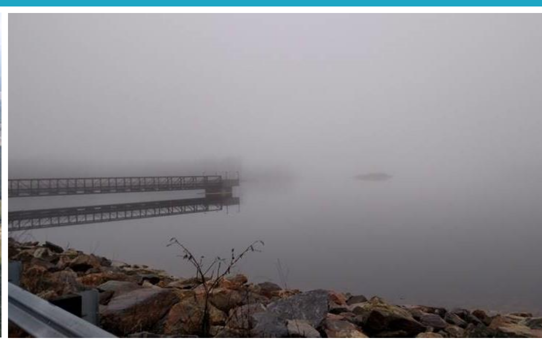
MASTER PLAN REPORT

Stafford County, Department of Public Works, Water and Sewer System Master Plan


Stafford County, VA
Department of Public Works

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OBG

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Terminology, Definitions, Glossary and Abbreviations

Average Dry Weather Flow (ADWF) – ADWF consists of average daily sewage flows and groundwater infiltration (GWI). ADWF is the average flow that occurs on a daily basis with no evident reaction to rainfall.

C-factor – A measure of the interior roughness of a pipe***.***

Diurnal Demand or Flow – Fluctuation of water demands or wastewater flows over a 24-hour period.

Effective Storage – Effective storage for each storage facility is determined by establishing the level in each tank above which all points in the water system can be served at 20 psi or higher (based on peak hour or maximum day plus fire flow).

Equalization Storage – The treated water storage needed to meet daily fluctuations in water demand or storage of peaking flows to prevent overflows from the sewer collection and conveyance systems.

Groundwater Infiltration (GWI) – Groundwater that infiltrates pipeline and manhole defects located below the ground surface. Groundwater infiltration is separate and distinguished from inflow resulting from storm events. Infiltration is a steady 24-hour flow that usually varies during the year in relation to the groundwater levels above the sewers. Infiltration rates are normally estimated from wastewater flows measured in the sewers during the early morning hours when water use is at a minimum and the flow is essentially infiltration.

InfoWater™ – InfoWater is a computer software modeling package used for modeling the Department of Utilities' water distribution system under various demand conditions.

InfoSewer™ – InfoSewer is a computer software modeling package used for modeling the Department of Utilities' sanitary sewer system under various wastewater flow conditions.

Inflow – Drainage that enters the collection system through illegal or permitted connections, such as catch basins, downspouts, area drains and manhole covers. Inflow is separate and distinguished from infiltration. The inflow rate can be determined from the flow hydrographs recorded with flow meters by subtracting the normal dry weather flow and the infiltration from the measured flowrate.

Infiltration/Inflow (I/I) – The wastewater component caused by rainfall-dependent infiltration/inflow (RDI/I) and groundwater infiltration (GWI).

Maximum Day Demand – The water demand on the one day in the year when the consumption is the highest.

Maximum Hour Demand – The water demand during the one hour in the year when water consumption is the highest.

Node – A junction of two or more pipes, commonly representing a point where pipe characteristics change.

Peak Dry Weather Flow (PDWF) – PDWF consists of peak sewage flows plus GWI. PDWF is the highest measured hourly flow that occurs on a dry weather day.

Peak Wet Weather Flow (PWWF) – PWWF consists of ADWF plus RDI/I. PWWF is the highest measured hourly flow that occurs during wet weather.

Peak Factor – Peak factor for water system is MDD/ADD and for the sewer system the peak factor is PWWF/ADWF.

Pressure Reducing Valve (PRV) – A valve that will maintain a specified downstream pressure.

Pressure Zone – A network of water pipes having a common static hydraulic grade line. Pressure zones are separated by closed valves, pressure regulating valves, pumping stations, and water storage tanks.

Rainfall-Dependent Infiltration/Inflow (RDI/I) – RDI/I consists of rainfall that enters the collection system through direct connections (roof leaders, manholes, etc.) and causes an almost immediate increase in wastewater flow.

Service Area – The area served by the water distribution or wastewater collection system.

Steady State Simulation – A network model solution for a single point in time.

Tributary Area – The tributary area of a sewage system consists of all areas that contribute flow to the sewer by gravity and/or force main discharges.

ADD	Average Day Demand
ADWF	Average Dry Weather Flow
AWWA	American Water Works Association
CIP	Capital Improvement Program
cfs	Cubic Feet per Second
CMOM	Capacity, Management, Operation and Maintenance
CWA	Clean Water Act
DPW	Stafford County Department of Public Works
D/DBP	Disinfectants/Disinfection Byproducts
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	US Environmental Protection Agency
EPS	Extended Period Simulation
ft	Feet
FY	Fiscal Year
gpcpd	Gallons per Capita per Day
gpd	Gallons per Day
gpm	Gallons per Minute
gpdidm	Gallons per Day per Inch Diameter – Mile
GWI	Groundwater Infiltration
HAAs	Haloacetic Acids
HGL	Hydraulic Grade Line
ICR	Information Collection Rule
I/I	Infiltration and Inflow
IESWTR	Interim Enhanced Surface Water Treatment Rule

ISO	Insurance Service Organization
L	Liter
LFR	Little Falls Run
MCL	Maximum Contaminant Level
MDD	Maximum Day Demand
MG	Million Gallons
mgd	Million Gallons Per Day
mg/l	Milligrams per Liter
NEPA	National Environmental Policy Act
O&M	Operations and Maintenance
OBG	O'Brien & Gere Engineers, Inc.
PDWF	Peak Dry Weather Flow
PHD	Peak Hour Demand
PRV	Pressure Reducing Valve
psi	Pounds per Square Inch
PSV	Pressure Sustaining Valve
PWWF	Peak Wet Weather Flow
PWS	Public Water Supply
RDI/I	Rainfall-Dependent Infiltration/Inflow
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
SSO	Sanitary Sewer Overflows
SWTR	Surface Water Treatment Rule
TCR	Total Coliform Rule
THMs	Trihalomethanes
TMDL	Total Mass Discharge Limit
TN	Total Nitrogen
TP	Total Phosphorus
UFW	Unaccounted-for Water
ug/L	Micrograms per Liter
USACE	US Army Corps of Engineers
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
VDEQ	Virginia Department of Environmental Quality
VDH	Virginia Department of Health
WLA	Waste Load Allocation
WTP	Water Treatment Plant
WWTF	Wastewater Treatment Facility

ACKNOWLEDGEMENTS

The Stafford County Water and Sewer System Master Plan and supporting Technical Memoranda were developed through a collaborative effort by the staff of the Stafford County Department of Public Works (DPW) and O'Brien and Gere Engineers, Inc (OBG). The Master Plan was developed throughout 2017, with final editing completed in early 2018.

Chapter 1 INTRODUCTION

This Stafford County Water and Sewer Master Plan is the product of an effort to assess the Department of Public Works many separate water and sewer elements, and combine these elements into a single "roadmap" for the future. This Master Plan will serve as a guide to future system development and investment decisions. Based on the shared values of the County and the customers it serves, the Master Plan provides a holistic vision for the future of Stafford's public water and sewer systems, as well as strategies to carry out this vision.

1. OVERVIEW

The Stafford County Department of Public Works is under the direction of the County Board of Supervisors and provides public water and sewer service in Stafford County. The Department of Utilities was formed in 1982. The Utilities Department was merged with the Department of Public Works in 2018. Before 1982, the Aquia Sanitary District and the South Stafford Sanitary District provided public water and sewer services for Stafford County. In 1982, the Sanitary Districts were abolished and replaced with the Department of Utilities under the County Board of Supervisors. The service area population and the demand for water and sewer services have increased approximately five-fold in the last 35 years and continue to grow. The demand for services is expected to nearly triple again during the next 40 years. Today, the Utilities Division of DPW is a 140-employee utility serving a residential population of approximately 105,000, over 1,300 businesses, and a portion of the Quantico Marine Corps Base.

To assist the growth and development of the County's utility systems, the Board of Supervisors established the Utilities Commission. The Utilities Commission has the following functions, powers, and duties as established by the Stafford County Code:

- The Commission shall annually recommend to the Board of Supervisors a proposed rate and fee structure which shall be designed to ensure long-term self-sufficiency of the utility system and the financial integrity of the utility enterprise fund.
- The Commission shall recommend ordinance amendments to the Board of Supervisors regarding the utilities system.
- The Commission shall make recommendations regarding neighborhood water and sewer projects.
- The Commission shall make recommendations regarding the expansion of utility facilities and services.

The Commission conducts public hearings on the following issues:

- Rate and fee structure.
- Ordinance amendments.
- Amendments to the water and sewer elements of the Comprehensive Plan.
- Other matters which have been specifically requested by the Board of Supervisors.

DPW operates as an enterprise fund separate from the County's General Fund. The Utilities Division of DPW is solely funded by the fees and charges that it collects from its customers.

2. MASTER PLANNING PROCESS

O'Brien & Gere has been working with DPW to update the 2006 Water and Sewer System Master Plan, including the chapters addressing the water demand and sewer load projections, raw water supply, water treatment, water distribution, wastewater collection, and wastewater treatment. As part of this master planning effort, the staff of the DPW recognized the need to review all elements of the Master Plan. It was observed that planning for future development in a compartmentalized fashion would not allow DPW to directly address the linkages among operations – water supply, treatment and distribution; wastewater collection and treatment; and residuals management. DPW recognized the need to view these components holistically and to develop a vision for the long-range provision of water and sewer service to its customers.

The Master Plan effort has focused on the issues and challenges DPW will face through buildout, which is likely to occur over the next 40 years (i.e., 2020 through 2060). The Master Plan highlights the implementation of specific utility system improvements and provides action plans and decision points for each of the utility system elements.

The Master Plan has been completed through the sustained efforts of the DPW staff, the County's Planning Department staff, the Planning Commission, the Utilities Commission, and with input from the Board of Supervisors.

The Master Plan is one of Stafford's key policy instruments. The Master Plan will serve as a guide to annual investment decisions. In turn, implementation strategies in the Master Plan will be reviewed and updated periodically to reflect new information and changing community conditions.

3. ORGANIZATION OF THE MASTER PLAN

The Water and Sewer Master Plan has two components – the *Water and Sewer System Master Plan* and the supporting *Technical Memoranda*.

This *Master Plan* provides a comprehensive assessment of the water and wastewater systems and the challenges confronting DPW as it plans for buildout, which is anticipated to occur over the next 40 years. The Master Plan is intended to provide guidance to DPW staff who are charged with making strategic and facility planning decisions.

The first two chapters, Chapter 1 (*Introduction)* and Chapter 2 *(Guiding Principles),* summarize the foundation of the Master Plan.

Chapter 3 *(Water Demands and Sewer Flows*) includes forecasts of future demands for water and sewer service as the DPW service area develops through buildout.

Chapters 4 (*Raw Water Supply*), 5 (*Water Treatment*), and 6 (*Water Distribution*) focus on the challenges of providing water service to meet future demands and adapting DPW's facilities and infrastructure to anticipated regulatory programs affecting water supply, treatment, and distribution.

Chapters 7 (*Wastewater Collection*) and 8 (*Wastewater Treatment*) focus on the same challenges as water service for the wastewater system.

Chapter 9 (*Cost Estimates and Project Timing*) outlines the basis for costs presented in the Master Plan along with timing for implementation of proposed improvements.

The *Technical Memoranda* completed by OBG are included in Sections 1 through 9 of the Appendices in this volume. These memoranda contain detailed technical information about the individual components of DPW's utility system and are intended to be used by DPW technical staff and consultants to support planning and design decisions.

Chapter 2 GUIDING PRINCIPLES

The Stafford County DPW will provide water and wastewater services which satisfy the present and future needs and expectations of our customers. Our performance is directed at meeting or exceeding all regulatory requirements. We are committed to excellence in all that we do.

The Water and Sewer System Master Plan embodies the shared principles and values of Stafford County. Guiding principles serve as the framework for the objectives and solutions formulated for the Master Plan.

This chapter defines these five guiding principles:
1. Customer Service
2. Proactive Planning
3. Sustainability
4. Fiscal Responsibility
5. Adaptability

1. CUSTOMER SERVICE

Customer satisfaction is DPW's number one priority. DPW provides water and wastewater services that meet or exceed the requirements of residential, commercial, and industrial customers. A high level of customer satisfaction is maintained in terms of customer service, quality of water supplied, government and community relations, and environmental stewardship.

2. PROACTIVE PLANNING

Proactive planning and growth-neutral utility services are central tenets of the Master Plan and of DPW's long-term strategy in general. Growth-neutral means that DPW's policies and actions do not stimulate or inhibit growth, but merely respond to the growth policies and any changes thereto embodied in Stafford County's Comprehensive Plan.

The Master Plan is based on the anticipated utility needs of the Stafford customer base within the service area as defined in this plan.

Faced with complex issues that involve competing goals and objectives, DPW supports an integrated resource planning approach to its full range of services and facilities. Integrated resource planning involves coordination with different stakeholders, resolution of competing issues, and sensitivity to community needs. Integrated resource planning helps develop solutions that achieve level-of-service requirements while meeting financial, economic, environmental and other community constraints. Five key elements of integrated resource planning that are fundamental to the Master Plan include:

- <u>Systems Evaluation</u> - Rather than finding answers to individual system problems, DPW looks holistically at the systems of water, wastewater and the environment.

- <u>Supply and Demand Management</u> - DPW looks for both supply-side and demand-side solutions. Traditional supply-side solutions for meeting increased demand would include seeking a new water supply. Demand management slows the growth of water usage through conservation and enhancing the efficiency of the supply and delivery systems.

- Self-Sufficiency and Regional Cooperation - DPW's policy is to provide services to its customers through facilities and resources it owns and controls, wherever practical. It also maintains interconnections and relationships with utility service providers in other municipalities to enable cooperation during emergencies. Stafford County is always open to regional approaches for water and wastewater services.

- Public Involvement - DPW works directly with other County departments and individuals to meet customer needs. Customers and citizens are provided with timely, clear and understandable information and opportunities for constructive participation in DPW's planning and decision-making process.

- Price of Being Wrong - In making decisions, DPW always asks: What is the price if we are wrong? What will the consequences be both financially and environmentally if the wrong option is selected?

3. SUSTAINABILITY

Sustainable development can be defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs. *Sustainability* is a fundamental value shared by Stafford County and the community. Both Stafford County and the community strive to limit their impact on the environment so that it can continue to provide the life-supportive resources that sustain the economic and social quality of lives for all. By systematically balancing short-term desires with nature's requirements, we can achieve sustainability. Obviously, this task goes beyond the role of a single water and sewer utility. Still, Stafford County can make progress toward sustainability with an integrated and long-term approach to resource planning.

4. FISCAL RESPONSIBILITY

DPW is financially independent from Stafford County's other functions and departments. DPW is funded entirely by water sales, water and sewer user fees and fees assessed on developers and new connections (e.g., "availability fees" and "Pro Rata charges"). These revenues are collected into an "Enterprise Fund" and other dedicated accounts which are then used to pay for operations, maintenance and debt service for the water and sewer systems. No County taxes are used for DPW operations. For large capital investments, DPW can accumulate availability fees and Pro Rata charges in order to reduce the amount of future borrowings. As an example, for the $150 million Lake Mooney water supply program, over 60% of the costs were paid using accumulated "availability" funds. DPW is committed to prudent financial decisions that minimize the need to borrow money to finance current or future operations.

DPW also recognizes the importance and implications of the costs of planning, constructing, upgrading, rehabilitating, operating, and properly maintaining water and sewer systems and customer services in today's regulatory, environmental, and economic climate. Through increased efficiency and cost management, DPW responds to the challenge of providing customers with high-quality water and sewer services in a sustainable and economic manner, despite rising costs. The long-range financial planning and management objectives of DPW include the following:

Sound Financial Management

- Sustain equity, fairness, and efficiency in all financial decisions.

- Sustain reliable revenue.
- Promote efficient use of water resources, reclaimed water, and demand management to defer capacity-related capital investments.
- Maintain a favorable credit rating.
- Create a favorable context for issuing County bonds.

Risk Management
- Maintain an appropriate risk management program.
- Minimize uncertainty in revenue, capital, and expense forecasts.

Rate Stability
- Establish rates, fees, and charges that reflect the costs of supplying services.
- Implement gradual, programmed rate adjustments.
- Maintain rates, fees, and charges at levels competitive with similar water and sewer service providers.

Cooperation with Other Entities
- Operate in compliance with legal requirements and interlocal agreements.
- Foster cooperative provision of water and sewer services with other municipalities and authorities.

Customer Involvement
- Encourage input by customers, elected officials, and the general public in DPW's financial decisions.
- Motivate staff to provide quality services to customers.

Fiscal responsibility is one of the criteria used by DPW to evaluate strategic alternatives – for all aspects of a project and for capital improvements.

5. ADAPTABILITY

Because regulatory requirements, regional development, and customer demands will change over the next 40 years, DPW must be capable of adaptability as an organization. Future conditions may require modification, even reversal, of present approaches to facilities planning and operations.

The guiding principle of adaptability underscores the value of continuing to explore and develop multiple options for water supply, water treatment, wastewater treatment, and resource recovery since future development will affect the feasibility or effectiveness of the options in ways the present-day perspective cannot fully anticipate.

Some options have only windows of availability – land for future facility expansion may be developed for other purposes if not obtained when it becomes available; a utility tunnel can be easily installed during a road construction project, but bore-and-jack construction while that busy road is in service will be more costly and, in some cases, no longer feasible.

An adaptable organization can respond to such unforeseen challenges with creative leadership. Without adaptability, an organization will rush to implement change with higher costs and uncertainty.

The Master Plan emphasizes active monitoring of trends in regulations, technology, and development, and encourages taking stock of DPW's current plans as new information becomes available. The long-term plan is viewed as a dynamic model that is adaptable to changes.

Chapter 3 WATER DEMANDS AND SEWER FLOWS

The Stafford County Department of Utilities provides water and sewer service to the central portion of the County generally extending east and west of the Interstate 95 corridor. The current and future water and sewer needs of its customers in the County are of central focus as DPW considers its long-range development options.

1. DPW SERVES ITS CUSTOMERS

The service area population and the demand for water and sewer services have increased approximately five-fold in the last 35 years and continues to grow. The demand for services is expected to nearly triple again during the next 40 years. Today, DPW serves a residential population of approximately 105,000, over 1,300 businesses, and a portion of the Quantico Marine Corps Base.

Stafford County is located approximately 40 miles south of Washington, DC and 60 miles north of Richmond, VA. The County covers 277 square miles of which 51 square miles in the northern portion of the County comprise the Quantico Marine Corps Base. With its proximity to major industrial and commercial markets and its high percentage of undeveloped land, the County is experiencing rapid residential and commercial development. The number of water/sewer accounts has increased from 6,000 in 1982 to over 35,000 in 2017. Between 2014 and 2017, the public utility customer base increased at an annual rate of approximately 2%. This recent increase in the number of customers aligns with the goal of 2% annual population increase, adopted by the Stafford County Board of Supervisors.

2. PLANNING HORIZON

DPW's Master Plan attempts to anticipate long-term utility needs through buildout (roughly 2060). This long "planning horizon" allows sustainability considerations to affect DPW's decision-making processes for maintaining adequate water and wastewater facilities. Decisions must not only make sense as short-term solutions, but as long-range investments in the community's future.

Although a 40-year planning horizon is a valuable tool for planning, long-term growth rates and scenarios for eventual buildout conditions are not well established and are subject to considerable uncertainty. While DPW's water demand and sewer flow projections assume a constant increase throughout the planning period, actual growth may occur differently, and full buildout may occur before 2060.

Near-term water demand and sewer flow projections were developed to identify the water and sewer improvements needed to satisfy near-term water demands and sewer flows. To estimate near-term water demands and sewer flows, DPW consulted with the County's Planning Department to identify developments that are in progress or anticipated within the next ten years (through 2028). The objective of this analysis was to identify what facilities may be needed and the size of those facilities to deliver water from Lake Mooney and Smith Lake WTP's to DPW's customers. The completion of the Lake Mooney WTP is causing a shift in transmission of water from the current condition, with two-thirds of water production in the north from Smith Lake WTP and one-third production in the south from Lake Mooney WTP, to the opposite (i.e., two-thirds delivery from the south from Lake Mooney WTP and one-third from the north from Smith Lake WTP). This change represents a significant shift, requiring careful planning to optimize use of existing facilities and properly size and locate proposed facilities so that they operate well under near-term and buildout conditions.

The near-term sewer flow (through 2028) represents the quantity of existing sewer flow plus the projected flow from developments that are currently under consideration. While there is considerable uncertainty associated with the timing (and in some cases the future) of some of these future developments, it is prudent to plan the infrastructure needed to allow adequate time for planning, permitting, design and construction of the required facilities.

3. KEY ASSUMPTIONS AND UNCERTAINTIES

The overall planning approach outlined in this Master Plan gives reasonable projections of future water demands and sewer flows and allows DPW to build conservatism into the sizing of facilities and piping in the latter stages of the planning process, thereby minimizing the amount of rework required to update plans and proposed improvement projects.

The disaggregated water demand/sewer load method was used to separate (disaggregate) the water demands and sewer loads into more uniform groups of users as the basis for future projections. This method provides accuracy and flexibility in analyzing alternatives because of the ability to use different consumption and generation rates within each group and different growth rates among groups. This approach can be used with land use information and water/sewer duties (gallons per day per acre) to develop water demands and sewer flows.

Water and sewer utilities have traditionally adopted a conservative approach when planning and sizing facilities with high capital costs and long lead times required for planning, permitting, design and construction. This approach typically includes diligent efforts to avoid underestimating the level of future demands that those facilities will serve. Within this context, it is important to include allowances for the wide range of unknowns inherent in long-range forecasts.

A summary of the assumptions that underlie the projected water demands and sewer flows follows. Changes in these conditions could require modification of the Master Plan.

- Service area boundaries – The Urban Service Area serves as the basis for projecting growth in water demands and sewer flows. For water, this is a significant change from the 2006 Master Plan where the long-term water service area encompassed the entire County. The 2006 Master Plan and this Master Plan both used the Urban Service Area for projecting growth of the sewer service area. The Urban Service Area boundary for buildout conditions was developed by DPW and Planning Department staff based on future development and policies. The Urban Service Area boundary represents a "wall" and water and sewer service for areas outside the Urban Service Area are not planned and no demands or flows from these areas are included in this Master Plan.

- Future water demands remain internal (except for Quantico Marine Corps Base) – Future water demands will continue to be determined by retail water and sewer sales within the service area (except for wholesale water delivery and sewer flows from Quantico Marine Corps Base). The demand forecasts do not anticipate retail or wholesale delivery of service outside of the service area (except for Quantico Marine Corps Base).

- Linear forecasts show moderate growth – Forecasts of water demand and sewer flows are essentially a linear extrapolation of current water demand and sewer flows through the buildout condition based on land use.

- Land Use and water/sewer duties - Land use information and water/sewer duties (gallons per day per acre) were used to define how water demands and sewer flows were allocated to the various land use categories throughout the County. Changes to the characteristics of a land use category over time could impact the water/sewer duties (i.e., quantity of water consumed or sewer flow generated). In addition, changing the land use for a specific geographic area could impact the water/sewer duties and alter the sizing of water or sewer facilities serving the area.

- Peaking factors – Peak water demands (maximum day or peak hour) and peak sewer flows (peak wet weather flows) are important because their magnitude drives the size and cost of future water and sewer facilities. Maximum day water demands were based on a global peaking factor of 1.5 times the average day water demand. Diurnal water demand patterns for each pressure zone were used to characterize the change in water demand at each node in the system throughout the maximum day, including the peak hour. Of particular importance is the application of the same global peaking factor and diurnal curve to each land use category. It is understood that water demands and sewer flows vary by land use category and fluctuate differently throughout the day depending on the type of land use.

  For the sewer flows, a peaking factor of 3.5 times the sanitary base flow plus groundwater infiltration was used to estimate the magnitude of the design wet weather storm event. The peaking factor was applied globally to the sewer loads at each manhole which were derived from the sewer duties and land use tributary to the manhole. The peaking factor for the sewer system is intended to reflect the sewer system's response to a design storm event. Throughout the planning period, DPW should continue to refine the water and sewer models and investigate storm events and I/I concerns.

4. FOUNDATION FOR WATER DEMANDS AND SEWER LOADS

In terms of the total quantity of water required or sewer flow generated, water demands and sewer loads are usually estimated based on per capita usage. Variations in water use or sewer flow depend on size of community, geographic location, climate, season, day of week, time of day, and the extent of industrialization. Because of these variations, the only reliable way to estimate future water demands and sewer loads is to study each community separately. To define how the total water use is distributed within a community throughout the day, the best indicator is land use. Table 1 identifies the per capita water demands and water duties (gpd/acre) for Stafford County.

Table 1 – Per Capita Water Demands and Water Duties

Category	Per Capita Water Demands and Water Duties
Residential (GPD/ERC)	200
Commercial: Business Office (GPD/10,000 sq ft)	390
Commercial: Business Retail (GPD/10,000 sq ft)	750
Industrial (GPD/10,000 sq ft)	576
Semi-Public (GPD/10,000 sq ft)	343
Public (GPD/10,000 sq ft)	2201
Residential (GPD/ERC)	200
Commercial: Business Office (GPD/10,000 sq ft)	390

Category	Per Capita Water Demands and Water Duties
Commercial: Business Retail (GPD/10,000 sq ft)	750
Industrial (GPD/10,000 sq ft)	576
Semi-Public (GPD/10,000 sq ft)	343
Public (GPD/10,000 sq ft)	2201

Many utilities apply a global reduction factor after the total water demand or sewer flow is computed (total typically reduced to 70% - 90%) to reflect the projected reduction in the level of development of the land use category (i.e., the gross area that includes the area required for existing and future road corridors, on-site stormwater facilities, on-site open space, etc.). Rather than apply a global reduction factor after computing the total water demand and sewer load, the water/sewer duties were reduced for each land use category prior to compiling the water demands and sewer flows.

5. PROJECTED WATER DEMANDS

Computation of Average Day Water Demands

The objective of the water demand analysis for this Master Plan was to determine how and where the water demands should be allocated throughout the Urban Service Area. The County's Planning Department developed an independent water demand projection for each parcel in the Urban Service Area based on the most recent Land Use information.

Using water pressure zone and land use information provided by DPW and the Planning Department, OBG developed water demand forecasts and distributed the demands throughout the system. The following steps summarize the general methodology that was used to estimate the future water demands:

- Compute the acreage for each parcel in the Urban Service Area.
- Apply water duties (gpd/acre) for each parcel.
- Add the projected Federal or Military (FED) demand.
- Add the unaccounted-for water (UAW) portion of the total demand (15%).
- Subtract the conservation component of the total demand (8%).

Peaking Factors and Diurnal Curves

Water systems are required to supply flow at rates that fluctuate over a wide range from day-to-day and hour-to-hour. Rates most important to planning, design and operation of a water system are average day, maximum (peak) day, maximum (peak) hour, and maximum hour plus fire flow.

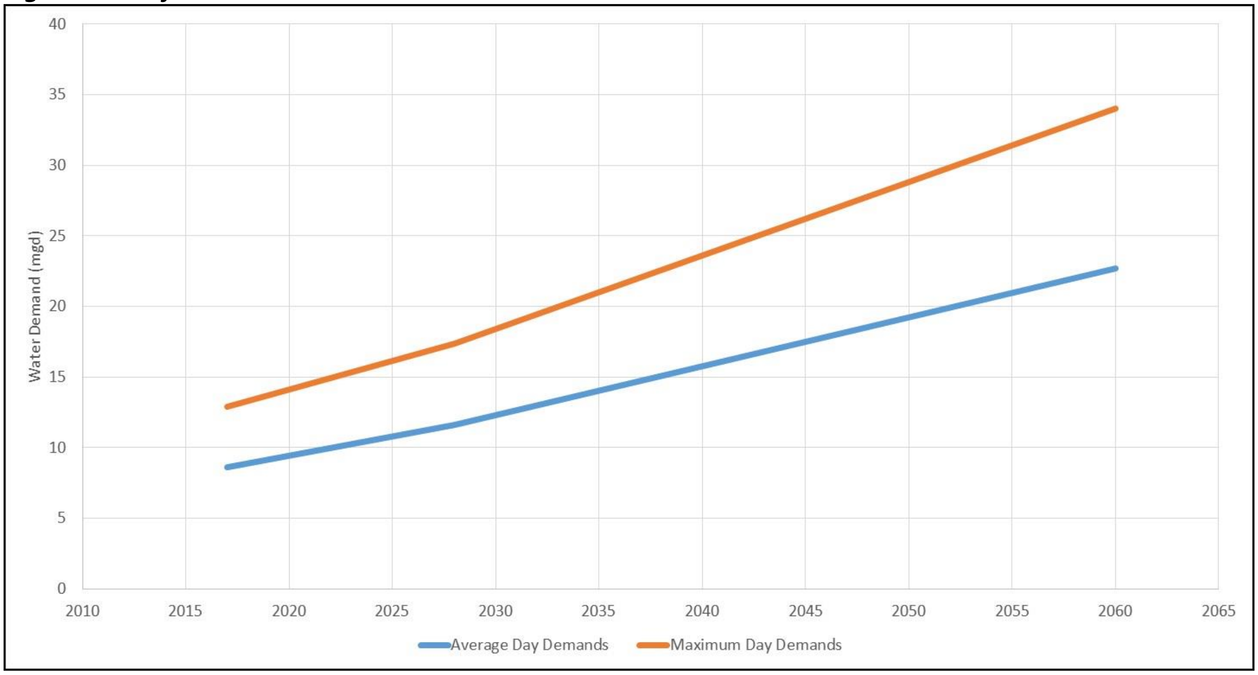
- Average day demand is the total volume of water delivered to the system in a given year divided by the number of days in the year.
- Maximum (peak) day demand is the largest quantity of water supplied to the system on any day of the year.
- Maximum (peak) hour demand is the highest rate of flow for any hour in a year.
- Maximum day plus fire flow considers the possibility of a fire event under maximum day demand conditions.

Diurnal curves are frequently used to represent how water is used over time of day. Diurnal curves are different for each house, each industry and each water user. However, for the purpose of creating a model to represent a water distribution system, simplifications are generally made such that residential, commercial, industrial, and other water use classifications are each assumed to have consistent water demand (diurnal) curves.

Different demand patterns can be applied to individual water nodes or groups of nodes to accurately represent water use categories (e.g., residential, commercial, etc.). For this Master Plan, the diurnal data from the 2006 Master Plan was used to conduct the modeling analyses. Diurnal water demand patterns were developed and used for each pressure zone. Consequently, the average day demand at each water node was multiplied by the diurnal demand pattern for the pressure zone to predict the water use at the node throughout the day.

Average day water demands are expected to increase from approximately 8.6 mgd (2017) to 22.7 mgd under buildout (2060) conditions. During the same period, the maximum day demands are expected to increase from approximately 12.9 mgd (2017) to 34.1 mgd at buildout (2060) based on a peaking factor of 1.5 times the average day demand (Figure 1).

Figure 1. Projected water demands



6. PROJECTED SEWER FLOWS

Methodology for Projecting Sewer Flows

Wet weather flows are used to assess the hydraulic capacity of sewer systems and are composed of three components:

- Sanitary base flow generated by homes, businesses, etc.,
- Infiltration due to normal groundwater levels (dry weather infiltration), and
- I/I due to rainfall and high groundwater levels (rainfall-dependent I/I)

The formula for calculating the sewer loads for wet weather conditions is as follows:

Peak Wet Weather Flow (PWWF) = Average Dry Weather Flow (ADWF) + Rainfall-Dependent I/I (RDI/I)

Where:

Peak Wet Weather Flow (PWWF) equals the peak hourly flow during wet weather conditions.

Average Dry Weather Flow (ADWF) is the average flow that occurs in sanitary sewers on a daily basis with no evident reaction to rainfall. The ADWF is composed of sanitary base flow and groundwater infiltration. For Stafford, sanitary base flows are roughly equal to 65% to 80% of the average day water demand which approximates the customers' water demand that is returned to the sanitary sewer. Groundwater infiltration (GWI) is an allowance that is added to the sanitary base flow (derived from sewage flow factors) to obtain the dry weather flow. GWI represents flow that is separate and distinguished from inflow resulting from storm events during wet weather conditions. The allowance used in this Master Plan for GWI is estimated to be 500 gpd/inch diameter-mile (gpdidm).

Rainfall-Dependent I/I consists of rainfall that enters the collection system through direct connections (roof leaders, manholes, etc.) and causes an almost immediate increase in wastewater flows. RDI/I data was used to establish an overall sewer system peaking factor of 3.5 in the 2006 Master Plan. The 3.5 peaking factor for the overall sewer system was also used in this Master Plan to reflect RDI/I.

To define the design flow conditions for the sewer system, the equation presented above was modified as follows:

Peak Wet Weather Flow (PWWF) = (Sanitary Base Flow x Peak Factor) + Groundwater Infiltration

In the sewer model, a global peak factor is multiplied by the sanitary base flow at each manhole in the sewer system and the GWI component (500 gpdidm) is subsequently added to the computed manhole flow as the flow is routed through the downstream sewer piping.

Sanitary Base Flows for Near-term Conditions

Near-term flows were developed based on existing and proposed developments. Average sewer flows were applied to the nearest manholes. This approach results in an accurate allocation of current sewer flow to the nearest sewer manhole. Sewer loads for developments which could occur through 2028 were provided by Stafford's Planning Department and applied to the existing InfoSewer™ model to test the capabilities of the existing infrastructure to handle the proposed near-term flows.

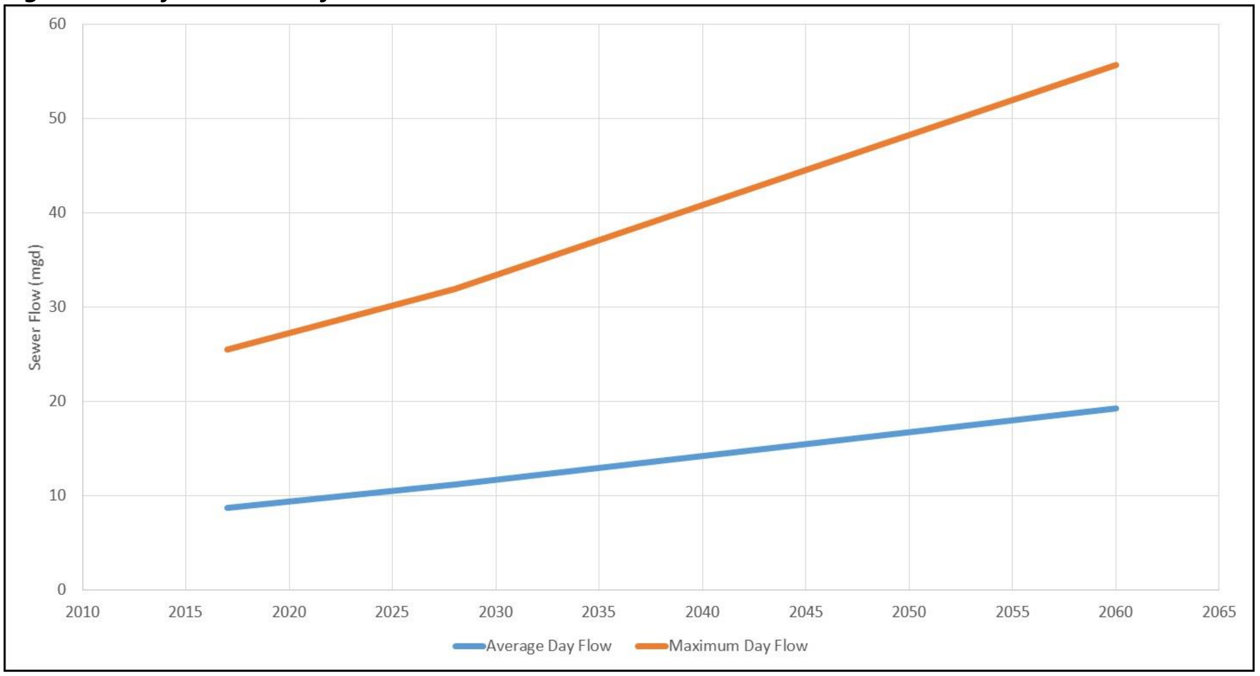
Sanitary Base Flows for Buildout Conditions

Similar to near-term flows, buildout flows were developed based on existing development, proposed near-term development (through 2028) and projected land use (development beyond 2028). Average sewer flows were applied to the nearest manholes.

Determination of Total Peak Design Flow

Design flow for a sewer is defined as the maximum flow rate that occurs under selected weather and growth conditions. The peak factor is used to convert projected average sewer flows through the planning period to peak wet weather flows. Average daily sewer flows are expected to increase from approximately 8.7 mgd (2017) to roughly 19.2 mgd under buildout (2060) conditions. During the same period, the maximum day sewer flows are expected to increase from approximately 25.5 mgd (2017) to 55.7 mgd at buildout (2060). The sewer flow projections are shown in Figure 2.

Figure 2. Projected sewer flows



7. KEY FINDINGS

- Bringing the Lake Mooney Reservoir water facilities on-line and shifting the direction of water flow from the supply sources through a major portion of the transmission system requires careful planning to optimize use of existing facilities and properly size and locate proposed facilities so that they operate well under near-term and buildout conditions.

- Water and sewer service area boundaries form the Urban Service Area envelope and water demands and sewer flows from areas outside the Urban Service Area were not included in this Master Plan.

- Average daily water demands are expected to increase from approximately 8.6 mgd (2017) to 22.7 mgd under buildout (2060) conditions. During the same period, the maximum day water demands are expected to increase from approximately 12.9 mgd (2017) to 34.1 mgd at buildout (2060) based on a peaking factor of 1.5 times the average day demand.

- A peak factor of 3.5 times the sanitary base flow plus groundwater infiltration was used to derive the peak wet weather flow for the sewer system.

- Average daily sewer flows are expected to increase from approximately 8.7 mgd (2017) to roughly 19.2 mgd under buildout (2060) conditions. During the same period, the peak flows are expected to increase from approximately 25.5 mgd (2017) to 55.7 mgd at buildout (2060).

8. PLAN OF ACTION

- DPW will continue to monitor growth in water and sewer accounts and update water demands and sewer flows.

- DPW will continue to refine techniques used to develop water demand and sewer load forecasts and update projections provided in the Master Plan. Changes in the characteristics of land use categories (i.e., number of housing units per acre, persons per household, etc.) and patterns for water use and sewer flow generation will be routinely reviewed.

- If water demand or sewer load forecasts are revised, DPW will review the timing for capital projects identified in the Master Plan and possibly revise the sizing or timing of projects.

- DPW will continue to monitor the sewer system's response to storm events with varying characteristics (i.e., intensity, duration, etc.) and, if necessary, modify the peaking factor used to represent the design storm event.

- DPW will continue to conduct I/I studies and implement cost-effective measures to reduce I/I.

Chapter 4 RAW WATER SUPPLY

Stafford County Department of Utilities' reservoirs and raw water supply infrastructure are projected to be sufficient to meet present demands and future demands through 2045. Limitations on the system's ability to reliably meet water demands during drought conditions were addressed through construction of the Lake Mooney Reservoir. Through its source water protection efforts and ongoing treatment research, DPW continually works to improve and safeguard the quality of its water supply.

1. STAFFORD COUNTY RESERVOIRS

The County's water comes from Lake Mooney and Smith Lake Reservoirs. The reservoirs store water that DPW eventually treats to supply customer demands. The reservoirs must be large enough to meet the County's current and future demands in drought years. In addition, the reservoirs must be kept safe from sources of health-related water quality constituents, and other constituents that could affect the water's aesthetics (e.g., taste and odor). To protect its water supplies, DPW has several programs to minimize the potential for contamination of the reservoirs.

In 1992, the Stafford Board of Supervisors selected Lake Mooney (formerly named Rocky Pen Run Reservoir) as the new source of water supply to meet the County's needs well into the future. The reservoir is located in the southern portion of the County and is filled from the Rappahannock River using a 40 mgd river pumping station. The reservoir holds approximately 5.5 billion gallons of water.

Smith Lake is located on Aquia Creek in the northern portion of the County. The reservoir holds approximately 1.8 billion gallons of water.

2. SUSTAINABLE YIELD OF EXISTING RAW WATER SUPPLY SYSTEM

The adequacy of drinking water supply sources to reliably meet water demands is based on safe yield which is the amount of water that the supply can safely provide, even during a critical drought. In Virginia, the adequacy of surface water supplies with storage reservoirs is based upon the most severe drought since 1930. Recent studies of the safe yield of Lake Mooney and Smith Lake Reservoirs are shown in Table 2.

Table 2 – Safe Yield

Source	Safe Yield (mgd)
Lake Mooney	11.9
Smith Lake	5.1
Total	17.0

OBG obtained the safe yield for Lake Mooney Reservoir (11.9 mgd) from the County. The safe yield for Smith Lake Reservoir (5.1 mgd) was computed by OBG based on the following:

- Useable water storage volume in Smith Lake is 1,775 MG with 60 days of storage held in reserve (DEQ requirement).
- Minimum release requirements from Smith Lake were obtained from DEQ permit for Smith Lake WTP.
- Assumes a continuous release of 0.75 mgd from Lunga Reservoir (Quantico Marine Corps Base) upstream of Smith Lake (note that the drainage area upstream of Lunga Reservoir was not

included in Smith Lake Reservoir drainage area). Stafford's current contract with the Quantico Marine Corps Base requires that they provide water for treatment by releasing water from the Lunga Reservoir. The Lunga Reservoir has the potential to provide the additional water that Quantico may request in the future. A contract amendment to provide the Marine Corps Base with water above the current 0.75 mgd allocation should include a requirement that the Marine Corps Base release additional water from the Lunga Reservoir to provide the water supply.
- Assumes unrestricted average day water demands (i.e., no customer water use restrictions in effect).
- A daily mass balance model was used to compute yield based on daily streamflow data from January 1, 1930 through December 27, 2016.
- The critical drought of record for Smith Lake occurred in the 1930's.

The centerpieces of DPW's raw water supply system are its reservoirs – Lake Mooney and Smith Lake. In order to use these reservoirs, DPW must maintain reservoir intakes and raw water pipelines to deliver raw water from the reservoirs to the WTPs. Each of these components is critical to the operation of the raw water supply system, and the limitations of each are factors in planning for future needs.

In 2010 through 2011, an emergency water interconnection between Stafford County and Spotsylvania County was investigated in the vicinity of the Lake Mooney WTP and the Motts Run WTP. This interconnection was further evaluated during this Master Plan and would enable the transfer of treated water from one locality to the other at up to 5 to 10 mgd. This project would greatly increase Stafford County's capability to transfer treated water to or from Spotsylvania County on an emergency basis and will enhance reliability to each locality's water system. The localities are currently limited to a transfer capacity of approximately 1.5 mgd through the existing Chatham and Falmouth interconnection with the City of Fredericksburg. At the time the project was developed in 2011, Stafford and Spotsylvania were each expected to cover 40% of the project cost and Fredericksburg was expected to cover the remaining 20% of the cost. Stafford County portion (40%) of the overall cost of the regional interconnection is approximately $6 million. The cost sharing arrangement may be revisited if the interconnection project is implemented.

3. RAW WATER SUPPLY IMPROVEMENTS

The sustainable yield of the existing raw water system is primarily limited by the available storage in the Lake Mooney and Smith Lake Reservoirs. Under anticipated growth rates, the existing raw water supply is expected to meet Stafford's raw water needs until roughly 2045, when the anticipated average day demand of 17 mgd will exceed the safe yield of the existing reservoirs. The community will then become increasingly vulnerable to drought-related water shortages, but the timing and degree of that risk will depend on the rate of growth in demand. Managing those demands and providing additional water supply capacity will reduce risks.

Existing supplies are expected to meet the County's needs through 2045, but numerous factors could cause DPW's water supply to fall short of what is required. These factors may include, but are not limited to, the following:
- Further revisions to the safe yield calculations.
- A drought more severe than the critical drought could occur.
- Residential population or employment increases could exceed projected estimates.
- Water conservation programs could fall short of their goals or per capita demand could exceed the projections.

- Quantico Marine Corps Base could request more water than projected.
- A water intensive industry could locate in Stafford.
- Customer use patterns could change.

Potential Additional Water Supply Sources

The average day buildout demand is projected to be 22.7 mgd. The available safe yield (17 mgd) is expected to be sufficient to meet water demands through about 2045. The County could consider the following options (at a minimum):

- Potomac River Intake (Unlimited).
- Rappahannock River Intake below Fall Line (Unlimited).
- Groundwater.
- Vulcan Quarry (3.2 mgd).
- Abel Lake Reservoir (4 mgd).
- Water recycling.

A brief description and summary of the advantages and disadvantages of each option follows.

- Potomac River Intake. A water intake on the Potomac River would provide an almost unlimited supply of water. However, a high degree of water treatment would have to be provided due to the salt content of the river during droughts, and this source is miles away from the County's existing water treatment and distribution system. As improvements in treatment technology (i.e., reverse osmosis membranes) are made and if the County growth expands towards the Potomac River, this option could become more viable in the future.
- Rappahannock River Intake below Fall Line. A water intake on the Rappahannock River below the Fall Line could provide an almost unlimited supply of water. The water could be treated at either a new water treatment facility adjacent to the intake or it could be pumped to the Lake Mooney Reservoir. Permitting issues exist under current regulatory agency requirements (including several wastewater treatment facilities that discharge to this section of the river). An unknown is the risk of high salt content during a drought.
- Groundwater. Groundwater from the Middle Potomac aquifer could be a viable option that would require multiple well fields spread out over a large area east of the existing service area. The amount of groundwater available could be limited by the groundwater concerns in the Coastal Plain Aquifer (i.e., declining water levels, salt water intrusion, and subsidence and loss of storage). The area east of I-95 in Stafford County is located in Virginia's Groundwater Management Area (GWMA) that was established in 2014. The Eastern Virginia Groundwater Management Advisory Committee was established in 2015 and is developing, revising, and implementing a management strategy for groundwater in the Eastern Virginia Groundwater Management Area.
- Vulcan Quarry. This option considers construction of a pumping station at the quarry and a 12-inch or 16-inch bi-directional raw water main from the Vulcan Quarry along Garrisonville Road to Smith Lake WTP (3.5 miles). This configuration would allow the County to pump storage directly from the quarry to the WTP if Smith Lake Reservoir or raw water facilities were offline for maintenance or an emergency or if storage was needed during a drought. This storage would also likely not be subject to the release requirements downstream of Smith Lake if it was pumped directly to Smith Lake WTP. In addition, water could be pumped directly from Smith Lake through the proposed pipeline to the quarry when Smith Lake is full and spilling water downstream and the quarry needs to be refilled. There is a proffer for the Vulcan Quarry that requires the owner of the quarry to provide the quarry to the County in 2035. The owner and the County are currently discussing options to continue mining through 2055. Using the quarry as supplemental storage for Smith Lake could increase the safe yield by about 3.2 mgd assuming

2 BG of storage in the quarry. The cost is estimated at approximately $5 million for raw water pumping station and 16-inch raw water main from Vulcan Quarry to Smith Lake WTP. This option has the advantage of being close to the existing customer water demands and the Smith Lake Water Treatment Plant.

- Abel Lake. This option considers transferring raw water from Abel Lake through a 16-inch raw water main directly to the Lake Mooney WTP (approximately 6 miles). Water from Abel Lake could be used to supplement yields from Lake Mooney Reservoir during drought conditions or if the County has Lake Mooney raw water facilities offline for maintenance. Pumping water directly from Abel Lake to Lake Mooney WTP would likely mean that this storage would not be subject to the release requirements downstream of Lake Mooney and would not impact the ability to withdraw water from the Rappahannock River to refill Lake Mooney during drought conditions. The cost is approximately $5.8 million for Abel Lake Dam upgrades, which are currently in design, and $8.7 million for raw water pumping station and 16-inch raw water main from Abel Lake to Lake Mooney WTP.
- Water Recycling. As technologies continue to improve, the recycling of treated wastewater for use as a water supply source becomes more feasible. For example, discharges from the Aquia Wastewater Treatment Facility could be treated with advanced technology, such as membranes, and pumped to Smith Lake Reservoir (roughly 3 miles). Again, current Virginia Department of Health regulations would not allow this practice. This may change in the future due to advancements in treatment and additional research into the recycling of wastewater flows.

4. RESERVOIR WATER QUALITY

The County's water comes from Lake Mooney and Smith Lake Reservoirs. As water passes over land and through the ground toward the reservoirs, it may dissolve minerals and pick up substances resulting from the presence of animals or from human activity. By the time it gets to the reservoirs, it may contain microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, storm water runoff, industrial or domestic wastewater discharges, and other sources. To ensure that tap water is safe to drink, EPA prescribes regulations that limit the amount of certain contaminants in water provided to public water systems.

In 2002, the Virginia Department of Health (VDH) conducted an assessment of Smith Lake Reservoir to determine how susceptible it is to contamination. An assessment of Lake Mooney and the Rappahannock River has not yet been completed by VDH. Since there are industrial, commercial, agricultural and residential land uses in the watersheds for both reservoir and these reservoirs are open to the environment, they are considered to be susceptible to contamination.

Through a combination of source water protection and treatment technology, Stafford is committed to multiple-barrier practices of ensuring drinking water quality. Stafford's source water protection efforts include a variety of techniques and programs to keep pollutants out of the water supply reservoirs.

5. KEY FINDINGS

- The existing raw water reservoirs have enough storage capacity to provide a combined safe yield of approximately 17 mgd (11.9 mgd for Lake Mooney and 5.1 mgd for Smith Lake) based on the critical drought of record.
- The current raw water system's safe yield (17 mgd) will satisfy projected customer demands through approximately 2045.

- When the County's demands exceed the safe yield of 17 mgd, there are several water supply options that may be viable to meet the County's projected water demands through buildout. The most promising water supply options include the following:
  - Approximately $8.7 million for raw water pumping station and 16-inch raw water main from Abel Lake to Lake Mooney WTP.
  - Approximately $5 million for raw water pumping station and 16-inch raw water main from Vulcan Quarry to Smith Lake WTP.
- The cost for the raw water supply improvements presented in this Master Plan in the near-term (FY2019 - FY2028) is approximately **$12 million**. This cost includes the following:
  - $6 million for Abel Lake Dam upgrades.
  - $6 million for the regional interconnection between Stafford County and Spotsylvania County.
- The County is budgeting an additional **$9 million** to cover the cost for development of the Abel Lake option to meet long-term needs (beyond 2045).
- The overall cost for the raw water supply improvements presented in this Master Plan through the buildout condition is approximately **$21 million**. See Chapter 9 for details on costs estimating.

6. PLAN OF ACTION

- DPW will continue to investigate methods to reduce the per capita use of water.
- DPW will continue to investigate long-term water supply options.
- DPW will continue to monitor and safeguard water quality in the water supply reservoirs.
- DPW will continue the commitment to multiple-barrier practices for ensuring drinking water quality.

Chapter 5 WATER TREATMENT

Water from the County's reservoirs is treated at Lake Mooney and Smith Lake WTPs. As Stafford County's population and water demands continue to increase, water treatment plant expansions and upgrades will be required.

1. INTRODUCTION

One of DPW's primary goals is supplying high quality drinking water to its customers. The Safe Drinking Water Act (SDWA) is the federal law that protects public drinking water supplies throughout the nation. Originally passed by Congress in 1974, the law was amended in 1986 and 1996. Under SDWA, the US Environmental Protection Agency (USEPA) has enacted regulations and standards for drinking water quality by establishing maximum contaminant limits (MCLs) on parameters such as turbidity (physical), trihalomethanes (chemical) and coliform (bacteria). The SDWA also establishes secondary (aesthetic) standards related to the taste, odor and color of tap water.

DPW purifies raw water at the Lake Mooney and Smith Lake WTPs so that the finished water meets customer expectations and complies with the SDWA. The treatment processes remove impurities, such as algae and soil particles, that occur in streams and reservoirs, as well as potentially harmful organic matter, bacteria, viruses, and other microbes, through a combination of conventional and advanced physical and chemical treatment processes.

DPW is committed to consistently meeting the following level-of-service objectives for drinking water treatment over the 50-year planning horizon used for this Master Plan:

- Increase water treatment capacity as needed to meet anticipated growth in water demands.
- Produce high-quality drinking water, which complies with current and future SDWA regulations and meets customer expectations.
- Maintain a high level of reliability at the treatment plants.

2. EXISTING WATER TREATMENT FACILITIES

DPW operates two water treatment plants (WTPs). The Lake Mooney WTP was placed in operation in December 2014 and it treats raw water pumped from the recently constructed Lake Mooney Reservoir. Smith Lake WTP has been in operation since 1991 and it treats raw water from Smith Lake Reservoir. Both WTPs treat their source water with chemicals to remove color, iron, manganese, turbidity, organic materials and other impurities. Smith Lake WTP uses conventional dual media (sand and anthracite) filters, while the new Lake Mooney WTP uses membrane-based filtration technology. Fluoride is added to provide dental protection, and the water is disinfected to protect against waterborne disease. Both water treatment facilities use on-site laboratories as well as State and private laboratories to analyze the water, and both WTPs consistently produce water better than that required by the SDWA.

3. WATER TREATMENT CHALLENGES AND REQUIREMENTS

Over the next 50 years, Stafford is prepared to address the drinking water treatment challenges posed by each of the three level-of-service objectives noted above.

Increasing Water Treatment Capacity

Because of projected population growth and planned development in the service area over the next 40 years, more finished water treatment capacity will be needed. Unlike raw water supply facilities (e.g., reservoirs) that are sized to meet annual average day demands, water treatment plants must be capable of supplying the maximum day demands. Maximum day demands are projected to reach approximately 17.4 mgd in the near-term (through the year 2028) and grow to approximately 34 mgd at buildout.

The current combined production capacity of existing WTPs is adequate to satisfy near-term demands, but will require expansion to meet buildout conditions. This assessment is based on the following key factors:

- Net firm capacity of Smith Lake WTP is approximately 12.5 mgd.
- Net firm capacity of the existing Lake Mooney WTP is approximately 9.1 mgd in summertime, when the maximum day demand occurs. (Note: the membrane filters at Lake Mooney WTP have different capacities in summer and winter, based on water temperature).
- Total net firm treatment capacity is therefore approximately 21.6 mgd (9.1 mgd at Lake Mooney WTP + 12.5 mgd at Smith Lake WTP), providing a surplus of approximately 4.2 mgd compared with estimated "near-term" (2028) maximum day demands of 17.4 mgd.

When more treatment capacity is needed, DPW would add additional membrane cassettes at Lake Mooney WTP, to expand from 9.1 mgd to 12.5 mgd (net firm summertime capacity). This would be a relatively economical expansion, because the Lake Mooney WTP was designed to require only the addition of membrane cassettes for this next increment of capacity. With 12.5 mgd at both WTPs, the combined treatment capacity would be 25 MGD. Based on the County's growth projections, this WTP expansion would not be required in the near-term, unless the County decided to sell its otherwise surplus water to a neighboring utility(s).

To meet buildout demands estimated at 34 mgd, DPW would add the additional membrane cassettes at Lake Mooney WTP, and then implement the planned expansion at Lake Mooney WTP via duplication of the treatment trains, to achieve 25 mgd net firm summertime capacity. That would increase total net treatment capacity to 37.5 mgd (25 mgd at Lake Mooney WTP + 12.5 mgd at Smith Lake WTP), providing approximately 10% more capacity than projected maximum day water demands at buildout.

High Quality Drinking Water

In addition to requiring USEPA to establish MCLs for known contaminants, the SDWA also requires USEPA to evaluate the need for more stringent drinking water quality standards. As a result, there will almost certainly be an expansion to the list of regulated constituents, as well as lower MCLs for constituents that are already regulated, based on new information regarding health effects. DPW's challenge is to continue to comply with these new or more stringent water quality regulations. DPW routinely analyzes water for regulated constituents, and on a less frequent basis, for unregulated constituents that have been identified by USEPA. Few of the regulated or monitored substances were detected in Stafford County's treated water, and all those present were below state and federal regulatory limits. Stafford County is committed to monitor SDWA regulatory developments, and proactively assess how and when to adapt its water treatment processes in order to maintain compliance with pending and future regulations. In the near-term, DPW will focus on these currently identified water quality challenges:

- Disinfection by-products - Disinfection by- products are formed when chlorine, the primary disinfectant, is added to water containing naturally occurring organic materials that derive from plant decay. Trihalomethanes (THMs) and haloacetic acids (HAAs) are two groups of disinfection by-products that are regulated by the SDWA because of their suspected long term health effects. As documented in Stafford County's annual Water Quality Report, the County's tap water is safe to drink, and complies with the MCLs for disinfection by-products. However, in the quest for even better water quality, DPW is assessing means for lowering THM's so they are more comfortably below the MCL.

- Manganese – Manganese is a naturally occurring inorganic compound for which there is currently no primary (health-based) MCL, but for which there is a secondary (aesthetic) standard of 0.05 mg/l, based on its ability to discolor water and stain laundry and plumbing fixtures. Dissolved manganese is present in the raw water at both Smith Lake and Lake Mooney. Both WTPs have chemicals that oxidize manganese, so it can be removed by clarification and filtration. In the case of Smith Lake WTP, the occurrence of manganese is routine, and the plant is able to consistently remove it. At Lake Mooney, manganese levels were relatively high as the lake filled, and there were some episodes where manganese levels exceeded the secondary standard. As the lake matures, it appears that manganese is becoming more predictable, and the plant has consistently removed it. However, as a proactive measure, DPW is assessing means for even more reliably controlling manganese, in order to consistently meet customer expectations for excellent water quality.

- Algal toxins – Highlighted by the algal bloom in 2014 near Toledo, Ohio, algal toxins are considered an emerging contaminant. USEPA will require Stafford County to monitor for 10 algal toxins beginning in 2018 as part of its Unregulated Contaminants Monitoring Rule 4 (UCMR4). USEPA may issue enforceable MCLs for some of these algal toxins in the future. Lake Mooney has experienced algal blooms in its first few years of existence, but to-date, there is no evidence for the presence of microcystis, the type of algae that produce the algal toxin, microcystin. DPW has implemented operating procedures that have apparently controlled the proliferation of algae in Lake Mooney. However, as a proactive measure, and in anticipation for potential future SDWA requirements, DPW will expand its laboratory analyses to monitor for algal toxins, and will take appropriate measures based on the results.

Reliability

In addition to planning for additional treatment capacity and excellent water quality, DPW is also committed to meeting its customer's expectations for a high level of reliability. The challenges here involve:

- Keeping key assets, some of which are approaching their expected useful life, in good operating condition.
- Assuring there is adequate "stand-by" capacity and "factors of safety", to allow for planned and unexpected needs for maintenance and repairs, and the implementation of expansions in advance of when they are needed.

With respect to aging assets, the Smith Lake WTP is now approaching 30 years of reliable operation. Most mechanical and electrical components at water treatment plants have a useful life of 15 to 30 years. DPW has regularly maintained and as needed, replaced equipment that is no longer functional. DPW expects the need for reinvestment into critical equipment at Smith Lake WTP to increase in the future. For example, DPW anticipates the need to invest in filter repairs, replace filtered water pumps, and renovate or replace major electrical equipment in the near-term at Smith Lake WTP.

At the recently constructed Lake Mooney WTP, DPW would not expect near-term reinvestments into its relatively new mechanical or electrical systems. However, DPW recognizes that the membrane cassettes have an expected useful life of about 10 years, and therefore has programmed the replacement of membrane cassettes into its near-term operation and maintenance plans.

With respect to "stand-by" capacity and "factors of safety", DPW has revisited the treatment processes capacities to determine the "net firm capacities" for each WTP. This involved identifying those items, such as pumps, which require a spare unit, in case one pump is out of operation for servicing when a maximum day demand occurs. The "net firm capacities" also allow for about 5% of plant production to be used for filter backwashing and clarifier blowdowns. These "net firm capacities" provide a reliable basis for determining when the next increment of capacity is required.

DPW has also identified several operations at Lake Mooney WTP that rely on the availability of a single process unit. In each case, the plant design has space for a second process unit, which was planned to be constructed when the plant was "built-out" to 25 mgd. However, the significantly lower demand projections presented in this Master Plan could result in a deferral of the plant expansion for at least a decade and probably longer. DPW therefore plans to install the planned back-up units, including a second residuals thickener and second centrifuge, in the near-term, so that the existing single units can be taken offline for maintenance, thereby enhancing reliability during unexpected events or operational disruptions.

4. WATER TREATMENT PLANT CAPACITY IMPROVEMENTS

The existing capacity of Lake Mooney WTP and Smith Lake WTP (combined approximately 21.6 mgd) will meet projected consumer demand well into the planning period. Based on the County's growth projections, no expansion of WTP capacity would be required in the near-term (through 2028), unless the County decides to sell its otherwise "surplus" water to a neighboring utility(s). When more treatment capacity is needed, DPW would first add additional membrane cassettes at Lake Mooney WTP. This would be a relatively economical expansion, because the Lake Mooney WTP was designed to require only the addition of membrane cassettes for this next increment of capacity (adds about 3.4 mgd).

To meet maximum day buildout demand estimated at 34 mgd, DPW would add the additional membrane cassettes at Lake Mooney WTP, and then implement the planned expansion at Lake Mooney WTP via duplication of the treatment trains, to achieve 25 mgd net firm summertime capacity. That would increase total net treatment capacity to 37.5 mgd (25 mgd at Lake Mooney WTP + 12.5 mgd at Smith Lake WTP), providing approximately 10% more capacity than projected maximum day water demands at buildout.

5. KEY FINDINGS

DPW is committed to consistently meet the following finished water level-of-service requirements over the 40-year planning horizon used for this Master Plan. Key findings related to its three level-of-service requirements are:

- Increase water treatment capacity as needed to meet anticipated growth in water demands:
  - Currently, the combined treatment capacity of the Lake Mooney WTP and Smith Lake WTP is approximately 21.6 mgd. Based on the County's growth projections, no expansion of WTP capacity would be required in the near-term (through 2028).

- ➢ Based on projected growth and water demands, DPW will need to develop sufficient drinking water supply facilities to accommodate a maximum day water demand of approximately 34 mgd when the service area is reaches buildout. Implementation of the planned duplication of the Lake Mooney WTP treatment units will accommodate the projected buildout demand.

- Provide high-quality drinking water, which complies with current and future SDWA regulations and meets customer expectations:
  - ➢ Finished water quality meets current SDWA requirements.
  - ➢ To meet anticipated future SDWA regulations and customer expectations for excellent water quality, DPW will proactively evaluate potential improvements in the processes used to manage disinfection byproducts, manganese, and algal toxins.

- Maintain a high level of reliability at the treatment plants:
  - ➢ Smith Lake WTP is in good operating condition, but some mechanical and electrical assets are approaching their expected useful life. DPW is performing condition assessments, and will implement renovations and replacements as needed to maintain reliability at Smith Lake WTP.
  - ➢ At the recently constructed Lake Mooney WTP, DPW does not anticipate near-term investments into its relatively new mechanical or electrical systems. However, DPW recognizes that the membrane cassettes have an expected useful life of about 10 years, and therefore is programming the replacement of membrane cassettes into its near-term operation and maintenance plans. DPW also has identified a few operations at Lake Mooney WTP that rely on the availability of a single process unit. In each case, the plant design has space for a second process unit, which was planned to be constructed when the plant was "built-out" to 25 mgd. However, the significantly lower demand projections presented in this Master Plan could result in a deferral of the plant expansion for at least a decade. DPW therefore plans to install back-up units in the near-term to enhance reliability.

- The overall cost for the water treatment improvements presented in this Master Plan through the buildout condition is approximately **$84 million**. Approximately **$11 million** is proposed through the next ten-year planning period (FY2019 - FY2028). See Chapter 9 for details on costs estimating.

6. PLAN OF ACTION

- While no expansion of WTP capacity is required to meet projected water demands in the near-term (through 2028), DPW will continue to monitor finished water demands and periodically update water demand forecasts. Changes in projected water demands will affect the timing for water treatment plant expansions.

- DPW will stay informed about upcoming SDWA regulations and plan for future water quality improvements at water treatment facilities.

- To meet anticipated pending SDWA regulations and customer expectations for excellent water quality, DPW will proactively evaluate potential improvements in the processes used to manage disinfection byproducts, manganese, and algal toxins.

- DPW will design and construct improvements to address aging assets at Smith Lake WTP and to enhance reliability at Lake Mooney WTP. Technical Memorandum 5 summarizes the recommended upgrades for water treatment.

Chapter 6 WATER DISTRIBUTION

Drinking water from Lake Mooney and Smith Lake Water Treatment Plants (WTPs) is provided to Stafford's customers through a network of pipes. Storage tanks throughout the water distribution system provide equalization storage and reserve capacity for fires and emergencies. The water distribution system must respond to increasing water demands, maintaining targeted water pressure, and the challenges of aging infrastructure.

1. DELIVERING DRINKING WATER FROM THE WATER TREATMENT PLANTS TO THE CUSTOMERS

The Stafford County water distribution system includes two ground-level water storage tanks, six major water pumping stations, 12 elevated water storage tanks, and approximately 617 miles of pipes ranging in size from 4 to 30 inches in diameter. The most common pipe materials in the water distribution system are ductile iron pipe (DIP), cast iron pipe (CIP), asbestos-cement (A-C) pipe, or polyvinyl chloride (PVC) pipe.

The County's current and future water distribution system is divided into pressure zones essentially extending east and west from the Interstate 95 corridor:

- 310 Zone in the northeast portion of the County
- 433 Zone in the north-central portion of the County
- 450 Zone in the northwest portion of the County (to be merged with 472 Zone in future)
- 472 Zone in the northwest portion of the County
- 370 Zone in the central portion of the County
- 342 Zone in the southeast portion of the County (eliminate 320 Zone)
- 480 Zone in the south-central portion of the County
- 410 Zone in the southern portion of the County
- 520 Zone in the southwest portion of the County (future).

A map showing the future water system is included in the back pocket at the end of this Master Plan (Stafford County Water System Proposed Improvements).

2. LEVEL OF SERVICE REQUIREMENTS FOR WATER DISTRIBUTION

The performance of a finished water distribution system is judged by its ability to deliver the required flows while maintaining desirable pressure and water quality. Customer water demands and fire flow requirements must be met. Meeting these requirements depends upon the proper design and performance of distribution and transmission piping, elevated and ground storage tanks, and high service and booster pumping stations.

Planning and design guidelines vary from state to state and from utility to utility. While national organizations, such as the American Water Works Association (AWWA), provide some guidelines and many states regulate certain performance criteria, planning and design criteria are often left to the discretion of the water utility. The planning and design criteria used in the County's 2006 Water and Sewer System Master Plan project were used here. It is important to recognize that the planning and design criteria should be applied on a case-by-case basis and may change over time.

DPW's planning and design criteria for waterworks facilities are summarized below.

Pumping Stations

Water booster pumping stations shall be adequate to pump the maximum day water demand. While pumping stations are typically sized for maximum day demands, it may be desirable to size pumping facilities for peak hour demand (or a portion of peak hour demand) if the pumping station serves a pressure zone with a single storage tank that must be taken out-of-service for maintenance.

Pipelines

Pipelines are sized for the following:

- The largest of maximum hour flow, maximum day flow plus fire flow, or storage replenishment flow. Fire flow requirements are a primary factor affecting the sizing of piping in the water distribution system (6-inch and 8-inch mains).
- A targeted velocity of less than 5 ft/sec.
- A targeted headloss of less than 5 feet/1,000 feet of pipeline.

Maximum Pressure

Maximum pressure refers to the maximum pressure that the customer will experience. It is often in the range of 90-110 psi. The maximum pressure is based on common household appliance limitations (water heaters can withstand 120-130 psi). Maximum water pressures at the service connections were set at 120 psi for this Master Plan.

Minimum Pressure

Minimum pressure is the minimum pressure at a customer's tap. A common minimum pressure objective among utilities is 40 psi. If pressures are less than 40 psi, there could be a noticeable pressure decrease when more than one device (e.g., faucet, toilet, shower, etc.) is used. The Virginia Department of Health's Waterworks Regulations require that the water system shall provide a minimum pressure of 20 psi at the service connection based on the greater of maximum hour or maximum day plus fire flow demand condition.

Pressure Fluctuation

Pressure fluctuation is the difference between maximum hour and minimum hour conditions at any one location in the system. An acceptable pressure fluctuation is 20-30 psi. Customers come to rely on steady pressure; thus in the interest of providing good service, large pressure fluctuations should be avoided in design. The maximum pressure fluctuation criteria used for this Master Plan was 30 psi.

Pressure Zone Layout

Pressure zone layout refers to the design and layout of pressure zones across the system. Because pressure is related to ground elevation, a system covering hilly or mountainous terrain will have more pressure zones than one covering relatively flat terrain. The minimum pressure establishes the highest ground elevation that can be supplied, and the maximum pressure establishes the lowest ground elevation. Pressure zone boundaries can be moved to increase or decrease pressures and resolve pressure complaints from customers in the vicinity of the boundaries.

Pipeline Looping

Looping refers to providing supply to a specific location or an area through two or more pipelines. This practice provides a higher level of reliability (i.e., if one source is out-of-service to the area, supply can be provided from a second source).

Pipe Materials

Pipe materials generally accepted include ductile iron, steel, concrete, and polyvinyl chloride (plastic or PVC).

Water Storage

DPW's finished water storage facilities are located throughout the distribution system – providing flexibility to meet highly variable customer demands throughout each day. Storage facilities are sized to provide for:

- Equalization Storage – to meet fluctuating water demands that exceed the WTP pumping capacity.
- Fire Flow Storage – to meet the demands for fire fighting.
- Emergency Storage – to provide water reserves for contingencies such as system failures, power outages, main breaks, and other emergencies.

It is generally desirable to provide at least two storage tanks per pressure zone to maintain stable pressures even when a tank is taken out-of-service. However, a single tank is considered acceptable in zones where an adjacent, higher pressure zone can be used to stabilize pressures.

According to the Virginia Department of Health (VDH), water utilities must have storage equal to or greater than one-half of the average day demand.

Water Quality

The quality of the water in the distribution system can be affected by design and operation of the system, such as:

- Oversized pipelines and storage facilities, which increase the "water age" (i.e., the time it takes for water to travel from the WTP to the customer). Excessive water age can degrade the quality of finished water.
- Operating practices for storage facilities that result in long detention times for the water stored, thereby increasing "water age".
- Corrosion of pipeline materials or increased growth potential of microorganisms.
- Backflow and cross-connection prevention.

There is a need to balance storage requirements with water quality. A utility cannot discount the need for adequate storage for fire flow and flow equalization. However, excess storage in storage tanks increases water residence time in the system, which can cause low disinfectant residuals, higher disinfection byproducts, and bacterial regrowth. Water quality in the distribution system can be improved by:

- Optimizing the operation of existing storage facilities by matching tank levels and turnover rate to water demands.
- Optimizing the operation of the distribution system and pressure zones.
- Providing an effective backflow prevention program.

Monitoring of some water quality issues in the distribution system is regulated (e.g., lead, copper, etc.) while others are identified by customer complaints (e.g., taste, odor, etc.). DPW has placed increased emphasis on understanding its water system, including data collection for the GIS and hydraulic computer models. In addition, the County plans to install active tank mixers to maintain and improve water quality in the water storage tanks in the distribution system.

Regulatory Requirements

Water distribution systems are regulated under Safe Drinking Water Act rules, as described below.

- Lead and Copper Rule – The Lead and Copper Rule sets action levels for lead and copper. DPW monitors sites throughout its distribution system for lead and copper; the results confirm that

Stafford County is well under the action levels for lead and copper.

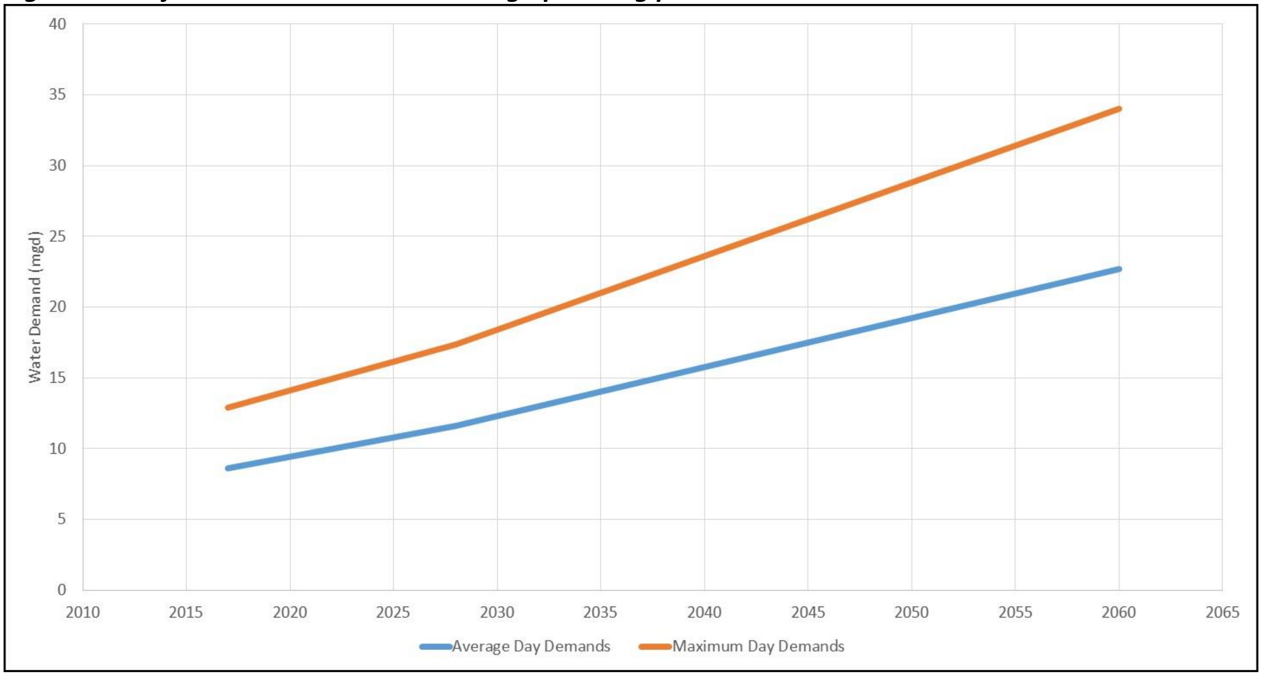
- Total Coliform Rule – The Total Coliform Rule sets the Maximum Contaminant Level goal of zero for total coliforms. Water systems must monitor for the presence of total coliforms and for chlorine to ensure that adequate chlorine residuals are maintained throughout the distribution system. The results confirm that Stafford County is in compliance with the Total Coliform Rule.
- Backflow Prevention/Cross-Connection Control Program – The Safe Drinking Water Act Amendments of 1986 and the Uniform Building Code require that DPW protect its potable water supply from contamination by unapproved sources or any other substances by cross-connecting or back-siphoning. DPW administers a cross-connection program to eliminate existing cross-connections. Approved backflow-prevention devices are installed and maintained at any water service connections with a potential hazard.

3. ALLOCATION OF PROJECTED WATER DEMANDS

As part of the Master Plan, OBG updated the County's water system hydraulic model, which is used to simulate a range of demand events and predict the resulting flows and pressures. A critical part of the modeling effort is allocating the current and future water demands throughout the County, based on the estimated usage. Nodes represent points in the water system hydraulic model where water demands are taken from the system. DPW provided the water demands based on customer billing data. The demands were applied to the nearest water node which results in an accurate allocation of water demands.

Future water demands were projected using land use, customer class consumption values, and consumption ratios (diurnal demand curves) to determine the maximum day and peak hour demand conditions. The average and maximum day demands through the planning period are shown in Figure 3.

Figure 3. Projected water demands through planning period



4. EXISTING WATER SYSTEM LIMITATIONS AND PROPOSED IMPROVEMENTS

The condition and performance of the components of DPW's water distribution system are influenced by hydraulic capacity, age, material and service conditions (i.e., line pressures, soils, and installation). DPW reviews the characteristics of the water system piping and facilities during day-to-day operations and maintenance activities as well as specific condition and modeling studies. Although this Master Plan does not directly evaluate system integrity (i.e., condition assessments), hydraulic modeling was performed using InfoWater™ to assess the capabilities of the existing and future water system under near-term (2028) and buildout (2060) demand conditions. The near-term and buildout maximum day demands used for hydraulic modeling were 17.4 mgd and 34.1 mgd, respectively.

The proposed water system improvements are shown on the figure in the pocket at the end of this Master Plan (*Stafford County Water System Proposed Improvements*) and the timing for implementation of the improvements is included in the pocket at the end of this Master Plan (*Stafford County General Water Improvement Program*)). In addition, a detailed description of each project is presented in Technical Memorandum 6 (*Finished Water Pumping, Storage and Distribution Facilities*).

Hydraulic Modeling

A functional, calibrated model was used to assess the performance of DPW's water distribution and transmission system. The hydraulic model can be used to better understand and assess the capabilities of DPW's system by simulating and identifying hydraulic limitations – low pressures and fire flow limitations – within the system under specified demand conditions. The model was initially calibrated using conditions that occurred during field testing in April 2003. Calibration of the water system model over a range of demand conditions has been occurring on a day-to-day basis since that time. By using a variety of demand conditions, the response of the system under critical demand conditions can be tested and the level of confidence in the model results can be assessed.

The hydraulic model has been a very valuable tool for DPW, and it is worthwhile for the model to be maintained so that it is ready for use when needed to assess changes to the water system. Model maintenance requires updating the input files as the distribution and transmission system expands and changes. This also includes collecting additional data on demand conditions with varying characteristics. When used in conjunction with the other tools, such as GIS and SCADA, the model is integral to the successful management and operation of DPW's water distribution and transmission system.

5. KEY FINDINGS

♦ Planning and design criteria used in this Master Plan are consistent with the criteria adopted by national organizations, local utilities, and state regulatory agencies. In addition, planning and design criteria should be applied on a case-by-case basis and may change over time.

♦ Hydraulic modeling was performed using InfoWater™ to assess the capabilities of the existing and future water system under near-term (2028) and buildout (2060) demand conditions. The near-term and buildout maximum day demands used for hydraulic modeling were 17.4 mgd and 34.1 mgd, respectively.

♦ The overall cost for the water treatment improvements presented in this Master Plan through the buildout condition is approximately **$57 million**. Approximately **$26 million** is proposed through the next ten-year planning period (FY2019 - FY2028). See Chapter 9 for details on costs estimating.

6. PLAN OF ACTION

- DPW will continue to assess water distribution system conditions by conducting field investigations and periodically reviewing physical attributes (pipe diameter and material), incidence of water quality complaints, results of hydraulic modeling (high pressure and high headloss), and locations of water main breaks and other maintenance history (work orders).

- DPW will continue to review water system planning and design criteria and make changes to the proposed improvement projects, as needed.

- DPW will continue to collect data for various design demand conditions and refine the hydraulic model of the water system.

- DPW will collect site-specific cost information on proposed projects, if available, and refine the budget-level costs presented in this Master Plan.

- DPW will routinely review the timing of water projects proposed in this Master Plan and coordinate these water projects with sewer projects, roadway projects and other related activities.

Chapter 7 WASTEWATER COLLECTION

Wastewater from the County's customers is conveyed through a network of pipes and pumping stations to the Aquia and Little Falls Run Wastewater Treatment Facilities (WWTF) for treatment and discharge. Focus by DPW and regulatory agencies on wastewater collection systems has been increasing, and regulations to protect public health and water quality will include stricter standards that prevent sanitary sewer spills and overflows. DPW will continue to upgrade, replace, and rehabilitate wastewater collection system components to improve performance, reduce WWTF impacts, and prepare for regulatory changes.

1. COLLECTION AND TRANSPORT OF WASTEWATER TO TREATMENT FACILITIES

Stafford's wastewater collection and conveyance system is served by two wastewater treatment facilities (WWTFs):

- Aquia WWTF – Located in the northern portion of the service area along Austin Run and adjacent to Jefferson Davis Highway.
- Little Falls Run WWTF – Located in the southeastern portion of the County along Kings Highway and near the confluence of Little Falls Run and the Rappahannock River.

DPW's wastewater collection system consists of approximately 453 miles of pipe, 57 miles of sewer force mains, 12,250 manholes, and 93 pumping stations. Pipe sizes in the collection system range from 4 to 60 inches in diameter. The most common pipe materials in the collection and conveyance system are reinforced concrete pipe (RCP), cast iron pipe (CIP), ductile iron pipe (DIP), polyvinyl chloride (PVC), and asbestos cement pipe (ACP). Prior to 1978, ACP was primarily used. In more recent construction, PVC pipe has been used extensively. The first conventional wastewater collection facilities in Stafford County were constructed in the 1930's.

A map showing the current and future sewer system is presented in the back pocket at the end of this Master Plan (*Stafford County Wastewater Improvements*).

2. LEVEL OF SERVICE REQUIREMENTS FOR SANITARY SEWER SYSTEM

In general, the regulatory requirements for collection systems have been more vigorously enforced in recent years, specifically in regard to sanitary sewer overflows. A sanitary sewer overflow (SSO) is the discharge of raw sewage from a municipal sanitary sewer system into basements, or out of manholes and pumping stations and onto streets, playgrounds, and streams without any form of treatment. The USEPA and the Virginia Department of Environmental Quality (VDEQ) believe that inadequate management, operation and maintenance for sewage collection and conveyance systems pose a significant threat to receiving water quality and public health through the discharge of SSOs. However, the USEPA and VDEQ recognize that SSOs cannot be completely eliminated, and that sanitary sewer systems that are designed to not overflow when a given design storm occurs, may nonetheless experience wet weather induced overflows as the result of conditions other than the design storm.

Planning and Design Criteria

A sanitary sewer collection system has basically two main functions: (1) to convey the design peak discharge, and (2) to transport solids so that deposits are kept to a minimum. It is imperative, therefore, that the sanitary sewer has adequate capacity for the peak flow and that it functions at minimum flows without excessive maintenance and generation of odors.

The planning and design criteria used in the 2006 Water and Sewer System Master Plan are used in this Master Plan to evaluate the sewer system and to plan future improvements, upgrades, and expansions of facilities. The planning and design criteria were reviewed with DPW to identify any modifications needed to reflect recent or anticipated future changes and to document policy decisions regarding application of the criteria. Understanding the potential impacts that revising the planning and design criteria may have on the existing and proposed capital improvements is essential.

The sewer planning and design criteria used in this Master Plan include the following:

"n" value = 0.013 for all pipe materials
Minimum Velocity = 2.25 ft/sec
Maximum Velocity = 15 ft/sec
Minimum Depth of Cover = 3 feet
Maximum Depth of Cover = 20 feet

For this study, “threshold” values were established to identify the point at which capacity enhancement measures for pipelines within the sanitary sewer system should be undertaken. There are no established requirements or guidelines for partial-to-full flow (q/Q) ratios. Selection of the q/Q ratios and the associated range of pipeline sizes are based on best professional judgement taking into consideration the following:

- Potential delays associated with implementation of future improvements (e.g., planning, siting, design, and construction).
- Risk of sanitary sewer system overflows.
- Excess capacity in sanitary sewer pipelines resulting in higher maintenance and possible odors.
- Rate of development (i.e., timing for additional future improvements).
- Potential for additional future development.

Based on these considerations, the values shown in Table 3 were used in this study.

Table 3 – Threshold Values for Gravity Sewers

Pipeline Diameter	q/Q Ratio
8-inch through 12-inch	0.50
15-inch and up	0.85

The q/Q ratio of 0.85 (d/D ratio of 0.75) for the large diameter pipelines reflects the desire to maximize flow in the existing interceptor sewers while maintaining some reserve capacity. The q/Q ratio of 0.50 for smaller diameter pipelines reflects the uncertainty in the spatial distribution of sewer loads served by the smaller piping in the sewer system. By applying relatively conservative q/Q ratios for the analysis curve, pipelines will be identified prior to reaching full capacity and thus reduce the likelihood of surcharge and/or overflow conditions. It should be noted that existing pipelines that exceeded the design criteria and were less than full through buildout conditions (q/Q less than 1.0) were not recommended for replacement. Rather, these pipelines were flagged for future investigation and possible flow monitoring during the planning period.

3. REVIEW OF PROJECTED SEWER FLOWS

Methodology for Projecting Sewer Flows

Wet weather flows are used to assess the hydraulic capacity of sewer systems and are composed of three components:

- Sanitary base flow generated by homes, businesses, etc.
- Infiltration due to normal groundwater levels (dry weather infiltration).
- I/I due to rainfall and high groundwater levels (rainfall-dependent I/I).

The formula for calculating the sewer loads for wet weather conditions is as follows:

Peak Wet Weather Flow (PWWF) = Average Dry Weather Flow (ADWF) + Rainfall-Dependent I/I (RDI/I)

Where:

Peak Wet Weather Flow (PWWF) equals the peak hourly flow during wet weather conditions.

Average Dry Weather Flow (ADWF) is the average flow that occurs in sanitary sewers on a daily basis with no evident reaction to rainfall. The ADWF is composed of sanitary base flow and groundwater infiltration. For Stafford, the sanitary base flows through the planning period are roughly equal to 65% to 80% of the average day water demand which approximates the customers' water demand that is returned to the sanitary sewer. Groundwater infiltration (GWI) is an allowance that is added to the sanitary base flow (derived from sewage flow factors) to obtain the dry weather flow. GWI represents flow that is separate and distinguished from inflow resulting from storm events during wet weather conditions. The allowance used in this Master Plan for GWI is estimated to be 500 gpd/inch diameter-mile (gpdidm).

Rainfall-Dependent I/I consists of rainfall that enters the collection system through direct connections (roof leaders, manholes, etc.) and causes an almost immediate increase in wastewater flows. RDI/I data was used to establish an overall sewer system peaking factor of 3.5 in the 2006 Master Plan. The 3.5 peaking factor for the overall sewer system was also used in this Master Plan to reflect RDI/I.

To define the design flow conditions for the sewer system, the equation presented above was modified as follows:

Peak Wet Weather Flow (PWWF) = (Sanitary Base Flow x Peak Factor) + Groundwater Infiltration

In the sewer model, a global peak factor is multiplied by the sanitary base flow at each manhole in the sewer system and the GWI component (500 gpdidm) is subsequently added to the computed manhole flow as the flow is routed through the downstream sewer piping.

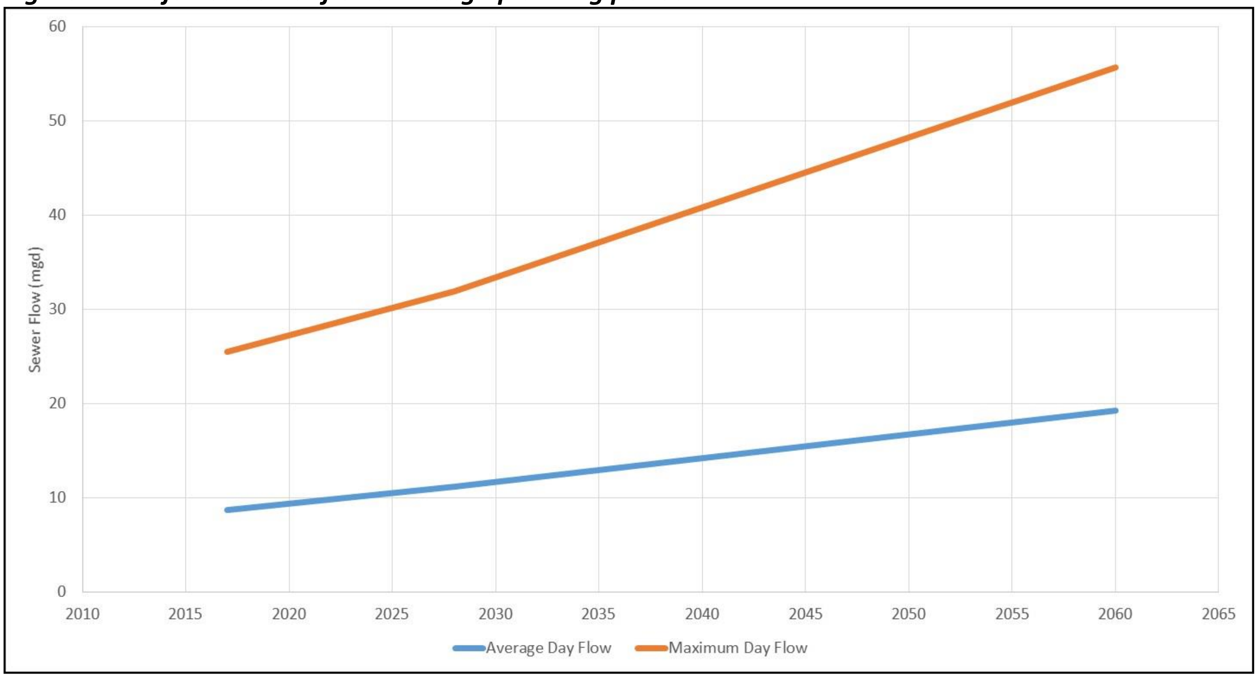
Sanitary Base Flows for Near-term Conditions

Near-term flows were developed using estimated sewer flows from existing and proposed near-term development. Average sewer flows were applied to the nearest manholes.

Sanitary Base Flows for Buildout Conditions
Buildout flows were developed using estimated sewer flows from existing and proposed near-term development as well as future land use. Average sewer flows were applied to the nearest manholes.

Determination of Total Peak Design Flow
Design flow for a sewer is defined as the maximum flow rate that occurs under selected weather and growth conditions. Average daily sewer flows are expected to increase from approximately 8.7 mgd (2017) to roughly 19.2 mgd under buildout (2060) conditions. During the same period, the maximum day flows are expected to increase from approximately 25.5 mgd (2017) to 55.7 mgd at buildout (2060) based on a peaking factor of 3.5 times the average base sanitary flow. The sewer flow projections are shown in Figure 4.

Figure 4. Projected sewer flows through planning period



4. EXISTING WASTEWATER SYSTEM LIMITATIONS AND PROPOSED IMPROVEMENTS

Hydraulic modeling was performed using InfoSewer™ to assess the capabilities of the existing and future sewer system under near-term (2028) and buildout (2060) flow conditions. The near-term and buildout peak flows used for hydraulic modeling were approximately 25.5 mgd and 55.7 mgd, respectively.

The sewer system improvements presented in this Master Plan are shown on the figure in the pocket at the end of this Master Plan (*Stafford County Wastewater Improvements*) and the timing for implementation of the improvements is included in the pocket at the end of this Master Plan (*Stafford County General Sewer Improvement Program*). In addition, a detailed description of each project is presented in Technical Memorandum 7 (*Wastewater Collection, Pumping and Conveyance Facilities*).

Hydraulic Modeling

A functional, calibrated model was used to assess the performance of DPW's sewer system. The hydraulic model is a valuable tool for DPW and will continue to demonstrate benefits provided that the input files are maintained and updated as the collection and conveyance system expands and changes. This includes collecting additional data on the system's response to storm events with varying intensity and duration (i.e., data collection and investigations under DPW's I/I program).

5. KEY FINDINGS

- Planning and design criteria used in this Master Plan are consistent with the criteria adopted by national organizations, local utilities, and state regulatory agencies. In addition, planning and design criteria should be applied on a case-by-case basis and may change over time.

- Regulations governing wastewater collection systems will continue to be rigorously enforced.

- Hydraulic modeling was performed using InfoSewer™ to assess the capabilities of the existing and future sewer system under near-term (2028) and buildout (2060) flow conditions. The near-term and buildout maximum day flows used for hydraulic modeling were 25.5 mgd and 55.7 mgd, respectively.

- The overall cost for the water treatment improvements presented in this Master Plan through the buildout condition is approximately **$86 million**. Approximately **$48 million** is proposed through the next ten-year planning period (FY2019 - FY2028). See Chapter 9 for details on costs estimating.

6. PLAN OF ACTION

- DPW will continue to maintain the GIS database on the wastewater collection system and sewer hydraulic model with complete and up-to-date information.

- DPW will continue to assess sewer system conditions by conducting field investigations and periodically reviewing physical attributes (pipe diameter and material), results of hydraulic modeling, and locations of sewer main breaks and other maintenance history (work orders).

- DPW will continue to review sewer system planning and design criteria and make changes to the proposed improvement projects, as needed.

- DPW will continue to collect data for various design storm events and proactively investigate I/I problems.

- DPW will collect site-specific cost information on proposed projects, if available, and refine the budget-level costs presented in this Master Plan.

- DPW will routinely review the timing of sewer projects proposed in this Master Plan and coordinate these sewer projects with water projects, roadway projects and other related activities.

Chapter 8 WASTEWATER TREATMENT

As Stafford County's population grows, the influent flows to the County's wastewater treatment facilities also increase. The increased flows to the facilities, as well as more stringent effluent regulations, require the County's treatment facilities to make plans for expansions and upgrades.

1. STAFFORD COUNTY WASTEWATER TREATMENT APPROACH

Stafford County Wastewater Treatment Facilities Overview

Stafford County currently operates two wastewater treatment facilities (WWTFs):

- Aquia WWTF which treats flows from northern Stafford County.
- Little Falls Run (LFR) WWTF which treats flows from southern Stafford County.

The Aquia WWTF provides service to a predominantly residential area, as well as a small commercial district. The collection system also receives flow from the Quantico Marine Corps Base, part of which is located in the northern part of Stafford County. Treated effluent from Aquia WWTF is discharged to Austin Run approximately 1 mile upstream of its confluence with Aquia Creek (tidal), a tributary to the Potomac River Basin and Chesapeake Bay. The Aquia WWTF was built in 1980 at a capacity of 3 mgd average daily flow. Since then, the plant has undergone several upgrades and expansion of the liquid process trains (Table 4). The capacity of all major processes are listed in Table 4 and detailed in Technical Memorandum 8. The current permit allows for 8 mgd on the basis of wasteload, and 10 mgd on the basis of average day flow.

Table 4 – Aquia WWTF Major Plant Upgrades and Expansions

Date	Aquia WWTF Major Upgrade/Expansion
1980	Original plant construction at 3 mgd capacity
1990	Expansion to 4.2 mgd, including nutrient removal processes
1994	Expansion increased permitted capacity to 6.5 mgd
2003	Plant was upgraded by adding redundancy to existing systems
2011	Plant was upgraded to meet Enhanced Nutrient Removal (ENR) requirements and redundancy was added to existing systems; treatment capacity increased to 8 mgd

The Little Falls Run WWTF is located in the southern part of the County with a tributary service area that is predominantly residential, commercial and light industrial. Treated effluent is discharged directly to the tidal Rappahannock River, which is tributary to the Chesapeake Bay. Little Falls Run WWTF was built in 1991 to replace the Claiborne Run Treatment Plant. The plant has also undergone several upgrades, which are listed in Table 5. The current permit allows for 8 mgd on the basis of wasteload, and 8 mgd on the basis of flow. The capacity of all major processes are listed in Table 5 and detailed in Technical Memorandum 8.

Table 5 – Little Falls Run WWTF Major Plant Upgrades and Expansions

Date	Little Falls Run WWTF Major Upgrade/Expansion
1991	Original plant construction at 4 mgd
1996	Biosolids handling upgrade
2005	Filtration and disinfection upgrade
2010	Plant was upgraded to meet Enhanced Nutrient Removal (ENR) requirements; rerated to 8 mgd

Stafford County also has a VPDES permit to construct a third wastewater treatment facility in the Widewater section of the County, located east of the Aquia WWTF. The prospective facility would have an initial capacity of 0.5 mgd and an ultimate capacity of 2.2 mgd, but there is no current Chesapeake Bay wasteload allocation (WLA) assigned to this facility. As a result, the County would need to transfer some wasteload allocation or purchase nutrient credits, along with providing ENR level treatment. Construction of this facility is on hold pending a review of the County's Land Use Plan.

Septic systems are used in those areas within Stafford County that are not served by one of the two treatment plants.

Treatment Processes

The Aquia and LFR WWTF's employ similar processes for treating wastewater with some key differences in capacity and treatment capabilities.

As noted above, the Aquia WWTF is currently permitted to treat 8 mgd based on wasteload and 10.0 mgd, on the basis of average day flow. Its VPDES permit, as issued by VDEQ, has an effective date of 11/20/2013 with an expiration date of 11/19/2018. As part of that permit the plant's discharge of the nutrient Nitrogen is limited to 73,093 lbs/year, while the discharge of Phosphorus is limited to 4,386 lbs/year by the permit's wasteload allocation (WLA). Under those WLAs, the plant is certified to meet some key effluent limitations including an annual average TN limit of 3.0 mg/L and an annual average TP limit of 0.18 mg/L. The full permit and associated fact sheet can be found in Technical Memorandum 8 of this report. As part of its last major upgrade, the Aquia WWTF was outfitted with a third main biological train as well as upgrades to other parts of the plant. This upgrade brought the peak capacity of specific parts of the plant to 36 mgd. A breakdown of the main treatment processes for the plant as well as the current available capacity for each of these processes is shown in Table 6 below. Please see Technical Memorandum 8 for other details related to the design capacities at Aquia WWTF.

Table 6 – Aquia WWTF Permitted Flow and Main Treatment Process Capacities

Unit Process	Current Capacity (mgd)
Permitted Flow	10.0
WLA Flow-Basis	8.0
Influent Screens	36.0
Grit/grease Removal	36.0
Biological Treatment	36.0
Tertiary Filtration	30.0
UV Disinfection	36.0
Aerobic Digestion	6.5
Dewatering	12.0

Aquia WWTF's current permit allows for 8 mgd on the basis of wasteload, and 10 mgd on the basis of flow. Improvements to the aerobic digestion/solids processing train, which has a current capacity of 6.5 mgd, will be required to operate at 8 mgd.

The Little Falls Run WWTF is currently permitted to treat an average daily flow of 8.0 mgd. Its VPDES permit, as issued by VDEQ, has an effective date of 10/1/2015 with an expiration date of 9/30/2020. A potential future flow tier of 13.0 mgd is identified. The plant is currently operating under Phase II of the VPDES permit, with respect to flow tier and effluent limits. As part of that permit the plant's discharge of the nutrient Nitrogen is limited to 97,458 lbs/year, while the discharge of Phosphorus is limited to 7,309 lbs/year by the permit's wasteload allocation (WLA). Under those WLAs, the plant is certified to meet some key effluent limitations including an annual average TN of 4.0 mg/L and an annual average TP of 0.30 mg/L. The full permit and associated fact sheet can be found in Technical Memorandum 8 of this report. A breakdown of the main treatment processes for the plant as well as the current available capacity for each of these processes is shown in Table 7 below. Please see Technical Memorandum 8 for other details related to the design capacities at Little Falls Run WWTF.

Table 7 – Little Falls Run WWTF Permitted Flow and Main Treatment Process Capacities

Unit Process	Current Capacity (mgd)
Permitted Flow	8.0
WLA Flow-Basis	8.0
Influent Screens	36.0
Grit/grease Removal	24.0
Biological Treatment	24.0
Tertiary Filtration	24.0
UV Disinfection	24.0
Aerobic Digestion	8.0
Dewatering	11.0

Little Falls Run WWTF's effective capacity and permitted capacity is 8.0 mgd.

As part of this Master Plan, a Basis of Design (BOD) table was prepared for each WWTF. The BOD table contains information such as existing capacity, design parameters, peak capacity, and manufacturer information. The BOD table for both plants as well as process flow diagrams and site plans are provided in Technical Memorandum 8. Current and anticipated regulatory impacts on the WWTFs are described below in *Regulatory Requirements* and *New Regulatory Requirements* sections, respectively.

Historical Performance

An integral part of determining the need for any future improvements is an analysis of historical performance data. As part of the Master Plan effort, County staff and OBG compiled and reviewed operating data from both WWTFs and compared historical performance to permit limits and plant design capacities. Technical Memorandum 8 includes an extensive description of the historical performance review. A simplified summary of that review is that:

- Both WWTFs are currently in compliance with their VPDES permit conditions.
  - While the plants are performing better than the permits require, it is expected that as flows increase closer to the plants' nominal capacities, they will be challenged to meet the effluent requirements.
- In the near-term (through year 2028), the permitted capacities at both WWTFs are adequate for projected growth
- More stringent effluent limits, including seasonal limits that could result from the Fresh Water Nutrient Criteria/Ammonia Rule may require process upgrades at one or both plants, and that need may occur prior to the plants reaching their rated capacities.

- There may be near-term opportunities to optimize treatment performance via increasing use of chemicals and power and modest revisions to the process facilities in order to defer major capital investments.

See Technical Memorandum 8 for a more extensive discussion of plant performance.

Process and Hydraulic Peaking Factors

WWTFs are typically sized to achieve the maximum month and peak day influent conditions to ensure unit processes and interunit piping are adequately sized to meet the maximum plausible influent conditions. A peak flow analysis to estimate maximum month and peak day flows was performed using a combination of existing data and future County projections. An analysis of the projected peaking factors for both plants is presented later in this chapter.

Effects of Infiltration and Inflow Reduction

Inflow is defined as flow entering the collection system during wet weather events or through unpermitted connections such as catch basins, downspouts, area drains, and manhole covers. Infiltration is defined as water that infiltrates pipelines and manhole defects located below the ground surface. Typical allowances for inflow and infiltration (I&I) are considered in the sizing of wastewater collection and treatment systems. However, excessive amounts of I&I contribute to higher than normal flow peaks. Excessive peak day flows could cause performance problems at a WWTF, via a "washout" of biological processes or could inhibit biological activity due to significantly lower temperatures.

In recent years, the County has been making progress with controlling I&I within the County's sewer system. It is expected that this progress will continue, resulting in lower "peaking factors" (ratio of peak to average flows), thereby avoiding excessive peak day flows and their consequences.

Regulatory Requirements

The Virginia Department of Environmental Quality (VDEQ) is responsible for issuing the Virginia Pollutant Discharge Elimination System (VPDES) permits, as they apply to Stafford County's wastewater treatment facilities. These permits set effluent water quality requirements based on average monthly and average weekly concentrations and loads of specific constituents. Please see Technical Memorandum 8 for copies of the VPDES Permits for Aquia WWTF and Little Falls Run WWTF, and for additional details on permitting issues.

Aquia WWTF's current permitted effluent requirements apply through November 19, 2018. Little Falls Run WWTF's current permitted effluent requirements apply through September 30, 2020. Before the permits expire, VDEQ will issue new permits for each facility. Due to the nature and duration of the permitting process, DPW will need to begin the reapplication process for Aquia WWTF in the near future, so that the reapplication can be submitted well in advance of the expiration date.

The expected promulgation of the Fresh Water Nutrient Criteria (FWNC) / Ammonia Rule in Spring 2018 by VDEQ and VA's State Water Control Board (SWCB) introduces uncertainty regarding the need for upgrades at the WWTFs. Improvements may be needed to meet more stringent limitation of discharges at both WWTFs, and to increase permitted discharge at Little Falls Run beyond 8 mgd. If DEQ policies and procedures for zero-flow "unnamed tributaries" such as Austin Run do not provide relief from the new Ammonia rule, Aquia WWTF effluent discharge may need to be moved downstream (if improved mixing conditions are achievable) to meet what could otherwise be a very low seasonal ammonia limit starting with its November, 2018 renewal.

Additional, more stringent effluent limits may also be required at those WWTFs that participated in VDEQ Water Quality Improvement Fund (WQIF) Grant Agreements. Such facilities may be required to optimize plant performance to achieve lower TN and TP concentrations than assigned in their WLAs. However, neither plant was entered into any additional grant agreement that would impose these additional performance constraints, beyond Phase II requirements, as defined in the Little Falls Run WWTF VPDES.

With respect to biosolids management, Stafford County currently landfills the sludge collected and produced at Aquia WWTF and contract land applies (currently, Recyc) at LFR WWTF. The landfill daily sludge acceptance rate is greater than Aquia's production level but below a combined Aquia and LFR amount. It is expected that this approach will continue for the foreseeable future.

2. STAFFORD COUNTY WASTEATER TREATMENT SYSTEM CHALLENGES AND REQUIREMENTS

New Regulatory Requirements

The Chesapeake Bay Program (CBP) established its Total Mass Daily Loadings action plan (TMDL) in December 2010. Phase 1 of the TMDL action plan (2011-2017), has operated under Virginia's Phase II Watershed Implementation Plan (WIP) as approved by USEPA Region 3. CBP TMDL Phase 2 is scheduled for 2018-2025, with 2024 established as the year to assess if further improvements or phases are required to achieve TMDL compliance. The Virginia Phase III WIP is being drafted by VDEQ, and scheduled to be reviewed and approved by USEPA Region 3 in 2018 or early 2019. The Phase III WIP developments will need to be monitored to see if any changes relative to WWTF discharge requirements or assigned WLAs are proposed. Beyond CBP TMDL requirements, local water quality concerns or documented impairments could result in needing to upgrade WWTF treatment in some fashion, although DPW is unaware of any such concerns.

USEPA published revised Fresh Water Nutrient Criteria (FWNC) in November 2013 (prior federal criteria were issued in 1999). The FWNC related rules are based on freshwater mussels' presence and their susceptibility to ammonia toxicity. The mussels are reportedly present in 80-90% of all freshwater U.S. waterways and freshwater-dominated estuary reaches. As described above under *Regulatory Requirements*, the expected promulgation of the FWNC / Ammonia Rule in Spring 2018 by VDEQ and the State Water Control Board (SWCB) could require upgrades at the County's WWTFs, which would entail substantial capital investments and increase O&M costs. Based on OBG's technical review and work around the same Rappahannock River segment as the Little Falls Run WWTF discharge, the new rule could result in 60% lower (approximate, preliminary) ammonia limits, as discussed in more detail in Technical Memorandum 8.

In brief, improvements may be needed in the near-term to meet more stringent limitation of discharges at both WWTFs, and in the long-term, to increase permitted flows at the WWTFs beyond 8 mgd. Further, if VDEQ policies and procedures for zero-flow "unnamed tributaries" such as Austin Run do not provide relief from the new Ammonia Rule, Aquia WWTF effluent discharge may need to be moved downstream (if improved mixing conditions are achievable) to meet what could otherwise be a very low seasonal ammonia limit starting with its November, 2018 renewal.

Typically, a 4-year (48-month) compliance schedule (for planning, engineering, design, bidding, construction, startup / online) is included in a VPDES Permit renewal if physical upgrades are needed to meet a substantive lower effluent limitation. This typical timeframe allows a 5th year of a 5-year VPDES Permit cycle for monitoring of performance as a result of the upgrade before the next renewal cycle comes due. Administrative extension of the existing Permit is an option that may be available to DEQ.

Regarding Aquia WWTF, there are no known plans by VDEQ or USEPA to tighten nutrient concentration goals for significant dischargers in the Potomac Basin. However, with WLAs based on 8 mgd ADF, it may become more difficult for Aquia WWTF to comply with its annual nutrient load caps as flows or equivalent loadings increase towards 8 mgd. Beyond 8 mgd, performance would need to be even better than its current basis-of-design. The Aquia WWTF will also be subject to the Potomac River TMDL for polychlorinated biphenyls (PCBs), and as such, must monitor influent and effluent PCB concentrations, and the County must enforce its prohibition of PCB discharge to its sewer system. There is no specific treatment process at Aquia WWTF, or publicly-owned treatment works in general, for PCB removal. It is therefore not anticipated that this new TMDL would result in changes at the WWTF; rather any PCBs issues would best be handled through enforcement of the County's sewer use ordinance.

Similarly, regarding Little Falls Run WWTF, there are no stated plans by VDEQ or USEPA to tighten nutrient concentration goals for significant dischargers in the Rappahannock Basin. However, there have been recent (2013-2017), periodic reports by third parties or Virginia state agencies of potential dissolved oxygen impairment in segments of the Rappahannock River that are downstream of the Little Falls Run WWTF discharge point. Based on knowledge gained on other OBG projects in the Rappahannock Basin, it appears that VDEQ is considering the development of a Rappahannock River Water Quality Policy. Other VPDES Permits in the same river segment that expired in 2017 are currently in administrative extension by VDEQ, and the FWNC rule is scheduled to be in place by mid-2018. The basis for a new Rappahannock River Water Quality Policy is not yet clear. It may or may not rely upon the long-standing VIMS water quality model used in the past as part of various Rappahannock River VPDES Permit renewals. While the details of such Policy are uncertain, it is likely that tighter VPDES Permit effluent limits are in consideration as a means for reducing point source discharger contributions (as measured by BOD_5 and NH_3-N), which could otherwise impair water quality during low streamflow conditions. Spotsylvania County (Massaponax WWTP, FMC WWTP) and City of Fredericksburg WWTP VPDES Permit reapplication packages are currently under review by VDEQ. Also of note, with WLAs based on 8 mgd ADF, it may become more difficult for Little Falls Run WWTF to comply with its annual nutrient load caps as flows or equivalent loadings increase toward 8 mgd. Beyond 8 mgd, performance would need to be better than the WWTF's current basis-of-design. Potential limits on wasteloads could require treatment to levels below generally-accepted limits of technology, thereby impairing the ability of the Little Falls Run WWTF to process flows at buildout of the sewershed. DPW will monitor this situation as it develops (long-term), and if appropriate, consider substantial upgrades to treatment processes or realignment of the sewersheds based on future wasteload constraints.
Biosolids management and disposal methods in VA is a subject of on-going debate. In general, currently, there do not appear to be any biosolids rulemaking that would significantly impact Stafford County solids management practices (screenings, grit, biological sludge, or regional septage receiving / treatment).

In summary, with respect to pending regulatory changes, there are multiple reasons why Little Falls Run WWTF performance may need to improve further in the next 1-2 Permit cycles (5-year & 10-year planning timetables). Changes to the Aquia WWTF permit conditions are also possible, with perhaps a focus on ammonia rule. Building upon this master planning evaluation, facilities planning may be needed at one or both WWTFs in the coming years (2018-2020) to study and quantify upgrade requirements.

Anticipated Capacity Issues

As part of the overall master planning process the County has performed an analysis of anticipated future wastewater flow capacity required at both plants. Through existing water meter data, data provided by the Stafford County Planning Department, and input from DPW staff and OBG, wastewater flow projections were developed for the current scenario, a near-term (10-year) scenario and at buildout (2060 and beyond) scenario. Table 8 shows the projected wastewater flows for the two wastewater treatment facilities.

Table 8 – Aquia and Little Falls Run (LFR) WWTF Projected Wastewater Flows

WWTF	Base Sanitary Flow (mgd)	Infiltration (mgd)	Average Day Flow (mgd)*	Peak Hour Flow (mgd)**
		Current		
Aquia	4.2	1.1	5.3	15.8
LFR	2.5	0.9	3.4	9.7
Total	6.7	2.0	**8.7**	**25.5**
		Near-Term		
Aquia	5.0	1.6	6.6	19.1
LFR	3.3	1.3	4.6	12.9
Total	8.3	2.9	**11.2**	**32.0**
		Buildout		
Aquia	7.1	2.5	9.6	27.4
LFR	7.5	2.1	9.6	28.4
Total	14.6	4.6	**19.2**	**55.7**

*Average wastewater flow estimated as base sanitary flow + dry weather infiltration

**Peak hour, which is used to size WWTF hydraulic capacity, estimated at infiltration + 3.5 times base sanitary flow

Plant Site Visits

As part of the wastewater system review, site visits were made to the two plants in order to better assess their existing processes and to understand the potential existing, intermediate or long-term needs. Please see Technical Memorandum 8 for a summary of the notes and observations taken during the plant site visits.

Reliability Issues

In addition to the regulatory issues and future capacity issues discussed previously in this chapter, DPW anticipates the need for investments at their WWTF's to address the useful life and maintain reliable operations. The Aquia WWTF has been in operation for 38 years, and Little Falls Run WWTF for 27 years. Based on the age of these important assets, further investigation is appropriate to assess the remaining life of equipment, structural concrete issues and power reliability.

As part of the Master Plan effort, DPW and OBG have reviewed plant historical drawings and O&M manuals and prepared a table with expected remaining life for the major equipment table at each plant. For master planning purposes, most mechanical equipment items are projected to have a 25-year life span; UV equipment is considered to have a 15-year life span due to the frequent required maintenance on bulbs and the sensitivity of the equipment. The Tables with information on the remaining useful life for each plant can be found in Technical Memorandum 8.

Structures are projected for a 40-year life span before the need for significant rehabilitation. The original concrete structures at Aquia are nearly at that age, and those at Little Falls Run WWTF will approach that age in the next 10 years. The structures at Stafford County's WWTFs, especially those seeing constant wear like the Schreiber Process aeration basins with the rotating bridge are showing significant concrete issues that have been addressed by the plants as part of yearly maintenance. During site visits, only issues that were visible (above the water line) could be assessed. DPW has recently initiated comprehensive facility assessments, including more thorough observation of structural conditions, to refine the useful life of the structures and equipment, and develop a prioritized list of repairs and replacements. This assessment will be completed in 2018, and its results used to update the annual capital and operating budget in FY2019.

Electric power to the Aquia WWTF is furnished by two feeder lines from Dominion Power. Two generators are also available at the facility as backup power sources. Although these existing power supplies are adequate to comply with prevailing code and regulations, based on discussions with Stafford County O&M staff regarding the current power distribution system, it would be prudent to improve the electrical distribution interconnections and controls to enhance power supply resiliency, since the current electrical configuration could leave up to half the plant without power under certain conditions.

Electric power to the Little Falls Run WWTF is furnished by a single feeder line from Dominion Power. In addition to the feeder, the plant has a backup generator, to be used in the event of a power outage. Future expansion may require the installation of an additional generator or a redundant Dominion Power feeder line. If the redundant Dominion Power feed line is not installed, as the plant continues to be expanded in the future, additional generators may be needed to provide additional reliability capacity.

Reuse and Resource Recovery Opportunities

During preparation of the Preliminary Engineering Report for the nutrient removal projects at Aquia and Little Falls Run, the County investigated opportunities to reuse effluent from the WWTFs, thereby reducing the effluent flow discharged into the Chesapeake Bay watershed. Large industrial and commercial water users within the County were identified and investigated to determine whether plant effluent could be used in place of the potable water currently being supplied to these industries. The outcome of this investigation was that DPW found no significant commercial or industrial potable water users located close enough to either WWTF to make it economical to furnish them with reuse effluent. Thus, implementation of a reuse system is not considered viable at this time.

3. INTERMEDIATE AND LONG-TERM IMPROVEMENTS

The Stafford Department of Utilities has identified certain proposed modifications as part of its on-going asset renewal program. Aging infrastructure, including the original Schreiber process trains at each plant, require periodic major maintenance or upgrades. Additionally, the FWNC/Ammonia rule will likely be adopted by VDEQ before or around the next VPDES permit expiration dates. This regulatory change may require upgrades to the biological treatment system and/or chemical feed facilities at either or both WWTFs.

Aquia WWTF

Based on the site visit, review of existing data, historical information and discussions with DPW staff, the following recommendations are made for intermediate improvements to the Aquia WWTF.

Table 9 – Aquia WWTF Intermediate Improvements

Unit Process	Priority*	Proposed Improvements
Facilities Planning	2	• Facilities Structural Assessment • General review of mechanical equipment for remaining useful life and possible efficiency upgrades
General Upgrades	2	• Concrete Repair • Headworks – possible replacement of grit and grease system • Power Supply – Arc flash study, and improve the electrical distribution interconnections and controls to enhance power supply resiliency
Solids Handling	1	• Sludge Storage Expansion • Dewatering Unit
Nitrification Upgrades	1	• FWNC/NH_3 compliance, anticipating the need for finer aeration control for both summer and winter seasons, to meet lower monthly and weekly limits
General Upgrades	2	• Filtration • UV • Controls • Miscellaneous

*Priority 1 – Critical to the current and future operation of the system or needed to serve future projected wastewater flows
*Priority 2 – Necessary to meet basic performance requirements and improve system operation and reliability

The ultimate capacity projected for buildout at the Aquia WWTF is 10 mgd average day flow. For the plant to reach this ultimate capacity a variety of expansions and changes would need to be made. As discussed in the regulatory section above, the ultimate plant effluent requirements could change in the future, which would in turn require plant improvements. As nutrient limits tighten and plant capacity increases it may at some point be necessary to remove the existing Schreiber process and install a new secondary treatment system more capable of meeting these future limits.

Little Falls Run WWTF

Based on the site visit, review of existing data, historical information and discussions with DPW staff, the following recommendations are made for intermediate improvements to the LFR WWTF.

Table 10 – LFR WWTF Intermediate Improvements

Unit Process	Priority*	Proposed Improvements
Facilities Planning	2	• Facilities Structural Assessment • General review of mechanical equipment remaining useful life and efficiency upgrades
General Upgrades	2	• Concrete Repair • Headworks • UV
Denitrification Upgrades	1	• Addition of new tanks to help provide additional denitrification capacity
Upgrade Allowance	1	• Rappahannock Policy

Unit Process	Priority*	Proposed Improvements
		• FWNC/NH_3 Allowance
General Upgrades	2	• Filtration • Miscellaneous

*Priority 1 – Critical to the current and future operation of the system or needed to serve future projected wastewater flows
*Priority 2 – Necessary to meet basic performance requirements and improve system operation and reliability

The ultimate capacity projected for buildout at the Little Falls Run WWTF is also 10 mgd average day flow. For the plant to reach this ultimate capacity a variety of expansions and changes would need to be made. As discussed in the regulatory section above, the ultimate plant effluent requirements could change in the future, which would in turn require plant improvements. As nutrient limits tighten and plant capacity increases it may at some point be necessary to remove the existing Schreiber process, re-purpose or re-configure tankage, and/or install a new biological treatment system more capable of meeting these future limits.

4. KEY FINDINGS

Overall both the Aquia WWTF and the Little Falls Run WWTF are currently performing well. Both plants are slightly underloaded in regards to average flow capacity and both plants consistently meet their VPDES permit requirements. Future improvements and the timing for expansions at each plant will be impacted by potential regulatory changes that govern WWTFs in the Rappahannock River Basin (Little Falls Run WWTF) and the Potomac River Basin (Aquia WWTF), as well as growth projections in the County's sewer service area.

Aquia WWTF

- Increase wastewater treatment capacity as needed to serve anticipated growth.
  - Flow at the treatment plant is projected to remain within the plant's design capacity through the near-term, with the exception of solids processing. However, an upgrade to the treatment processes sooner than 10 years may be needed to comply with potential future regulations that could reduce future wasteload allocations and/or tighter nutrient effluent limits.
- Perform a full facilities assessment.
  - Now 38 years old, parts of the original plant may be at or near the end of their useful service life. Normal maintenance will continue to prolong the life of the equipment and structures, but a full facility assessment is underway to establish a prioritized plan and schedule for repairs and upgrades to serve the needs of the County in both the immediate and long-term scenarios.
- The ultimate capacity projected for the Aquia WWTF is 10 mgd, which is adequate to handle the projected flows at buildout of the sewershed under the County's current land use and zoning.

Little Falls Run WWTF

- Increase wastewater treatment capacity as needed to meet anticipated growth.
  - Flow at the treatment plant is projected to remain within the plant's design capacity through the near-term, and likely for at least 20 years. However, regulatory changes could drive the need for improvements to comply with future reductions in wasteload allocations and/or tighter nutrient effluent limits.

- Continue to track regulatory changes for dischargers to the Rappahannock River.
  - It appears that VDEQ is considering the development of a Rappahannock River Water Quality Policy which could result in more stringent permit limits for Little Falls Run WWTF and several other plants discharging to the Rappahannock River in this area of the state. DPW will continue to track state and federal regulations in order to proactively plan for future changes at Little Falls Run WWTF, to comply with potentially more stringent permit limits.
- Perform a full facilities assessment.
  - Now 27 years old, parts of the original plant may be at or near the end of their useful service life. Normal maintenance will continue to prolong the life of the equipment and structures' but a full facility assessment is recommended to establish a prioritized plan and schedule for repairs and upgrades to serve the needs of the County in both the immediate and long term scenarios.
- The ultimate capacity projected for the Little Falls Run WWTF is 10 mgd, which is adequate to handle the projected flows at buildout of the sewershed under the County's current land use and zoning. However, potentially more stringent waste load constraints may cause the County to assess other approaches for handling the sewershed's buildout flows.
- The overall cost for the wastewater treatment improvements presented in this Master Plan through the buildout condition is approximately **$88 million**. Approximately **$32 million** is proposed through the next ten-year planning period (FY2019 - FY2028). See Chapter 9 for details on costs estimating

5. PLAN OF ACTION

- No expansion of either WWTF is required to meet projected growth of wastewater flow in the near-term (through 2028).
- Stricter regulations in the Potomac River basin and Rappahannock River basin may require significant investments at the Aquia WWTF and Little Falls Run WWTF, possibly within the next 10 years. The County should continue to monitor regulatory developments and proactively plan for potentially more stringent permit requirements.
- The County will conduct a full facilities assessment for each WWTF in order to estimate the remaining service life of its equipment and facilities. Pending the results of this assessment and in conjunction with the regulatory drivers, this Master Plan includes "budgetary placeholders" to assist the County in planning for potential near-term capital investments at both plants.
- As part of addressing aging infrastructure and pending nutrient limit reductions, the Little Falls Run WWTF should be further investigated to determine possible upgrades and improvements to both the headworks facility and expanded denitrification capacity.
- In the long-term, DPW will monitor the regulatory situation, and if appropriate, consider substantial upgrades to wastewater treatment processes, realignment of the sewersheds, or other holisitic approaches to meet future waste load constraints at buildout flows.

Chapter 9 COST ESTIMATES AND PROJECT TIMING

Cost Estimates

The unit costs and assumptions used for estimating construction costs for water and sewer system improvements are presented in Technical Memorandum 9 (*Cost Estimates*). Project costs to be incorporated into the County's capital improvements program were generated by adding allowances to the estimated construction costs.

The cost estimates generated for this study are termed "budget" estimates and are appropriate for the level of detail associated with concept level planning. Budget level estimates are made without detailed engineering data or information on site-specific conditions (e.g., final pipeline alignments, aesthetics, etc.). The intended use of these estimates is for developing budgets for inclusion in the County's capital program. Budget level estimates are considered accurate within +30% and -15%.

Construction cost estimates were converted to total project costs by adding an allowance of 20% for engineering, legal and administrative fees. Project cost estimates are intended for use in budget development, wherever site-specific costs are not utilized. They represent typical experience and should be adjusted, where appropriate, to meet special needs.

A summary of the project costs for the near-term and buildout improvements (includes near-term costs) identified in this Master Plan are shown in Table 11.

Table 11 – Summary of Project Costs for Near-term and Buildout Improvements

Category	Near-term Costs ($ millions)	Buildout Costs ($ millions)
Water Supply	12	21
Water Treatment	11	84
Water System	26	57
Sewer System	48	86
Wastewater Treatment	32	88
Total	**129**	**336**

Timing of Proposed Improvements

The timing of each proposed improvement identified in this Master Plan is shown in the pockets at the end of this Master Plan. The timing for implementation of the proposed improvements is based on projected water demands or sewer flows, hydraulic modeling of the capabilities of the existing water and sewer system and facilities, as well as water and wastewater treatment capabilities. A number of factors may dictate that projects be accelerated or deferred (e.g., changes in regulations, timing of water demands or developments, public health issues, physical condition of facilities or piping, upcoming maintenance expenditures, etc.). While the timing of the proposed projects shown in the implementation schedule was developed to allow for a smooth transition through the planning period, it should be noted that projects were generally deferred to the extent possible to allow as much time as possible for assessment of these factors prior to implementation. Stafford County will conduct an annual review of the proposed projects and revise the timing for improvements as necessary.

TECHNICAL MEMORANDUM 1

Summary of Water Planning and Design Criteria

Prepared for: Stafford County Department of Public Works
Prepared by: O'Brien & Gere
Date: February 2018

This technical memorandum is one of a series being prepared for the Water and Sewer Master Plan project. The purpose of this technical memorandum is to summarize the approach and water planning and design criteria used in the Master Plan and identify the location in the Master Plan for the supporting documentation.

CONTENTS

1.1 WATER DEMAND FACTORS

Note to Reader: Refer to Technical Memorandum 3 (Water Demands and Sewer Flows) for a detailed discussion of the information in this section.

Table 1.1.1 – Per Capita Water Demands and Water Duties

Category	Per Capita Water Demands and Water Duties
Residential (GPD/ERC)	200
Commercial: Business Office (GPD/10,000 sq ft)	390
Commercial: Business Retail (GPD/10,000 sq ft)	750
Industrial (GPD/10,000 sq ft)	576
Semi-Public (GPD/10,000 sq ft)	343
Public (GPD/10,000 sq ft)	2201
Residential (GPD/ERC)	200
Commercial: Business Office (GPD/10,000 sq ft)	390
Commercial: Business Retail (GPD/10,000 sq ft)	750
Industrial (GPD/10,000 sq ft)	576
Semi-Public (GPD/10,000 sq ft)	343
Public (GPD/10,000 sq ft)	2201

1.2 WATER DEMANDS

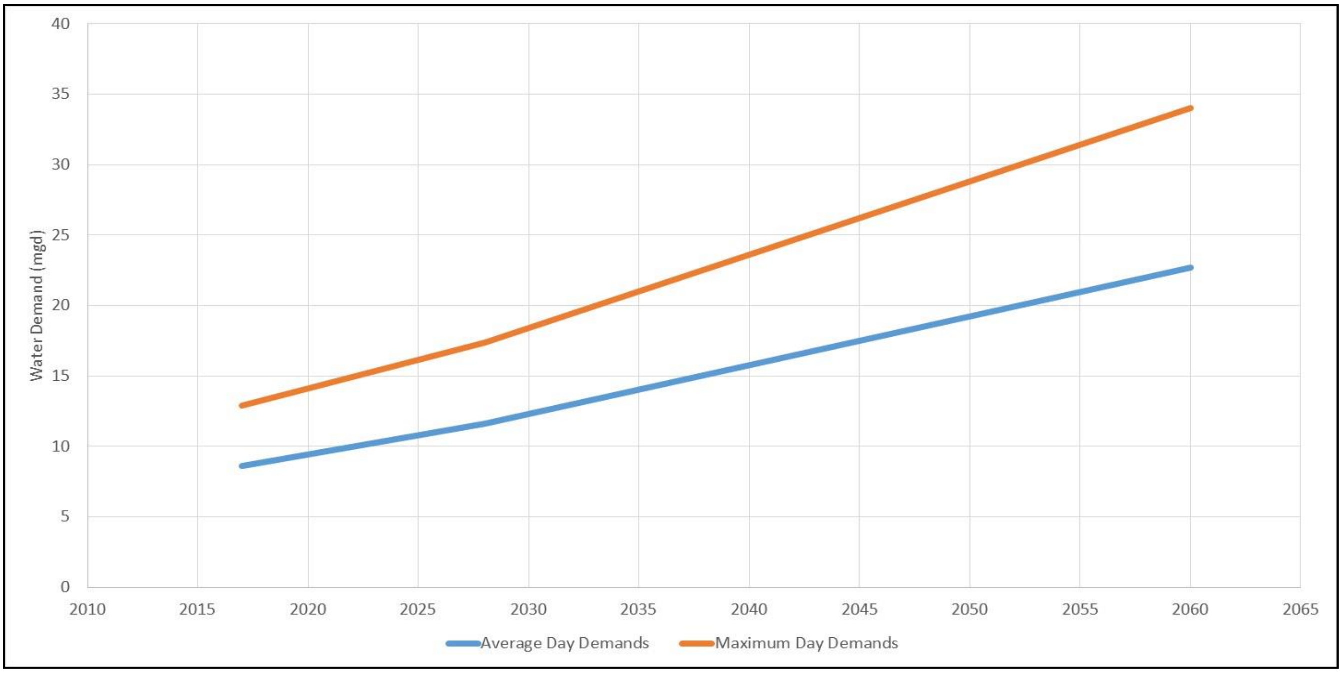
Note to Reader: Refer to Technical Memorandum 3 (Water Demands) for a detailed discussion of the information in this section.

Water systems are required to supply flow at rates that fluctuate over a wide range from day-to-day and hour-to-hour. Rates most important to planning, design and operation of a water system are annual average day, maximum (peak) day, maximum (peak) hour, and maximum day plus fire flow.

- Annual average day demand is the total volume of water delivered to the system in a given year divided by the number of days in the year.
- Maximum (peak) day demand is the largest quantity of water supplied to the system on any given day of the year.
- Maximum (peak) hour demand is the highest rate of flow for any hour in a year.
- Maximum day plus fire flow considers the possibility of a fire event under maximum day demand conditions.

Average day water demands are expected to increase from approximately 8.6 mgd (2017) to 22.7 mgd under buildout (2060) conditions. During the same period, the maximum day demands are expected to increase from approximately 12.9 mgd (2017) to 34.1 mgd at buildout (2060) based on a peaking factor of 1.5 times the average day demand (Figure 1.2.1).

Figure 1.2.1 - Projected Water Demands



1.3 WATER SYSTEM PLANNING AND DESIGN CRITERIA

Note to Reader: Refer to Technical Memorandum 6 (Finished Water Pumping, Storage and Distribution Facilities) for a detailed discussion of the information in this section.

1.3.1 Overview of Water System Planning and Design Criteria

For this Master Plan, the UD's planning and design criteria for waterworks facilities is summarized as follows:

- Water treatment facilities shall be adequate to provide the maximum day water demand.
- Water booster pumping stations shall be adequate to pump the maximum day water demand. The Virginia Department of Health's (VDH) "Waterworks Regulations" require that each pumping station shall have at least two pumping units. Pumps should have sufficient capacity so that if any one pump is out-of-service (firm capacity) the remaining units shall be capable of providing the maximum day demand.
- Pipelines are sized for the following:
  - The largest of maximum hour flow, maximum day flow plus fire flow, or storage replenishment flow. Fire flow requirements are a primary factor affecting the sizing of piping in the water distribution system (6-inch and 8-inch mains).
  - A targeted velocity of less than 5 ft/sec.
  - A targeted headloss of less than 5 feet/1,000 feet of pipeline.
- Maximum water pressures at the service connections were 120 psi.
- Minimum water pressures were 45 psi at the service connection at maximum day demand rates and water storage tanks at 10 feet below overflow levels, and 20 psi at the service connection based on the greater of maximum hour or maximum day plus fire flow demand condition.
- Pressure fluctuation was limited to 20-30 psi.

- Pressure zone layout was based on the minimum pressure established by the highest ground elevation that can be supplied, and the maximum pressure established by the lowest ground elevation.
- Pressure regulating valves were proposed with a minimum pressure differential of 10 psi for small valves (6-inch and smaller) and 5 psi for large valves (8-inch and larger). The maximum velocity allowed through the valve is typically 15-20 feet/sec.
- Looping was considered to provide a higher level of reliability (i.e., if one source is out-of-service to the area, supply can be provided from a second source).
- Pipe materials generally accepted include ductile iron, steel, concrete, and polyvinyl chloride (plastic or PVC).

1.3.2. Fire Flow Requirements

Fire flow requirements are typically dependent on the land use and vary by community. Stafford County's fire flow requirements are shown in Table 1.3.1.

Table 1.3.1 – Fire Flow Requirements

Source	Land Use		
	Residential	Commercial	Industrial
Stafford County	1000-2500 gpm	2500 gpm	2500 gpm

1.3.3. Storage Criteria

According to the VDH "Waterworks Regulations", the minimum acceptable effective finished water storage for domestic purposes must be greater than 200 gallons per equivalent residential connection at minimum pressure (this essentially equates to one-half of the annual average day demand). For this Master Plan, the volume of storage needed will be equal to one-half of the annual average day demand.

1.4 SUMMARY

The approach and criteria outlined in this technical memorandum are based on sound engineering and give reasonable projections of future water demands and design demand conditions.

TECHNICAL MEMORANDUM 2

Summary of Sewer Planning and Design Criteria

Prepared for: Stafford County Department of Public Works
Prepared by: O'Brien & Gere
Date: February 2018

This technical memorandum is one of a series being prepared for the Water and Sewer Master Plan project. The purpose of this technical memorandum is to summarize the approach and sewer planning and design criteria used in the Master Plan and identify the location in the Master Plan for the supporting documentation.

CONTENTS

2.1 METHODOLOGY FOR PREDICTING SEWER FLOWS

Note to Reader: Refer to Technical Memorandum 3 (Water Demands and Sewer Flows) for a detailed discussion of the information in this section.

Wet weather flows are used to assess the hydraulic capacity of sewer systems and are composed of three components:

- Sanitary base flow generated by homes, businesses, etc.,
- Infiltration due to normal groundwater levels (dry weather infiltration), and
- I/I due to rainfall and high groundwater levels (rainfall-dependent I/I)

The formula for calculating the sewer loads for wet weather conditions is as follows:

Peak Wet Weather Flow (PWWF) = Average Dry Weather Flow (ADWF) + Rainfall-Dependent I/I (RDI/I)

Where:

Peak Wet Weather Flow (PWWF) equals the peak hourly flow during wet weather conditions.

Average Dry Weather Flow (ADWF) is the average flow that occurs in sanitary sewers on a daily basis with no evident reaction to rainfall. The ADWF is composed of sanitary base flow and groundwater infiltration. For Stafford, sanitary base flows are roughly equal to 65% to 80% of the average day water demand which approximates the customers' water demand that is returned to the sanitary sewer. Groundwater infiltration (GWI) is an allowance that is added to the sanitary base flow (derived from sewage flow factors) to obtain the dry weather flow. GWI represents flow that is separate and distinguished from inflow resulting from storm events during wet weather conditions. The allowance used in this Master Plan for GWI is estimated to be 500 gpd/inch diameter-mile (gpdidm).

Rainfall-Dependent I/I consists of rainfall that enters the collection system through direct connections (roof leaders, manholes, etc.) and causes an almost immediate increase in wastewater flows. RDI/I data was used to establish an overall sewer system peaking factor of 3.5 in the 2006 Master Plan. The 3.5 peaking factor for the overall sewer system was also used in this Master Plan to reflect RDI/I.

To define the design flow conditions for the sewer system, the equation presented above was modified as follows:

Peak Wet Weather Flow (PWWF) = (Sanitary Base Flow x Peak Factor) + Groundwater Infiltration

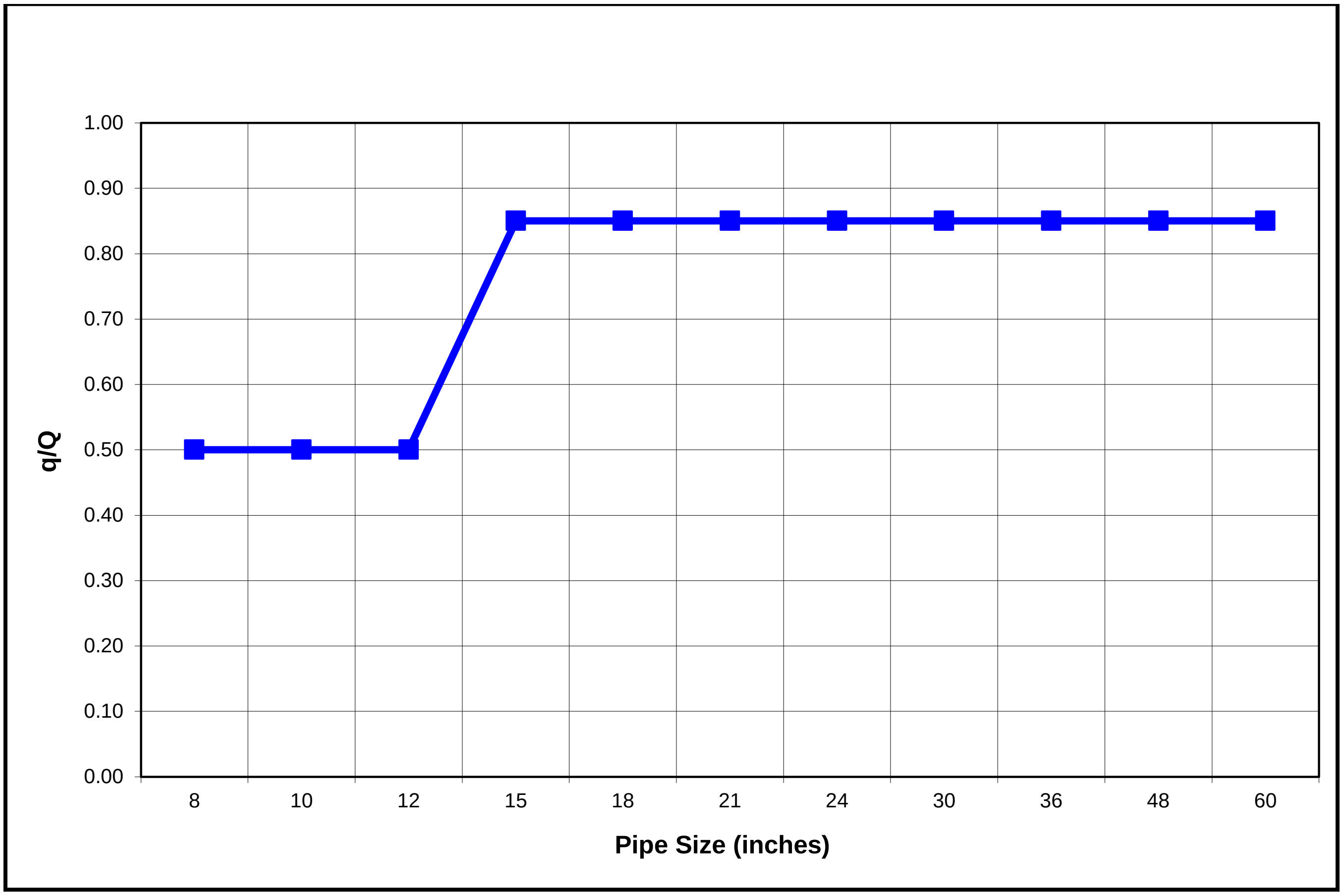
In the sewer model, a global peak factor is multiplied by the sanitary base flow at each manhole in the sewer system and the GWI component (500 gpdidm) is subsequently added to the computed manhole flow as the flow is routed through the downstream sewer piping.

2.2 SEWER SYSTEM DESIGN CRITERIA

"n" value	0.013 for all pipe materials
Minimum Velocity	2.25 ft/sec
Maximum Velocity	15 ft/sec

Criteria were developed for this study to define the "threshold" values at which point capacity enhancement measures for pipelines within the sanitary sewer system should be evaluated and rehabilitated or replaced. The partial flow-to-full flow ratios used to develop the analysis criteria curve are shown in Figure 2.2.1 and were less conservative for the large diameter sewer pipelines (15 inches and larger in diameter). The q/Q ratio of 0.85 (d/D ratio of 0.75) for the large diameter pipelines reflects the desire to maximize flow in the existing interceptor sewers. The q/Q ratio for small diameter pipelines maintains some reserve capacity and reflects the uncertainty in the spatial distribution of sewer loads served by the smaller piping in the sewer system. By applying relatively conservative q/Q ratios for the analysis curve, pipelines will be identified prior to reaching full capacity and thus reduce the likelihood of surcharge and/or overflow conditions. It should be noted that existing pipelines that exceeded the design criteria and were less than full through buildout conditions (q/Q less than 1.0) were not recommended for replacement. Rather, these pipelines were flagged for future investigation and possible flow monitoring during the planning period.

Figure 2.2.1 - Pipeline Capacity Criteria



2.3 SUMMARY

The approach and criteria outlined in this technical memorandum are based on sound engineering and give reasonable projections of future sewer flows and design flow conditions.

TECHNICAL MEMORANDUM 3

Water Demands and Sewer Flows

Prepared for: Stafford County Department of Public Works
Prepared by: O'Brien & Gere
Date: February 2018

This technical memorandum is one of a series being prepared for the Water and Sewer Master Plan project. The purpose of this technical memorandum is to summarize the approach for development of water demands and sewer flows for near-term and buildout conditions.

CONTENTS

3.1 OVERVIEW OF WATER DEMANDS AND SEWER FLOWS

3.1.1 DPW Service Area

The service area population and the demand for water and sewer services have increased approximately five-fold in the last 35 years and continues to grow. The demand for services is expected to nearly triple again during the next 40 years. Today, DPW serves a residential population of approximately 105,000, over 1,300 businesses, and a portion of the Quantico Marine Corps Base.

Stafford County is located approximately 40 miles south of Washington, DC and 60 miles north of Richmond, VA. The County covers 277 square miles of which 51 square miles in the northern portion of the County comprise the Quantico Marine Corps Base. With its proximity to major industrial and commercial markets and its high percentage of undeveloped land, the County is experiencing rapid residential and commercial development. The number of water/sewer accounts has increased from 6,000 in 1982 to over 35,000 in 2017. Between 2014 and 2017, the public utility customer base increased at an annual rate of approximately 2%. This recent increase in the number of customers aligns with the goal of 2% annual population increase, adopted by the Stafford County Board of Supervisors.

3.1.2 Planning Horizon

DPW's Master Plan attempts to anticipate long-term utility needs through buildout (roughly 2060). This long "planning horizon" allows sustainability considerations to affect the DPW's decision-making processes for maintaining adequate water and wastewater facilities. Decisions must not only make sense as short-term solutions, but as long-range investments in the community's future.

Although a 40-year planning horizon is a valuable tool for planning, long-term growth rates and scenarios for eventual buildout conditions are not well established and are subject to considerable uncertainty. While the UD's water demand and sewer flow projections assume a constant increase throughout the planning period, actual growth may occur differently, and full buildout may occur before 2060.

Near-term water demand and sewer flow projections were developed to identify the water and sewer improvements needed to satisfy near-term water demands and sewer flows. To estimate near-term water demands and sewer flows, the DPW consulted with the County's Planning Department to identify developments that are in progress or anticipated within the next ten years (through 2028). The objective of this analysis was to identify what facilities may be needed and the size of those facilities to deliver water from Lake Mooney and Smith Lake WTP's to the DPW's customers. The completion of the Lake Mooney WTP is causing a shift in transmission of water from the current condition, with two-thirds of water production in the north from Smith Lake WTP and one-third production in the south from Lake Mooney WTP, to the opposite (i.e., two-thirds delivery from the south from Lake Mooney WTP and one-third from the north from Smith Lake WTP). This change represents a significant shift, requiring careful planning to optimize use of existing facilities and properly size and locate proposed facilities so that they operate well under near-term and buildout conditions.

The near-term sewer flow (through 2028) represents the quantity of existing sewer flow plus the projected flow from developments that are currently under consideration. While there is considerable uncertainty associated with the timing (and in some cases the future) of some of these future developments, it is prudent to plan the infrastructure needed to allow adequate time for planning, permitting, design and construction of the required facilities.

3.1.3 Key Assumptions and Uncertainties

The overall planning approach outlined in this Master Plan gives reasonable projections of future water demands and sewer flows and allows the DPW to build conservatism into the sizing of facilities and piping in the latter stages of the planning process, thereby minimizing the amount of rework required to update plans and proposed improvement projects.

A disaggregated water demand/sewer load method was used to separate (disaggregate) the water demands and sewer loads into more uniform groups of users as the basis for future projections. This method provides accuracy and flexibility in analyzing alternatives because of the ability to use different consumption and generation rates within each group and different growth rates among groups. This approach can be used with land use information and water/sewer duties (gallons per day per acre or square foot) to develop water demands and sewer flows.

Water and sewer utilities have traditionally adopted a conservative approach when planning and sizing facilities with high capital costs and long lead times required for planning, permitting, design and construction. This approach typically includes diligent efforts to avoid underestimating the level of future demands that those facilities will serve. Within this context, it is important to include allowances for the wide range of unknowns inherent in long-range forecasts.

A summary of the assumptions that underlie the projected water demands and sewer flows follows. Changes in these conditions could require modification of the Master Plan.

- Service area boundaries – The Urban Service Area serves as the basis for projecting growth in water demands and sewer flows. For water, this is a significant change from the 2006 Master Plan where the long-term water service area encompassed the entire County. The 2006 Master Plan and this Master Plan both used the Urban Service Area for projecting growth of the sewer service area. The Urban Service Area boundary for buildout conditions was developed by DPW and Planning Department staff based on future development and policies. The Urban Service Area boundary represents a "wall" and water and sewer service for areas outside the Urban Service Area are not planned and no demands or flows from these areas are included in this Master Plan.
- Future water demands remain internal (except for Quantico Marine Corps Base) – Future water demands will continue to be determined by retail water and sewer sales within the service area (except for wholesale water delivery and sewer flows from Quantico Marine Corps Base). The demand forecasts do not anticipate retail or wholesale delivery of service outside of the service area (except for Quantico Marine Corps Base).
- Linear forecasts show moderate growth – Forecasts of water demand and sewer flows are essentially a linear extrapolation of current water demand and sewer flows through the buildout condition based on land use.
- Land Use and water/sewer duties - Land use information and water/sewer duties (gallons per day per acre or square foot) were used to define how water demands and sewer flows were allocated to the various land use categories throughout the County. Changes to the characteristics of a land use category over time could impact the water/sewer duties (i.e., quantity of water consumed or sewer flow generated). In addition, changing the land use for a specific geographic area could impact the water/sewer duties and alter the sizing of water or sewer facilities serving the area.
- Peaking factors – Peak water demands (maximum day or peak hour) and peak sewer flows (peak wet weather flows) are important because their magnitude drives the size and cost of future water and sewer facilities. Maximum day water demands were based on a global peaking factor of 1.5 times the average day water demand. Diurnal water demand patterns for each pressure zone were used to characterize the change in water demand at each node in the system throughout the maximum day, including the peak hour. Of particular importance is the application of the same global peaking factor and diurnal curve to each land use category. It is understood that water demands and sewer flows vary by land use category and fluctuate differently throughout the day depending on the type of land use.

For the sewer flows, a peaking factor of 3.5 times the sanitary base flow plus groundwater infiltration was used to estimate the magnitude of the design wet weather storm event. The peaking factor was applied globally to the sewer loads at each manhole which were derived from the sewer duties and land use tributary to the manhole. The peaking factor for the sewer system is intended to reflect the sewer system's response to a design storm event. Throughout the planning period, the DPW should continue to refine the water and sewer models and investigate storm events and I/I concerns.

3.2 Projected Water Demands

3.2.1 Methodology for Projecting Water Demands

Nearly all techniques and approaches for projecting future water demands are based on the premise that an analysis of historic trends can serve as the basis for predicting future trends. Annual increases in total water demands for the DPW service area have followed a consistent pattern of growth. These trends provide a strong basis for predicting future water demands for the DPW service area. The three most commonly used methods for applying historic trends as a means for predicting future demands include:

- Extrapolation of Historic Demands - The extrapolation method is used by many utilities to conduct short-term water demand forecasts of three to five years, but few use this technique for long-term forecasting. The extrapolation method is typically used to assess the overall operational, facility and financial implications of observed trends.
- Per Capita Demand Forecasting - The per capita method is similar to the extrapolation method in that all water users are grouped together. The per capita method, however, links future water uses directly to a projection of population growth. For many water utilities, the per capita method is the long-range forecasting method of choice.
- Disaggregated Demand Forecasting - The disaggregated demand method separates (disaggregates) the water demands of a utility into more uniform groups of users as the basis for future projections. This method provides greater accuracy and flexibility in analyzing alternatives because of the ability to use different consumption rates within each sector and different growth rates among sectors. This approach can be used with land use information and water duties (gallons per day per acre or square foot) to generate water demands.

Water and sewer utilities have traditionally adopted a conservative approach when planning and sizing facilities with high capital costs and long lead times required for planning, permitting, design and construction. This approach typically includes diligent efforts to avoid underestimating the level of future demands that those facilities will serve. Within this context, it is important to include allowances for the wide range of unknowns inherent in long-range forecasts.

For this study, the disaggregated demand forecasting approach is used for projecting future demands because it provides greater accuracy than the other approaches and flexibility in analyzing alternatives. The accuracy and flexibility of this method are based on the ability to use different consumption rates within each sector and different growth rates among sectors.

3.2.2 Per Capita Water Demands and Water Duties

In terms of the total quantity of water required, water demands are usually estimated on the basis of per capita demand. Variations in water use depend on size of community, geographic location, climate, season, day of week, time of day, and the extent of industrialization. Because of these variations, the only reliable way to estimate future water demands is to study each community separately. To define how the total water use is distributed within a community throughout the day, the best indicator is land use. A summary of the water demand and water duties provided by the County's Planning Department is presented in Table 3.2.1.

Table 3.2.1 – Per Capita Water Demands and Water Duties

Category	Per Capita Water Demands and Water Duties
Residential (GPD/ERC)	200
Commercial: Business Office (GPD/10,000 sq ft)	390
Commercial: Business Retail (GPD/10,000 sq ft)	750
Industrial (GPD/10,000 sq ft)	576
Semi-Public (GPD/10,000 sq ft)	343
Public (GPD/10,000 sq ft)	2201
Residential (GPD/ERC)	200
Commercial: Business Office (GPD/10,000 sq ft)	390
Commercial: Business Retail (GPD/10,000 sq ft)	750
Industrial (GPD/10,000 sq ft)	576
Semi-Public (GPD/10,000 sq ft)	343
Public (GPD/10,000 sq ft)	2201

3.2.3 Historic Water Losses

It is important to note that the total “water sold” to DPW customers, or water measured at water meters, is typically 15 percent less than the “water produced” at the WTPs. This is due to normal consumptive losses in the water distribution system. Losses in the water distribution system are typically labeled *unmetered water*.

Unmetered water is a term commonly used in the water industry and is calculated as the difference between water produced by DPW and that metered (billed) to DPW’s retail customers. DPW’s water demand projections include an unmetered water allowance of 15% of the total demand. The unmetered water allowance was factored into the water demands as a global demand increase of 15% in the water model.

3.2.4 Water Conservation

For this study, water conservation at the buildout condition was factored in as a global water demand reduction of 8% in the water model.

3.2.5 Computation of Average Day Water Demands

The objective of the water demand analysis for this Master Plan was to determine how and where the water demands should be allocated throughout the Urban Service Area. The County’s Planning Department developed an independent water demand projection for each parcel in the Urban Service Area based on the most recent Land Use information.

Using water pressure zone and land use information provided by DPW and the Planning Department, OBG developed water demand forecasts and distributed the demands throughout the system. The following steps summarize the general methodology that was used to estimate the future water demands:

- Compute the acreage for each parcel in the Urban Service Area.
- Apply water duties (gpd/acre) for each parcel.
- Add the projected Federal or Military (FED) demand.
- Add the unmetered water allowance to the total demand (15%).
- Subtract the conservation allowance from the total demand (8%).

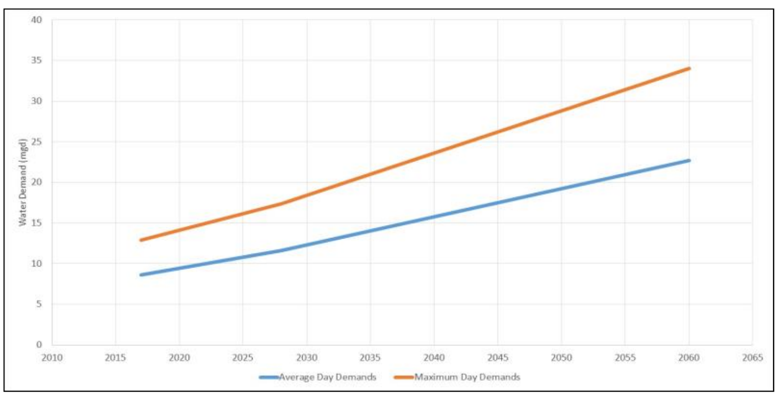
3.2.6 Projected Water Demands

Water systems are required to supply flow at rates that fluctuate over a wide range from day-to-day and hour-to-hour. Rates most important to planning, design and operation of a water system are annual average day, maximum (peak) day, maximum (peak) hour, and maximum day plus fire flow.

- Annual average day demand is the total volume of water delivered to the system in a given year divided by the number of days in the year.
- Maximum (peak) day demand is the largest quantity of water supplied to the system on any given day of the year.
- Maximum (peak) hour demand is the highest rate of flow for any hour in a year.
- Maximum day plus fire flow considers the possibility of a fire event under maximum day demand conditions.

Average day water demands are expected to increase from approximately 8.6 mgd (2017) to 22.7 mgd under buildout (2060) conditions. During the same period, the maximum day demands are expected to increase from approximately 12.9 mgd (2017) to 34.1 mgd at buildout (2060) based on a peaking factor of 1.5 times the average day demand (Figure 3.2.1).

Figure 3.2.1 - Projected Water Demands



3.3 DIURNAL CURVES

Diurnal curves are simply representations of how water is used over time of day. Diurnal curves are different for each house, each industry and each water user. However, for the purpose of creating a model to represent a water distribution system, simplifications are generally made such that all residential, commercial, industrial, and other water use classifications are each assumed to have consistent water demand (diurnal) curves.

Demands in water systems vary throughout the day with peaks in the morning and evening and low flows in the early morning hours. Patterns are used to represent the daily temporal variations within the water system. They consist of a collection of multipliers (multiplication factors) that are applied to the daily demand to allow it to vary over time during an extended period simulation (EPS). Different patterns can be applied to individual nodes or groups of nodes to accurately represent water duties (e.g., residential, commercial, etc.). In 2003, diurnal demand curves were developed for each of the five existing pressure zones based on monitoring data collected over a period of several days. These diurnal curves are used in this 2018 Master Plan and are shown in Figure 3.3.1. The diurnal curves used for modeling each pressure zone are based on combined demand categories (i.e., separate diurnal curves for various land use types such as residential and commercial were not generated). The diurnal curves were based on average hourly factors (pattern timestep in model) over a 24-hour period (duration in model). The diurnal demand curve was considered to be uniform throughout the pressure zone. Consequently, average daily water demands at nodes in each pressure zone were multiplied by their respective diurnal demand curve to generate daily variations in water demand.

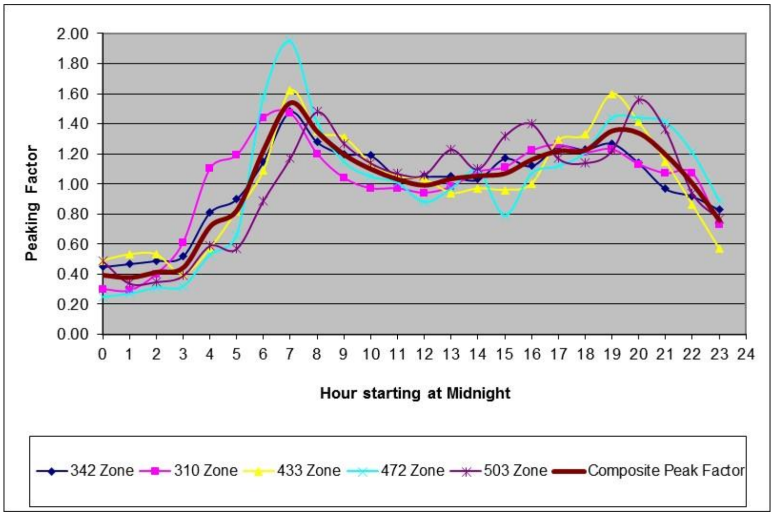


Figure 3.3.1 – Diurnal Demand Curves

3.4 PROJECTED SEWER FLOWS

3.4.1 Methodology for Projecting Sewer Flows

Wet weather flows are used to assess the hydraulic capacity of sewer systems and are composed of three components:

- Sanitary base flow generated by homes, businesses, etc.,
- Infiltration due to normal groundwater levels (dry weather infiltration), and
- I/I due to rainfall and high groundwater levels (rainfall-dependent I/I)

The formula for calculating the sewer loads for wet weather conditions is as follows:

Peak Wet Weather Flow (PWWF) = Average Dry Weather Flow (ADWF) + Rainfall-Dependent I/I (RDI/I)

Where:

Peak Wet Weather Flow (PWWF) equals the peak hourly flow during wet weather conditions.

Average Dry Weather Flow (ADWF) is the average flow that occurs in sanitary sewers on a daily basis with no evident reaction to rainfall. The ADWF is composed of sanitary base flow and groundwater infiltration. For Stafford, sanitary base flows are roughly equal to 65% to 80% of the average day water demand which approximates the customers' water demand that is returned to the sanitary sewer. Groundwater infiltration (GWI) is an allowance that is added to the sanitary base flow (derived from sewage flow factors) to obtain the dry weather flow. GWI represents flow that is separate and distinguished from inflow resulting from storm events during wet weather conditions. The allowance used in this Master Plan for GWI is estimated to be 500 gpd/inch diameter-mile (gpdidm).

Rainfall-Dependent I/I consists of rainfall that enters the collection system through direct connections (roof leaders, manholes, etc.) and causes an almost immediate increase in wastewater flows. RDI/I data was used to establish an overall sewer system peaking factor of 3.5 in the 2006 Master Plan. The 3.5 peaking factor for the overall sewer system was also used in this Master Plan to reflect RDI/I.

To define the design flow conditions for the sewer system, the equation presented above was modified as follows:

Peak Wet Weather Flow (PWWF) = (Sanitary Base Flow x Peak Factor) + Groundwater Infiltration

In the sewer model, a global peak factor is multiplied by the sanitary base flow at each manhole in the sewer system and the GWI component (500 gpdidm) is subsequently added to the computed manhole flow as the flow is routed through the downstream sewer piping.

3.4.2 Sanitary Base Flows for Near-term Conditions

Near-term flows were developed based on existing and proposed developments. Average sewer flows were applied to the nearest manholes. This approach results in an accurate allocation of current sewer flow to the nearest sewer manhole. Sewer loads for developments which could occur through 2028 were provided by Stafford's Planning Department and applied to the existing InfoSewer™ model to test the capabilities of the existing infrastructure to handle the proposed near-term flows.

3.4.3 Sanitary Base Flows for Buildout Conditions

Similar to near-term flows, buildout flows were developed based on existing development, proposed near-term development (through 2028) and projected land use (development beyond 2028). Average sewer flows were applied to the nearest manholes.

3.4.4 Determination of Total Peak Sewer Flow

Design flow for a sewer is defined as the maximum flow rate that occurs under selected weather and growth conditions. The peak factor is used to convert projected average sewer flows through the planning period to peak wet weather flows. Average daily sewer flows are expected to increase from approximately 8.7 mgd (2017) to roughly 19.2 mgd under buildout (2060) conditions. During the same period, the maximum day sewer flows are expected to increase from approximately 25.5 mgd (2017) to 55.7 mgd at buildout (2060). The sewer flow projections are shown in Figure 3.4.1.

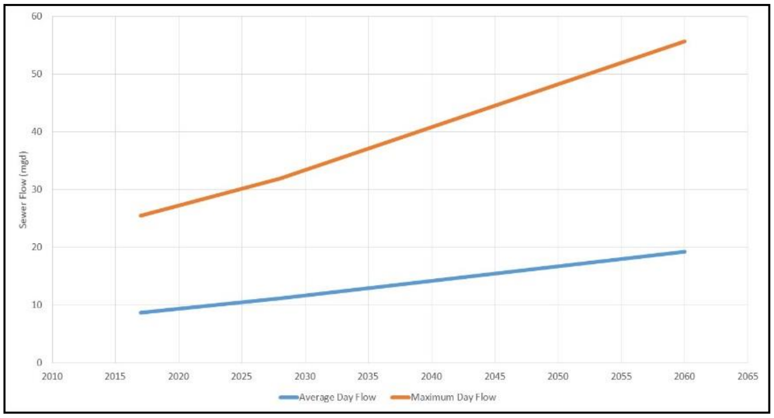


Figure 3.4.1 - Projected Sewer Flows

3.5 KEY FINDINGS

- Bringing the Lake Mooney Reservoir water facilities on-line and shifting the direction of water flow from the supply sources through a major portion of the transmission system requires careful planning to optimize use of existing facilities and properly size and locate proposed facilities so that they operate well under near-term and buildout conditions.

- Water and sewer service area boundaries form the Urban Service Area envelope and water demands and sewer flows from areas outside the Urban Service Area were not included in this Master Plan.

- Average daily water demands are expected to increase from approximately 8.6 mgd (2017) to 22.7 mgd under buildout (2060) conditions. During the same period, the maximum day water demands are expected to increase from approximately 12.9 mgd (2017) to 34.1 mgd at buildout (2060) based on a peaking factor of 1.5 times the average day demand.

- A peak factor of 3.5 times the sanitary base flow plus groundwater infiltration was used to derive the peak wet weather flow for the sewer system.

- Average daily sewer flows are expected to increase from approximately 8.7 mgd (2017) to roughly 19.2 mgd under buildout (2060) conditions. During the same period, the peak flows are expected to increase from approximately 25.5 mgd (2017) to 55.7 mgd at buildout (2060).

3.6 PLAN OF ACTION

- DPW will continue to monitor growth in water and sewer accounts and update water demands and sewer flows.

- DPW will continue to refine techniques used to develop water demand and sewer load forecasts and update projections provided in the Master Plan. Changes in the characteristics of land use categories (i.e., number of housing units per acre, persons per household, etc.) and patterns for water use and sewer flow generation will be routinely reviewed.

- If water demand or sewer load forecasts are revised, DPW will review the timing for capital projects identified in the Master Plan and possibly revise the sizing or timing of projects.

- DPW will continue to monitor the sewer system's response to storm events with varying characteristics (i.e., intensity, duration, etc.) and, if necessary, modify the peaking factor used to represent the design storm event.

- DPW will continue to conduct I/I studies and implement cost-effective measures to reduce I/I.

TECHNICAL MEMORANDUM 4

Raw Water Supply

Prepared for: Stafford County Department of Public Works
Prepared by: O'Brien & Gere
Date: February 2018

This technical memorandum is one of a series being prepared for the Stafford County Water and Sewer Master Plan project. The purpose of this technical memorandum is to summarize the ability of DPW's existing raw water supplies to reliably meet the water demands associated with future growth and development.

CONTENTS

4.1 DPW'S EXISTING RAW WATER SUPPLIES

The County's water supply comes from Lake Mooney and Smith Lake Reservoirs. The reservoirs store water that DPW treats to supply customer demands. The reservoirs must be large enough to meet the County's current and future water demands in drought years. In addition, the reservoirs must be kept safe from sources of health-related water quality constituents, and other constituents that could affect the water's aesthetics (e.g., taste and odor). To protect its water supplies, DPW has several programs to minimize the potential for contamination of the reservoirs.

In 1992, the Stafford Board of Supervisors selected Lake Mooney (formerly named Rocky Pen Run Reservoir) as the new source of water supply to meet the County's needs well into the future. The reservoir is located in the southern portion of the County and is filled from the Rappahannock River using a 40 mgd river pumping station. The reservoir holds approximately 5.5 billion gallons of water. Smith Lake is located on Aquia Creek in the northern portion of the County. The reservoir holds approximately 1.8 billion gallons of water.

4.2 SAFE YIELD OF EXISTING RAW WATER SUPPLIES

The safe yield for Lake Mooney (11.9 mgd) was computed during the planning and permitting phases of the work on the reservoir according to the County. The safe yield for Smith Lake was calculated in this study based on its characteristics (i.e., storage volume, surface area, streamflow, etc.). In Virginia, safe yield for a water supply source is defined as the maximum sustainable withdrawal rate available to withstand the worst drought of record in Virginia since 1930 with 60 days of reserve water storage. For this evaluation, hydrologic data from 1930 through 2016 were used to simulate daily operation of the reservoir during the historical droughts of known severity.

4.2.1 Reservoir Yield Model Theory

A PC-based reservoir model developed by O'Brien & Gere in 2003 was updated to simulate operation of the reservoir had it been in place over the period of historical streamflow records. The hydrologic model developed to analyze Smith Lake calculates the average annual yield for the reservoir for a given set of operating characteristics. Yield is determined by solution of a water balance equation using an iterative approach, based on constraints on the input data. Solution of the water balance equation occurs when the difference in reservoir inflow and outflow equals the change in reservoir storage volume. Model inflows include daily streamflows. Outflows include factored user demands and reservoir releases. Bank storage and seepage are assumed to be negligible, and therefore no adjustments were made. The water balance equation used in the reservoir yield model is:

$$END = [BEG + INFLOW] - [(YIELD \times FCTR) + REL)]$$

The variables in the equation are defined as:

END = reservoir volume at end of the day

BEG = reservoir volume at the beginning of the day

INFLOW = volume of inflow during the day

YIELD = volume of yield during the day

FCTR = daily demand factor for seasonal adjustment

REL = daily release from the reservoir to the downstream channel

4.2.2 Reservoir Inputs

Reservoir inflows

For the safe yield analyses performed in this study, the US Geological Survey stream gage station at Goose Creek near Leesburg was used.

Table 4.2.1 – Streamflow Gage

Stream Gage	Drainage Area (square miles)	Period of Record Used in Analysis
Goose Creek near Leesburg, VA (01644000)	332	1/1/30 - 12/27/16

To identify representative streamflow gages for Aquia Creek inflows, the daily streamflow data at several stream gages were compared in the 2003 work for the period of October 1, 1962 through December 31, 1986. It was determined in 2003 that the Goose Creek gage was representative. The period of record used in this study for the Goose Creek gage was from January 1930 through December 2016. The gage data at the Goose Creek gage was transferred to the reservoir intake location using the following equation:

$$Q_{intake} = Q_{gage} \text{ x (intake drainage area/gage drainage area)}$$

The drainage area for the Aquia Creek stream gage (01660400) upstream of Smith Lake is approximately 35 square miles which includes the drainage area for Lunga Reservoir (12 square miles). A 1991 study identifies that releases (constant 0.75 mgd) from storage in Lunga Reservoir during dry periods could increase the safe yield of Smith Lake. It is assumed that Lunga Reservoir would remain full during a critical drought event and consequently, its drainage area is included in the Smith Lake drainage area. For this study, a drainage area of 47 square miles was used for Smith Lake.

Reservoir elevation-surface area-storage relationship

The reservoir elevation-surface area-storage characteristics were based on limited data obtained from previous studies (*Comprehensive Water Supply Study, O'Brien & Gere, 1991*). For Smith Lake, the 1991 study identified that increasing the height of Smith Lake Dam by 20 feet would increase the usable storage volume by 1,100 MG. Dead storage requirements (sediment storage and poor water quality in lower strata) of 25% of existing total storage (900 MG) plus 10% of expanded storage capacity (1,100 MG). The dead storage volume identified in the 1991 study for the increased Aquia Dam elevation was 350 MG.

Yield and demand factors

The hydrologic model used to compute the safe yield accounts for daily fluctuations in demand. The daily demand factors used in the 2003 study were used in the 2018 work. The daily demand factors were based on actual daily production data compiled for the Rivanna Water & Sewer Authority's water system, and are considered to be representative of Stafford County's demand factors for this planning study. A demand factor was computed for each day of the year by dividing the actual production for that day by the average annual production. These demand factors were multiplied by the County's projected average day demand to obtain daily water demands.

Reservoir Release

The amount of water released from Smith Lake is based on the available storage capacity. The reservoir release requirements are established by regulatory agencies and represent the flow that is required to remain in the stream for protection of aquatic habitat, wasteload assimilation and other uses. In this study, the reservoir releases or flowby used to calculate the safe yield for Smith Lake are shown in Table 4.2.2.

Table 4.2.2 – Smith Lake Release Requirements

Date	Water Supply Storage in Smith Lake	Release Requirement from Smith Lake
March 1st to May 31st	Greater than or equal to 80% full	At least equal to 40% of the mean annual flow or natural inflow whichever is less
March 1st to May 31st	Less than 80% full	At least equal to 20% of the mean annual flow or natural inflow whichever is less
June 1st to February 29th	Greater than or equal to 80% full	At least equal to 20% of the mean annual flow or natural inflow whichever is less
June 1st to February 29th	Less than 80% full, but greater than 60% full	At least equal to 15% of the mean annual flow or natural inflow whichever is less
June 1st to February 29th	Less than 60% full, but greater than 40% full	At least equal to 7.5% of the mean annual flow or natural inflow whichever is less
June 1st to February 29th	Less than 40% full, but greater than 60% full	At least 0.7 mgd or natural inflow whichever is less

4.2.3 Modeling Results

As part to this Water and Sewer Master Plan, hydrologic modeling was performed to estimate the existing safe yield for Smith Lake. The safe yield for Smith Lake (1,775 MG) is approximately 5.1 mgd based on the period of record from 1930 through 2016. For this study, 5.1 mgd is used as the safe yield of Smith Lake based on the 1930's critical drought. The combined safe yield of Smith Lake and Lake Mooney is approximately 17 mgd based on the period of record which includes the 1930's drought.

4.3 SUSTAINABLE YIELD OF EXISTING RAW WATER SUPPLY SYSTEM

The adequacy of drinking water supply sources to reliably meet water demands is based on safe yield which is the amount of water that the supply can safely provide, even during a critical drought. In Virginia, the adequacy of surface water supplies with storage reservoirs is based upon the most severe drought since 1930. The safe yield of Lake Mooney and Smith Lake Reservoirs are shown in Table 4.3.1.

Table 4.3.1 – Safe Yield

Source	Safe Yield (mgd)

Lake Mooney	11.9
Smith Lake	5.1
Total	17.0

OBG obtained the safe yield for Lake Mooney Reservoir (11.9 mgd) from the County. The safe yield for Smith Lake Reservoir (5.1 mgd) was computed by OBG based on the following:

- Useable water storage volume in Smith Lake is 1,775 MG with 60 days of storage held in reserve (DEQ requirement).
- Minimum release requirements from Smith Lake were obtained from DEQ permit for Smith Lake WTP.
- Assumes a continuous release of 0.75 mgd from Lunga Reservoir (Quantico Marine Corps Base) upstream of Smith Lake. Stafford's current contract with the Quantico Marine Corps Base requires that they provide water for treatment by releasing water from the Lunga Reservoir. The Lunga Reservoir has the potential to provide the additional water that Quantico may request in the future. A contract amendment to provide the Marine Corps Base with water above the current 0.75 mgd allocation should include a requirement that the Marine Corps Base release additional water from the Lunga Reservoir to provide the water supply.
- Assumes unrestricted average day water demands (i.e., no customer water use restrictions in effect).
- A daily mass balance model was used to compute yield based on daily streamflow data from January 1, 1930 through December 27, 2016.
- The critical drought of record for Smith Lake occurred in the 1930's.

The centerpieces of DPW's raw water supply system are its reservoirs – Lake Mooney and Smith Lake. In order to use these reservoirs, DPW must maintain reservoir intakes and raw water pipelines to deliver raw water from the reservoirs to the WTPs. Each of these components is critical to the operation of the raw water supply system, and the limitations of each are factors in planning for future needs.

In 2010 through 2011, an emergency water interconnection between Stafford County and Spotsylvania County was investigated in the vicinity of the Lake Mooney WTP and the Motts Run WTP. This interconnection was further evaluated during this Master Plan and would enable the transfer of treated water from one locality to the other at up to 5 to 10 mgd. This project would greatly increase Stafford County's capability to transfer treated water to or from Spotsylvania County on an emergency basis and will enhance reliability to each locality's water system. The localities are currently limited to a transfer capacity of approximately 1.5 mgd through the existing Chatham and Falmouth interconnection with the City of Fredericksburg. At the time the project was developed in 2011, Stafford and Spotsylvania were each expected to cover 40% of the project cost and Fredericksburg was expected to cover the remaining 20% of the cost. Stafford County portion (40%) of the overall cost of the regional interconnection is approximately $6 million. The cost sharing arrangement may be revisited if the interconnection project is implemented.

4.4 RAW WATER SUPPLY IMPROVEMENTS

4.4.1 Need for Additional Water Supply

The sustainable yield of the existing raw water system is primarily limited by the available storage in the Lake Mooney and Smith Lake Reservoirs. Under anticipated growth rates, the existing raw water supply is expected to meet Stafford's raw water needs until roughly 2045, when the anticipated average day demand of 17 mgd will exceed the safe yield of the existing reservoirs. The community will then become increasingly vulnerable to drought-related water shortages, but the timing and degree of that risk will depend on the rate of growth in demand. Managing those demands and providing additional water supply capacity will reduce risks.

Existing supplies are expected to meet the County's needs through 2045, but numerous factors could cause DPW's water supply to fall short of what is required. These factors may include, but are not limited to, the following:

- Further revisions to the safe yield calculations.
- A drought more severe than the critical drought could occur.
- Residential population or employment increases could exceed projected estimates.
- Water conservation programs could fall short of their goals or per capita demand could exceed the projections.
- Quantico Marine Corps Base could request more water than projected.
- A water intensive industry could locate in Stafford.
- Customer water use patterns could change.

4.4.2 Potential Additional Water Supply Sources

The average day buildout demand is projected to be 22.7 mgd. The available safe yield (17 mgd) is expected to be sufficient to meet water demands through about 2045. The County could consider the following options (at a minimum):

- Potomac River Intake (Unlimited).
- Rappahannock River Intake below Fall Line (Unlimited).
- Groundwater.
- Vulcan Quarry (3.2 mgd).
- Abel Lake Reservoir (4 mgd).
- Water recycling.

A brief description and summary of the advantages and disadvantages of each option follows.

- Potomac River Intake. A water intake on the Potomac River would provide an almost unlimited supply of water. However, a high degree of water treatment would have to be provided due to the salt content of the river during droughts, and this source is miles away from the County's existing water treatment and distribution system. As improvements in treatment technology (i.e., reverse osmosis membranes) are made and if the County growth expands towards the Potomac River, this option could become more viable in the future.
- Rappahannock River Intake below Fall Line. A water intake on the Rappahannock River below the Fall Line could provide an almost unlimited supply of water. The water could be treated at either a new water treatment facility adjacent to the intake or it could be pumped to the Lake Mooney Reservoir. Permitting issues exist under current regulatory agency requirements (including several wastewater treatment facilities that discharge to this section of the river). An unknown is the risk of high salt content during a drought.
- Groundwater. Groundwater from the Middle Potomac aquifer could be a viable option that would require multiple well fields spread out over a large area east of the existing service area. The amount of groundwater available could be limited by the groundwater concerns in the Coastal Plain

Aquifer (i.e., declining water levels, salt water intrusion, and subsidence and loss of storage). The area east of I-95 in Stafford County is located in Virginia's Groundwater Management Area (GWMA) that was established in 2014. The Eastern Virginia Groundwater Management Advisory Committee was established in 2015 and is developing, revising, and implementing a management strategy for groundwater in the Eastern Virginia Groundwater Management Area.

- Vulcan Quarry. This option considers construction of a pumping station at the quarry and a 12-inch or 16-inch bi-directional raw water main from the Vulcan Quarry along Garrisonville Road to Smith Lake WTP (3.5 miles). This configuration would allow the County to pump storage directly from the quarry to the WTP if Smith Lake Reservoir or raw water facilities were offline for maintenance or an emergency or if storage was needed during a drought. This storage would also likely not be subject to the release requirements downstream of Smith Lake if it was pumped directly to Smith Lake WTP. In addition, water could be pumped directly from Smith Lake through the proposed pipeline to the quarry when Smith Lake is full and spilling water downstream and the quarry needs to be refilled. There is a proffer for the Vulcan Quarry that requires the owner of the quarry to provide the quarry to the County in 2035. The owner and the County are currently discussing options to continue mining through 2055. Using the quarry as supplemental storage for Smith Lake could increase the safe yield by about 3.2 mgd assuming 2 BG of storage in the quarry. The cost is estimated at approximately $5 million for raw water pumping station and 16-inch raw water main from Vulcan Quarry to Smith Lake WTP. This option has the advantage of being close to the existing customer water demands and the Smith Lake Water Treatment Plant.
- Abel Lake. This option considers transferring raw water from Abel Lake through a 16-inch raw water main directly to the Lake Mooney WTP (approximately 6 miles). For Abel Lake, the 1991 study identified that the usable storage volume was estimated to be 1,140 MG and dead storage is approximately 25% of the existing total storage (1,512 MG) or 370 MG. The safe yield for Abel Lake based on the period of record (1/1/30 – 12/27/16) and 60 days of reserve storage is approximately 4 mgd. Water from Abel Lake could be used to supplement yields from Lake Mooney Reservoir during drought conditions or if the County has Lake Mooney raw water facilities offline for maintenance. Pumping water directly from Abel Lake to Lake Mooney WTP would likely mean that this storage would not be subject to the release requirements downstream of Lake Mooney and would not impact the ability to withdraw water from the Rappahannock River to refill Lake Mooney during drought conditions. The cost is approximately $5.8 million for Abel Lake Dam upgrades, which are currently in design, and $8.7 million for raw water pumping station and 16-inch raw water main from Abel Lake to Lake Mooney WTP.
- Water Recycling. As technologies continue to improve, the recycling of treated wastewater for use as a water supply source becomes more feasible. For example, discharges from the Aquia Wastewater Treatment Facility could be treated with advanced technology, such as membranes, and pumped to Smith Lake Reservoir (roughly 3 miles). Again, current Virginia Department of Health regulations would not allow this practice. This may change in the future due to advancements in treatment and additional research into the recycling of wastewater flows.

4.5 RESERVOIR WATER QUALITY

The County's water comes from Lake Mooney and Smith Lake Reservoirs. As water passes over land and through the ground toward the reservoirs, it may dissolve minerals and pick up substances resulting from the presence of animals or from human activity. By the time it gets to the reservoirs, it may contain microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, storm water runoff, industrial or domestic wastewater discharges, and other sources. To ensure that tap water is safe to drink, EPA prescribes regulations that limit the amount of certain contaminants in water provided to public water systems.

In 2002, the Virginia Department of Health (VDH) conducted an assessment of Smith Lake Reservoir to determine how susceptible it is to contamination. An assessment of Lake Mooney and the Rappahannock River has not yet been completed by VDH. Since there are industrial, commercial, agricultural and residential land uses in the watersheds for both reservoir and these reservoirs are open to the environment, they are considered to be susceptible to contamination.

Through a combination of source water protection and treatment technology, Stafford is committed to multiple-barrier practices of ensuring drinking water quality. Stafford's source water protection efforts include a variety of techniques and programs to keep pollutants out of the water supply reservoirs.

4.6 KEY FINDINGS

- The existing raw water reservoirs have enough storage capacity to provide a combined safe yield of approximately 17 mgd (11.9 mgd for Lake Mooney and 5.1 mgd for Smith Lake) based on the critical drought of record.
- The current raw water system's safe yield (17 mgd) will satisfy projected customer demands through approximately 2045.
- When the County's demands exceed the safe yield of 17 mgd, there are several water supply options that may be viable to meet the County's projected water demands through buildout. The most promising water supply options include the following:
  - Approximately $8.7 million for raw water pumping station and 16-inch raw water main from Abel Lake to Lake Mooney WTP.
  - Approximately $5 million for raw water pumping station and 16-inch raw water main from Vulcan Quarry to Smith Lake WTP.
- The cost for the raw water supply improvements presented in this Master Plan in the near-term (FY2019 - FY2028) is approximately $12 million. This cost includes the following:
  - $6 million for Abel Lake Dam upgrades.
  - $6 million for the regional interconnection between Stafford County and Spotsylvania County.
- The County is budgeting an additional $9 million to cover the cost for development of the Abel Lake option to meet long-term needs (beyond 2045).
- The overall cost for the raw water supply improvements presented in this Master Plan through the buildout condition is approximately $21 million.

4.7 PLAN OF ACTION

- DPW will continue to investigate methods to reduce the per capita use of water.
- DPW will continue to investigate long-term water supply options.
- DPW will continue to monitor and safeguard water quality in the water supply reservoirs.
- DPW will continue the commitment to multiple-barrier practices for ensuring drinking water quality.

4.8 RECOMMENDED WATER SYSTEM IMPROVEMENTS

AL-001: Abel Lake Dam Upgrades

Abel Lake was until recently one of two sources of raw water used by DPW. Water from Abel Lake was treated at the Abel Lake WTP. The Abel Lake WTP was decommissioned when Lake Mooney WTP went into operation in December 2014. The yield from Abel Lake will be needed to meet buildout water demand projections, and as a result, DPW plans to retain this asset. The dam that creates Abel Lake is does not comply with current dam safety design standards. This project includes improvements to the dam such that it is compliant with current standards. Consulting engineers were engaged in 2017 to assess alternatives for the dam upgrades, and the costs shown here may be revised based on the outcome of the ongoing evaluation. Construction is expected to be deferred, if possible, to FY2023 while external funding sources are explored.

Priority	*2 - Necessary (for capacity to meet buildout water demands)*
Design	*FY2023*
Construct	*FY2023*
Total Project Cost	*$6,000,000*

RWI - 001: Regional Water Supply Interconnection

This project involves an emergency water interconnection with Spotsylvania County in the vicinity of the Rocky Pen Run Water Treatment Facility and the Motts Run Water Treatment Facility. This will enable the transfer of treated water from one locality to the other at up to 5 to 10 MGD. Stafford and Spotsylvania are expected to each cover 40% of the total project cost, and Fredericksburg is expected to cover the remaining 20% of the cost. This CIP project is for Stafford's 40% of the total cost. The project will greatly increase the County's capability to transfer treated water to or from Spotsylvania on an emergency basis and will enhance the reliability of each locality's water distribution system. The County is currently limited to a transfer capacity of approximately 1.5 mgd through the existing Chatham and Falmouth interconnections with the City of Fredericksburg.

Priority	*2 - Necessary (reliability)*
Design	*FY2023*
Construct	*FY2024*
Total Project Cost	*$6,000,000*

AL-001: Abel Lake Raw Water Transfer to Lake Mooney

Abel Lake was until recently one of two sources of raw water used by DPW. Water from Abel Lake was treated at the Abel Lake WTP. The Abel Lake WTP was decommissioned when Lake Mooney WTP went into operation in December 2014. The yield from Abel Lake will be needed to meet buildout water demand projections, and as a result, DPW plans to retain this asset. This project includes construction of a new raw water pumping station at Abel Lake and a new 16-inch raw water main from Abel Lake to Lake Mooney WTP (approximately 5.5 miles).

Priority	*2 - Necessary (for capacity to meet buildout water demands)*
Design	*Beyond FY2028*

Construct	*Beyond FY2028*
Total Project Cost	*$9,000,000*

TECHNICAL MEMORANDUM 5

Water Treatment

Prepared for: Stafford County Department of Public Works
Prepared by: O'Brien & Gere
Date: February 2018

This technical memorandum is one of a series being prepared for the Stafford County Water and Sewer System Master Plan project. The purpose of this technical memorandum is to summarize information for DPW's existing water treatment plants and to present recommendations for capital improvements to enhance system operations and performance, to accommodate for future growth and development, and to maintain system reliability and redundancy.

CONTENTS

5.1 REVIEW OF LAKE MOONEY AND SMITH LAKE WTPS

The contents of this memorandum reflect input from a work session held at Stafford County on August 29, 2017, and information from the Preliminary Engineering Report (PER) for the Rocky Pen Run Water Treatment Facility, April 2007, by CH2MHILL, which was approved on 6/12/2009 by Hugh Eggborn of the Virginia Department of Health.

Lake Mooney WTP

Meeting notes based on discussions with Matt Sauter, WTP Superintendent

- Plant layout allows expansion to 20-25 MGD. This agrees with the PER: 20 MGD winter and 25 MGD summer.
- WTP has been in operation since December 2014 (almost 3 years).
- Water Quality
  - Manganese. Mn reached levels of 1 mg/l when WTP started-up, and reservoir was filling. At that time, the lower gate on the reservoir intake was being used. Plant had difficulty removing all manganese. Now that reservoir is full, the upper intake gate is used, and the highest Mn level appear to be around 0.2 mg/l. The maximum levels have been occurring in Spring. Operators use potassium permanganate to oxidize Mn.
  - Algae. Algae was an issue in the reservoir last year. WTP removed algae, but noticeable taste/odor in drinking water. Operators used EarthTec (liquid copper sulfate) to treat the lake (treat front 60 acres of reservoir), which was effective at controlling algae and taste/odor. Operators start treating the reservoir at the end of March then fed every 2-4 weeks.
  - Organics/DBPs. Raw TOC around 4-5 mg/l. WTP achieving up to 60% removal of TOC. Matt reported no significant concerns over DBP's. 2016 WQ report (system-wide, not necessarily related to Lake Mooney WTP) shows: TTHMs ranging from 25-79 ppb, and the highest 4 quarter LRAA was reported at 73 ppb, versus a SDWA limit of 80 ppb. HAAs ranging from 15-45 ppb, and the highest LRAA was reported at 41 ppb, versus a SDWA limit of 60 ppb. 2015 WQ report shows TTHMs ranging from 22-114 ppb, and the highest four quarter LRAA was reported at 67 ppb, versus a SDWA limit of 80 ppb and HAAs ranging from 13-58 ppb, and the highest LRAA was reported at 32 ppb, versus a SDWA limit of 60 ppb.
  - Disinfectant. Adding ammonia at plant after clearwell to create combined residual.
  - Lead and Copper. No lead or copper issues.
- Raw Water Pumps. Three pumps capacity of approximately 8 MGD/pump. Space for 1 more pump.
- Permanganate Contact Tank. There is one tank that provides approximately 15 minutes of contact time at 15 MGD for potassium permanganate to oxidize raw water manganese. There is space for a second tank.
- Raw Water Flash Mixing. Coagulants do not evenly split to match flows through the two flash mixers. Need 2nd feed pump to allow for equal feed to both raw water mixers.
- SuperPulsators. 3 trains, normally all in service. Working well. PER states design for 3.3 MGD with maximum of 5.0 MGD per train. Matt considers the reliable capacity at 4 MGD per train. For 12.5 MGD net, SuperPulsators would need to process approximately 13.1 MGD, which equates to 4.4 MGD each train. County will look for start-up records to see if the maximum capacity (5 MGD/train) was demonstrated. Pending documentation of the start-up tests, or a new "stress test", OBG will use the

PER design criteria, 12.5 MGD net production capacity, which equates to 4.4 MGD/train of SuperPulsators.

- Membrane Feed Pumps. Four pumps. Pump capacity (per design point) is 2900 gpm each with a firm capacity is 12.52 MGD and total connected capacity is 16.69 MGD.
- Membranes. Pall membranes. Five skids (aka racks), with 94 cassettes installed in each rack. Current capacity based on Pall membrane document is 7.66 MGD winter at flux rate of 45 GFD and 4 racks in service and 9.63 MGD summer at flux rate of 58 GFD and 4 racks in service. OBG assumes the above would be reduced by the backwash volumes, to derive the net capacity. A total of 44 modules can be added per rack. At the above flux rates, this would increase capacities up to 11.15 MGD winter and 14.1 MGD summer. Note that current membrane feed pumps have firm capacity of 12.5 MGD. Anticipate membrane replacement in about 7 more years (10 years operation).
- High Service HLPS. High Service pumping is controlled by Celebrate Virginia water storage tank. Three pumps at approximately 4.1 MGD each.
- Low Service HLPS. Pumping is controlled manually. Three pumps at approximately 4.1 MGD each at 80% speed.
- Waste/Residual Treatment. WTP has one thickener and one centrifuge.
- Chemical Feed. Chemical systems were installed for buildout capacity. Use caustic to raise pH to 9.5-10 prior to permanganate contact chamber. Ferric sulfate is used as coagulant. Raw water pH is about 7. Manganese contact tank ~pH 9.5 to 10. After ferric sulfate addition pH is 5.5 to 6.
- Matt would like consideration for post-membrane treatment for manganese polishing, (e.g., using greensand contactors).
- Matt noted that coagulant feed rates (50-70 mg/l) were high in part because the ferric is fed in excess to drop the pH from approximately 9.5-10 to pH 6. This creates a lot of sludge and fully exhausts the alkalinity.
- Clearwell. One 2 MG nominal (1.5 MG usable) clearwell (according to PER) with space at the site for second clearwell.

Table 5.1.1 - Summary of the capacities of the Lake Mooney WTP treatment processes

	Raw Water Pumps	Permanganate Contact Tank	Super Pulsators	Membrane Feed Pumps	Current Membranes (94 cassettes per rack) (winter/Summer/Net Summer[4])	Membranes with full racks (add 44 cassettes per rack) (winter/Summer/Net Summer[4])	Clearwells (3 MG)	High Service HLPS	Low Service HLPS	Thickeners	Centrifuge
Trains or Units	3[1]	1[2]	3[2]	4[1]	5[2]	5[2]	1[2]	3[3]	3[3]	1[2]	1[1]
Capacity per Unit (MGD)	8.8	15	4.4	4.17	1.915/2.408	2.81/3.54		4.12	4.12		
Firm Capacity (MGD)	17.6		8.8	12.5	7.66/9.63/9.1	11.25/14.1/13.4		8.24	8.24		
Connected Capacity (MGD)	26.4		13.2	16.7	9.58/12.04	14.06/17.68		12.36	12.36		

Notes:

1. One open bay for additional unit
2. Plant layout has room for expansion to duplicate the process units
3. No spare pump bays at HLPS, assume replacement with larger pumps for additional capacity
4. Net summer capacity assumes 5% loss for backwash of membrane filters

Smith Lake WTP

Meeting notes based on discussions with David Raines, WTP Superintendent

- 7.7 MGD operating permit based on reservoir safe yield
- Design plant capacity 15 MGD and has produced up to 13 MGD in past
- Caustic feed on raw water
- Permanganate is fed year-round to raw water
- Ferric sulfate used as coagulant
- Chloramines used for disinfectant
- David noted some DBPs concerns. Have seen TTHM spikes in the past (see system-wide TTHM and HAA data above).
- No mixers in distribution system water storage tanks
- Potential Projects:

- Filter repair or replacement
- Replace vertical split case pumps
- Inspect electrical motor control center which is near the end of its useful life

Table 5.1.2 - Summary of the capacities of the Smith Lake WTP treatment processes

	Raw Water Pumps	Super Pulsators	Filters	Filtered water pumps	Clearwell	High Lift/Distribution pumps	Lagoon (backwsh water settling)
Trains/Units	3	2	2 trains; 4 filters per train		1	4	1
Capacity per Unit (MGD)	7.5	7.5	1.88			4.73	
Firm Capacity/Net Firm Capacity [3] (MGD)	15.0	7.5[1]	13.16[2]/12.5	17.5		14.2	
Connected Capacity (MGD)	22.5	15[1]	15.0			18.9	

Notes:

1. 2005 Operating Permit indicates plant rating based on both SuperPulsators in service
2. Based on one filter out of service for maintenance or backwashing
3. Net firm capacity assumes 5% loss for filter backwash

Table 5.1.3 - Summary of treatment capacities and requirements

	Average Day (MGD)	Maximum Day (MGD)[1]	Smith Lake WTP Net Firm Capacity	Lake Mooney WTP Net Firm Summertime Capacity	Total Firm Treatment Capacity	Surplus[2,3] Treatment Capacity
Current (MGD)	8.6	12.9	12.5	9.1	21.6	8.7
Near-Term (MGD)/full membrane cassettes	11.6	17.4	12.5	9.1/12.5[4]	21.6/25.0	4.2/7.6
Buildout (MGD)	22.7	34	12.5	25.0[6]	37.5	3.5

Notes:

1. Maximum day based on 1.5 times average day
2. Surplus capacity based on total net treatment capacity – maximum day demands
3. Above surplus does not consider safe yields. Safe yield is compared against average day demands.
4. Lake Mooney WTP net firm summertime capacity of 12.5 MGD is based on PER, which effectively equates to SuperPulsator capacity of 4.4 MGD per train and 5% loss for membrane backwash. Note that with full racks, the membranes would be 13.4 MGD net of membrane backwash, which exceeds the membrane pumps (12.5 MGD) and the SuperPulsators. The membrane pumps could be upsized, and then the lower capacity of the SuperPulsators would determine the rated capacity.
5. If SuperPulsator "stress test" confirms higher capacity or 4.7 MGD or more, the limiting capacity could be 13.4 MGD (membrane net).
6. Lake Mooney WTP net firm summertime capacity at build-out is estimated at 25.0 MGD, based on PER; doubling the anticipated SuperPulsator rated capacity of 4.4 MGD per train. With full racks, the membranes would be 26.8 MGD net of membrane backwash, which exceeds the membrane pumps (25 MGD) and the SuperPulsators (25 MGD). The membrane pumps could be upsized, and then the lower capacity of the SuperPulsators would determine the rated capacity. If SuperPulsator "stress test" confirms higher capacity or 4.7 MGD/train, the Lake Mooney WTP buildout could be up 26.8 MGD (membrane net). Pending the "stress test" of SuperPulsators and membranes, OBG will use the PER ratings of 10.0 MGD winter/12.5 MGD summertime for the capacity of the existing WTP after filling all membrane cassettes, and 20.0 MGD winter/25.0 MGD summertime for the capacity of the expanded WTP, with all membrane cassettes. These net production rates rely on Pall's anticipated flux rates for the membranes, and SuperPulsator rates of 4.4 MGD per train, to allow for 5% loss in filter backwashing/cleaning.

5.2 PRELIMINARY FINDINGS

- Based on the net firm capacity of 12.5 MGD at Smith Lake WTP and net firm, summertime capacity of 9.1 MGD at Lake Mooney WTP, the total plant capacity of 21.6 MGD provides a surplus of approximately 4.2 MGD compared with "Near-Term" maximum day capacity requirement of 17.4 MGD.
- If the membrane cassettes were filled out, the net summertime membrane capacity could increase up to 13.4 MGD, at which point the limiting process at Lake Mooney WTP would be the SuperPulsators, at 12.5 MGD. That would increase combined treatment capacity to 25 MGD, and increase the near-term surplus to approximately 7.6 MGD. This rating should be confirmed by a full-scale demonstration ("stress test") of both SuperPulsators and membranes.
- If Lake Mooney WTP is expanded, with duplication of the treatment trains, the limiting process would be the SuperPulsators at 25 MGD. That would increase total net treatment capacity (both WTPs) to 37.5 MGD, providing a surplus of approximately 3.5 MGD over projected maximum day at buildout conditions.

- Distribution of finished water: Historically, about two-thirds of treatment occurred at Smith Lake WTP and one-third at Abel Lake WTP. The current production split is still about two-thirds at Smith Lake WTP and one-third at Lake Mooney WTP. As the County grows, and Lake Mooney WTP expands, the split will shift to nearly two-thirds at Lake Mooney WTP and one-third at Smith Lake WTP. This is aligned with the future increase in water use in the southern part of the County, and the recommendations for water distribution system buildout.

5.3 PROPOSED NEAR-TERM AND LONG-TERM IMPROVEMENTS

Based on a review of the water treatment plants, the following potential detailed evaluations and improvements are identified to improve reliability and water quality in the near-term (next ten years).

- **Water quality evaluations**: The two primary water quality issues identified to-date are manganese at Lake Mooney WTP and TTHMs in the distribution system. More detailed evaluations of both issues are recommended to:
  - Identify whether manganese can be adequately controlled via operational enhancements, or whether a capital investment is needed for post-membrane treatment.
  - Identify how to lower TTHM levels to below 64 ppb, to provide a 20% buffer below the SDWA LRAA limit of 80 ppb. This may involve optimizing disinfection, accelerating ammonia feed, improving organics removal, and/or distribution system management techniques.
- **Treatment capacity evaluations**: Conduct a full-scale performance test to determine maximum reliable treatment capacity of existing Lake Mooney WTP. This may involve isolating one SuperPulsator and two membrane racks and push to (or beyond) Pall's recommended flux rates by treating up to 5 MGD.
  - Treatment optimization - Conduct bench and potentially full scale tests to reduce ferric dosage and resulting sludge quantities. This could involve a lower pH (lower than pH 10) for permanganate contact and/or different oxidants that are less pH sensitive.
- **Lake Mooney WTP: Potential CIPs –** The $24M item in current CIP is for expansion. The above analysis demonstrates that this expansion can be deferred, but the following investments should be considered in the 10-year CIP:
  - Install second thickener tank - This redundancy will allow a thickener to be taken offline for maintenance without impact to plant operation. ***(Reliability)***
  - Install second centrifuge - This redundancy will allow a centrifuge to be taken offline for maintenance without impact to plant operation. ***(Reliability)***
  - Install second clearwell - This redundancy will allow a clearwell to be taken offline for maintenance without impact to plant operation. ***(Reliability)***
  - Install second permanganate contact tank - This redundancy will allow the existing contact tank to be taken offline for maintenance without impact to plant operation. ***(Reliability)***
  - Membrane cassettes - Add a CIP placeholder for replacing the existing membrane cassettes in 2024, at the point when the membranes are approximately 10 years old. ***(Maintenance)***
  - Membrane cassettes - Add membrane cassettes, up to the full capacity of each rack, if the County wants to increase surplus water up to the maximum possible without a plant expansion. ***(Capacity)***

- **Smith Lake WTP: Potential CIPs** - This plant is approaching 30 years, and it would be appropriate to include CIP placeholders for expected repairs or replacements of critical equipment and facilities, such as:
  - Filter repair or replacement - Several filters have cracked underdrains which is causing loss of media. Filters need to be either repaired or replaced. Need to determine whether this is already funded in O&M budget, or whether it should be added to the CIP. Repair may be adequate to address cracked underdrains, but replacement may be required to increase backwash rate to recommended 20 gpm/sf (currently 15 gpm/sf). ***(Maintenance)***
  - UV disinfection - May want to consider adding UV disinfection post filter, and minimize the need for free chlorine disinfection, to reduce DBP formation before adding ammonia. ***(Water Quality)***
  - Replace vertical split case pumps - These pumps are difficult to maintain. Pumps could be replaced with vertical can pumps. ***(Maintenance)***
  - Motor control center - Inspect electrical motor control center, which is near the end of its useful life, and repair or replace if needed. ***(Maintenance)***
- Rappahannock River raw water pumping station – At the work session, it was noted that there is a question as to the actual capacity of the river pumping station. It was designed for 40 MGD, but DPW reports that measured flows are 32 MGD. There is question whether flow measurement is accurate, but if so, DPW needs to resolve to realize full safe yield.

A more detailed description of each proposed project follows.

LMWTP-001: Lake Mooney WTP - Install Second Centrifuge

DPW has identified several operations at Lake Mooney WTP that rely on the availability of a single process unit. In each case, the plant design has space for a second process unit, which was planned to be constructed when the plant was "builtout" to 25 MGD. However, the significantly lower demand projections presented in the 2018 Master Plan results in a deferral of the plant expansion for at least a decade and probably longer. DPW therefore plans to install the back-up units, including a second centrifuge, in the near-term. The centrifuge is used to dewater the plant's thickened residuals, so they can be disposed of off-site. The second centrifuge will allow the existing centrifuge to be taken off-line for maintenance, thereby enhancing reliability during unexpected events or operational disruptions.

Priority	*2 – Necessary (to improve reliability)*
Design	*FY2019*
Construct	*FY2020*
Total Project Cost	*$700,000*

LMWTP-002: Lake Mooney WTP - Install Second Thickener

DPW has identified several operations at Lake Mooney WTP that rely on the availability of a single process unit. In each case, the plant design has space for a second process unit, which was planned to be constructed when the plant was "builtout" to 25 MGD. However, the significantly lower demand projections presented in the 2018 Master Plan results in a deferral of the plant expansion for at least a decade and probably longer. DPW therefore plans to install the back-up units, including a second thickener, in the near-term. The thickener is used to settle and thicken the plant's backwash waste and clarifier blowdowns, so they can then be dewatered by the centrifuge(s). The second thickener will allow the existing thickener to be taken offline for maintenance, thereby enhancing reliability during unexpected events or operational disruptions.

Priority	*2 – Necessary (to improve reliability)*
Design	*FY2021*
Construct	*FY2022*

Total Project Cost	*$620,000*

LMWTP-003: Lake Mooney WTP - Add Membrane Cassettes to Increase Summertime Rating to 12.5 MGD

The existing capacity of Lake Mooney WTP and Smith Lake WTP (combined approximately 21.6 MGD) will meet projected consumer demand well into the planning period. Based on the County's growth projections, no expansion of WTP capacity would be required through 2030, unless the County decides to sell its otherwise surplus water to a neighboring utility(s). When more treatment capacity is needed, DPW would first add additional membrane cassettes at Lake Mooney WTP. This would be a relatively economical expansion, because the Lake Mooney WTP was designed to require only the addition of membrane cassettes (220 cassettes) to increase its summertime rating from 9.1 MGD to 12.5 MGD (adds about 3.4 MGD).

Priority	*1 – Critical (to increase capacity for projected growth)*
Design	*Beyond FY2027*
Construct	*Beyond FY2027*
Total Project Cost	*$780,000*

LMWTP-004: Lake Mooney WTP - Long-term Expansion to 25 MGD

To meet build-out demands estimated at 34 MGD, DPW would first add the additional membrane cassettes at Lake Mooney WTP (LMWTP-003), and then implement the long-term planned expansion at Lake Mooney WTP (this project) via duplication of the treatment trains and clearwell, to achieve 25 MGD net firm summertime capacity at Lake Mooney WTP. That would increase total net treatment capacity to 37.5 MGD (25 MGD at Lake Mooney WTP + 12.5 MGD at Smith Lake WTP), providing approximately 10% more capacity than projected maximum day water demands at buildout conditions.

Priority	*1 – Critical (to increase capacity for projected growth)*
Design	*Beyond FY2027*
Construct	*Beyond FY2027*
Total Project Cost	*$48,000,000*

LMWTP-005: Lake Mooney WTP - Water Treatment Optimization Studies

DPW is committed to providing excellent quality drinking water, and anticipates that the USEPA will continue to enact more stringent standards and regulations governing drinking water quality. While the County's drinking water meets all current requirements of the Safe Drinking Water Act (SDWA), this project would assess how DPW can address challenges related to these drinking water constituents:

- **Disinfection by-products** - Disinfection by-products are formed when chlorine, the primary disinfectant, is added to water containing naturally occurring organic materials that derive from plant decay. In the quest for even better water quality, DPW is assessing means for lowering THMs so they are more comfortably below the current maximum contaminant limit (MCL).
- **Manganese** – Manganese is a naturally occurring inorganic compound for which there is currently no primary (health-based) MCL, but for which there is a secondary (aesthetic) standard of 0.05 mg/l, based on its ability to discolor water and stain laundry and plumbing fixtures. At Lake Mooney, manganese levels were relatively high as the lake filled for the first time, and there were some episodes where manganese levels exceeded the secondary standard. As the lake matures, it appears that manganese is becoming more predictable, and the plant has consistently removed it. However, as a proactive measure, DPW is assessing means for even more reliably controlling manganese, in order to consistently meet customer expectations for excellent water quality.
- **Algal toxins** – Highlighted by the algal bloom in 2014 near Toledo, Ohio, algal toxins are considered an emerging contaminant. USEPA will require large water systems, such as Stafford County, to monitor for 10 algal toxins beginning in 2018 as part of its Unregulated Contaminate Monitoring Rule 4 (UCMR4). USEPA may issue enforceable MCLs for some of these algal toxins in the future. Lake Mooney has experienced algal blooms in its first few years of existence, but to-date, there is no evidence for the presence of microcystis, the type of algae that produce the algal toxin, microcystin. DPW has implemented operating procedures that have apparently controlled the proliferation of algae in Lake

Mooney. However, as a proactive measure and in anticipation of potential future SDWA requirements, DPW will expand its laboratory analyses to monitor for algal toxins.

To meet anticipated future SDWA regulations and customer expectations for excellent water quality, DPW will undertake this study to evaluate potential improvements at the Lake Mooney WTP to enhance its management of disinfection byproducts, manganese, and algal toxins.

Priority	*2 – Necessary (to address water quality objectives)*
Study	*FY2020*
Design/Construct	*TBD (see LMWTP-006, Future treatment process upgrades)*
Total Project Cost	*$500,000*

LMWTP-006: Lake Mooney WTP - Future Treatment Process Upgrades

To meet anticipated future SDWA regulations and customer expectations for excellent water quality, DPW will undertake studies (LMWTP-005: Lake Mooney WTP: Water treatment optimization studies) to evaluate potential improvements at the Lake Mooney WTP. Depending on the results of these studies, and the enactment of more stringent water quality standards, DPW would design and construct upgrades to the water treatment processes at Lake Mooney WTP. The scope and cost of these upgrades is yet to be determined, and this project is considered a "placeholder", recognizing that some level of investment in water treatment processes is likely.

Priority	*2 – Necessary (to address water quality objectives)*
Design	*Beyond FY2027*
Construct	*Beyond FY2027*
Total Project Cost	*$16,000,000*

LMWTP-007: Lake Mooney WTP - Replace membrane cassettes (at 10 years of operation)

Lake Mooney WTP went into operation in December 2014. The membrane cassettes which are a key part of the filtration process have an expected useful life of about 10 years. DPW has therefore programmed the replacement of the existing membrane cassettes when they reach 10 years of operation.

Priority	*1 – Critical (to maintain rated treatment capacity)*
Design	*NA*
Construct	*FY2025*
Total Project Cost	*$1,500,000*

SLWTP-001: Smith Lake WTP - Filter repairs

Smith Lake WTP has experienced failures in the existing filter underdrains. The failures have been investigated, and it has been determined that the filters must be repaired in order to maintain rated plant capacity and to achieve water quality objectives.

Priority	*1 – Critical (to maintain rated treatment capacity)*
Design	*FY2018*
Construct	*FY2019*
Total Project Cost	*$4,650,000*

SLWTP-002: Smith Lake WTP - Facility upgrades

In addition to planning for more treatment capacity and excellent water quality, DPW is also committed to meeting its customer's expectations for a high level of reliability. The challenges here involve:

- Maintaining key assets, some of which are approaching their expected useful life, in good operating condition,
- Assuring there is adequate "stand-by" capacity and "factors of safety", to allow for planned and unexpected needs for maintenance and repairs, and implementing expansions in advance of when they are needed.

With respect to aging assets, Smith Lake WTP is now approaching 30 years of reliable operation. Most mechanical and electrical components at water treatment plants have useful lifetimes of 15 to 30 years. DPW has regularly maintained and (as needed) replaced equipment that is no longer functional. DPW expects the need for reinvestment into critical equipment at Smith Lake WTP to increase in the future. While a detailed condition assessment would be required to define and schedule renovations, as a placeholder, this project assumes the need to upgrade or replace electrical motor controls, instrumentation, and the finished water pumps at Smith Lake WTP.

Priority	*2 – Necessary (to address reliability)*
Design	*FY2022*
Construct	*FY2023*
Total Project Cost	*$3,100,000*

SLWTP-003: Smith Lake WTP - Water treatment optimization studies

As described above, (see LMWTP-005: Lake Mooney WTP - Water treatment optimization studies)

DPW is committed to providing excellent quality drinking water, and anticipates that the USEPA will continue to enact more stringent standards and regulations governing drinking water quality. There are similar water quality concerns that may arise at Smith Lake WTP and Lake Mooney WTP, involving disinfection by-products, manganese, and algae, most of which would be addressed under LMWTP-005. This task (SLWTP-003) is a companion project to LMWTP-005, that extends the water treatment optimization study to specific issues at Smith Lake WTP, primarily to address disinfection by-products at Smith Lake WTP.

Priority	*2 – Necessary (to address water quality objectives)*
Study	*FY2020*
Design/Construct	*BD (see SLWTP-004, Future treatment process upgrades)*
Total Project Cost	*$100,000*

SLWTP-004: Smith Lake WTP - Future treatment process upgrades

To meet anticipated future SDWA regulations and customer expectations for excellent water quality, DPW will undertake studies (SLWTP-003: Smith Lake WTP - Water treatment optimization studies) to evaluate potential improvements at the Smith Lake WTP. Depending on the results of these studies, and the enactment of more stringent water quality standards, DPW would design and construct upgrades to the water treatment processes at Smith Lake WTP. The scope and cost of these upgrades is yet to be determined, and this project is considered a "placeholder", recognizing that some level of investment in water treatment processes is likely.

Priority	*2 – Necessary (to address water quality objectives)*
Design	*Beyond FY2027*
Construct	*Beyond FY2027*
Total Project Cost	*$8,000,000*

TECHNICAL MEMORANDUM 6

Finished Water Pumping, Storage and Distribution Facilities

Prepared for: Stafford County Department of Public Works
Prepared by: O'Brien & Gere
Date: February 2018 (revised May 2018)

This technical memorandum is one of a series being prepared for the Stafford County Water and Sewer Master Plan project. The purpose of this technical memorandum is to summarize the performance of DPW's existing finished water pumping, storage and distribution facilities and to present recommendations for capital improvements to enhance system operations and performance, to accommodate for future growth and development, and to maintain system reliability and redundancy.

CONTENTS

6.1 DPW'S EXISTING AND FUTURE WATER SYSTEM

6.1.1 Overview of DPW's Water System

The Stafford County water distribution system includes two ground-level water storage tanks, six major water pumping stations, 12 elevated water storage tanks, and approximately 617 miles of pipes ranging in size from 4 to 30 inches in diameter. The most common pipe materials in the water distribution system are ductile iron pipe (DIP), cast iron pipe (CIP), asbestos-cement (A-C) pipe, or polyvinyl chloride (PVC) pipe.

The County's current and future water distribution system is divided into pressure zones essentially extending east and west from the Interstate 95 corridor:

- 310 Zone in the northeast portion of the County
- 433 Zone in the north-central portion of the County
- 450 Zone in the northwest portion of the County (to be merged with 472 Zone in future)
- 472 Zone in the northwest portion of the County
- 370 Zone in the central portion of the County
- 342 Zone in the southeast portion of the County (eliminate 320 Zone)
- 480 Zone in the south-central portion of the County
- 410 Zone in the southern portion of the County
- 520 Zone in the southwest portion of the County (future).

DPW has two raw water supply reservoirs: Smith Lake and Lake Mooney in the northern and southern portions of the County, respectively. Each of the water supply reservoirs has a water treatment facility adjacent to it. Although the water distribution system is interconnected, it is currently operated as essentially two separate service areas.

In general, finished water is pumped from the clearwells of the Smith Lake and Lake Mooney WTP's to the distribution system as follows:

- Smith Lake WTP supplies five zones with hydraulic grade lines of 310, 370, 433, 450 and 472 feet. Water from Smith Lake WTP clearwells is pumped to a 3.3 MG ground level water storage tank. Water from the 3.3. MG water tank near Smith Lake WTP is pumped to the 310 Zone and boosted from the 310 Zone to the 433 Zone through the Moncure Pumping Station. Water from the 433 Zone is boosted to the 472 Zone through the Vista Woods Pumping Station.
- Lake Mooney WTP supplies water to four zones with hydraulic grade lines of 342, 410, 480 feet and 520 feet. Water from the Lake Mooney WTP is pumped directly to 342, 410 and 480 Zones and will be repumped to the 520 Zone from the 480 Zone by a proposed pumping station near the intersection of Cardinal Forest Drive and Warrenton Road. Note that booster pumping also occurs at the Abel Lake Tank which is a 4 MG ground level tank with an overflow elevation of 298 feet. Water is pumped from Lake Mooney WTP to the Abel Lake Tank and repumped to the 342 Zone through the Cranes Corner Pumping Station (also referred to as the Enon Road Pumping Station and located on the Abel Lake Tank site).

Figure 6.1.1 and 6.1.2 show the maximum day zone flow balances for near-term and buildout, respectively.

Figure 6.1.1 – Maximum Day Zone Flow Balance for Near-Term (2028) Conditions

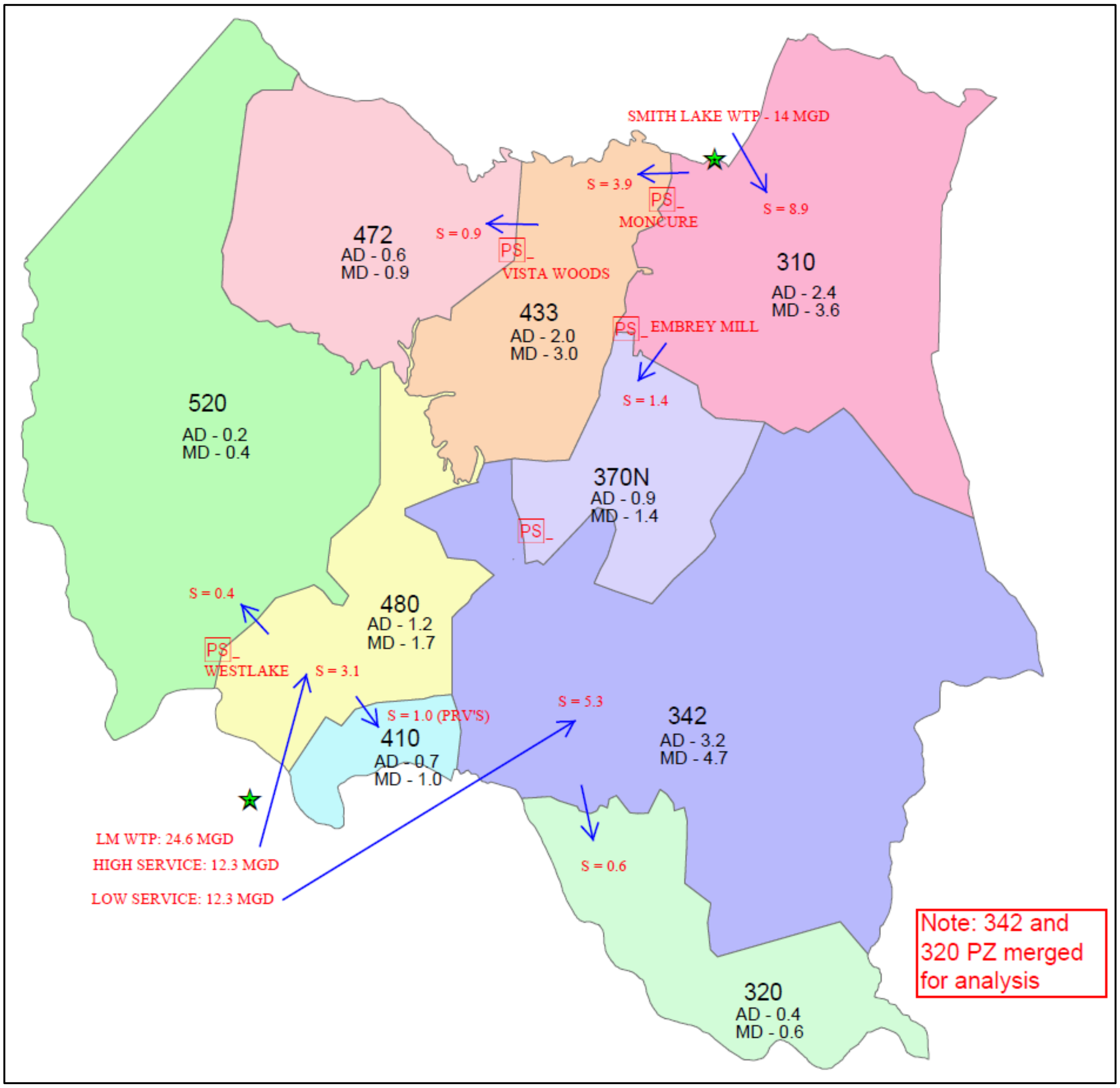
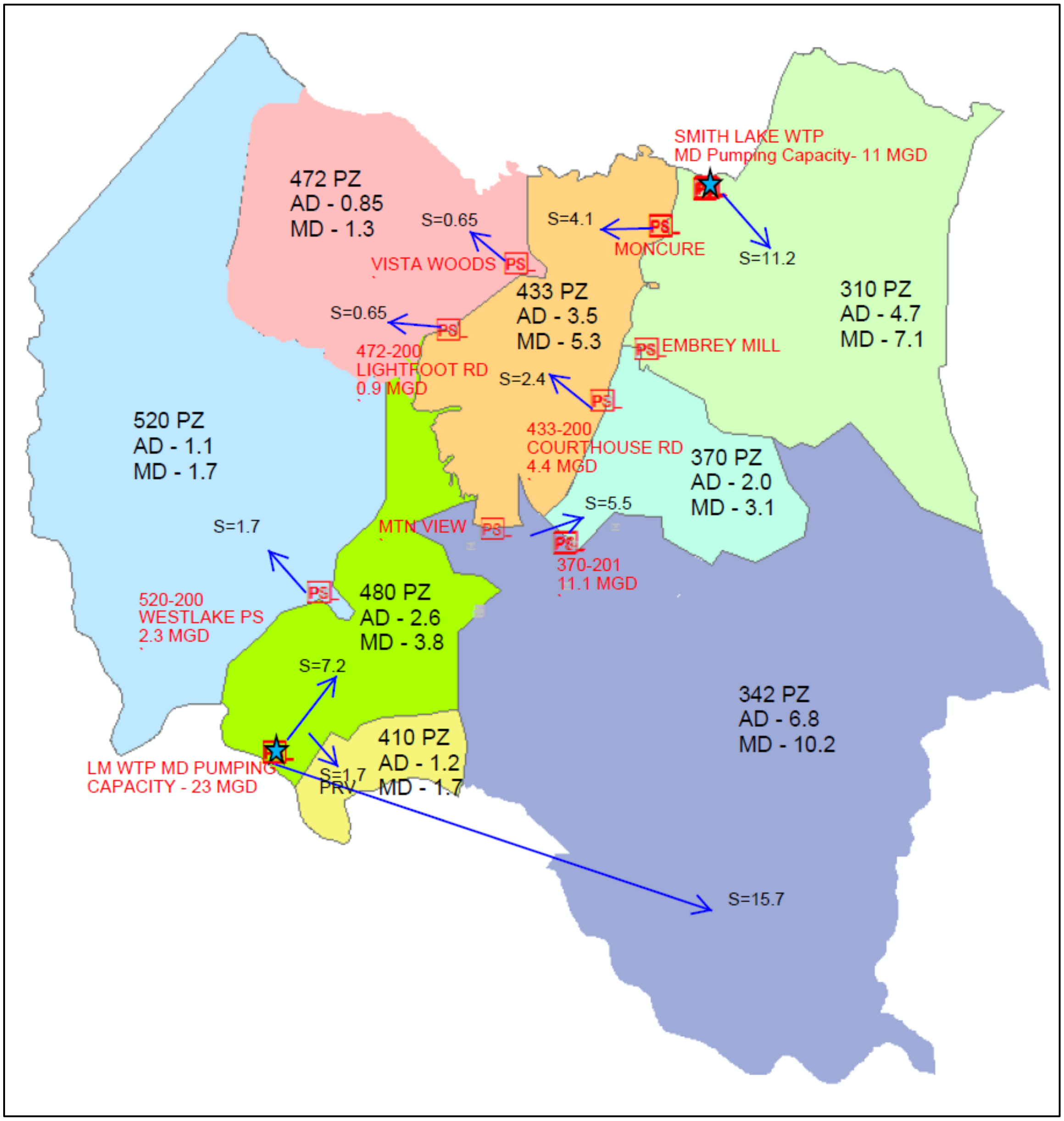


Figure 6.1.2 – Maximum Day Zone Flow Balance for Buildout (2060) Conditions



6.1.2 Water Transmission and Distribution Mains

The hydraulic model of DPW's water distribution and transmission system includes approximately 617 miles of pipes ranging in size from 4 to 30 inches in diameter. The key data for the pipes in the model include pipe name, upstream node, downstream node, cross-section type, pipe diameter, and pipe length. DPW provided this information from GIS which serves as the physical foundation for the model.

6.1.3 Pumping Station Data

DPW currently operates six major water pumping stations:

- Smith Lake
- Moncure
- Vista Woods

- Embrey Mill
- Lake Mooney
- Cranes Corner (also referred to as Enon Road)

Several pumping stations (Potomac Creek, M&M, and Mountain View Pumping Stations) are typically used for backup service.

The InfoWater model simulates the on/off operation of each individual pump, accounting for static and dynamic head and downstream losses. The data needed for physical pumps include pump on/off elevations and pump operating curves for each pump.

6.1.4 Finished Water Storage

There are currently 14 finished water storage facilities in the DPW distribution system. The characteristics of each tank are summarized in Table 6.1.1.

Table 6.1.1 – DPW distribution system storage facilities

Name	Zone Location	Maximum Water Level (ft)	Ground Elevation (ft)	Overflow Elevation (ft)	Volume (MG)
Stone River	310	140	172	312	2.00
Courthouse	310	60	250	310	0.25 (new tank 1 MG Spring 2018)
Midway	310	86.1	227	313.1	0.20
Moncure	310	108.5	211.5	320	0.75
Shelton Shop	433	95	338	433	1.375
Amyclae	433	155.3	282	437.3	1.50
Vista Woods	472	163.5	308.5	472	0.50
Cranes Corner	342	119	223.5	342.5	0.20
Bandy	342	122.3	219	341.3	0.15
Grafton	342	124	196.4	320.4	1.00
Celebrate VA	480	131	349	480	1.00
Abel	342 (pumped)	34	264	298	4.00
Smith Lake	310	44	71	114.75	3.22
Lake Mooney	342/480 (pumped)				3.00

6.2 UPDATE AND CALIBRATION OF WATER SYSTEM MODEL

A functional, calibrated model was used to assess the performance of DPW's water distribution and transmission system. The hydraulic model can be used to better understand and assess the capabilities of the DPW's system by simulating and identifying hydraulic limitations – low pressures and fire flow limitations – within the system under specified demand conditions. It is important to note that the model calibration has been ongoing since 2003 using data collected in the field during operation and maintenance activities. The model was initially calibrated in April 2003 by conducting field tests for pipe roughness and fire hydrant flow tests. Field testing and calibration of the water model was not performed for the 2018 water and sewer system master planning work.

The hydraulic model is a very valuable tool for DPW and will continue to be of value provided that the input files are maintained and updated as the distribution and transmission system expands and changes. This includes collecting additional data on demand conditions with varying characteristics and updating system piping. When used in conjunction with the other tools, such as GIS and SCADA, the model will serve as an integral part to the successful management and operation of the DPW distribution and transmission system.

6.3 REVIEW OF WATER DEMANDS AND NODAL ALLOCATION

Water systems are required to supply flow at rates that fluctuate over a wide range from day-to-day and hour-to-hour. Rates most important to planning, design and operation of a water system are average day, maximum (peak) day, maximum (peak) hour, and maximum hour plus fire flow.

- Average day demand is the total volume of water delivered to the system in a given year divided by the number of days in the year.
- Maximum (peak) day demand is the largest quantity of water supplied to the system on any day of the year.
- Maximum (peak) hour demand is the highest rate of flow for any hour in a year.
- Maximum day plus fire flow considers the possibility of a fire event under maximum day demand conditions.

Diurnal curves are frequently used to represent how water is used over time of day. Diurnal curves are different for each house, each industry and each water user. However, for the purpose of creating a model to represent a water distribution system, simplifications are generally made such that residential, commercial, industrial, and other water use classifications are each assumed to have consistent water demand (diurnal) curves.

Different demand patterns can be applied to individual water nodes or groups of nodes to accurately represent water use categories (e.g., residential, commercial, etc.). For this Master Plan, the diurnal data from the 2006 Master Plan was used to conduct the modeling analyses. Diurnal water demand patterns were developed and used for each pressure zone. Consequently, the average day demand at each water node was multiplied by the diurnal demand pattern for the pressure zone to predict the water use at the node throughout the day.

Average day water demands are expected to increase from approximately 8.6 mgd (2017) to 22.7 mgd under buildout (2060) conditions. During the same period, the maximum day demands are expected to increase from approximately 12.9 mgd (2017) to 34.1 mgd at buildout (2060) based on a peaking factor of 1.5 times the average day demand (Figure 6.3.1).

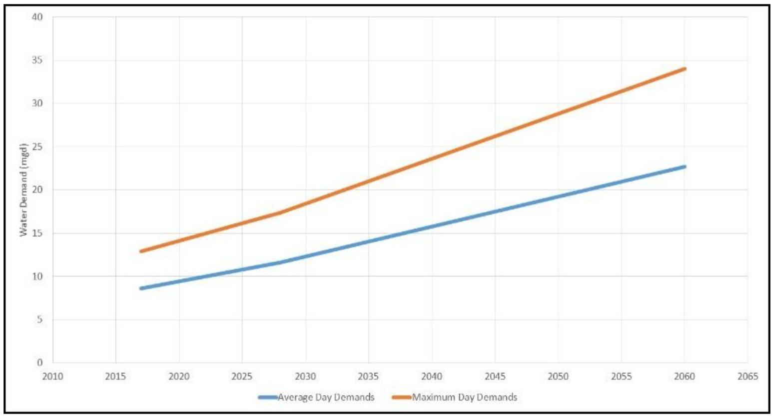


Figure 6.3.1 - Projected Water Demands

Demands in water systems vary throughout the day with peaks in the morning and evening and low flows in the early morning hours. Patterns are used to represent the daily temporal variations within the water system. They consist of a collection of multipliers (multiplication factors) that are applied to the daily demand to allow it to vary over time during an extended period simulation (EPS). Different patterns can be applied to individual nodes or groups of nodes to accurately represent water duties (e.g., residential, commercial, etc.). In 2003, diurnal demand curves were developed for each of the five existing pressure zones based on monitoring data collected over a period of several days. These diurnal curves are used in this 2018 Master Plan and are shown in Figure 6.3.2. The diurnal curves used for modeling each pressure zone are based on combined demand categories (i.e., separate diurnal curves for various land use types such as residential and commercial were not generated). The diurnal curves were based on average hourly factors (pattern timestep in model) over a 24-hour period (duration in model). The diurnal demand curve was considered to be uniform throughout the pressure zone. Consequently, average daily water demands at nodes in each pressure zone were multiplied by their respective diurnal demand curve to generate daily variations in water demand.

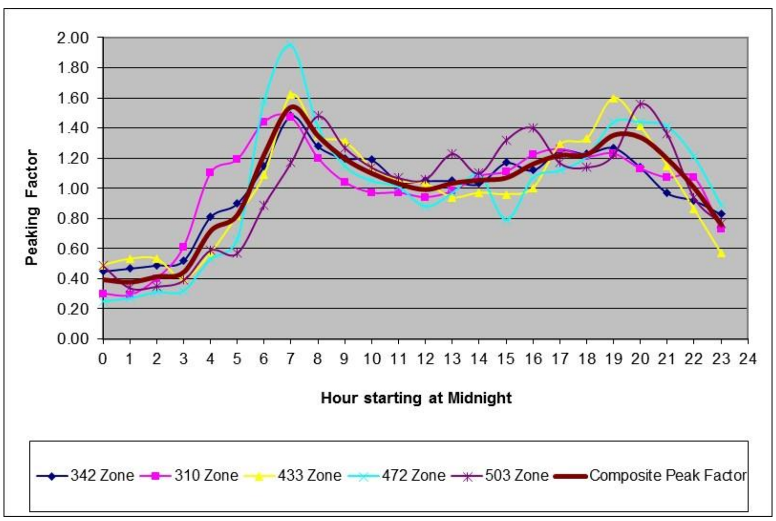


Figure 6.3.2 – Diurnal Demand Curves

6.4 OVERVIEW OF WATER SYSTEM PLANNING CRITERIA

Level of service refers to the adequacy and reliability of service provided to customers. Water utilities want to provide a safe, reliable supply of water at a reasonable level of service (and reasonable cost). A reasonable level of service can be defined in many ways, but it should generally include provisions for adequate pressure, fire protection, and reliability of supply:

- Adequate pressure can be defined in terms of the minimum pressure under specific consumption conditions. Water systems are commonly designed to provide adequate pressure during maximum hour or maximum day plus fire flow conditions.
- Adequate fire protection refers to providing adequate flow to meet specific flow requirements for fire fighting.
- Reliability refers to the consistency of supply with which water is delivered. Redundancy is provided by looping of water mains, extra pumps, additional reservoirs, and backup sources of supply. Looping

refers to providing a second feed to an area so that if one supply source is out of service, the other will still be available.

The performance of a finished water distribution system is judged by its ability to deliver the required flows while maintaining desirable pressure and water quality. Customer water demands and fire flow requirements must be met. Meeting these requirements depends upon the proper design and performance of distribution and transmission piping, elevated and ground storage tanks, and high service and booster pumping stations.

Planning and design guidelines vary from state to state and from utility to utility. While national organizations, such as the American Water Works Association (AWWA), provide some guidelines and many states regulate certain performance criteria, planning and design criteria are often left to the discretion of the water utility. In DPW's 2006 Water and Sewer Master Plan, the planning and design criteria proposed for use were compared with the criteria used by similar utilities in the region (e.g., location, estimated population served, growth rate, customer demographic, etc.). It is important to recognize that the planning and design criteria should be applied on a case-by-case basis and may change over time.

DPW's planning and design criteria for waterworks facilities is summarized as follows:

- Water treatment facilities shall be adequate to provide the maximum day water demand.
- Water booster pumping stations shall be adequate to pump the maximum day water demand. The Virginia Department of Health's (VDH) "Waterworks Regulations" require that each pumping station shall have at least two pumping units. Pumps should have sufficient capacity so that if any one pump is out-of-service (firm capacity) the remaining units shall be capable of providing the maximum day demand.
- Pipelines are sized for the following:
  - The largest of maximum hour flow, maximum day flow plus fire flow, or storage replenishment flow. Fire flow requirements are a primary factor affecting the sizing of piping in the water distribution system (6-inch and 8-inch mains).
  - A targeted velocity of less than 5 ft/sec.
  - A targeted headloss of less than 5 feet/1,000 feet of pipeline.
- Maximum water pressures at the service connections were based on 120 psi.
- Minimum water pressures were 45 psi at the service connection under maximum day demand rates and water storage tanks at 10 feet below overflow levels, and 20 psi at the service connection based on the greater of maximum hour or maximum day plus fire flow demand condition.
- Pressure fluctuation was limited to 20-30 psi.
- Pressure zone layout was based on the minimum pressure established by the highest ground elevation that can be supplied, and the maximum pressure established by the lowest ground elevation.
- Pressure regulating valves were proposed with a minimum pressure differential of 10 psi for small valves (6-inch and smaller) and 5 psi for large valves (8-inch and larger). The maximum velocity allowed through the valve is typically 15-20 feet/sec.
- Looping was considered to provide a higher level of reliability (i.e., if one source is out-of-service to the area, supply can be provided from a second source).
- Pipe materials generally accepted include ductile iron, steel, concrete, and polyvinyl chloride (plastic or PVC).

6.5 DISTRIBUTION SYSTEM STORAGE FACILITY CRITERIA AND CONSIDERATIONS

6.5.1 Water Storage Facility Components

Storage facilities must be sized to provide equalization, fire and emergency storage. Each of these components and other storage facility considerations are described in the following section.

Equalization Storage - Equalization storage is the amount of storage required to meet water demands in excess of the system delivery capability. The intent of equalization storage is to make up the difference between the consumers' peak demand and the system's available supply. It is the amount of desirable stored water to accommodate fluctuations in demand so that extreme variations in flow will not be imposed on the supply facilities.

The amount of equalization storage required is a function of the high service pumping capacity at the water treatment plant, distribution system capacity, and system demand characteristics. Equalization storage is generally less expensive than increased pumping capacity (including additional treatment capacity) and transmission and distribution system piping beyond that required to meet the maximum day demand (MDD). Consequently, it is desirable to size the pumping and piping systems to carry MDD with equalization storage sized to carry demands in excess of the MDD up to the peak hour demand (PHD). Plots showing the fluctuation in tank levels over a 24-hour periods were used to assess the volume of equalizing storage available.

Fire Storage - Fire flows have four characteristics: flow, duration, residual pressure, and looping. The volume of fire storage needed is primarily dependent on flow and duration:

- Flow is defined in terms of flowrate (typically gallons per minute) and can vary from 750 gpm for single family housing to 10,000 gpm for shopping malls. It is generally assumed that a major fire will not occur during maximum hour because the chance of this happening is so small. However, it is more likely that a fire would occur on maximum day so fire flow rates are usually imposed on maximum day demand. A fire flow rate of 2,500 gpm was used in this study.
- Duration of the fire generally ranges from two hours to eight hours and is important in the planning and design of new storage facilities because it affects the sizing. A fire flow duration of two hours was used in this study.

Each system storage facility should have reserves of fire storage equal to the amount required to furnish fire flow requirements within the area of influence for the individual storage facility. The area of influence is a function of area water consumption demands, fire flow demands and distribution system piping. For a large fire flow demand (in excess of 3000 gpm), more than one storage facility may be necessary to overcome limitations in piping or other distribution features. In some cases, smaller fire flow demands may be met by more than one facility due to particular features of the distribution system.

Steady-state modeling runs were performed under maximum day demand plus fire flow conditions to assess fire flow availability at each node at a minimum system pressure of 20 psi. Plots showing the fire flow availability at each node were used to assess the need for system improvements. The required fire flow should be specified for each node based on the type of land use served by the node (i.e., residential, commercial, etc.). For this study, the required fire flow was based on DPW's knowledge of the existing and proposed land use within the water system. Nodes that have deficient fire flow based on modeling can be field tested or reviewed to identify whether reduced fire flow rates are acceptable. Correcting fire flow deficiencies by replacing smaller piping with larger mains could result in longer water age and potential water quality problems.

Emergency Storage - Emergency storage is required to provide water during emergencies such as pipeline failures, main breaks, equipment failures, electrical power outages, water treatment facility failures, or natural disasters. The most likely emergency is a power failure lasting several hours or a trunk main failure, either of which would limit distribution capacity in a localized area. The DPW service area also could be subjected to a major disaster such as a hurricane, tornado or extended flooding. However, it is not economically feasible to provide sufficient emergency storage to accommodate emergency circumstances as severe as a hurricane or extended flooding.

The amount of emergency storage included within a particular water distribution system is an owner's option based on an assessment of risk and a capability to pay for the standby provisions. Unlike equalization and fire storage, which should generally be at all system storage sites, emergency storage may be included at only one or a limited number of storage sites.

Clearwell Storage - In addition to using different parameters to set the storage allocation, these parameters are often used in different ways (e.g., many utilities choose to determine equalization storage volume for each individual pressure zone in the system, some utilities choose to include clearwell storage at the treatment facilities, etc.).

Clearwell storage duplicates the function of system storage in that it compensates for system demands in excess of the water treatment plant capacity and allows a more stable rate of water treatment plant operation.

6.5.2 Impact of System Storage on Water Quality

The guidelines presented in this technical memorandum for sizing distribution system storage are intended to meet fire flow requirements and provide equalization and emergency storage. Excess storage or low turnover in storage tanks impacts water quality adversely by increasing residence time in the system, which may result in the following:

- Low disinfectant residual
- Higher disinfection byproducts
- Bacterial regrowth

There is a need to balance storage requirements with water quality. In general, storage for fire protection and flow equalization should not be modified from the required or recommended amounts. Water quality in the distribution system can be optimized by:

- Optimizing operation of existing storage facilities (increasing tank turnover).
- Optimizing operation of the distribution system and pressure zones.
- Design of emergency or reserve storage in new storage facilities.

It is recommended that the County consider installing active mixers in existing and proposed water storage tanks to maintain and improve water quality.

6.5.3 Summary of Storage Requirements

Tables 6.5.1 and 6.5.2 summarize the storage requirements by pressure zone for near-term and buildout conditions.

Table 6.5.1 – Water Distribution System Storage Adequacy (Near-term)

Zone	Average Day Demand (MGD)	Required Storage at 50% of Average Day Demand (MG)	Existing Storage at Near-term (MG)	Storage Deficit (-) or Surplus (+) at Near-term (MG)	Additional Storage Proposed at Near-term (MG)
310	2.4	1.2	Stone River - 2.0 Midway - 0.2 Moncure - 0.75 Smith Lake - 3.22	5.0	0
342	4.6	2.3	Abel Lake (new elevated tank) – 2.0 Grafton – 1.0 Lake Mooney – 0.83	1.5	0
370	1.0	0.5	Embrey Mill – 0.5 Courthouse – 1.0	1.0	0
410/480	1.9	1.0	Celebrate VA – 1.0 Lake Mooney – 0.83	0.8	0
433	2.1	1.0	Amyclae - 1.5 Shelton Shop – 0.36 *	0.86	0
472	0.6	0.3	Vista Woods - 0.5	0.2	0
520	0.2	0.1	Westlake (new elevated tank) – 0.75	0.65	0
Total	12.8	6.4	16.44	10.0	0

* Based on top 25 feet of standpipe (total height = 95 feet).

<u>Tanks Replaced at Near-term</u>

Abel Lake – 4 MG with 2 MG

Courthouse - 0.25 MG with 1 MG

<u>Tanks Removed at Near-term</u>

Bandy - 0.15 MG

Cranes Corner – 0.2 MG

Table 6.5.2 – Water Distribution System Storage Adequacy (Buildout)

Zone	Average Day Demand (MGD)	Required Storage at 50% of Average Day Demand (MG)	Existing Storage at Buildout (MG)	Storage Deficit (-) or Surplus (+) at Buildout (MG)	Additional Storage Proposed at Buildout (MG)
310	4.7	2.4	Stone River - 2.0 Midway - 0.2 Moncure - 0.75 Smith Lake - 3.22	3.8	0
342	6.8	3.4	Abel Lake (new elevated tank) – 2.0 Grafton – 1.0 Lake Mooney – 0.83	0.4	0
370	2.0	1.0	Embrey Mill – 0.5 Courthouse – 1.0	1.0	0
410/480	3.8	1.9	Celebrate VA – 1.0 Lake Mooney – 0.83	-0.1	0
433	3.5	1.7	Amyclae - 1.5 Shelton Shop – 0.36 *	0.2	0
472	0.85	0.4	Vista Woods - 0.5 Garrisonville (new elevated tank) – 0.5	0.6	0
520	1.1	0.6	Westlake (new elevated tank) – 0.75	0.1	0
Total	22.7	11.4	16.44	6.0	0

6.6 RECOMMENDED WATER SYSTEM IMPROVEMENTS

This section identifies the major components of DPW's water distribution system and evaluates the performance and operation of the system compared with the criteria presented previously and in Technical Memorandum 1 (*Summary of Water Planning and Design Criteria*). The evaluation is based on a review of existing operational data, discussions with DPW staff, and results of the simulations from the InfoWater modeling. The water system improvements presented in this section are shown on the figure in the pocket at the end of this Master Plan (Water System – Proposed Improvements) and the schedule showing the timing for implementation of the improvements is included in the pocket at the end of this Master Plan (Summary of Costs and Schedule for Recommended CIP Improvements).

The water system improvements presented in this Master Plan are for the area inside the Urban Service Area.

310-01: Construct 8-inch main from Jib Drive to Hope Springs Lane (1,917 feet)

This project includes design and construction of an 8-inch water main from Jib Drive to Hope Springs Lane (1,917 feet). The purpose of the project is to improve fire flows and enhance reliability to customers in the vicinity of Hope Springs Lane that are served by a single 6-inch main and Walker Way and Jib Drive that are currently served by a single 8-inch water main. This project is independent of other proposed water system improvements in the 310 Zone and the timing for implementation is driven by the need to increase fire flow capabilities or reliability in this area.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$450,000*

310-03: Construct 12-inch main along Jefferson Davis Highway from Sunnyside Drive to Slake Drive (801 feet)

This project includes design and construction of a 12-inch water main along Jefferson Davis Highway from Sunnyside Drive to Slake Drive (801 feet). The purpose of the project is to connect the 12-inch mains along Jefferson Davis Highway to improve flows from Smith Lake WTP to customers along the Jefferson Davis Highway corridor.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$208,000*

310-05: Construct 12-inch main along Aquia Drive from Coal Landing Road to Washington Drive (4,129 feet)

This project includes design and construction of a 12-inch water main along Aquia Drive from Coal Landing Road to Washington Drive (4,129 feet). The purpose of the project is to increase transmission capacity between Smith Lake WTP and the Stone River Tank to improve operation of the tank (i.e., drawdown and refill characteristics), as well as enhance reliability in Aquia Harbour and the southeastern portion of the 310 Zone. The timing for implementation is based on improving operation of the Stone River Tank. As demands in the vicinity of the Stone River Tank increase through the planning period, the volume of water depleted from the Stone River Tank during high demand periods will increase requiring a larger quantity of water through the transmission system to replenish the depleted tank storage.

As an alternative to construction of the 12-inch main along Aquia Drive, the existing 12-inch main along the Jefferson Davis Highway could be replaced with a larger main to increase transmission capacity to the Stone River Tank.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,070,000*

310-06: Construct 12-inch main along Washington Drive from Aquia Drive to Jefferson Davis Highway (5,841 feet)

This project includes design and construction of a 12-inch water main along Washington Drive from Aquia Drive to Jefferson Davis Highway (5,841 feet). The purpose of the project is to increase transmission capacity between Smith Lake WTP and the Stone River Tank to improve operation of the tank (i.e., drawdown and refill characteristics), as well as enhance reliability in Aquia Harbour and the southeastern portion of the 310 Zone. The timing for implementation is based on improving operation of the Stone River Tank. As demands in the vicinity of the Stone River Tank increase through the planning period, the volume of water depleted from the Stone River Tank during high demand periods will increase requiring a larger quantity of water through the transmission system to replenish the depleted tank storage.

As an alternative to construction of the 12-inch main along Washington Drive, the existing 12-inch main along the Jefferson Davis Highway could be replaced with a larger main to increase transmission capacity to the Stone River Tank.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,514,000*

310-07: Construct 24-inch main along Garrisonville Road (Rt. 610) from Salisbury Drive to Jefferson Davis Highway (2,375 feet)

This project includes design and construction of a 24-inch water main along Garrisonville Road (Route 610) from Salisbury Drive to Jefferson Davis Highway (2,375 feet). The purpose of the project is to increase transmission capacity between Smith Lake WTP and the eastern portion of the 310 Zone, increase flow to the Stone River Tank to improve operation of the tank, and enhance reliability in Aquia Harbour and the eastern portion of the 310 Zone. This project provides a strong second connection across I-95 from Smith Lake WTP to the piping in the eastern portion of the 310 Zone. The 24-inch main from the Smith Lake WTP to the Moncure PS serves as a strong feed for the proposed 24-inch main under I-95. The timing for this project is dictated by the need for increased transmission capacity due to higher demands during the planning period.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,175,000*

310-08: Replace existing 8-inch main along Coal Landing Road with a 12-inch main from Greenridge Drive east to existing 12-inch main (1,873 feet)

This project includes replacement of the existing 8-inch main along Coal Landing Road with a 12-inch main from Greenridge Drive east to the existing 12-inch main (1,873 feet). The purpose of the project is to increase conveyance capacity between Smith Lake WTP and the Stone River Tank to improve operation of the tank (i.e., tank drawdown and refill), as well as enhance reliability in Aquia Harbour and the southeastern portion of the 310 Zone. The timing for this project is dictated by the need to improve operation of the Stone River Tank for increased transmission capacity due to higher demands during the planning period. As demands in the vicinity of the Stone River Tank increase through the planning period, the volume of water depleted from the Stone River Tank during high demand periods will increase requiring a larger quantity of water through the transmission system to replenish the depleted tank storage.

Priority	*2 - Necessary*
Design	*Beyond FY2028*

Construct	*Beyond FY2028*
Total Project Cost	*$485,000*

310-10: Construct 24-inch main from I-95 to 12-inch main along Jefferson Davis Highway near Sunnyside Drive (2,120 Feet)

This project includes design and construction of a 24-inch water main from I-95 to the 12-inch main along Jefferson Davis Highway near Sunnyside Drive (2,120 feet). The purpose of the project is to increase transmission capacity from Smith Lake WTP to the 12-inch mains along Jefferson Davis Highway to improve flows to customers along the Jefferson Davis Highway corridor.

Priority	*2 – Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,092,000*

310-12: Construct 12-inch main along Forest Woods Drive from White Pine Circle to connect to existing 12-inch main along Aquia Drive (1,160 Feet)

This project includes design and construction of a 12-inch water main along Jefferson Davis Highway from Terrace Lane near Sunnyside Drive (1,160 feet). The purpose of the project is to increase conveyance capacity from the 12-inch main along Jefferson Davis Highway to the northern area of the 310 Zone.

Priority	*2 – Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$301,000*

310-13: Construct 6-inch main along Pilgrim Drive to connect existing 6-inch to the new 12-inch main along Forest Wood Drive (175 Feet)

This project includes design and construction of a 6-inch water main along Pilgrim Drive to connect an existing 6-inch main to the new 12-inch main along Forest Wood Drive (175 feet). The purpose of the project is to increase conveyance capacity from the 6-inch main along Pilgrim Drive to the northern area of the 310 Zone.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$37,000*

310-200: Expand Smith Lake Pumping Station to 14 mgd

Smith Lake WTP currently supplies water to four pressure zones with hydraulic grade lines of 310, 370, 433 and 472 feet through 30-inch and 24-inch water mains. Water from the Smith Lake WTP is pumped to the Moncure PS on the western border of the 310 Zone which pumps flow to the 433 Zone. Flow from the 433 Zone is boosted to the 472 Zone through the Vista Woods PS which is located on the western border of the 433 Zone along Shelton Shop Road. The 310 Zone has three tanks (Midway, Stone River and Moncure), the 433 Zone has two tanks (Shelton Shop and Amyclae), and the 472 Zone has one tank (Vista Woods).

This project involves expansion of the Smith Lake Pumping Station from 10 mgd to 14 mgd. The purpose of this project is to expand the pumping capacity to fully utilize the available treatment capacity from Smith Lake WTP and meet projected demands.

Priority	*1 - Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,944,000*

310-300: Construct emergency pressure reducing valve between 370/310 Zone near Wallace Lane

Three pressure reducing valves (PRVs) are proposed on transmission mains along the southern border of the 310 Zone to provide flow from the 370 Zone to the 310 Zone under emergency conditions that cause a disruption in service in the 310 Zone (e.g., major main breaks, Smith Lake WTP out-of-service, etc.). In the future, flow to the 370 Zone will be provided by Lake Mooney WTP while the 310 Zone will be served solely by Smith Lake WTP. Consequently, these PRVs significantly enhance system reliability by providing a second source of supply to the 310 Zone. The timing for construction of the PRVs is dictated by the establishment of the 370 Zone.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$81,000*

310-301: Construct emergency pressure reducing valve between 370/310 Zone along Bells Hill Road near Byrum Street

Three pressure reducing valves (PRVs) are proposed on transmission mains along the southern border of the 310 Zone to provide flow from the 370 Zone to the 310 Zone under emergency conditions that cause a disruption in service in the 310 Zone (e.g., major main breaks, Smith Lake WTP out-of-service, etc.). In the future, flow to the 370 Zone will be provided by the Lake Mooney WTP while the 310 Zone will be served solely by Smith Lake WTP. Consequently, these PRVs significantly enhance system reliability by providing a second source of supply to the 310 Zone. The timing for construction of the PRVs is dictated by the establishment of the 370 Zone.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$81,000*

310-302: Construct emergency pressure reducing valve between 370/310 Zone along Olde Concord Road near Somerset Lane

Three pressure reducing valves (PRVs) are proposed on transmission mains along the southern border of the 310 Zone to provide flow from the 370 Zone to the 310 Zone under emergency conditions that cause a disruption in service in the 310 Zone (e.g., major main breaks, Smith Lake WTP out-of-service, etc.). In the future, flow to the 370 Zone will be provided by Lake Mooney WTP while the 310 Zone will be served solely by Smith Lake WTP. Consequently, these PRVs significantly enhance system reliability by providing a second source of supply to the 310 Zone. The timing for construction of the PRVs is dictated by the establishment of the 370 Zone.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$81,000*

342-01: Construct 24-inch main along Lendall Lane, Ingleside Drive, and King Street from Olde Forge Drive to Cambridge Street (8,183 feet)

This project involves design and construction of a 24-inch main along Lendall Lane, Ingleside Drive, and King Street from Olde Forge Drive to Cambridge Street (8,183 feet). The purpose of the project is to convey flows from the 30-inch main connecting Lake Mooney WTP to the 342 Zone. A major problem in the near-term and future water system is the limiting transmission capacity from the western to eastern portions of the 342 Zone. This transmission main is a necessary feed for the eastern portion of the 342 Zone as water demands increase through the planning period.

Priority	*1 - Critical*
Design	*FY2019*
Construct	*FY2019*
Total Project Cost	*$6,669,000*

342-02: Construct 16-inch main along River Road and Chatham Heights Road from Cambridge Street to Cool Springs Road (7,057 feet)

This project involves design and construction of a 16-inch main along River Road and Chatham Heights Road from Cambridge Street to Cool Springs Road (7,057 feet). The purpose of the project is to convey flows to the eastern and southern portions of the 342 Zone A major problem in the near-term and future water system is the limiting transmission capacity from the western to eastern portions of the 342 Zone. This project is proposed for the near-term to create a strong connection between the 12-inch mains in the vicinity of Jefferson Davis Highway with the 12-inch main along Cool Springs Road/Deacon Road.

Priority	*1 - Critical*
Design	*FY2020*
Construct	*FY2020*
Total Project Cost	*$5,145,000*

342-05: Construct 24-inch main from Middle Run Drive along Olde Forge Road and along RV Parkway to Kelley Road (5,124 feet)

This project involves design and construction of a 24-inch main from Middle Run Drive along Olde Forge Drive and RV Parkway to Kelley Road (5,124 feet). The purpose of the project is to convey large quantities of flow from Lake Mooney WTP to both the southern and northern zones in the water system. This project significantly increases both the reliability and flexibility of the overall system. This project conveys flows from the 30-inch main from Lake Mooney WTP to the 342 and 370 Zones. A major problem in the near-term and future water system is the limiting transmission capacity to the Centreport Parkway portion of the 342 Zone. The project is proposed for the near-term to strengthen the connections between the existing 12-inch mains in order to convey flows north and east through the 342 Zone.

Priority	*1 - Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,660,000*

342-06: Construct 24-inch main along Truslow Road and Enon Road to Hulls Chapel Road (8,365 feet)

This project includes design and construction of a 24-inch water main along Truslow Road to Hulls Chapel Road (8,365 feet). The purpose of the project is to convey large quantities of flow from Lake Mooney WTP to both the southern and northern zones in the water system. This project significantly increases both the reliability and flexibility of the overall system. The project conveys flow to the Abel Lake Tank, Centreport portion of the 342 Zone, and to the 370 Zone and the northern zones by transferring flows to the 370 Zone Pumping Station near the airport. Having the ability to convey water from Lake Mooney WTP to the northern zone provides operational flexibility that may be important for maintenance of facilities, temporary disruptions in water service (i.e., electrical outages, main breaks, plant shutdowns, etc.), changes in raw water quality, availability of raw water supply, etc.

Priority	*1 – Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$3,115,000*

342-10: Construct 12-inch main along Primmer House Road (350 feet)

This project includes design and construction of a 12-inch water main along Primmer House Road (350 feet). The purpose of this project is to connect the existing water mains which should improve flow and reliability to customers north of the Grafton Tank.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$650,000*

342-15: Replace existing 16-inch main with 24-inch main along Hulls Chapel Road from Abel Lake Tank to Stones Mill Lane and construct new 24-inch main along Stones Mill Lane to intersection of Mountain View Road and Centreport Parkway (8,712 feet)

Prior to decommissioning, water from the Abel Lake WTP was pumped through a 16-inch water main to the Abel Lake Tank. The Abel Lake Tank is a 4 MG ground level tank with an overflow elevation of 298 feet. The 16-inch main has a history of breaks and is currently out-of-service due to a severe break. This project involves replacement of the existing 16-inch water main with a 24-inch main along Hulls Chapel Road from Abel Lake Tank to Stones Mill Lane and construct new 24-inch main along Stones Mill Lane to intersection of Mountain View Road and Centreport Parkway (8,712 feet). The purpose of the project is to convey flows from Lake Mooney WTP to the Centreport area of the 342 Zone as well as the 370 and northern Zones.

Priority	*1 - Critical*
Design	*FY2020*
Construct	*FY2021*
Total Project Cost	*$2,823,000*

342-101: Construct 2.0 MG elevated tank in vicinity of Abel Lake Tank

The Abel Lake Tank is a 4 MG ground level tank with an overflow elevation of 298 feet. Water is pumped from the Abel Lake Tank to the 342 Zone through the Cranes Corner Pumping Station. Three elevated storage tanks are located in the 342 Zone:

- Cranes Corner (0.2 MG, 342 ft OF)
- Grafton (1 MG, 342 ft OF)
- Bandy (0.15 MG, 341 ft OF)

Until the 24-inch mains from Warrenton Road are extended to the Abel Lake Tank site, the Cranes Corner Pumping Station will be used to fill the new 2 MG 342 Zone Tank on the Abel Lake Tank site (342-101). After the 342 Zone transmission mains from Lake Mooney WTP are complete, the 342 Zone Tank at the Abel Lake Tank site will be fed from Lake Mooney WTP and the Corner Pumping Station will be decommissioned along with the Abel Lake Tank. In addition, the small tanks at Cranes Corner (0.2 MG) and Bandy (0.15 MG) will be decommissioned following construction of the new 2 MG tank at Abel Lake Tank site.

The 2 MG elevated tank at the Abel Lake Tank site would typically provide storage to the 342 Zone in the Centreport area, and it would provide suction storage for the pumping station serving the 370 Zone. The tank would be refilled from Lake Mooney WTP.

Priority	*1 - Critical*
Design	*FY2020*
Construct	*FY2021*
Total Project Cost	*$5,520,000*

370-02: Construct 12-inch main along Ramoth Church Road and American Legion Road from 24-inch at Ramoth Church Road to 12-inch main on Jefferson Davis Highway (2,850 feet)

This project includes design and construction of a 12-inch water main along Ramoth Church Road and American Legion Road from the 24-inch main at Ramoth Church Road to Jefferson Davis Highway (2,850 feet). The purpose of the project is to create a strong connection under I-95 from the proposed transmission main on Centreport Parkway to the existing 12-inch main on Jefferson Davis Highway which serves the Courthouse Tank.

Priority	*1 - Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$982,000*

370-03: Construct 24-inch main from Ramoth Church Road to Courthouse Road (9,700 feet)

This project includes design and construction of a 24-inch water main from Ramoth Church Road to Courthouse Road (9,700 feet). The purpose of the project is to convey flow north from Lake Mooney WTP to the northern zones and to the 433 Zone through the proposed pumping station along Courthouse Road. Currently, a single 12-inch main along Jefferson Davis Highway conveys flow through the future 370 Zone. The proposed 24-inch transmission main would be a significant component in DPW's ability to transfer large quantities of flow to the northern zones from Lake Mooney WTP and to the southern zones from Smith Lake WTP; thereby providing a high level of overall system reliability. As the area of the 370 Zone west of I-95 develops, DPW could construct a network of 16-inch, 12-inch and 8-inch mains to provide the transmission capacity needed to achieve the level of reliability associated with the proposed 24-inch main. Alternatively, the 12-inch main along Jefferson Davis Highway from Ramoth Church Road to Courthouse Road could be replaced with a larger main to increase transmission capacity through the 370 Zone. Under buildout conditions, demands for the 433 Zone (3.5 mgd) and transfers to the 472 Zone (0.85 mgd) will be satisfied by the Moncure PS and the 433 Zone PS along Courthouse Road.

Priority	*1 - Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$3,143,000*

370-05: Construct 16-inch main along Courthouse Road from west of I-95 west to 433 Zone pumping station near Snowbird Lane (3,257 feet)

This project includes design and construction of a 16-inch water main along Courthouse Road from west of I-95 west to 433 Zone pumping station near Snowbird Lane (3,257 feet). The purpose of the project is to provide flow from the existing water main in Embrey Mill and the proposed 24-inch water main (370-03) to the proposed 433 Zone Pumping Station. This pumping station will provide a second source of supply to the 433 Zone and utilize the transmission system in the southern portion of the 433 Zone to deliver flow to the customers in the southern portion of the 433 Zone and to the 472 Zone. The timing for construction of this main will be concurrent with the 433 Zone Pumping Station (433-200).

Priority	*1 - Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$950,000*

370-201: Construct 11.1 mgd Pumping Station along Centreport Parkway near Aviation Way

In the near-term, the 370 Zone will be limited to Embrey Mill area which will be served by the Embrey Mill Pumping Station and a 0.5 MG tank in Embrey Mill. After the 370 Zone is established, the Embrey Mill PS will serve as an emergency backup for delivering flow from Smith Lake WTP to the southern pressure zones.

The adequacy of storage for each pressure zone was assessed using the required volume of effective storage equal to one-half of the average day demand in accordance with VDH requirements. The average day demand under buildout conditions for the 370 Zone will be 2.0 mgd. Consequently, the volume of storage needed in the 370 Zone under buildout conditions is roughly 1.0 MG which is met by the Courthouse Tank (1.0 MG) and Embrey Mill Tank (0.5 MG).

The boundary for the 370 Zone was established based on ground elevations obtained from County GIS data along with maximum and minimum pressure requirements. Modeling runs indicated that constructing a 0.5 MG storage tank in Embrey Mill significantly improved fire flows in Embrey Mill compared with providing this storage for Embrey Mill at the Courthouse Tank site. In addition, a tank in Embrey Mill along with the emergency backup service from the Embrey Mill PS will significantly improve reliability in the northern portion of the 370 Zone which will be distant from the proposed pumping station for the 370 Zone near the airport.

The proposed 370 Zone Pumping Station will be approximately 11.1 mgd with a pumping head of 60-70 feet. Suction for the pumping units will be from the proposed 342 Zone Tank (2.0 MG, 342 ft OF). The pumping station will be capable of meeting the average day demand of the 370, 433, 472 and 310 Zones at buildout (11.1 mgd) from Lake Mooney WTP.

Priority	*1 - Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$5,395,000*

410-300: Construct pressure reducing valve between 480/410 Zone along Warrenton Road near Sanford Drive

Two pressure reducing valves (PRVs) are proposed on transmission mains along the southern border of the 480 Zone to provide flow from the 480 Zone to the 410 Zone. Flow to the 410 Zone will be provided by Lake Mooney WTP through the 480 Zone.

Priority	*2 - Necessary*
Design	*FY2019*
Construct	*FY2020*
Total Project Cost	*$81,000*

410-301: Construct pressure reducing valve between 480/410 Zone along Celebrate VA Parkway near Sanford Drive

Two pressure reducing valves (PRVs) are proposed on transmission mains along the southern border of the 480 Zone to provide flow from the 480 Zone to the 410 Zone. Flow to the 410 Zone will be provided by Lake Mooney WTP through the 480 Zone.

Priority	*2 - Necessary*
Design	*FY2019*
Construct	*FY2020*
Total Project Cost	*$81,000*

433-04: Construct 10-inch main from Embrey Mill Road to the existing 10-inch main on White Chapel Lane (3,132 feet)

This project includes design and construction of 10-inch water main from Embrey Mill Road to the existing 10-inch main on White Chapel Lane (3,132 feet). The purpose of these projects is to connect the existing 12-inch main along Courthouse Road to the piping network north of Courthouse Road.

Priority	*2 - Necessary*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$761,000*

433-05: Construct 16-inch main along Courthouse Road from pumping station at 433/370 Zone boundary to Rollinswood Lane (2,720 feet)

This project includes design and construction of a 16-inch main along Courthouse Road from pumping station at 433/370N Zone boundary to Rollinswood Lane (2,720 feet). The purpose of the project is to provide flow from the pumping station to the 12-inch mains on Courthouse Road, Danielle Way and Ramoth Church Road. This pumping station will provide a second source of supply to the 433 Zone and utilize the transmission system in the southern portion of the 433 Zone to deliver flow to the customers in the southern portion of the 433 Zone and to the 472 Zone. The timing for construction of this main will be concurrent with the 433 Zone Pumping Station (433-200).

Priority	*1 - Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$793,000*

433-06: Construct 12-inch main from Moncure Pumping Station to 8-inch main south of the pumping station (330 feet)

This project includes design and construction of a 12-inch water main from Moncure Pumping Station to an 8-inch main south of the pumping station (327 feet). The purpose of the project is to strengthen the connection to the water system south of Garrisonville Road in the immediate vicinity of the Moncure PS.

Priority	*2- Necessary*
Design	*FY2019*
Construct	*FY2020*
Total Project Cost	*$86,000*

433-200: Construct 4.4 mgd 433 Zone Pumping Station along Courthouse Road near Snowbird Lane

Smith Lake WTP currently supplies water to four pressure zones with hydraulic grade lines of 310, 370, 433 and 472 feet. Water from the Smith Lake WTP is pumped to the Moncure PS on the western border of the 310 Zone which pumps flow to the 433 Zone. Flow from the 433 Zone is boosted to the 472 Zone through the Vista Woods PS which is located on the western border of the 433 Zone along Shelton Shop Road. The 472 Zone has one elevated tank along Mountain View Road in the vicinity of Spy Glass Lane (0.5 MG Vista Woods Tank at overflow elevation 472 feet).

Under buildout conditions, maximum day demands for the 433 Zone (5.3 mgd) and transfers to the 472 Zone (1.3 mgd) will be satisfied by the Moncure PS and the 433 Zone PS along Courthouse Road.

The 4.4 mgd capacity of the 433 Zone PS along Courthouse Road was based on meeting the average day buildout demands in the 433 Zone (3.5 mgd) and the 472 Zone (0.85 mgd) with the Moncure PS out-of-service.

Currently, the Moncure PS is operated off of the water levels in the Shelton Shop Tank. In the future, a second 0.9 mgd pumping station is proposed on the 12-inch main on Lightfoot Drive at the intersection of Mountain View Road at the 472/433 Zone border. The pumping capacity of each pumping station will satisfy the projected average day buildout demand of 0.85 mgd in the 472 Zone. Due to the future pumping and piping configuration through the 433 Zone, the pumping stations serving the 472 Zone would primarily be served by separate supply sources:

- Vista Woods PS would essentially be supplied from Smith Lake WTP through the Moncure PS and water mains along Garrisonville Road.
- Lightfoot Drive PS would be fed from the Lake Mooney WTP through the pumping station along Courthouse Road at the 370/433 Zone border.

Priority	*1 - Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$2,138,000*

472-01: Construct 8-inch main along Shelton Shop Road from existing 12-inch at Soaring Eagle Drive and existing 6-inch on Oakwood Drive (413 feet)

This project includes design and construction of an 8-inch main along Shelton Shop Road from existing 12-inch at Soaring Eagle Drive and existing 6-inch on Oakwood Drive (413 feet). The purpose of the project is to eliminate the 450 Zone.

Priority	*2 – Necessary*
Design	*FY2019*
Construct	*FY2020*
Total Project Cost	*$97,000*

472-100: Construct 0.5 MG storage tank along Garrisonville Road near Ripley Road

The adequacy of storage for each pressure zone was assessed using the required volume of effective storage equal to one-half of the average day demand in accordance with VDH requirements. The average day demand under buildout conditions for the 472 Zone will be 0.85 mgd. Consequently, the volume of storage needed in the 472 Zone under buildout conditions is roughly 0.4 MG which is met by the existing 0.5 MG Vista Woods Tank. A second 0.5 MG elevated tank is proposed for the 472 Zone to provide operational flexibility if the Vista Woods Tank is temporarily taken out-of-service. The proposed site for the new tank is along Garrisonville Road near Ripley Road. This tank would typically provide storage to the northern portion of the 472 Zone.

Priority	*2 - Necessary*
Design	*FY2026*
Construct	*FY2027*
Total Project Cost	*$1,380,000*

472-200: Construct 0.9 mgd pumping station along Lightfoot Road near Mountain View Road

Smith Lake WTP currently supplies water to four pressure zones with hydraulic grade lines of 310, 370, 433 and 472 feet. Water from the Smith Lake WTP is pumped to the Moncure PS on the western border of the 310 Zone which pumps flow to the 433 Zone. Flow from the 433 Zone is boosted to the 472 Zone through the Vista Woods PS which is located on the western border of the 433 Zone along Shelton Shop Road. The 472 Zone has one elevated tank along Mountain View Road in the vicinity of Spy Glass Lane (0.5 MG Vista Woods Tank at overflow elevation 472 feet).

Currently, the Vista Woods PS is operated off of the water levels in the Vista Woods Tank. In the future, a second 0.9 mgd pumping station is proposed on the 12-inch main on Lightfoot Drive at the intersection of Mountain View Road at the 472/433 Zone border. The 0.9 mgd pumping capacity from either the Vista Woods PS or the proposed Lightfoot Drive PS satisfies the projected average day buildout demand of 0.85 mgd in the 472 Zone. Due to the future pumping and piping configuration through the 433 Zone, the pumping stations serving the 472 Zone would primarily be served by separate supply sources:

- Vista Woods PS would essentially be supplied from Smith Lake WTP through the Moncure PS and water mains along Garrisonville Road.
- Lightfoot Drive PS would be fed from Lake Mooney WTP through the pumping station along Courthouse Road at the 370/433 Zone border.

Priority	*1 - Critical*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$437,000*

480-01: Construct 16-inch main from the existing 16-inch main at Celebrate VA Tank to Jewett Lane and along Jewett Lane to the existing 12-inch main on Celebrate Virginia Parkway (600 feet)

This project involves design and construction of a 16-inch main from the existing 16-inch main at Celebrate VA Tank to Jewett Lane and along Jewett Lane to the existing 12-inch main on Celebrate Virginia Parkway (600 feet). The purpose of the project is to eliminate a transmission restriction from Lake Mooney WTP and the Celebrate Virginia water storage tank to the 480 and 520 Zones.

Priority	*2 - Necessary*
Design	*FY2024*

Construct	*FY2025*
Total Project Cost	*$418,000*

480-02: Construct 16-inch main from existing 12-inch main at Celebrate Virginia Parkway under Warrenton Road to the existing 12-inch mains along Warrenton Road and International Parkway (500 feet)

This project involves design and construction of a 16-inch main along Celebrate Virginia Parkway under Warrenton Road to the existing 12-inch mains along Warrenton Road and International Parkway (500 feet). The purpose of the project is to provide a strong connection between the existing 12-inch mains on the south side of Warrenton Road and the existing 12-inch mains on the north side of Warrenton Road.

Priority	*2 – Necessary*
Design	*FY2024*
Construct	*FY2025*
Total Project Cost	*$535,000*

480-300: Construct pressure reducing valve between 520/480 Zone along Village Parkway

Construct a pressure reducing valve (PRV) on the transmission main along the 12-inch main on Village Parkway to provide flow from the 520 Zone to the 480 Zone in an emergency.

Priority	*2 - Necessary*
Design	*FY2027*
Construct	*FY2028*
Total Project Cost	*$81,000*

520-02: Construct 16-inch main along Warrenton Road from 520 Zone Pumping Station near Cardinal Forest Drive to the Westlake Tank (8,958 feet)

This project involves design and construction of a 16-inch main along Warrenton Road from the Warrenton Road PS near Cardinal Forest Drive to the Westlake Tank (8,958 feet). The purpose of the project is to convey flows from the Warrenton Road PS to the proposed Westlake Development. Construction of the water main should be concurrent with establishment of the 520 Zone (i.e., construction of the Warrenton Road PS and storage tank at Westlake Industrial Park). In addition, the timing for construction of the water main should be consistent with construction of the infrastructure in this area.

Priority	*1 - Critical*
Design	*FY2022*
Construct	*FY2023*
Total Project Cost	*$2,612,000*

520-100: Construct 0.75 MG elevated storage tank along Warrenton Road in vicinity of Clark Patton Road

After Lake Mooney WTP was complete, the existing Berea Tank (overflow elevation 503 ft) was eliminated and the 503 Zone was split into two pressure zones: 520 Zone and 480 Zone. The 520 Zone will be established to satisfy low pressure problems at the higher ground elevations along Warrenton Road west of Estes Road while maintaining acceptable operating pressures at the lower elevations in the eastern portion of the existing 503 Zone by dropping the hydraulic grade in this area to 480 feet. A new 24-inch water main from Lake Mooney WTP will be extended to the transmission mains on Warrenton Road to supply the 480 Zone. The 480 Zone includes the Celebrate VA Tank (1.0 MG) elevated tank along Greenbank Road in the vicinity of Good Neighbor Lane. Two PRVs along the southern border of the 480 Zone are proposed to serve the 410 Zone: one PRV on the transmission main along Virginia Parkway and one PRV on the 12-inch main on Sanford Drive near Warrenton Road. A new 0.6 mgd pumping station will be constructed on the transmission mains along Warrenton Road near Cardinal Forest Drive to pump the 520 Zone maximum day demand (1.7 mgd) from the 480 Zone at buildout. The lower elevations on the southern portion of Stafford Lakes Village are planned to be part of the 480 Zone. A PRV is recommended on the 12-inch main along Village Parkway to serve as a backup supply to Stafford Lakes Village. A new 0.75 MG elevated tank in the 520 Zone will be used to control the pumps at the Warrenton Road PS that feed the 520 Zone.

The adequacy of storage for each pressure zone was assessed using the required volume of effective storage equal to one-half of the average day demand in accordance with VDH requirements. The average day demand under buildout conditions for the 520 Zone will be 1.1 mgd. Consequently, the volume of storage needed in the 520 Zone under buildout conditions is roughly 0.55 MG. A new 0.75 MG elevated storage tank is proposed along Warrenton Road near Clark Patton Road to satisfy the projected storage deficit. Construction of the storage tank should be concurrent with establishment of the 520 Zone (i.e., construction of the Warrenton Road PS and transmission mains). In addition, the timing for construction of the storage tank should be consistent with construction of the infrastructure in this area.

Priority	*1 - Critical*
Design	*FY2022*
Construct	*FY2023*
Total Project Cost	*$2,070,000*

520-200: Construct 2.3 mgd pumping station along Warrenton Road near Cardinal Forest Drive

After Lake Mooney WTP was complete, the existing Berea Tank (overflow elevation 503 ft) was eliminated and the 503 Zone was split into two pressure zones: 520 Zone and 480 Zone. The 520 Zone will be established to satisfy low pressure problems at the higher ground elevations along Warrenton Road west of Estes Road while maintaining acceptable operating pressures at the lower elevations in the eastern portion of the existing 503 Zone by dropping the hydraulic grade in this area to 480 feet. A new 24-inch water main from Lake Mooney WTP will be extended to the transmission mains on Warrenton Road to supply the 480 Zone. The 480 Zone includes a new 1.0 MG elevated tank along Greenbank Road in the vicinity of Good Neighbor Lane. Two PRVs along the southern border of the 480 Zone are proposed to serve the 410 Zone: one PRV on the transmission main along Virginia Parkway and one PRV on the 12-inch main on Sanford Drive near Warrenton Road. A new 0.6 mgd pumping station will be constructed on the transmission mains along Warrenton Road near Cardinal Forest Drive to pump the 520 Zone maximum day demand (1.7 mgd) from the 480 Zone at buildout. The lower elevations on the southern portion of Stafford Lakes Village are planned to be part of the 480 Zone. A PRV is recommended on the 12-inch main along Village Parkway to serve as a backup supply to Stafford Lakes Village. A new 0.75 MG elevated tank in the 520 Zone will be used to control the pumps at the Warrenton Road PS that feed the 520 Zone.

The adequacy of storage for each pressure zone was assessed using the required volume of effective storage equal to one-half of the average day demand in accordance with VDH requirements. The average day demand under buildout conditions for the 520 Zone will be 1.1 mgd. Consequently, the volume of storage needed in the 520 Zone under buildout conditions is roughly 0.55 MG. A new 0.75 MG elevated storage tank is proposed along Warrenton Road near Clark Patton Road to satisfy the projected storage deficit. Construction of the storage tank should be concurrent with establishment of the 520 Zone (i.e., construction of the Warrenton Road PS and transmission mains). In addition, the timing for construction of the storage tank should be consistent with construction of the infrastructure in this area.

Priority	*1 - Critical*
Design	*FY2022*
Construct	*FY2023*

Total	*$1,118,000*

TECHNICAL MEMORANDUM 7

Wastewater Collection, Pumping, and Conveyance Facilities

Prepared for: Stafford County Department of Public Works
Prepared by: O'Brien & Gere
Date: February 2018 (revised May 2018)

This technical memorandum is one of a series being prepared for the Stafford County Water and Sewer Master Plan project. The purpose of this technical memorandum is to document specific sewer system construction, upgrade and expansion options that can be implemented to meet DPW's wastewater collection and conveyance needs through the buildout planning horizon.

CONTENTS

7.1 DPW'S EXISTING AND FUTURE SEWER SYSTEM

Stafford's wastewater collection and conveyance system is served by two wastewater treatment facilities (WWTFs):

- Aquia WWTF – Located in the northern portion of the service area along Austin Run and adjacent to Jefferson Davis Highway.
- Little Falls Run WWTF – Located in the southeastern portion of the County along Kings Highway and near the confluence of Little Falls Run and the Rappahannock River.

DPW's wastewater collection system consists of approximately 453 miles of pipe, 57 miles of sewer force mains, 12,250 manholes, and 93 pumping stations. Pipe sizes in the collection system range from 4 to 60 inches in diameter. The most common pipe materials in the collection and conveyance system are reinforced concrete pipe (RCP), cast iron pipe (CIP), ductile iron pipe (DIP), polyvinyl chloride (PVC), and asbestos cement pipe (ACP). Prior to 1978, ACP was primarily used. In more recent construction, PVC pipe has been used extensively. The first conventional wastewater collection facilities in Stafford County were constructed in the 1930's.

A map showing the current and future sewer system is presented in the back pocket at the end of this Master Plan (*Stafford County Wastewater Improvements*).

7.2 UPDATE AND CALIBRATION OF SEWER SYSTEM MODEL

A functional, calibrated model was used to assess the performance of DPW's sewer system. The hydraulic model can be used to better understand and assess the capabilities of the DPW's system by simulating and identifying hydraulic limitations within the system under specified flow conditions. The sewer model was initially calibrated in April 2003 by conducting flow monitoring. Flow monitoring and calibration of the sewer model was not performed for the 2018 water and sewer system master planning work.

The sewer model is a very valuable tool for DPW and will continue to be of value provided that the input files are maintained and updated as the sewer system expands and changes. This includes collecting additional data on sewer flow conditions and updating system piping. When used in conjunction with the other tools, such as GIS and SCADA, the model will serve as an integral part to the successful management and operation of the DPW sewer system.

7.3 REVIEW OF SEWER FLOWS AND MANHOLE ALLOCATION

7.3.1 Methodology for Projecting Sewer Flows

Wet weather flows are used to assess the hydraulic capacity of sewer systems and are composed of three components:

- Sanitary base flow generated by homes, businesses, etc.
- Infiltration due to normal groundwater levels (dry weather infiltration).
- I/I due to rainfall and high groundwater levels (rainfall-dependent I/I).

The formula for calculating the sewer loads for wet weather conditions is as follows:

Peak Wet Weather Flow (PWWF) = Average Dry Weather Flow (ADWF) + Rainfall-Dependent I/I (RDI/I)

Where:

Peak Wet Weather Flow (PWWF) equals the peak hourly flow during wet weather conditions.

Average Dry Weather Flow (ADWF) is the average flow that occurs in sanitary sewers on a daily basis with no evident reaction to rainfall. The ADWF is composed of sanitary base flow and groundwater infiltration. For Stafford, the sanitary base flows through the planning period are roughly equal to 65% to 80% of the average day water demand which approximates the customers' water demand that is returned to the sanitary sewer. Groundwater infiltration (GWI) is an allowance that is added to the sanitary base flow (derived from sewage flow factors) to obtain the dry weather flow. GWI represents flow that is separate and distinguished from inflow resulting from storm events during wet weather conditions. The allowance used in this Master Plan for GWI is estimated to be 500 gpd/inch diameter-mile (gpdidm).

Rainfall-Dependent I/I consists of rainfall that enters the collection system through direct connections (roof leaders, manholes, etc.) and causes an almost immediate increase in wastewater flows. RDI/I data was used to establish an overall sewer system peaking factor of 3.5 in the 2006 Master Plan. The 3.5 peaking factor for the overall sewer system was also used in this Master Plan to reflect RDI/I.

To define the design flow conditions for the sewer system, the equation presented above was modified as follows:

Peak Wet Weather Flow (PWWF) = (Sanitary Base Flow x Peak Factor) + Groundwater Infiltration

In the sewer model, a global peak factor is multiplied by the sanitary base flow at each manhole in the sewer system and the GWI component (500 gpdidm) is subsequently added to the computed manhole flow as the flow is routed through the downstream sewer piping.

7.3.2 Sanitary Base Flows for Near-term Conditions

Near-term flows were developed using estimated sewer flows from existing and proposed near-term development. Average sewer flows were applied to the nearest manholes.

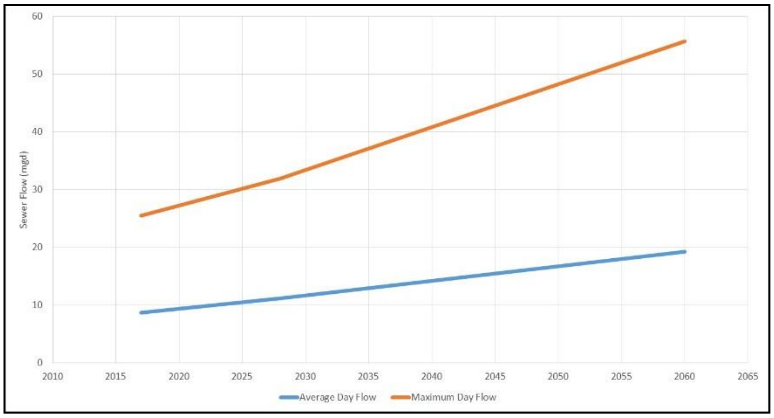
7.3.3 Sanitary Base Flows for Buildout Conditions

Buildout flows were developed using estimated sewer flows from existing and proposed near-term development as well as future land use. Average sewer flows were applied to the nearest manholes.

7.3.4 Determination of Total Peak Design Flow

Design flow for a sewer is defined as the maximum flow rate that occurs under selected weather and growth conditions. Average daily sewer flows are expected to increase from approximately 8.7 mgd (2017) to roughly 19.2 mgd under buildout (2060) conditions. During the same period, the maximum day flows are expected to increase from approximately 25.5 mgd (2017) to 55.7 mgd at buildout (2060) based on a peaking factor of 3.5 times the average base sanitary flow. The sewer flow projections are shown in Figure 7.3.1.

Figure 7.3.1 - Projected Sewer Flows



7.4 OVERVIEW OF SEWER SYSTEM PLANNING AND DESIGN CRITERIA

In general, the regulatory requirements for collection systems have been more vigorously enforced in recent years, specifically in regard to sanitary sewer overflows. A sanitary sewer overflow (SSO) is the discharge of raw sewage from a municipal sanitary sewer system into basements, or out of manholes and pumping stations and onto streets, playgrounds, and streams without any form of treatment. The USEPA and the Virginia Department of Environmental Quality (VDEQ) believe that inadequate management, operation and maintenance for sewage collection and conveyance systems pose a significant threat to receiving water quality and public health through the discharge of SSOs. However, the USEPA and VDEQ recognize that SSOs cannot be completely eliminated, and that sanitary sewer systems that are designed to not overflow when a given design storm occurs, may nonetheless experience wet weather induced overflows as the result of conditions other than the design storm.

- A sanitary sewer collection system has basically two main functions: (1) to convey the design peak discharge, and (2) to transport solids so that deposits are kept to a minimum. It is imperative, therefore, that the sanitary sewer has adequate capacity for the peak flow and that it functions at minimum flows without excessive maintenance and generation of odors.

- The planning and design criteria used in the 2006 Water and Sewer System Master Plan are used in this Master Plan to evaluate the sewer system and to plan future improvements, upgrades, and expansions of facilities. The planning and design criteria were reviewed with DPW to identify any modifications needed to reflect recent or anticipated future changes and to document policy decisions regarding application of the criteria. Understanding the potential impacts that revising the planning and design criteria may have on the existing and proposed capital improvements is essential.

The sewer planning and design criteria used in this Master Plan include the following:

"n" value = 0.013 for all pipe materials

Minimum Velocity = 2.25 ft/sec

Maximum Velocity = 15 ft/sec

For this study, “threshold” values were established to identify the point at which capacity enhancement measures for pipelines within the sanitary sewer system should be undertaken. There are no established requirements or guidelines for partial-to-full flow (q/Q) ratios. Selection of the q/Q ratios and the associated range of pipeline sizes are based on best professional judgement taking into consideration the following:

- Potential delays associated with implementation of future improvements (e.g., planning, siting, design, and construction).
- Risk of sanitary sewer system overflows.
- Excess capacity in sanitary sewer pipelines resulting in higher maintenance and possible odors.
- Rate of development (i.e., timing for additional future improvements).
- Potential for additional future development.

Based on these considerations, the values shown in Table 7.4.1 were used in this study.

Table 7.4.1 – Partial-to-Full Flow Ratios for Gravity Sewers

Pipeline Diameter	q/Q Ratio
8-inch through 12-inch	0.50
15-inch and up	0.85

The q/Q ratio of 0.85 (d/D ratio of 0.75) for the large diameter pipelines reflects the desire to maximize flow in the existing interceptor sewers while maintaining some reserve capacity. The q/Q ratio of 0.50 for smaller diameter pipelines reflects the uncertainty in the spatial distribution of sewer loads served by the smaller piping in the sewer system. By applying relatively conservative q/Q ratios for the analysis curve, pipelines will be identified prior to reaching full capacity and thus reduce the likelihood of surcharge and/or overflow conditions. It should be noted that existing pipelines that exceeded the design criteria and were less than full through buildout conditions (q/Q less than 1.0) were not recommended for replacement. Rather, these pipelines were flagged for future investigation and possible flow monitoring during the planning period.

7.5 OVERVIEW OF SEWER SYSTEM IMPROVEMENTS

Hydraulic modeling was performed using InfoSewer™ to assess the capabilities of the existing and future sewer system under near-term (2028) and buildout (2060) flow conditions. The near-term and buildout peak flows used for hydraulic modeling were approximately 25.5 mgd and 55.7 mgd, respectively.

The sewer system improvements presented in this Master Plan are shown on the figure in the pocket at the end of this Master Plan (*Stafford County Wastewater Improvements*) and the timing for implementation of the improvements is included in the pocket at the end of this Master Plan (*Stafford County General Sewer Improvement Program*).

7.6 KEY FINDINGS

- Planning and design criteria used in this Master Plan are consistent with the criteria adopted by national organizations, local utilities, and state regulatory agencies. In addition, planning and design criteria should be applied on a case-by-case basis and may change over time.
- Regulations governing wastewater collection systems will continue to be rigorously enforced.
- Hydraulic modeling was performed using InfoSewer™ to assess the capabilities of the existing and future sewer system under near-term (2028) and buildout (2060) flow conditions. The near-term and buildout maximum day flows used for hydraulic modeling were 25.5 mgd and 55.7 mgd, respectively.

- The overall cost for the sewer system improvments presented in this Master Plan through the buildout condition is approximately **$86 million**. Approximately **$48 million** is proposed through the next ten-year planning period (FY2019 - FY2028).

7.7 PLAN OF ACTION

- DPW will continue to maintain the GIS database on the wastewater collection system and sewer hydraulic model with complete and up-to-date information.
- DPW will continue to assess sewer system conditions by conducting field investigations and periodically reviewing physical attributes (pipe diameter and material), results of hydraulic modeling, and locations of sewer main breaks and other maintenance history (work orders).
- DPW will continue to review sewer system planning and design criteria and make changes to the proposed improvement projects, as needed.
- DPW will continue to collect data for various design storm events and proactively investigate I/I problems.
- DPW will collect site-specific cost information on proposed projects, if available, and refine the budget-level costs presented in this Master Plan.
- DPW will routinely review the timing of sewer projects proposed in this Master Plan and coordinate these sewer projects with water projects, roadway projects and other related activities.

7.8 RECOMMENDED SEWER SYSTEM IMPROVEMENTS

This section identifies the major components of DPW's sewer system and evaluates the performance and operation of the system compared with the criteria presented previously and in Technical Memorandum 2 (*Summary of Sewer Planning and Design Criteria*). The evaluation is based on a review of existing operational data, discussions with DPW staff, and results of the simulations from the InfoSewer™ modeling. The sewer system improvements presented in this section are shown on the figure in the pocket at the end of this Master Plan (Sewer System – Proposed Improvements) and the schedule showing the timing for implementation of the improvements is included in the pocket at the end of this Master Plan (Summary of Costs and Schedule for Recommended CIP Improvements).

The sewer system improvements presented in this Master Plan are for the area inside the Urban Service Area.

A-4: Construct 12-inch gravity main along Accokeek Creek from location downstream of Rowser PS

This project includes design and construction of a 12-inch gravity main along Accokeek Creek from location downstream of Rowser PS (3,121 feet). The purpose of the project is to serve future customers in the area tributary to Accokeek Creek between I-95 and Jefferson Davis Highway. The timing for construction of this project is dependent on the timing of future flows in the area.

Priority	*2 – Near-term*
Design	*FY2021*
Construct	*FY2022*
Total Project Cost	*$819,000*

A-14: Construct 18-inch and 24-inch gravity main along Jefferson Davis Highway from Lakeview Court to Coal Landing Road

This project includes design and construction of 18-inch and 24-inch gravity main along Jefferson Davis Highway from Lakeview Court to Coal Landing Road (4,895 feet). The purpose of the project is to serve future customers along the Jefferson Davis Highway corridor south of Aquia WWTP. The timing for construction of this project is dependent on the timing of flows in the area between Jefferson Davis Highway and Olde Concord Road.

Priority	*1 – Current operations*
Design	*FY2021*
Construct	*FY2022*
Total Project Cost	*$1,459,000*

A-16: Replace 8-inch with 12-inch gravity main from vicinity of Nina Cove to Jefferson Davis Highway

This project includes replacement of the existing 8-inch with 12-inch gravity main from vicinity of Nina Cove to Jefferson Davis Highway (1,427 feet). The purpose of the project is to increase the conveyance capacity of the existing 8-inch gravity main. Prior to replacing the existing gravity main, it is recommended that flow monitoring and/or sewer modeling be performed over a 10-year period to assess the available capacity remaining in the existing gravity main.

Priority	*7 – Flow monitoring*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$375,000*

A-18: Replace 24-inch with 36-inch gravity main along Austin Run from Whitsons Run to Austin Run PS

This project includes replacement of the existing 24-inch with 36-inch gravity main along Austin Run from Whitsons Run to Austin Run PS (2,354 feet). The purpose of the project is to increase the capacity of this critical interceptor which conveys flow from the interceptors along Austin and Whitsons Run under I-95 to the Austin Run PS. This project serves a large area and a major source of flow impacting the timing for replacing the existing gravity main is the quantity of flow through the Camp Barrett PS (Quantico Marine Corps Base). Delays in the quantity of flow from Quantico Marine Corps Base could delay the construction of this project.

Priority	*2 – Near-term*
Design	*FY2021*
Construct	*FY2022*
Total Project Cost	*$1,393,000*

A-23: Replace 10-inch with 12-inch gravity main along unnamed tributary to Aquia Creek and Choptank Road from Garrisonville Road to Huckstep Avenue

This project includes replacement of the existing 10-inch with 12-inch gravity main along unnamed tributary to Aquia Creek and Choptank Road from Garrisonville Road to Huckstep Avenue (4,193 feet). The purpose of the project is to increase conveyance capacity of the existing 10-inch gravity main. Prior to replacing the existing gravity main, it is recommended that flow monitoring and/or sewer modeling be performed over a 10-year period to assess the available capacity remaining in the existing gravity main.

Priority	*7 – Flow monitoring*

Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,100,000*

A-27: Construct 8-inch gravity main along South Austin Run from Mine Road to PS on September Lane

This project includes design and construction of an 8-inch gravity main along South Austin Run from Mine Road to PS on September Lane (4,928 feet). The purpose of the project is to serve future customers along South Austin Run and eliminate the pumping station along September Lane. The timing for construction of this project is dependent on the timing of flows in this area and should be implemented prior to exceeding the capacity of the pumping station along September Lane.

Priority	*5 – Growth and operations driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,038,000*

A-31: Construct 12-inch gravity main along unnamed tributary to Accokeek Creek from Wyche Road PS to interceptor along Accokeek Creek

This project includes design and construction of a 12-inch gravity main along unnamed tributary to Accokeek Creek from Wyche Road PS to interceptor along Accokeek Creek (1,638 feet). The purpose of the project is to eliminate the Wyche Road PS and serve future customers downstream of the Wyche Road PS. The timing for construction of this project is dependent on the timing for construction of the Lower Accokeek PS and interceptor.

Priority	*2 – Near-term*
Design	*FY2023*
Construct	*FY2024*
Total Project Cost	*$430,000*

A-32: Construct 10-inch gravity main from Rowser PS to interceptor along Accokeek Creek

This project includes design and construction of a 10-inch gravity main from Rowser PS to interceptor along Accokeek Creek (532 feet). The purpose of the project is to eliminate the Rowser PS and serve future customers downstream of the Rowser PS. The timing for construction of this project is dependent on the timing for construction of the Lower Accokeek PS and interceptor.

Priority	*2 – Near-term*
Design	*FY2023*
Construct	*FY2024*
Total Project Cost	*$130,000*

A-33: Construct 18-inch gravity main along Accokeek Creek from vicinity of Jumping Branch Road to Lower Accokeek PS

This project includes design and construction of an 18-inch gravity main along Accokeek Creek from vicinity of Jumping Branch Road to Lower Accokeek PS (4,816 feet). The purpose of the project is to serve future customers in the vicinity of the Lower Accokeek PS and convey flows from the Wyche Road PS and the Rowser PS. The timing for construction of this project is dependent on the timing for construction of the Lower Accokeek PS.

Priority	*2 – Near-term*

Design	*FY2023*
Construct	*FY2024*
Total Project Cost	*$1,436,000*

A-37: Construct 8-inch gravity main from interceptor along Austin Run near Winding Creek Road and Marshall Road to Heritage Oaks II PS

This project includes design and construction of an 8-inch gravity main from interceptor along Austin Run near Winding Creek Road and Marshall Road to Heritage Oaks II PS (2,635 feet). The purpose of the project is to eliminate the Heritage Oaks II PS. The timing for construction of this project is dependent on growth and available capacity of the Heritage Oaks II PS.

Priority	*5 – Growth and operations driven*
Design	*FY2024*
Construct	*FY2025*
Total Project Cost	*$555,000*

A-38: Replace 10-inch and 12-inch with 18-inch gravity main along unnamed tributary to Whitsons Run from Onville Road to interceptor along Whitsons Run

This project includes replacement of the existing 10-inch and 12-inch with 18-inch gravity main along Garrisonville Road and unnamed tributary to Whitsons Run from Onville Road to interceptor along Whitsons Run (3,439 feet). The purpose of the project is to increase the conveyance capacity of the existing 10-inch and 12-inch gravity mains to handle flows from Quantico Marine Corps Base. The timing for construction of this project is dependent on the timing of flows from Quantico Marine Corps Base.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,025,000*

A-39: Replace 18-inch with 24-inch gravity main along Whitsons Run from vicinity of Highpointe Boulevard to interceptor along Austin Run

This project includes replacement of the existing 18-inch with 24-inch gravity main along Whitsons Run from vicinity of Highpointe Boulevard to interceptor along Austin Run (7,481 feet). The purpose of the project is to increase the conveyance capacity of the existing 18-inch gravity mains to handle flows from Quantico Marine Corps Base. The timing for construction of this project is dependent on the timing of flows from Quantico Marine Corps Base.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$2,484,000*

A-40: Replace 8-inch with 12-inch gravity main along Aquia Drive from Delaware Drive to Vessel Drive

This project includes replacement of the existing 8-inch with 12-inch gravity main along Aquia Drive from Delaware Drive to Vessel Drive (2,028 feet). The purpose of the project is to increase the conveyance capacity of the existing 8-inch gravity main. Prior to replacing the existing gravity main, it is recommended that flow monitoring and/or sewer modeling be performed to assess the available capacity remaining in the existing gravity main.

Priority	*7 – Flow monitoring*
Design	*FY2025*
Construct	*FY2026*
Total Project Cost	*$532,000*

A-42: Replace 8-inch with 18-inch gravity main along Jefferson Davis Highway from Aquia Creek to Potomac Hills Drive

This project includes replacement of the existing 8-inch with 18-inch gravity main along Jefferson Davis Highway from Aquia Creek to Potomac Hills Drive (717 feet). The purpose of the project is to significantly increase the capacity of the interceptor serving the northern portion of the Jefferson Davis Highway corridor.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$214,000*

A-47: Replace 8-inch with 15-inch gravity main near Voyage Drive

This project includes replacement of the existing 8-inch with 15-inch gravity main near Voyage Drive (1,206 feet). The purpose of this project is to increase the capacity of the existing 8-inch gravity main. Prior to replacing the existing gravity main, it is recommended that flow monitoring be performed to assess the available capacity remaining in the existing gravity main.

Priority	*7 – Flow monitoring*
Design	*FY2025*
Construct	*FY2026*
Total Project Cost	*$338,000*

A-48: Construct 8-inch gravity main to serve area near Sheron Lane to PS along Aquia Creek

This project includes design and construction of an 8-inch gravity main to serve area near Sheron Lane to PS along Aquia Creek (3,500 feet). The purpose of the project is to serve future customers in this area.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$737,000*

A-51: Replace 12-inch with 15-inch gravity main along Coal Landing Rd from Jefferson Davis Hwy to Knightsbridge Way

This project includes replacement of the existing 12-inch with 15-inch gravity main along Coal Landing Rd from Jefferson Davis Hwy to Knightsbridge Way (1,586 feet). The purpose of the project is to serve future customers in this area.

Priority	*1 – Current operations*
Design	*FY2020*
Construct	*FY2021*
Total Project Cost	*$444,000*

A-53: Replace 8-inch with 12-inch gravity main along Courthouse Rd

This project includes replacement of the 8-inch with a 12-inch gravity main along Courthouse Rd (2,191 feet). The purpose of the project is to serve future customers in this area.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$575,000*

A-55: Construct 8-inch gravity main from Stafford Hospital PS to Lower Accokeek PS

This project includes design and construction of an 8-inch gravity main to serve area near Sheron Lane to PS along Aquia Creek (6,771 feet). The purpose of the project is to eliminate the Stafford Hospital PS and to serve future customers in this area.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,426,000*

A-56: Construct 8-inch gravity main from Abberly PS to Lower Accokeek PS

This project includes design and construction of an 8-inch gravity main from Abberly PS to Lower Accokeek PS (1,434 feet). The purpose of the project is to eliminate the Abberly PS and to serve future customers in this area.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$302,000*

A-57: Construct 8-inch gravity main from Stafford Middle School PS to near Old Potomac Church Rd

This project includes design and construction of an 8-inch gravity main from Stafford Middle School PS to near Old Potomac Church Road (1,675 feet). The purpose of the project is to eliminate the Stafford Middle School PS and to serve future customers in this area.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$353,000*

A-100: Replace 10-inch with 16-inch force main along Cedar Lane from Upper Accokeek PS to Rocky Run Interceptor

This project includes replacement of 10-inch with 16-inch force main along Cedar Lane from Upper Accokeek PS to Rocky Run Interceptor (7,820 feet). The purpose of the project is to convey flows from the Upper Accokeek PS to the Rocky Run Interceptor. The timing for construction of this project is dependent on the timing of improvements to the Upper Accokeek PS.

Priority	*2 – Near-term*
Design	*FY2027*
Construct	*FY2028*
Total Project Cost	*$2,280,000*

A-103: Construct 12-inch force main along Jefferson Davis Highway from Lower Accokeek PS

This project includes design and construction of a 12-inch force main along Jefferson Davis Highway from Lower Accokeek PS (12,248 feet). The purpose of the project is to convey flows from the Lower Accokeek PS which will serve future customers in the Accokeek basin east of I-95. The timing for construction of this project is dependent on the timing of sewer flows in the area.

Priority	*2 – Near-term*
Design	*FY2023*
Construct	*FY2024*
Total Project Cost	*$3,175,000*

A-106: Construct 4-inch force main from Sunflower Dr PS to Mine Road

This project includes design and construction of a 4-inch force main from Sunflower Dr PS to Mine Road (1,300 feet). The purpose of this project is to serve future customer west of I-95. The timing for construction of this project is dependent on the timing for new customers in the area.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$253,000*

A-112: Construct 6-inch force main from Sheron Lane PS near Aquia Creek

This project includes design and construction of a 6-inch force main from Sheron Lane PS near Aquia Creek (6,500 feet). The purpose of the project is to serve future customers in the area near Sheron Lane. The timing for construction of this project is dependent on the timing of flows in this area and construction of the Sheron Lane PS (A-231).

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,369,000*

A-114: Replace 8-inch and 10-inch force mains with an 18-inch force main from Aquia Creek PS at Crucifix

This project includes replacement of the 8-inch and 10-inch force mains with an 18-inch force main from Aquia Creek PS at Crucifix to existing 14-inch force main near Aquia Drive (2,600 feet). The purpose of the project is to alleviate capacity concerns in the 8-inch and 10-inch force mains.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$800,000*

A-115: Replace 14-inch and 12-inch force mains with an 18-inch force main from Aquia at Bridge PS to existing 18-inch force main near Starboard Cove Lane

This project includes replacement of the 14-inch and 12-inch force mains from Aquia at Bridge PS to the existing 18-inch force main near Starboard Cove Lane (6,976 feet). The purpose of the project is to increase the capacity of the force main. The timing for construction of this project is dependent on the timing of flows in this area.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$2,147,000*

A-205: Expand Upper Accokeek PS

This project includes expansion of the Upper Accokeek PS by 1.15 mgd. The purpose of this project is to serve growth in the vicinity of the pumping station.

Priority	*1 – Current operations*
Design	*FY2027*
Construct	*FY2028*
Total Project Cost	*$559,000*

A-207: Construct Lower Accokeek PS

This project includes design and construction of the Lower Accokeek PS at 1.65 mgd. The purpose of the project is to serve future customers in the vicinity of the Lower Accokeek PS and convey flows from the Wyche Road PS, Rowser PS and a few others in the area which will be abandoned.

Priority	*2 – Near-term*
Design	*FY2023*
Construct	*FY2024*
Total Project Cost	*$802,000*

A-209: Construct Sunflower Drive PS

This project includes expansion of the Route 630 PS by 0.612 mgd. The purpose of the project is to serve future customers in the vicinity of the Route 630 PS.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$297,000*

A-212: Expand Aquia Creek PS

This project includes expansion of the Aquia Creek PS by 0.881 mgd. Prior to expanding the existing pumping station, it is recommended that flow monitoring and/or sewer modeling be performed over a 10-year period to assess the available capacity remaining in the existing pumping station.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$428,000*

A-231: Construct Sheron Lane PS

This project includes design and construction of the Sheron Lane PS at 0.04 mgd. The purpose of the project is to serve future customers in the area near Sheron Lane.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$19,000*

A-236: Decommission Stafford Middle School PS

This project includes decommissioning Stafford Middle School PS. The purpose of the project is to convey flow by gravity thereby reducing maintenance costs and energy costs associated with pumping. The timing for construction of this project is dependent on the timing for construction of Lower Accokeek PS.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$100,000*

A-237: Decommission Stafford Hospital PS

This project includes decommissioning Stafford Hospital PS. The purpose of the project is to convey flow by gravity thereby reducing maintenance costs and energy costs associated with pumping. The timing for construction of this project is dependent on the timing for construction of Lower Accokeek PS.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$100,000*

A-238: Decommission Rowser PS

This project includes decommissioning Rowser PS. The purpose of the project is to convey flow by gravity thereby reducing maintenance costs and energy costs associated with pumping. The timing for construction of this project is dependent on the timing for construction of Lower Accokeek PS.

Priority	*2 – Near-term*
Design	*FY2019*
Construct	*FY2020*
Total Project Cost	*$100,000*

A-239: Decommission Wyche Industrial Park PS

This project includes decommissioning Wyche Industrial Park PS. The purpose of the project is to convey flow by gravity thereby reducing maintenance costs and energy costs associated with pumping. The timing for construction of this project is dependent on the timing for construction of Lower Accokeek PS.

Priority	*2 – Near-term*
Design	*FY2019*
Construct	*FY2020*
Total Project Cost	*$100,000*

A-241: Decommission Autumn Ridge PS

This project includes decommissioning Autumn Ridge PS. The purpose of the project is to convey flow by gravity thereby reducing maintenance costs and energy costs associated with pumping.

Priority	*5 – Operations driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$100,000*

LFR-3: Replace 15-inch and 12-inch with 24-inch gravity main along Falls Run from 30-inch in vicinity of Stanstead Road to Pennsbury Court

This project includes replacement of the existing 15-inch and 12-inch with 24-inch gravity main along Falls Run from 30-inch in vicinity of Stanstead Road to Pennsbury Court (12,338 feet). The purpose of the project is to significantly increase the conveyance capacity of interceptor along Falls Run to satisfy future needs. The timing for this project is dependent on the timing for development of Westlake and the area along Potomac Creek west of Abel Lake.

Priority	*2 – Near-term*
Design	*FY2019*
Construct	*FY2020 - FY2021*
Total Project Cost	*$4,097,000*

LFR-12: Replace 15-inch with 21-inch gravity main along Potomac Creek from vicinity of I-95 to Potomac Creek PS

This project includes replacement of the existing 15-inch with 21-inch gravity main along Potomac Creek from vicinity of I-95 to Potomac Creek PS (3,950 feet). The purpose of this project is to convey flows from existing and future customers in the Centreport area to the Potomac Creek PS.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,241,000*

LFR-14: Replace 18-inch and 24-inch with 27-inch gravity main along Claiborne Run from vicinity of White Oak Road to Morton Road

This project includes replacement of the existing 18-inch and 24-inch with 27-inch gravity main along Claiborne Run from vicinity of White Oak Road to Morton Road (12,424 feet). The timing for this project will be dependent on the timing of flows from the Potomac Creek PS. The County has been replacing segments of interceptor along Claiborne Run downstream of this segment due to poor structural condition.

The County may decide to replace the 18-inch and 24-inch mains earlier than capacity would dictate if these mains are also found to be in poor condition.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$4,347,000*

LFR-15: Replace 18-inch, 15-inch and 12-inch with 24-inch gravity main along Claiborne Run from Morton Road to Kings Hill Road

This project includes replacement of the existing 18-inch, 15-inch and 12-inch with 24-inch gravity main along Claiborne Run from Morton Road to Kings Hill Road (6,212 feet). The timing for this project will be dependent on the timing of flows from the Potomac Creek PS. The County has been replacing segments of interceptor along Claiborne Run downstream of this segment due to poor structural condition. The County may decide to replace the 18-inch, 15-inch and 12-inch mains earlier than capacity would dictate if these mains are also found to be in poor condition.

Priority	*2 – Near-term*
Design	*FY2021*
Construct	*FY2022*
Total Project Cost	*$2,063,000*

LFR-22: Construct 15-inch gravity main from force main serving Upper Potomac Creek PS No. 1 to Falls Run interceptor near Berea Church Road

This project includes design and construction of a 15-inch gravity main from force main serving Upper Potomac Creek PS No. 1 to Falls Run interceptor near Berea Church Road (3,000 feet). The purpose of the project is to serve future customers in this area. Due to the significant improvements needed for the interceptor along Falls Run which serves this area, it is recommended that the timing for construction of sewer facilities in Westlake and the area along Potomac Creek west of Abel Lake be deferred until development in the area warrants replacement of the Falls Run Interceptor.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$841,000*

LFR-24: Construct 15-inch gravity main along Horsepen Run from Westlake Industrial Park PS in vicinity of Cedar Grove Road

This project includes design and construction of a 15-inch gravity main along Horsepen Run from the Westlake Industrial Park PS in the vicinity of Cedar Grove Road (3,600 feet). The purpose of the project is to serve future customers in this area. Due to the significant improvements needed for the interceptor along Falls Run which serves this area, it is recommended that the timing for construction of sewer facilities in Westlake and the area along Potomac Creek west of Abel Lake be deferred until development in the area warrants replacement of the Falls Run Interceptor.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,009,000*

LFR-27: Construct 12-inch gravity main along unnamed tributary to Potomac Creek from area near airport to Centreport Parkway

This project includes design and construction of a 12-inch gravity main along unnamed tributary to Potomac Creek from Centreport Parkway (3,800 feet). The purpose of the project is to serve future customers in this area.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$997,000*

LFR-30: Construct 12-inch gravity main along unnamed tributary to England Run from England Run PS to Days Inn PS

This project includes design and construction of a 12-inch gravity main along unnamed tributary to England Run from England Run PS to Days Inn PS (4,500 feet). The purpose of the project is to convey flows from the upstream interceptors which were constructed to eliminate the Days Inn PS and the Heritage CC PS.

Priority	*5 – Operations driven*
Design	*FY2025*
Construct	*FY2026*
Total Project Cost	*$1,181,000*

LFR-31: Replace 15-inch with 21-inch gravity main along Falls Run from Pennsbury Court to vicinity of Averil Court

This project includes replacement of the existing 15-inch with 21-inch gravity main along Falls Run from Pennsbury Court to vicinity of Averil Court (5,987 feet).

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,882,000*

LFR-32: Construct 21-inch gravity main along Falls Run from vicinity of Averil Court to vicinity of Holly Corner Road

This project includes design and construction of a 21-inch gravity main along Falls Run from vicinity of Averil Court to vicinity of Holly Corner Road (2,815 feet). The purpose of the project is to serve future customers in Westlake. Due to the significant improvements needed for the interceptor along Falls Run which serves this area, it is recommended that the timing for construction of sewer facilities in the Westlake Development and the area along Potomac Creek west of Abel Lake be deferred until development in the area warrants replacement of the Falls Run Interceptor.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$885,000*

LFR-34: Construct 15-inch gravity main along Potomac Creek upstream of Upper Potomac Creek PS

This project includes design and construction of a 15-inch gravity main along Potomac Creek upstream of Upper Potomac Creek PS (2,256 feet). The purpose of the project is to serve future customers in this area. Due to the significant improvements needed for the interceptor along Falls Run which serves this area, it is recommended that the timing for construction of sewer facilities in the Westlake Development and the area along Potomac Creek west of Abel Lake be deferred until development in the area warrants replacement of the Falls Run Interceptor.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$632,000*

LFR-46: Construct 8-inch gravity main along unnamed tributary to Potomac Creek in vicinity of Potomac Creek Industrial Park

This project includes design and construction of an 8-inch gravity main along unnamed tributary to Potomac Creek in vicinity of Potomac Creek Industrial Park (2,121 feet). The purpose of the project is to serve future customers in the vicinity of the Potomac Creek Industrial Park.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$447,000*

LFR-51: Construct 10-inch gravity main to serve future Central PDA growth

This project includes design and construction of a 10-inch gravity main to serve future Central PDA growth (1,000 feet).

Priority	*5 – Growth driven*
Design	*FY2023*
Construct	*FY2024*
Total Project Cost	*$245,000*

LFR-55: Construct 21-inch gravity main along Warrenton Rd from Holly Corner Rd to Poplar Rd

This project includes design and construction of a 21-inch gravity main along Warrenton Road from Holly Corner Road to Poplar Road (3,200 feet). The purpose of the project is to serve future customers in the Westlake area.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,006,000*

LFR-58: Replace 8-inch with 15-inch gravity main along Cambridge St from the FM to Michael Street

This project includes replacement of the existing 8-inch main with a 15-inch gravity main along Cambridge Street from the force main to Michael Street (480 feet). The purpose of the project is to serve future customers in this area.

Priority	*2 – Near-term*
Design	*FY2021*

Construct	*FY2022*
Total Project Cost	*$135,000*

LFR-59: Replace 8-inch with 10-inch gravity main from Nelms Circle to Auction Drive

This project includes replacement of 8-inch main with a 10-inch gravity main from Nelms Circle to Auction Drive (5,638 feet). The purpose of the project is to serve future customers in this area.

Priority	*2 – Near-term*
Design	*FY2027*
Construct	*FY2028*
Total Project Cost	*$1,379,000*

LFR-101: Construct 10-inch force main from Westlake Industrial Park PS to Falls Run interceptor

This project includes design and construction of a 10-inch force main from the Westlake PS to Falls Run interceptor (13,397 feet). The purpose of the project is to serve future customers in this area. Due to the significant improvements needed for the interceptor along Falls Run which serves this area, it is recommended that the timing for construction of sewer facilities in the Westlake Development and the area along Potomac Creek west of Abel Lake be deferred until development in the area warrants replacement of the Falls Run Interceptor.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$3,364,000*

LFR-102: Construct 8-inch force main from Upper Potomac Creek PS No. 1 to 15-inch gravity main connected to Falls Run interceptor

This project includes design and construction of an 8-inch force main from Upper Potomac Creek PS No. 1 to 15-inch gravity main connected to Falls Run interceptor (6,631 feet). The purpose of the project is to serve future customers in this area. Due to the significant improvements needed for the interceptor along Falls Run which serves this area, it is recommended that the timing for construction of sewer facilities in the Westlake Development and the area along Potomac Creek west of Abel Lake be deferred until development in the area warrants replacement of the Falls Run Interceptor.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$1,611,000*

LFR-120: Construct a 24-inch force main from Falls Run PS to Little Falls Run WWTP

This project includes constructing a 24-inch force main from the Falls Run PS to the Little Falls Run WWTP (33,400 ft). The Claiborne Run PS is currently served by a single 24-inch force main. This option would reduce the size of the expansion required at the Claiborne Run PS (LFR-214) and eliminate the need for repumping flows at the Claiborne Run PS. The ability to pump flows for this long distance (roughly 35,000 feet) through the force main would need to be evaluated.

Priority	*2 – Near-term*
Design	*FY2019*
Construct	*FY2020 – FY2021*
Total Project Cost	*$10,822,000*

LFR-129: Replace 8-inch with 16-inch force main from Potomac Creek PS

This project includes replacement of the existing 8-inch with a 16-inch force main from Potomac Creek PS (9,055 feet). The purpose of the project is to serve future customers in the area served by the Potomac Creek PS.

Priority	*2 – Near-term*
Design	*FY2022*
Construct	*FY2023*
Total Project Cost	*$2,640,000*

LFR-202: Construct Westlake Industrial Park PS

This project includes design and construction of the Westlake PS at 1.8 mgd. The purpose of the project is to serve future customers in this area.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$875,000*

LFR-204: Expand Celebrate VA PS

This project includes design and construction of the expansion of the Celebrate VA PS by 1.53 mgd. The purpose of the project is to serve future customers in this area.

Priority	*5 – Growth driven*
Design	*FY2025*
Construct	*FY2026*
Total Project Cost	*$744,000*

LFR-209: Replace Falls Run PS

This project includes design and construction of the Falls Run PS at 17.6 mgd.

Priority	*2 – Near-term*
Design	*FY2021*
Construct	*FY2022 – FY2023*
Total Project Cost	*$8,554,000*

LFR-214: Expand Claiborne Run PS

This project includes expansion of the Claiborne Run PS by 6.93 mgd.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$3,368,000*

LFR-215: Expand Hickory Ridge PS

This project includes expansion of the Hickory Ridge PS from 0.306 mgd.

Priority	*3 – Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$149,000*

LFR-217: Expand Stratford Place PS

This project includes expansion of Stratford Place PS by 0.165 mgd. This pumping station serves an area that is partially developed and is served by public sewer.

Priority	*2 – Near-term*
Design	*FY2024*
Construct	*FY2025*
Total Project Cost	*$80,000*

LFR-222: Construct Upper Potomac Creek PS

This project includes design and construction of the Upper Potomac Creek PS at 1.2 mgd. The purpose of the project is to serve future customers in this area.

Priority	*5 – Growth driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$588,000*

LFR-226: Expand Potomac Creek PS

This project includes expansion of the Potomac Creek PS by 2.04 mgd.

Priority	*2 – Near-term*
Design	*FY2023*
Construct	*FY2024*
Total Project Cost	*$991,000*

LFR-227: Expand Cannon Ridge PS

This project includes expansion of the Cannon Ridge PS by 0.313 mgd.

Priority	*3 - Buildout*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$152,000*

LFR-228: Expand Ingleside PS

This project includes expansion of the Ingleside PS by 0.311 mgd.

Priority	*2 – Near-term*
Design	*FY2023*
Construct	*FY2024*
Total Project Cost	*$151,000*

LFR-229: Expand Sweetbriar Woods PS

This project includes expansion of the Sweetbriar Woods PS by 0.195 mgd.

Priority	*1 – Current operations*
Design	*FY2019*
Construct	*FY2020*
Total Project Cost	*$95,000*

LFR-230: Decommission Day's Inn PS

This project includes decommissioning Day's Inn PS. The purpose of the project is to convey flow by gravity thereby reducing maintenance costs and energy costs associated with pumping.

Priority	*5 – Operations driven*
Design	*Beyond FY2028*
Construct	*Beyond FY2028*
Total Project Cost	*$100,000*

TECHNICAL MEMORANDUM 9

Cost Estimates

Prepared for: Stafford County Department of Public Works
Prepared by: O'Brien & Gere
Date: February 2018

This technical memorandum is one of a series being prepared for the Water and Sewer Master Plan project. The purpose of this technical memorandum is to summarize the approach for estimating "order-of-magnitude" project costs to be used for planning and budgeting.

CONTENTS

9.1 CONSTRUCTION COSTS

The budget level cost estimates prepared for this study are based on cost curves, previous estimates and historical data from comparable work, estimating guides and handbooks, and local manufacturers' cost data. Cost assumptions for the water and sewer system follow.

9.1.1 Water Pumping Stations

Construction costs for pumping stations were based on installed capacity before allowances. Construction costs for water pumping stations were estimated based on $0.30/gallon.

9.1.2 Water Storage Facilities

Finished water storage facilities proposed for this study were elevated water storage tanks. Construction costs for elevated water storage were estimated based on $2/gallon.

9.1.3 Water Pipelines and Valving

The costs for installing pipe are dependent on ground conditions (land use) and geography (roads, rivers, railroad crossings, etc.). For example, installing pipe in an urban setting is typically more costly than installation in a rural area for a variety of reasons. The reasons include a greater likelihood of construction in the roadway instead of the right-of-way, a higher potential for conflict with other utilities and greater difficulty in maintaining traffic. Costs for tunneling (railroad and highway crossings) were added to the baseline costs for installing water mains.

Table 9.1.1 shows the estimated cost for installation of water pipelines. The major assumptions follow:

- Costs for pipelines include basic costs, pavement restoration and traffic control.
- Pipelines would be installed in the public rights-of-way.

Detailed alignment studies will be required prior to design and construction.

Table 9.1.1 – Construction Costs for Water Pipelines

Pipeline Diameter (inches)	Construction Cost ($/ft)
6	130
8	145
10	150
12	160
16	180
20	190
24	200

Construction costs for pressure reducing valves in vaults were estimated based on $50,000/valve.

9.1.4 Sewer Pipelines

The unit cost for gravity sewer pipelines will be dependent on the trench depth and the potential for utility conflicts, maintaining traffic control, and other construction difficulties. Tables 9.1.2 shows the unit costs for construction and replacement of proposed gravity sewer pipelines. The major assumptions follow:

- Costs for pipelines include basic costs, pavement restoration and traffic control.
- Pipelines would be installed in the public rights-of-way.

Table 9.1.2 – Construction Costs for Gravity Sewer Pipelines

Pipeline Diameter (inches)	Construction Cost ($/ft)
8	130
10	151
12	162
15	173
18	184
21	194
24	205
27	216
30	227
42	292

The unit cost for construction of force mains is shown in Table 9.1.3. The basic cost assumptions used for water mains in Table 9.1.1 apply to force mains.

Table 9.1.3 – Construction Costs for Sewer Force Mains

Pipeline Diameter (inches)	Construction Cost ($/ft)
4	120
6	130
8	150
10	155
12	160
16	180
18	190
24	200

9.1.5 Wastewater Pumping Stations

Construction costs for wastewater pumping stations were based on installed capacity before allowances. Construction costs for wastewater pumping stations were estimated based on $0.30/gallon.

9.1.6 Construction Cost Contingency Allowance

Construction cost estimates were based on planning level unit costs and include an allowance of 35% for construction contingencies.

9.2 PROJECT COSTS

Construction and replacement cost estimates presented in this Technical Memorandum were converted to total project costs by adding an allowance of 20% for engineering, legal and administrative fees. Project cost estimates are intended for use in budget development, wherever site-specific costs are not utilized. They represent typical experience and should be adjusted, where appropriate, to meet special needs.

TECHNICAL MEMORANDUM 8

Wastewater Treatment

Prepared for: Stafford County Department of Public Works
Prepared by: O'Brien & Gere
Date: February 2018

This technical memorandum is one of a series being prepared for the Water and Sewer Master Plan project. The purpose of this technical memorandum is to identify plans for expansion and upgrades to accommodate increased wastewater flows and more stringent effluent regulations.

CONTENTS

8.1 STAFFORD COUNTY WASTEWATER TREATMENT APPROACH

8.1.1 Stafford County Wastewater Treatment Facilities Overview

Stafford County currently operates two wastewater treatment facilities (WWTFs):

- Aquia WWTF which treats flows from northern Stafford County, and
- Little Falls Run (LFR) WWTF which treats flows from southern Stafford County.

The Aquia WWTF provides service to a predominantly residential area, as well as a small commercial district. The collection system also receives flow from the Quantico Marine Corps Base, part of which is located in the northern part of Stafford County. Treated effluent from Aquia WWTF is discharged to Austin Run approximately 1 mile upstream of its confluence with (tidal) Aquia Creek, a tributary to the Potomac River Basin and Chesapeake Bay. The Aquia WWTF was built in 1980 at a capacity of 3 MGD average daily flow. Since then, (see Table 8.1.1 below) the plant has undergone several upgrades and expansion of the liquid process trains. The capacities of the major processes are listed in Table 8.1.3. The current permit allows for 8 MGD on the basis of wasteload, and 10 MGD on the basis of average day flow.

Table 8.1.1 – Aquia WWTF Major Plant Upgrades and Expansions

Date	Aquia WWTF Major Upgrade/Expansion
1980	Original plant construction at 3 MGD capacity
1990	Expansion to 4.2 MGD, including nutrient removal processes
1994	Expansion increased permitted capacity to 6.5 MGD
2003	Plant was upgraded by adding redundancy to existing systems
2011	Plant was upgraded to meet Enhanced Nutrient Removal (ENR) requirements and redundancy was added to existing systems; treatment capacity increased to 8 MGD

The Little Falls Run WWTF is located in the southern part of the County with a tributary service area that is predominantly residential, commercial and light industrial. Treated effluent is discharged directly to the tidal Rappahannock River, which is tributary to the Chesapeake Bay. Little Falls Run WWTF was built in 1991 to replace the Claiborne Run Treatment Plant. The plant has also undergone several upgrades, which are listed in Table 8.1.2 below. The current permit allows for 8 MGD on the basis of wasteload, and 8 MGD on the basis of flow. The capacities of the major processes are listed in Table 8.1.4.

Table 8.1.2 – Little Falls Run WWTF Major Plant Upgrades and Expansions

Date	Little Falls Run WWTF Major Upgrade/Expansion
1991	Original plant construction at 4.0 MGD
1996	Biosolids handling upgrade
2005	Filtration and disinfection upgrade
2010	Plant was upgraded to meet Enhanced Nutrient Removal (ENR) requirements; rerated to 8 MGD

Stafford County also has a VPDES permit to construct a third wastewater treatment facility in the Widewater section of the County, located east of the Aquia WWTF. The prospective facility would have an initial capacity of 0.5 MGD and an ultimate capacity of 2.2 MGD, but there is no current Chesapeake Bay wasteload allocation (WLA) assigned to this facility. As a result, the County would need to transfer some wasteload allocation or purchase nutrient credits, along with providing ENR level treatment. Construction of this facility is on hold pending a review of the County's Land Use Plan.

Septic systems are used in those areas within Stafford County that are not served by one of the two treatment plants.

8.1.2 Treatment Processes

The Aquia and LFR WWTF's employ similar processes for treating wastewater with some key differences in capacity and treatment capabilities.

As noted above, the Aquia WWTF is currently permitted to treat 8 MGD based on wasteload and 10.0 MGD, on the basis of average day flow. Its VPDES permit, as issued by VDEQ, has an effective date of 11/20/2013 with an expiration date of 11/19/2018. As part of that permit the plant's discharge of the nutrient Nitrogen is limited to 73,093 lbs/year, while the discharge of Phosphorus is limited to 4,386 lbs/year by the permit's wasteload allocation (WLA). Under those WLAs, the plant is certified to meet some key effluent limitations including an annual average TN limit of 3.0 mg/L and an annual average TP limit of 0.18 mg/L. The full permit and associated fact sheet can be found in Appendix A of this Technical Memorandum. As part of its last major upgrade, the Aquia WWTF was outfitted with a third main biological train as well as upgrades to other parts of the plant. This upgrade brought the peak capacity of specific parts of the plant to 36 MGD. A breakdown of the main treatment processes for the plant as well as the current available capacity for each of these processes is shown in Table 8.1.3 below.

Table 8.1.3 – Aquia WWTF Permitted Flow and Main Treatment Process Capacities

Unit Process	Current Capacity – (MGD)
Permitted Flow	10.0
WLA Flow-Basis	8.0
Influent Screens	36.0
Grit/grease Removal	36.0
Biological Treatment	36.0
Tertiary Filtration	30.0
UV Disinfection	36.0
Aerobic Digestion	6.5
Dewatering	12.0

Aquia WWTF's current permit allows for 8 MGD on the basis of wasteload, and 10 MGD on the basis of flow. Improvements to the aerobic digestion/solids processing train, which has a current capacity of 6.5 MGD, may be required to operate at 8 MGD.

The Little Falls Run WWTF is currently permitted to treat an average daily flow of 8.0 MGD. Its VPDES permit, as issued by VDEQ, has an effective date of 10/1/2015 with an expiration date of 9/30/2020. A potential future flow tier of 13.0 MGD is identified. The plant is currently operating under Phase II of the VPDES permit, with respect to flow tier and effluent limits. As part of that permit the plant's discharge of the nutrient Nitrogen is limited to 97,458 lbs/year, while the discharge of Phosphorus is limited to 7,309 lbs/year by the permit's wasteload allocation (WLA). Under those WLAs, the plant is certified to meet some key effluent limitations including an annual average TN of 4.0 mg/L and an annual average TP of 0.30 mg/L. The full permit and associated fact sheet can be found in Appendix B of this report. A breakdown of the main treatment processes for the plant as well as the current available capacity for each of these processes is shown in Table 8.1.4 below.

Table 8.1.4 – Little Falls Run WWTF Permitted Flow and Main Treatment Process Capacities

Unit Process	Current Capacity – (MGD)
Permitted Flow	8.0

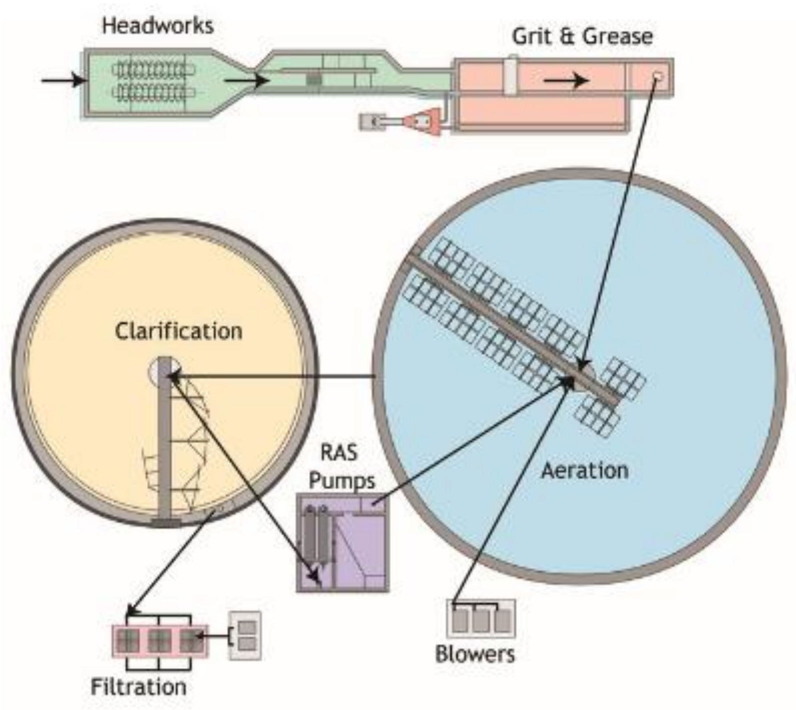
WLA Flow-Basis	8.0
Influent Screens	36.0
Grit/grease Removal	24.0
Biological Treatment	24.0
Tertiary Filtration	24.0
UV Disinfection	24.0
Aerobic Digestion	8.0
Dewatering	11.0

Little Falls Run WWTF's effective capacity and permitted capacity is 8.0 MGD.

LFR WWTF receives the majority of its flow from the Claiborne Run PS. Bar screens are used to separate trash and debris from influent wastewater in the headworks of the plant. A similar grit and grease cleaning system as Aquia WWTF is installed at the LFR WWTF. From this unit, wastewater is distributed to one of two main treatment trains. This biological system was also supplied by the Schreiber Corporation and consists of similarly-sized circular basins. Downstream of the biological treatment process, flow is sent to a set of traveling bridge (diamond-shaped) cloth-media filters followed by UV disinfection. Effluent flow from the LFR WWTF is sent to the Rappahannock River.

As described above, both plants utilize the Schreiber Corporation biological treatment system as their main treatment process. Over the years, Schreiber has installed these biological treatment basins and associated clarifiers in slightly different configurations depending on a variety of factors. Some older installations, like those in Stafford, have been installed as overlapping circular configurations between the biological basin and the clarifier, i.e., "peanut".

Figure 8.1.1 – Typical Overall Schreiber Corporation Process Flow Diagram



Biosolids produced as a byproduct of the secondary treatment process are thickened (by gravity), digested aerobically, and mechanically dewatered in centrifuges. Dried sludge is stored onsite until it is hauled away for land application.

As part of this report, a Basis of Design (BOD) table was prepared for each facility. The BOD table contains information such as existing capacity, design parameters, peak capacity, and manufacturer information. The BOD table for both plants as well as process flow diagrams and site plans are provided in Appendix C of this Technical Memorandum.

Note that Aquia must monitor for PCBs due to a Potomac River PCB TMDL. There is no designated treatment at the WWTF for the removal of PCBs, upstream monitoring and prohibitions are required.

Based on OBG's work within the Rappahannock River watershed, the Virginia Institute of Marine Science (VIMS) Rappahannock River Model will likely no longer be utilized for VPDES Permit renewals. Change in river policy due to recent environmental conditions and/or water quality model replacement introduces uncertainty into the 2020 LFR permit renewal process.

The promulgation of the Fresh Water Nutrient Criteria (FWNC) / Ammonia rule Fall 2017 to Spring 2018 by DEQ and VA's State Water Control Board (SWCB) introduces uncertainty (Aquia September 2018 renewal, LFR September 2020 renewal), risk of future non-compliance, and/or limitations on the ability to increase permitted LFR discharge beyond 8-MGD. If DEQ policies and procedures for zero-flow "unnamed tributaries" such as Austin Run do not provide relief from the new Ammonia rule, Aquia WWTF effluent discharge may need to be moved downstream (if improved mixing conditions are achievable) to meet what could otherwise be a very low seasonal ammonia limit starting with its September 2018 renewal.

8.1.3 Historical Performance

An integral part of determining the need for any future improvements is an analysis of historical performance data. Plant data are compiled on a daily, weekly, monthly and yearly basis depending on the parameter. A lot of this information can be found in the monthly Discharge Monitoring Report (DMR) that the plants are required to submit to DEQ. Performance of both plants were reviewed compared to existing VPDES effluent limits and general permit WLAs, as well as for general trends that may help show aspects of how the plants are performing relative to future capacity needs or regulatory requirements.

DMR data were provided for review from January 2015 to June 2017 (Aquia) and January 2015 to July 2017 (LFR). Table 8.1.5 and 8.1.6 present a summary of some of the key parameters that were reviewed and compared to the VPDES permits.

Table 8.1.5 – Aquia WWTF DMR Data

Parameter	Unit	Average	Max	Min
Flow	MGD	5.08	10.93	2.75
Influent TSS	mg/L	346	1,513	71
	lbs/day	14,523	59,356	2,779
Influent BOD_5	mg/L	232	600	30
	lbs/day	9,724	24,149	1,302
Influent TKN	mg/L	41	73	21
BOD/TKN Ratio	Ratio	5.7	8.2	1.4
Influent TP	mg/L	9.6	117.5	1.8

Table 8.1.6 – LFR WWTF DMR Data

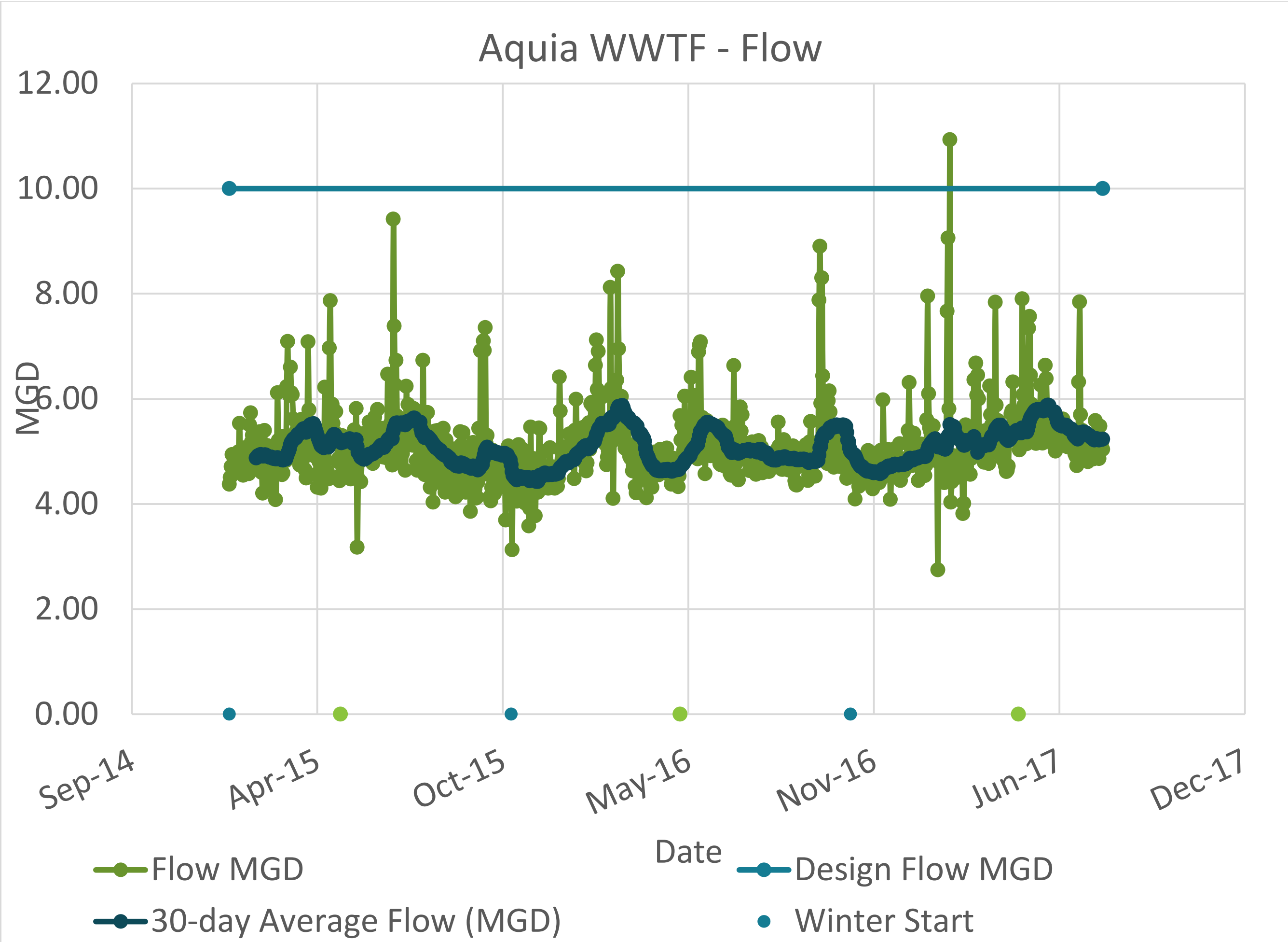
Parameter	Unit	Average	Max	Min
Flow	MGD	3.16	7.10	2.01
Influent TSS	mg/L	345	1,110	34
	lbs/day	8,899	30,257	960

Influent BOD_5	mg/L	235	560	22
	lbs/day	6,067	15,742	822
Influent NH_3-N	mg/L	39	78	10
	lbs/day	1,001	2,339	195
Influent TKN	mg/L	42	70	5
BOD_5/TKN Ratio	Ratio	5.6	8	4.4
Influent TP	mg/L	9.6	36	1.4

In addition to the graphs provided below, a variety of additional data on each plant have been compiled and analyzed. This information has been provided in the Appendix D of this Technical Memorandum.

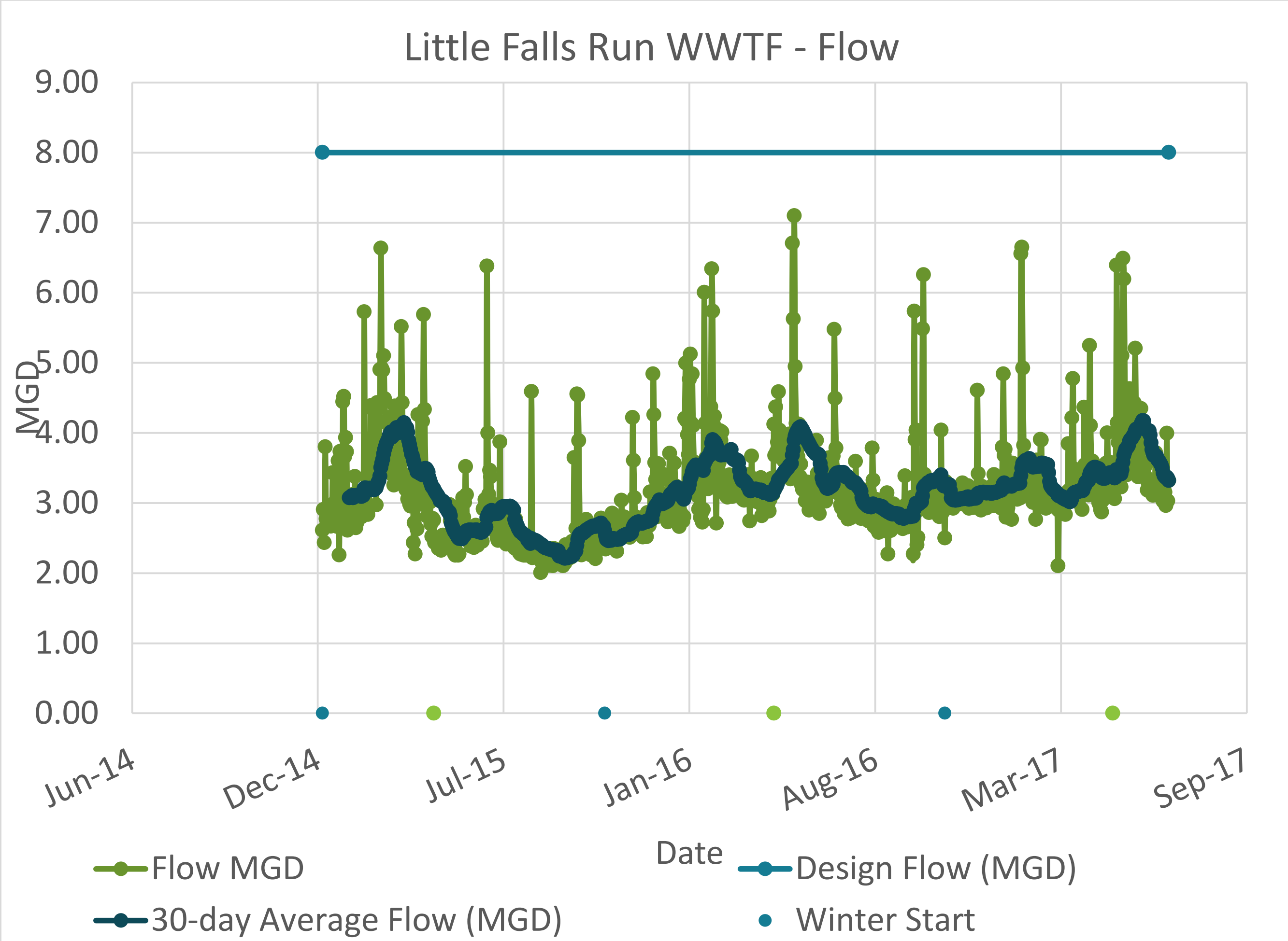
From January 2015 through July 2017, the average daily flow at the Aquia WWTF was 5.08 MGD with daily values ranging from 2.75 MGD to 10.93 MGD. The plant is currently permitted for an average design flow of 10 MGD and is running at approximately 55% of ADF hydraulic rating. Flow data shows a typical PDF roughly 2 times the ADF with little to no AAF increase over the last 3 years.

Figure 8.1.2 – Aquia WWTF Influent Flow



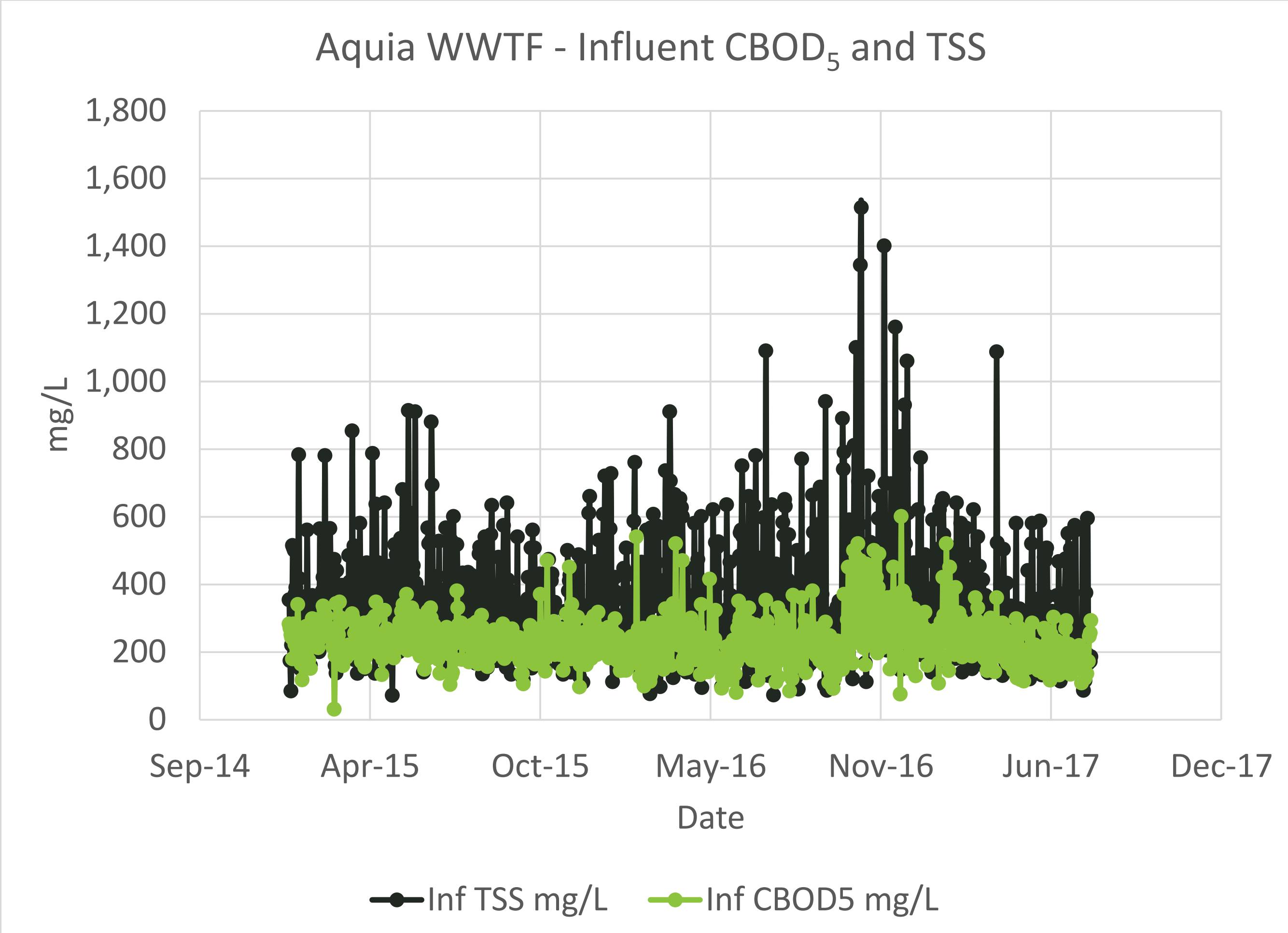
From January 2015 through June 2017, the average daily flow at the LFR WWTF was 3.16 MGD with daily values ranging from 2.01 MGD to 7.10 MGD. The plant is currently permitted for an average design flow of 8 MGD and is running at approximately 40% of ADF hydraulic rating. Flow data shows a typical PDF roughly 2.5 times the ADF with little to no AAF increase over the last 3 years. During the period of this data the plant has typically been run using only 1 of 2 available trains.

Figure 8.1.3 – LFR WWTF Influent Flow



The Aquia WWTF has shown relatively consistent flows and loads over the last three years. The plant sees an average influent of 5.08 MGD with an average influent BOD_5 load of 9,724 lbs/day and average TSS load of 14,523 lbs/day. Of note is that influent TSS is significantly higher than BOD_5 for the plant. For a municipal plant these parameters are typically of similar magnitude (concentrations, loads). High relative influent TSS loads could contribute to more sludge production at the plant compared to typical plants (per MG treated). The following figure shows historical BOD_5 and TSS influent loading.

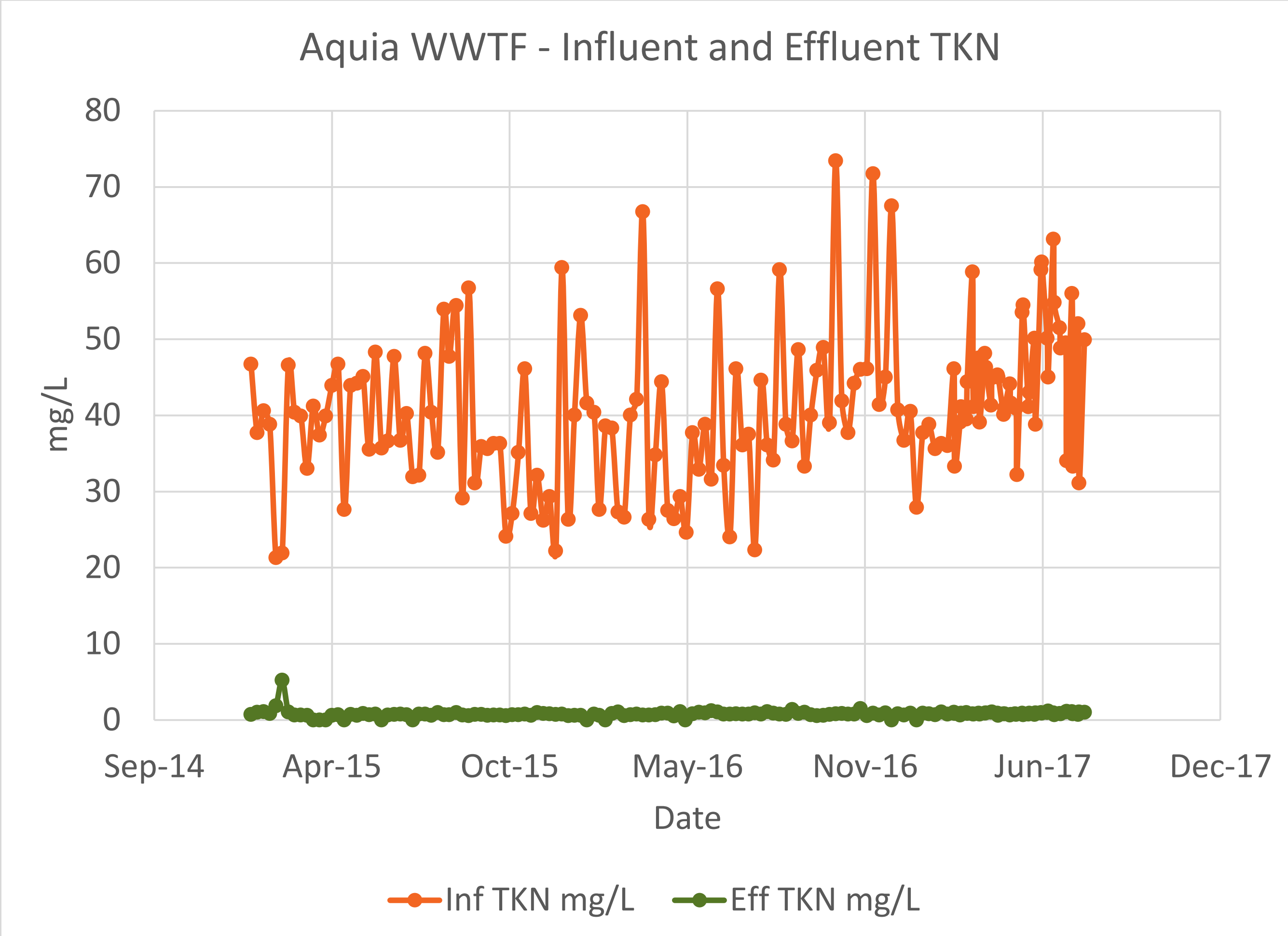
Figure 8.1.4 – Aquia WWTF Influent CBOD and TSS



The plant's current VPDES permit does not require monitoring of influent nutrients (nitrogen or phosphorus). However, an understanding of influent nutrients and the ratio of nutrients to available food, or BOD/CBOD is imperative for the design of BNR systems.

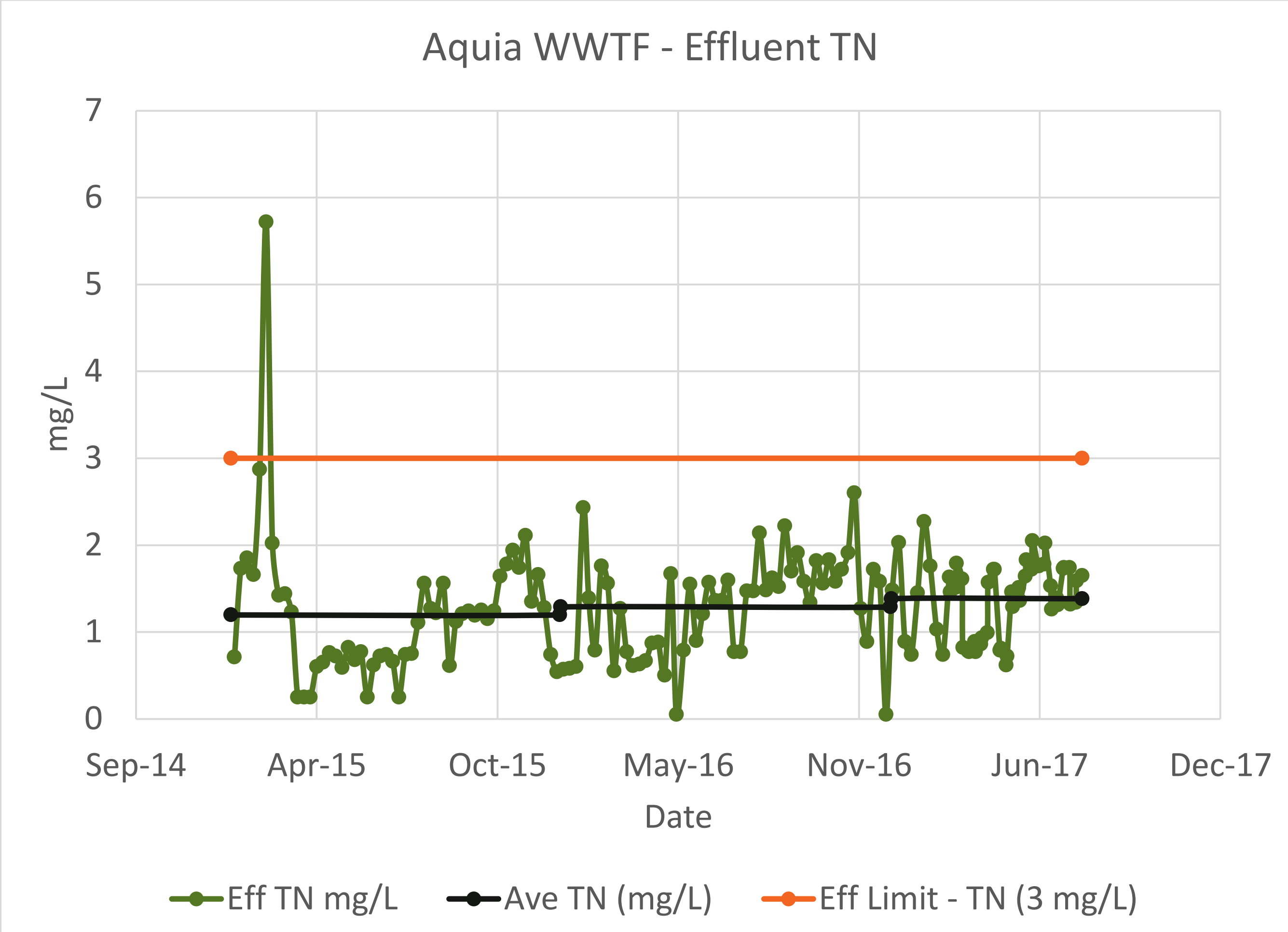
The plant sees an average influent TKN concentration of 41 mg/L, a typical concentration and range for this parameter. The average BOD_5/TKN ratio of 5.7 is greater than the recommended value for BNR design and shows that the plant is set up well to perform effective biological nutrient removal without routine (continuous) supplemental carbon feed.

Figure 8.1.5 – Aquia WWTF Influent and Effluent TKN



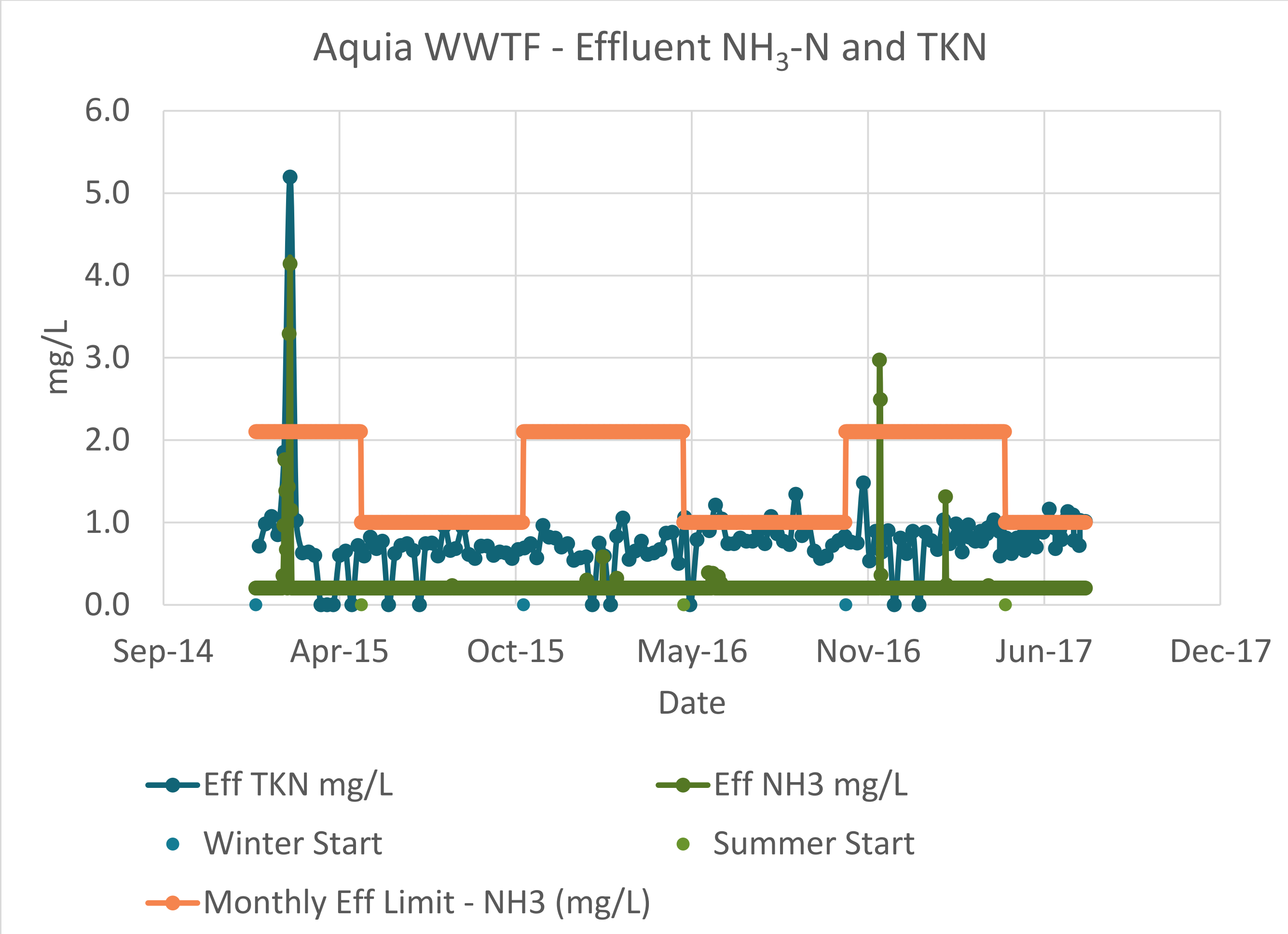
The annual average limit for TN is 3.0 mg/L. The plant has shown excellent effluent TN performance and is consistently meeting its WLA and permit limit goals for TN. This data shows good denitrification sizing for the plant and consistent performance through each train.

Figure 8.1.6 – Aquia WWTF Effluent TN



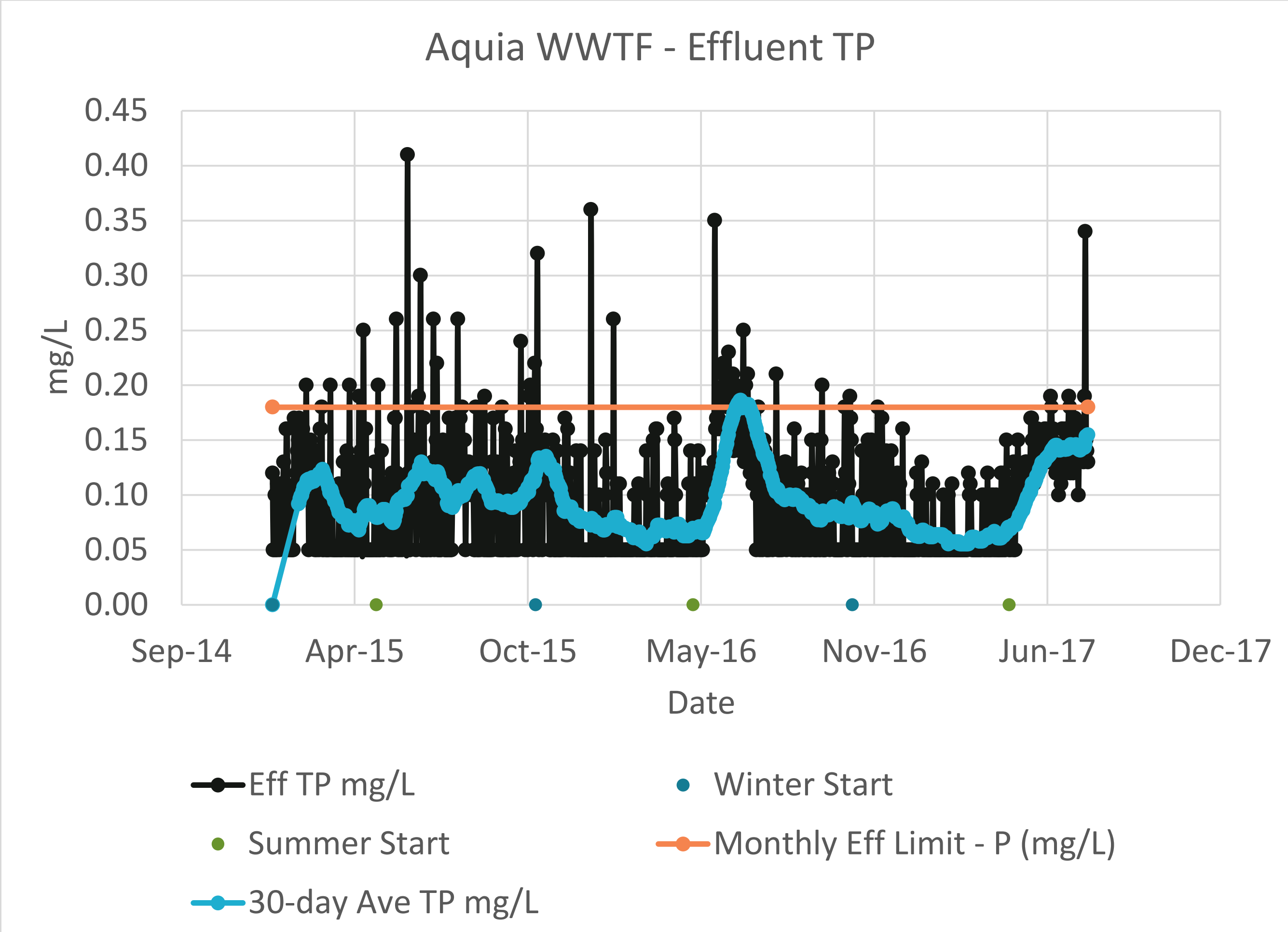
Effluent TKN minus effluent ammonia represents the organic nitrogen parameter of the plant flow. Typical concentrations below 0.75 as seen at the Aquia WWTF show good overall nitrification and effluent quality. The plant has also shown a consistent ability to meet both its winter and summer effluent NH_3-N limit with one or two outliers. Future regulatory changes to this region may require the plant to adhere to lower seasonal limits or a single, calendar year limit which may require consistently lower effluent NH_3-N discharge.

Figure 8.1.7 – Aquia WWTF Effluent NH3 and TKN



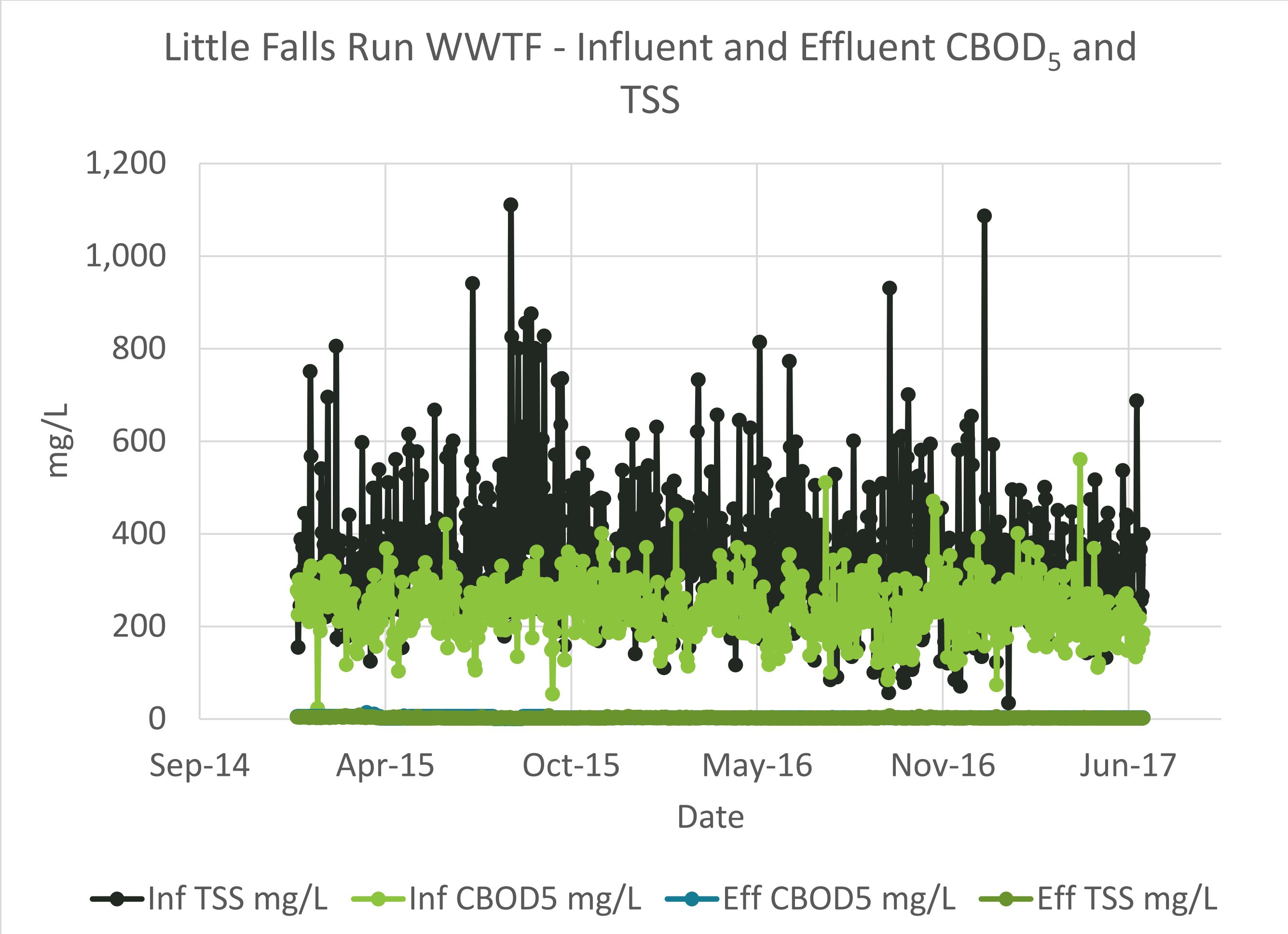
The annual average limit for TP is 0.18 mg/L. Effluent TP concentrations look to be adequate for current TP WLA in the VPDES Permit. It is unclear at this time as to the nature of the spikes seen in the graph below, but they do not seem to be impacting the overall average effluent TP concentration. It is possible that coagulant feed is being limited to save operational cost and achieve the desired effluent concentration. Coagulant feed could be increased if stricter TP requirements were implemented.

Figure 8.1.8 – Aquia WWTF Effluent TP



The LFR WWTF has also shown relatively consistent flows and loads over the last three years. The plant sees an average influent of 3.16 MGD with an average influent BOD_5 load of 6,067 lbs/day and average TSS load of 8,899 lbs/day. Of note is that influent TSS is significantly higher than BOD_5 for the plant. For a municipal plant these parameters would typically be linked more closely. This could contribute to more sludge production at the plant. The following figure shows historical BOD_5 and TSS influent loading.

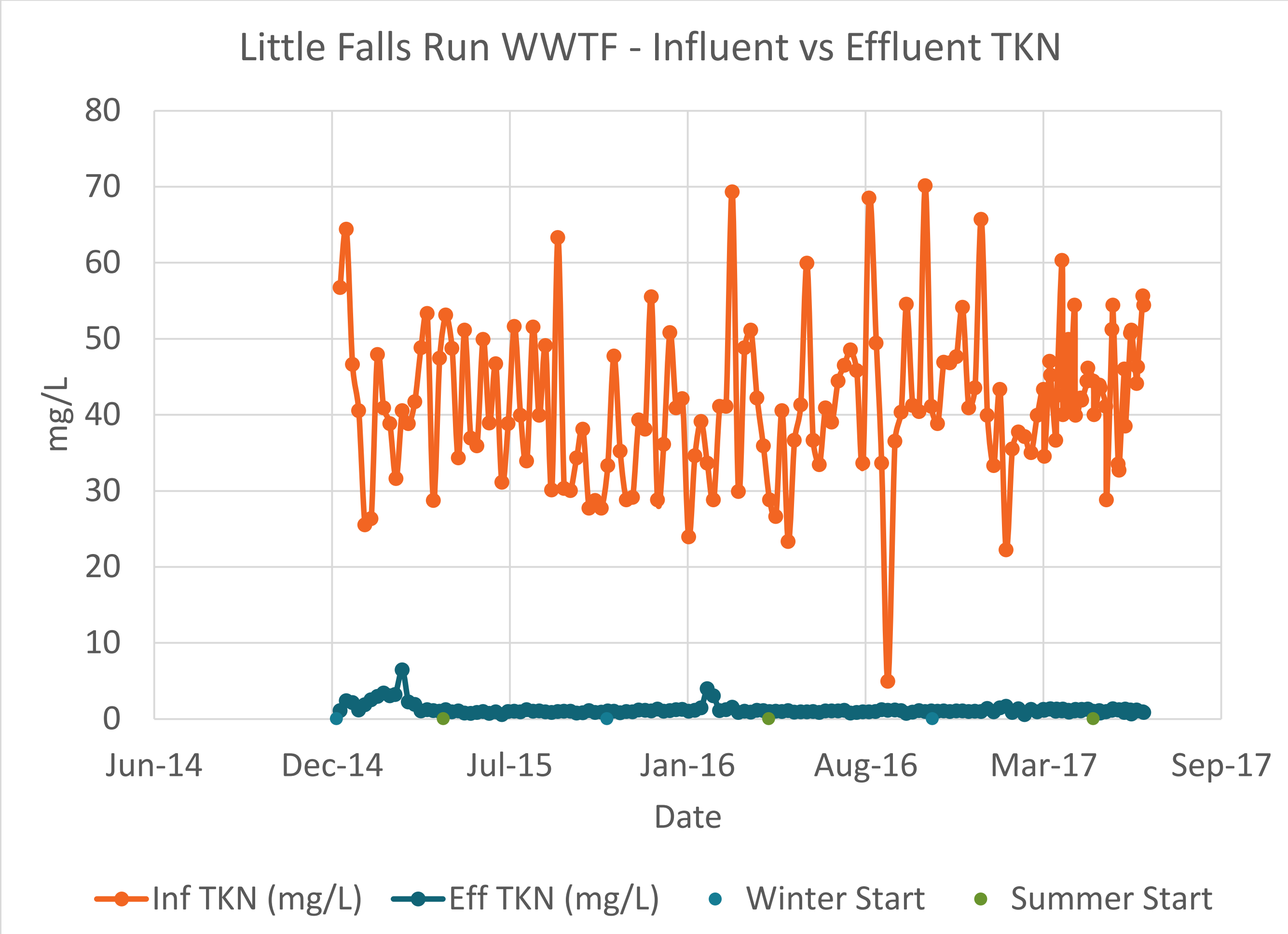
Figure 8.1.9 – LFR WWTF Influent and Effluent CBOD and TSS



The plant's current VPDES permit does not require monitoring of influent nutrients (nitrogen or phosphorus). However, an understanding of influent nutrients and the ratio of nutrients to available food, or BOD/CBOD is imperative for the design of BNR systems.

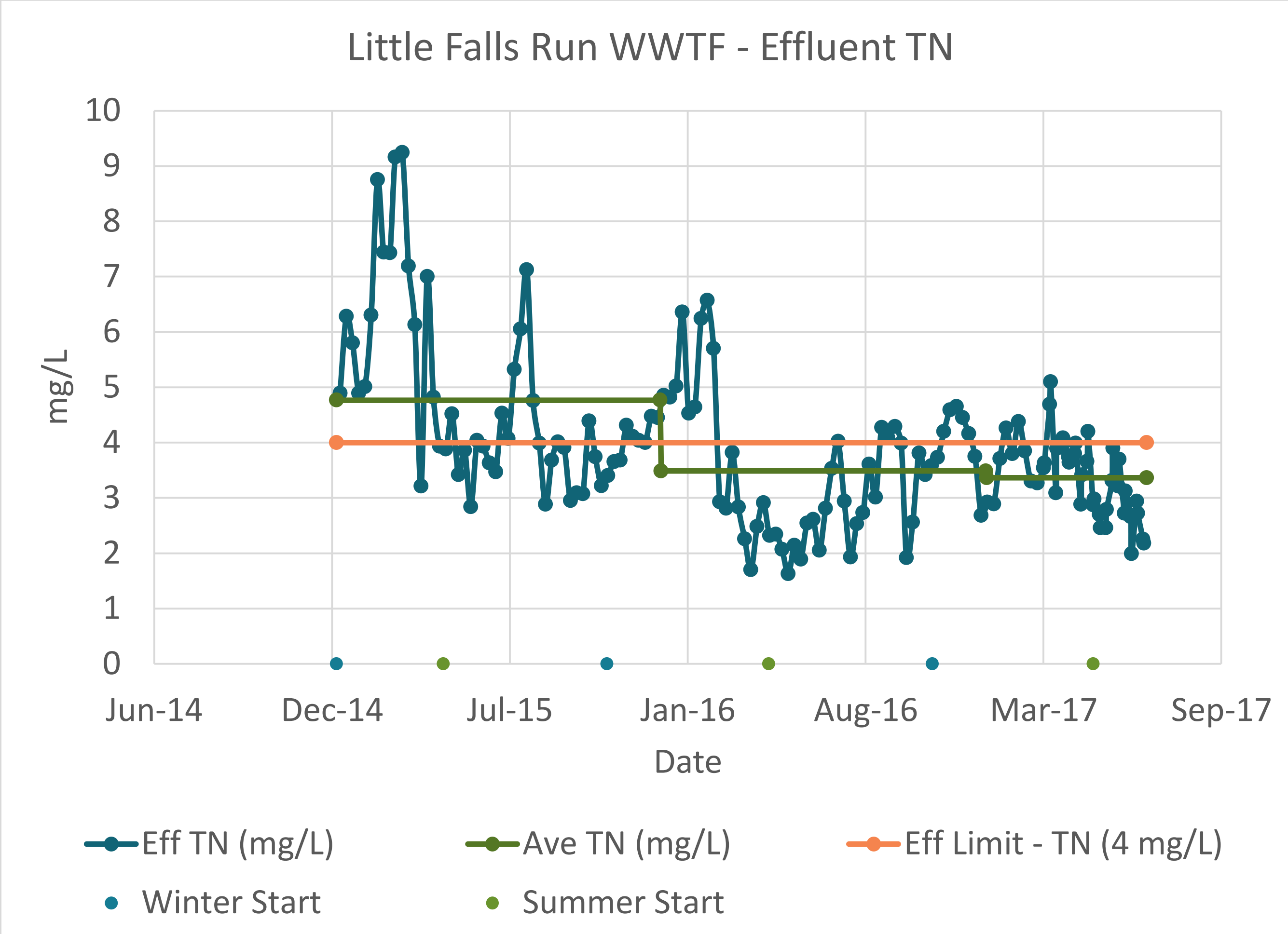
The plant sees an average influent TKN concentration of 42 mg/L, a typical concentration and range for this parameter. The average BOD_5/TKN ratio of 5.6 is greater than the recommended value for BNR design and shows that the plant is set up well to perform effective biological nutrient removal without routine (continuous) supplemental carbon feed.

Figure 8.1.10 – LFR WWTF Influent and Effluent TKN



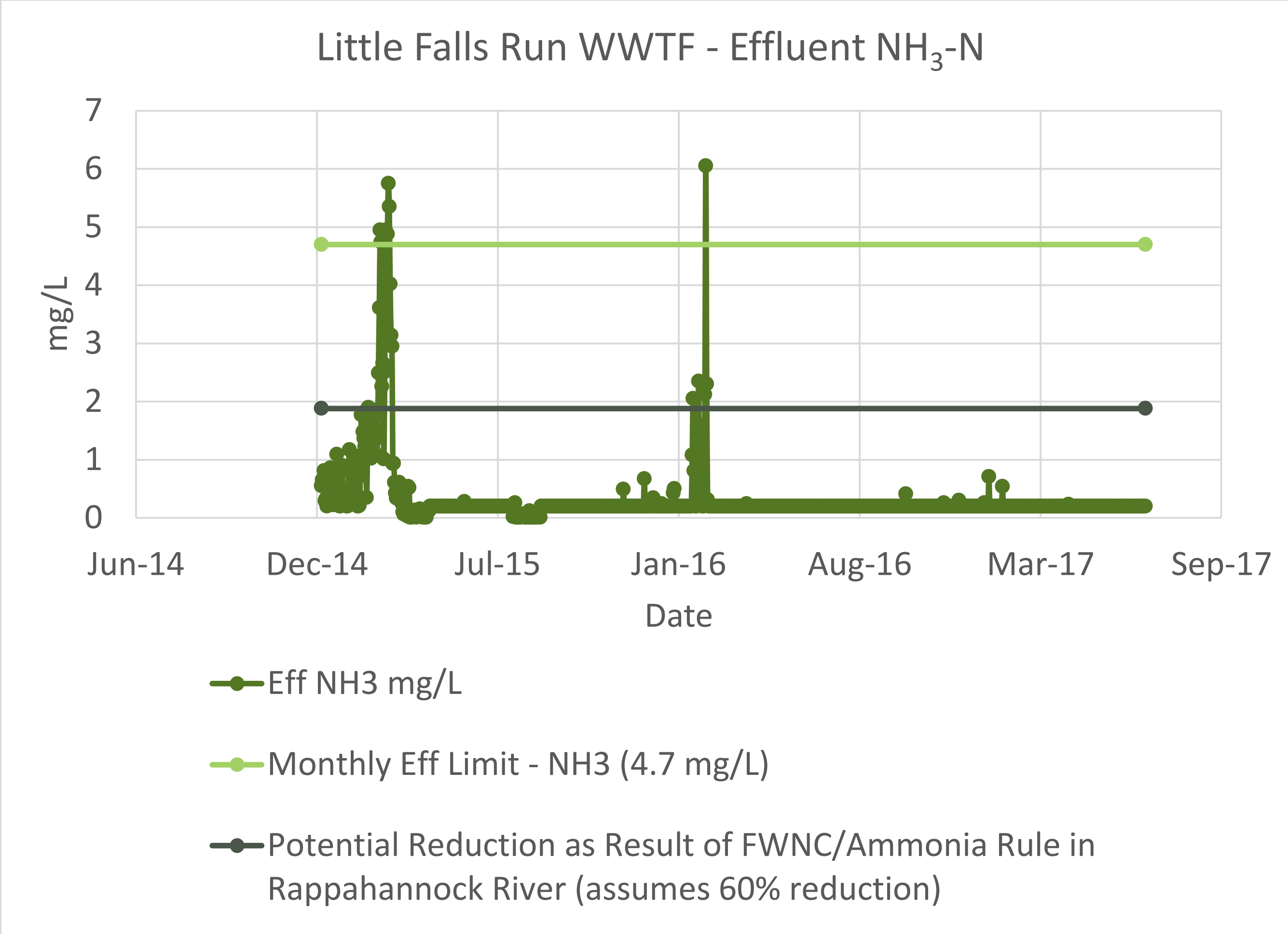
The LFR WWTF is expected to meet an annual average limit for TN of 4.0 mg/L. Although the plant has been effective at meeting this yearly limit it has been difficult. Any additional regulatory changes that affect this limit or a change in growth or population from the collection system could cause issues with meeting this limit in the future.

Figure 8.1.11 – LFR WWTF Effluent TN



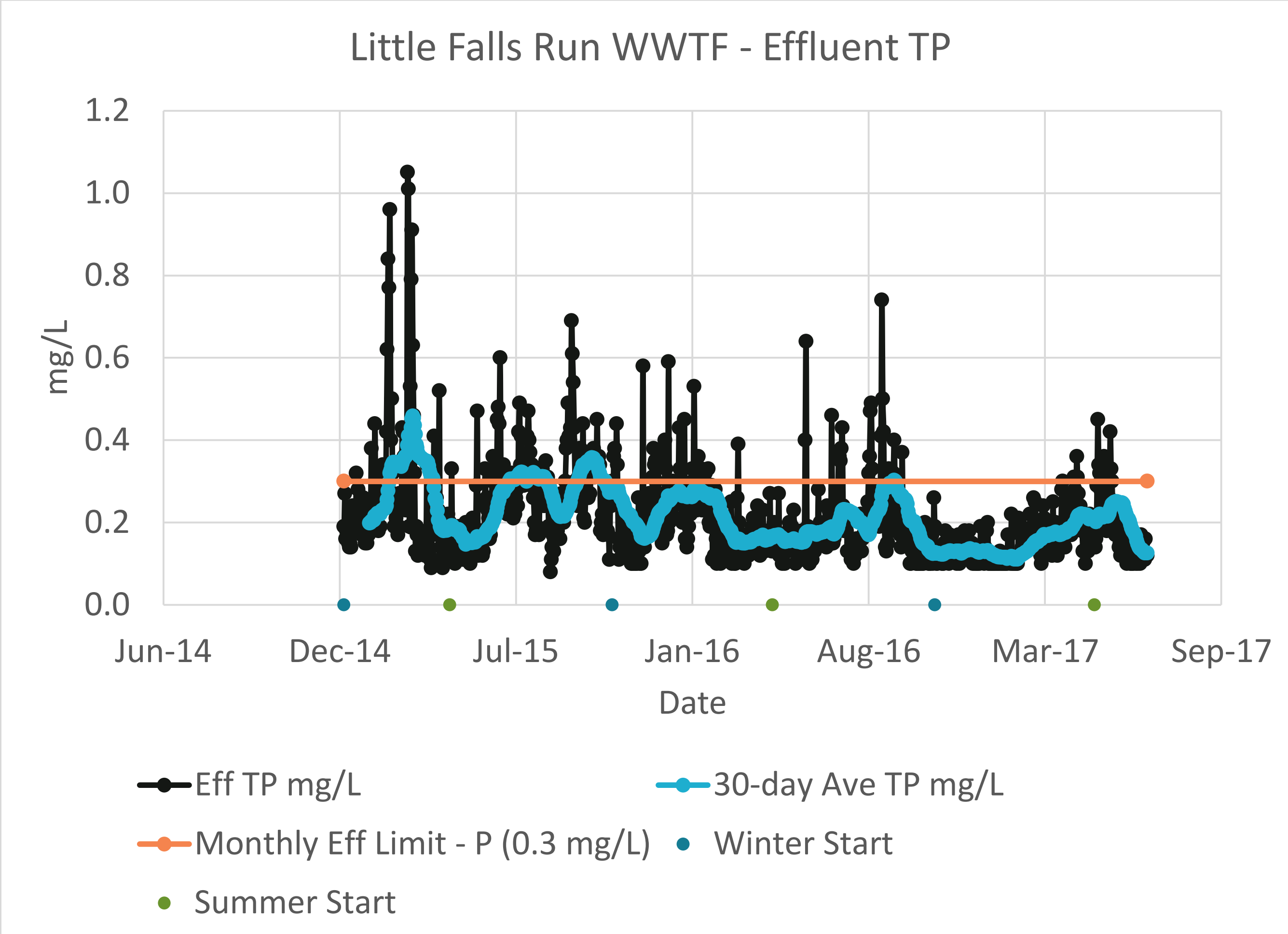
The plant sees an average influent NH_3-N concentration of 39 mg/L. Effluent TKN minus effluent ammonia represents the organic nitrogen parameter of the plant flow. Typical concentrations below 1.0 as seen at the LFR WWTF show good overall nitrification and effluent quality. The plant has also shown a consistent ability to meet its monthly NH_3-N limit with one or two major outliers. Regulatory changes including a potential reduction in effluent ammonia concentrations as a result of the FWNC/Ammonia rule in the Rappahannock River (discharging body) could trigger reductions of up to 60%, based on OBG's analyses in similar circumstances elsewhere in the region. As shown in the graph below, at this reduced level the plant may have difficulty meeting the new permit limits and changes to the biological system would be required.

Figure 8.1.12 – LFR WWTF Effluent NH3



The plant sees an average influent TP concentration of 9.6 mg/L. The annual average limit for TP is 0.3 mg/L. Effluent TP concentrations look to be adequate for current TP WLA in the VPDES Permit. It is unclear at this time as to the nature of the spikes seen in the graph below, but they do not seem to be impacting the overall average effluent TP concentration. It is possible that coagulant feed is being limited to save operational cost and achieve the desired effluent concentration. Coagulant feed could be increased if stricter TP requirements were implemented.

Figure 8.1.13 – LFR WWTF Effluent TP



As part of the 2018 Master Plan, a Basis of Design (BOD) table was prepared for each WWTF. The BOD table contains information such as existing capacity, design parameters, peak capacity, and manufacturer information. The BOD table for both plants as well as process flow diagrams and site plans are provided in Appendix C. Current and anticipated regulatory impacts on the WWTFs are described in sections 8.1.6 and 8.2.1, respectively.

A simplified summary of OBG's review of historical performance is that:

- Both WWTFs are currently in compliance with their VPDES permit conditions.
  - ➢ While the plants are performing better than the permits require, it is expected that as flows increase closer to the plants' nominal capacities, they will be challenged to meet the effluent requirements.
- In the near-term (through year 2028), the permitted capacities at both WWTFs are adequate for projected growth.
- More stringent effluent limits, including seasonal limits that could result from the Fresh Water Nutrient Criteria/Ammonia Rule may require process upgrades at one or both plants, and that need may occur prior to the plants reaching their rated capacities.

- There may be near-term opportunities to optimize treatment performance via increasing use of chemicals and power and modest revisions to the process facilities in order to defer major capital investments.

8.1.4 Process and Hydraulic Peaking Factors

WWTFs are typically sized to achieve the maximum month and peak day influent conditions to ensure unit processes and interunit piping are adequately sized to meet the maximum plausible influent conditions. A peak flow analysis to estimate maximum month and peak day flows was performed using a combination of existing data and future County projections. An analysis of the projected peaking factors for both plants is presented later in this chapter.

8.1.5 Effects of Infiltration and Inflow Reduction

Inflow is defined as flow entering the collection system during wet weather events or through unpermitted connections such as catch basins, downspouts, area drains, and manhole covers. Infiltration is defined as water that infiltrates pipelines and manhole defects located below the ground surface. Typical allowances for inflow and infiltration (I&I) are considered in the sizing of wastewater collection and treatment systems. However, excessive amounts of I&I contribute to higher than normal flow peaks. Excessive peak day flows could cause performance problems at a WWTF, via a “washout” of biological processes or could inhibit biological activity due to significantly lower temperatures.

In recent years, the DPW has been making progress with controlling I&I within the County’s sewer system. It is expected that this progress will continue, resulting in lower “peaking factors” (ratio of peak to average flows), thereby avoiding excessive peak day flows and their consequences.

8.1.6 Regulatory Requirements

The Virginia Department of Environmental Quality (VDEQ) is responsible for issuing the Virginia Pollutant Discharge Elimination System (VPDES) permits, as they apply to Stafford County’s wastewater treatment facilities. These permits set effluent water quality requirements based on average monthly and average weekly concentrations and loads of specific constituents. The Chesapeake Bay Program (CBP) TMDL was finalized in December 2010. Currently, the TMDL action plan is in Phase 1 (2011-2017), operating under VA’s Phase II Watershed Implementation Plan (WIP) as approved by USEPA Region 3. As part of the CBP, DEQ issues General Permits to utilities owning more than one point source significant discharger in the same major watershed Basin. Since the Aquia WWTF effluent discharge is tributary to the Potomac Embayment (Potomac Basin) and Little Falls Run WWTF discharges to the Rappahannock River (Rappahannock Basin), sharing nutrient TN and TP, and sediment WLAs between the two WWTFs is currently not feasible (inter-Basin). There are DEQ Registration Lists for the major Basins, whereby multi-party of VNCEA-based nutrient credit trading (selling, buying) may occur as a means to balance operational or capacity goals and actual O&M costs within the Basin (inter-Basin or inter-state CBP trading is not yet feasible). Please see Appendix A for copies of the VPDES Permits for Aquia WWTF and Little Falls Run WWTF.

Aquia WWTF’s current permitted effluent requirements apply through November 19, 2018. Little Falls Run WWTF’s current permitted effluent requirements apply through September 30, 2020. Before the permits expire, VDEQ will issue new permits for each facility. Due to the nature and duration of the permitting process, DPW will need to begin the reapplication process for Aquia WWTF in the near future, so that the reapplication can be submitted well in advance of the expiration date.

The expected promulgation of the Fresh Water Nutrient Criteria (FWNC) / Ammonia Rule in Spring 2018 by VDEQ and VA’s State Water Control Board (SWCB) introduces uncertainty regarding the need for upgrades at the WWTFs. Improvements may be needed to meet more stringent limitation of discharges at both WWTFs, and to increase permitted discharge at Little Falls Run beyond 8-MGD. If DEQ policies & procedures for zero-flow “unnamed tributaries” such as Austin Run do not provide relief from the new

Ammonia rule, Aquia WWTF effluent discharge may need to be moved downstream (if improved mixing conditions are achievable) to meet what could otherwise be a very low seasonal ammonia limit starting with its November, 2018 renewal.

Additional, more stringent effluent limits may also be required at those WWTFs that participated in VDEQ Water Quality Improvement Fund (WQIF) Grant Agreements. Such facilities may be required to optimize plant performance to achieve lower TN and TP concentrations than assigned in their WLAs. Aquia WWTF (VPDES VA0060968, GP VAN010023) permit flow tiers are 10-MGD and 12-MGD ADF. Nutrient WLAs are 73,093 #TN/year and 4,386 #TP/year (as discharged, 8-MGD & 3.0 mg/L TN & 0.18 mg/L TP basis, List last updated 2/2017). Little Falls Run WWTF (VPDES VA0076392, GP VAN020031) permit flow tiers are 8-MGD and 13-MGD ADF. Nutrient WLAs are 97,458 #TN/year and 7,309 #TP/year (as discharged, 8-MGD ADF & 4.0 mg/L TN & 0.3 mg/L TP basis, List last updated 2/2017).

Additionally, DEQ Water Quality Improvement Fund (WQIF) Grant Agreement, BNR and/or ENR, for a particular point source discharger can impose additional performance constraints such as optimization, i.e., meet annual TN and TP concentration goals regardless of assigned WLAs, which are based on DEQ-assigned design ratings at the time of Registration). However, DPW has advised that neither plant was entered into any additional grant agreement that would impose these additional performance constraints, beyond Phase II requirements, as defined in the Little Falls Run WWTF VPDES.

With respect to biosolids management, Stafford County currently landfills the sludge collected and produced at both WWTFs. It is expected that this approach will continue for the foreseeable future.

8.2 STAFFORD COUNTY'S WASTEWATER TREATMENT SYSTEM CHALLENGES AND REQUIREMENTS

8.2.1 New Regulatory Requirements

The Chesapeake Bay Program (CBP) established its Total Mass Daily Loadings action plan (TMDL) in December 2010. Phase 1 of the TMDL action plan (2011-2017), has operated under Virginia's Phase II Watershed Implementation Plan (WIP) as approved by USEPA Region 3. CBP TMDL Phase 2 is scheduled for 2018-2025, with 2024 established as the year to assess if further improvements or phases are required to achieve TMDL compliance. The Virginia Phase III WIP is being drafted by VDEQ, and scheduled to be reviewed and approved by USEPA Region 3 in 2018 or early 2019. The Phase III WIP developments will need to be monitored to see if any changes relative to WWTF discharge requirements or assigned WLAs are proposed. Beyond CBP TMDL requirements, local water quality concerns or documented impairments could result in needing to upgrade WWTF treatment in some fashion, although DPW is unaware of any such concerns.

USEPA published revised Fresh Water Nutrient Criteria (FWNC) in November 2013 (prior federal criteria were issued in 1999). The FWNC related rules are based on freshwater mussels' presence and their susceptibility to ammonia toxicity. The mussels are reportedly present in 80-90% of all freshwater U.S. waterways and freshwater-dominated estuary reaches. As described in Section 8.1.6, the expected promulgation of the FWNC / Ammonia Rule in Spring 2018 by VDEQ and the State Water Control Board (SWCB) could require upgrades at the County's WWTFs, which would entail substantial capital investments and increase O&M costs. Based on OBG's technical review and work around the same Rappahannock River segment as the Little Falls Run WWTF discharge, the new rule could result in 60% lower (approximate, preliminary) ammonia limits.

In brief, improvements may be needed in the near-term to meet more stringent limitation of discharges at both WWTFs, and in the long-term, to increase permitted flows at the WWTFs beyond 8-MGD. Further, if VDEQ policies & procedures for zero-flow "unnamed tributaries" such as Austin Run do not provide relief from the new Ammonia Rule, Aquia WWTF effluent discharge may need to be moved downstream (if improved mixing conditions are achievable) to meet what could otherwise be a very low seasonal ammonia limit starting with its November, 2018 renewal.

Regarding Aquia WWTF, there are no known plans by VDEQ or USEPA to tighten nutrient concentration goals for significant dischargers in the Potomac Basin. However, with WLAs based on 8-MGD ADF, it may become more difficult for Aquia WWTF to comply with its annual nutrient load caps as flows or equivalent loadings increase towards 8-MGD. Beyond 8-MGD, performance would need to be even better than its current basis-of-design. The Aquia WWTF will also be subject to the Potomac River TMDL for polychlorinated biphenyls (PCBs), and as such, must monitor influent and effluent PCB concentrations, and the County must enforce its prohibition of PCB discharge to its sewer system. There is no specific treatment process at Aquia WWTF, or publicly-owned treatment works in general, for PCB removal. It is therefore not anticipated that this new TMDL would result in changes at the WWTF; rather any PCBs issues would best be handled through enforcement of the County's sewer use ordinance.

Similarly, regarding Little Falls Run WWTF, there are no stated plans by VDEQ or USEPA to tighten nutrient concentration goals for significant dischargers in the Rappahannock Basin. However, there have been recent (2013-2017), periodic reports by third parties or Virginia state agencies of potential dissolved oxygen impairment in segments of the Rappahannock River that are downstream of the Little Falls Run WWTF discharge point. Based on knowledge gained on other OBG projects in the Rappahannock Basin, it appears that VDEQ is considering the development of a Rappahannock River Water Quality Policy. Other VPDES Permits in the same river segment that expired in 2017 are currently in administrative extension by VDEQ, and the FWNC rule is scheduled to be in place by mid-2018. The basis for a new Rappahannock River Water Quality Policy is not yet clear. It may or may not rely upon the long-standing VIMS water quality model used in the past as part of various Rappahannock River VPDES Permit renewals. While the details of such Policy are uncertain, it is likely that tighter VPDES Permit effluent limits are in consideration as a means for reducing point source discharger contributions (as measured by BOD_5 and NH_3-N), which could otherwise impair water quality during low stream flow conditions. Spotsylvania County (Massaponax WWTP, FMC WWTP) and City of Fredericksburg WWTP VPDES Permit reapplication packages are currently under review by VDEQ. Also of note, with WLAs based on 8-MGD ADF, it may become more difficult for Little Falls Run WWTF to comply with its annual nutrient load caps as flows or equivalent loadings increase toward 8-MGD. Beyond 8-MGD, performance would need to be better than the WWTF's current basis-of-design. Potential limits on wasteloads could require treatment to levels below generally-accepted limits of technology, thereby impairing the ability of the Little Falls Run WWTF to process flows at buildout of the sewershed. DPW will monitor this situation as it develops (long-term), and if appropriate, consider substantially upgrades to treatment processes or realignment of the sewersheds based on future wasteload constraints.

Also of note, because Aquia WWTF discharges to Austin Run, Unnamed Tributary to Potomac River, the VPDES permit contains restrictive effluent $CBOD_5$ and TSS limits. If current monthly average and weekly limit discharge wasteload caps are maintained, as flows exceed the 10-MGD design flow rating conditions, the effluent limits will tighten further, potentially to levels below generally-accepted limits of technology. With respect to Little Falls Run WWTF, which discharges to the Rappahannock River, $CBOD_5$ and TSS limits are already somewhat restrictive, and it is less likely that they would be tightened below generally-accepted limits of technology.

Further, the USEPA published revised FWNC in November 2013 (prior federal criteria were issued in 1999). State-by-state, these new toxicity rules (based on freshwater mussels' presence and susceptibility to ammonia toxicity) and this revised ammonia water quality rule is taking effect. In VA, promulgation of this rule was separated from the rest of DEQ's Triennial Water Quality Review process, with a separate timetable for consideration. EPA Region 3 approved DEQ's Triennial Review on 6/5/17, published 6/27/17, with relatively little impact on POTWs. Based on the current Freshwater Ammonia criteria schedule (proposed revisions published 9/18/17), the revised ammonia rule could be adopted by State Water Control Board by March or June 2018, and then be considered in VPDES Permits' issuance, modification, or renewal thereafter. Technical information states that the mussels are in 80-90% of all freshwater U.S. waterways (and freshwater-dominated estuary reaches). The rule change could have substantial impacts to POTWs (compliance, upgrade capital cost, O&M costs) and other dischargers, especially where pH and alkalinity conditions in the combined receiving stream and treated effluent result in much lower NH_3-N limits (summer and winter). This may be the case even for POTWs that have advanced nutrient removal in place, where nitrification (ammonia conversion) is required as part of the removal process. Based on OBG technical review and work around the same Rappahannock River segment as the Little Falls Run WWTF discharge, low 7Q10 upstream flows coupled with in-stream and effluent pH and alkalinity values could result in 60% lower (approximate, preliminary) ammonia limits (possibly more reduction if summer or winter conditions are somewhat relaxed, currently, in individual Permits). These lower limits could be difficult to achieve at all times, with monthly average and weekly limits employed, without significant aeration control system, process equipment / technology, or tankage modifications - especially near design rating, during cold wastewater temperatures, and/or higher peak flow rates. Environmental study of the presence of mussels, receiving stream mixing zone analysis, and/or upstream / downstream chemical analyses for (conductivity,) pH and alkalinity may be methods to mitigate the rule's impact for a particular discharger (increasing new lower ammonia limits?) – but outcomes of these studies could also adversely change the derivation of new ammonia limits (even lower?). Details such as compliance schedule, tiered antidegradation procedures, affordability, and concentration percentile (90^{th}, 50^{th}, or 75^{th}) are subjects of the current rule development. Aquia WWTF ammonia limits are already somewhat restrictive, including a summer NH_3-N limit of 1.0 mg/L monthly average. It is unknown what water quality modeling may be relied upon by DEQ in its assessment of Aquia WWTF discharge requirements, a topic for future discussions with DEQ (before or during the reapplication process). Little Falls Run WWTF ammonia and TKN limits may be revised downward for multiple reasons when the VPDES Permit is renewed.

Typically, a 4-year (48-month) compliance schedule (for planning, engineering, design, bidding, construction, startup / online) is included in a VPDES Permit renewal if physical upgrades are needed to meet a substantive lower effluent limitation. This typical timeframe allows a 5^{th} year of a 5-year VPDES Permit cycle for monitoring of performance as a result of the upgrade before the next renewal cycle comes due. Administrative extension of the existing Permit is an available option to DEQ with each expiration / anticipated renewal date, under certain circumstances, if approved by the SWCB as part of rule adoption. VAMWA has estimated state-wide cost impacts to be $512M capital for POTWs and $34M/year O&M. This estimate may not be sensitive to how DEQ policies / procedures treat unique circumstances such as unnamed tributaries and local water quality issues such as what is being considered by DEQ for the Rappahannock River. Also, currently, nitrification upgrades are not eligible for grant funding such as WQIF.

Biosolids management and disposal methods in VA is a subject of on-going debate. In general, currently, there do not appear to be any biosolids rulemaking that would significantly impact Stafford County solids management practices (screenings, grit, biological sludge, or regional septage receiving / treatment).

In summary, with respect to pending regulatory changes, there are multiple reasons why Little Fall Run WWTF performance may need to improve further in the next 1-2 Permit cycles (5-year and 10-year planning timetables). Changes to the Aquia WWTF permit conditions are also possible, with perhaps a focus on the ammonia rule. Building upon this master planning evaluation, facilities planning may be needed at one or both WWTFs in the coming years (2018-2020) to study and quantify upgrade requirements.

8.2.2 Anticipated Capacity Issues

As part of the overall master planning process, the County has performed an analysis of anticipated future wastewater flow capacity required at both plants. Using existing water meter data, data provided by the Stafford County Planning Department, and input from DPW staff and OBG, wastewater flow projections were developed for the current scenario, a near-term (10-year) scenario and a buildout (2060 and beyond) scenario. The following Table 8.2.1 shows the projected wastewater flows for the two wastewater treatment facilities.

Table 8.2.1 – Aquia and Little Falls Run (LFR) WWTF Projected Wastewater Flows

WWTF	Base Sanitary Flow (MGD)	Infiltration (MGD)	Average Day Flow (MGD)*	Peak Hour Flow (MGD)**
		Current		
Aquia	4.2	1.1	5.3	15.8
LFR	2.5	0.9	3.4	9.7
Total	6.7	2.0	**8.7**	**25.5**
		Near-Term		
Aquia	5.0	1.6	6.6	19.1
LFR	3.3	1.3	4.6	12.9
Total	8.3	2.9	**11.2**	**32.0**
		Buildout		
Aquia	7.1	2.5	9.6	27.4
LFR	7.5	2.1	9.6	28.4
Total	14.6	4.6	**19.2**	**55.7**

*Average wastewater flow estimated as base sanitary flow + dry weather infiltration
**Peak hour, which is used to size WWTF hydraulic capacity, estimated as infiltration + 3.5 times base sanitary flow

8.2.3 Plant Site Visits

As part of the wastewater treatment review, site visits were made to the two plants in order to better assess their existing processes and to understand the potential existing, intermediate or long term needs. A summary of the notes and observations taken during the plant site visits follows.

<u>Aquia WWTF Site Visit Notes</u>

- Plant operator attendance 24/7, two 12-hr shifts. 14 total people on staff (2 managers).
- TN/TP - no issues per season, works well during the winter.
  - 1-1.5 TN, 0.18 TP limit
  - 6 mg/L BOD/TSS
  - Awaiting PCB PMP protocol from DEQ, as a result of Potomac River PCB TMDL in development.
- Upgrades - built in 1992, 2004 and 2011 upgrades
  - 2004 filter expansion
  - 2011 nutrient removal upgrade
- Plant rated for 10 MGD, sees an average of 5.5 MGD.
  - Influent meter goes to 20 MGD. Have seen meter maxed during heavy rain. Plant can handle to 20 MGD.
- Biological Process – Counter-current, Cyclic-aeration mode (Schreiber).
  - Schreiber working well. Targets 5,000 mg/L MLSS. "Very forgiving". Potomac watershed WLA based on TN 3.
  - Tanks use coating on concrete. Not as much H_2S damage.
  - Can handle 8 MGD hydraulically, 4 MGD biologically.
  - 3 trains, running 2 of them currently. 2 of the trains are "peanut", 1 circular.
  - 1992 tank, 2004 tank, and 2011 tank.
  - Post anoxic tanks installed in 2011.
  - Issues during contractor installation of new clarifiers in 2011. Train 3 clarifier is built 2 feet below the rest. Needs to be pumped.
  - Blowers installed 2004/2011, mix of Aerzen and Kaeser.
- Filters – Aqua-Aerobic disks, located indoors.

- Disinfection
  - Trojan UV 3000+ installed in 2007. May be getting to the end of their service life and need to be addressed.
    - 4 banks, runs 3 full power, no control by UVT.
- Dewatering
  - 5 days/wk, 16 hrs/day typically.
  - Currently trying to increase the capacity of the dewatering system.
    - Goal is 400 gpm through all units, wants to switch from Andritz to Westfalia.
  - $28/wet ton for hauling to landfill (no backup permitted), different from LFR (County-owned landfill in north).
    - 18-19% cake
    - Future dryer possible?
- Digesters
  - Running full for sludge storage, typically does not gravity decant.
- Chemicals
  - Alum feed (45%) for P removal, stored outside.
  - Mag for alk supplement, stored inside.
    - Possibly new tank for Mag storage?
- Miscellaneous
  - 2x, 2 megawatt generators, fully powers plant (installed 2011), other generators on-site (including new lift station), all diesel-fueled.
    - No tie breaker between the generators, if one goes down, would lose half the plant.
    - Plant has portable generator for real emergencies.
  - A lot of screw pump lifts throughout the plant.
    - Clarifier on train 2 built to low, lifted to bio tanks
    - Lifts to filters
    - Lifts to anoxic tanks
    - Influent PS lifts to headworks
  - County owns trucks for hauling to landfill.
    - County owned landfill (50 yrs of life left at landfill, assumed).
  - Permit expires 2018, should submit reapplication at this point.
  - All analytical done by LFR Lab, except settleability testing on-site.
  - PCB question - plant has been tested, no results to date.
  - Electronics on PLC's are getting old. Need full modernization.

<u>LFR WWTF Site Visit Notes</u>

- Plant built in 1991, took over for old Claiborne Run WWTP.
- Plant upgrade in 2010 - SCADA upgrades, new aeration blowers across the plant, new diffusers.
- Plant operator attendance Mon through Fri, 7am-11pm and weekends, 7am-5pm.
- Typically, 15-20 3,000-gal Septage trucks per day.
- Plant Performance
  - 3.5 MGD average flow. Only run one side of the plant at this point. Plant built to handle 8 MGD, permit is set at 6 MGD. Have seen peaks of 15-20 MGD (10 MGD through EF).
  - Existing effluent meter only reads up to 10 MGD so difficult to say exact peaks.
  - P - 0.31 mg/L annual limit. Feed alum for P removal.
  - N – Permit tiers include 6.0 mg/L and 4.0 mg/L. Clarified after the meeting after permit review that LFR is expected to meet TN 4.0 mg/L (historical performance suggests difficult to do so).
- Headworks
  - Influent Structure contains screens, grit and grease setup from Schreiber.
    - Overhead bridge system needs to be completely replaced.

    - Floating grease makes it past headworks system on regular basis and shows up throughout rest of the plant.
    - Discussed BMP grease program outside the fence, no current enforcement by County.
- Biological Process – Counter-current, Cyclic-aeration operating mode (Schreiber)
  - Concrete tanks for Schreiber Process may be a significant plant issue.
    - Problems with concrete both above and below water.
  - No major issues with Schreiber main equipment (motors, wheels, etc.).
  - Targets 5,000 mg/L MLSS. Can't completely denitrify with the current Schreiber process and tankage. Has post anoxic issues with current size of tanks, noted that post-DN zone is smaller than Aquia, relatively speaking.
  - Typically, water blasts and brushes Schreiber SC launders and weirs every Friday.
  - Issues with winter Ammonia limits, especially if limits are lowered.
- Disinfection
  - 2010 upgrade to UV system, Trojan 3000+, typically operate 1 of 3 banks (full-on, not based on UVT), up to 8-MGD per channel.
  - No issues, have 10 MGD limit they can get through the filters.
- Filters
  - Aqua-Diamonds (15 years old)
    - Computer and electrical issues.
    - Cleaned twice per year, clean them out and review frequently.
    - Retrofit from old sand filters.
    - O&M on Diamonds is difficult for the plant.
    - Bridge system issues, 3-year life expectancy on the filter material as a whole.
- Digestion
  - Aerobic Digestion, new digesters built in 2010 upgrade, capable of gravity decant but does not utilize.
  - Use as sludge storage. Tanks are oversized during parts of the year. Typically operates half.
  - Adds polymer to digesters.
- Sludge Dewatering
  - 2x centrifuges. Both Andritz machines. One new, one 5-6 years old but replaced interior. components so basically new. Typically run dewatering 4 d/wk 16 hr/d and 1 d/wk 8 hr/d (1.5% -> 17-19%).
  - Land apply biosolids. Use RECYC contractor and like how the system is working.
    - Sludge holding pad built in 2010.
    - Class B solids.
- Chemicals
  - Mag for alkalinity buffer.
  - Alum feed to SCs for TP polishing in SC & EF.
  - No supplemental carbon at plant.
- Miscellaneous
  - Would like plant dedicated dump trucks to haul sludge around.
  - Lab onsite, all lab work for both plants done at LFR.
  - Discussion of DEQ wanting to purchase land just across the road from plant and install anoxic zones.
    - All surrounding useable land is owned by a single family in the area, and it may be difficult to secure additional land if upgrades or expansion is needed.
  - VPDES Permit expires in 2020.
  - Electric generator (diesel-fueled) installed during 2010 upgrade. Can run entire site with no issues, typically does not dewater during outage. Use as peak shave system. Diesel engine.

8.2.4 Reliability Issues

The Stafford County Department of Public Works Utilities Fund is a proprietary enterprise fund used to account for funds needed to operate, maintain and expand the County's Water and Wastewater System. As part of the FY18 Adopted Budget, the County has allocated money for a variety of wastewater projects with the majority of these projects located out in the collection system. Money allocated to the wastewater treatment plants consist of a total projected cost of $16,608,000 allocated for an expansion of the LFR WWTF to add a third treatment train (which, is based on no change in effluent limitations and adequate WLA). This project was identified for planning, design and construction from 2022-2023.

In addition to the regulatory issues and future capacity issues discussed previously in this technical memorandum, remaining life of equipment, structural concrete issues and power reliability need to be addressed.

As part of the Master Plan effort, DPW and OBG have reviewed plant historical drawings and O&M manuals and prepared a table with expected remaining life for the major equipment at each plant. For master planning purposes, most mechanical equipment items are projected to have a 25-year life span and UV equipment is considered to have a 15-year life span due to the frequent required maintenance on bulbs and the sensitivity of the equipment. The tables with information on the remaining useful life for each plant can be found in Appendix C.

Structures are projected for a 40-year life span before the need for significant rehabilitation. The original concrete structures at Aquia are nearly at that age, and those at Little Falls Run WWTF will approach that age in the next 10 years. The structures at Stafford County's WWTFs, especially those experiencing constant wear (like the Schreiber Process aeration basins with the rotating bridge) are showing significant concrete issues that have been addressed by the plants as part of yearly maintenance. During site visits, only issues that were visible (above the water line) could be assessed. DPW has recently initiated comprehensive facility assessments, including more thorough observation of structural conditions, to refine the useful life of the structures and equipment, and develop a prioritized list of repairs and replacements. This assessment will be completed in 2018, and its results will be used to update the annual capital and operating budget in FY2019.

Electric power to the Aquia WWTF is furnished by two feeder lines from Dominion Power. Two generators are also available at the facility as backup power sources. Although these existing power supplies are adequate to comply with prevailing code and regulations, based on discussions with Stafford County O&M staff regarding the current power distribution system, it would be prudent to improve the electrical distribution interconnections and controls to enhance power supply resiliency, since the current electrical configuration could leave up to half the plant without power under certain conditions.

Electric power to the Little Falls Run WWTF is furnished by a single feeder line from Dominion Power. In addition to the feeder, the plant has a backup generator, to be used in the event of a power outage. Future expansion may require the installation of an additional generator or a redundant Dominion Power feeder line. If the redundant Dominion Power feed line is not installed, as the plant continues to be expanded in the future, additional generators may be needed to provide additional reliability capacity.

8.2.5 Reuse and Resource Recovery Opportunities

During preparation of the Preliminary Engineering Report for the nutrient removal projects at Aquia and Little Falls Run, the DPW investigated opportunities to reuse effluent from the WWTFs, thereby reducing the effluent flow discharged into the Chesapeake Bay watershed. Large industrial and commercial water users within the County were identified and investigated to determine whether plant effluent could be used in place of the potable water currently being supplied to these industries. The outcome of this investigation was that DPW found no significant commercial or industrial potable water users located close enough to either WWTF to make it economical to furnish them with reuse effluent. Thus, implementation of a reuse system is not considered viable at this time.

8.3 OVERVIEW OF INTERMEDIATE AND LONG-TERM IMPROVEMENTS

The DPW has identified certain proposed modifications as part of its on-going asset renewal program. Aging infrastructure, including the original Schreiber process trains at each plant, require periodic major maintenance or upgrades. Additionally, the FWNC/Ammonia rule will likely be adopted by VDEQ before or around the next VPDES permit expiration dates. This regulatory change may require upgrades to the biological treatment system and/or chemical feed facilities at either or both WWTFs.

8.3.1 Aquia WWTF

Based on the site visit, review of existing data, historical information and discussions with DPW staff, the following recommendations are made for intermediate improvements to the Aquia WWTF.

Table 8.3.1 – Aquia WWTF Intermediate Improvements

Unit Process	Priority*	Proposed Improvements
Facilities Planning	2	• Facilities Structural Assessment • General review of mechanical equipment for remaining useful life and possible efficiency upgrades
General Upgrades	2	• Concrete Repair • Headworks – possible replacement of grit and grease system • Power Supply – Arc flash study, and improve the electrical distribution interconnections and controls to enhance power supply resiliency
Solids Handling	1	• Sludge Storage Expansion • Dewatering Unit
Nitrification Upgrades	1	• FWNC/NH_3 compliance (Allowance), anticipating the need for finer aeration control for both summer and winter seasons, to meet lower monthly and weekly limits
General Upgrades	2	• Filtration • UV • Controls • Miscellaneous

*Priority 1 – Critical to the current and future operation of the system or needed to serve future projected wastewater demands
*Priority 2 – Necessary to meet basic performance requirements and improve system operation and reliability

The ultimate buildout projected capacity of the Aquia WWTF is 10 MGD average day flow. For the plant to reach this ultimate capacity, a variety of expansions and changes would need to be made. As discussed in the regulatory section above, the ultimate plant effluent requirements could change in the future, which would in turn require plant improvements. As nutrient limits tighten and plant capacity increases it may at some point be necessary to remove the existing Schreiber process and install a new secondary treatment system more capable of meeting these future limits.

8.3.2 Little Falls Run WWTF

Based on the site visit, review of existing data, historical information and discussions with DPW staff, the following recommendations are made for intermediate improvements to the LFR WWTF.

Table 8.3.2 – LFR WWTF Intermediate Improvements

Unit Process	Priority*	Proposed Improvements
Facilities Planning	2	• Facilities Structural Assessment

		• General review of mechanical equipment remaining useful life and efficiency upgrades
General Upgrades	2	• Concrete Repair • Headworks • UV
Denitrification Upgrades	1	• Addition of new tanks to help provide additional denitrification capacity
Upgrade Allowance	1	• Rappahannock Policy • FWNC/NH_3 Allowance
General Upgrades	2	• Filtration • Miscellaneous

*Priority 1 – Critical to the current and future operation of the system or needed to serve future projected wastewater demands
*Priority 2 – Necessary to meet basic performance requirements and improve system operation and reliability

The ultimate buildout projected capacity of the LFR WWTF is 10 MGD average day flow. For the plant to reach this ultimate capacity, a variety of expansions and changes would need to be made. As discussed in the regulatory section above, the ultimate plant effluent requirements could change in the future, which would in turn require plant improvements. As nutrient limits tighten and plant capacity increases it may at some point be necessary to remove the existing Schreiber process, re-purpose or re-configure tankage, and/or install a new biological treatment system more capable of meeting these future limits.

8.4 KEY FINDINGS

Overall both the Aquia WWTF and the Little Falls Run WWTF are currently performing well. Both plants are slightly underloaded in regards to average flow capacity and both plants consistently meet their VPDES permit requirements. Future improvements and the timing for expansions at each plant will be impacted by potential regulatory changes that govern WWTFs in the Rappahannock River Basin (Little Falls Run WWTF) and the Potomac River Basin (Aquia WWTF), as well as growth projections in the County's sewer service area.

8.4.1 Aquia WWTF

- Increase wastewater treatment capacity as needed to serve anticipated growth in sewer flows.
  - Flow at the treatment plant is projected to remain within the plant's design capacity through the near-term, with the exception of solids processing. However, an upgrade to the treatment processes sooner than 10 years may be needed to comply with potential future regulations that could reduce future wasteload allocations and/or tighter nutrient effluent limits.
- Perform a full facility assessment.
  - Now 38 years old, parts of the original plant may be at or near the end of their useful service life. Normal maintenance will continue to prolong the life of the equipment and structures, but a full facility assessment is underway to establish a prioritized plan and schedule for repairs and upgrades to serve the needs of the County in both the immediate and long-term scenarios.
- The ultimate buildout capacity for the Aquia WWTF is 10 MGD, which is adequate to handle the projected flows at buildout of the sewershed under the County's current land use and zoning.

8.4.2 Little Falls Run WWTF

- Increase wastewater treatment capacity as needed to meet anticipated growth in sewer flows.
  - Flow at the treatment plant is projected to remain within the plant's design capacity through the near-term, and likely for at least 20 years. However, regulatory changes could drive the need for

improvements to comply with future reductions in wasteload allocations and/or tighter nutrient effluent limits.

- Continue to track regulatory changes for dischargers to the Rappahannock River.
  - It appears that VDEQ is considering the development of a Rappahannock River Water Quality Policy which could result in more stringent permit limits for Little Falls Run WWTF and several other plants discharging to the Rappahannock River in this area of the state. DPW will continue to track state and federal regulations in order to proactively plan for future changes at Little Falls Run WWTF, to comply with potentially more stringent permit limits.
- Perform a full facilities assessment.
  - Now 27 years old, parts of the original plant may be at or near the end of their useful service life. Normal maintenance will continue to prolong the life of the equipment and structures, but a full facility assessment is recommended to establish a prioritized plan and schedule for repairs and upgrades to serve the needs of the County in both the immediate and long-term scenarios.
- The ultimate buildout capacity for the LFR WWTF is 10 MGD, which is adequate to handle the projected flows at buildout of the sewershed under the County's current land use and zoning. However, potentially more stringent wasteload constraints may cause the County to assess other approaches for handling the sewershed's buildout flows.

8.5 PLAN OF ACTION

- No expansion of either WWTF is required to meet projected growth of wastewater flow in the near-term (through 2028).
- However, stricter regulations in the Potomac River basin and Rappahannock River basin may require significant investments at the Aquia WWTF and Little Falls Run WWTF, possibly within the next 10 years. The County should continue to monitor regulatory developments and proactively plan for potentially more stringent permit requirements.
- DPW will conduct a full facilities assessment for each WWTF in order to estimate the remaining service life of its equipment and facilities. Pending the results of this assessment and in conjunction with the regulatory drivers, this Master Plan includes "budgetary placeholders" to assist the County in planning for potential near-term capital investments at both plants.
- As part of addressing aging infrastructure and pending nutrient limit reductions, the Little Falls Run WWTF should be further investigated to determine possible upgrades and improvements to both the headworks facility and expanded denitrification capacity.
- In the long-term, DPW will monitor the regulatory situation, and if appropriate, consider substantial upgrades to wastewater treatment processes, realignment of the sewersheds, or other holisitic approaches to meet future wasteload constraints at buildout flows.
  - As part of the evaluation of wastewater conveyance and treatment requirements in the Aquia and LFR service areas, OBG identified a potential future contingency plan where load (i.e., flow) is transferred from one service area to another if or when needed to accommodate growth relative to regulatory discharge limitations. If there is a cost-effective way to transfer flow / loading from Aquia to Little Falls Run (Lower Accokeek PS to Potomac PS) and Little Falls Run to Aquia (Potomac PS to Lower Accokeek PS) in the future, this could be one means to balance wastewater needs with regulations and water quality. The key is that this feature be bi-directional to have value (flexibility, contingency for change in Basin WLAs, actual growth rates, actual WWTP performance, actual I&I removal rates, etc.). Aquia (Potomac Basin) already has tight limits and nutrient

wasteload caps (and discharges to a small creek). Little Falls Run (Rappahannock Basin) could see tighter limits due to Rappahannock River water quality concerns and/or high WWTP effluent to upstream low-flow conditions. It may be difficult for either WWTP to expand, without "reuse quality" upgrades or other holistic watershed management approaches.

8.6 PROPOSED NEAR-TERM AND LONG-TERM IMPROVEMENTS

AWWTF-001: Aquia WWTF Upgrade - Facilities Planning

DPW has identified certain proposed modifications as part of its on-going asset renewal program. These upgrades include on-going concrete repair to process units, power distribution main-tie-main configuration, potential headworks upgrade, and a higher-capacity dewatering centrifuge. Aging infrastructure, including the original Schreiber process train and the effluent filtration system, require periodic major maintenance or upgrades. Existing sludge storage volume is somewhat limited for current sludge processing operations and plant capacity rating. Also, the Aquia WWTF VPDES Permit expires in September 2018, the reapplication process may identify other upgrades or modifications. The Fresh Water Nutrient Criteria / Ammonia rule will likely be adopted by VA and DEQ before the Permit expiration date. This regulatory change may suggest biological treatment system and/or chemical feed upgrades. In addition, the master planning process has identified near-term and longer-term wastewater system growth that may affect the timing of certain capacity upgrades. The proposed, limited WWTF facilities planning would build upon the master plan evaluation and baseline condition assessments at Aquia to prioritize and aggregate various upgrades and modifications – a platform for subsequent capital improvement projects.

Priority	*2 – Necessary (to improve reliability, water quality)*
Design	*FY2019*
Construct	*---*
Total Project Cost	*$75,000*

AWWTF-002: Aquia WWTF General Upgrades – Concrete Repair, Headworks, Power Distribution

DPW has identified certain proposed modifications as part of its on-going asset renewal program. These upgrades include on-going concrete repair to process units, power distribution main-tie-main configuration, and potential headworks upgrade. These general upgrades are compatible and consistent with other anticipated near-term upgrades and modifications for firm capacity, efficient operations, system reliability, and effluent compliance.

Priority	*2 – Necessary (repair, improve reliability)*
Design	*FY2019-2020*
Construct	*FY2019-2021*
Total Project Cost	*$3,500,000*

AWWTF-003: Aquia WWTF Solids Handling – Sludge Storage Expansion, Dewatering Unit

DPW has identified the need for higher sludge dewatering capacity to optimize its current solids processing operation. The current sludge storage (aerobic digestion) capacity is less than the rated plant capacity sludge production levels, and additional sludge storage would improve sludge stabilization prior to dewatering and disposal, and facilitate the use of a higher capacity centrifuge. Supplemental sludge storage tankage, with aeration / mixing / pumping, is proposed. These general upgrades are compatible and consistent with other anticipated near-term upgrades and modifications for firm capacity, efficient operations, system reliability, and biosolids management permit compliance.

Priority	*1 – Critical (capacity)*
Design	*FY2020*
Construct	*FY2021-2022*

Total Project Cost	*$2,100,000*

AWWTF-004: Aquia WWTF Nitrification Upgrades (FWNC / NH3 – Allowance)

The Aquia WWTF VPDES Permit expires in September 2018, the reapplication process may identify wastewater treatment upgrades or modifications. The Fresh Water Nutrient Criteria / Ammonia rule will likely be adopted by VA and DEQ before the Permit expiration date. The Aquia WWTF treated effluent discharges to Austin Run "UT", an "Unnamed Tributary", with low or no upstream flow that would provide mixing and dilution critical to reducing ammonia toxicity. The change in ammonia toxicity water quality criteria may result in a lower NH3-N limit that requires additional nitrification capacity and/or process control to meet monthly average and weekly limits. This regulatory change may suggest biological treatment system and/or chemical feed upgrades. This CIP line item is an Allowance, which would be defined and detailed as the water quality criteria is adopted, DEQ policies & procedures are reviewed, and the new rule is applied to VPDES Permit renewals in 2018.

Priority	*1 – Critical (water quality)*
Design	*FY2019*
Construct	*FY2020-2021*
Total Project Cost	*$1,600,000*

AWWTF-005: Aquia WWTF General Upgrades – Filtration, UV, Controls, Miscellaneous

DPW has identified certain proposed modifications as part of its on-going asset renewal program. These upgrades include mechanical and control upgrades to effluent filtration, plant SCADA and overall process control system updates, and other miscellaneous treatment upgrades. Effluent UV disinfection equipment has limited remaining life, technology upgrade may be part of asset renewal. These general upgrades are compatible and consistent with other anticipated near-term upgrades and modifications for firm capacity, efficient operations, system reliability, and effluent compliance.

Priority	*2 – Necessary (improve reliability)*
Design	*FY2024*
Construct	*FY2025-2027*
Total Project Cost	*$3,900,000*

AWWTF-006: Aquia WWTF Expansion & Upgrade (Allowance)

The master planning process has delineated anticipated remaining life for process / mechanical, instrumentation & control, and structural / architectural facilities at the Aquia WWTF. In addition to aging infrastructure that will need to be addressed in a longer-term upgrade project, the Schreiber biological treatment process technology may need to be updated or replaced to produce high-quality effluent. The current and anticipated future Aquia WWTF VPDES Permit includes wasteload allocations for total nitrogen, total phosphorus, CBOD5, TSS, and other parameters. Regulatory changes may require higher-quality effluent and/or reclaimed water quality to meet point source discharge limitations. In addition, the master planning process has identified near-term and longer-term wastewater system growth (9.6-MGD future ADF) that exceeds the nutrient (TN, TP) wasteload allocations that are based on 8-MGD ADF, 3 mg/L TN, and 0.18 mg/L TP. Higher flows would require lower effluent concentrations to meet the same wasteload allocations. The current limit of ENR treatment technology is generally considered to be 3 mg/L TN. Additional chemical feed and filtration may be required to meet lower TP concentrations. It is assumed that limited nutrient credits will be available in subsequent decades given the point source and non-point source reduction goals of the Chesapeake Bay Program overall and for the Potomac Basin. This CIP entry is an Allowance, for higher-quality effluent to discharge greater than 8-MGD actual ADF.

Priority	*1 – Critical (capacity)*

Design	*Beyond FY2027*
Construct	*Beyond FY2027*
Total Project Cost	*$28,000,000*

LWWTF-001: Little Falls Run WWTF Upgrade - Facilities Planning

DPW has identified certain proposed modifications as part of its on-going asset renewal program. These upgrades include on-going concrete repair to process units, potential headworks upgrade, and UV disinfection performance improvements. Aging infrastructure, including the original Schreiber process train and the effluent filtration system, require periodic major maintenance or upgrades. The site may be constrained with respect to pending or future upgrades or expansion, treatment technologies and configurations should be studied. Also, the Little Falls Run WWTF VPDES Permit expires in September 2020, DEQ is proposing a Rappahannock River Water Quality Policy due to low downstream dissolved oxygen levels, so the reapplication process may identify other upgrades or modifications. Facilities planning would be initiated to identify and prioritize on-going renovations. The Fresh Water Nutrient Criteria / Ammonia rule will likely be adopted by VA and DEQ by mid-2018, the Rappahannock Policy is expected by the time of other VPDES Permit renewals (Spotsylvania County, City of Fredericksburg; 2017-8). These regulatory changes suggest biological treatment system and/or chemical feed upgrades. In addition, the master planning process has identified near-term and longer-term wastewater system growth that may affect the timing of certain capacity upgrades. The proposed, step-wise WWTF facilities planning would build upon the master plan evaluation and baseline condition assessments at Little Falls Run to prioritize and aggregate various upgrades and modifications – a platform for subsequent capital improvement projects.

Priority	*2 – Necessary (to improve reliability, water quality)*
Design	*FY2019-2021*
Construct	*---*
Total Project Cost	*$125,000*

LWWTF-002: Little Falls Run WWTF General Upgrades – Concrete Repair, Headworks, UV

DPW has identified certain proposed modifications as part of its on-going asset renewal program. These upgrades include on-going concrete repair to process units, potential headworks upgrade, and UV disinfection updates. These general upgrades are compatible and consistent with other anticipated near-term upgrades and modifications for firm capacity, efficient operations, system reliability, and effluent compliance.

Priority	*2 – Necessary (repair, improve reliability)*
Design	*FY2019-2020*
Construct	*FY2019-2021*
Total Project Cost	*$3,300,000*

LWWTF-003: Little Falls Run WWTF Denitrification Upgrade

The Little Falls Run WWTF VPDES Permit expires in September 2020, DEQ is proposing a Rappahannock River Water Quality Policy due to low downstream dissolved oxygen levels, so the reapplication process may identify other upgrades or modifications. The Fresh Water Nutrient Criteria / Ammonia rule will likely be adopted by VA and DEQ by mid-2018, the Rappahannock Policy is expected by the time of other VPDES Permit renewals in the same reach of the river (Spotsylvania County, City of Fredericksburg; 2017-8). These regulatory changes suggest biological treatment system and/or chemical feed upgrades. This CIP project specifically addresses post-denitrification (Post-DN) capabilities and capacities of LFR. Increasing tankage volume and overall DN capabilities, with or without supplemental carbon feed, lowers effluent nitrate and overall total nitrogen, to meet current 6 mg/L TN (and 0.3 mg/L TP) goals and pending tighter TN & TP requirements due to either by Rappahannock Policy and/or near-term wastewater growth projections, requiring lower effluent concentrations for the same permitted wasteload allocations. These upgrades are compatible and consistent with other anticipated near-term upgrades and modifications for firm capacity, efficient operations, system reliability, and nutrient removal permit compliance.

Priority	*1 – Critical (water quality)*
Design	*FY2020*
Construct	*FY2021-2022*
Total Project Cost	*$3,500,000*

LWWTF-004: Little Falls Run WWTF Upgrades (Rappahannock Policy, FWNC / NH3 – Allowance)

The Little Falls Run WWTF VPDES Permit expires in September 2020, DEQ is proposing a Rappahannock River Water Quality Policy due to low downstream dissolved oxygen levels, so the reapplication process may identify other upgrades or modifications. The Fresh Water Nutrient Criteria / Ammonia rule will likely be adopted by VA and DEQ by mid-2018, the Rappahannock Policy is expected by the time of other VPDES Permit renewals in the same reach of the river (Spotsylvania County, City of Fredericksburg; 2017-8). The change in ammonia toxicity water quality criteria will likely result in a lower NH3-N limit (by season) that requires additional nitrification capacity and/or process control to meet monthly average and weekly limits. Additionally, it is likely that LFR will need to meet lower TN levels than the current 6 mg/L TN goal, on the order of 3-4 mg/L TN annual average concentration. These regulatory changes suggest extensive biological treatment system and/or chemical feed upgrades. This CIP project specifically addresses nitrogen removal and phosphorus polishing. These upgrades are compatible and consistent with other anticipated near-term upgrades and modifications for firm capacity, efficient operations, system reliability, and nutrient removal permit compliance. This CIP line item is an Allowance, which would be defined and detailed as the water quality criteria is adopted, DEQ policies & procedures are reviewed, and the new rule is applied to VPDES Permit renewals in 2018. There is no property acquisition cost included in this budgetary allowance.

Priority	*1 – Critical (water quality)*
Design	*FY2021*
Construct	*FY2022-2024*
Total Project Cost	*$11,600,000*

LWWTF-005: Little Falls Run WWTF General Upgrades – Filtration, Miscellaneous

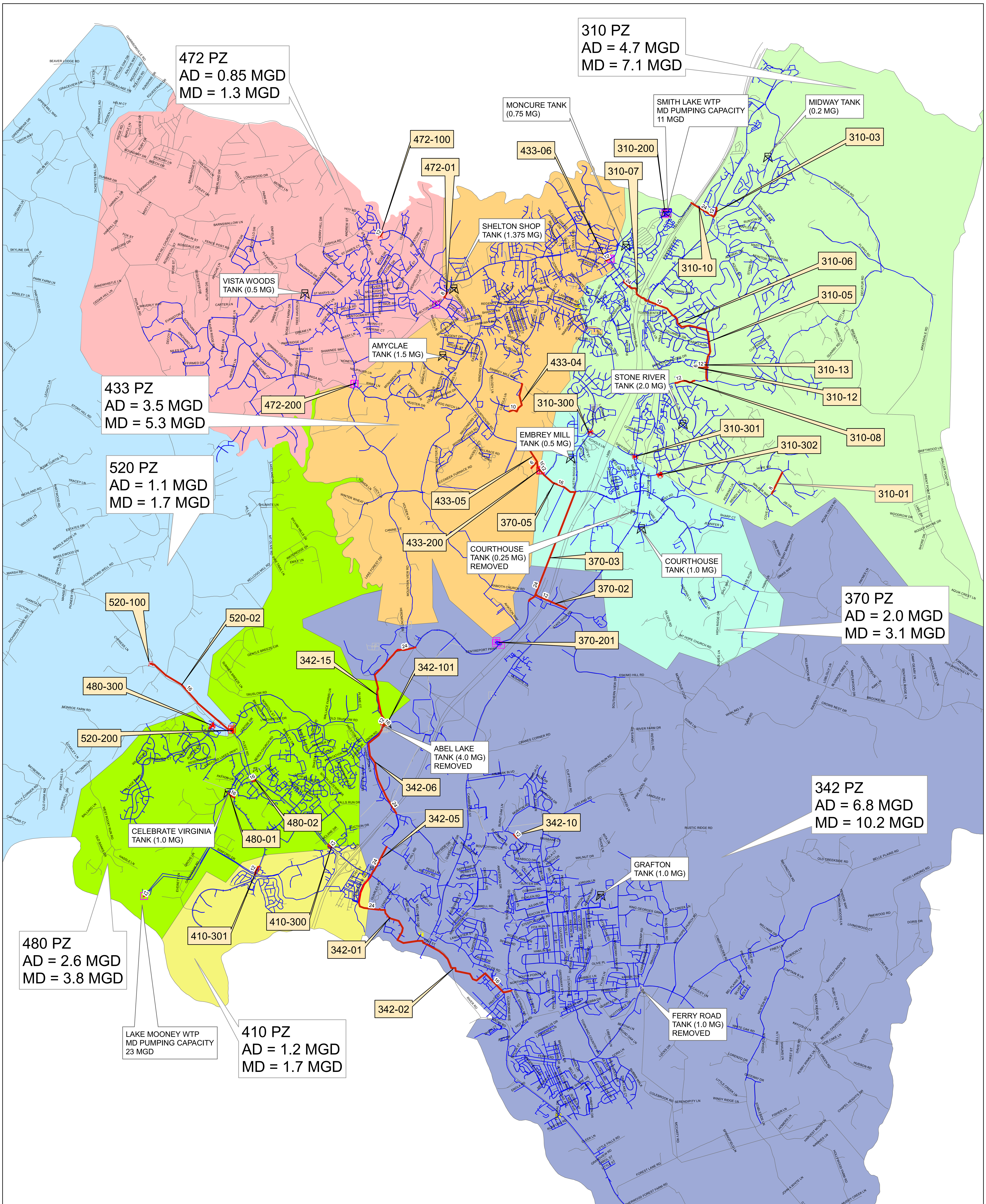
DPW has identified certain proposed modifications as part of its on-going asset renewal program. These upgrades include mechanical and control upgrades to effluent filtration, plant SCADA and overall process control system updates, and other miscellaneous treatment upgrades. These general upgrades are compatible and consistent with other anticipated near-term upgrades and modifications for firm capacity, efficient operations, system reliability, and effluent compliance.

Priority	*2 – Necessary (improve reliability)*
Design	*FY2024-2025*
Construct	*FY2025-2027*
Total Project Cost	*$2,700,000*

LWWTF-006: Little Falls Run WWTF Expansion & Upgrade (Allowance)

The master planning process has delineated anticipated remaining life for process / mechanical, instrumentation & control, and structural / architectural facilities at the Little Falls Run WWTF. In addition to aging infrastructure that will need to be addressed in a longer-term upgrade project, the Schreiber biological treatment process technology may need to be updated or replaced to produce high-quality effluent. The current and anticipated future Little Falls Run WWTF VPDES Permit includes wasteload allocations for total nitrogen, total phosphorus, and other parameters. Regulatory changes may require higher-quality effluent and/or reclaimed water quality to meet point source discharge limitations. In addition, the master planning process has identified near-term and longer-term wastewater system growth (9.6-MGD future ADF) that exceeds the nutrient (TN, TP) wasteload allocations that are based on 8-MGD ADF, 3 mg/L TN, and 0.18 mg/L TP. Also, according to DEQ, the Rappahannock Policy is likely to introduce low CBOD5 and TSS limits with wasteload allocations with any expansion. Higher flows would require lower effluent concentrations to meet the same wasteload allocations, nutrients and conventional parameters. The current limit of ENR treatment technology is generally considered to be 3 mg/L TN. Additional chemical feed and filtration may be required to meet lower TP concentrations. It is assumed that limited nutrient credits will be available in subsequent decades given the point source and non-point source reduction goals of the Chesapeake Bay Program overall and for the Rappahannock Basin. This CIP entry is an Allowance, for higher-quality effluent to discharge greater than 8-MGD actual ADF.

Priority	*1 – Critical (capacity)*
Design	*Beyond FY2027*
Construct	*Beyond FY2027*
Total Project Cost	*$28,000,000*



Notes:
1. AD and MD represent Average Day Demand and Maximum Day Demand, respectively.
2. Units: MGD for flow, feet for hydraulic head and inches for pipe diameter.
3. "Tanks Removed" represent existing tanks to be removed.
4. Proposed improvements include both near-term and buildout scenarios.
5. Refer to "Summary of Costs and Schedule of Improvements for Recommended CIP Improvements" for additional details on Projects.
6. Proposed water mains are limited to pipes greater than 6 inches in diameter.

TOTAL BUILDOUT SYSTEM DEMAND
AD = 22.7 MGD
MD = 34.1 MGD

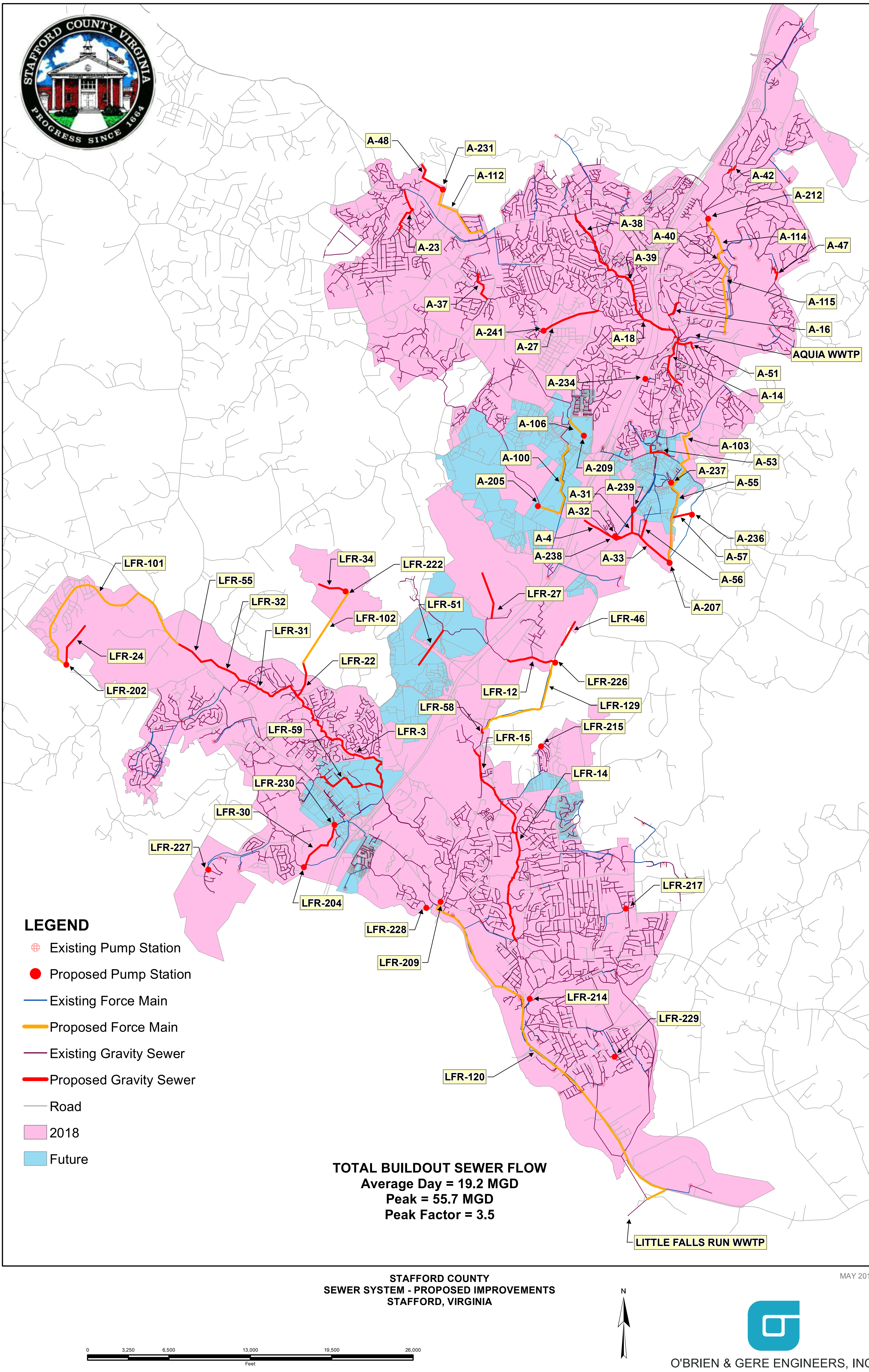
STAFFORD COUNTY
WATER SYSTEM - PROPOSED IMPROVEMENTS
STAFFORD, VIRGINIA

0 0.5 1 2 3 4 Miles

N W E S

MAY, 2018

O'BRIEN & GERE ENGINEERS, INC.



MAY 2018

STAFFORD COUNTY
SEWER SYSTEM - PROPOSED IMPROVEMENTS
STAFFORD, VIRGINIA

O'BRIEN & GERE ENGINEERS, INC.

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Stafford County Water and Sewer Master Plan - Water System Improvements

Summary of Costs and Schedule for Recommended CIP Improvements

5/13/2018

Project #	Project Name	Type	Reason	Proposed Pipe Size (inches)	Quantity	Unit	Unit Cost ($)	Interstate and Roadway Boring Costs	Construction Contingency Allowance	Eng., Legal and Administrative Allowance (% of Construction w/ Contingency Allowance)	Total Construction Cost in 2017 Dollars	Category	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	Beyond FY2028	Project #
310 Zone																								
Piping																								
310-01	Construct 8-inch main from Jib Drive to Hope Springs Lane	Piping	Improve Fire Flow	8	1,917	ft	$145	$0	35%	20%	$450,000	2											$450,000	310-01
310-03	Construct 12-inch main along Jefferson Davis Highway from Sunnyside Drive to Slake Drive	Piping	Transmit Flow	12	801	ft	$160	$0	35%	20%	$208,000	2											$208,000	310-03
310-05	Construct 12-inch main along Aquia Drive from Coal Landing Road to Washington Drive	Piping	Transmit Flow	12	4,129	ft	$160	$0	35%	20%	$1,070,000	2											$1,070,000	310-05
310-06	Construct 12-inch main along Washington Drive from Aquia Drive to Jefferson Davis Highway	Piping	Transmit Flow	12	5,841	ft	$160	$0	35%	20%	$1,514,000	2											$1,514,000	310-06
310-07	Construct 24-inch main along Garrisonville Road (Rt. 610) from Salisbury Drive to Jefferson Davis Highway	Piping	Transmit Flow	24	2,375	ft	$200	$250,000	35%	20%	$1,175,000	2											$1,175,000	310-07
310-08	Replace existing 8-inch main along Coal Landing Road with a 12-inch main from Greenridge Drive east to existing 12-inch main	Piping	Transmit Flow	12	1,873	ft	$160	$0	35%	20%	$485,000	2											$485,000	310-08
310-10	Construct 24-inch main from I-95 to 12-inch main along Jefferson Davis Highway near Sunnyside Drive	Piping	Transmit Flow	24	2,120	ft	$200	$250,000	35%	20%	$1,092,000	2											$1,092,000	310-10
310-12	Construct 12-inch main along Forest Wood Drive from White Pine Circle to connect to existing 12-inch on Aquia Drive	Piping	Transmit Flow	12	1,160	ft	$160	$0	35%	20%	$301,000	2											$301,000	310-12
310-13	Construct 6-inch main along Pilgrim Drive to connect the existing 6-inch to the new 12-inch on Forest Wood Drive	Piping	Transmit Flow	6	175	ft	$130	$0	35%	20%	$37,000	2											$37,000	310-13
Pumping																								
310-200	Expand Smith Lake Pumping Station to 14 mgd	Pumping	Supply		4,000,000	gal/day	$0.3	$0	35%	20%	$1,944,000	1											$1,944,000	310-200
Valving																								
310-300	Construct emergency pressure reducing valve between 370/310 Zone near Wallace Lane	Valving	Reliability		1	ea	$50,000	$0	35%	20%	$81,000	2											$81,000	310-300
310-301	Construct emergency pressure reducing valve between 370/310 Zone along Bells Hill Road near Byrum Street	Valving	Reliability		1	ea	$50,000	$0	35%	20%	$81,000	2											$81,000	310-301
310-302	Construct emergency pressure reducing valve between 370/310 Zone along Olde Concord Road near Somerset Lane	Valving	Reliability		1	ea	$50,000	$0	35%	20%	$81,000	2											$81,000	310-302
342 Zone																								
Piping																								
342-01	Construct 24-inch main along Lendall Lane, Ingleside Drive, and King Street from Olde Forge Road to Cambridge Street	Piping	Transmit Flow	24	8,183	ft	$500	$25,000	35%	20%	$6,669,000	1	$6,669,000											342-01
342-02	Construct 16-inch main along River Road and Chatham Heights Road from Cambridge Street to Cool Springs Road	Piping	Transmit Flow	16	7,057	ft	$450	$0	35%	20%	$5,145,000	1		$5,145,000										342-02
342-05	Construct 24-inch main along Olde Froge Road and RV Parkway to Kelley Road	Piping	Transmit Flow	24	5,124	ft	$200	$0	35%	20%	$1,660,000	1											$1,660,000	342-05
342-06	Construct 24-inch main along Truslow Road and Enon Road to Hulls Chapel Road	Piping	Transmit Flow	24	8,365	ft	$200	$250,000	35%	20%	$3,115,000	1											$3,115,000	342-06
342-10	Construct 12-inch main along Primmer House Road	Piping	Transmit Flow	12	350	ft	$160	$345,000	35%	20%	$650,000	2											$650,000	342-10
342-15	Replace existing 16-inch main with 24-inch main along Hulls Chapel Road from Abel Lake Tank to Stones Mill Lane and construct new 24-inch main along Stones Mill Lane to intersection of Mountain View Road and Centreport Parkway	Piping	Transmit Flow	24	8,712	ft	$200	$0	35%	20%	$2,823,000	1											$2,823,000	342-15
Storage																								
342-101	Construct new 2 MG elevated storage tank at the site of the existing Abel Lake Tank with overflow of 342 ft	Storage	Required Storage		2,000,000	gal	$2	$0	15%	20%	$5,520,000	1		$552,000	$4,968,000									342-101
370 Zone																								
Piping																								
370-02	Construct 12-inch main along Ramoth Church Road and American Legion Road from 24-inch at Ramoth Church Road to 12-inch main on Jefferson Davis Hwy	Piping	Transmit Flow	12	2,850	ft	$160	$150,000	35%	20%	$982,000	1											$982,000	370-02
370-03	Construct 24-inch main from Ramoth Church Road to Courthouse Road	Piping	Transmit Flow	24	9,700	ft	$200	$0	35%	20%	$3,143,000	1											$3,143,000	370-03
370-05	Construct 16-inch main along Courthouse Road from west of I-95 west to 433 Zone pumping station near Snowbird Lane	Piping	Transmit Flow	16	3,257	ft	$180	$0	35%	20%	$950,000	1											$950,000	370-05
Pumping																								
370-201	Construct 11.1 mgd pumping station along Centreport Parkway near Aviation Way	Pumping	Supply		11,100,000	gal/day	$0.3	$0	35%	20%	$5,395,000	1											$5,395,000	370-201
410 Zone																								
Valving																								
410-300	Construct pressure reducing valve between 480/410 Zone along Warrenton Road near Sanford Drive	Valving	Supply		1	ea	$50,000	$0	35%	20%	$81,000	2	$8,100	$72,900										410-300
410-301	Construct pressure reducing valve between 480/410 Zone along Celebrate VA Parkway near Sanford Drive	Valving	Supply		1	ea	$50,000	$0	35%	20%	$81,000	2	$8,100	$72,900										410-301
433 Zone																								
Piping																								
433-04	Construct 10-inch main from Embrey Mill Road to existing 10-inch main on White Chapel Lane	Piping	Transmit Flow	10	3,132	ft	$150	$0	35%	20%	$761,000	2											$761,000	433-04
433-05	Construct 16-inch main along Courthouse Road from pumping station at 433/370 zone boundary to existing 12-inch at Rollinswood Lane	Piping	Transmit Flow	16	2,720	ft	$180	$0	35%	20%	$793,000	1											$793,000	433-05
433-06	Construct 12-inch main from Moncure Pumping Station to 8-inch main south of the pumping station	Piping	Transmit Flow	12	330	ft	$160	$0	35%	20%	$86,000	2	$8,600	$77,400										433-06
Pumping																								
433-200	Construct 4.4 mgd pumping station along Courthouse Road at 433 Zone boundary near Snowbird Lane	Pumping	Transfer Flow		4,400,000	gal/day	$0.3	$0	35%	20%	$2,138,000	1											$2,138,000	433-200
472 Zone																								
Piping																								
472-01	Construct 8-inch main along Shelton Shop Road from existing 12-inch at Soaring Eagle Drive and existing 6-inch on Oakwood Drive	Piping	Transmit Flow	8	413	ft	$145	$0	35%	20%	$97,000	2	$9,700	$87,300										472-01
Storage																								
472-100	Construct 0.5 MG storage tank along Garrisonville Road near Ripley Road	Storage	Required Storage		500,000	gal	$2	$0	15%	20%	$1,380,000	2								$138,000	$1,242,000			472-100
Pumping																								
472-200	Construct 0.9 mgd pumping station along Lightfoot Road near Mountain View Road	Pumping	Transfer Flow		900,000	gal/day	$0.3	$0	35%	20%	$437,000	1											$437,000	472-200
480 Zone																								
Piping																								
480-01	Construct 16-inch main from the existing 16-inch main at Greenbank Road at Celebrate VA Tank to Jewett Road to existing 12-inch main on Celebrate Virginia Parkway	Piping	Transmit Flow	16	600	ft	$180	$150,000	35%	20%	$418,000	2						$41,800	$376,200					480-01
480-02	Construct 16-inch main from existing 12-inch main at Celebrate Virginia Parkway under Warrenton Road to the existing 12-inch mains along Warrenton Road and International Parkway	Piping	Transmit Flow	16	500	ft	$160	$250,000	35%	20%	$535,000	2						$53,500	$481,500					480-02
Valving																								
480-300	Construct pressure reducing valve between 520/480 Zone along Village Parkway	Valving	Supply		1	ea	$50,000	$0	35%	20%	$81,000	2									$8,100	$72,900		480-300
520 Zone																								
Piping																								
520-02	Construct 16-inch main along Warrenton Road from New Pump Station to Westlake Tank	Piping	Transmit Flow	16	8,958	ft	$180	$0	35%	20%	$2,612,000	1				$261,200	$2,350,800							520-02
Storage																								
520-100	Construct 0.75 MG elevated storage tank along Warrenton Road in vicinity of Clark Patton Road	Storage	Required Storage		750,000	gal	$2	$0	15%	20%	$2,070,000	1				$207,000	$1,863,000							520-100
Pumping																								
520-200	Construct 2.3 mgd pumping station along Warrenton Road near Cardinal Forest Drive	Pumping	Transfer Flow		2,300,000	gal/day	$0.3	$0	35%	20%	$1,118,000	1				$111,800	$1,006,200							520-200
Total FY2019-FY2028 Planning Period (Near-term)											**$25,893,000**		**$6,703,500**	**$6,007,500**	**$4,968,000**	**$580,000**	**$5,220,000**	**$95,300**	**$857,700**	**$138,000**	**$1,250,100**	**$72,900**		
Total FY2019-Buildout Planning Period (Buildout)											**$57,259,000**		**$6,703,500**	**$6,007,500**	**$4,968,000**	**$580,000**	**$5,220,000**	**$95,300**	**$857,700**	**$138,000**	**$1,250,100**	**$72,900**	**$31,366,000**	

Legend

1 **Priority 1 - Critical to the current and future operation of the system or supplies areas not previously served.**

2 **Priority 2 - Necessary to meet basic hydraulic performance requirements and improve system operation and reliability.**

Stafford County Water and Sewer Master Plan - Sewer System Improvements
Summary of Costs and Schedule for CIP Improvements

5/14/2018

Project #	Project Name	Type	Proposed Pipe Size (inches)	Quantity	Unit	Unit Cost ($)	Interstate and Roadway Boring Costs	Construction Contingency Allowance	Eng., Legal and Administrative Allowance (% of Construction w/ Contingency Allowance)	Total Construction Cost in 2017 Dollars	Priority Category	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	Beyond FY2028	Project #
Aquia Wastewater Treatment Facility Service Area																							
Gravity Piping																							
A-4	Construct 12-inch gravity main along Accokeek Creek from location downstream of Rowser PS	Piping	12	3,121	ft	162	$0	35%	20%	$819,000	2			$81,900	$737,100								A-4
A-14	Construct 18-inch and 24-inch gravity main along Jefferson Davis Highway from Lakeview Ct to Coal Landing Rd	Piping	18	4,895	ft	184	$0	35%	20%	$1,459,000	1			$145,900	$1,313,100								A-14
A-16	Replace 8-inch with 12-inch gravity main from vicinity of Nina Cove to Jefferson Davis Highway	Piping	12	1,427	ft	162	$0	35%	20%	$375,000	7											$375,000	A-16
A-18	Replace 24-inch with 36-inch gravity main along Austin Run from Whitsons Run to Austin Run PS	Piping	36	2,354	ft	259	$250,000	35%	20%	$1,393,000	2			$139,300	$1,253,700								A-18
A-23	Replace 10-inch with 12-inch gravity main along unnamed tributary to Aquia Creek and Choptank Road from Garrisonville Road to Huckstep Avenue	Piping	12	4,193	ft	162	$0	35%	20%	$1,100,000	7											$1,100,000	A-23
A-27	Construct 8-inch gravity main along South Austin Run from Mine Road to PS on September Lane	Piping	8	4,928	ft	130	$0	35%	20%	$1,038,000	5											$1,038,000	A-27
A-31	Construct 12-inch gravity main along unnamed tributary to Accokeek Creek from Wyche Road PS to interceptor along Accokeek Creek	Piping	12	1,638	ft	162	$0	35%	20%	$430,000	2					$43,000	$387,000						A-31
A-32	Construct 10-inch gravity main from Rowser PS to interceptor along Accokeek Creek	Piping	10	532	ft	151	$0	35%	20%	$130,000	2					$13,000	$117,000						A-32
A-33	Construct 18-inch gravity main along Accokeek Creek from vicinity of Jumping Branch Road to Lower Accokeek PS	Piping	18	4,816	ft	184	$0	35%	20%	$1,436,000	2					$143,600	$1,292,400						A-33
A-37	Construct 8-inch gravity main from interceptor along Austin Run near Winding Creek Road and Marshall Road to Heritage Oaks II PS	Piping	8	2,635	ft	130	$0	35%	20%	$555,000	5						$55,500	$499,500					A-37
A-38	Replace 10-inch and 12-inch with 18-inch gravity main along unnamed tributary from Garrisonville Rd to interceptor along Whitsons Run	Piping	18	3,439	ft	184	$0	35%	20%	$1,025,000	3											$1,025,000	A-38
A-39	Replace 18-inch with 24-inch gravity main along Whitsons Run from vicinity of Highpointe Blvd to interceptor along Austin Run	Piping	24	7,481	ft	205	$0	35%	20%	$2,484,000	3											$2,484,000	A-39
A-40	Replace 8-inch with 12-inch gravity main along Aquia Drive from Delaware Drive to Vessel Drive	Piping	12	2,028	ft	162	$0	35%	20%	$532,000	7							$53,200	$478,800				A-40
A-42	Replace 8-inch with 18-inch gravity main along Jefferson Davis Highway from Aquia Creek to Potomac Hills Drive	Piping	18	717	ft	184	$0	35%	20%	$214,000	3											$214,000	A-42
A-47	Replace 8-inch with 15-inch gravity main near Voyage Drive	Piping	15	1,206	ft	173	$0	35%	20%	$338,000	7							$33,800	$304,200				A-47
A-48	Construct 8-inch gravity main to serve area near Sheron Lane to PS along Aquia Creek	Piping	8	3,500	ft	130	$0	35%	20%	$737,000	5											$737,000	A-48
A-51	Replace 12-inch with 15-inch gravity main along Coal Landing Rd from Jefferson Davis Hwy to Knightsbridge Way	Piping	15	1,586	ft	173	$0	35%	20%	$444,000	1		$44,400	$399,600									A-51
A-53	Replace 8-inch with 12-inch gravity main along Courthouse Rd	Piping	12	2,191	ft	162	$0	35%	20%	$575,000	3											$575,000	A-53
A-55	Construct 8-inch gravity main from Stafford Hospital PS to Lower Accokeek PS	Piping	8	6,771	ft	130	$0	35%	20%	$1,426,000	3											$1,426,000	A-55
A-56	Construct 8-inch gravity main from Abberly PS to Lower Accokeek PS	Piping	8	1,434	ft	130	$0	35%	20%	$302,000	3											$302,000	A-56
A-57	Construct 8-inch gravity main from Stafford Middle School PS to near Old Potomac Church Rd	Piping	8	1,675	ft	130	$0	35%	20%	$353,000	3											$353,000	A-57
Force Mains																							
A-100	Replace 10-inch with 16-inch force main along Cedar Lane from Upper Accokeek PS to Rocky Run Interceptor	Piping	16	7,820	ft	180	$0	35%	20%	$2,280,000	2									$228,000	$2,052,000		A-100
A-103	Construct 12-inch force main along Jefferson Davis Highway from Lower Accokeek PS	Piping	12	12,248	ft	160	$0	35%	20%	$3,175,000	2					$317,500	$2,857,500						A-103
A-106	Construct 4-inch force main from Sunflower Dr PS to Mine Rd	Piping	4	1,300	ft	120	$0	35%	20%	$253,000	3											$253,000	A-106
A-112	Construct 6-inch force main from Sheron Lane PS near Aquia Creek	Piping	6	6,500	ft	130	$0	35%	20%	$1,369,000	3											$1,369,000	A-112
A-114	Replace 8-inch and 10-inch force mains with 18-inch force main from Aquia Creek PS at Crucifix	Piping	18	2,600	ft	190	$0	35%	20%	$800,000	3											$800,000	A-114
A-115	Replace 14-inch and 12-inch force mains with an 18-inch force main from Aquia at Bridge PS to existing 18-inch force main near Starboard Cove Lane	Piping	18	6,976	ft	190	$0	35%	20%	$2,147,000	3											$2,147,000	A-115
Pumping																							
A-205	Expand Upper Accokeek PS	Pumping		1,150,000	gal/day	0.3	$0	35%	20%	$559,000	1									$55,900	$503,100		A-205
A-207	Construct Lower Accokeek PS	Pumping		1,650,000	gal/day	0.3	$0	35%	20%	$802,000	2					$80,200	$721,800						A-207
A-209	Construct Sunflower Dr PS	Pumping		612,000	gal/day	0.3	$0	35%	20%	$297,000	3											$297,000	A-209
A-212	Expand Aquia Creek PS	Pumping		881,000	gal/day	0.3	$0	35%	20%	$428,000	3											$428,000	A-212
A-231	Construct Sheron Lane PS	Pumping		40,000	gal/day	0.3	$0	35%	20%	$19,000	3											$19,000	A-231
A-236	Decommission Stafford Middle School PS	Pumping		0	gal/day	0.3	$0	35%	20%	$100,000	3											$100,000	A-236
A-237	Decommission Stafford Hospital PS	Pumping		0	gal/day	0.3	$0	35%	20%	$100,000	3											$100,000	A-237
A-238	Decommission Rowser PS	Pumping		0	gal/day	0.3	$0	35%	20%	$100,000	2	$10,000	$90,000										A-238
A-239	Decommission Wyche Industrial Park PS	Pumping		0	gal/day	0.3	$0	35%	20%	$100,000	2	$10,000	$90,000										A-239
A-241	Decommission Autumn Ridge PS	Pumping		0	gal/day	0.3	$0	35%	20%	$100,000	5											$100,000	A-241
Little Falls Run Wastewater Treatment Facility Service Area																							
Gravity Piping																							
LFR-3	Replace 15-inch and 12-inch with 24-inch gravity main along Falls Run from 30-inch in vicinity of Stanstead Road to Pennsbury Court	Piping	24	12,338	ft	205	$0	35%	20%	$4,097,000	2	$409,700	$1,843,650	$1,843,650									LFR-3
LFR-12	Replace 15-inch with 21-inch gravity main along Potomac Creek from vicinity of Jefferson Davis Highway to Potomac Creek PS	Piping	21	3,950	ft	194	$0	35%	20%	$1,241,000	3											$1,241,000	LFR-12
LFR-14	Replace 18-inch and 24-inch with 27-inch gravity main along Claiborne Run from vicinity of White Oak Road to Morton Road	Piping	27	12,424	ft	216	$0	35%	20%	$4,347,000	3											$4,347,000	LFR-14
LFR-15	Replace 18-inch, 15-inch and 12-inch with 24-inch gravity main along Claiborne Run from Morton Road to Kings Hill Road	Piping	24	6,212	ft	205	$0	35%	20%	$2,063,000	2			$206,300	$1,856,700								LFR-15
LFR-22	Construct 15-inch gravity main from force main serving Upper Potomac Creek PS No. 1 to Falls Run interceptor near Berea Church Road	Piping	15	3,000	ft	173	$0	35%	20%	$841,000	5											$841,000	LFR-22
LFR-24	Construct 15-inch gravity main along Horsepen Run from Westlake Industrial Park PS in vicinity of Cedar Grove Road	Piping	15	3,600	ft	173	$0	35%	20%	$1,009,000	5											$1,009,000	LFR-24
LFR-27	Construct 12-inch gravity main along unnamed tributary to Potomac Creek from area near airport to Centreport Parkway	Piping	12	3,800	ft	162	$0	35%	20%	$997,000	5											$997,000	LFR-27
LFR-30	Construct 12-inch gravity main along unnamed tributary to England Run from England Run PS to Days Inn PS	Piping	12	4,500	ft	162	$0	35%	20%	$1,181,000	5							$118,100	$1,062,900				LFR-30
LFR-31	Replace 15-inch with 21-inch gravity main along Falls Run from Pennsbury Court to vicinity of Averil Court	Piping	21	5,987	ft	194	$0	35%	20%	$1,882,000	3											$1,882,000	LFR-31
LFR-32	Construct 21-inch gravity main along Falls Run from vicinity of Averil Court to vicinity of Holly Corner Road	Piping	21	2,815	ft	194	$0	35%	20%	$885,000	5											$885,000	LFR-32
LFR-34	Construct 15-inch gravity main along Potomac Creek upstream of Upper Potomac Creek PS	Piping	15	2,256	ft	173	$0	35%	20%	$632,000	5											$632,000	LFR-34
LFR-46	Construct 8-inch gravity main along unnamed tributary to Potomac Creek in vicinity of Potomac Creek Industrial Park	Piping	8	2,121	ft	130	$0	35%	20%	$447,000	5											$447,000	LFR-46
LFR-51	Construct 10-inch gravity main to serve future Central PDA growth	Piping	10	1,000	ft	151	$0	35%	20%	$245,000	5					$24,500	$220,500						LFR-51
LFR-55	Construct 21-inch gravity main along Warrenton Rd from Holly Corner Rd to Poplar Rd	Piping	21	3,200	ft	194	$0	35%	20%	$1,006,000	3											$1,006,000	LFR-55
LFR-58	Replace 8-inch with 15-inch gravity main along Cambridge St from the FM to Michael St	Piping	15	480	ft	173	$0	35%	20%	$135,000	2			$13,500	$121,500								LFR-58
LFR-59	Replace 8-inch with 10-inch gravity main from Nelms Cir to Auction Dr	Piping	10	5,638	ft	151	$0	35%	20%	$1,379,000	2									$137,900	$1,241,100		LFR-59
Force Mains																							
LFR-101	Construct 10-inch force main from Westlake Industrial Park PS to Falls Run interceptor	Piping	10	13,397	ft	155	$0	35%	20%	$3,364,000	3											$3,364,000	LFR-101
LFR-102	Construct 8-inch force main from Upper Potomac Creek PS No. 1 to 15-inch gravity main connected to Falls Run interceptor	Piping	8	6,631	ft	150	$0	35%	20%	$1,611,000	5											$1,611,000	LFR-102
LFR-120	Construct 24-inch force main from Falls Run PS to Little Falls Run WWTP	Piping	24	33,400	ft	200	$0	35%	20%	$10,822,000	2	$1,082,200	$4,869,900	$4,869,900									LFR-120
LFR-129	Replace 8-inch with 16-inch force main from Potomac Creek PS	Piping	16	9,055	ft	180	$0	35%	20%	$2,640,000	2				$264,000	$2,376,000							LFR-129
Pumping																							
LFR-202	Construct Westlake Industrial Park PS	Pumping		1,800,000	gal/day	0.3	$0	35%	20%	$875,000	5											$875,000	LFR-202
LFR-204	Expand Celebrate VA PS	Pumping		1,530,000	gal/day	0.3	$0	35%	20%	$744,000	5							$74,400	$669,600				LFR-204
LFR-209	Replace Falls Run PS	Pumping		17,600,000	gal/day	0.3	$0	35%	20%	$8,554,000	2			$855,400	$3,849,300	$3,849,300							LFR-209
LFR-214	Expand Claiborne Run PS	Pumping		6,930,000	gal/day	0.3	$0	35%	20%	$3,368,000	3											$3,368,000	LFR-214
LFR-215	Expand Hickory Ridge PS	Pumping		306,000	gal/day	0.3	$0	35%	20%	$149,000	3											$149,000	LFR-215
LFR-217	Expand Stratford Place PS	Pumping		165,000	gal/day	0.3	$0	35%	20%	$80,000	2						$8,000	$72,000					LFR-217
LFR-222	Construct Upper Potomac Creek PS	Pumping		1,210,000	gal/day	0.3	$0	35%	20%	$588,000	5											$588,000	LFR-222
LFR-226	Expand Potomac Creek PS	Pumping		2,040,000	gal/day	0.3	$0	35%	20%	$991,000	2					$99,100	$891,900						LFR-226
LFR-227	Expand Cannon Ridge PS	Pumping		313,000	gal/day	0.3	$0	35%	20%	$152,000	3											$152,000	LFR-227
LFR-228	Expand Ingleside PS	Pumping		311,000	gal/day	0.3	$0	35%	20%	$151,000	2					$15,100	$135,900						LFR-228
LFR-229	Expand Sweetbriar Woods PS	Pumping		195,000	gal/day	0.3	$0	35%	20%	$95,000	1	$9,500	$85,500										LFR-229
LFR-230	Decommission Day's Inn PS	Pumping		--	gal/day	0.3	$0	35%	20%	$100,000	5											$100,000	LFR-230
Total FY2019-FY2028 Planning Period (Near-term)										$47,729,000		$1,521,400	$7,023,450	$8,555,450	$9,395,400	$6,961,300	$6,687,500	$851,000	$2,515,500	$421,800	$3,796,200		
Total FY2019-Buildout Planning Period (Buildout)										$86,465,000		$1,521,400	$7,023,450	$8,555,450	$9,395,400	$6,961,300	$6,687,500	$851,000	$2,515,500	$421,800	$3,796,200	$38,736,000	

Legend

1	**Priority 1 - Operations: Essential to the current operation of the system or serves areas not previously served.**
2	**Priority 2 - Near-term: Essential to the near-term operation of the system or serves areas not previously served**
3	**Priority 3 - Buildout: Essential to the buildout condition of the system or serves areas not previously served**
5	**Priority 5 - Operations/Near-term/Buildout: serves areas not previously served**
7	**Priority 7 - Candidate Projects for Flow Monitoring Prior to Recommendation for Implementation**

Stafford County Water and Sewer Master Plan - Water Treatment Improvements

Summary of Costs and Schedule for Recommended CIP Improvements

Project #	Project Name	Type	Reason	Quantity	Unit	Unit Cost ($)	Construction Contingency Allowance	Eng., Legal and Administrative Allowance (% of Construction w/ Contingency Allowance)	Total Construction Cost in 2017 Dollars	Category	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	Beyond FY2028
Water Treatment																					
LMWTP-001	Lake Mooney WTP - Install second centrifuge	Treatment	Reliability	1	LS	$450,000	35%	20%	$700,000	2	$70,000	$630,000									
LMWTP-002	Lake Mooney WTP - Install second thickener	Treatment	Reliability	1	LS	$400,000	35%	20%	$620,000	2			$62,000	$558,000							
LMWTP-003	Lake Mooney WTP - Add membrane cassettes to increase summertime rating to 12.5 MGD	Treatment	Capacity	1	LS	$600,000	20%	10%	$780,000	1											$780,000
LMWTP-004	Lake Mooney WTP - Long-term expansion to 25 MGD	Treatment	Capacity	12,500,000	GPD	$2.50	35%	20%	$48,000,000	1											$48,000,000
LMWTP-005	Lake Mooney WTP - Water treatment optimization studies	Treatment	Water Quality	1	LS	$500,000	NA	NA	$500,000	2		$500,000									
LMWTP-006	Lake Mooney WTP - Future treatment process upgrades	Treatment	Water Quality	1	LS	$10,000,000	35%	20%	$16,000,000	2											$16,000,000
LMWTP-007	Lake Mooney WTP - Replace membrane cassettes (at 10 years of operation)	Treatment	Maintenance	1	LS	$1,500,000	NA	NA	$1,500,000	1							$1,500,000				TBD
SLWTP-001	Smith Lake WTP - Filter repairs	Treatment	Repair	1	LS	$3,000,000	35%	20%	$4,650,000	1	$465,000	$4,185,000									
SLWTP-002	Smith Lake WTP - Facility upgrades	Treatment	Repair	1	LS	$2,000,000	35%	20%	$3,100,000	2				$310,000	$2,790,000						
SLWTP-003	Smith Lake WTP - Water treatment optimization studies	Treatment	Water Quality	1	LS	$100,000	NA	NA	$100,000	2		$100,000									
SLWTP-004	Smith Lake WTP - Future treament process upgrades	Treatment	Water Quality	1	LS	$5,000,000	35%	20%	$8,000,000	2											$8,000,000
Total FY2019-FY2028 Planning Period (Near-term)									**$11,170,000**		**$535,000**	**$5,415,000**	**$62,000**	**$868,000**	**$2,790,000**	**$0**	**$1,500,000**	**$0**	**$0**	**$0**	
Total FY2019-Buildout Planning Period (Buildout)									**$83,950,000**		**$535,000**	**$5,415,000**	**$62,000**	**$868,000**	**$2,790,000**	**$0**	**$1,500,000**	**$0**	**$0**	**$0**	**$72,780,000**

Legend

1	**Priority 1 - Critical to the current and future operation of the system or needed to serve future projected water demands**
2	**Priority 2 - Necessary to meet basic performance requirements and improve system operation and reliability.**

Stafford County Water and Sewer Master Plan - Wastewater Treatment Improvements

Summary of Costs and Schedule for Recommended CIP Improvements

Project #	Project Name	Type	Reason	Unit	Unit Cost ($)	Construction Contingency Allowance	Construction Contingency Allowance	Eng., Legal and Administrative Allowance (% of Construction w/ Contingency Allowance)	Total Construction Cost in 2017 Dollars	Category
Wastewater Treatment										
AWWTF-001	Aquia WWTF Upgrade - Facilities Planning	Treatment	Reliability, WQ	1	LS	$75,000	NA	NA	$75,000	2
AWWTF-002	Aquia WWTF General Upgrades - Concrete Repair, Headworks, Power Distribution	Treatment	Repair, Reliability	1	LS	$2,250,000	35%	20%	$3,500,000	2
AWWTF-003	Aquia WWTF Solids Handling - Sludge Storage Expansion, Dewatering Unit	Treatment	Capacity	1	LS	$1,600,000	20%	10%	$2,100,000	1
AWWTF-004	Aquia WWTF Nitrification Upgrades (FWNC / NH3 - Allowance)	Treatment	Water Quality	1	LS	$1,000,000	35%	20%	$1,600,000	1
AWWTF-005	Aquia WWTF General Upgrades - Filtration, UV, Controls, Miscellaneous	Treatment	Reliability	1	LS	$2,500,000	35%	20%	$3,900,000	2
AWWTF-006	Aquia WWTF Expansion & Upgrade (Allowance)	Treatment	Capacity	1	LS	$18,000,000	35%	20%	$28,000,000	1
LWWTF-001	Little Falls Run WWTF Upgrade - Facilities Planning	Treatment	Reliability, WQ	1	LS	$125,000	NA	NA	$125,000	2
LWWTF-002	Little Falls Run WWTF General Upgrades - Concrete Repair, Headworks, UV	Treatment	Repair, Reliability	1	LS	$2,500,000	20%	10%	$3,300,000	2
LWWTF-003	Little Falls Run WWTF Denitrification Upgrade	Treatment	Water Quality	1	LS	$2,500,000	25%	15%	$3,500,000	1
LWWTF-004	Little Falls Run WWTF Upgrade (Rappahannock Policy, FWNC / NH3 - Allowance) (No. P.A.)	Treatment	Water Quality	1	LS	$7,500,000	35%	20%	$11,600,000	1
LWWTF-005	Little Falls Run WWTF General Upgrades - Filtration, Miscellaneous	Treatment	Reliability	1	LS	$1,750,000	35%	20%	$2,700,000	2
LWWTF-006	Little Falls Run Expansion & Upgrade (Allowance)	Treatment	Capacity	1	LS	$18,000,000	35%	20%	$28,000,000	1
Total FY2019-FY2028 Planning Period (Near-term)									**$32,400,000**	
Total FY2019-Buildout Planning Period (Buildout)									**$88,400,000**	

Project #	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	Beyond FY2028	Project #
AWWTF-001	$75,000											AWWTF-001
AWWTF-002	$700,000	$1,050,000	$1,750,000									AWWTF-002
AWWTF-003		$210,000	$1,050,000	$840,000								AWWTF-003
AWWTF-004	$160,000	$800,000	$640,000									AWWTF-004
AWWTF-005						$390,000	$1,560,000	$1,560,000	$390,000			AWWTF-005
AWWTF-006											$28,000,000	AWWTF-006
LWWTF-001	$25,000	$62,500	$37,500									LWWTF-001
LWWTF-002	$330,000	$1,650,000	$1,320,000									LWWTF-002
LWWTF-003		$350,000	$1,750,000	$1,400,000								LWWTF-003
LWWTF-004			$1,160,000.0	$3,480,000.0	$3,480,000.0	$3,480,000						LWWTF-004
LWWTF-005						$270,000	$1,080,000	$1,080,000	$270,000			LWWTF-005
LWWTF-006											$28,000,000	LWWTF-006
Total FY2019-FY2028 Planning Period (Near-term)	**$1,290,000**	**$4,122,500**	**$7,707,500**	**$5,720,000**	**$3,480,000**	**$4,140,000**	**$2,640,000**	**$2,640,000**	**$660,000**	**$0**		
Total FY2019-Buildout Planning Period (Buildout)	**$1,290,000**	**$4,122,500**	**$7,707,500**	**$5,720,000**	**$3,480,000**	**$4,140,000**	**$2,640,000**	**$2,640,000**	**$660,000**	**$0**	**$56,000,000**	

NOTE: Current Permit or Pending Regulatory Requirements may limit Aquia WWTF and/or Little Falls Run WWTF to 8-MGD ADF rated capacity, or the degree of feasible Expansion.