proper infrastructure design. Based on the distribution system hydraulic feasibility assessment, the following should be considered:

- A pressure reducing valve along the distribution main is required to control downstream pressures.
    - Multiple PRVs may be necessary to help with low flow and high-pressure conditions, to be determined based on specific PFRV manufacturers' capabilities.
    - A pressure setting adjustment for the PRV is necessary from 30 psi (Phase 1) to 50 psi (Phase 2) to support the large elevation differences of the larger service area.
    - A pressure relief valve is recommended near the low point of the system to improve system resilience and mitigate risk of system over pressurization if the PRV were to fail.
- Individual private home PRV's are also necessary to further control pressures and help lower pressure to protect interior plumbing which typically experiences a pressure in the range of 40 psi to 60 psi for private wells.
- A hydropneumatic tank can be considered as an option to help regulate diurnal flow conditions
    - This may be in addition to a PRV to help support low flow conditions when it may be a challenge for a PRV to effectively provide a low flow rate while maintaining low downstream pressure.
    - Necessity may be determined during detailed design because of concerns expressed by vendors with large pressure differential and low flow conditions.
    - Larger ground or elevated storage options should be considered and evaluated if future growth beyond the Phase 2 area requires additional fire protection or diurnal variability

During water supply evaluations, some metrics had different limiting factors that led to different overall capacity results (specifically for the treatment plant). Table 5 summarizes the capacity results for each of these supply 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 component capacities. This represents the City's system expansion capabilities based on each of these categories.

Table 5. 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

During Phase 2 of development, the City may encounter capacity limitations related to water softening at the treatment plant. The softening capacity was estimated by considering a 0.66 softening ratio which is currently used by the City. Other supply capacities are sufficient for the anticipated Phase 2 demand estimates. The next closest capacity limitations are the plant filters (considering backwash downtime) and storage volume (distribution only). 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 for the Phase 2 service area evaluation, key recommendations were developed for each of the criteria, as follows:

1. **Water Distribution**
    a. An 8-inch diameter water main extension along Streetsboro Road into Peninsula (around 10,600 feet of pipe) along with additional 8-inch and 6-inch mains on cross streets
    b. The distribution pipelines shall be looped were possible (especially west of the river) to provide redundancy and reduce the amount of dead-end pipes for water quality purposes
    c. A pressure regulation station along the distribution main is required that includes:
        i. Pressure reducing valve(s) to control downstream pressures
        ii. A Hydropneumatic tank to support low flow conditions (to be determined during design)
        iii. Pressure relief and blowoff valve(s) downstream of the PRV to help with pressure control
    d. Individual home PRV's are required to protect interior plumbing at each service connection
2. **Well Field Capacity**
    a. No changes are necessary to support the Phase 2 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).
3. **Water Treatment Plant Capacity**

a. Additional softening capacity is required to support the Phase 2 Peninsula expansion.
b. The City should continue tracking system growth and demand forecasts to determine if additional treatment plant capacity changes may be needed in the future since the filters only have capacity for an additional 224 gpm max day demands (approximately 800 new residential customers).

4. **Pumping Capacity**
    a. No changes are necessary to support the Phase 2 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).
5. **Storage Capacity**
    a. No changes are necessary to support the Phase 2 Peninsula expansion.
    b. Additional distribution storage may be necessary if additional customers are added beyond 271 gpm maximum 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 Phase 2 evaluation area requires additional fire protection or support for diurnal variability.

All of the above recommendations are based on an estimated maximum daily flow served to the Village of 120,130 gallons per day (peak hour of 116.7 gpm). This represents the maximum anticipated flow for the service area and any flows to the Village beyond this, or any service area expansions beyond the Phase 2 boundaries, will need to be re-evaluated for engineering feasibility. Additionally, the City has additional potential service expansions to over 1,000 new homes that are currently supplied by individual wells throughout the City of Hudson. Any additional service expansions from the City should be considered alongside anticipated Village flow rates when developing capital improvements to the system.

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