7.0 WATER DISTRIBUTION/TREATMENT SYSTEM ANALYSIS

7.1 Existing System Inventory

General Description

The water distribution system in Spotsylvania County currently serves the Primary Settlement Area, the Courtland and Thornburg communities of the Secondary Service Area, and the Fawn Lake, Golin Run (bounded on the west by Rt. 688, on the south by Rt. 3; and on the east by River Road /Rt. 618) and Motts Run communities of the Resource Protection Service Area. The remainder of Spotsylvania County is supplied by individual wells.

Figure 1 (Section 2) shows a schematic of the Spotsylvania County and City of Fredericksburg service area hydraulic grade line. All existing facilities and interconnections are identified, along with their corresponding pressure zones. Storage tanks are labeled with their existing size, as well as their minimum and maximum elevations. Transmission mains are labeled with their size, and PRVs are labeled with their hydraulic grade line setting.

Pressure Zones

There are five pressure zones in Spotsylvania County and three in the City of Fredericksburg, as shown in Table 7.1. Water is initially supplied to the Five Mile Fork pressure zone from the Ni WTP and the Motts Run WTP, then provided to the Battlefield pressure zone through three PRVs. The County's City zone is supplied from the Fredericksburg Courtland zone, and the Mine Road pressure zone receives water from a PRV from the Battlefield zone.

Table 7.1 – Water Pressure Zones

Pressure Zone	Hydraulic Grade Line (feet)
Spotsylvania County	
American Central	(465 to 650)*
Five Mile Fork	465
Battlefield	431
City	395
Mine Road	265
City of Fredericksburg	
Courtland	396
College	270
Downtown	195

*Pressure varies depending on when pumps are on or off

Water Pumping Facilities

There are nine pump stations located within Spotsylvania County and the City of Fredericksburg. In the past, the Route 3 booster pump station delivered water to the Five Mile Fork Zone from the City of Fredericksburg Courtland Zone. Following start-up of the Motts Run WTP, the Route 3 booster pump station was no longer necessary and Motts Run and Ni WTP now directly feed the Five Mile Fork Zone. Before the City of Fredericksburg WTP (Kenmore) was decommissioned, water from the City's WTP went into the Downtown Zone and was pumped to the Powhatan Reservoir; the Powhatan Reservoir pumping station would then pump to the College Zone and Courtland Zone. Now water enters the Courtland Zone and is fed by gravity to the College and Downtown Zones. The Lafayette and Powhatan pump stations are no longer active. Table 7.2 shows all the pumping facilities for both Spotsylvania County and the City of Fredericksburg.

Table 7.2 – City and County Water Pumping Facilities

Pump Station	Number of Pumps	Total Discharge Head (feet)	Capacity (gpm)	Status
Motts Run WTP-City	3	210	6300	In service
Motts Run WTP-County	3	290, 300	8400	In service
Ni River WTP	4	240, 300	4820	In service
Gordon Road	3	160	4800	In service
Mine Road	2	183.5	1200	In service
American Central	3	220, 180, 205	1235	In service
Lafayette – City	2	N/A	N/A	In stand-by mode
Powhatan – City	4	N/A	N/A	In stand-by mode
Route 3*	2	N/A	N/A	Out of service

* The Route 3 pump station is functional and can be used if needed, but is not currently operating.

Finished Water Storage Facilities

Table 7.3 shows information about the water storage tanks serving Spotsylvania County and the City of Fredericksburg. Storage facilities are very important in the water distribution system as they balance pressure variations, supply peak hourly demands, and provide emergency and fire reserve storage.

Table 7.3 – Water Storage Tanks, Spotsylvania County and City of Fredericksburg

Tank	Overflow Elev. (ft)	Bottom of Tank Elev. (ft)	Tank Height (ft)	Tank Diameter (ft)	Tank Volume (gal)	Pressure Zone	Maximum Zone Elevation (ft.)	Effective Storage (gal)
Spotsylvania County								
Five Mile Fork	465.24	444.16	21	28.42	100,000	Five Mile Fork	360*	100,000
Battlefield	431.25	403.00	28	38.81	250,000	Battlefield	342	250,000
Mine Road	267.33	239.30	28	110.27	2,000,000	Mine Road	165	2,000,000
Courthouse	429	408	21	28.42	100,000	Battlefield	342	100,000
Courtland	431.25	403	28	77.6	1,000,000	Battlefield	342	1,000,000
Onduline	431.25	403	28	38.81	250,000	Battlefield	342	250,000
Thornburg	431.25	404.75	26.5	40.07	250,000	Battlefield	342	250,000
Gordon Rd	348	320	28	110.27	2,000,000	Five Mile Fork	360*	2,000,000
City of Fredericksburg								
Courtland 2	395	360	35	85.8	1,500,000	Courtland	270	1,500,000
Powhatan Reservoir	195	145	50	119	4,150,000	Downtown	100	4,077,000

* Excludes Fawn Lake's maximum zone elevation of 410 feet.

7.2 Hydraulic Modeling Analysis

Hydraulic analysis of the Spotsylvania County water distribution system was completed using a merged Spotsylvania County/City of Fredericksburg model and Cybernet software platform. Because the two distribution systems are integrally connected, it was vital to all analyses that system-wide conditions be thoroughly understood. Once the physical geometry of the model was completed, the various demand alternatives and operational scenarios were developed.

During evaluation of each scenario, hydraulic deficiencies were identified such as: high or low operating pressure, inadequate storage, high pipeline head loss or velocity, and inadequate fire flow. Each of these deficiencies and the criteria by which they were evaluated are described further in Section 7.3. Corrective actions and projects were identified for each known deficiency and evaluated on the basis of cost and desired flexibility.

7.3 Water System Deficiencies

Water Pressure

Design pressure criteria may vary with the particular features and conditions of individual distribution systems. References such as the American Water Works Association (AWWA), the Ten States Standards, and the Virginia Department of Health (VDH) agree on the range of pressures that are most efficient and effective for operation of a water distribution system. The minimum required pressure at a service connection is 20 psi as directed by the VDH Waterworks Regulations. This standard is set to allow for pressure to serve upper dwelling floors as well as to serve hoses in a fire-fighting situation. The maximum water pressure at a service connection allowed by the Spotsylvania County Building Code is 80 psi, to protect and facilitate consistent operation of household appliances. AWWA literature recommends a range of pressures between 30 psi and 90 psi. For a target operating pressure, the Recommended Standards for Water Works (Ten States Standards) recommends that normal working pressure in a water distribution system be approximately 60 psi. In recent years, Spotsylvania County has experienced distribution system pressure as low as 35 psi.

Incorporating all of these pressure recommendations, the recommended operating pressure range for Spotsylvania County is a target of 45 psi to 60 psi. Due to rolling topography, however, there may be isolated, low elevation areas within the County that regularly see operating pressures of 65-85 psi.

Water Storage

Storage requirements for both Spotsylvania County and the City of Fredericksburg are determined by the Virginia Department of Health (VDH). Normal waterworks practice indicates that effective finished water storage for domestic purposes shall not be less than one-half of the average day demand. Effective storage is defined as the available storage in a tank above and beyond what is needed to serve the highest ground elevation in a pressure zone. Therefore, effective storage in an elevated tank or standpipe is measured from the highest ground elevation in a service area (pressure zone) plus 20 psi, or 46 feet.

The effective storage of each tank within the Spotsylvania and Fredericksburg distribution system was calculated and summed for each pressure zone. The available stored water volume within each pressure zone was compared to the VDH-required effective storage. The surpluses and/or deficits for 1999 conditions are shown in Table 7.4.

Table 7.4 - Effective Finished Water Storage For 1999 Conditions

Pressure Zone	1999 Demand (mgd)	Required Storage (Mgal)	1999 Effective Storage (Mgal)	Deficit/Surplus (Mgal)
Spotsylvania County				
Five Mile Fork	1.66	0.83	0.10	-0.73
Battlefield	2.61	1.30	1.85	0.55
Mine Road	0.39	0.19	2.00	1.81
City	0.51	0.25	0	-0.25
American Central	0.04	0.02	0	-0.02
Other	0.03			
Total	5.24	2.59	3.95	1.36
City of Fredericksburg				
Courtland	1.03	0.52	0.20*	-0.32
College	0.38	0.19	0.12	-0.07
Downtown	1.12	0.56	4.10	3.54
Total	2.53	1.27	4.42	3.15
System Total	7.77	3.86	8.37	4.51

*In 1999 the 200,000-gallon Courtland tank is in operation and the 1,500,000-gallon tank is under construction.

As shown above, both Spotsylvania County and the City of Fredericksburg had a system-wide effective finished water storage surplus in 1999. In Spotsylvania County, the surplus is located primarily within the Battlefield and Mine Road Zones. The Five Mile Fork zone is greatly affected by storage deficiencies because both the Ni and Motts Run WTP pump into the zone, which has limited storage to provide pressure variations. Therefore, the Five Mile Fork Zone can experience pressure fluctuations dependent on WTP operation. This analysis does not include clearwell or ground level storage as provided at Gordon Road. Ground level storage can be considered in these analyses to meet peaking demands if equipped with emergency power and pumping to meet demand variations.

As the population in Spotsylvania County and the City of Fredericksburg grow, the effective storage surplus will be greatly affected as shown in Table 7.5, depicting build-out conditions.

Table 7.5 - Effective Finished Water Storage For Build-Out Conditions

Pressure Zone	Build-out Demand (mgd)	Required Storage (Mgal)	1999 Effective Storage (Mgal)	Deficit/Surplus (Mgal)
Spotsylvania County				
Five Mile Fork	2.96	1.68	0.10	-1.58
Battlefield	9.06	4.91	1.85	-3.06
Mine Road	3.55	1.49	2.00	0.51
City	0.76	0.63	0	-0.63
American Central	0.36	0.20	0	-0.20
Thornburg Commercial	3.00	1.00*	0	-1.00
Other	0.03			
Total	19.72	9.91	3.95	-5.96
City of Fredericksburg				
Courtland	2.37	1.19	1.50	0.31
College	0.38	0.19	0	-0.19
Downtown	1.13	0.57	4.10	3.53
Other	0.37	0.19	0	-0.19
Total	4.25	2.14	5.60	3.46
System Total	23.97	11.78	9.55	-2.23

* The volume of the elevated storage tank to serve the 3 million gallon commercial enterprise is dependent upon required commercial fire flows, not on the average daily demand.

In build-out conditions, the Spotsylvania County effective storage decreases to a deficit of approximately 6.0 mg. Half of the Spotsylvania County deficit occurs within the Battlefield Zone due to projected demand growth south of Courthouse Road. Similarly, the Five Mile Fork Zone deficit is exacerbated by demand growth. Spotsylvania County City Zone also sees a shortage in effective storage, but this is mitigated by the surplus in the City of Fredericksburg Courtland Zone, which is connected to the Spotsylvania County City Zone. With the recent completion of a 1.5 mg City Courtland tank and the additional growth experienced by the City of Fredericksburg, the City of Fredericksburg overall storage remains in compliance with VDH regulations. Incremental storage improvements within Spotsylvania County will eliminate the effective storage deficit projected with build-out conditions.

Water Distribution

Several conditions in a water distribution system indicate need for improvements. For example, water velocities in pipes greater than 3 feet per second indicate that a pipe should be evaluated, while velocities over 6 feet per second indicate that a pipe is undersized and requires improvement. Also, pressures lower than the minimum VDH required pressure of 20 psi or greater than the maximum allowable pressure of 80 psi specified by the Spotsylvania County Building Code show that flows and head conditions in those specific areas need to be reevaluated. Low pressures in the system may indicate that the area distribution mains are undersized and head loss in the pipe has increased to a point where the area's operating pressure has been greatly diminished, or where elevations in the area are too high relative to the water service level, or both. Frequent customer complaints can be an indicator of inadequate or excessively high pressures. Lastly, as development progresses in previously undeveloped areas, additional transmission mains will be needed to serve the new areas. As new mains are planned careful attention must be given to assure that long detention times do not result which can result in deterioration of water quality and increases in disinfection byproducts.

Fire Flow Requirements

Three methods exist for calculating fire flow requirements that are accepted and approved within the industry. These are the Insurance Services Office method (ISO), the Iowa State University method (ISU), and the Illinois Institute of Technology Research Institute method (IITRI). Using zoning data from Spotsylvania County, each of these methods were used to calculate fire flow requirements for specific zoning types. Several assumptions were included when making the calculations. The buildings were assumed to be non-sprinkled, and the worst-case building representing the zoning type was used to allow for the maximum fire flow requirement to be calculated.

The ISO method uses building characteristics, such as construction class, area, type of occupancy, exposure to adjacent buildings and the ability of a structure to prevent fire spread internally, to calculate the flow needed to suppress a fire. Using this calculation for each of the residential, commercial and industrial zoning types, all needed fire flow results except the Industrial 2 and Commercial 3 zoning types fell below the minimum AWWA required fire flow of 500 gpm. According to AWWA, the supply available at a given point in the system should be no less than 500 gpm at a residual pressure of 20 psi. This represents the amount of water required to supply two standard hose streams to a given fire.

The ISU method is dependent on the volume of space available for a fire to occur multiplied by a factor representing the rate of reaction of the fire. Results from the ISU method yielded larger fire flow requirements varying directly with the size of the building assumed to be the average representative of the zoning type. The IITRI method is an empirical equation, developed from surveys of actual fire occurrences. The calculation is different for residential and non-residential occupancies and is dependent on the area of the building in square footage. The IITRI calculations yielded the highest fire flow requirement of the three methods, but the results remained within reasonable amounts. The duration of the fire demand was determined from

AWWA standards (AWWA M31 – Distribution System Requirements for Fire Protection) dependent on the flow required.

Table 7.6 - Fire Flow Calculations

Zoning Type	ISO Method (gpm)	ISU Method (gpm)	IITRI Method (gpm)	Duration (hours)
R1	500*	500*	1,360	2
R2	500*	500*	1,360	2
R3	500*	500*	1,360	2
I1	500*	2,178	2,981	3
I2	647	2,178	2,981	3
C1	500*	500	1,775	2
C2	500*	762	2,446	2
C3	503	1,089	3,032	3

*The minimum fire flow requirement by AWWA is 500 gpm.

The ISO method includes an alternate reference for determining fire flow requirements for residential buildings. These totals cover one- and two-family dwellings not exceeding two stories in height. The needed fire flows are determined from the density of buildings as shown below. This type of building falls into all three of the zoning types that are encountered in the primary settlement area of Spotsylvania County. The three zoning types differ in the density of residential units. The R1 zoning type corresponds to low density (approximately 2 units per acre) and the R2 and R3 types correspond to low to medium density (approximately 2.5 units per acre).

Table 7.7 - Needed Fire Flow For One and Two Family Dwellings

Distance Between Buildings (ft)	Needed Fire Flow (gpm)
Over 100	500
31-100	750
11-30	1000
Less than 11	1500

*Dwellings not to exceed two stories in height.

The final recommendations for fire flow requirements are summarized in Table 7.8.

Table 7.8 - Recommended Fire Flow Requirements

Zoning Type	Fire Flow Requirement (gpm)	Duration (hours)
R1	Refer to Table above	2
R2	Refer to Table above	2
R3	Refer to Table above	2
I1	3,000	3
I2	3,000	3
C1	1,750	2
C2	2,500	2
C3	3,000	3

The distribution system evaluation criteria described above dictate the sequence and sizing of the water system improvement projects. These criteria for each operational condition can be used as a basis for phasing future transmission, storage, and distribution projects

7.4 Synopsis of Existing Safe Yield Studies

In addition to distribution and storage expansion projects discussed above, future growth will depend upon adequate water supply. This section presents the available safe yield data for the water supply sources currently under operation by Spotsylvania County. Each evaluation was completed using separate methodologies, assumptions, and operating conditions. The evaluations are listed in reverse chronological order, to present the most recent findings first. The key assumptions and conclusions are discussed for each evaluation.

Ni River Reservoir Drought Severity Evaluation

The purpose of the March 1999 letter report and analysis by HSMM was to evaluate the impact of the 1998-1999 drought on the Ni River Reservoir and the anticipated remaining safe yield of the facility from March 1999 through December 1999. In addition, the evaluation examined the impact of the five droughts of record since 1930 and delineated each associated maximum safe yield withdrawal. As part of this analysis, a safe yield model was developed using the following assumptions:

- The Ni River Reservoir maximum surface elevation is 237.5 feet and the maximum intake elevation is 218 feet with a calculated usable volume of 1,087mg.
- During a given drought, the safe yield withdrawal rates would result in the reservoir depleting the storage volume within the reservoir.
- Sedimentation storage is below the 218 feet minimum intake elevation, which contradicts earlier Soil Conservation Service estimates of 224.8 feet elevation.

- Three nearby river gauging stations were used to estimate the watershed / reservoir inflows. Flow at the Ni Reservoir was estimated at 1.5 % of the Rappahannock River gauge, 9.6% of the Mattaponi River gauge, and 31.8 % of the Po River flow measuring station.
- Evaporation losses were based on April through October data from 1972-1997 from the Piedmont Research station in Orange, Virginia.
- Seepage losses are assumed to be a constant 0.5 mgd.

Based on review of watershed information and the safe yield model for the past five known droughts of record, Table 7.9 depicts the reported Ni River Reservoir safe yield results.

Table 7.9 – Ni River Reservoir Safe Yield

Drought Period	Calculated Safe Yield (mgd)
March 1980-February 1983	4.37
March 1930-November 1932	4.54
March 1953-March 1956	4.86
March 1991-December 1992	5.24
March 1986-March 1987	5.98

Calculations and conclusions specific to the 1998-1999 drought, are as follows:

- The 1998-1999 drought may be the new drought of record (pending collection of final river gauge data from the Po River measuring station).
- When the normal pool elevation at the Ni River Reservoir is below 237.5 feet in the spring, excessive reservoir draw-down can be expected during severe droughts.
- The Ni River Reservoir could have sustained a continuous withdrawal of 3.1 mgd from June 1998-March 1999 and a projected withdrawal of 4.33 mgd from March 1999-December 1999 (assuming March 1981-February 1982 climate conditions). Alternatively, the projected withdrawal would be 3.1 mgd from March 1999-December 1999 (assuming 1998 climate conditions).

Motts Run Reservoir Safe Yield Study

The purpose of the 1996 study and its supplement by Gannett Fleming was to determine the safe yield of the Motts Run Reservoir pump-storage project utilizing the operating requirements of Virginia Water Protection Permit # 94-1134. This study focused on available safe yield of the combined Motts Run Reservoir and the Rappahannock River intake operation during the single worst drought of record. As part of this analysis, a safe yield model was developed using the following assumptions:

- The Motts Run Reservoir has a surface area of 160 acres at a normal pool elevation of 150 feet with a total reservoir volume of 1,328 mg.

- The sedimentation storage is 123 mg while the fish and recreation volume is 250 mg (as determined by Dewberry and Davis 1988). The usable storage, therefore, is 1,205 mg and 955 mg respectively.
- River and reservoir inflows were estimated using the Rappahannock River gauge located near Fredericksburg. River inflows were adjusted to 98% of the Rappahannock River measuring station, while the Motts Run Reservoir was 0.6% of the Rappahannock River measuring station.
- Seepage through the reservoir was assumed to be negligible.
- Precipitation data was based on the use of a NOAA-NWS gauge located at the Fredericksburg National Park, while evaporation losses/rates were based on the Meyer Evaporation Study conducted by the National Resources Planning Board.
- Operating rules were based on the VWP Permit, which stipulated requirements based on month, emergency reservoir volumes, and minimum in-stream flows.

A monthly safe yield program (excluding evaporation and seepage), calculated over 84 years, was used to determine the two worst droughts of record as 1931 and 1966. The daily safe yield analysis (including seepage and net evaporation) was then completed for January 1930-December 1932 and January 1964 – December 1966. The 1931 drought was determined to be the drought of record.

Excluding only sedimentation storage, the calculated safe yield was determined to be 4.67 mgd. Considering both recreational (250 mg) and sedimentation storage (123 mg) needs (defined by the 1988 Dewberry & Davis study), the calculated safe yield was determined to be 3.94 mgd. Both calculations assume a fixed recharge-pumping rate of 10 mgd.

The model was modified using the operating rules utilized by Dewberry and Davis in the 1988 Fredericksburg/Spotsylvania County Joint Water Treatment Facilities Study and HSMM in the 1994 Final Environmental Impact Report – Water Supply System. In each case the model provided similar safe yield results as the original assumptions (within 2.6% and 12% respectively).

Final Environmental Impact Report – Water Supply System

The purpose of this March 1994 report was to identify and evaluate environmental impacts of the proposed water supply system projects in Spotsylvania County. As part of this evaluation, studies were performed on the effects and feasibility of the Hunting Run Reservoir based on safe yield studies, and minimum in-stream flow requirements for the Rapidan and Rappahannock Rivers downstream of the proposed Hunting Run Reservoir withdrawal site.

The information in this report presented the evaluation of the Hunting Run Reservoir Water Supply Project using data from several models developed by HSMM. The initial model developed in 1988 used the following assumptions:

- The Ni River Reservoir has a safe yield of 4.0 mgd.

- The proposed Hunting Run Reservoir will have a surface water area of 420 acres, a normal pool elevation of 246 feet, and a total volume of 2,409 mg (water supply is 2,196 mg, evaporation consists of 149 mg, and dead storage is 64 mg).
- The Rapidan River intake pump station capacity is 20 mgd.
- Water supply is based on the use of the reservoir volume below 224 feet for sediment storage.
- Flows are adjusted for drainage area and documented average flows.

The results of the 1988 HSMM model indicated that the safe yield of the proposed Hunting Run Reservoir would be 8 mgd.

In preparation for the 1994 Final Environmental Impact Report, HSMM created another model of the Hunting Run Reservoir in November of 1992. The model analyzed the proposed Hunting Run Reservoir during drought conditions, by calculating daily average supply flow rates. Assumptions used to develop the model include:

- Hunting Run Reservoir safe yield is an average of 8 mgd (the estimated values vary monthly from 6.4 mgd in the winter to 9.6 mgd in the summer).
- Up to 20 mgd is pumped from the Rapidan River intake to refill the reservoir.
- Minimum in-stream flow is calculated using the Norfolk Corps of Engineers 1992 proposal for recommended minimum in-stream flow with a mean annual flow of 1,620 cfs on the Rappahannock River just below the confluence with the Rapidan River.
- Critical low flow period was identified as May 1964 through December of 1966.
- City of Fredericksburg has a continuous withdrawal of 12 mgd.
- Model does not include evaporation rates.

The 1994 HSMM report, using the Hunting Run Reservoir model, concluded that reservoir depletion would occur in September of 1966, confirming the reservoir has an 8 mgd safe yield. The study also found that for each 10 mgd increase in pumping station capacity, approximately 1 mgd could be added to the safe yield of the reservoir.

In 1993, HSMM modeled in-stream flow impacts associated with the Hunting Run Reservoir, as well as overall impacts on in-stream flow resulting from water withdrawals in the critical segment of the Rappahannock River (the critical segment is defined by the Norfolk District Corps of Engineers as the segment below the confluence with the Rapidan River, and above the fall line at Falmouth.) For the model, it was assumed that regional water withdrawals consisted of:

- City of Fredericksburg has a continuous withdrawal of 6.0 mgd. (Model runs were also developed with a 12 mgd City of Fredericksburg withdrawal, with no differing effect on the safe yield outcome.)
- Town of Orange has a continuous net Rapidan River withdrawal of 1.0 mgd for the municipal and industrial use for the Towns of Orange and Gordonsville.
- The Motts Run Reservoir has a water storage volume of 955 Mgal, and a safe yield of 3.4 mgd, with a maximum Rappahannock River withdrawal of 10 mgd.

- Stafford County's Rocky Pen Reservoir has a 4,600 mg water supply volume, a 17.5 mgd safe yield (or 20 mgd safe yield with storage transfer to Able Reservoir), and a 68 mgd maximum withdrawal from the Rappahannock River.

Other assumptions were also needed to create an accurate model of the Hunting Run Reservoir including:

- Proposed Hunting Run Reservoir will have a 2,196 mg storage volume, and a safe yield of 8.0 mgd (as determined by HSMM 1988 reservoir model), with a maximum Hunting Run Reservoir Rapidan River withdrawal of 20 mgd.
- Drought of record was 1965-1966.
- Model does not include evaporation rates.
- The minimum in-stream flows for the critical segment of the Rappahannock River are defined by the Corps of Engineers as a percentage of a mean annual flow (1,620 cfs) ranging from 20- to 60-percent.

The first application of the model was based on monthly river flows and monthly water demands. From this application, the river model found that the safe yield of the Hunting Run Reservoir was 7.8 mgd and the critical river in-stream flow occurred during the 1965-1966 drought of record.

The second application of the model was based on daily river flows and daily water demands (based on monthly water demands) for the period between May 1, 1964 and December 31, 1966. The model incorporated different minimum in stream-flows for weekends and weekdays based on the 1992 proposal by the Norfolk Corps of Engineers. This application confirmed the safe yield of the Hunting Run Reservoir to be 8.0 mgd, and estimated the critical low flow period to occur in September of 1966.

Using the information gathered from the initial applications of the model, further studies using the HSMM 1993 river model program were conducted under both average and drought of record conditions. During periods of low flow, such as the 1965-1966 drought of record, the model simulated water release from Hunting Run Reservoir to the Rapidan River to supplement the intake at the Motts Run WTP. During average flow periods, water withdrawal was used to fill the Hunting Run Reservoir or to directly supply the Motts Run WTP.

The following conclusions were made by analyzing the HSMM 1993 model:

- Under Average Year Conditions (modeled monthly for 56 years) the average river flow exceeds the Corps of Engineers minimum in-stream flow requirements by 400 to 2,000 mgd.
- The average water withdrawal rate for the Hunting Run Reservoir and the Motts Run WTP supply will be 10.8 mgd.
- Water released from the Hunting Run Reservoir will augment river flows in the Rapidan and Rappahannock Rivers to the proposed intake site near Motts Run Reservoir.
- Under average year and drought year conditions, the Hunting Run Reservoir will not result in contravention of the Corps of Engineer's minimum in-stream flow requirements.

- Even during drought conditions, withdrawals can be made on certain days when the minimum in-stream flow requirements are exceeded to fill Hunting Run Reservoir and supply water to the Motts Run WTP.
- The cumulative effect of all known water withdrawals (Town of Orange, Hunting Run Reservoir, Motts Run WTP use, City of Fredericksburg, and Stafford County Rocky Pen Reservoir) will not result in contravention of the Corps of Engineer's minimum in-stream flow requirements under average year conditions.

In August of 1995, HSMM issued a letter revising the usable estimates for the Hunting Run Reservoir based on digitally prepared 2-foot contour maps. The revised "cumulative volume" at elevation 246 feet is 2.242 billion gallons as usable water supply storage. The total reservoir volume was reported to be 3.053 billion gallons at normal pool elevation of 246 feet.

Fredericksburg/Spotsylvania Joint Water Treatment Facilities Study

This 1988 report was referenced within the 1996 Gannett Fleming Motts Run Reservoir Safe Yield Study. The intent of this study was to determine the safe yield of the Motts Run Reservoir without pumping from the Rappahannock River. The assumptions of the safe yield determination were as follows:

- Reservoir inflow was estimated from flow measurements from similar watersheds in the area.
- Evaporation rates were zero from November through March and varied from 3.38 inches to 7.28 inches the remainder of the year.
- A constant seepage rate of 109.5 mg/year
- Calculations were based on monthly data.

The report indicated that the constant withdrawal safe yield without recharge from the Rappahannock River is 2.32 mgd.

7.5 Future Water Supply and Treatment Needs

The combined Spotsylvania County and City of Fredericksburg average day demand under build-out conditions is approximately 23 mgd; refer to Section 3.12. The current, most restrictive, permitted use of source water is approximately 15.4 mgd, while the most restrictive assumed safe yield is approximately 16.3 mgd. An additional 6.7 to 7.6 million gallons per day will be required to satisfactorily meet these build-out conditions. However, if further discussions with DEQ confirm that the 6.0 mgd of permitted Rappahannock River withdrawal, previously held by the City of Fredericksburg, is available to the County without restrictions, the capacity can be used to meet the future source water capacity needs of the combined regional system (as shown in Table 7.10).

Table 7.10 - Estimated Safe Yield of Existing Reservoirs

Source	Permitted Source Water Contribution (mgd)	Calculated Safe Yield (mgd)
Ni River Reservoir	4.0	4.37
Motts Run Reservoir	3.4	3.94
Rappahannock River	0 (6.0)	0 (6.0)
Hunting Run Reservoir	8.0	8.0
Total	15.4 (21.2)	16.31 (22.11)

Current safe yield estimates are based upon the four studies as discussed in Section 7.4. In each of these studies, the safe yield values were developed using different input assumptions, calculation methodologies, and permit requirements. A comprehensive system-wide study, however, could better pinpoint actual total system safe yield and could be used for final determination with the Corps of Engineers and Department of Environmental Quality of allowable Rappahannock River withdrawal. In addition, a comprehensive safe yield study would provide operational criteria to optimize the joint operation of all existing supply sources.

As discussed in Section 3, the Spotsylvania County and the City of Fredericksburg future projected maximum day build-out demand is approximately 36 mgd. The current maximum water treatment capacity within the Spotsylvania County and City of Fredericksburg water systems is 18.0 mgd. The Ni WTP and reservoir are capable of a peak production rate of 6.0 mgd and the Motts Run WTP has a rated capacity of 12.0 mgd.

An additional 18 mgd of treatment capacity will be required to meet the future build-out demands. A portion of this treatment capacity is anticipated to be provided at the Motts Run WTP, which was designed such that treatment capacity can be incrementally expanded by 12 mgd to an ultimate capacity of 24 mgd. The remaining 6 mgd of water treatment capacity has not been sited.