George Mason University

Quantifying upstream reservoirs mitigation towards water supply consumptive use on the Potomac River

CEIE 395 – Mentored Research in Civil and Environmental Engineering

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The Potomac River basin is home to more than six million residents and has experienced moderate and severe droughts in the past (e.g., 1930, 1966, 1999, and 2002). With population growth and consequential increasing water demands, net water withdrawals by upstream users can impact the water supplies for downstream populations, as for example in the Washington Metropolitan Area (WMA). Three reservoirs, Jennings Randolph, Savage, and Little Seneca, are part of the WMA water supply system, and are used to augment Potomac River flow during droughts. This study focuses on investigating if upstream reservoirs which are not part of the WMA system partially mitigate the impacts of Upstream Consumptive Use (CU) on the Potomac River. Therefore, a GIS inventory of the ten largest reservoirs located in West Virginia, Pennsylvania, Maryland, and Virginia was created. The GIS database includes the following information: location, owner, storage capacity, reservoir inflows, and current water supply demands. Each parameter listed above was analyzed along with a safe yield calculation for each reservoir. All of this information is useful and must be considered in order to properly determine the impacts upstream reservoirs. Therefore, through this study we aim to support the planning and management of water resources in the region.

I. INTRODUCTION

Recently, the State of California has experienced the worst drought in a century. The drought has drawn the reservoir storage down way below its normal operations and has impacted the state's agricultural production and drinking water supply (Mao et al. 2015). In comparison, the Washington Metropolitan Area (WMA) can potentially be at risk. The WMA relies solely on the Potomac River for supplying water to approximately 6.11 million people. Recently, the Interstate Commission on the Potomac River Basin (ICPRB) published a study on the Washington Metropolitan Area Water Supply. The study includes a section about Upstream Consumptive Use (CU) which refers to water withdrawn that is not filtered back into the basin for future use. Basically this water is lost and no gain comes from it. For instance, evaporation and transpiration are major natural causes of CU; however, there are manmade components. Upstream of Little Falls Dam (Figure 1) on the Potomac River we find excessive withdrawals for industry, agriculture, water supply, and livestock which all fall under the category of consumptive use. In the study they were able to determine that “Total summer upstream consumptive use is estimated to be 111 million gallons per day (MGD) in 2010 and 141 MGD in 2040” (Ahmed et al. 2015). All things considered, this is a major cause for water level decline and flow diminishment on the Potomac River. Therefore, a CU mitigation strategy is needed. CU mitigation amounts to the elimination of “manmade impacts caused by CU during low flows and returning to natural flow conditions” (Swartz et al. 2014). According to Zhang and Balay (2014) some agencies collect water withdrawal data but not consumptive use data; however agencies like the Susquehanna River Basin Commission and Interstate Commission on the Potomac River

Basin (ICPRB) do. Through analysis, the Susquehanna Commission insures that the one way to mitigate CU is by “providing flow augmentation releases from storage” (Zhang and Balay 2014).

With the support of Dr. Cherie Schultz from ICPRB and Dr. Celso Ferreira , this study focuses on quantifying upstream reservoir storage mitigation towards upstream consumptive use on the Potomac River. Reservoir storage can help store and slowly release water when needed during CU or droughts. Since water supply accounts for a vast majority of consumptive use, the project will focus only on municipalities. Therefore, the big idea is to investigate how effective are these reservoirs in the mitigation process regarding the constant water supply withdrawal.

2. METHODS

2.1 Reservoir Inventory

This study initiated by compiling information on existing upstream reservoir that are used by municipalities in Maryland, Virginia, Pennsylvania, West Virginia for water supply. This information was taken from the Army Corps of Engineers National Inventory of Dams (CorpsMap). A GIS inventory (Table 1.1 and Map 1) was then created by selecting the reservoirs with a storage capacity greater than 500 acre-feet. The inventory included the following information: location, usable storage capacity, owner, operator, current water withdrawals by the municipality. Existing state and federal dam inventories will be used in this process. During the process, we noticed some of the information taken from the CorpsMap was not correct. Therefore, a thorough investigation was conducted for each state's county, municipalities, and operator by using sources like their Annual Water Quality Report (WQR) and Comprehensive Plan. This process was very important in order to make sure all of the information displayed in the inventory was up to date.

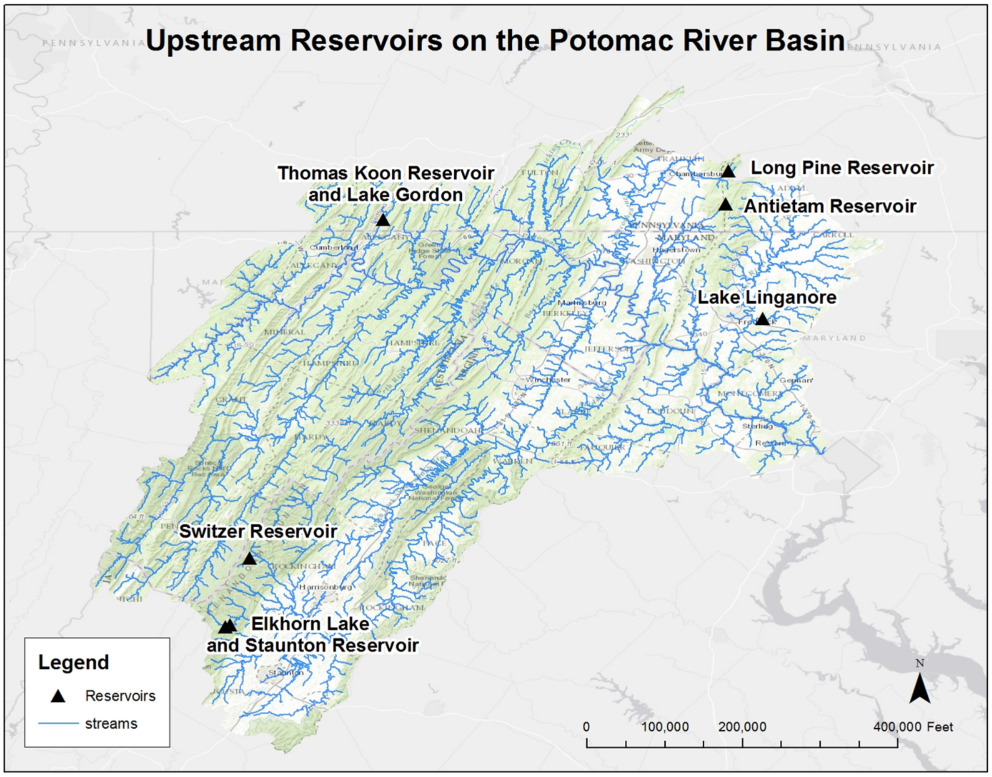
Table 1.1: Inventory

FC=Flood Control, SWM= Stormwater Management, WS= Water Supply, and REC

UPSTREAM RESERVOIR INVENTORY

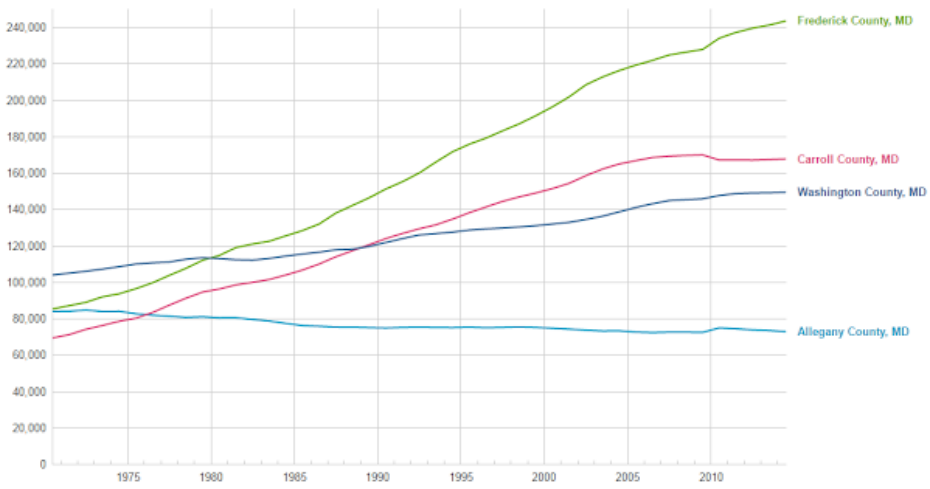
#	Dam Name	Other Name	Owner Type	Owner	County	State	Storage (ac-ft)	Purpose	Longitude	Latitude	Rivers
1	Upper North River No.76	Elkhorn Lake	Local Gov.	City of Staunton	Augusta	VA	10500	Water Supply	-79.2237	38.3263	North River
	Staunton Dam	-	Local Gov.	City of Staunton	Augusta	VA	416	Water Supply			North River
	Elkhorn Lake and Staunton Dam Total Storage						10916				
2	Lower North River #81C	Switzer Dam	Local Gov.	City of Harrisonburg	Rockingham	VA	10357	Water Supply	-79.1376	38.5718	Skidmore Fork
3	Lake Linganore	Brosius Dam	Private	City of Frederick	Frederick	MD	7900	Water Supply	-77.3262	39.4157	Linganore Creek
4	Long Pine Run	-	Local Gov.	Borough of Chambersburg	Adams	PA	7490	Water Supply	-77.4454	39.9372	Birch Run
5	Antietam	-	Local Gov.	Borough of Waynesboro	Adams	PA	866	Water Supply	-77.4551	39.818	East Branch Antietam Creek
6	Thomas W. Koon		Private	City of Cumberland	Bedford	PA	12400	Water Supply	-78.6639	39.7636	Evitts Creek
	Lake Gordon		Private	City of Cumberland	Bedford	PA	5290	Water Supply	-78.6761	39.7476	Evitts Creek
	Thomas W. Koon and Lake Gordon TOTAL STORAGE						17690				

Map 1: Reservoir Locations



2.1.1 Maryland Reservoir

In the upper Potomac River Basin, the state of Maryland includes a total of five counties (Frederick, Washington, Carroll, Allegany, Garrett). However, the basin does not cover some these counties entirely. Within these counties we find several reservoirs used for water supply. However, most of those reservoirs are less than the 500 ac-ft. thresholds assigned in this study. With that being said, Lake Linganore, was the only Maryland reservoir selected for this research. Lake Linganore is situated in Frederick, Maryland and owned by the City of Frederick. Below is a graph showing the population growth in Maryland's upstream counties.



Graph 1: Maryland Counties Population Increase

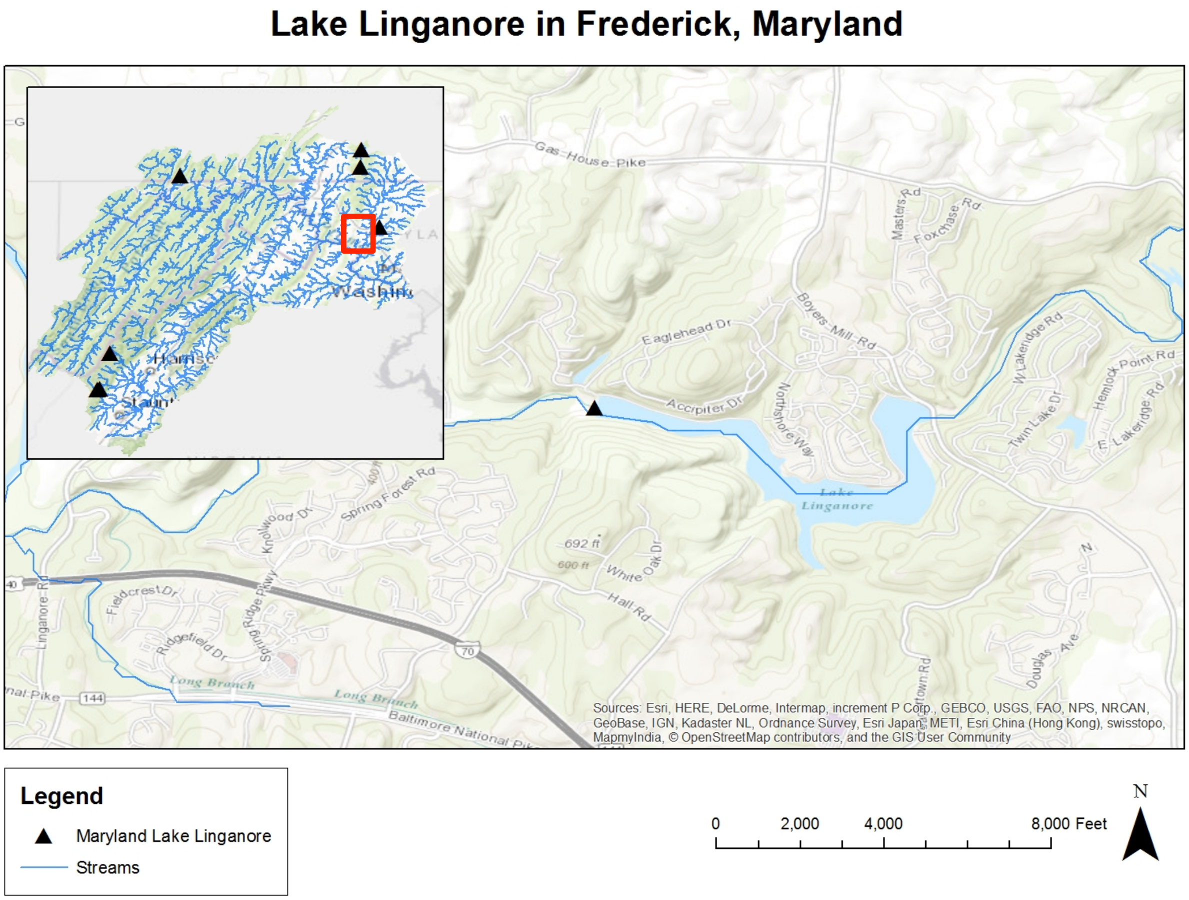
2.1.1a City of Frederick

According to the City of Frederick's 2016 Water Quality report, the city utilizes four different sources. A total of 6.53 million gallons per day (MGD) is produced on average for the city. From that amount, 44% comes from Lake Linganore. A total of 25.7% comes from Monocacy River, 11.2% from Fishing Creek, and 19.1% from the Potomac River. Lake Linganore, amounts to most of the water supply demands.

Table 2.1.1: City of Frederick Water Supply

Sources	Water Supply (MGD)
Lake Linganore	2.87
Monocacy River	1.68
Fishing Creek	0.73
Potomac River	1.25

Map 2.1.1: Lake Linganore

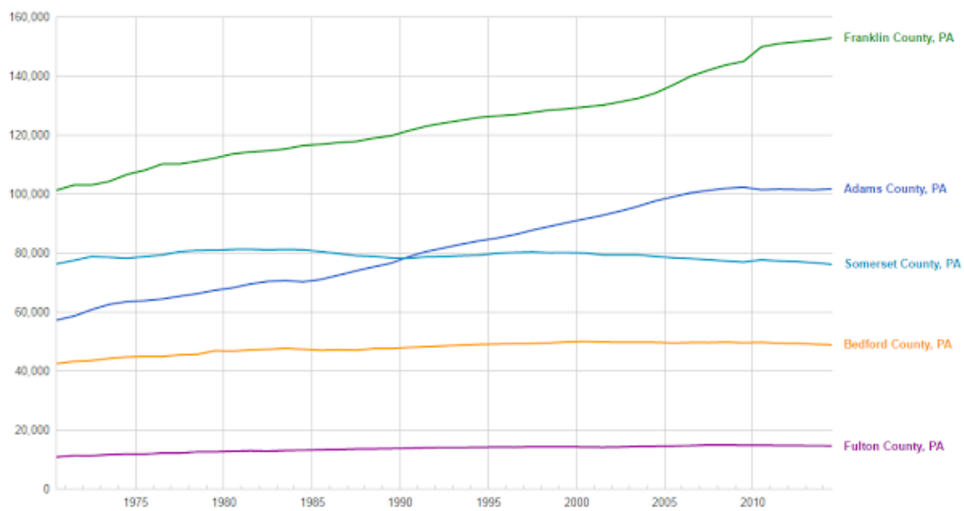


2.1.2 Virginia Reservoirs

The following Virginia counties are included in the upper Potomac River Basin: Frederick, Shenandoah, Rockingham, Augusta, Page, Warren, Clarke, Loudoun, and Faquier. Most of these counties have a small population; therefore, most of the water supply is withdrawn from wells. Just a few reservoirs are used for public water supply. Of all the Virginia reservoirs only a couple exceeded the 500 ac-ft. storage threshold; Staunton Reservoir and Switzer Reservoir. Even though, Loudoun County's Beaverdam Reservoir exceeds the threshold capacity assigned, it was excluded due to an already existing research study.

1. Staunton Reservoir (Map 2.1.2a) is located in Augusta County. It is owned and operated by the City of Staunton.
2. Switzer Reservoir (Map 2.1.2b) are located in Rockingham County. They both are owned and operated by the City of Harrisonburg Public Utilities.

Below is a graph from Google's Public Database showing the population growth from 1970-2015 of Virginia counties.



Graph 2: Virginia Counties Population Increase

2.1.2a City of Staunton

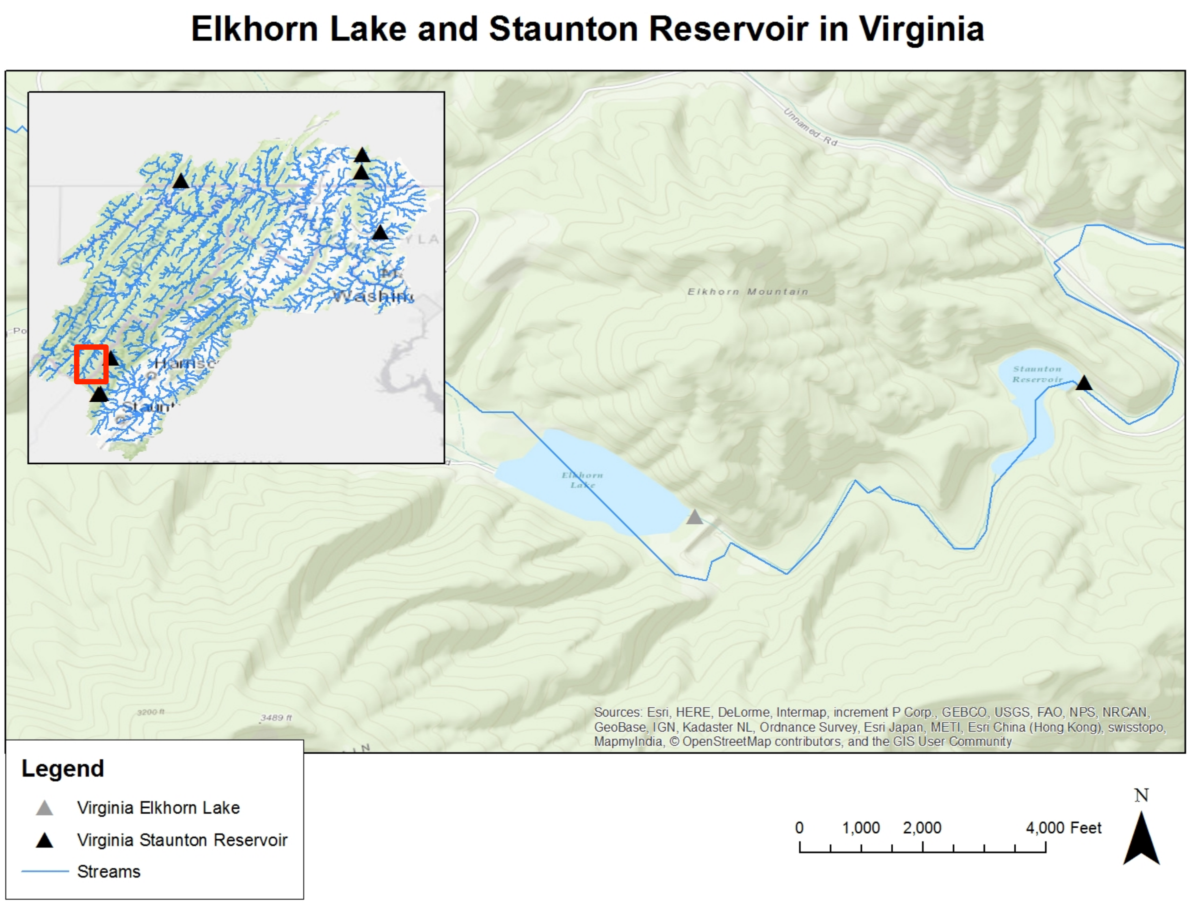
Staunton is located in Augusta County and was established in 1761. After the city was established, the population started growing. By 1850, the population grew to 2,500. Since the city served a Southern army base by 1870 the population doubled in size. In 1905, when the city joined Augusta County, the population grew to 11,000 people. According to the 2015 US Census, the population is 24,416.

In the 2010-2030 Comprehensive Plan it states their two main sources of water are Gardner Springs and Staunton Dam connecting with Elkhorn Lake Dam. Elkhorn and Staunton supplies 1.7 MGD of water. On the other hand, Gardner Springs located near Frank's Mill and Middle River provides 6 MGD of water supply. In 1951, the water treatment plant was built and in 1977 it was enlarged. At that time it provided about 8 MGD.

Table 2.1.2a: City of Staunton Water Supply

Sources	Water Supply (MGD)
Gardner Springs	6
Staunton and Elkhorn Reservoirs	1.7

Map 2.1.2a: Staunton and Elkhorn Reservoirs



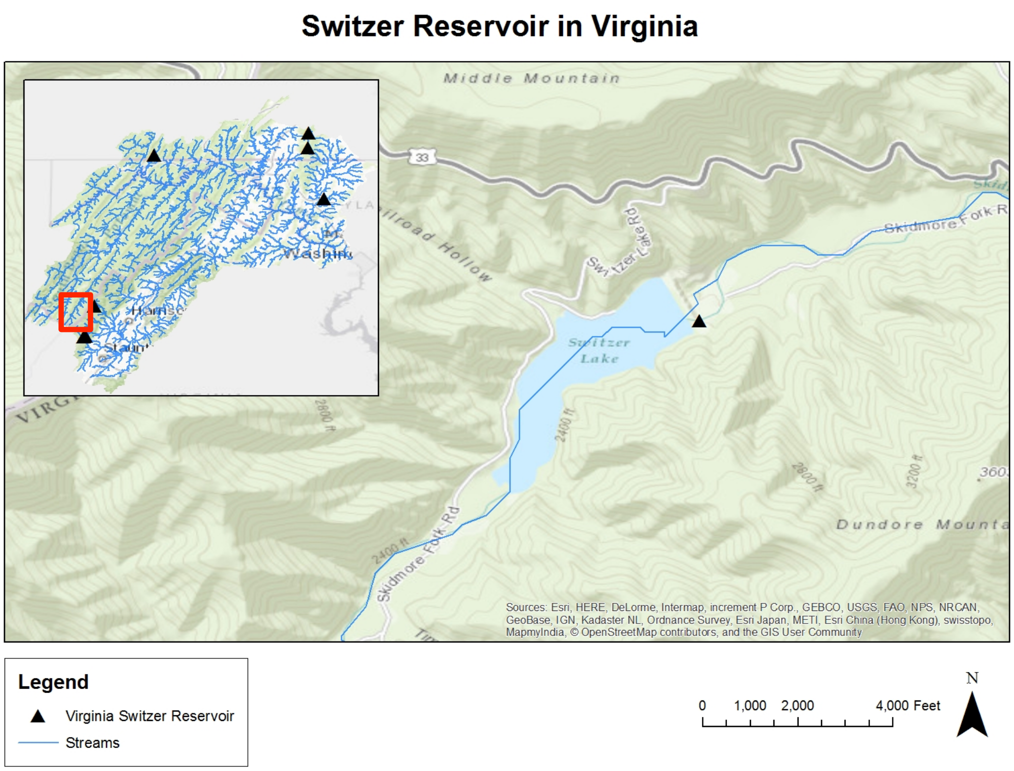
2.1.2b City of Harrisonburg

The City of Harrisonburg withdrawals water from two main sources Rawley Springs, which includes Switzer Reservoir; and finally North River. Based on the 2015 WQR, Switzer Reservoir supplies about 4 MGD, excluding drought periods. North River supplies 7.5 MGD with 5.5 MGD for drought periods. According to the 2011 Comprehensive Plan, during drought periods and without the availability of Switzer Dam, the source capacity is 6.9 MGD. However, the city's current demand is about 8.54 MGD. The current capacity is way below the actual demand. Therefore, the city is starting a new project. This project consists of upgrading the existing water line from Rawley Springs. The project will also involve constructing a new water line from the Shenandoah River into the water treatment plant. They are predicting a future city demand of 14.26 MGD. Therefore, with the new system it will reach a capacity of 15 MGD.

Table 2.1.2b: City of Harrisonburg Water Supply

Sources	Water Supply (MGD)
Dry Run and Switzer Reservoirs	4
North River	7.5

Map 2.1.2b: Switzer Reservoirs

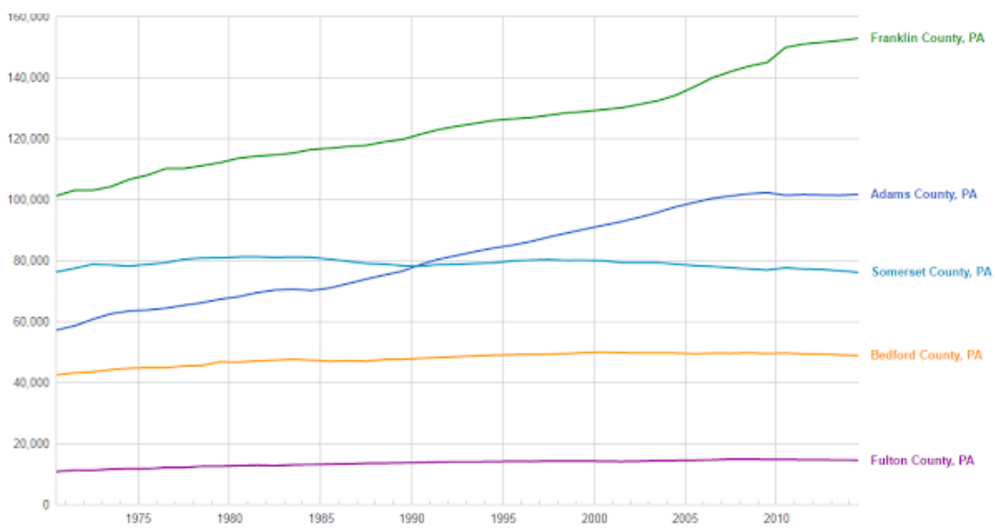


2.1.3 Pennsylvania Reservoirs

Similarly, Pennsylvania's major water supply sources are wells. From the following counties: Adams, Franklin, Fulton, Bedford, and Somerset only four reservoirs were selected for this study. Listed below are the four reservoirs and their locations.

1. Long Pine Run is located in Adams County and is owned and operated by the Borough of Chambersburg.
2. Antietam Creek Reservoir also known as Waynesboro Reservoir is located in Adams County and is owned and operated by the Waynesboro Borough Authority in Borough of Waynesboro.
3. Thomas W. Koon Reservoir is connected to Lake Gordon and they are located in Bedford County. They are operated and owned by Evitts Creek Water Company and managed by the City of Cumberland.

Below is a graph showing the population growth from 1970- 2015 of Pennsylvania counties upstream on the Potomac River Basin.



Graph 3: Pennsylvania Counties Population Increase

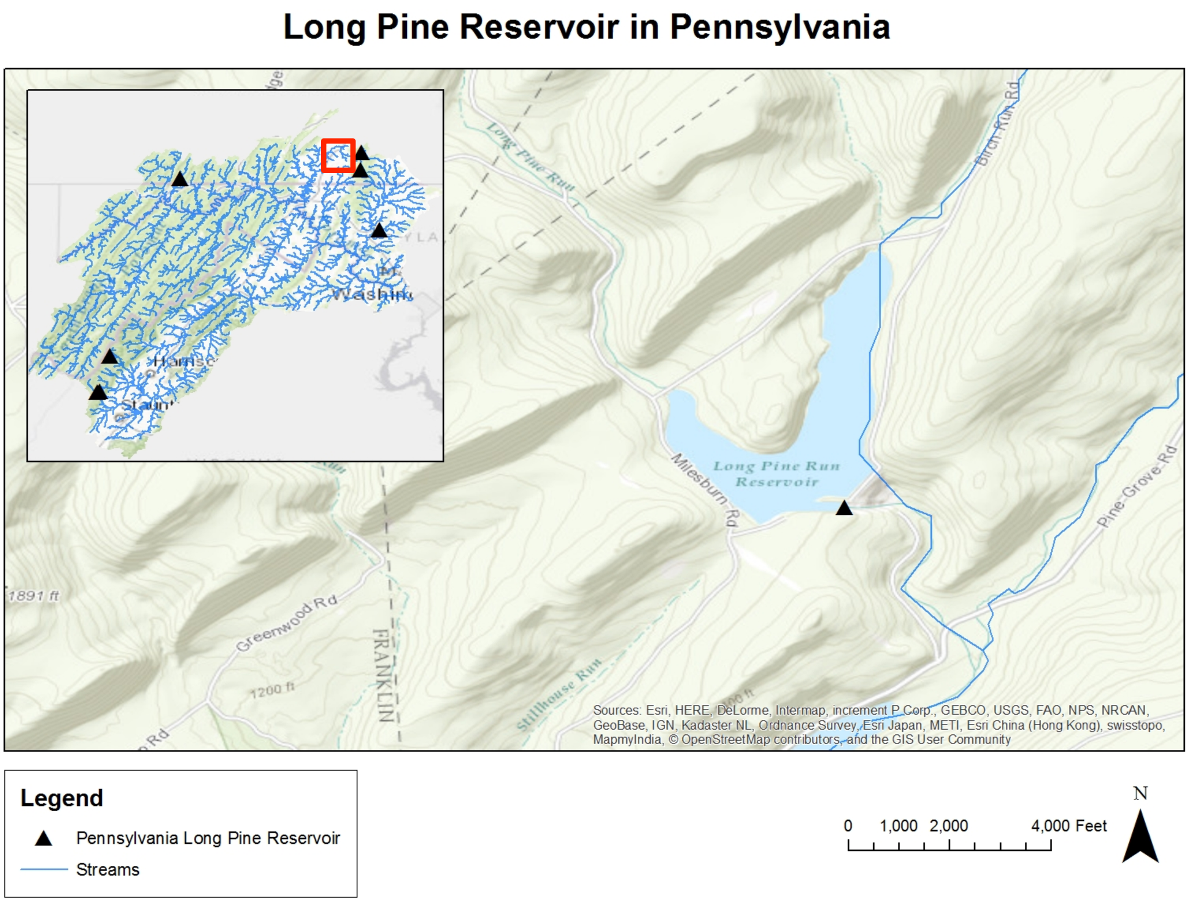
2.1.3a Borough of Chambersburg

The Borough of Chambersburg is situated in Franklin County and was incorporated in 1803 by an Act of the State Legislators. Chambersburg has its own water system operated by the Borough, unlike other municipalities which are operated by an Authority. According to their 2016 WQR their main water source is Long Pine Run Reservoir. Long Pine Reservoir is within the Conococheague Creek Watershed. Based on the CorpsMap information, the reservoirs capacity is 2.44 billion gallons (BG) In contrast, the municipalities WQR states that Long Pine can store up to 1.8 BG. The water treatment plant in Fayetteville, PA treats 6 MGD with an average production of 4 MGD.

Table 2.1.3a: Borough of Chambersburg Water Supply

Sources	Water Supply (MGD)
Long Pine Run Reservoir	4

Map 2.1.3a: Long Pine Run Reservoirs



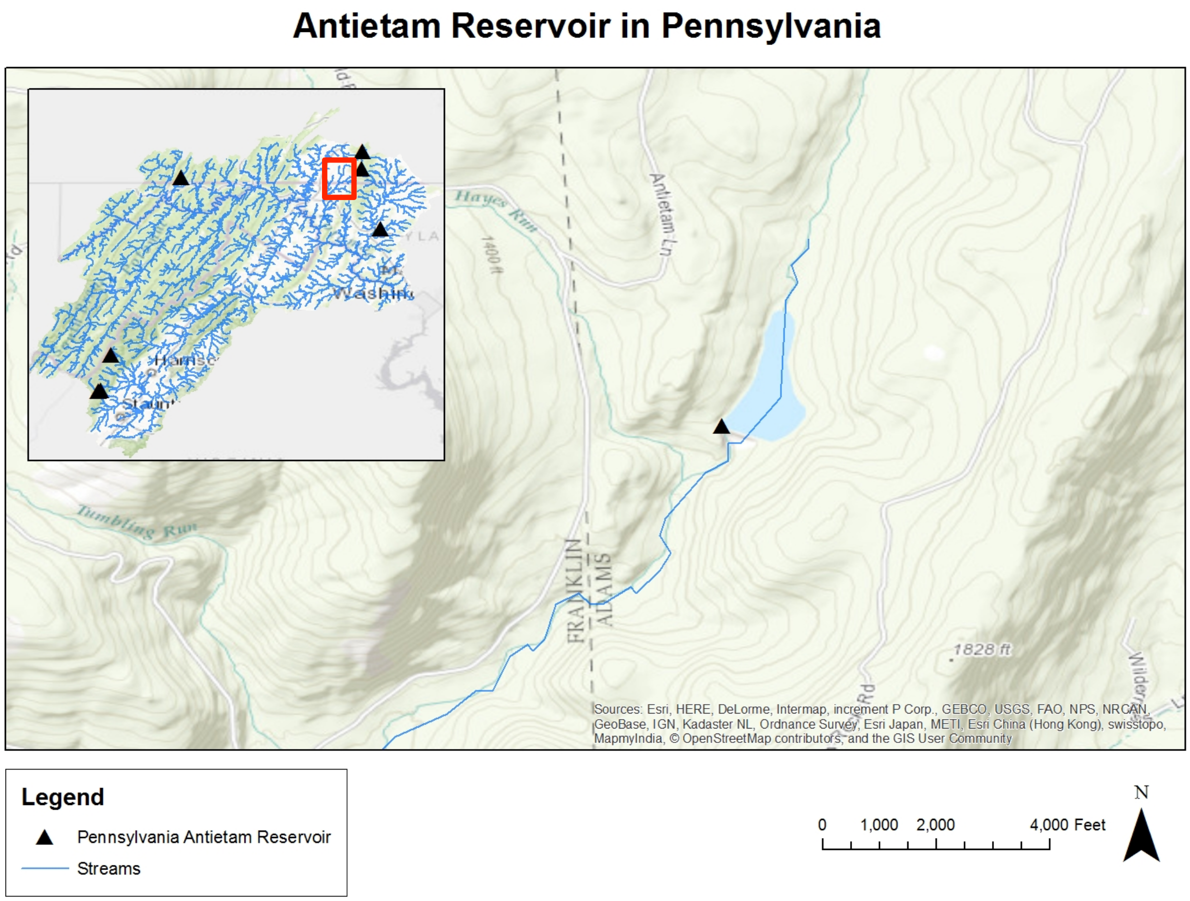
2.1.3b Borough of Waynesboro

The Borough of Waynesboro is also located in Franklin County and was incorporated in 1818. In Waynesboro 2016 WQR it states that their primary water source is Antietam Creek Reservoir. The reservoir is situated within the Antietam Creek Watershed on the Appalachian Highlands Region surrounded by green forest land cover. Antietam Creek Reservoir supplies approximately 4 MGD and has a storage capacity of 150 MG.

Table 2.1.3b Borough of Waynesboro Water Supply

Sources	Water Supply (MGD)
Antietam Creek Reservoir	4

Map 2.1.3b: Antietam Reservoirs



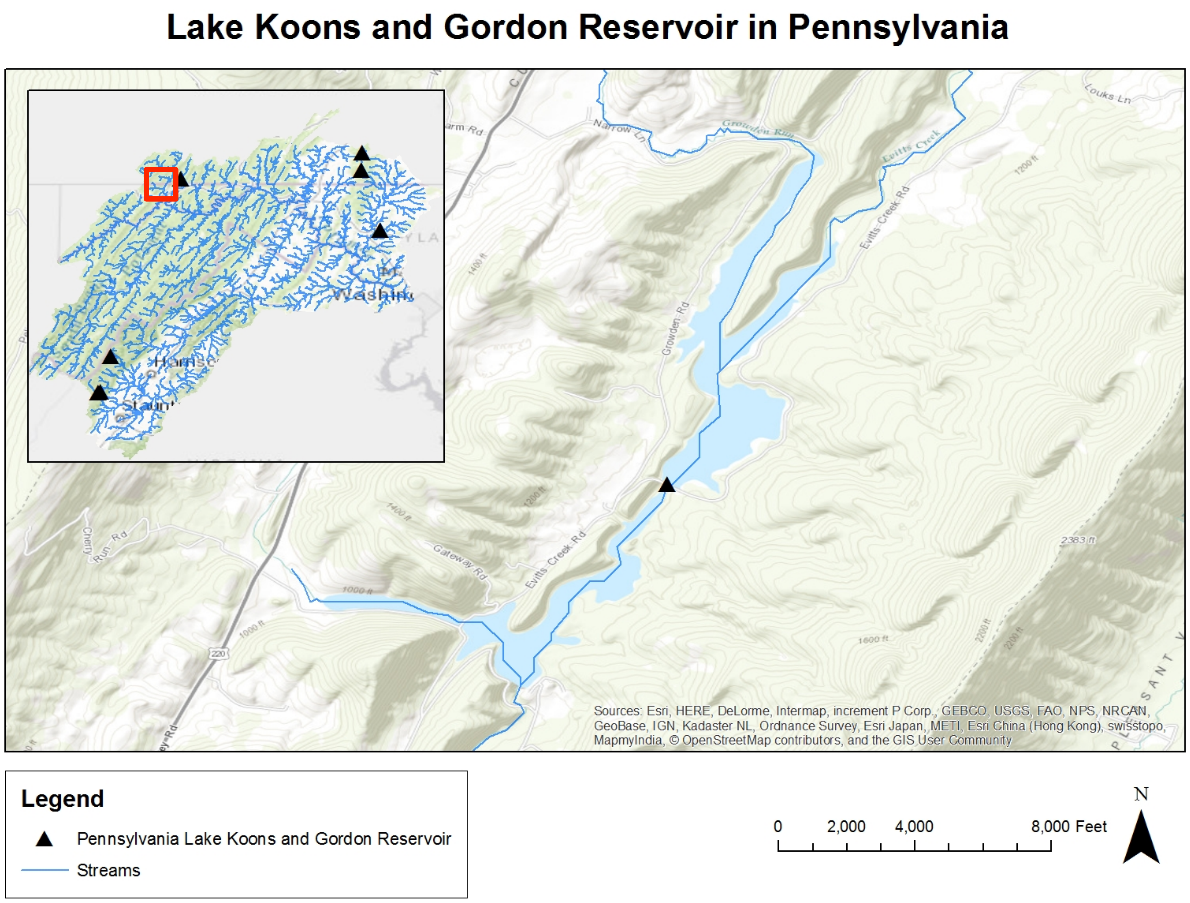
2.1.3c City of Cumberland

The City of Cumberland is located Bedford County, Pennsylvania. Cumberland's main source of water is Lake Koon and Gordon. These reservoirs are located within the Evitts Creek Watershed. According to the 2013 Comprehensive Plan, Lake Koon has a storage capacity of 2.2 BG which feeds into Lake Gordon. Lake Gordon has a storage capacity of 1.2 BG. The lakes have a combined inflow rate of 30 MGD. The plan also states that the reservoirs have a permitted withdrawal of 15 MGD and a maximum safe yield of 16 MGD. A total of seven storage tanks are maintained with a total capacity of 7.8 million gallons. The average system demand is approximately 6.1 MGD. In the service capacity analysis from Comprehensive Plan, they looked into population growth and future water demands. The city concluded that the future water demand would still not exceed the current capacity of 12 MGD.

Table 2.1.3c: City of Cumberland Water Supply

Sources	Water Supply (MGD)
Lake Koons and Gordon	6.1
- Residential (2007-2011)	1.5
- Outside Contract Customers (2007-2011)	4.6

Map 2.1.3c: Lake Koons and Gordon

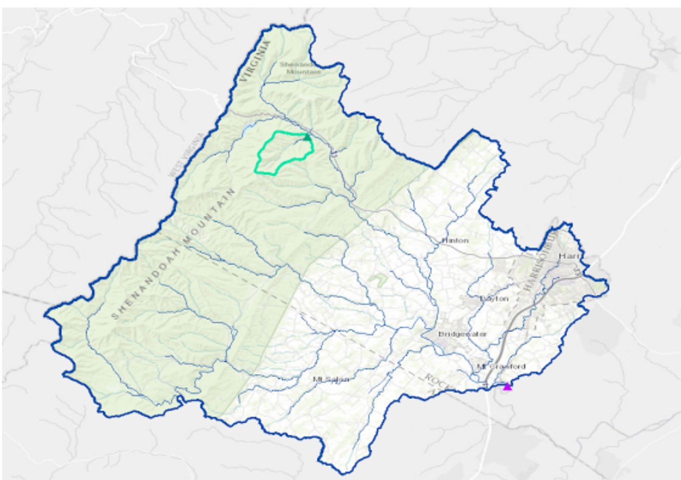


2.3 HYDROLOGIC STUDY

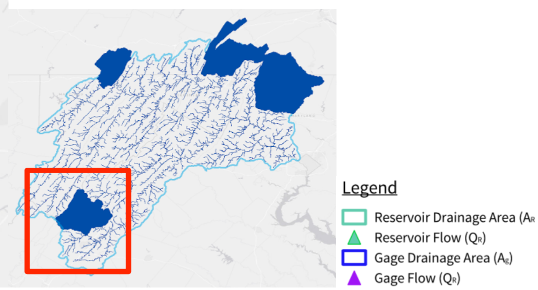
All of the reservoirs in this study were ungaged sites. In order to determine discharge data into the reservoirs, a streamflow estimation method (Eq 1.1) was used. This method involves using the closet gage site, with similar watershed characterizes as the reservoir. The reservoir watershed and the gage watershed areas were very important input values. The reservoir watershed area was computed using USGS StreamStats Ver. 4. Gage sites selected had data dating back to 1930. The gages needed to date back to 1930 because it is one of the worst drought periods recorded. Drought data from 1930, 1966, 1999, and 2002 was later used to determine a safe yield for each reservoir.

$$Q_R = Q_g(A_R/A_g) \tag{Eq 1.1}$$

Below is a demonstration of how an inflow was estimated for each reservoir.



Sub Map 3.0: Gage Watershed and Reservoir Watershed



Map 3.0: Gage Watersheds

2.4 SAFE YIELD

Drought analysis can help dictate the amount of storage needed and the time duration for water to be released, to keep flow in its natural state (Swartz et al. 2008). Using this same approach it can help analyze upstream reservoir storage. A safe yield calculation will determine a maximum capacity for the reservoir during dry periods. For example a water balance formulation was used to determine the Beginning of Day Storage which would then be used to determine the Safe Yield. This water balance procedure was done for all drought periods (1930, 1966, 1999, and 2002). One parameter that was difficult to find on the municipalities website was the reservoirs minimum release value. If we had the minimum release value we would obtain an even more accurate safe yield value. Lake Linganore is the only reservoir that has a minimum release value.

In order to determine the safe yield we must determine the largest demand value for which the storage remains above zero. But in this case we decided to keep the storage above 10% of storage capacity. We used Excel Solver to determine the safe yield.

STAUNTON RESERVOIR WATER BALANCE:

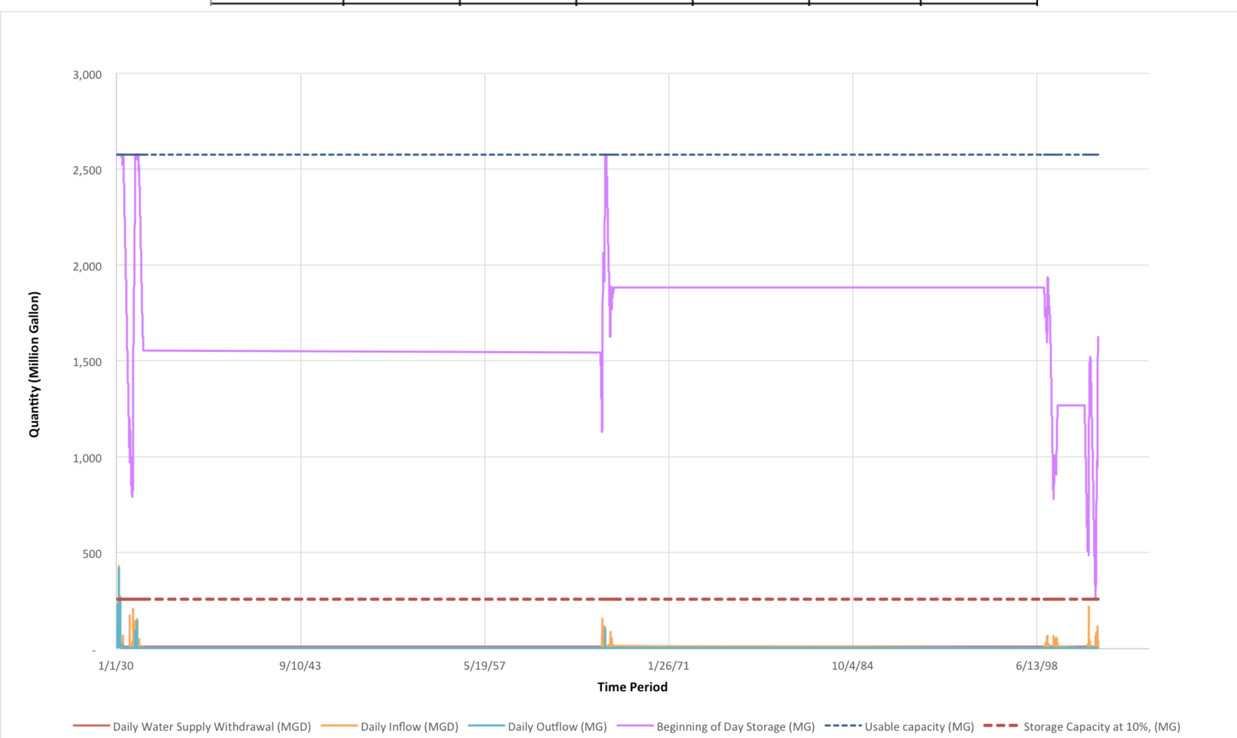
Capacity at 10%, MG:	355.7	
Reservoir usable capacity, MG:	3,557	
Reservoir starting storage, MG:	3,557	<- can pick any starting storage
Daily demand, MGD:	2	
Safe Yield, MGD:	10	
Minimum release, MGD:	0.0	
Minimum release, MG:	-	

Maximum	10	152	24	24	3,557	
Average	10	9	0	0	2,073	
Minimum	10	1	-	-	356	
Time	Daily Water Supply Withdrawal (MGD)	Daily Inflow (MGD)	Daily Overflow (Spill) (MG)	Daily Outflow (MG)	Beginning of Day Storage (MG)	Usable capacity (MG)
	Wi	Qin	Qspill	Qout	Si+1	Si
1/1/30	10	19	8	8	3,557	3,557
1/2/30	10	17	7	7	3,557	3,557
1/3/30	10	15	4	4	3,557	3,557
1/4/30	10	14	4	4	3,557	3,557
1/5/30	10	13	2	2	3,557	3,557
1/6/30	10	13	2	2	3,557	3,557
↓	↓	↓	↓	↓	↓	↓

2.4.1 Lake Linganore

A total safe yield of **9.06 MGD** was calculated. Out of all the reservoirs, we were only able to find the minimum release for Lake Linganore.

LAKE LINGANORE WATER BALANCE						
Capacity at 10%, MG:		257.4				
Reservoir usable capacity, MG:		2,574				
Reservoir starting storage, MG:		2,574	<- can pick any starting storage			
Daily demand, MGD:		2.87				
Safe Yield, MGD:		9.06				
Minimum release, MGD:		3.7				
Minimum release, MGD:		3.7				
Maximum	9	430	421	421	2,574	
Average	9	16	5	8	1,661	
Minimum	9	2	-	4	257	
Time	Daily Water Supply Withdrawal (MGD)	Daily Inflow (MGD)	Daily Overflow (Spill) (MG)	Daily Outflow (MG)	Beginning of Day Storage (MG)	Usable capacity (MG)
	Wi	Qin	Qspill	Qout	Si+1	Si
1/1/30	9	106.3	97	97	2,574	2,574
1/2/30	9	82.2	73	73	2,574	2,574
1/3/30	9	79.0	70	70	2,574	2,574
1/4/30	9	69.4	60	60	2,574	2,574
1/5/30	9	49.6	40	40	2,574	2,574
1/6/30	9	42.1	33	33	2,574	2,574
↓	↓	↓	↓	↓	↓	↓



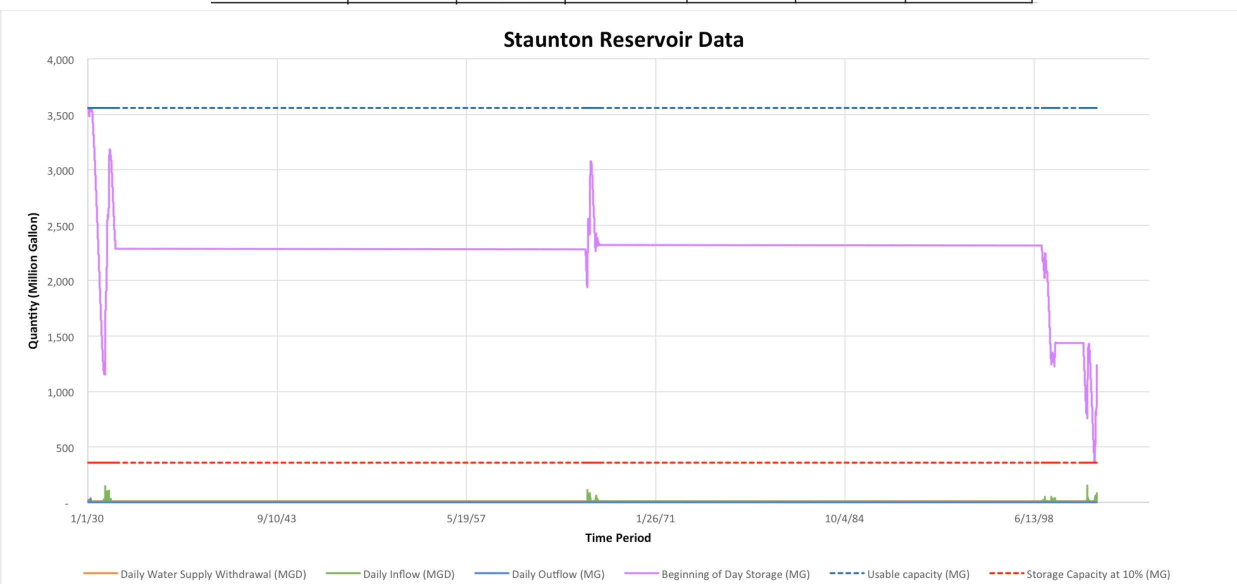
2.4.2 Staunton Reservoir

A total safe yield of **10 MGD** was obtained for Staunton Reservoir.

STAUNTON RESERVOIR WATER BALANCE:

Capacity at 10%, MG:	355.7	
Reservoir usable capacity, MG:	3,557	
Reservoir starting storage, MG:	3,557	<- can pick any starting storage
Daily demand, MGD:	2	
Safe Yield, MGD:	10	
Minimum release, MGD:	0.0	
Minimum release, MG:	-	

Time	Daily Water Supply Withdrawal (MGD)	Daily Inflow (MGD)	Daily Overflow (Spill) (MG)	Daily Outflow (MG)	Beginning of Day Storage (MG)	Usable capacity (MG)
Maximum	10	152	24	24	3,557	
Average	10	9	0	0	2,073	
Minimum	10	1	-	-	356	
	Wi	Qin	Qspill	Qout	Si+1	Si
1/1/30	10	19	8	8	3,557	3,557
1/2/30	10	17	7	7	3,557	3,557
1/3/30	10	15	4	4	3,557	3,557
1/4/30	10	14	4	4	3,557	3,557
1/5/30	10	13	2	2	3,557	3,557
1/6/30	10	13	2	2	3,557	3,557

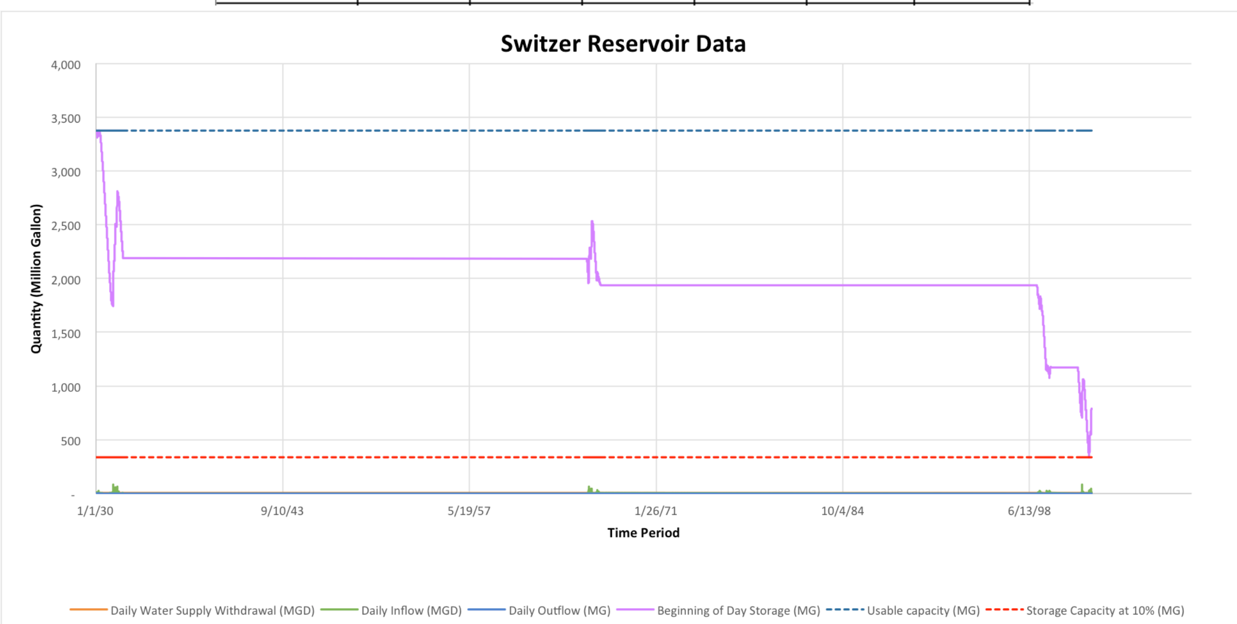


2.4.3 Switzer Dam

A safe yield of **7 MGD** was determined for Switzer Dam.

SWITZER RESERVOIR WATER BALANCE		
Capacity at 10%, MG:	337.5	
Reservoir usable capacity, MG:	3375	
Reservoir starting storage, MG:	3375	<- can pick any starting storage
Daily demand, MGD:	4	
Safe Yield, MGD:	7	
Minimum release, MGD:	0.0	
Minimum release, MG:	0	

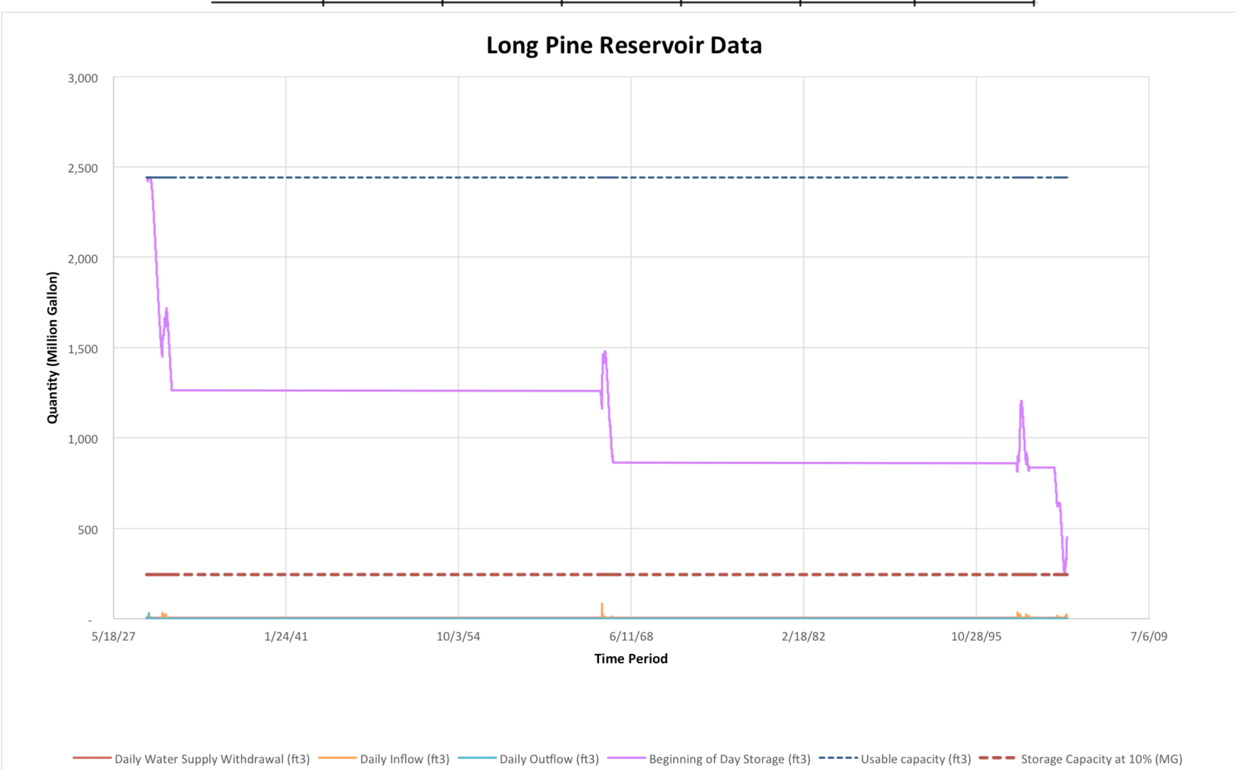
Time	Daily Water Supply Withdrawal (MGD)	Daily Inflow (MGD)	Daily Overflow (Spill) (MG)	Daily Outflow (MG)	Beginning of Day Storage (MG)	Usable capacity (MG)
Maximum	7	86	6	6	3,375	
Average	7	5	0	0	1,929	
Minimum	7	0	-	-	337	
	Wi	Qin	Qspill	Qout	Si+1	Si
1/1/30	7	11	4	4	3,375	3,375
1/2/30	7	10	3	3	3,375	3,375
1/3/30	7	8	2	2	3,375	3,375
1/4/30	7	8	2	2	3,375	3,375
1/5/30	7	7	1	1	3,375	3,375
1/6/30	7	7	1	1	3,375	3,375



2.4.4 Long Pine Reservoir

A total safe yield of **3.93 MGD** was calculated for Long Pine Reservoir.

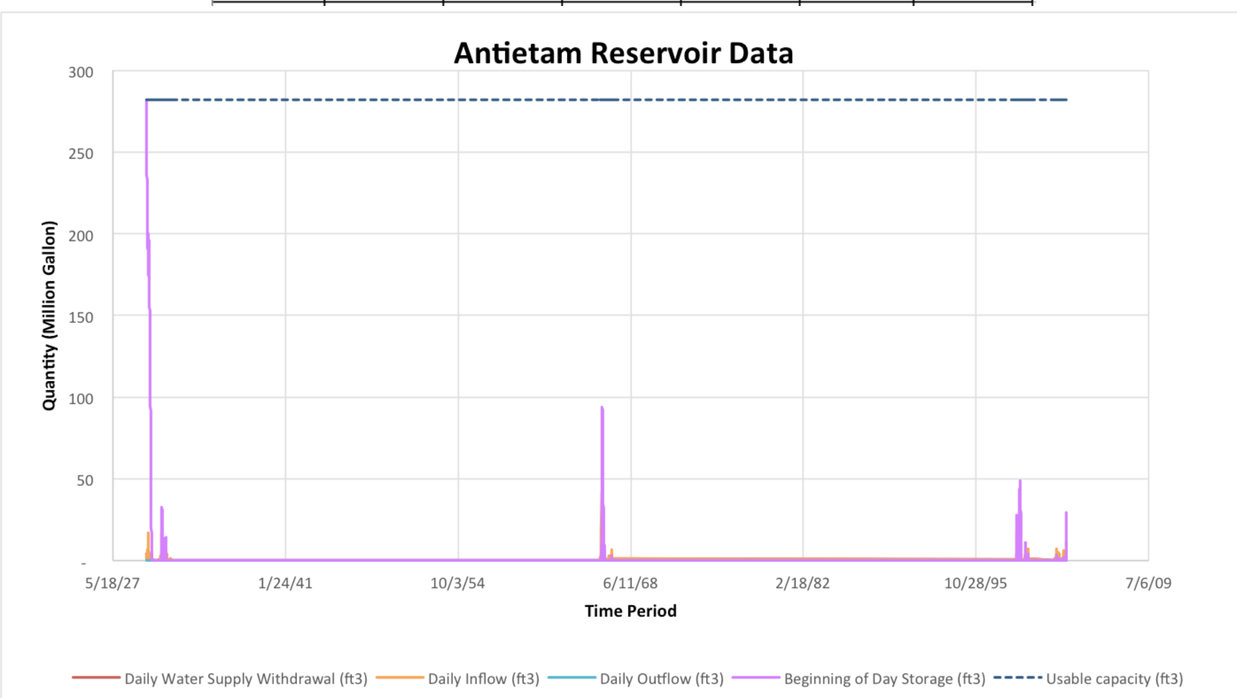
LONG PINE RESERVOIR WATER BALANCE						
Capacity at 10%, MG:		244.1				
Reservoir usable capacity, MG:		2441				
Reservoir starting storage, MG:		2441	<- can pick any starting storage			
Daily demand, MGD:		4				
Safe Yield, MGD:		3.93				
Minimum release, MGD:		0.0				
Minimum release, MG:		0				
Maximum	4	84	30	30	2,441	
Average	4	3	0	0	1,294	
Minimum	4	0	-	-	244	
Time	Daily Water Supply Withdrawal (MGD)	Daily Inflow (MGD)	Daily Overflow (Spill) (MG)	Daily Outflow (MG)	Beginning of Day Storage (MG)	Usable capacity (MG)
	Wi	Qin	Qspill	Qout	Si+1	Si
1/1/30	4	7.22	3	3	2,441	2,441
1/2/30	4	6.95	3	3	2,441	2,441
1/3/30	4	6.69	3	3	2,441	2,441
1/4/30	4	6.16	2	2	2,441	2,441
1/5/30	4	5.12	1	1	2,441	2,441
1/6/30	4	4.62	1	1	2,441	2,441



2.4.5 Antietam Reservoir

A total safe yield of **4 MGD** was calculated for Antietam Reservoir.

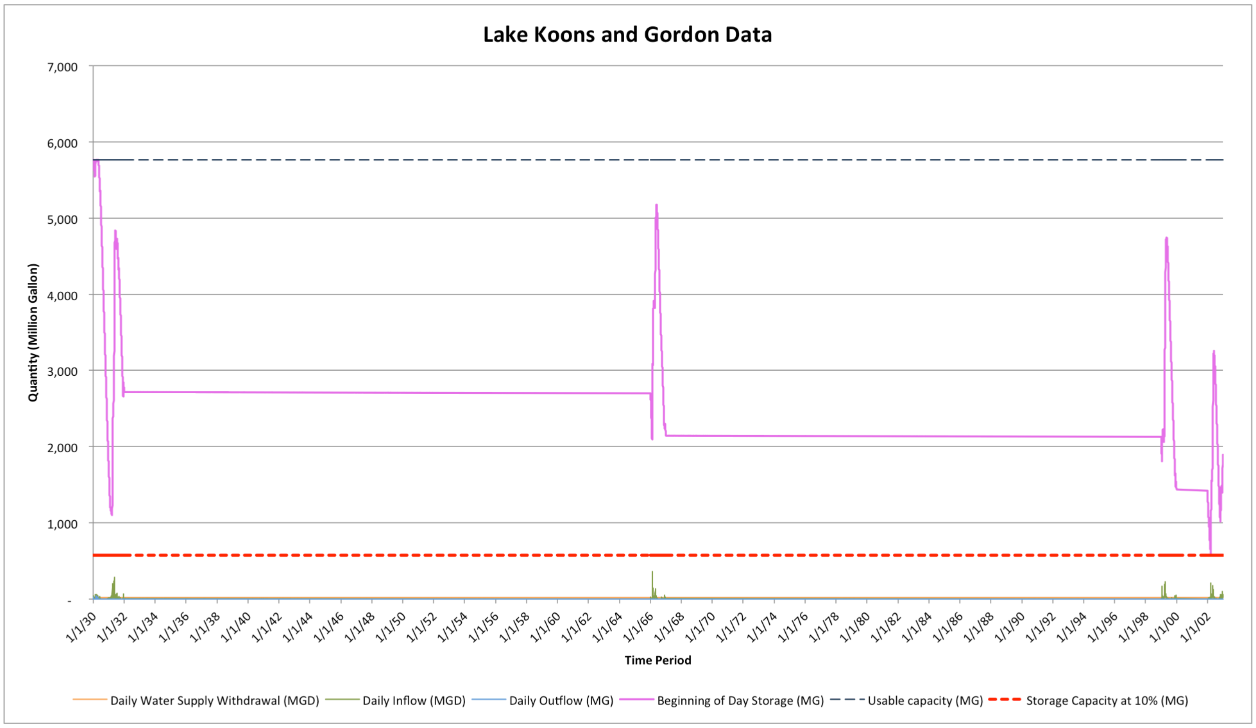
ANTIETAM RESERVOIR WATER BALANCE						
Capacity at 10%, MG:		28.2				
Reservoir usable capacity, MG:		282				
Reservoir starting storage, MG:		282	<- can pick any starting storage			
Daily demand, MGD:		4				
Safe Yield, MGD:		4.0				
Minimum release, MGD:		0.0				
Minimum release, MG:		-				
Maximum	4	41	-	-	282	
Average	2	1	-	-	19	
Minimum	0	0	-	-	-	
Time	Daily Water Supply Withdrawal (MGD)	Daily Inflow (MGD)	Daily Overflow (Spill) (MG)	Daily Outflow (MG)	Beginning of Day Storage (MG)	Usable capacity (MG)
	Wi	Qin	Qspill	Qout	Si+1	Si
1/1/30	4	3.58	-	-	282	282
1/2/30	4	3.45	-	-	282	282
1/3/30	4	3.32	-	-	281	282
1/4/30	4	3.05	-	-	280	282
1/5/30	4	2.54	-	-	279	282
1/6/30	4	2.29	-	-	278	282



2.4.6 Lake Thomas Koon and Lake Gordon

A safe yield of **20.2 MGD** was obtained for Lakes Koon and Gordon.

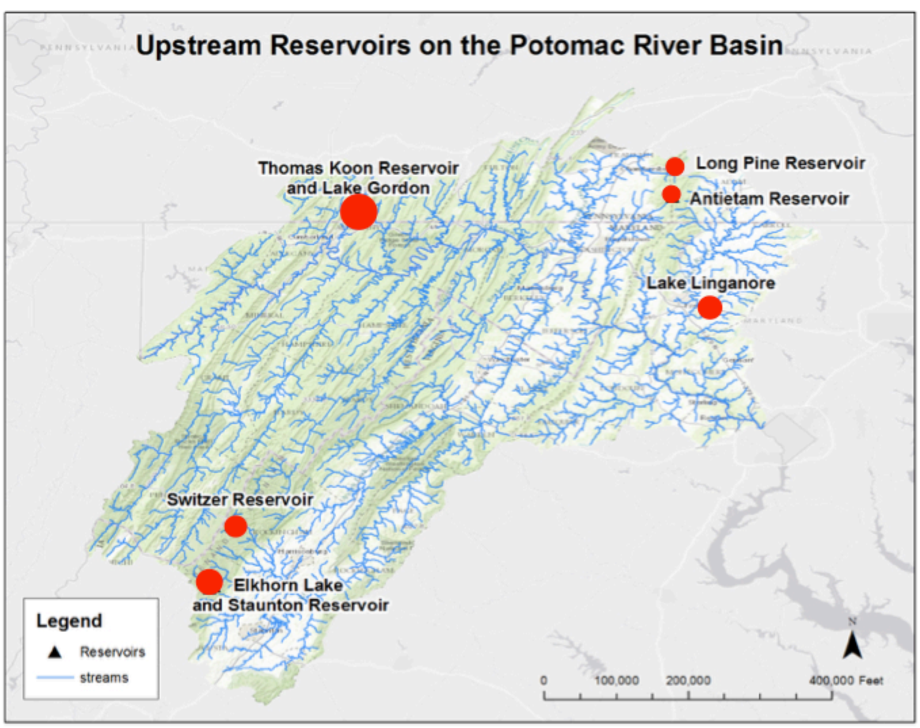
LAKE KOONS AND GORDON WATER BALANCE						
Capacity at 10%, MG:		576.4				
Reservoir usable capacity, MG:		5764				
Reservoir starting storage, MG:		5764	<- can pick any starting storage			
Daily demand, MGD:		6.1				
Safe Yield, MGD:		20.2				
Minimum release, MGD:		0.0				
Minimum release, MG:		0				
Maximum	20	361	41	41	5,764	
Average	20	19	1	1	3,183	
Minimum	20	1	-	-	576	
Time	Daily Water Supply Withdrawal (MGD)	Daily Inflow (MGD)	Daily Overflow (Spill) (MG)	Daily Outflow (MG)	Beginning of Day Storage (MG)	Usable capacity (MG)
	Wi	Qin	Qspill	Qout	Si+1	Si
1/1/30	20	36.91	17	17	5,764	5,764
1/2/30	20	38.82	19	19	5,764	5,764
1/3/30	20	45.80	26	26	5,764	5,764
1/4/30	20	44.56	24	24	5,764	5,764
1/5/30	20	38.82	19	19	5,764	5,764
1/6/30	20	35.28	15	15	5,764	5,764
↓	↓	↓	↓	↓	↓	↓



3. CONCLUSION

As demonstrated in the report, due to an increase in population upstream and excessive withdrawals during drought periods the Washington Metropolitan Area is at risk. The goal of this study was to quantify and determine if upstream reservoirs mitigate consumptive use (water supply). If we add up all the safe yield values calculated in this study we are able to determine how much water would be mitigated. In conclusion, a total of 54.26 MGD of water can still potentially be used. Therefore, this information is very useful for water utility companies. The below table shows the total safe yield:

SAFE YIELD		
#	**Dam Name**	**Safe Yield (MGD)**
1	Staunton & Elkhorn Reservoir	10
2	Switzer Reservoir	7
3	Lake Linganore	9.06
4	Long Pine Run Reservoir	4
5	Antietam Reservoir	4
6	Lake Thomas W. Koon & Lake Gordon	20.2
	Total Safe Yields:	**54.26**



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