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Appendix B: Conveyance Technical Report

Version	Authors	Reviewers	Date
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2.0	Aminata Ndiaye, Olivia Sherman, Sara Soluk, Emily Pytell	Clara Liao	3/12/2025
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1.0 SUMMARY

The Salem Meadows Development site currently lacks the infrastructure to support the water supply and wastewater needs of the proposed five mixed-use buildings. The water distribution and wastewater conveyance subteam is responsible for designing a reliable and cost-effective system to support these needs. To comply with the Owner's principle criterion of sustainability, the conveyance subteam will prioritize sustainability in the system design using guidelines from the University of Michigan Civil and Environmental Engineering vision for civil infrastructure, and guidelines from the Leadership in Energy and Environmental Design (LEED). The system involves maintaining potable water quality, transporting potable water to the buildings, transporting wastewater to the wastewater treatment facility, determining water demand, and evaluating potential pipe materials and system configurations. With this comes the tasks of ensuring regulatory compliance, estimating costs, and coordinating with other engineering sub teams. The purpose of this document is to present the conveyance sub team's understanding of these tasks and provide our current design recommendations.

The conclusions and recommendations for the system design have been determined for the Schematic Design phase in preparation for project execution. The full conveyance system has a preliminary capital cost of $16.2 million, including markups and contingencies but excluding long-term operations and maintenance, which will be assessed during construction. A 1.8 million gallon, 137 foot tall spherical water tower was selected to meet the total site demand of 690.45 gpm and fire flow requirements of 5,000 gpm for four hours because it is the most energy-efficient storage solution. A curricular water supply pipe layout was selected for pressure stability and minimal environmental disturbance. Water is routed from the treatment plant to a pump station, through the tower, and into the distribution network via 10-inch PVC pipes, selected for their standard usage in distribution systems and low head loss for this flow capacity. Sixteen valve vaults provide sectional control, and fourteen fire hydrants were strategically placed along some roadways. EPANET modeling confirmed stable pressures and continuous flow under typical conditions, with no dead zones across the five buildings and the Water Resource Recovery Facility (WRRF). However, under fire flow conditions, negative pressures occurred in parts of the system, and the pump appeared overworked. Future solutions may include emergency pumps that activate only during a fire, localized booster pumps, or redesigning the water tower to provide more demand. The wastewater system relies entirely on gravity flow, and the layout is aligned with the site's natural topography to maintain appropriate slopes and velocities. Most of the system uses 10 or 12 inch PVC pipes, with one 15 inch pipe at the end of the system that carries waste from all buildings under the river. The system has 22 manholes, two of which contain drops. Both the drinking and wastewater systems will be phased during construction as more buildings are constructed. The drinking water system will start with the main circular loop built and allow for branching to buildings 4 and 5. The wastewater system will start with the largest pipeline under the river and be built out for all known building locations and allow for branching to buildings 4 and 5. Both conveyance systems designs have been fully estimated for the schematic design phase.

2.0 INTRODUCTION

The following is a summary of the subsections of this Schematic Design document.

Section 3.0 overviews the project's organization and management, which includes,
- 3.1 Discipline-specific sub-team structure and team roles
- 3.2 Collaborations required to complete the tasks
- 3.3 Cost estimate
- 3.4 Tasks required for design
- 3.5 Project schedule and specific deliverables
- 3.6 Regulations, codes, and permits that need to be met

Section 4.0 overviews the specific systems of the conveyance system, which includes,
- 4.1 Water demand to service all five buildings on the site
- 4.2 Water supply pipe route
- 4.3 Water supply hydraulics system
- 4.4 Wastewater collection pipe route
- 4.5 Pipe materials for water supply and wastewater systems
- 4.6 Water tower structural materials
- 4.7 Scaling the conveyance system to accommodate construction phases

3.0 PROJECT MANAGEMENT

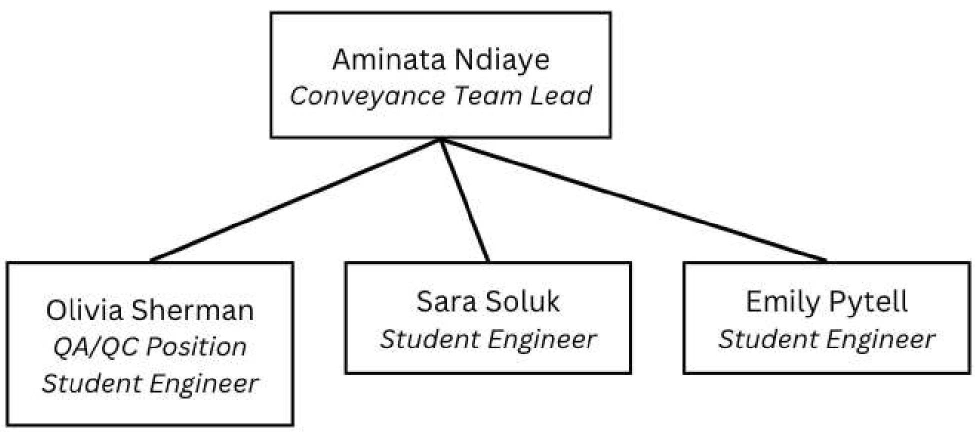

Figure B-1: The conveyance subteam is led by Aminata Ndiaye.

3.2 Interactions with Other Discipline-Specific Teams

To design a water distribution and collection system for a new development, collaboration with other skilled consulting firms in different specialties is vital. Table B-1 describes the tasks from Section 3.4 that require collaboration and how the collaborating team will be able to aid the design.

3.3 Cost Estimate

The total capital cost of the conveyance system for the Salem Meadows Development is estimated at $16.2 million. This value is calculated in Attachment C and is based on historical records of conveyance system component costs previously paid by the State of Michigan in 2024 as well as 2014 construction cost estimates adjusted to 2025. The full list of system components are included in Attachment C, linked as a spreadsheet. Capital investments in equipment and trained personnel are considered in the calculation, as they enhance system longevity and reduce maintenance costs. Installation costs include excavation depth requirements, trenching requirements, and additional components such as valves, fittings, and manholes.

Markups and contingencies are included in this initial capital cost estimate to anticipate any future unknown costs that may arise. Markups include the engineering fee of 17%, administrative fees at 5%, taxes at 4.5%, permits at 1% and insurance at 1%. The contingency percentages include estimates of the scope, bid and the Owner. Recommendation from senior design consultant Peter Klaver states that the scope contingency can be estimated at 20% for distribution systems (Klaver, 2025). The bid contingency is estimated at 10% and the Owner's contingency is estimated at 5%.

The conveyance design and construction costs past the point of the current 30% design completion will be tracked using a regularly updated spreadsheet to record expenses. Estimates from these future phases will be based on labor, materials, equipment, and documentation from the construction management consultant company. Regulatory and processing costs will be included to consider permit costs and any paperwork required to get approvals for construction. There will also be testing and inspections as well as required updates to adhere to environmental regulations.

Long-term costs will account for operation and maintenance needs over the system's life-span. Variable interest rates and inflation will be considered. Upfront costs, uniform annual costs, and future cash flows will be calculated to provide a comprehensive financial analysis. Regular maintenance on the pipes will be necessary to prevent buildup, especially in a mixed-use development where improper wastewater disposal is anticipated. Energy costs for the selected drinking water pump will be assessed based on electricity consumption. See Attachment C for all cost calculations.

3.4 Tasks

The following section describes the tasks associated with designing a water supply and collection system for the Salem Meadows Development.

TASK 1: IDENTIFY APPLICABLE REGULATIONS, CODES, AND PERMITS

Task 1A. Identification of the regulations and codes applicable to the conveyance system

TASK 2: ESTIMATE WATER REQUIREMENTS

Task 2A. Estimation of Drinking Water Demand and Wastewater Production

Task 2B. Development of Flow Balance

Task 2C. Determination of the Conveyance System Design Capacity

Task 2D. Calculation of Required Water Supply Storage for Fire Flows

TASK 3: DESIGN CONVEYANCE SYSTEM FOR POTABLE WATER SYSTEM

Task 3A. Evaluation of water storage and water distribution options

Task 3B. Design of water supply system layout

Task 3C. Design for disinfection residuals to stay present throughout the entire length of piping system

Task 3D. Implementation of LEED program details

Task 3E. Estimate cost for water supply conveyance system

TASK 4: DESIGN CONVEYANCE WASTEWATER SYSTEM

Task 4A. Evaluation of wastewater collection options

Task 4B. Design of the wastewater system layout

Task 4C. Estimation of wastewater pipe network cost

TASK 5: COORDINATE CONSTRUCTION

Task 5A. Coordinate construction with all teams to follow a logical timeline.

3.5 Schedule

The conveyance subteam schedule is represented with a Gantt chart (Figure B-4). It is divided into 4 phases, Project Definition, Concept Design, Schematic Design, and Project Execution. The project is projected to be completed in December 2026 (Figure B-3). The schedule is subject to change due to construction factors.

3.6 Regulations, Codes, and Permits

The tables below are a compilation of the major regulations and codes applicable to the conveyance system requirements. Many of these regulations are required for permitting.

Table B-2 outlines the fire protection for mixed development that is in the Recommended Standards for Water Works, Ten State Standards by the Great Lakes Upper Mississippi River Board (GLUMRB). Depending on the building services team material selection, the fire flow requirements will change. The materials used will determine how the building is characterized under international fire codes and therefore what the minimum flow rate is.

Table B-2: The standards for water works are required for fire protection (GLUMRB).

Design Requirement	**Regulations and Codes:** Ten State Standards	**Summary**
Water Main Pressure and Size	8.2.1 and 8.2.2	The system should maintain a pressure of >20 psi at ground level. The normal working pressure shall be >35 psi and generally 60-80 psi. To serve fire hydrants, water mains should be >6 inches in diameter
Hydrants	8.4.1- 8.4.4	Hydrants should be available near buildings and spaced every 350-600 feet and fitted with 6-inch leads and sufficient hydrant drainage
Fire flow	8.2.3	The rate of water supply measured at 20 psi residual pressure that is available for firefighting

Table B-3 outlines the conveyance systems requirements for water main design and pipe standards that are specific to Salem Meadow's. These are in accordance with Salem Township Engineering Standards (STES, 2017). This information will guide pipe system design to meet depth and county standards.

Table B-3: The conveyance system must be designed to fit Salem Township's Engineering Standards (STES, 2017).

Design Requirement	Regulations and Codes: Salem Township Engineering Standards	Summary
Pipe Depth	Section 3.03	Minimum depth is below the frost line. For this development 42 inches is a safe depth
Water Main Profile	Section 3.05	Information needed for water main approval. This includes a map with detailed labels, elevations, and flows
Leakage and Testing	Section 3.09	At least 2 hours of testing of pipes must occur and the leakage must be less than 0.092 gallons per inch diameter of pipe per 1000 feet of length per hour at an internal pressure of 150 psi

Table B-7 outlines the overall conveyance system design requirements and a summary of how they are regulated in accordance with The University of Michigan's Strategic Vision for Civil and Environmental Engineering (CEE). The conveyance system will operate efficiently and sustainably if following these criteria.

Table B-7: The Vision for Sustainable Civil & Environmental Engineering design criteria must be met (University of Michigan , 2019).

Design Requirement	**Regulations and Codes:** Strategic Vision for Civil and Environmental Engineering	Summary
Waste Reduction	Page 16, Paragraph 2	Reducing waste produced and repurposing waste collected as a recycling, energy production, and economic opportunity
Sustainable Resource Management	Page 16. Paragraph 1	Creating a sustainable balance of water supply to maintain healthy surrounding habitats
Resilient Infrastructure	Page 34. Paragraph 3	Implementing automated and adaptive systems to reduce costs and increase resilience in infrastructure

4.0 SPECIFIC SYSTEMS

The following section of the report details every system that is part of the Salem Meadows Development's conveyance system. These systems include the water demand, the water supply pipe route, the water supply hydraulic system, the wastewater collection pipe route, the components of the wastewater sewer system, the pipe materials and how to scale the system during each construction phase of the development.

4.1 Water Demand

The current estimate of the average water demand is 0.1 million gallons per day. This calculation is shown in Attachment A. The peaking hourly factor is 3.8 while the peaking daily factor is 2.8. These peaking factors have been calculated by the wastewater treatment team and can be found in Attachment A in Technical Appendix C.

4.1.1 Functional Objectives for Water Demand

The water demand includes a flow balance between the entire drinking and wastewater treatment and conveyance system, a fire flow balance, and a water storage component. The criteria for all three balances and components must be met to meet the water demand requirements.

<u>4.1.1.1 Flow Balance</u>

A flow balance of the entire system must specify the water and wastewater treatment system design flows so that the building water demand is met after accounting for treatment losses, conveyance losses, waste, infiltration, and inflow. Figure B-5 is a schematic diagram showing the water balance of the entire system. The flow balance should specify the flow rate at which water is drawn from the water source, the flow rate at which water is discharged into Ingall Drain, and the rate of inflow or outflow due to losses, waste, and infiltration.

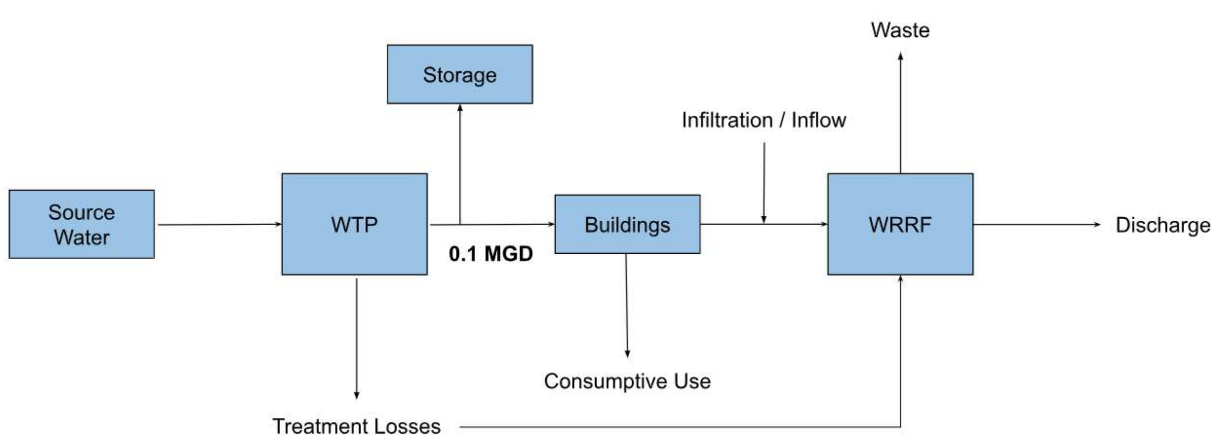

Figure B-5: Conveyance losses expected to be negligible to the average combined demand for all buildings at 0.1 MGD.

Losses during conveyance are expected to be negligible to the average demand of each building being 138 gallons per minute (gpm). The current flow balance design is shown in Figure B-5. The conveyance system is to be constructed with new pipes, so losses during conveyance were assumed to be negligible. All other flows are dependent on analysis of the alternatives. The final design will include the flows that correspond to the selected alternatives.

<u>4.1.1.2 Fire Flow</u>

Fire flow is a critical requirement for conveyance systems as a safety measure to supply adequate water supply and pressure for fire suppression. The system must be designed to provide sufficient water at the required pressure for a specified duration of time in the instance of a fire. This requirement is included in the water demand so that the system can function properly in all scenarios, such as a fire during a maximum demand period.

Fire flow requirements and the necessary suppression measures are based on the building type because the inherent potential fire risk is specific to each building. Key factors include the combustibility of the structural materials along with the inclusion of fire reduction methods such as sprinklers. Per the Owner's request, all buildings must be type I-A. Building services consultants have stated a usable square footage is 212,140 square feet. According to the International Fire Code, for a building of this size, the minimum fire flow must be 5000 gallons per minute (gpm) for 4 hours at a minimum residual pressure of 20 psi (IFC, 2018).

4.1.1.3 Water Storage

Water storage must be designed to handle each building demand and the fire flow for reliable water and adequate fire suppression. This includes properly sizing water storage to handle this capacity at all times even during peak demand scenarios. In the event of a fire, water storage should be used to prevent the exhaustion of water resources and contamination of the potable water due to a pressure drop. The storage tank must be able to supply the water demand both during low demand hours or in the event of a pump failure.

The water storage must be able to store 1.8 MG of water for 5 buildings, a treatment facility, and fire flow. This number includes the maximum daily demand for all buildings (0.2 MGD), a peaking factor for a conservative estimate (0.2), and the fire flow requirement (1.2 MG). Attachment B has more details on the water storage calculations.

4.1.2 Water Demand Alternatives

The water demand has no alternatives for the flow balance and fire flow as those are requirements stated by the Owner or regulations.

4.1.2.1 Water Storage Alternatives

Ground storage is widely used for smaller developments like this site. However, achieving the elevation needed to maintain system pressure and meet storage demands would exceed structural feasibility. Since pressure in ground storage relies solely on water level, it decreases significantly as the level drops. Additionally, without operational pumps, there is no backup pressure source, making ground storage less reliable for maintaining system pressure.

A water tower provides both water storage and the ability to maintain pressure in the system from stored energy in elevated water. This system works by utilizing hydrostatic pressure rather than constant pumping. There are additional costs with building the required height needed to maintain this pressure. A tower provides a fail-safe if pumps are not working properly through the stored energy in the elevated water. It also provides an ability to store water over diurnal demand usage throughout the day and for peak demands. This will be helpful to provide the fire flow needed, while still having enough water to supply residents for the day.

4.1.3 Water Demand Recommended Solutions

The recommended solutions for the water demand include the flow balance, fire flow, and water storage components. The solutions for the flow balance and fire flow components of the water demand are encompassed by the functional objectives.

4.1.3.1 Water Storage

The water tower option was chosen for its ability to store more energy in elevated water and its ability to distribute water with more reliability than ground storage by not requiring continuous pumping. The tower will be built with a capacity of 1.8 MG to meet the fire flow requirement for 4 hours and store the water required for building usage.

The proposed water tower design includes a spherical top intended to store a minimum of 1.2 MG of water for fire flow and a total storage of 1.8 MG of water. The resulting sphere has a radius of 39 feet, see more information in Attachment B. To determine the dimensions and analyze water volume at varying fill levels, the sphere is modeled using the geometric volume formula with Figure B-5 showing the resulting volume curve. The radius of the sphere is calculated from the total volume and the volume at different fill heights is derived using the spherical cap formula.

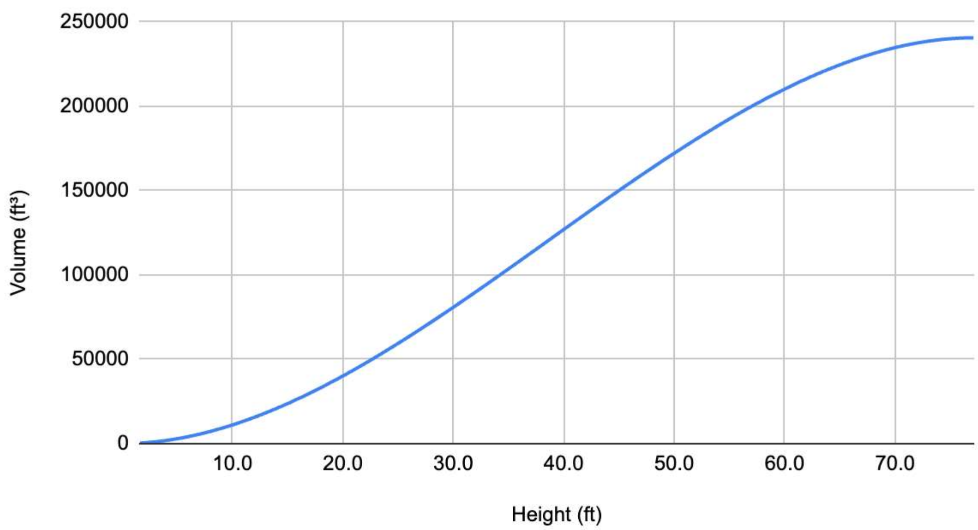

Figure B-5: Water tower volume curve shows the volume at different heights of the spherical water storage.

To confirm that the water demands could still be met during variable or peak demand times throughout the day, a diurnal pattern was selected and modeled in EPANET. The diurnal pattern selected for this site was determined using estimation for a general varied demand pattern taken from recent research into real-time water demand patterns (Attarzadeh, 2024). Figure B-6 displays the demand pattern and shows that peak times are around the morning when people are waking up and around when people get home or eat dinner. The demand stays high during the day; this is useful to demonstrate mixed use development. After running simulations in EPANET for a 24-hour time period, the water tower was successful in supplying the demand at all times.

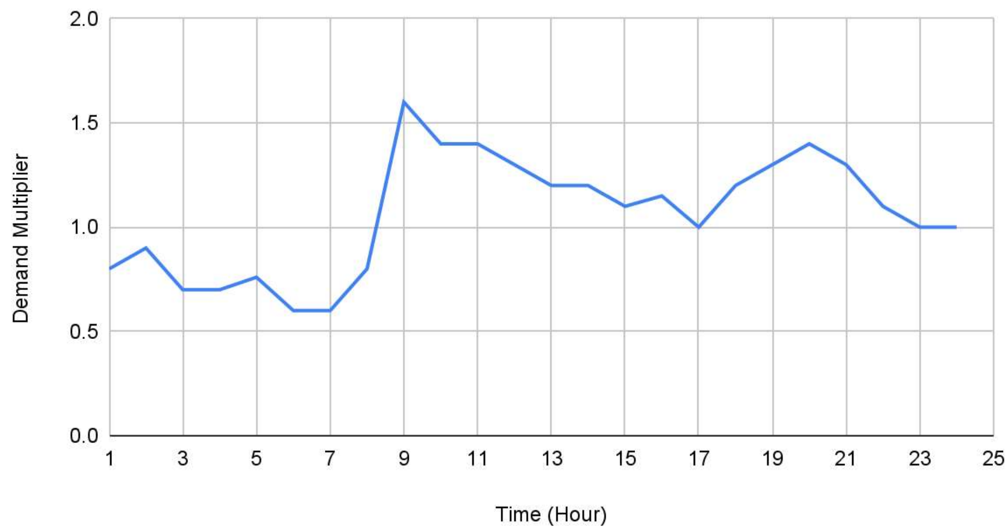

Figure B-6: Water demand for the site follows a typical hourly pattern for urban areas.

4.2 Water Supply Pipe Route

The conveyance system for water supply will provide distribution of potable water from the water supply treatment facility to each of the buildings. The design of this system must be reliable, efficient, and in compliance with regulatory requirements.

4.2.1 Functional Objectives of the Water Supply Route

The selection of the water supply pipe route is influenced by several factors, including topography, infrastructure layout, and regulatory constraints. The location of the treatment facility, water tower, and buildings determine the required conveyance distance and overall system layout. The placement of the water tower is essential because it establishes a critical reference point for system pressure and flow distribution.

Floodplains pose environmental and cost challenges. Routing pipes through floodplain areas requires additional permitting, dredging during excavation, and potential ecological restoration to offset damages. To prevent this, it would be best to route pipes around floodplains even if it is not the most direct route.

Large differences in elevation should be avoided and pipes should follow the least steep slope to maintain more consistent pressure throughout the system. However, if this is not possible, either pressure-reducing valves and booster pump stations or ground excavation and leveling can be used to address this issue.

Best practices should be followed throughout the design and development of the pipe network. Aligning the pipe routes with roadways, when possible, minimizes additional excavation by utilizing necessary road developments. This also makes placing and accessing fire hydrants easier. The fire hydrants should be placed 350-600 ft apart (Table B-2).

Regulatory requirements in relation to other utilities must be adhered to in determining pipe placement. A minimum 18 inch vertical and 10 feet horizontal distance should be kept from wastewater pipelines to prevent potential cross-contamination if there is leakage from either pipeline (Table B-4). Additionally, pipes should be built below the 42” frostline to prevent freezing and the potential bursting of pipes (Table B-3). Water supply lines should be vertically 5 feet lower than any streams to prevent contamination, however, river crossings should be avoided to reduce possible leakage into the water streams (Table B-5).

The size of Salem Meadows Development was determined to be incompatible and inefficient for water reuse after wastewater treatment. As such, the water supply conveyance system must also account for irrigation systems and be routed to areas that need irrigation.

4.2.2 Alternatives Evaluated of the Water Supply Pipe Route

Given the varied topography of the site, there are multiple routing options to be considered. The main determinants of routing include location of the treatment facilities, location of the water tower, and the presence of floodplains.

The water supply route should flow from the water treatment facility to the pump station, into the water tower, and then into the distribution system. The two primary layouts for the system are either a single mainline from the tower or a circular (looped) system. A non-circular layout would have branching out to each of the buildings, but there would be no mainline that connected back to itself. This could create dead ends where pressure can either be lost or build-up due to any stagnant flow. Alternatively, a looped system can accommodate bidirectional flow, reducing head losses and improving system reliability, particularly in high-demand scenarios such as in the event of a fire.

The terrain is varied in elevation in multiple areas, so hydraulics will not be consistent. Utilizing pressure reducing valves and booster pumps will be costly in both modeling time and capital costs. Excavating and leveling the land will also be costly in construction time and operations.

A river crossing may be necessary since the water resource recovery facility is located on the opposite of the river in comparison to most of the site and potable water must be supplied to the Water Resource Recovery Facility (WRRF). Alternatively, there could be a route on the southwest that goes around building one, the floodplain, and the river. That lengthy route would require extensive piping that is costly and a waste of useful pressure in the system.

Irrigation alternatives would include either encouraging the site-wide consultants to tap into the building water service already being supplied or installing a water faucet and hose connected to the conveyance system. Utilizing the water supply from the building would be the best option to reduce the need for extra costly excavation just for irrigation.

4.2.3 Recommended Solution for the Water Supply Pipe Route

The circular water supply pipe route was selected as the recommended solution to enhance system reliability and minimize pressure losses. Figure B-7 shows the full pipeline layout with other relevant system components. This layout is designed to be cost-effective, hydraulically efficient, and compliant with all relevant regulations. This design provides continuous water supply, even in the event of a pipeline failure, by allowing water to flow from multiple directions based on demand. Where pipes meet in the system is labelled as a junction in Figure B-7 below.

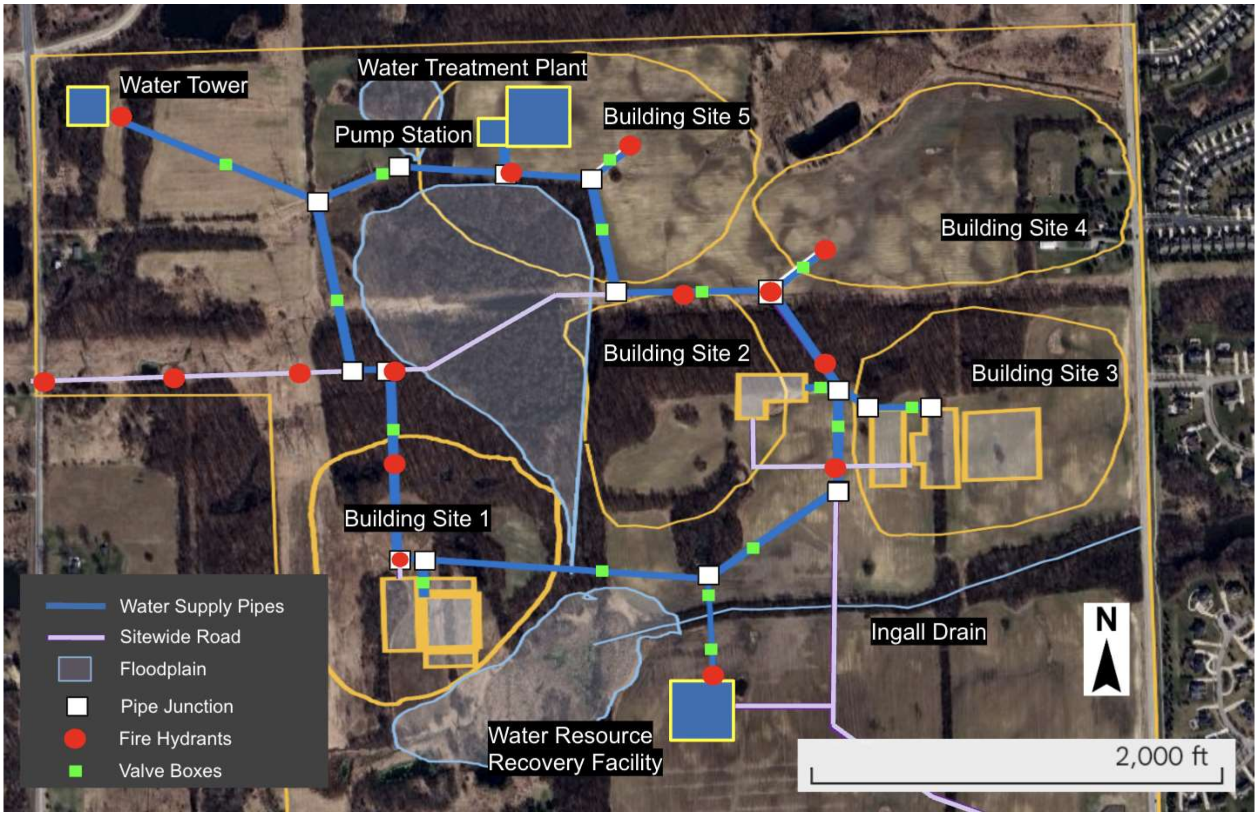

Figure B-7: The conveyance system will utilize a looped system to increase efficiency.

To support the CEE vision for reducing the need for additional environmental impact assessments, permitting delays, and costly mitigation measures, such as wetland restoration, the pipeline route has been strategically directed around floodplains. Additionally, there are minimal crossings through heavy vegetation. By designing the water supply pipe layout this way, the conveyance system aligns with the CEE vision for sustainable resource management by maintaining the water keeping habitats intact as much as possible.

To support a sustainable balance between water infrastructure and environmental preservation, the pipeline route was strategically planned to avoid floodplains and minimize crossings through heavy vegetation. This approach reduces the need for additional environmental impact assessments, potential permitting delays, and costly mitigation efforts such as wetland restoration. By proactively protecting sensitive ecosystems, this design layout promotes long-term resilience and supports the CEE vision of maintaining healthy surrounding habitats.

Where possible, the water supply system follows best practices for system development. Pipes close to roads align with existing roadways to minimize excavation and land disturbance. 14 fire hydrants have been placed along the roads as seen in Figure B-7. Due to unfinished designs from the transportation consultants, any fire hydrants that are not near the purple road are temporary. These hydrants were estimated in the total cost of the system, but will be officially placed during road construction. Additionally, wastewater pipe crossings have been minimized to reduce the risk of contamination. In areas where crossings are unavoidable, the system adheres to regulations by maintaining proper vertical and horizontal separation. To further safeguard water quality, potable water pipes are positioned on one side of the roadway, while wastewater pipes are placed on the opposite side. This is in compliance with regulatory guidelines for utility separation.

It was determined that a river crossing will be necessary to get potable water to the wastewater treatment facility. The pipe leading to the WRRF is 5 feet under the river bed to adhere to regulations (Table B-5). This regulation exists to prevent contamination in case of leakage from the pipe.

Booster pumps, pressure reducing valves, and leveling the land have all been determined to not be needed after further surveying of the land. The hydraulic system will operate with the varied terrain. All of the other options were determined to be too costly.

In collaboration with the site-wide consulting team, we have determined that irrigation of the site by the water distribution system is not necessary. This is because the site will be vegetated with native plants that are sustained by the natural precipitation trends of the area. These native plants will be planted around each building and along the roadways.

4.3 Water Supply Hydraulic System

The conveyance system is not just the distribution of water through pipes, but also the hydraulic system that maintains the pressures within the entire system.

4.3.1 Functional Objectives of the Water Supply Hydraulic System

The conveyance hydraulic system creates the pressurized system for drinking water distribution. It includes a pump station, water tower storage tank, and valve control boxes.

The pump station supplies the initial pressure needed for the entire system. The pump will send water out of the drinking water facility clear well into the distribution system. The size of the pump is based on the maximum daily flow rate and total dynamic head. There must be redundancy in the number of pumps as a fail-safe and to increase reliability in the pump station.

The water tower must have the capacity to maintain pressure in the system at a minimum of 35 psi, although the standard is between 60 and 80 psi (Table B-2). This should be the pressure maintained at the ground level of each building. The selected pressure in the system will influence the pipe diameters. The pipe diameter must be a minimum of 6 inches for water mains (Table B-2). The water tower must also be able to supply water at the selected pressure.

For long-term serviceability and efficient maintenance of the water supply system, strategically placed valve vaults should be installed at key control points to facilitate the operation, maintenance, and replacement of pipes without requiring extensive service issues to other facilities. Valve vaults should not be more than 800 feet apart from each other (Table B-5) and key points should be prioritized. Proper placement of these components is also crucial for routine inspections of the system. Early detection of pipe damage will prevent pipeline failures.

4.3.2 Alternatives Evaluated for the Water Supply Hydraulic System

For a site of this size, two pumps are suitable to meet redundancy requirements and be cost efficient. The pump capacity does not have any alternatives since it is based on the water demand of the site. The pump must meet the capacity of 5 buildings with a 138 gpm water demand each and the water resource recovery facility that has a 0.45 gpm water demand (Appendix C).

The pressure provided to the buildings at ground level pressure should fall within the standard range of 60 to 80 psi. For a site of this size, pressure loss is expected to be minimal due to the short distribution distances and little variability in building elevations. As a result, the pressure supplied by the water tower is unlikely to drop significantly throughout the system. A design pressure of 60 psi is appropriate for this scenario, as it delivers sufficient pressure without creating excessively high-pressure zones. The conveyance system is only responsible for providing pressure at ground level to each facility. For the tallest building on-site (90 feet), a base pressure of 60 psi would result in approximately 39 psi at the top floor—well above the minimum allowable pressure of 35 psi (as referenced in Table B-2). If additional pressure is needed within the building, booster pumps can be installed by the building services team. Supporting calculations for this scenario are included in Attachment D. The water tower elevation will be determined based on the decided pressure in the system.

The key points for the valve boxes should be at any point that would possibly need to be isolated in the system. More valve boxes can be added, but this would be an unnecessary cost for a system with only seven branches off of the mainline in the distribution system. A valve box should be included on the branch leading to buildings one through five, the water tower, the pump station, and the water resources recovery facility.

4.3.3 Recommended Solution for the Water Supply Hydraulic System

The pressure for the system was chosen to be 60 psi and is suitable for a small site to prevent excess pressures in some areas. A 10 inch pipe was selected for this system as it is most common to use the 10 inch diameter in water distribution systems (Klaver, 2025), and is able to transport the required flow demand. 16 valve vaults were placed at key points in the system to be able to isolate a specific building or facility, as seen in Figure B-8.

The pump station will include two pumps for redundancy. The static head and friction head were determined to be 5.76 feet and 162.76 feet respectively. This necessitates a pump that can operate with 162.76 feet of head for a demand of 690.45 gallons per minute. Further information about the pump capacity calculations can be found in Attachment D. A specific pump could not be selected in this stage of design due to limited time to talk to suppliers. However, we recommend using a centrifugal pump because they are ideal for handling relatively low-viscosity and high volume conditions and are typically used in municipal water distribution systems (Klaver, 2025).

Through running various tests in EPAnet, we found that the proper pressure in the system was maintained, solidifying the chosen design for the water tower and pump curve. The 60 feet tall water tower riser pipe sits at an elevation of 920 feet to maintain the necessary pressure of 20 psi in the system. A 77 foot spherical storage tank will be on top of the riser pipe to provide the additional head necessary for 60 psi and storage for the water demands. The water tower design for storage and hydraulics can be seen in Figure B-7 below. Further detail of water tower height calculations can be found in Attachment D. Further information about the EPANET process can be found in Attachment E.

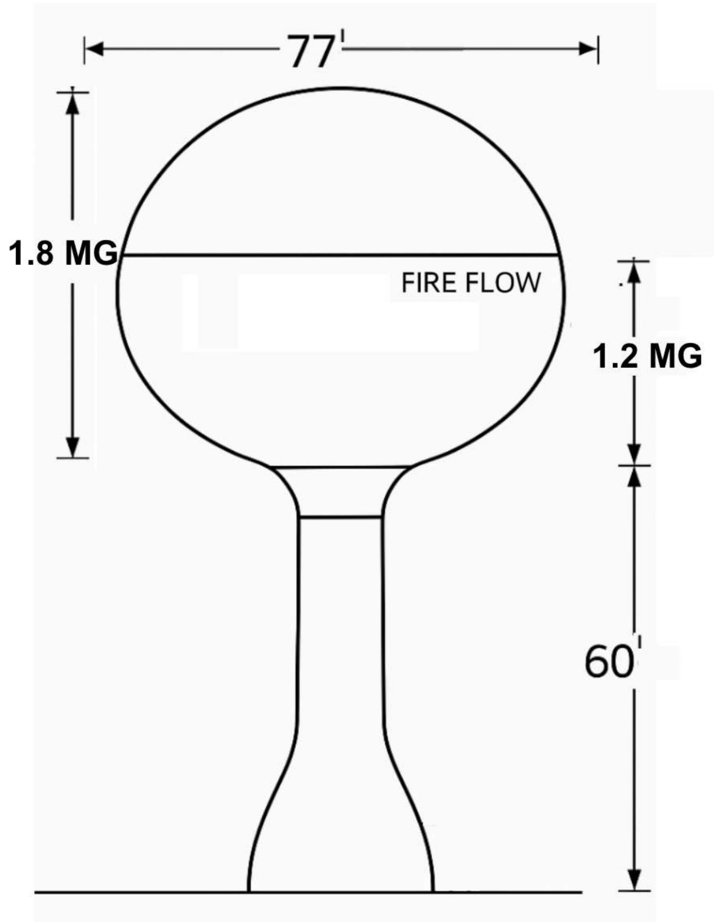

Figure B-7: The water tower height provides the adequate head for the required 20 psi and 60 psi.

EPANET was used throughout the iterative process to confirm that the chosen hydraulic parameters worked within the looped system layout. Figure B-8 displays the layout in EPANET. The arrows in the figure confirm that during a typical demand scenario of all five buildings operating at 139 gpm and the WRRF operating at 0.45 gpm, water is able to flow to each facility. The arrows also show that water flows in both directions of the loop, confirming that the looped system works to prevent dead zones. The legend in the figure shows that all facilities received flow around 60 psi and that there were no negative pressure zones.

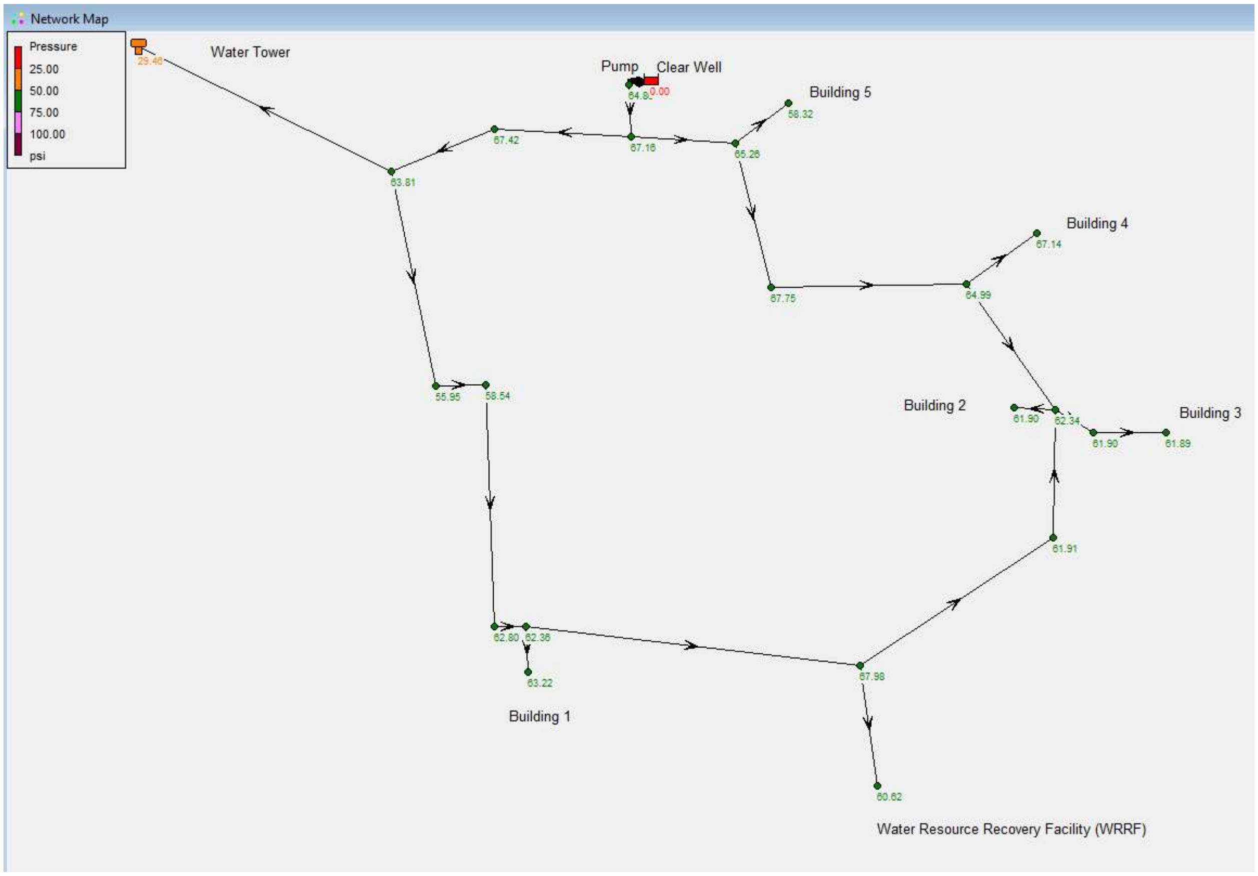

Figure B-8: EPANET model solidified the hydraulic system functionality in typical demand scenarios.

In the current EPANET model, the hydraulic system performs well under normal operating conditions, but fails under fire flow conditions. During the fire flow scenario—modeled as 5,000 gpm for 4 hours at a required residual pressure of 20 psi—the system experiences negative pressures in some areas. Due to time constraints, these issues could not be resolved before the end of the project design. To address this in the next phase, there are several options that could be tested. Firstly, a high-capacity fire pump could be introduced that would activate only during emergency events. Secondly, there could be booster pumps near critical areas to locally reinforce pressure without over-designing the entire system. The pipe diameters could also be increased to reduce head loss once flow increases significantly for fire flow but this would be costly and the system already uses relatively large 10 inch water mains. The elevated water tower plays a vital role in providing baseline system pressure and storage during peak demands. However, during fire flow events, even though the tower is designed to hold the capacity needed for fire flow, the pressures are not met for the general water demand of other buildings as the water level drops in the tower. Therefore, the tower alone may not supply sufficient flow and pressure, so relying on supporting infrastructure like the aforementioned pumps becomes essential to maintain service across the site.

4.4 Wastewater Collection Pipe Route

4.5 Pipe Materials

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ATTACHMENTS

Attachment A: Average Flow Estimation Calculations
Attachment B: Fire Flow and Water Storage
Attachment C: Cost Calculation Equations
Attachment D: Hydraulic Design Calculations
Attachment E: EPANET Model for Water Supply Distribution
Attachment F: Wastewater Conveyance Model

Attachment A: Average Flow Estimation Calculations

The average daily flow for the Salem Meadows completed development is estimated at 0.1 MGD, and was calculated as follows:

$$Q_{average,\, site} = N_{building} * Q_{average,\, building} \tag{1}$$

where

Q = average daily flow rate (MGD)
N = number of buildings on the site

The average daily flows for the buildings on site is estimated as 0.02 MGD, as was calculated as follows:

$$Q_{average,\, building} = \sum \left(Q_{retail} + Q_{office} + Q_{residential}\right)_{building} \tag{2}$$

The flows for each unit (retail, office, and residential) were calculated using Residential Equivalent Units (REU), as follows:

$$Q_{unit\ average,\, building} = \left(A_{unit} * \frac{REU}{1000\ sqft} * \frac{218\ gallons}{REU} * \frac{1\ MGD}{1{,}000{,}000\ gallons}\right)_{building} \tag{3}$$

where

A = usable area of unit (sqft)

Values for (REU per 1000 square feet) and (gallons per REU) were obtained using an REU Table from Genoa Township, which is located approximately 25 miles from the site. Information regarding the usable area of a unit is located in ‘Table 1: Basis of Design by Occupancy’ within the Notice of Award for the Building Services team.

Sample calculation for average daily flow of the retail unit using Equation 3:

$$Q_{retail,\, building} = \left((20{,}000\ sqft) * \frac{0.20\ REU}{1000\ sqft} * \frac{218\ gallons}{REU} * \frac{1\ MGD}{1{,}000{,}000\ gallons}\right)_{building}$$

$$Q_{retail,\, building} = 0.0009\ MGD$$

Remaining calculations for the building daily flow rates were performed using a spreadsheet as follows:

Table 1: Building Average Daily Wastewater Flow Calculations

User		Area (sqft)		REU / 1000 sqft		Q / REU (GPD)		Q (MGD)
Retail	=	20000	*	0.2	*	250	=	0.0010
Office	=	68000	*	0.14	*	250	=	0.00238
Residential	=	56000	*	1.00	*	250	=	0.0140
Storage	=	13600	*	0.05	*	250	=	0.0017
Pool	=	3000	*	3.00	*	250	=	0.00225
Totals	=							0.0198

The average flow from each building is used in Equation 1 to determine the average flow of the sites as follows:

$$Q_{average,\,site} = \left(\frac{5\ buildings}{site}\right) * \left(\frac{0.0198\ MDG}{building}\right) = 0.0990\ \frac{MGD}{site}$$

Attachment B: Fire Flow and Water Storage

The total necessary capacity of the water tower has been estimated. Equation 1 outlines the necessary information to get the total necessary capacity of the tower:

Full capacity storage = $S_{total} = S_{fire\ flow} + S_{max\ daily\ demand} + S_{peaking\ factor}$ (1)

where

- $S_{fire\ flow} = 5000\ gpm * 4\ hr * 60\ min/hr = 1.2\ MG$ (2)
- $S_{max\ daily\ demand} = 0.2\ MGD * 1d = 0.2\ MG$ (3)
- $S_{peaking\ factor} = f * S_{max\ daily\ demand} = 2 * 0.2\ MG = 0.4\ MG$ (4)
- $S_{total} = 1.2\ MG + 0.2\ MG + 0.4\ MG = 1.8\ MG$ (5)

The peaking factor multiplier, f, was determined to be 2 by the water supply team (see Appendix A).

The water tower volume curve is needed to model the pressurised conveyance system in EPAnet. Equation 1 shows the volume of water that can be stored in the water tower as a function of the height

$$V(h) = \frac{\pi h^2 (3R-h)}{3} \quad (1)$$

where

- $Volume\ V = 1.8\ MG = 240626\ ft^3$
- $Radius\ R = 38.15\ ft$
- Height from base h (ft)

Attachment C: Cost Calculation Equations
Cost estimates for drinking and wastewater distribution pipes come from material and installation costs.

The initial cost estimate of the conveyance system is calculated in this file, Salem Meadows Conveyance Cost Estimate, using construction cost pipe estimates from 2014 (Cavagnaro, 2014) and historical data from the Michigan Department of Transportation in 2024 (MDOT, 2024). The calculation includes the total capital cost of the pipe material, excavation and installation for both the water supply and wastewater system, as well as all system components such as pumps, hydrants, the water tower, manholes, valve boxes, and pipe fittings. Operation and maintenance costs and yet to be determined.

Markups included in the initial cost estimate include the engineering fee, administrative fees, taxes and permits as well as insurance. Percentages of each markup can be seen on page one of the file titled "Conveyance System Cost Summary".

Contingencies used are based on the scope of the project, the potential unknown costs and the Owner's reserve in case of scope modifications. The contingency percentages are shown in page one of the file titled "Conveyance System Cost Summary".

Attachment D: Hydraulic Design Calculations

The water tower elevation is based on the site-wide pressure requirements. The water tower must meet the pressure requirement for both the 20 psi for fire flow and the 60 psi for the buildings. The head required to meet the pressure demand is calculated as follows:

$$H\_pressure = \frac{P * 144 \frac{in^2}{ft^2}}{62.4 \frac{lb}{ft^3}} \quad (1)$$

where

- P = pressure (psi)

Below is a table describing the variables taken into consideration for the water tower elevation. The minimum elevation of the pipe riser tower base is 903 ft to meet the fire flow requirement. The head required for 60 psi is 92 feet more than the 903 feet. However, the diameter of the spherical tank is only 77 feet, therefore the pipe riser tower base must be raised at least 15 feet. The pipe riser tower base elevation was chosen to be 920 feet to accommodate the necessary 15 feet to meet the 60 psi requirement and an extra 2 feet for flexibility within the storage tank. The final elevation of the water tower is therefore 997 feet at the top of the storage tank.

Table D-1: The water tower elevation must satisfy the pressure and volume requirements.

Description	Units	Elevation or Height	Notes
Highest building ground elevation	ft	857	Building 2 is the highest ground elevation
Water tower ground elevation	ft	860	-
Head required for fire flow at 20 psi	ft	46	Equation 1
Minimum required tower elevation	ft	903	Elevation of riser pipe determined from the difference between the building ground elevation and the head required for 20 psi
Minimum riser pipe height	ft	43	Height of riser pipe determined from the addition of the water tower ground elevation and the minimum required tower elevation
Head required for 60 psi	ft	138	Equation 1
Water level height required to maintain 60 psi	ft	92	Water level above riser pipe
Diameter of sphere for 1.8 MG	ft	77	-

The capacity of the pump has been estimated based on the water demand of the site and the total dynamic head (TDH). The total dynamic head (TDH) accounts for the static head (difference in elevation between the clear well and water level in the water tower) and friction head (energy losses due to pipe material resistance).

The static head was calculated as follows:

$$\text{Static Head} = \text{H\_tower} - \text{H\_well} \qquad (2)$$

where

- H_tower is 1007 feet and represents the water tower maximum water level
- H_well is 850 feet and represents the clear well elevation

Using Equation 2, the static head is 157 feet.

The friction head is calculated using the Hazen-Williams equation for head loss that relates the flow in a pipe to pipe characteristics. The friction head was calculated as follow:

$$\text{H\_friction} = \frac{4.72 * L * Q^{1.85}}{C^{1.85} * d^{4.87}} \qquad (3)$$

where

- L is 2255 feet of pipe between the clear well and tower (feet)
- d is a 10 inch diameter pipe (feet)
- Q is a flow rate of 690 gpm in the pipe (cubic feet)
- C is a roughness coefficient of 145 for a smooth pipe (unitless)

Using Equation 3, the friction head is 5.76 feet.

The total dynamic head is 162.76 feet. The pump must be able to meet or exceed the total dynamic head, therefore the TDH was rounded to 163 feet for simplicity.

<u>Tall Building Scenario</u>

To provide service to a tall building, the minimum pressure at the peak of the building must be 35 feet to be within regulation (Table B-2). Using equation 1, the pressure at the peak of the tallest building on site of 90 feet was estimated:

$$\text{H\_pressure} = 90 \text{ feet} = \frac{P * 144 \frac{in^2}{ft^2}}{62.4 \frac{lb}{ft^3}}$$ giving a pressure of 39 psi.

Attachment E: EPANET Model for Water Supply Distribution

EPANET was utilized to run various hydraulics tests to solidify the hydraulic components. The process was iterative. The first test in the model was with all regulation minimums to understand if the system already worked at the minimum regulations. These regulations included the 6 inch pipe diameter and the pipe depths of being under the frost line at 4 feet and under the river at 5 feet. The water tower and pumps were also initially designed to meet the regulatory standard pressure of 60 psi. After running the model and getting negative pressures, we increased the pipe diameter to a more standard 10 inches and found that this worked and minimized head losses. The water tower and pump were less iteratively produced as they had to meet the necessary capacity and pressure. They are further discussed in the previous Attachment D. Below are some additional graphs to display the success of the system without fire flow demand.

The pressure received at each buildings ground level will generally be around $\pm$4 psi, as shown in Figure E-1. Even with this variation, the pressure received at the tallest building level will still meet the 35 psi regulatory requirement.

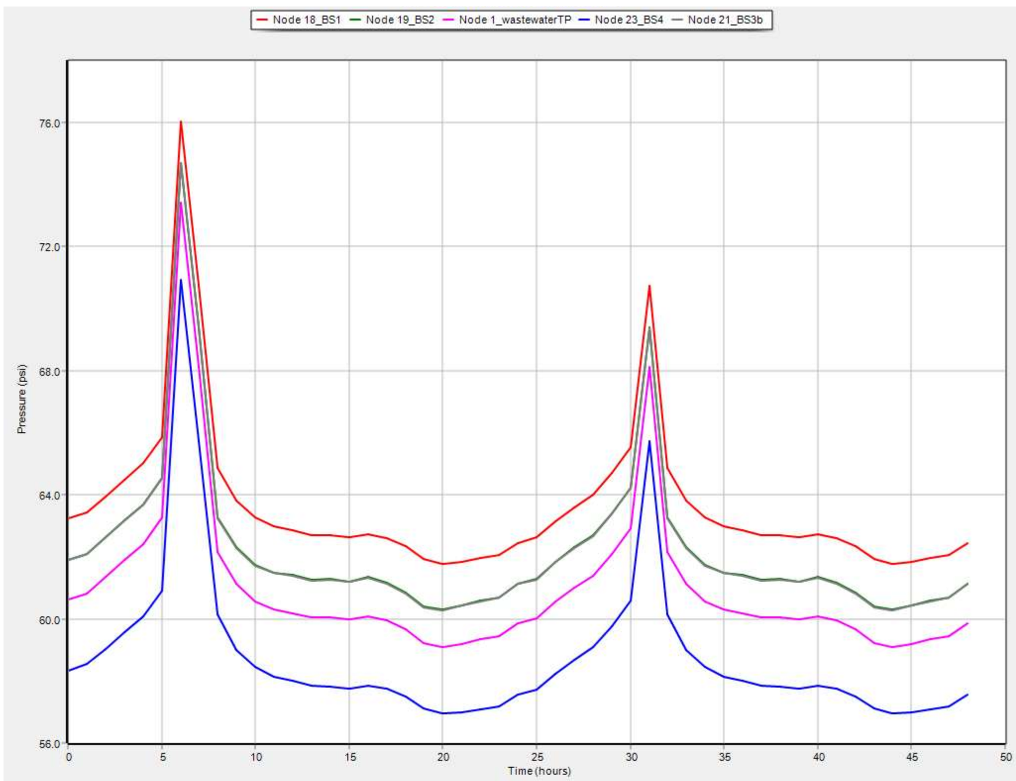

Figure E-1: All buildings receive the required 35 psi minimum at their tallest point.

After determining that the EPANET system works during a typical demand period, fire flow simulations were conducted and the system failed. Figure E-2 shows the head over time for the water tower in red and a building in green. Figure E-3 shows the head loss for the pump over the same time period. During peak demand hours the water tower is only supplying about 5 feet of head whereas the pumps supplying about 25 feet of head. This shows that the pump is being over-worked during peak demand hours and the water tower may need to be re-designed. This explains why the system does not work during fire flow scenarios as the pump is being forced to handle the fire flow capacity, which is nearly 7 times its designed capacity. Options to address this problem are discussed in section 4.3.3 of the main report.

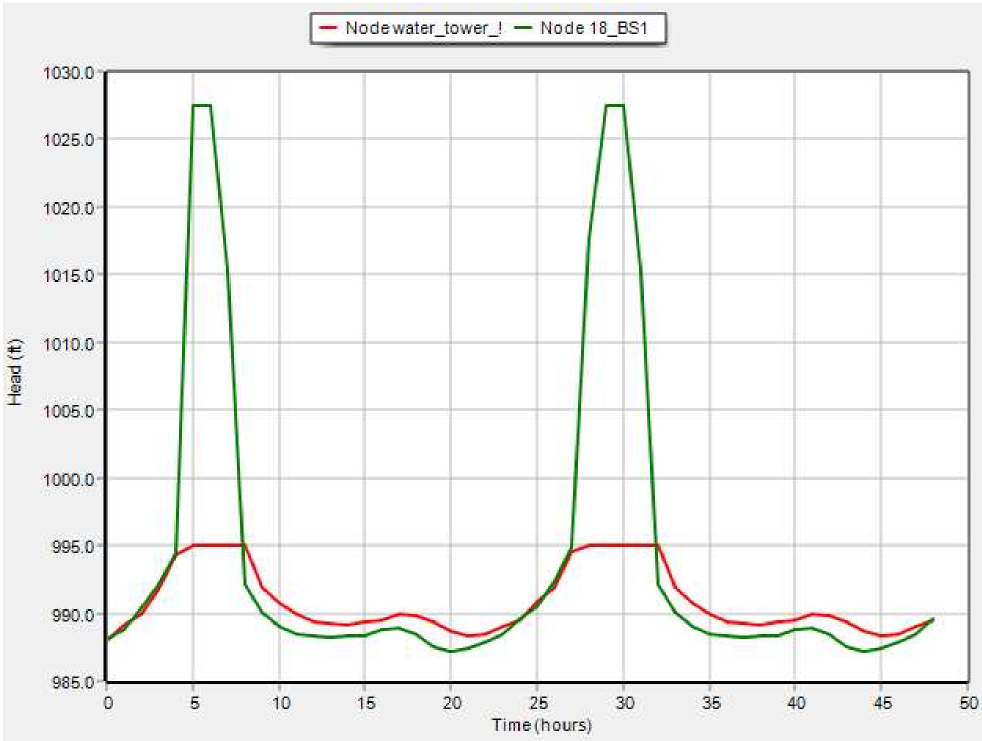

Figure E-2: The water tower supplies very little of the needed pressure head to fulfill the building demand.

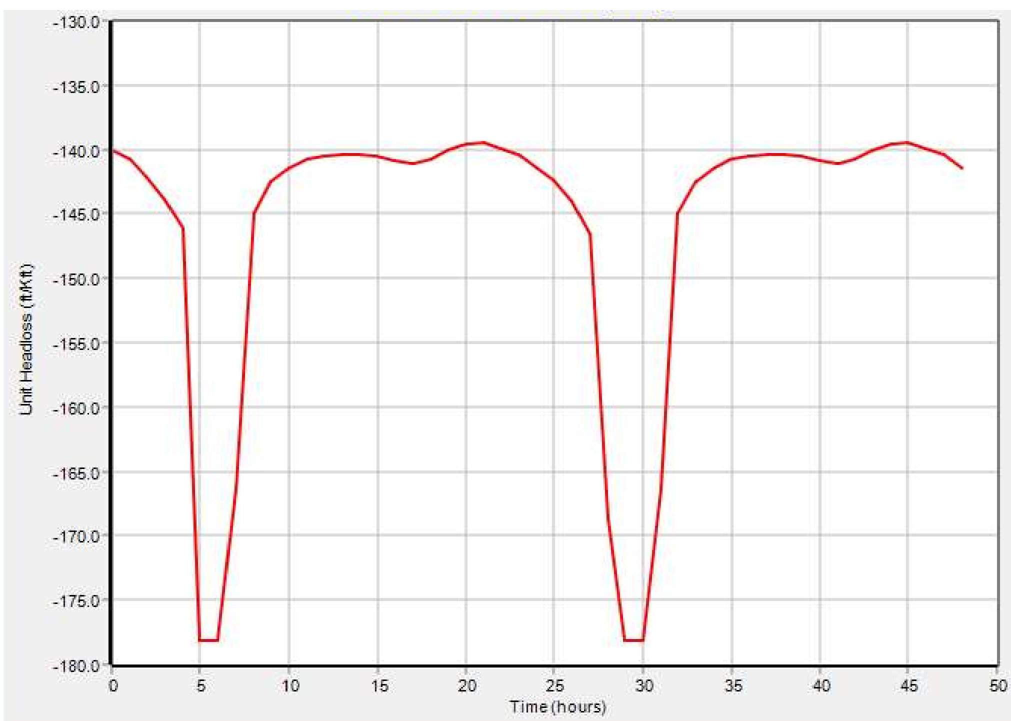

Figure E-3: The pump is being over-worked during peak demand hours.

Attachment F: Wastewater Conveyance Model

The network of wastewater pipes, nodes and junctions was created on Google Earth Pro and is shown labeled in Figure F-1. The same has been done for the manholes, shown in Figure F-2.

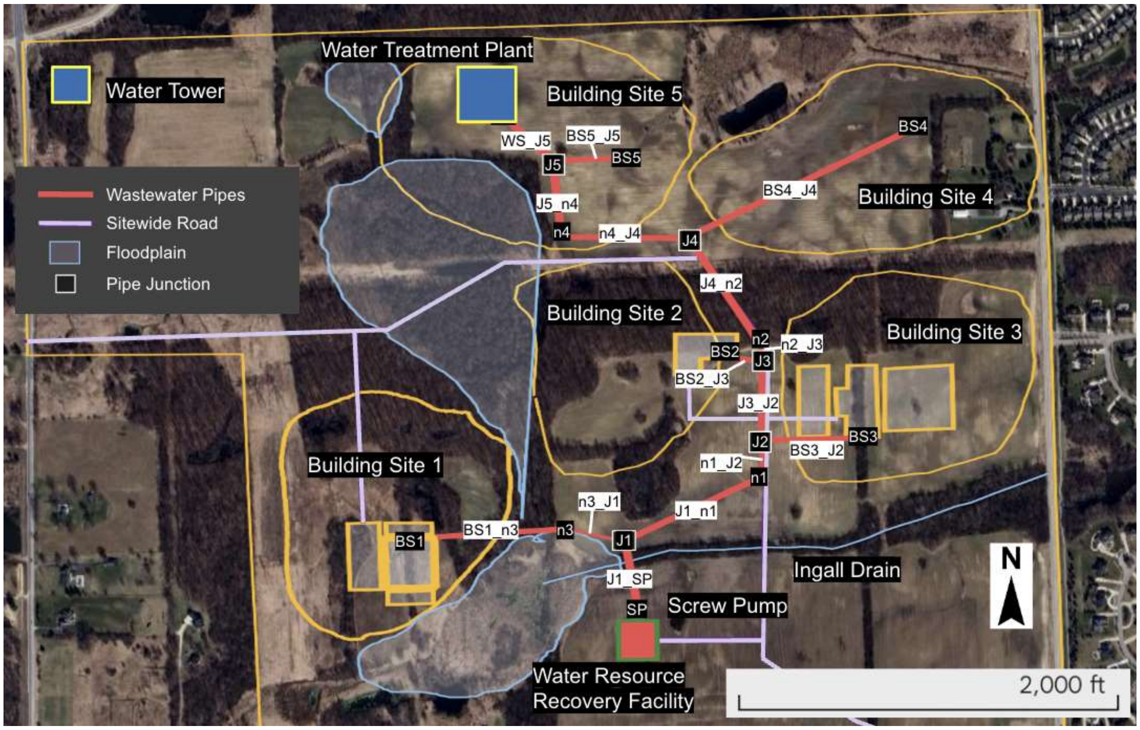

Figure F-1: Nomenclature of the wastewater pipe route

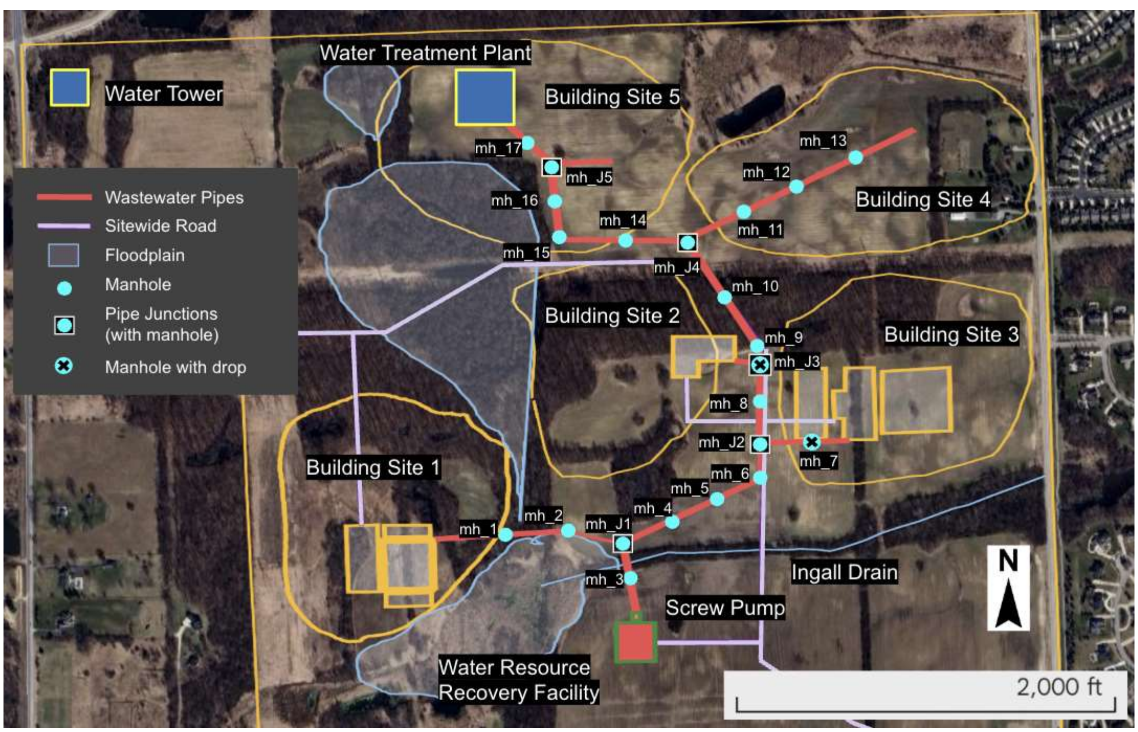

Figure F-2: Nomenclature of the manholes

The full set of calculations done to design the wastewater conveyance system can be found in the following Google Sheet: Wastewater Pipe Design Calculations.