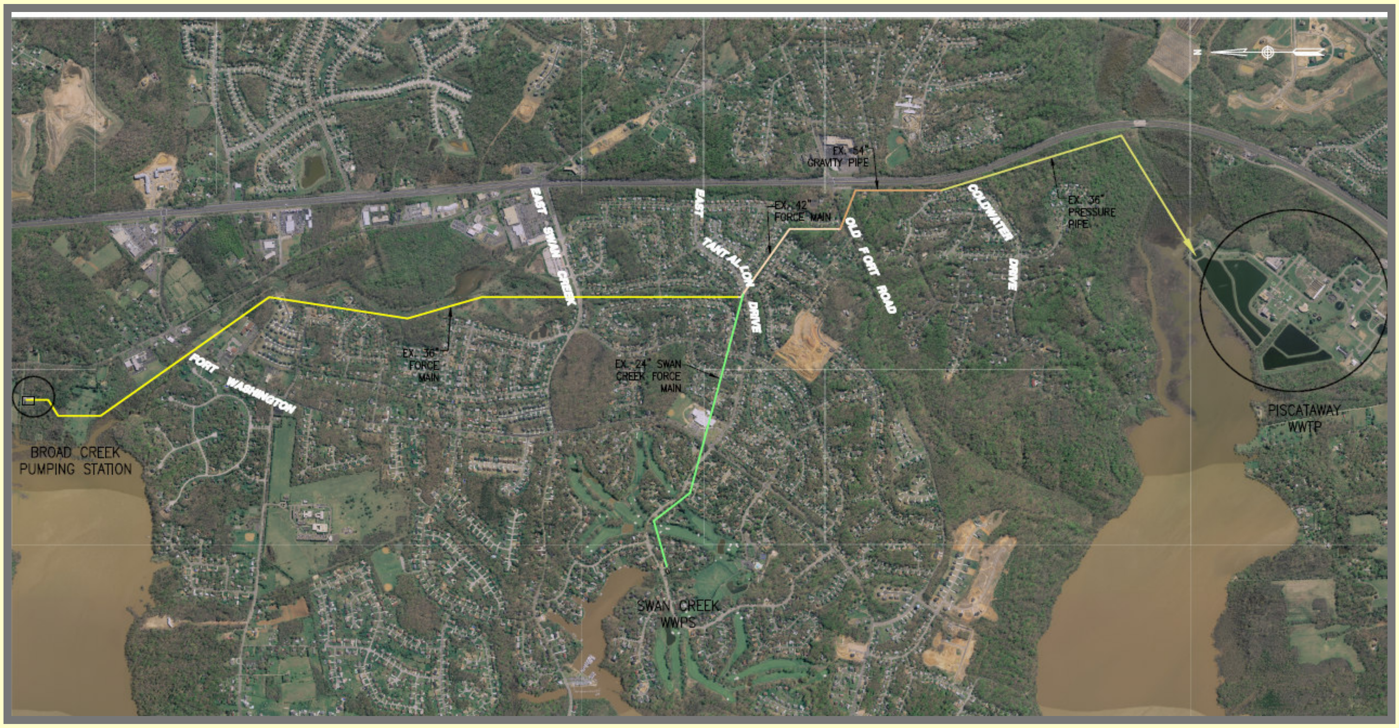
Washington Suburban Sanitary Commission

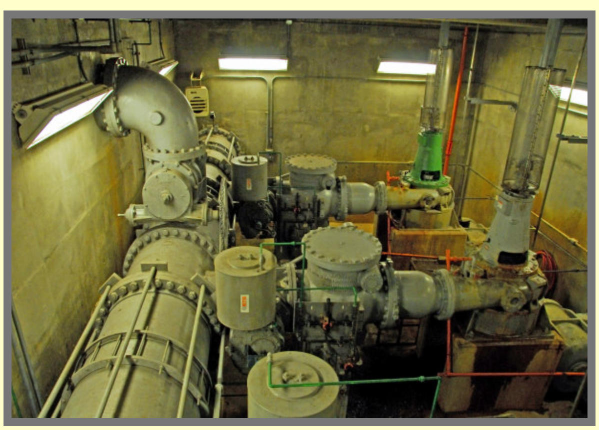
CONVEYANCE SYSTEM CONCEPTUAL REPORT

for the

Broad Creek WWPS Augmentation Project

WSSC Contract CP4231C05





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A Joint Venture

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1.0 INTRODUCTION

The purpose of the Broad Creek Wastewater Pump Station (WWPS) Augmentation Project is to evaluate, recommend, and design the necessary upgrades to the Broad Creek system in order to handle future peak flows and to eliminate sanitary overflows at the Broad Creek WWPS (for wet weather events up to the 10-year WSSC storm). This includes upgrades to the Broad Creek Pump Station, improvements at the Piscataway Wastewater Treatment Plant (WWTP), and a new force main/gravity pipe/pressure sewer to increase the conveyance capacity from the Broad Creek WWPS to the Piscataway WWTP.

This conceptual report will focus on evaluation and recommendations, modifications/upgrade of the following elements:

- Proposed force main sizing, hydraulics, and capacity.
- Alternative operating scenarios under average flow, wet weather flow conditions, and during main shut down.
- Maintenance implications.

Several projects have been conducted previously on the Broad Creek WWPS and sewer shed which presents a comprehensive history of this area. This background information has allowed the Hatch Mott MacDonald/Gannett Fleming Joint Venture (JV) to begin the study, in preparation of design, with a solid knowledge of the infrastructure. The purpose of this project is to evaluate alternatives to identify the optimum program of improvements that would eliminate the sewage overflows from the Broad Creek WWPS. This conceptual report will evaluate the hydraulics of the various alternatives and will outline the proposed conveyance system upgrades along with the associated operations and maintenance requirements. The proposed upgrades to the Broad Creek WWPS and the Piscataway WWTP will be submitted separately.

1.1 Background

The Broad Creek WWPS provides pumping for the collection system in the Broad Creek Basin. The WWPS consists of two buildings; a 3600 square foot (sf) screening building and an 11,200 sf pump station building. Adjacent to the buildings is an electrical equipment yard that consists of transformers, switchgears, and a standby generator facility.

The WWPS was originally built in 1968 with three (3) constant speed pumps and was expanded in 1993 to include an additional three (3) variable frequency drive pumps. The existing electrical service into the WWPS is supplied by two 13 kilovolt feeds supplied by the Pepco Gallahan Road Substation. According to the Broad Creek WWPS Standby Electrical Report (McKissick and

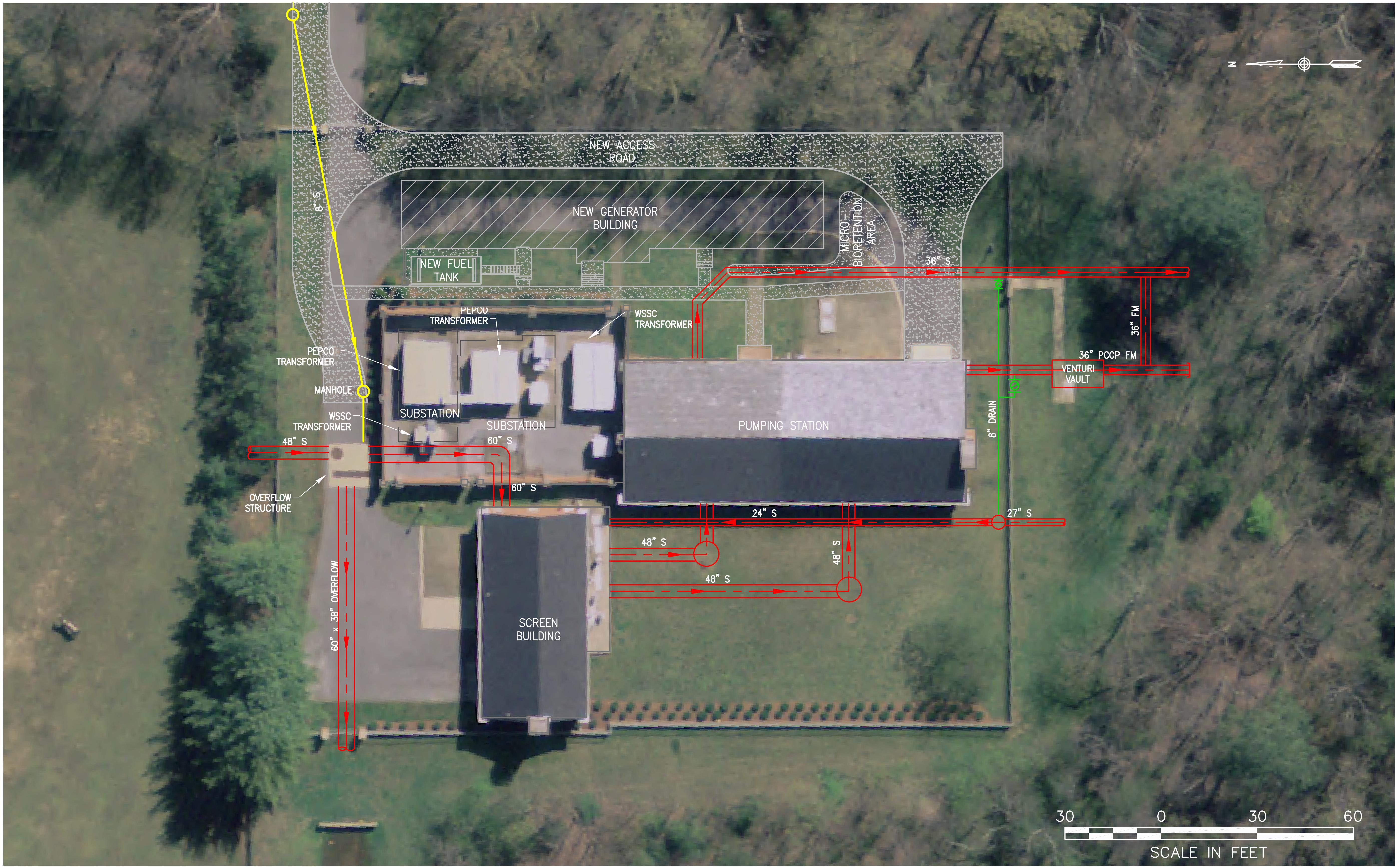
McKissick/Delon Hampton, 2007), the substation is operated so that half the main load is assigned to one feeder, and the other feeder takes the load of the other half of the station. The feeders were developed like this so that there would be some level of electrical redundancy at the WWPS. However there were several instances of power outages at the Pepco substation as well as the feeders. Some of these power outages resulted in overflow events at the WWPS. As a result, in 2007 a WWPS electrical design build package was developed for the purchase and installment of two standby diesel generators. An aerial plan of the WWPS with the existing piping and the proposed improvements associated with the generators can be found on Figure 1.

The Broad Creek WWPS has a current safe theoretical capacity of 38.3 MGD (with 5 pumps operating). Safe capacity is defined as the capacity with the largest pump out of service. The pumps discharge through a 36-inch/42-inch diameter force main, 54-inch gravity sewer, and 36-inch pressure sewer into the adjacent Piscataway Creek Basin for treatment at the Piscataway Wastewater Treatment Plant (WWTP).

The Broad Creek Sanitary Sewer Collection System contains approximately 315 miles of sewer ranging from 6 to 48-inch in diameter. Eighty percent (80%) of the sewers in the basin were built before 1980 and fifty percent (50%) of the sewers were built before 1970. The oldest sewers date back to the 1950s and are located in the farthest portions of Henson Creek (CDM, 2006).

A sewer system evaluation survey (SSES) was conducted as part of the Broad Creek basin investigation. To evaluate the existing sanitary system in different rain event scenarios, in 2006 WSSC contracted CDM to develop a model of the basin and publish a report. This report documented the capacity results with the existing facilities and planned improvements at National Harbor. The Broad Creek Basin InfoWorks model was developed using WSSC GIS information, record drawings, WWPS standard operating procedures reports, and other data sources. Observed flows from January 2003 through December 2005 were used as well as flow projections for the year 2020 which had been developed from the Metropolitan Washington Council for Governments. The capacity of the modeled portions of the network was analyzed for the peak flows generated by 2-year and 10-year design storms.

The Facility Plan prepared by McKissick and McKissick/Delon Hampton Joint Venture (2007) looked at the extent of the overflow problem for the existing and future wet weather conditions and developed recommended solutions to prevent sewage overflows at the Broad Creek WWPS. The Facility Plan recommended increasing the capacity of the WWPS to 55 MGD.



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Broad Creek WWPS Augmentation Project
Contract No. CP4231C05

FIGURE 1: EXISTING BROAD CREEK WWPS

The CDM sewer model was modified in 2008 to incorporate the recommendations from the Facility Plan. A large part of this modification was to extend the model to include the 54-inch gravity sewer and the 36-inch pressure sewer downstream from the Broad Creek WWPS force main leading to the Piscataway WWTP. These improvements and modifications were documented as a report addendum to the Broad Creek Basin Model Results with proposed Broad Creek WWPS Facilities Plan Improvements (CDM, 2008).

In addition, another modeling study is currently underway by CDM which reduces the Broad Creek Sewer network by eliminating sewers less than 15-inch in diameter, unless the smaller diameter pipe was downstream of a 15-inch or larger pipe. CDM believed that the previous model may have inaccurately simulated overflows in some small diameter (less than 15 inches) sewers which then inaccurately reduces the flow reaching Broad Creek WWPS. By removing the smaller diameter pipelines from the model the simulated overflows are eliminated and the peak flows are transmitted through the larger sewers. These results in a more realistic assessment of the flow in a draft of the modeling report and its corresponding results (published in May 2009).

1.2 Existing Conveyance System

1.2.1 Overview

The existing conveying system consists of a 36-inch force main, a 42-inch force main, a 54-inch gravity sewer, and a 36-inch pressure sewer. Currently, the majority of the flow enters the conveyance system at the Broad Creek Pumping Station; however there are additional sewer connections between the WWPS and the Piscataway WWTP. One of the connections is a 24-inch force main from the Swan Creek Pump Station which is connected to the conveyance system at the transition from the 36-inch to the 42-inch force main. The Swan Creek force main has a maximum flow of 6.8 MGD.

In addition to Swan Creek, there are two small gravity sewers connected to the 54-inch gravity sewer. The JV is still acquiring details of those flows because they were not accounted for in the CDM model. However, WSSC has informed the JV that 1.2 MGD is an appropriate flow to use in calculations and model simulations.

1.2.2 Force Main

Because of a lack of redundancy, WSSC has never been able to shut down the existing 36-inch force main for inspection. The new force main will allow WSSC the needed flexibility to isolate the existing pipeline and complete a thorough inspection. WSSC could then conduct any necessary repairs to the 36-inch pipeline.

As previously stated, the force main increases in size from 36-inch to 42-inch diameter after the connection of the 24-inch force main from Swan Creek WWPS. The 42-inch force main conveys wastewater from both pump station to the junction structure.

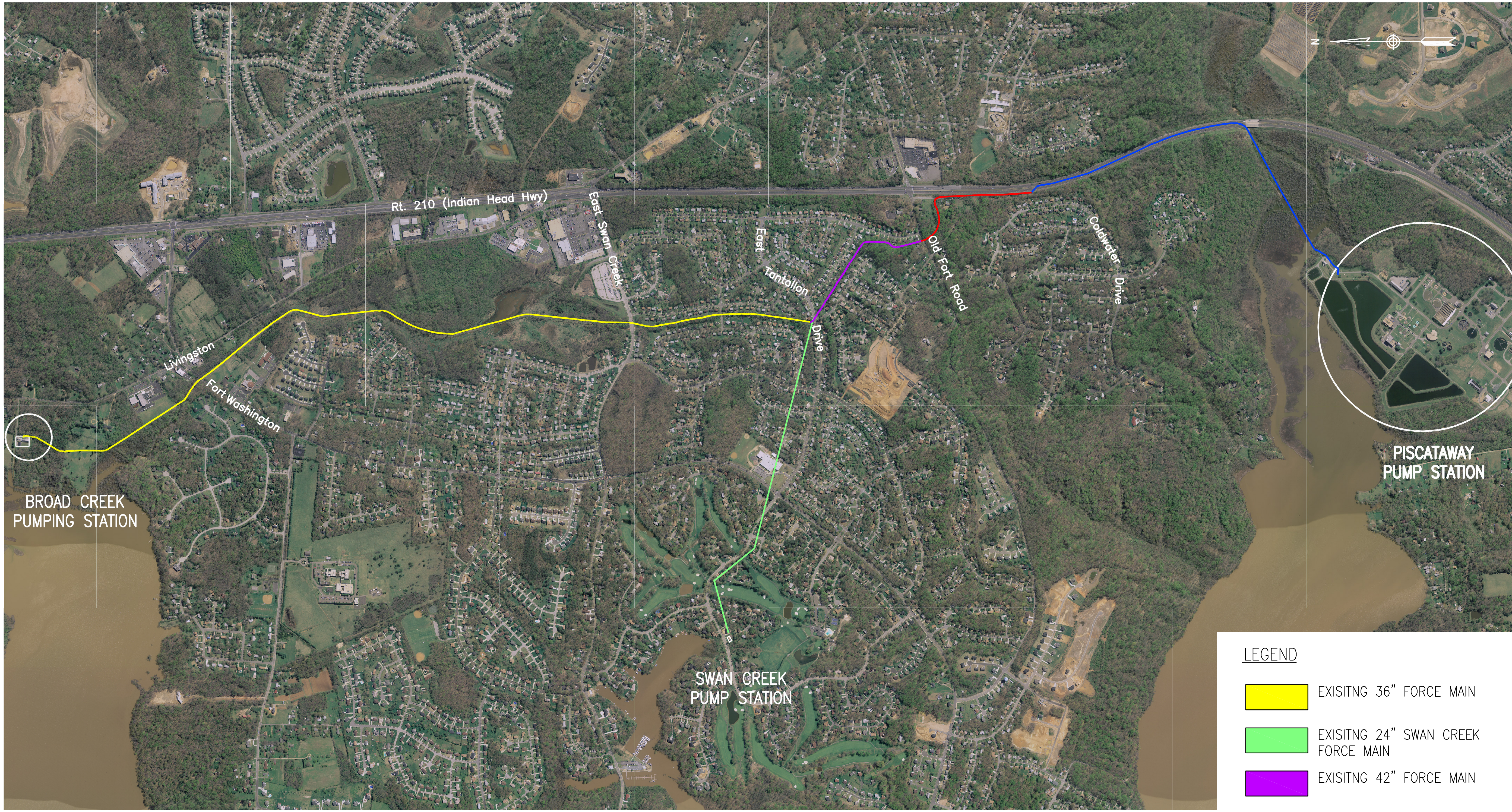

FIGURE 2: EXISTING BROAD CREEK CONVEYANCE SYSTEM

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1.2.3 54-inch Gravity Sewer

Approximately 2,300 feet of the 54-inch gravity sewer was investigated. Investigations in December 2006 and March 2007 were performed by RedZone Robotics and included full CCTV and partial laser investigation. The investigation documented that portions of the pipe had experienced some loss of internal diameter and several sections that have experienced significant, localized attack (2+ inches of pipe loss). The CCTV investigation documented two locations where surface reinforcement was visible (71 feet and 625 feet downstream of MH 3M. Based on comments from WSSC, it is understood that the entire length of the 54-inch gravity pipe was constructed with a 3-inch sacrificial coating. It is recommended that available drawings and specification sheets from the pipe manufacturer be reviewed, particularly in respect to the two locations with exposed reinforcement.

1.2.4 36-inch Pressure Sewer

Approximately 960 feet of the lined 36-inch pressure sewer (immediately downstream of the transition from 54-inch gravity sewer) was investigated by RedZone Robotics in March 2007. In June/July 2008 a follow-up effort by RedZone Robotics investigated 3,268 feet downstream of the 36-inch line (starting from the 54-inch transition). Both investigations noted several problems including liner failures and blisters and groundwater infiltration. The condition of the host pipe in the area of the noted failures is unknown. Similar to the 54-inch gravity pipeline, WSSC reports that the 36-inch pressure sewer was constructed with a 3-inch sacrificial concrete lining. Based on the findings of the investigation and the construction of the pipe, there does not appear to be any immediate areas of concern for this portion of the line. However, due to the potential for accumulated debris, the pipe should be inspected and cleaned as soon as possible.

1.3 Force Main Design Criteria

The goal of the force main project is to increase the existing Broad Creek WWPS capacity so that it can pump a peak flow of at least 55 MGD with five of its six pumps operating. This will be accomplished by providing a new larger diameter force main thus reducing the total dynamic head (TDH) on the existing pumps and essentially shifting the system curve to the right. It is anticipated that the new force main will discharge to a gravity sewer near the location where the existing force main does. Thus the static head (elevation head) on the existing pumps will not be changed. However, by increasing the diameter of the force main, the friction head can be greatly reduced. Because pipe material selection is influenced by installation method, materials will be discussed in the Alignment Study Report. For this conceptual study, the use of nominal pipe diameters and conservative "C" factors are sufficiently accurate.

1.3.1 Capacity

The 2007 Facility Plan document for the Broad Creek WWPS recommended that the safe pumping capacity be increased from approximately 38 MGD to a minimum of 55 MGD. Safe pumping capacity is defined as the pumping capacity with the largest pumping unit out of service; in this case, it means with five out of the six pumps operating. The 55 MGD capacity is based on the maximum flow that the existing gravity sewer system can convey to the Broad Creek pumping station under a 10-year WSSC storm event. According to the hydraulic model of the Broad Creek conveyance system, there are currently hydraulic restrictions upstream of the WWPS. If the current hydraulic restrictions are removed by constructing a parallel relief sewer, the future volume of flow to the WWPS could exceed 55 MGD. It makes sense to construct a force main that will increase the capacity of the WWPS to the greatest extent practice, using the existing pumps and motors. A capacity in the range of 55 MGD to 60 MGD is considered feasible.

1.3.2 Velocity

WSSC has stated that flow velocities in the force main of 2.0 to 6.0 feet per second (ft/sec) are desirable. Two feet per second is generally accepted as the minimum velocity necessary to prevent the deposition of solids in raw sewage. Velocities in excess of 6.0 ft/sec have high head loss, and could cause pipe wall erosion, depending on pipe material and lining. Flow velocities of the existing force main at varying flow rates are shown in Table 1.

Table 1: Flow Velocities (Ft/Sec) for Existing Force Main

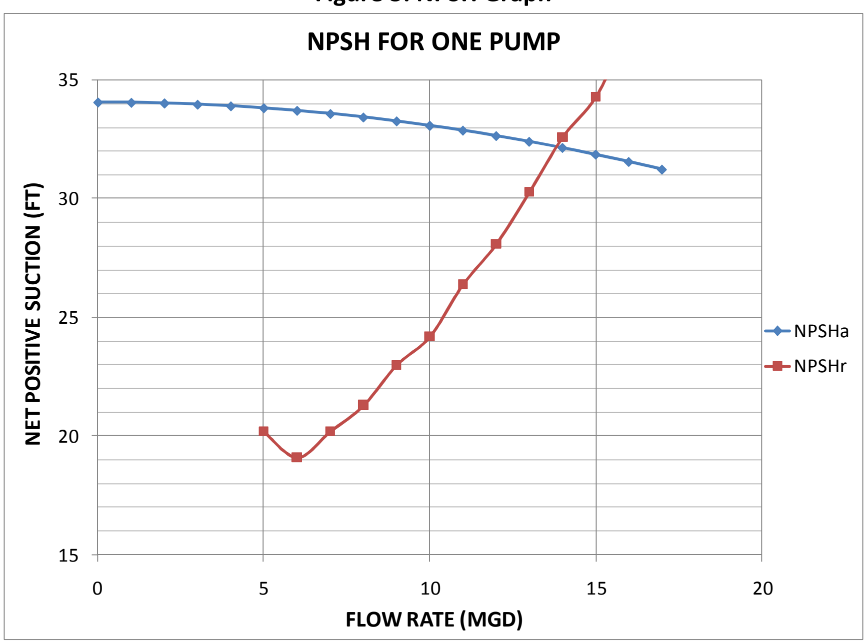
FLOW DESCRIPTION	FLOW (MGD)	Velocities in 36-inch (ft/sec)
Average 2009	10.3	2.25
Average 2020	11.44	2.50
One Pump Running, 36-inch FM	15	3.28
Two Pumps Running, 36-inch FM	26	5.69
Peak 2009	38.3	8.38
Design 2020	55	12.04
Future	60	13.13
Future	70	15.32

Currently, the Broad Creek WWPS has a variable speed pump as the lead pump and a constant speed pump as the first lag pump. During a typical dry-weather day, two pumps would typically run for at least a short time during high-use periods (such as 6:00 am to 9:00 am) and all pumps would probably shut down for at least a short time during low-use periods (such as 1:00 am to 5:00 am). The actual pump on/off cycles would depend on the specific diurnal patterns for the sewer service area. This means that there will typically be times when there is no flow in the force main so solids begin to settle. At other times during the day, the flow may be twice the average rate or more so solids could be re-suspended. It generally takes a velocity of 3.0 to 3.5 ft/sec to re-suspend solids (WSSC Pipeline Design Manual, 2008). It must be taken into account that although the sewage is screened at the Broad Creek WWPS prior to pumping, solids, especially grit, will still be present in the wastewater and will still settle out at low velocities.

1.3.3 Net Positive Suction Head

In order for centrifugal pumps to operate satisfactorily without cavitation, the NPSH available (NPSHa) must be greater than the NPSH required (NPSHr). NPSHa is the sum of the atmospheric pressure plus the static head of the water level in the wetwell above the centerline of the pump impeller minus the friction losses in the pump intake fittings and the vapor pressure of water. Making conservative assumptions of these parameters results in a range of NPSHa values from 34.06 feet at 0.0 MGD to 31.55 feet at 16 MGD, as shown in Figure 3. The NPSHr is determined by the pump manufacturer and is also shown in Figure 3. This analysis illustrates that the pumps will function without cavitation at flow rates (per pump) of 14 MGD or less. At flows above 14 MGD, cavitation could occur. The total flow of the WWPS could not exceed 70 MGD with five pumps running (5 x 14 MGD) or 84 MGD with six pumps running (6 x 14 MGD), if NPSH is the limiting factor.

Figure 3: NPSH Graph



2.0 CONVEYANCE SYSTEM ALTERNATIVES

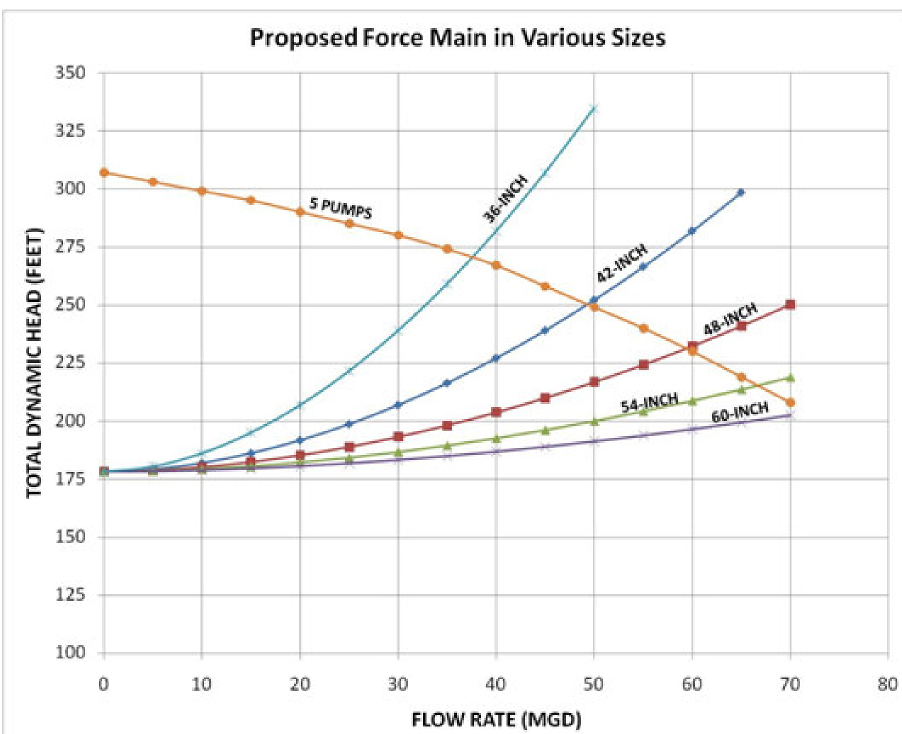
2.1 Capacity

The key to successful conveyance system upgrades is an accurate and thorough hydraulics analysis. As shown in Table 2, in order to meet the minimum design flow of 55 MGD, a new 48-inch force main, 60-inch gravity sewer, and 42-inch pressure sewer would have to be constructed.

Table 2: Alternatives for Conveyance System Pipeline Sizing

SUMMARY OF ALTERNATIVES FOR FORCE MAIN CAPACITY		CAPACITY IN MGD	VELOCITY IN FT/SEC
FM-1	Existing 36-inch force main	38.3	8.4
FM-2	New 42-inch force main	49.5	8.0
FM-3	New 48-inch force main	59.5	7.3
SUMMARY OF ALTERNATIVES FOR GRAVITY SEWER CAPACITY (DOWNSTREAM OF FORCE MAIN)		**CAPACITY IN MGD**	**VELOCITY IN FT/SEC**
GS-1	Existing 54-inch gravity sewer	54	5.3
GS-2	New 60-inch gravity sewer	71.6	5.6
SUMMARY OF ALTERNATIVES FOR PRESSURE SEWER CAPACITY (DOWNSTREAM OF FORCE MAIN AND GRAVITY SEWER)		**CAPACITY IN MGD**	**VELOCITY IN FT/SEC**
PS-1	Existing 36-inch pressure sewer	47.7	10.4
PS-2	New 42-inch pressure sewer	85.9	13.8

Figure 4: Proposed Force Main in Various Sizes



2.1.1 Maximum Pumping Capacity of the Force Main

It is important to look at the "maximum" pumping capacity in addition to the "safe" pumping capacity and to understand the differences between the two. The Consent Order for this project requires that the Broad Creek WWPS have a "safe" capacity of 55.0 MGD. Regulatory agencies define safe pumping capacity as the capacity which the WWPS can discharge with its largest pump out of service, while operating under "worst case" static head conditions. A new 48-inch force main, operating independently, would allow the Broad Creek WWPS to meet this criterion. However, it would be possible under emergency conditions to operate the new 48-inch force main in parallel with the existing 36-inch force main with all six pumps running (assume VFDs at 100 percent of full speed). Assuming 6.8 MGD for Swan Creek (its maximum capacity), the Broad Creek WWPS will discharge approximately 78 MGD. This is shown in the pump and system curves in Figure 5 and Table 3.

Figure 5: Parallel Force Mains

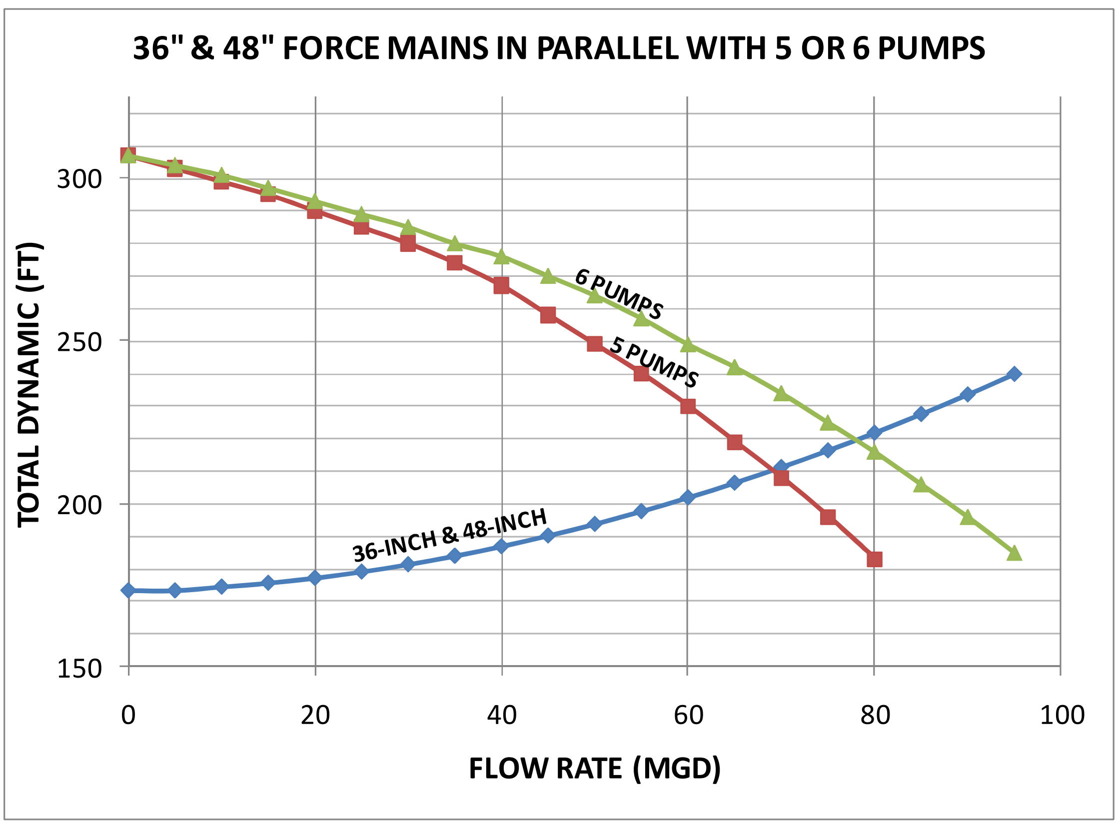


Table 3: Broad Creek WWPS Capacity Under Various Conditions

Flow Condition	From Swan Creek PS (MGD)	Broad Creek PS Capacity (MGD)
“Safe Capacity”, new 48” FM only, 5 pumps, includes Swan Creek	6.8	59.5
New 48” FM only, 5 pumps, without Swan Creek	0	61
New 48” FM only, 6 pumps, includes Swan Creek	6.8	66
New 48” FM only, 6 pumps, without Swan Creek	0	67
48” & 36-inch FMs in parallel, 5 pumps, includes Swan Creek	6.8	69
“Maximum Capacity”, 48” & 36-inch FMs in parallel, 6 pumps, includes Swan Creek	6.8	78

At the maximum capacity, each pump would discharge 13 MGD at approximately 219-feet of head, drawing 616 horsepower.

The flow from the Swan Creek pump station has been included in the Piscataway hydraulic model. The Swan Creek pump station normally contributes less than 0.5 MGD in dry weather, but could contribute up to 6.8 MGD in wet weather. The TDH of the proposed 48-inch pipe would increase only slightly with this additional flow of 6.8 MGD. The 48-inch pipe would still be adequate to handle the Broad Creek WWPS required flow of 55 MGD and the 6.8 MGD from Swan Creek. SewerCAD hydraulic modeling was performed with results closely matching Table 3. Refer to Appendix A. SewerCAD uses the Manning equation with n=0.013, whereas the calculations in Table 3 used the Hazen-Williams equation with C=120. An extension of the 24-inch Swan Creek force main may be required in order to connect it to the Broad Creek force main.

2.1.2 Capacity of the Gravity Sewer

The existing force main discharges to a transition structure at the high point of the conveyance system. The transition structure then discharges to a 54-inch gravity sewer, while keeping the force main full so that no air enters the force main. The existing gravity sewer has a capacity (flowing full) of 54.0 MGD. The required capacity is 63 MGD (55 from Broad Creek WWPS, 6.8 MGD from Swan Creek WWPS, and 1.2 MGD allowance for gravity sewers connected directly). A comparison of possible sizes for the gravity sewer and capacities is shown in Table 4.

Table 4: Gravity Sewer Capacity at Various Pipe Diameters

Diameter (inch)	Slope (Percent)	Capacity Full (MGD)	Capacity 2/3 Full (MGD)	Velocity Full (ft/sec)	Velocity 2/3 Full (ft/sec)
36	0.18	18.3	14.3	4.0	4.5
42	0.18	27.6	21.6	4.4	4.9
48	0.18	39.5	30.8	4.9	5.4
54	0.18	54.0	42.2	5.3	5.8
60	0.18	71.6	55.8	5.6	6.3
66	0.18	92.3	72.0	6.0	6.7
72	0.18	116.4	90.8	6.4	7.1

*Assumes Manning's "n" value = 0.013 and slope is the same as the existing 54-inch gravity sewer.

A 60-inch pipe installed at the same slope as the existing 54-inch pipe would have a capacity of 71.6 MGD flowing full, and would be only 2/3 full at 55 MGD. At a flow rate of 11.0 MGD (single pump at Broad Creek WWPS), the depth of flow in the 60-inch pipe would be 16 inches, and the velocity would be 4.1 ft/sec. Both the depth of flow and velocity are well within acceptable limits.

With the depth varying from 16-inches at average flow to 40-inches at 55 MGD, the alternating wet/dry conditions of the pipe walls would lead to corrosive attack. This is especially true being downstream of a 15,000 linear foot force main which could cause septic conditions. Therefore, selection of the appropriate pipe material is important to the longevity of this section of pipeline. Likewise, manholes would require corrosion protection, such as lining.

The existing 54-inch gravity sewer should remain in service. If the appropriate valving is installed, then either sewer could occasionally be taken off-line for inspection and cleaning.

2.1.3 Capacity of the Pressure Sewer

The existing 36-inch pressure sewer connects to the downstream end of the 54-inch gravity sewer at a transition manhole. It conveys sewage down a steep slope along Route 210, along a mild slope in the Piscataway Creek valley, and subaqueous crossing of Piscataway Creek, to the wastewater treatment plant. The invert elevation at the transition manhole is 156.0, the creek crossing is well below elevation 0.0 and the WWTP connection is approximately at elevation 64.75. The pressure sewer, over 7,000 linear feet in length, acts as a large inverted siphon with a net head difference of 91.25 feet.

The required capacity of the pressure sewer is 63.0 MGD; the same as the gravity sewer. The estimated capacity of the existing 36-inch pressure sewer (with C = 100) is 47.7 MGD. This assumes that the pipe is allowed to "back up" all the way to the transition manhole, which is not desirable. We have been informed a portion of the existing line reduces to 30-inch diameter. This has not been included in the calculations because the length of the constriction is unknown; however, it would further reduce the pipe's capacity. If debris, grease deposits, or pieces of lining (from previous rehabilitation) are partially obstructing flow, capacity would be greatly reduced from the calculated flow.

A replacement 42-inch pressure sewer would have a capacity (with C = 120) of 85.9 MGD. Again, this assumes that the pipe is allowed to "back up" all the way to the transition manhole, which is not desirable. At the design capacity of 63.0 MGD, the proposed 42-inch pressure sewer would have 51.4 feet of friction loss, so the "back-up" would be approximately 40 feet lower in elevation than the invert of the transition manhole. The flow velocity at 63.0 MGD would be 10.1 ft/sec; at average flow conditions of 15 MGD, the velocity would be 2.41 ft/sec. Both are within reasonable limits.

While the pressure sewer is in service, the "back-up" of sewage will vary up to 51.4 vertical feet, creating a zone of alternating wet/dry conditions. The alternating wet/dry condition will lead to corrosive attack of the pipe wall, especially if the sewage is already septic. Again, pipe material selection is important to resist this attack and degradation. If ductile iron pipe is used, it should be glass-lined or ceramic-epoxy-lined. Because pipe material selection is influenced by installation method, materials will be discussed in the alignment study.

The J-shaped vertical profile of the pressure sewer traps liquid. While in service, solids will be transported by the flow velocity. Once the pipe is shut down, solids will begin to settle to the low spot and sewage will begin to become septic. Two strategies may help to prevent these problems. First, a drainage connection could be constructed on the WWTP site (perhaps draining to the raw influent pump station wetwell) that could be as low as elevation -8.15. This might allow draining nearly all of the pressure sewer contents. If a blowoff could be constructed at the low point, then the remaining contents of the pressure sewer could be pumped out.

Second, the pressure sewer could be flushed with clean water, sending the sewage to the treatment plant and replacing the trapped liquid with a harmless substitute. The treatment plant would have plenty of treated effluent suitable for this purpose; however the logistics of pumping the effluent to the upstream end of the pressure sewer would be daunting. Potable water could be used from fire hydrants along Route 210 (with suitable backflow preventers); however the flow rates would have to be kept low to avoid overtaxing the potable water system. The required quantity of water for 5,000 linear feet of 42-inch pipe would be approximately 360,000 gallons (equal to a fire hydrant flowing at 1,500 gpm for 4 hours; producing a velocity in the 42-inch pressure sewer of 0.35 ft/sec).

A combination of the two strategies might be feasible: drain as much sewage as possible first, then flush with clean water and drain again. Hydro-jetting and cleaning "pigs" should also be considered. Draining the pressure sewer should be performed any time it will be out of service for more than 24 hours.

2.2 Velocities

As described in the design criteria section, the velocity of the force main should remain between 2 and 6 ft/s. Table 5 illustrates the projected velocities in various size force mains at different flows.

Table 5: Flow Velocities (Ft/Sec) for Various Pipe Diameters

FLOW DESCRIPTION	FLOW (MGD)	Velocities in 36-inch (ft/sec)	Velocities in 42-inch (ft/sec)	Velocities in 48-inch (ft/sec)
Average 2009	10.3	2.25	1.66	1.27
Average 2020	11.44	2.50	1.84	1.41
One Pump Running, 36-inch FM	15	3.28	2.41	1.85
Two Pumps Running, 36-inch FM	26	5.69	4.18	3.20
Peak 2009	38.3	8.38	6.16	4.72
Design 2020	55	12.04	8.84	6.77
Future	60	13.13	9.65	7.39
Future	70	15.32	11.26	8.62

As shown in Table 5, the existing 36-inch force main has adequate velocities at 2009 average and 2020 average flows; at a peak flow of 38.3 MGD, the velocity is excessive and head losses are high. A 48-inch pipe would provide reasonable velocities under higher flow conditions, but at average flow rates, the velocity would fall below the target of 2.0 ft/sec. Flushing may be required, as discussed later in this report.

2.3 Headloss

In addition to overcoming the static head (elevation change) of the force main, the pump station must also overcome the friction head in the pipeline. Headloss due to friction increases at the 1.85 power of velocity:

$$h_f = k \times V^{1.85}$$

Where: h_f is headloss due to friction

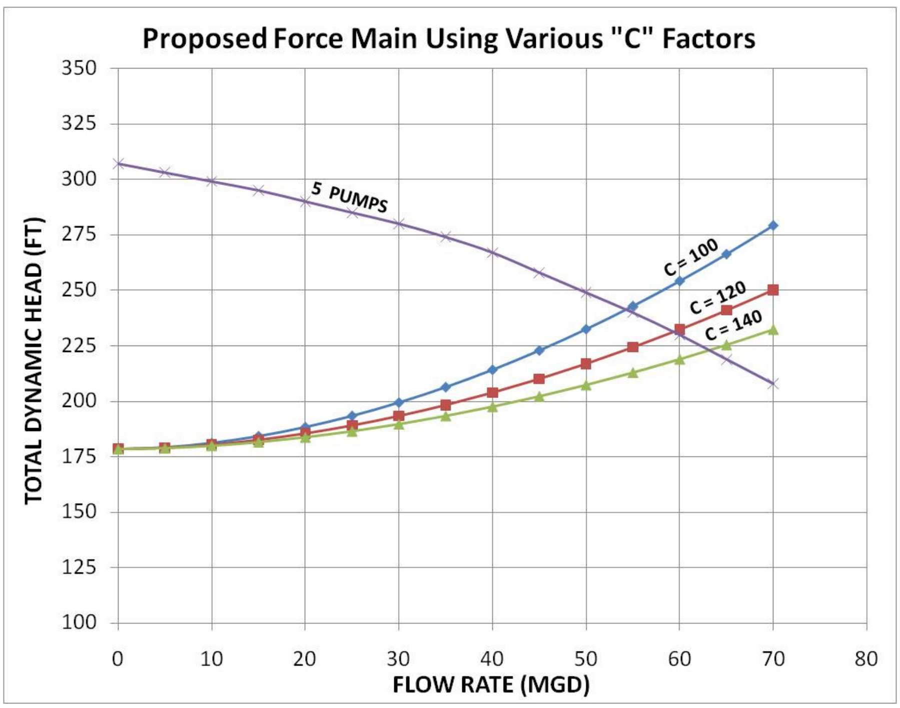
k is a constant that depends on pipe size and roughness

V is velocity

Thus, as velocity increases, headloss greatly increases. It is desirable, therefore, to keep velocities as low as possible while still keeping solids in suspension. The capacity of the Broad Creek WWPS is currently limited to 38.3 MGD by the friction headloss in the 36-inch force main. Constructing a larger diameter force main will lower the velocities and greatly lower the friction headloss, allowing the existing pumps to discharge 55 MGD or more.

The Hazen-Williams friction coefficient "C" represents the relative roughness of the inside of a pipe. Most pipe materials can provide a C factor of 140 when new. A C factor of 120 is typical for a pipe that has been in service for many years, but is still in good condition. A C factor of 100 indicates an older pipe in fair-to-poor condition. Hydraulic calculations for this project have been checked at C=100, C=120, and C=140. This is illustrated in Figure 6.

Figure 6: Proposed Force Main using various "C" Factors



The Hazen-Williams "C" factor has a dramatic effect on the computed capacity of a pipeline. A C factor of 120 has been used throughout the hydraulic calculations to best represent the roughness of a pipe after many years of service, but still in good condition. For comparison, the system curves have been recalculated using C=100 (to represent old pipe in fair-to-poor condition) and C=140 (to represent new pipe in excellent condition). The capacity of the proposed 48-inch force main with five pumps running would be as shown in Table 6.

Table 6: Capacity with Different "C" Factors

HAZEN-WILLIAMS "C" FACTOR	TO REPRESENT PIPE CONDITION	CAPACITY WITH 5 PUMPS OPERATING
100	Old pipe in fair-to-poor condition	54.3 MGD
120	Pipe in service for many years but still in good condition	59.5 MGD
140	Brand new pipe	63.1 MGD

Note that the calculated flow rate for C=100 falls below the 55 MGD required for this project. If the new 48-inch pipe were to deteriorate to the point where its effective C Factor dropped to 100, pipeline cleaning and/or lining would be warranted.

2.4 Hydraulics

As part of the 1993 improvements to the Broad Creek WWPS, provisions were made for a future 42-inch force main to replace the existing 36-inch force main (the force mains would not operate in parallel). According to the pump and system curves on the 1997 record drawings by Burns and McDonnell, the 2000 peak capacity was 37.0 MGD with the 36-inch force main alone, and the 2015 peak capacity would be 49.2 MGD using a proposed 42-inch force main alone. The 42-inch force main would not be adequate to convey the 55 MGD required in the current design criteria.

Figure 5 illustrates the pump curve for five existing pumps operating in parallel. These curves were developed assuming zero flow from the Swan Creek pump station. The results for the 36-inch and 42-inch force mains closely match the capacities stated by Burns and McDonnell: 37.5 MGD for the 36-inch force main; 49.5 MGD for the 42-inch force main. In order to provide the required 55 MGD capacity, a force main 48-inch diameter or larger would be required. As shown, a 48-inch force main could convey 59.5 MGD. The 54-inch and 60-inch force mains would cause low velocities and could cause the pumps to run-out too far on the right-hand side of the pump curve. Thus a 48-inch force main would meet the requirements.

Based on using a 48-inch force main, the operation of one, two, three, and four pumps was investigated. As shown in Figure 7, operation of three, four, or five pumps would be satisfactory; the pumps would operate within the range indicated on the pump curves provided by the manufacturer. Operation of two pumps would be marginal, and operation of one pump would be unsatisfactory. The solution is to use the lead pump's variable frequency drive (VFD) to decrease the pump speed to the range of 80 to 90 percent of full speed. As shown in Figure 8, the 80 to 90 percent speed range is well within the pumps operating limits. At 80 percent of full speed, the pump would discharge 5.0 MGD. At 90 percent of full speed, the pump would discharge 11.44 MGD (equal to the 2020 average daily flow). Note that the pump curve representing 70 percent of full speed does not intersect the system curve which means at 70 percent of full speed, the pump would not be able to overcome the static head of the system, so the flow rate would be zero.

Figure 7: 48-Inch Force Main with Six Pumps and Swan Creek

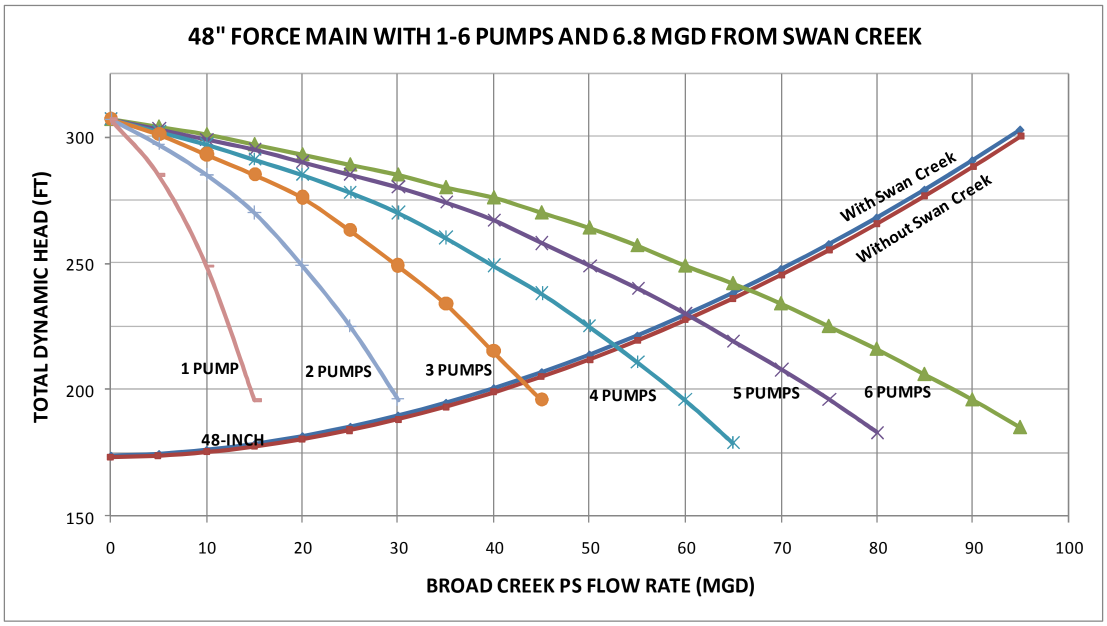
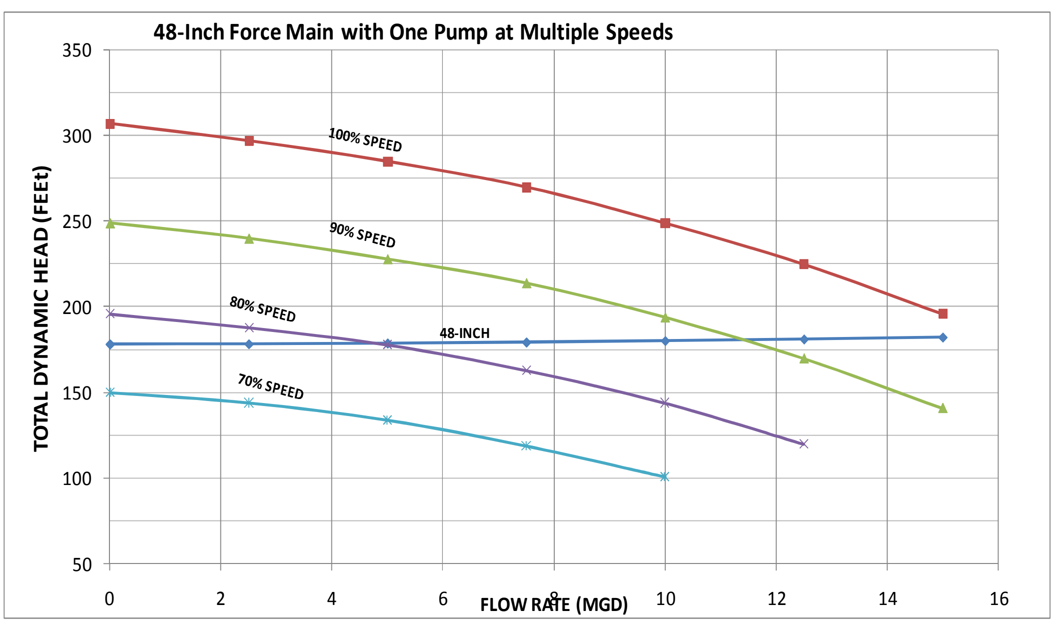


Figure 8: One Pump at Multiple Speeds

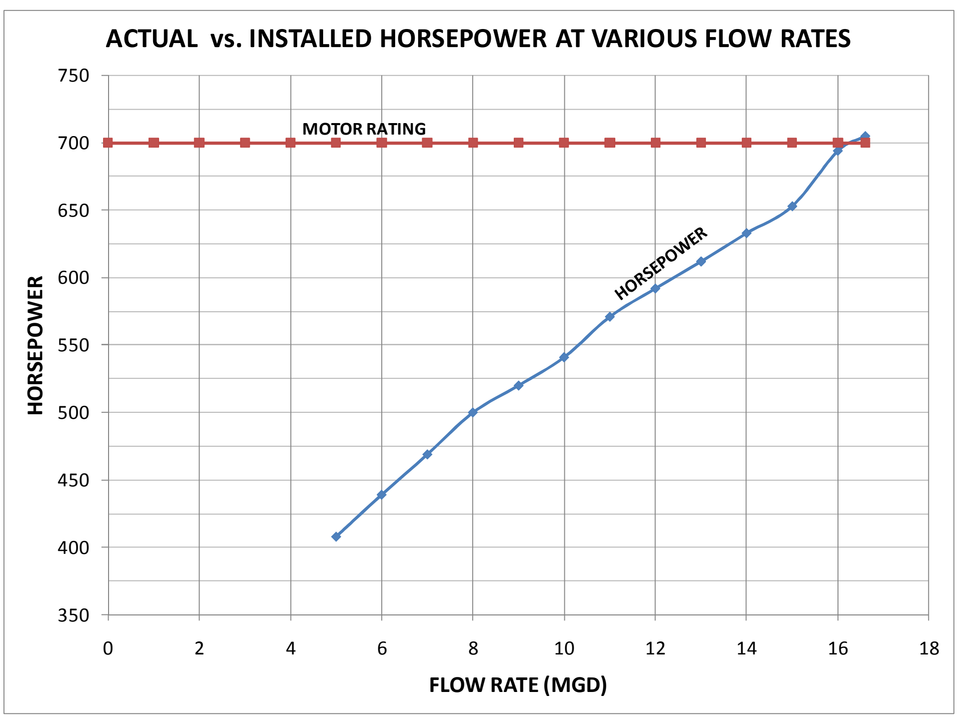


2.5 Electrical Requirements

The Broad Creek WWPS upgrade plans (as-built 1997) show a future 42-inch force main and future system curve. The existing pumps were selected so they could operate at a lower TDH without operating outside the limits of their pump curve. Note that as the operating point shifts to the right on the pump curve, the brake horsepower increases. From an analysis of the manufacturer's pump curves, it appears that the existing 700 horsepower motors will be adequate for the future operating point. The maximum horsepower "anywhere" on the curve is 705, although the horsepower at the actual operating point will be significantly less. All six existing motors are open-drip-proof (ODP) and have 1.15 service factors. The three constant speed motors should therefore be theoretically capable of handling 805 HP (momentarily) without damage. Three of the motors are equipped with variable frequency drives (VFDs) which could be damaged if the nominal 700 horsepower is exceeded.

In the range of pump operating points identified in this report, the actual brake horsepower required by any one of the existing pumps would not exceed 633 hp (at 14 MGD), which is well below the nominal horsepower rating of the motors and VFDs of 700 hp. Refer to Figure 9. The only time that the 700 hp would be (theoretically) exceeded would be at a flow of 16.6 MGD, where the "maximum power anywhere on the curve" would be 705 hp. Provided that "soft start" technology is used to start each of the pumps, this maximum point should never be reached.

Figure 9: Actual vs. Installed Horsepower at Various Flow Rates



2.6 Possible Interconnections

Interconnections will be a very important aspect of pipeline design. There are several areas in which interconnections will supply the system with needed operational flexibility to switch back and forth from the old conveyance system to the new conveyance system, as well as the ability to isolate sections of the pipeline for needed inspection and maintenance. Details of all of the interconnections will be described in the upcoming Force Main Alignment Report.

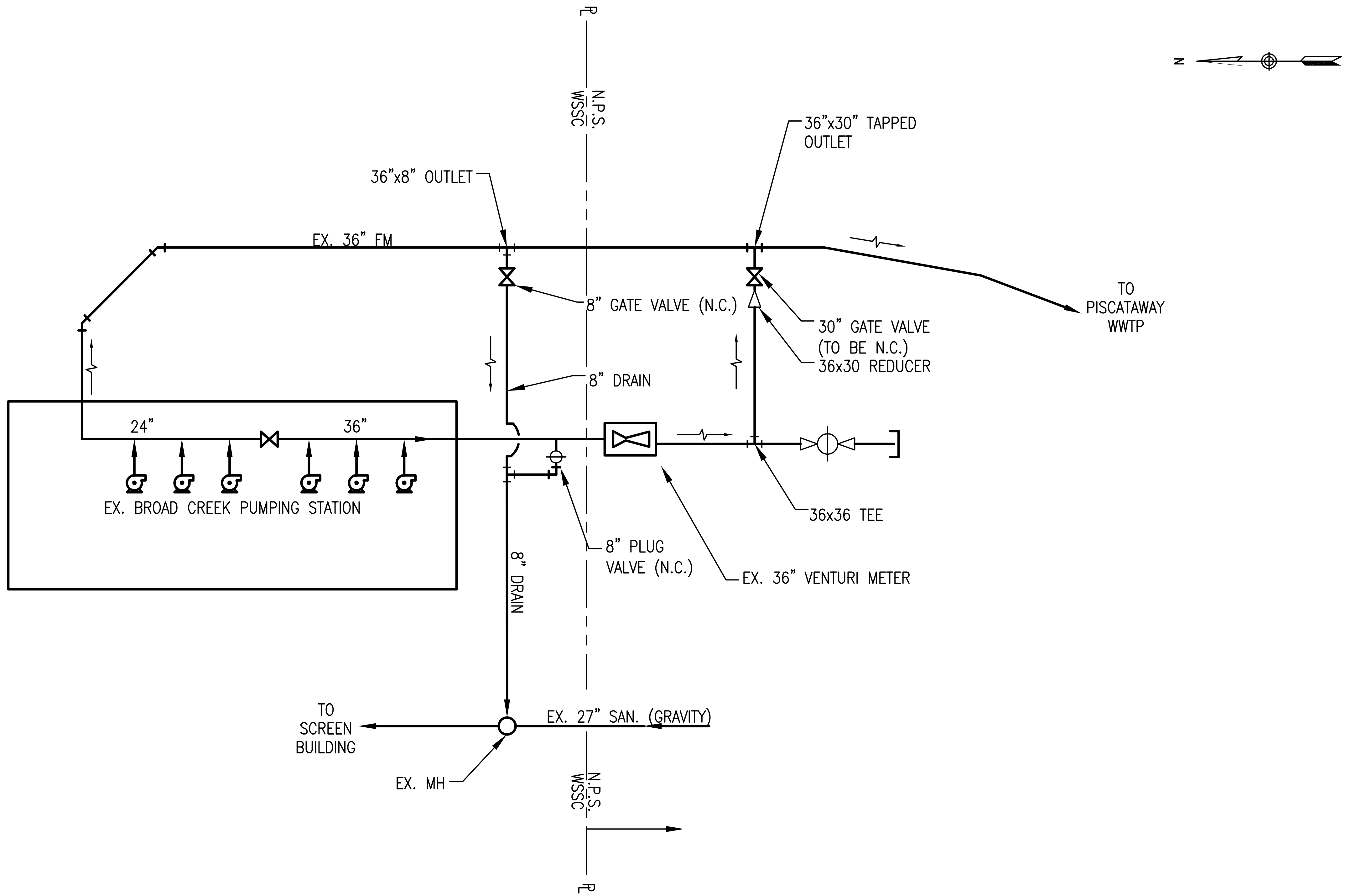
There are two fundamental interconnections that are necessary in order to design a new stand alone conveyance system. The first is at the Broad Creek WWPS. Currently, the WWPS is operated such that six pumps discharge to a common header which exits the building and proceeds through a venturi meter and through the 36-inch force main. As seen in Figure 10, there is also a second discharge available from the building which currently acts as a meter bypass.

Currently, the JV is investigating the possibility of replacing the existing 24-inch header with either a 36-inch or adding a 24-inch parallel header in order for both WWPS discharges to be used simultaneously, thereby reducing the headloss in the force main. By reducing the headloss, the WWPS capacity can be maximized.

Initial conversations with the National Parks Service (NPS) indicated that construction will not be allowed on their property south of the station; therefore the proposed force main will need to follow the existing station entrance road out to Livingston Road. The proposed arrangement is shown in Figure 11.

The second location where interconnections and valving are especially important is the junction of the 24-inch Swan Creek force main with the Broad Creek force main. A new interconnection must be made with the proposed 48-inch force main as well as maintain the connection with the existing force main.

Because it is unlikely that the proposed alignment will parallel the existing pipeline, the Swan Creek force main may need to be extended in order to connect to the proposed Broad Creek force main. A diagram showing the existing and proposed arrangement of pipes and valves at that intersection is shown in Figure 12. As shown in the diagram, the existing Broad Creek force main could be valved off, and all of the flow from the Swan Creek pump station could be diverted into the proposed Broad Creek force main via the Swan Creek force main extension. The 24-inch extension will tap into the existing 24-inch prestressed concrete cylinder pipe (PCCP) line upstream of its existing connection to the 36/42-inch force main. The extension will be independent of the existing 36/42-inch force main.



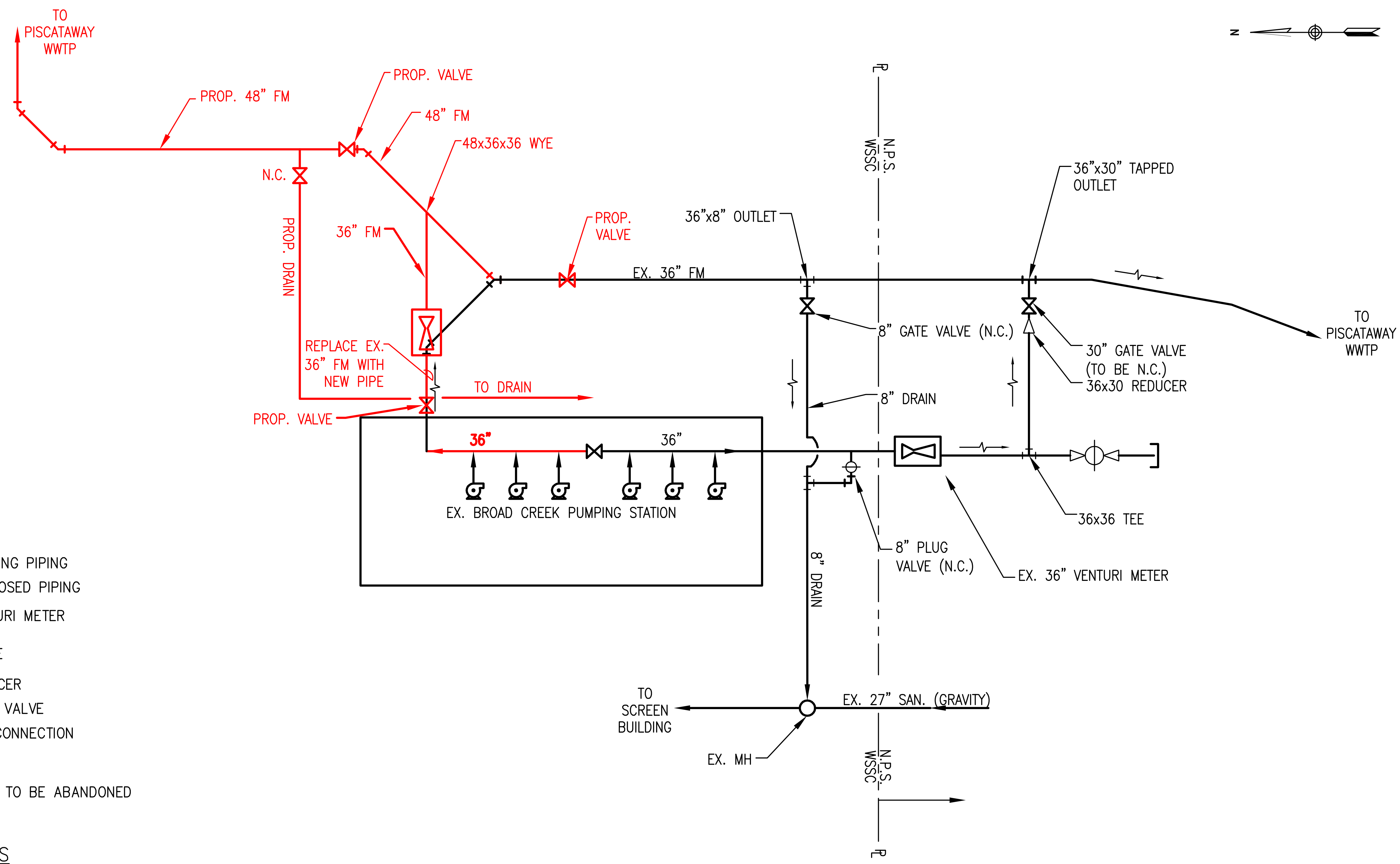
LEGEND

- EXISTING PIPING
- VENTURI METER
- VALVE
- REDUCER
- PLUG VALVE
- TEE CONNECTION
- PUMP

ABBREVIATIONS

EX	EXISTING
PROP	PROPOSED
NC	NORMALLY CLOSED
NPS	NATIONAL PARKS SERVICE
FM	FORCE MAIN

FIGURE 10: EXISTING BROAD CREEK WWPS PIPING SCHEMATIC



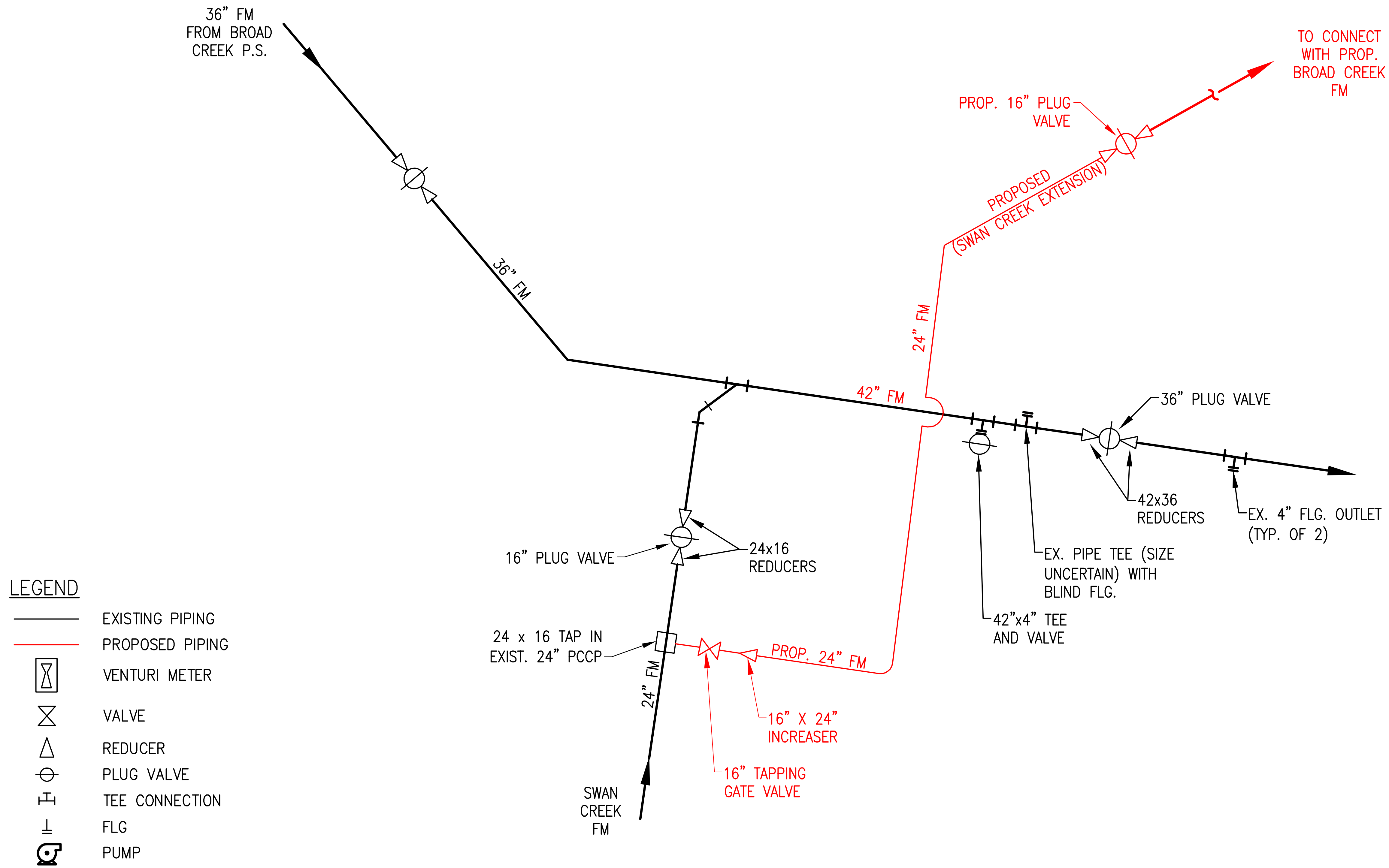
LEGEND

(black line)	EXISTING PIPING
(red line)	PROPOSED PIPING
	VENTURI METER
	VALVE
	REDUCER
	PLUG VALVE
	TEE CONNECTION
	PUMP
	AREA TO BE ABANDONED

ABBREVIATIONS

EX	EXISTING
PROP	PROPOSED
NC	NORMALLY CLOSED
NPS	NATIONAL PARKS SERVICE
FM	FORCE MAIN

FIGURE 11: PROPOSED BROAD CREEK WWPS PIPING SCHEMATIC



ABBREVIATIONS

EX	EXISTING
PROP	PROPOSED
NC	NORMALLY CLOSED
NPS	NATIONAL PARKS SERVICE
FM	FORCE MAIN

FIGURE 12: SWAN CREEK INTERCONNECTION PIPING SCHEMATIC

Alternative Operating Scenarios

Before the alignment study and piping system design can begin, alternative operating scenarios must be investigated and an appropriate scenario selected. The various scenarios are summarized in Table 7.

Table 7: Design Approach – Matrix of Alternative Operating Scenarios

SUMMARY OF ALTERNATIVES FOR FORCE MAIN		CAPACITY IN MGD	VELOCITY IN FT/SEC
FM-1	New 48-inch force main operating independently; use existing 36-inch force main for emergencies only	59.5	7.3
FM-2	Existing 36-inch force main and new 48-inch force main operating in parallel (6 Pumps Operating)	78.0	V_{36} = 5.0 V_{48} = 6.8
FM-3	Use existing 36-inch force main for dry weather flows; switch to new 48-inch force main for wet weather flows (Q > 35 MGD).	Q_{36} = 38.3 Q_{48} = 59.5	V_{36} = 8.4 V_{48} = 7.3
SUMMARY OF ALTERNATIVES FOR GRAVITY SEWER (DOWNSTREAM OF FORCE MAIN)		**CAPACITY IN MGD**	**VELOCITY IN FT/SEC**
GS-1	New 60-inch gravity sewer operating independently; use existing 54-inch gravity sewer for emergencies only	71.6	5.6
GS-2	Existing 54-inch gravity sewer and new 60-inch gravity sewer operating in parallel	125.6	V_{54} = 5.3 V_{60} = 5.6
GS-3	Use existing 54-inch gravity sewer for dry weather flows; switch to new 60-inch gravity sewer for wet weather flows (Q > 35 MGD).	Q_{54} = 54 Q_{60} = 71.6	V_{54} = 5.3 V_{60} = 5.6
SUMMARY OF ALTERNATIVES FOR PRESSURE SEWER (DOWNSTREAM OF FORCE MAIN AND GRAVITY SEWER)		**CAPACITY IN MGD**	**VELOCITY IN FT/SEC**
PS-1	New 42-inch pressure sewer operating independently; use existing 36-inch pressure sewer for emergencies only	85.9	13.8
PS-2	Existing 36-inch pressure sewer and new 42-inch pressure sewer operating in parallel	133.6	V_{36} = 10.4 V_{42} = 13.8
PS-3	Use existing 36-inch pressure sewer for dry weather flows; switch to new 42-inch pressure sewer for wet weather flows (Q > 35 MGD).	Q_{36} = 47.7 Q_{42} = 85.9	V_{36} = 10.4 V_{42} = 13.8

2.6.1 Assumptions

The operating scenarios are based on the following assumptions:

- All of the force main alternatives have the same goal: construct a new pipeline to lower the TDH on the existing Broad Creek WWPS, thereby increasing flow capacity without modifying the pumps.
- Each of the existing pipelines is in sufficiently good condition that it can be relied upon throughout the study, design, and construction periods, until the new facilities are completed and brought on-line. None of the pipes require "emergency replacement."

- For an initial period following construction, the new system will be used to convey all wastewater flow, so that the existing force main, gravity sewer, and pressure sewer can be shut down for cleaning, inspection, and (if necessary) repairs.
- "Switching" from one pipeline to another will need to be accomplished by operations personnel turning valves by hand. "Switching" will not be automatic.

When determining the appropriate pipeline scenario, an evaluation of the pros and cons of each alternative must be presented and assessed. The evaluation for the force main, gravity sewer, and pressure sewer can be found in Tables 8, 9, and 10 respectively.

2.6.2 Force Main

Table 8: Force Main Options

Pros	Cons
Alternative FM-1: New 48-inch force main operating independently; use existing 36-inch for main for emergencies only	
Existing force main can be taken out of service, if necessary	Under dry weather flow conditions, the velocities in the 48-inch force main would be somewhat low
New force main can convey entire 55 MGD flow	Existing 36-inch force main would be rarely used (under utilized)
In the future, the existing 36-inch force main could be shut down or abandoned, if ever necessary	N/A
Alternative FM-2: Existing 36-inch force main and new 48-inch force main operating in parallel	
Gives you the highest combined capacity	Parallel operation would only be needed at high flows (>35 MGD), one FM would have to be valved off during normal flow periods
	Operators would be required to manipulate valves between the two pipes
Alternative FM-3: Use existing 36-inch force main for dry weather flows; switch to new 48-inch force main for wet weather flows (Q > 35 MGD).	
Best choice to maintain desirable velocities	Operators would be required to manipulate valves between the two pipes
Existing force main can be taken out of service, if necessary	
New force main can convey entire 55 MGD flow	
In the future, the existing 36-inch force main could be abandoned, if necessary	

2.6.3 Gravity Sewer

Table 9: Gravity Sewer Options

Pros	Cons
Alternative GS-1: New 60-inch gravity sewer operating independently; use existing 54-inch gravity sewer for emergencies only	
Existing gravity sewer can be taken out of service, if necessary (provided that existing gravity sewer connections to the 54-inch line are re-connected to the new 60-inch line)	There are existing gravity sewer connections to the 54-inch line which must stay in service or be re-connected to the new 60-inch line
New gravity sewer can convey entire 55 MGD flow	
In the future, the existing 54-inch gravity sewer could be abandoned, if necessary	
Alternative GS-2: Existing 54-inch gravity sewer and new 60-inch gravity sewer operating in parallel	
Lowest cost of acceptable options	
The existing gravity sewer connections to the 54-inch line could stay as-is	
Alternative GS-3: Use existing 54-inch gravity sewer for dry weather flows; switch to new 60-inch gravity sewer for wet weather flows (Q > 35 MGD)	
Existing gravity sewer can be taken out of service, if necessary (provided that existing gravity sewer connections to the 54-inch line are re-connected to the new 60-inch line)	There are existing gravity sewer connections to the 54-inch line which must stay in service or be re-connected to the new 60-inch line
New force main can convey entire 55 MGD flow. In the future, the existing 54-inch gravity sewer could be abandoned, if necessary	Valving or stop plates would need to be constructed to divert flows between the two pipes
	Operators would be required to manipulate valves/plates between the two pipes

2.6.4 Pressure Sewer

Table 10: Pressure Sewer Options

Pros	Cons
Alternative PS-1: New 42-inch pressure sewer operating independently; use existing 36-inch pressure sewer for emergencies only	
Existing pressure sewer can be taken out of service, if necessary	The existing pressure sewer has had some maintenance issues; its long-term reliability is uncertain
New pressure sewer can convey entire 55 MGD flow	Existing 36-inch pressure sewer would be rarely used (under utilized)
Additional static head is available for diversion of excess flows at the Piscataway WWTP	Valving or stop plates would need to be constructed to divert flows between the two pipes
In the future, the existing 36-inch pressure sewer could be abandoned, if necessary	Operators would be required to manipulate valves/plates between the two pipes
Alternative PS-2: Existing 36-inch pressure sewer and new 42-inch pressure sewer operating in parallel.	
Option with most capacity in the pressure sections	The existing pressure sewer has had some maintenance issues; its long-term reliability is uncertain
Alternative PS-3: Use existing 36-inch pressure sewer for dry weather flows; switch to new 42-inch pressure sewer for wet weather flows (Q > 35 MGD)	
Existing pressure sewer can be taken out of service, if necessary	Valving or stop plates would need to be constructed to divert flows between the two pipes
New pressure sewer can convey entire 55 MGD flow	Operators would be required to manipulate valves/plates between the two pipes
In the future, the existing 36-inch pressure sewer could be abandoned, if necessary	

2.7 Implications for Maintenance

An important consideration in the design of the proposed improvements is that the facilities not become a maintenance burden for WSSC. For this reason, maintenance issues were included in the "pros and cons" of each operating scenario. In addition to the maintenance tasks already being performed on the Broad Creek WWPS, the following tasks will be required.

2.7.1 Valve turning

Any time the discharge from the WWPS is diverted from one force main to another (such as from the old force main to the new one) large diameter plug valves will need to be turned by hand. Some of the valves inside the pump station are pneumatically actuated by the station's compressed air system. Valves outside the WWPS are manually actuated. Some operating scenarios require "switching" force mains. All valves should be exercised once or twice a year to keep them from seizing, unless otherwise recommended by the valve manufacturer. One option is to have a valve maintenance contract with a firm that specializes in large diameter wastewater valves.

2.7.2 Draining

The existing force main has an 8-inch drainage (blow-off) system near the WWPS that allows draining the contents of the force main into a manhole on the 27-inch gravity sewer upstream of the screen building. When the force main is full there will be very high velocities (up to 40 ft/sec) in the 8-inch pipe that could cause problems for the pipe lining and in the receiving manhole. For the proposed main, the goal of the drain line sizing will be to create a velocity of at least 2.0 ft/sec in the force main (to carry solids) while limiting velocity in the drain line to less than 20 ft/sec as shown in Table 11. For a 48-inch force main, a 16-inch drain line would be needed. Consideration should be given to discharging the drain line into the Screen Building or WWPS wetwell, rather than into a manhole. A magnetic flow meter could be used to measure the drainage volume. Anytime that a force main is taken out of service for more than 24 hours, it should be drained. Note that the large volume of drained sewage could adversely affect the treatment process at the Piscataway WWTP and may require flow equalization or other measures.

Table 11: Draining Force Mains Back to Broad Creek WWPS

	Size (inches)	Velocity for Draining (ft/sec)	Flow Rate (MGD)	Approximate Length (feet)	Time to Drain (hrs:mins)	Total Volume (gal)
Existing Force Mains	36	2.0	9.1	12,512	2:02	818,600
	42	2.0	12.4	2,181		
Proposed Force Main	48	2.0	16.2	15,763	2:11	1,482,000

Once a force main is drained, great caution must be exercised in starting a pump against an empty force main. The pump operations will be discussed in the upcoming Pump Station Conceptual Memorandum.

2.7.3 Cleaning

After draining the force main, it may be desirable to flush and/or clean it. Potable water could be introduced at the force main high point, in similar fashion as described in section 2.1.3 for the pressure sewer. This flushing water would then be drained back to the Broad Creek WWPS. The pipe could then be cleaned by hydro-jetting or the use of poly-foam "pigs" available for this purpose. The pig could (conceivably) be launched from the transition structure (where the force main meets the gravity sewer), travel downhill propelled by potable flushing water, and be retrieved near the Broad Creek WWPS. A "pig catcher" could be temporarily attached to a pipe tee provided for this purpose. The pig should be equipped with a radio transponder so that its position can always be tracked. Note that there is some risk of getting the pig stuck and having to dig it up.

3.0 EFFECTS ON EXISTING PUMP STATIONS

3.1 Broad Creek WWPS

The most important effect on the Broad Creek WWPS will be to prevent overflows for rainfall events up to and including the WSSC 10-year storm. The increase in capacity from 38 MGD to 55 MGD will provide this benefit.

Mechanically, the pumps will be operating farther to the right on the pump curve, drawing more horsepower from the motors, and requiring somewhat greater NPSH. The lead pump can still be variable speed, but must operate between 80 percent and 90 percent of full speed in order to avoid shutoff head conditions (if speed is too low) or excessive horsepower (if speed is too high). The lowest flow rate while pumping will be approximately 5.0 MGD. The best efficiency point (BEP) of the existing pumps is 81.7 percent at a flow rate of 11.9 MGD. Currently, the pumps operate to the left of the BEP. With the new force main, the operating point will shift nearer the BEP or to its right, with efficiencies slightly better than the current conditions.

With the existing impeller trim of 25.125 inches, the maximum horsepower anywhere on the curve (at run-out) is 705 horsepower, which could slightly overload the existing 700 hp motors.

Major yard piping modifications will be required at the Broad Creek WWPS site in order to place the proposed force main along the WWPS entrance road. Large-diameter plug valves will need to be installed in vaults outside the station, as well as a new venturi meter in a vault, and drainage facilities to drain each force main (separately). On a site already crowded with pipes and conduits, this will be a challenge.

Finally, the WWPS entrance road may need to be reconstructed or additional easement acquired along the entrance road to accommodate the proposed 48-inch force main. During construction, the WWPS must remain operational and access to the WWPS must be maintained. This will be investigated further and presented in the upcoming alignment report.

3.2 Swan Creek Pump Station

The construction of the proposed Broad Creek 48-inch force main and the 24-inch Swan Creek force main extension will somewhat alter the hydraulic conditions under which the existing Swan Creek pumps operate. The static head will remain the same, but the friction head will change. The goal is to change the hydraulic conditions as little as possible. Once the alignment study is completed, the Swan Creek pump station hydraulics can be more closely analyzed. If the pump operating points (on the pump curves) are altered, the PUMP ON / PUMP OFF levels in the wetwell may need to be adjusted.

It should be noted that the JV is unaware of any proposed construction at or near the Swan Creek pump station.

4.0 RECOMMENDED DESIGN CRITERIA FOR CONVEYANCE SYSTEM

The JV recommends that the entire piping system (force main, gravity sewer, and pressure sewer) be designed to function as a complete system independent of existing piping, yet be interconnected with the existing to provide maximum operational flexibility. The recommended sizes and maximum capacities of the proposed conveyance system can be found in Table 12. Following construction, the new system could be used to convey all wastewater flow, so that the existing force main, gravity sewer, and pressure sewer can be shut down for cleaning, inspection, and (if necessary) repairs.

Table 12: Proposed Conveyance System

	Diameter (INCH)	Capacity (MGD)	Velocity (FT/SEC)
Force Main	48	59.5	7.3
Gravity Sewer	60	71.6	5.6
Pressure Sewer	42	85.9	13.8

Upon completion of inspection/repair of the existing piping, we recommend that the system be left intact for dry weather use. During wet weather events, the proposed conveyance system should be used. Under extreme conditions, the existing as well as the proposed system can operate in parallel to provide the system the maximum capacity.

Table 13: Proposed Maximum Conveyance System Capacity (Pipelines in Parallel)

	Diameter (INCH)	Capacity (MGD)
Force Main	36 & 48	78
Gravity Sewer	54 & 60	125.6
Pressure Sewer	36 & 42	133.6

It is the JV's recommendation that the existing and proposed systems be interconnected and valved in order to provide the maximum flexibility for operation and maintenance. Ideally, each section of the system including, force main, gravity sewer, and pressure sewer, will have the ability to be isolated for inspection and repair if necessary. The actual number and configuration will be determined during the design phase.

The recommendations for design will be incorporated in the upcoming preliminary design and are as follows:

- Use C = 120 for force main and pressure sewer
- A flow of 6.8 MGD will be used for the Swan Creek pump station
- A flow of 1.2 MGD will be used for the gravity lines discharging directly to the gravity sewer
- For the gravity sewer, use a Manning's "n" value of 0.013 and a slope of approximately 0.18 percent (same slope as existing pipe)
- Provide drains (blow-off) for each force main designed to discharge (directly or indirectly) back to the Broad Creek WWPS wetwell
- Metering capability will be supplied on the force mains and drain lines

Typical operating scenarios:

- Under dry weather conditions, use the existing conveyance system. That system is comprised of the 36-inch force main, 54-inch gravity sewer, and 36-inch pressure sewer.
- Under wet weather conditions, use the proposed conveyance system which will be comprised of a new 48-inch force main, 60-inch gravity sewer, and 42-inch pressure sewer.
- Under emergency conditions, the existing system and the proposed conveyance system can be used in parallel in order to obtain the maximum system capacity.

The force main alignment will be determined in a subsequent alignment study. If the chosen alignment affects the above criteria, the alignment report will outline those changes.

APPENDIX A
Hydraulic Modeling Results

WASHINGTON SUBURBAN SANITARY COMMISSION
BROAD CREEK WASTEWATER PUMP STATION
SEWER MODEL RESULTS

Broad Creek Pump Station @ 55 mgd (design criterion)

48-inch Force Main	Maximum Head	240.69 ft
	Maximum HGL	223.33 ft AD
	Maximum Velocity	7.16 fps
60-inch Gravity Sewer	Maximum Depth	3.34 ft
	Maximum Velocity	7.58 fps
42-inch Pressure Sewer	Maximum HGL	130.67 ft AD
	Maximum Velocity (full)	10.73 fps
	Maximum Velocity (freeflow)	23.86 fps

Broad Creek Pump Station @ 65.51 mgd (maximum flow)
Wet well surcharged to an elevation of +1.73 feet AD

48-inch Force Main	Maximum Head	254.98 ft
	Maximum HGL	237.62 ft AD
	Maximum Velocity	8.07 fps
60-inch Gravity Sewer	Maximum Depth	3.61 ft
	Maximum Velocity	7.72 fps
42-inch Pressure Sewer	Maximum HGL	146.36 ft AD
	Maximum Velocity (full)	11.98 fps
	Maximum Velocity (freeflow)	22.87 fps

Broad Creek Pump Station Peak Capacity…

with 4 pumps in operation =	50.80 mgd
with 5 pumps in operation =	58.22 mgd
with 6 pumps in operation =	65.51 mgd