A STUDY ON THE RELIABLE DROUGHT YIELDS OF POOLESVILLE'S PUBLIC WATER SUPPLY WELLS, MONTGOMERY COUNTY, MARYLAND

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THE TEAM

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Pat Hammond has been a hydrogeologist with the Maryland Department of the Environment for 35+ years. Extensive studies lead for the MDE include aquifer research throughout the state and most recently he was the lead researcher on an MDE report entitled "*The Effects of Climate Change on Maryland's Water Supplies*."

ROBERT TWORKOWSKI

Bob Tworkowski is an upcounty Montgomery resident and hydrogeologist working as an environmental manager in a number of different capacities, most recently the remediation of the former Sparrows Point steel plant in Baltimore.

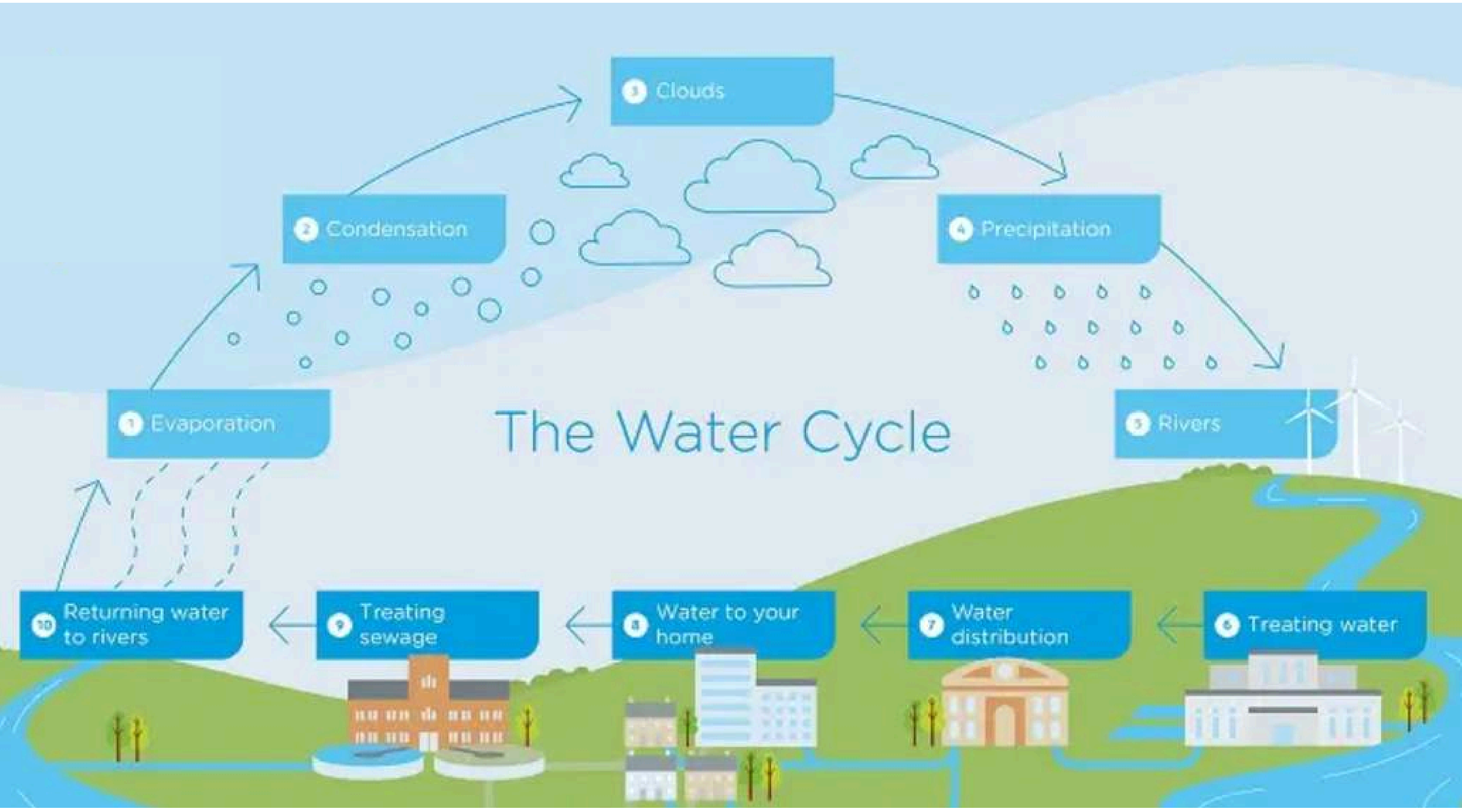
MONTGOMERY COUNTRYSIDE ALLIANCE

Since 2001 MCA has promoted and protected Montgomery County's Agricultural Reserve - 93,000 acres of land set aside for agriculture and resource protection - a nationally lauded preservation model. MCA's mission includes protection of the county's shared water resources including the Potomac watershed and groundwater aquifer.

PREFACE

Bob Tworkowski
Hydrogeologist

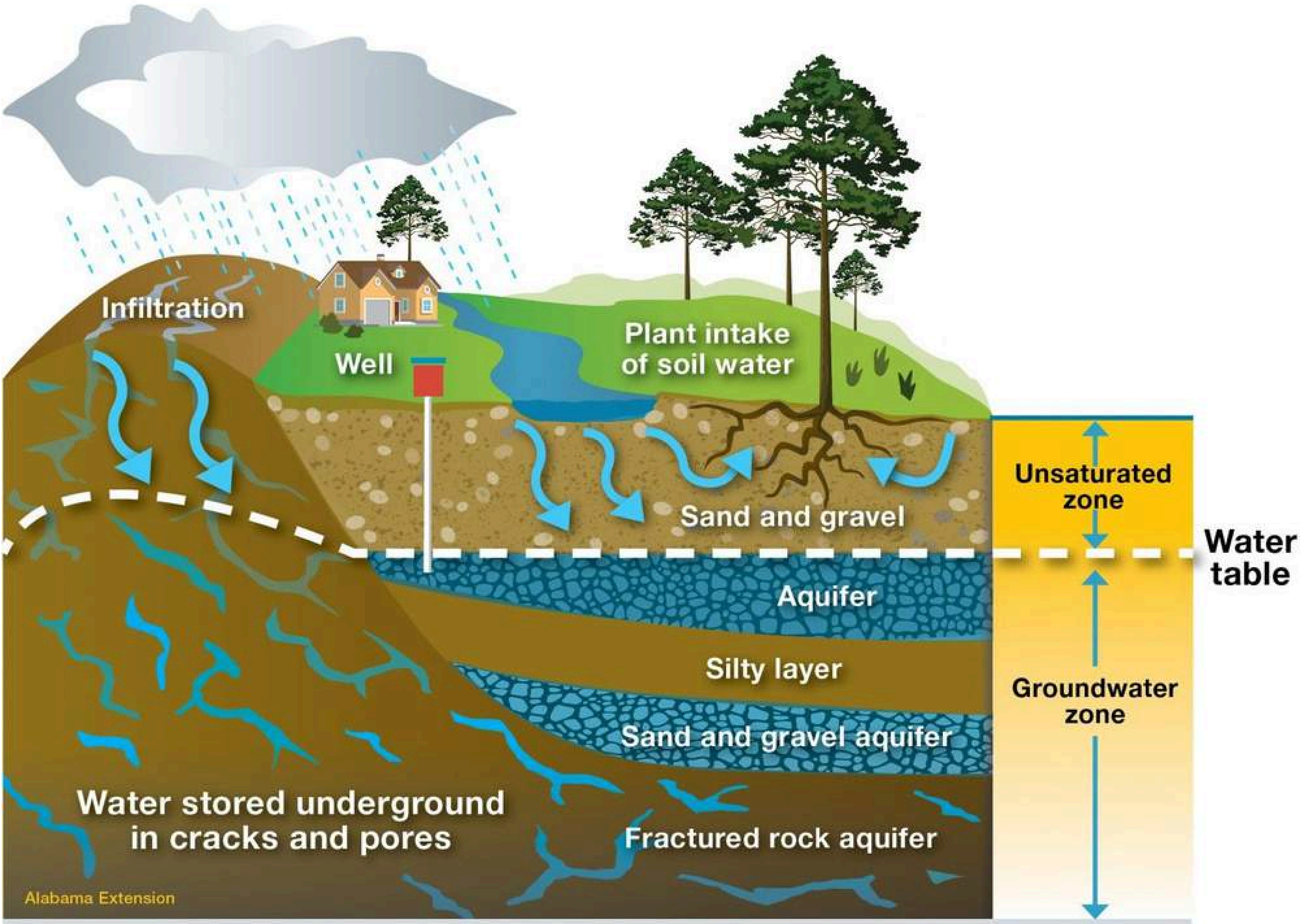
Nature is made up of multiple cycles, many of which have been repeating since our planet began. One that has always fascinated me is the water cycle. The finite supply of water – no more or less than we started with, is constantly being recycled to meet ever growing demand. A finite supply with infinite demand leads to a fragile balance. A primer on a water drop's journey – we learn the water cycle begins with precipitation where water in many forms falls from the sky and runs off into surface water (streams, rivers, oceans) to evaporate back into the clouds and rain down again, completing the cycle.



Thames Water Utility

The water cycle in a municipal water system

Less well known is the journey underground. Water falling on permeable surfaces (fields, forests) can sink into the ground and join up with other water in the sub surface which forms a water bearing zone that is called an **aquifer**. Aquifers are like nature's way of saving money in the bank – a limited sum of money/water that is being held in storage that can be tapped into and used. But just like a bank account it can be overdrawn and resulting problems can ensue.



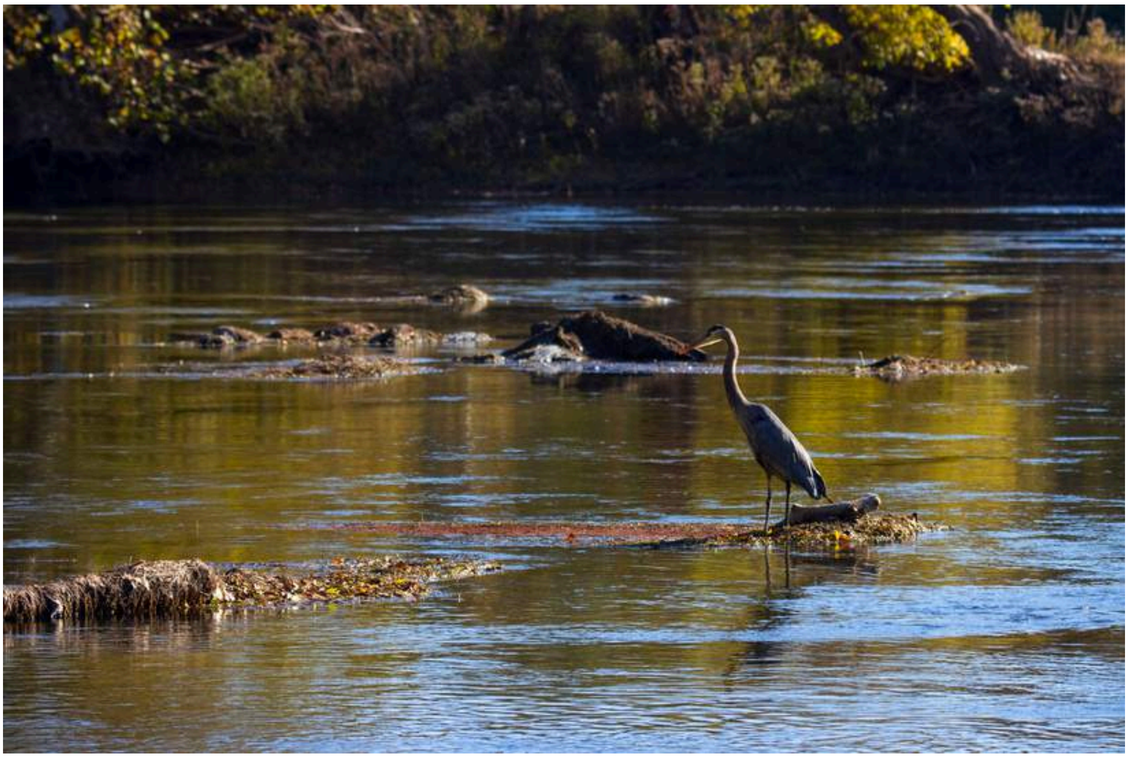
Alabama Extension

There are different types of aquifers. Montgomery County has a fractured rock aquifer, also called an "unconfined" aquifer

Presently about 115 million people—more than one-third of the Nation's population—rely on groundwater for drinking water. Since aquifers are typically recharged from water sinking directly in from the ground surface this makes them very prone to contamination as the surficial water can come in contact with and mix with many items compromising its quality. These are referred to as **unconfined aquifers.**

Aquifers can be very extensive, or they can be limited to a specific area due to various geographical factors and are referred to as watersheds. If a valley is bounded by some mountains – the valley will likely have a water bearing zone beneath it (an aquifer) that has a defined boundary. People using this aquifer may have no other source of water for their needs and such an aquifer can be referred to as a sole source aquifer. To further the metaphor, this type of aquifer is a bank with no overdraft protection.

The delicate balance between recharge and withdrawal as well as maintaining the purity of the resource is the subject of this paper. As the population creates more demand on the resource these issues need to be managed.



Susan Petro

Maryland's Piedmont Sole Source Aquifer has both of these characteristics – an aquifer that is both unconfined and sole source. The municipality of Poolesville as well as surrounding areas lie entirely within, and rely upon, this aquifer. (Aquifer border in green in the map below.)

The delicate balance between recharge and withdrawal as well as maintaining the purity of the resource is the subject of this paper. As the population creates more demand on the resource these issues need to be managed. Recharge is typically based on and includes the natural precipitation cycle, land use patterns and engineering controls.

The purity of the resource is addressed through regulatory compliance, education, waste management, housekeeping etc. There are limitations on what the aquifer can produce and if we extract more from it without proper management and planning, we will compromise the resource and jeopardize those that are already using it. The sole source aquifer designation is taken very seriously to the point that projects constructed in that area that receive federal funding are subject to EPA review to ensure that the project will not compromise the integrity of the resource which may create a hazard to the public.

Susan Petro

There are limitations on what the aquifer can produce and if we extract more from it without proper management and planning, we will compromise the resource and jeopardize those that are already using it.

Expanding development in a sensitive area such as this sole source aquifer is a serious concern and needs to be evaluated prior to it being permitted. This paper seeks to evaluate whether additional withdrawal from the aquifer is possible without having negative short/long term effects. This evaluation is performed through reviewing baseline data and then extrapolating it out – modeling it to see what may come of it. This paper also includes a view into the future and evaluates how global warming is predicted to affect this cycle and what conditions we may need to prepare for. The weather patterns we see today may not be the same in the coming years. So how do we prepare for them/anticipate them?

Wood Ducks on the C+O Canal - Susan Petro

It is expected that there may be swings in the weather patterns unlike today's more moderate fluctuations that will be more subject to heavy precipitation deluges, higher temperatures and prolonged droughts. How to plan for such items on a regional/global basis is a big question and outside the scope of this study. However, to be aware of these future concerns and bring them into the planning stage now on a more local basis is of paramount concern.

We need to continue to explore water conservation opportunities through expanding our public outreach/education and we need to look into the feasibility of recycling our water resource through such programs as reuse of treated municipal waste water. This will help offset our demand and make room for future use. This paper stands as just one example of the studies that will be required to maintain a fragile resource in order to benefit our future generations. We have the knowledge, and it is time that we show that on an individual and societal level we make decisions that fully embrace the facts underlying that knowledge in order to ensure the future security of our critical water resource.

Marking Flood Waters at White's Ferry

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Multiply	By	To obtain
Length		
inch (in)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square foot (ft^2)	0.0929	square meter (m^2)
square mile (mi^2)	2.59	square kilometer (km^2)
Volume		
gallon (gal)	3.785	liter (l)
gallon (gal)	3.785×10^{-3}	cubic meter (m^3)
Discharge Rate		
gallon per minute (gpm)	0.063	liter per second (l/s)
gallon per minute (gpm)	3.785	liter per minute (l/min)
Production Rate		
gallon per day (gpd)	3.785×10^{-3}	cubic meter per day (m^3/d)
Annual average use gallons per day gallons per day average (gpd avg)		
Use during the month of maximum use gallons per day maximum (gpd max)		
Transmissivity		
gallon per day per foot (gal/d-ft)	0.0124	square meter per day (m^2/d)
square foot per day (ft^2/d)	0.0929	square meter per day (m^2/d)

Use of notation: As close as possible, the original scientific or mathematical notations of any papers discussed have been retained, in case a reader wishes to review those studies.

KEY RESULTS

During the 1990's, the Town of Poolesville had to impose water restrictions multiple times due to declining well yields, especially in well 6. Since the droughts of 1998-1999 and 2001-2002, there have been few reported problems related to well yields due to upgrades to the system and relatively mild climatic conditions. In 2021, the town's consultant, S.S. Papadopulos & Associates, Inc. (SSP&A) completed a report concerning the ability of the system to supply a population increase from 5800 to 6500. The purpose of the present investigation is to review SSP&A report and other investigations concerning the water demand and reliable drought yield of the town's water supply. Other factors to be considered are the impacts of the water withdrawals on the resource and other users of the resource, as well as the effects of climate change on the water supply.

SSP&A assumed a current demand (2021) of 521,000 gpd avg (average use 2018-2020), a population of 5800, based on the 2020 census of 5742 and the addition of 14 new homes, at a yearly average of 90 gallons per day per capita (gpcd). It was then assumed that a population of 700 at 100 gallons per capita day (gpcd) were added for a total population of 6500. To that total demand were added 10% for a drought and 4,621 gpd avg for 30 days at 100 °F, producing a final demand of 654,621 gpd. The estimated maximum monthly use was based on the greatest recorded ratio between maximum month and annual use of 1.33 in January 2014, which was likely due to a system leak, not increased demand. To that result was added 55,000 gpd for 30 days at 100 °F, for a maximum monthly use of 919,633 gpd.

In the present evaluation, the average of the 2018-2023 reported water use 530,942 gpd avg is based on a population of 5772, including an occupancy rate of 97%. Adding 728 people at 100 gpcd, 10% for drought and 5434 gpd avg for 30 days at 100 °F, produces a total estimated demand of 669,550 gpd avg for a population of 6500. Since most of the increased demand during a drought occurs due to outdoor summertime use, the increase in the maximum monthly use would likely be more than 10%. The average maximum to average ratio during the period 2007 to 2020, that did not include a significant drought, is 1.23 to 1, reflecting average conditions. By increasing that value 15%, the ratio becomes 1.4:1. Using that ratio produces a maximum monthly demand of 937,370 gpd, to which is added 66,114 gpd for 30 days at 100 °F, for a maximum monthly demand of 1,003,484 gpd max (ratio of 1.5:1).

The well system needs to produce 699 gpm to meet maximum demand during a drought, assuming the wells operate 24 h/d. At a safe capacity of 92%, the wells would have to produce 760 gpm. Using the available operational and test data the total estimated drought yield in the present evaluation is 750 gpm, which includes interference testing between wells 2 and 12, and 9 and 10, but not well 11 with wells 6, 9 and 10, and 14 with well 4, and includes the damage to wells 6 and 7 due to dewatering of reservoir units. The estimate does not include operational efficiency, watershed limitations and effects of climate change.

The SSP&A estimate is 747 gpm, if the estimated yields in the Hammond (2021) report are used for wells 9 and 10. The close agreement with the present evaluation is primarily due to the fact that SSP&A used the Hammond (1999) estimates for wells 2-8, and wells 9 and 10 were mis-identified in that report, so the estimates for those last two wells were taken from the Hammond (2021) report.

The water balance limits withdrawals to 293,000 gpd avg in Horsepen Branch, an overallocation of 155,700 gpd avg to provide water for the existing use in 1999. A 2008 stream survey indicated the watershed was severely biologically impaired, at a lower withdrawal rate of 185,000 gpd avg. When the permit was issued, the town was notified that adjustments may be needed, if unreasonable impacts occurred. If only the over-allocation was reduced, there would be insufficient water for the town's existing use. The stream could be restored by using excess water balance capacity and additional wells in the Seneca Creek and Broad Run watersheds, which would then be sufficient to supply existing demand.

Friends of Ten Mile Creek and Little Seneca Reservoir

Using the seven applicable Interstate Commission on the Potomac River Basin (ICPRB) climate change scenarios, for the planning period from the base of 1989-1999 to 2040, the average reduction in baseflow (effective recharge to the wells) is 8.4%; however, this would be balanced by a 10% reduction in the existing water demand under average climatic conditions relative to that during a drought. During a drought the average reduction in baseflow at three stream gages on the Monocacy River and Seneca Creek is 16%. When this value is applied to the reliable average individual yields during a drought year (771,400 gpd avg) the result is a reliable system yield of 648,000 gpd avg, which does not include limitations due to the water balance and additional unidentified well interference during a drought.

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The total estimated maximum yield of the wells (2, 4, 6, 8, 11 and 14) in Horsepen Branch is 330 gpm. A reduction of 16% produces 277 gpm, but the permit is limited to 269 gpm. The total yield in the Russell Branch watershed (wells 7, 9 and 10) is 175 gpm. A reduction of 16% equals 147 gpm, but the use in that watershed is limited to 126 gpm. The remaining wells (3, 5, 12 and 13) have a total estimated yield of 223 gpm, which if reduced by 16%, produces a yield of 187 gpm. The total adjusted system yield is then 582 gpm or 838,100 gpd max. At the max:avg ratio of 1.5:1, the average use would be 558,700 gpd avg, which would be insufficient to meet existing demand without water restrictions in place.

Under average climatic conditions as a result of climate change, there should be an adequate water supply to serve the existing town population of 5772. During a moderately severe drought, water restrictions would likely be required. At a population of 6500, voluntary water restrictions may be required under dry, but non-drought, climatic conditions and mandatory water restrictions likely will be required during moderately severe droughts. The water supply system could be at higher risk during severe and extreme droughts. The frequency and severity of droughts are expected to increase due to climate change. A 40-year drought may occur on a 10-year interval, while a 10-year drought could occur on a 5-year interval.

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Susan Petro

Reduction of effective recharge by climate change could cause increased well interference and further degradation of the biological habitat of Horsepen Branch and Russell Branch. Careful monitoring of system production and periodic evaluations are needed to verify the effects of climate change on well yields. Additional biological surveys of Horsepen Branch and Russell Branch should be performed to better determine the degree of stream degradation in those watersheds.

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The frequency and severity of droughts are expected to increase due to climate change. A 40-year drought may occur on a 10-year interval, while a 10-year drought could occur on 5-year intervals. Reduction of effective recharge by climate change could cause increased well interference and further degradation of the biological habitat of Horsepen Branch and Russell Branch.

Dry spring soil at McKee Beshers National Wildlife Refuge

INTRODUCTION

During the drought period from 1998 to 2002, many municipal water suppliers, including the Town of Poolesville, in the fractured rock Piedmont/Blue Ridge areas of central Maryland, northwest of I-95, had to institute water restrictions due to declining well yields.

The unconfined groundwater systems in the region are affected by seasonal and climatic variations. During droughts groundwater levels drop causing decreasing well yields. Increased demand, over-allocation, population growth, and climate change can affect the future sustainability of water supplies in the areas of Maryland underlain by fractured rock.

Poolesville is proposing to increase the population served from about 5800 to 6500 people. Numerous studies have been conducted by the Maryland Geological Survey (MGS) (Otton, 1980), the Maryland Department of the Environment (MDE) (Hammond 1999 and 2021), Hammond (2018), Kamber Engineers (Recinos, 1996) and S.S. Papadopulos & Associates (SSP&A), 2021, to demonstrate the reliable drought yields of the town's wells.

The purpose of the study is to review and evaluate the previous studies on how effective they were in identifying the reliable yields of the town's wells and determine if there are other factors that should be considered prior to increasing the water use to meet the demand of the new development.

BACKGROUND- PREVIOUS STUDIES

Otten (1981) indicated that, prior to 1969, water supplies in Poolesville were taken from individual domestic wells and springs. Due to contamination from on-site septic systems, a central water supply required by the State was developed for the town in 1970. By 1977 wells 1 to 4, Fig. 1, were completed with a total tested yield of 298 gpm, however, the total yield had declined to 267 gpm and 172 gpm during the spring and fall of 1978, which was attributed to well interference not evident during individual testing of each of the wells.

Well 5 was completed in 1980, followed by well 6 in 1985. The annual average permitted water use was increased from 260,000 gpd to 580,000 gpd in 1986, an increase of 320,000 gpd (222 gpm), apparently based solely on the tested yield of well 6 (225 gpm). Recinos (1996) noted a dramatic decline in the yield of well 6 from its tested rate of 225 gpm to 80 gpm, which was attributed to dewatering of a major water-bearing zone at 230-310 ft. It is unclear if any actions were taken to correct the problems with well 6.

The situation remained unchanged until 1999, when Hammond (1999) completed a project evaluation of the system's yield for MDE. The Town Manager indicated that mandatory water restrictions were imposed during the drought of 1999, as well as the non-drought years of 1993 and 1995, and voluntary water restrictions in a number of other unspecified years. Hammond (1999) recommended changes to the water system that might increase well yields. One was to change the pump in well 2, which increased the yield from 20 gpm to about 100 gpm. The second was to pump well 7 and see where the water level stabilizes. The production increased from 27 gpm to 41 gpm with the water level stabilizing at 141 ft.

The final rate was near the initial test rate and estimated capacity of the well (50 gpm). A new 85-90 gpm pump was installed, probably since the single major water-bearing zone in the well was at a depth of 432 ft. Ultimately, the yield of the well eventually declined to about 28 gpm. For well 6, it was recommended that a smaller pump and a control valve be installed in the well to maintain the water level above the first major water-bearing zone at 180 ft. The pump was not changed, but the control valve was installed, resulting in a slight increase in yield from 80 gpm to 110 gpm. Hammond (1999) estimated that wells 3, 4, 5 and 8 were operated near peak efficiency, while attempts to rehabilitate well 1 were unsuccessful and that well was abandoned.

A common method for analyzing pumping test data from the 1970s to the 1990s was to use graphical type-curve matching techniques developed for various analytical models. These graphical methods are prone to errors in individual judgment, because different flow models can provide relatively good visual fits to the same set of data. Estimates of the well yields in Maryland were then based on extrapolating drawdowns, often from pseudo-equilibrium phases, measured during short-term, single well, hydraulic pumping tests to first, primary, water-bearing fractures. This method frequently resulted in substantially over-estimated well yields.

In addition to the graphical techniques, Hammond (2018) utilized specialized diagnostic plots, conducted inverse analyses using a computer-assisted automatic curve fitting program, and applied derivative analysis methods to pumping test data and deconvolution solutions to step-test data. The results were analyzed to determine the presence of internal or external boundaries, and the effects of aquifer dewatering. Once a solution was derived, the drawdown data was extrapolated forward to produce an estimated yield for a target operating water level in a well. It was determined that the appropriate target water levels were to reservoir units rather than first major water-bearing fractures in a well. The study included examples of reservoir units at the base of the weathered zone in crystalline rock aquifers (Emmitsburg well 3) and limestone/sandstone units in consolidated sedimentary rocks (Poolesville well 7 and Taneytown well 13). Hammond (2021) expanded his study on reliable yields to include the results of testing and monitoring of the yields of 35 public supply wells in central Maryland, including Poolesville wells 1, 2, 4-10 and 12. Included were the results of long-term testing for most of the wells, that included evidence of well interference between Poolesville's wells 9 and 10, and 2 and 12.

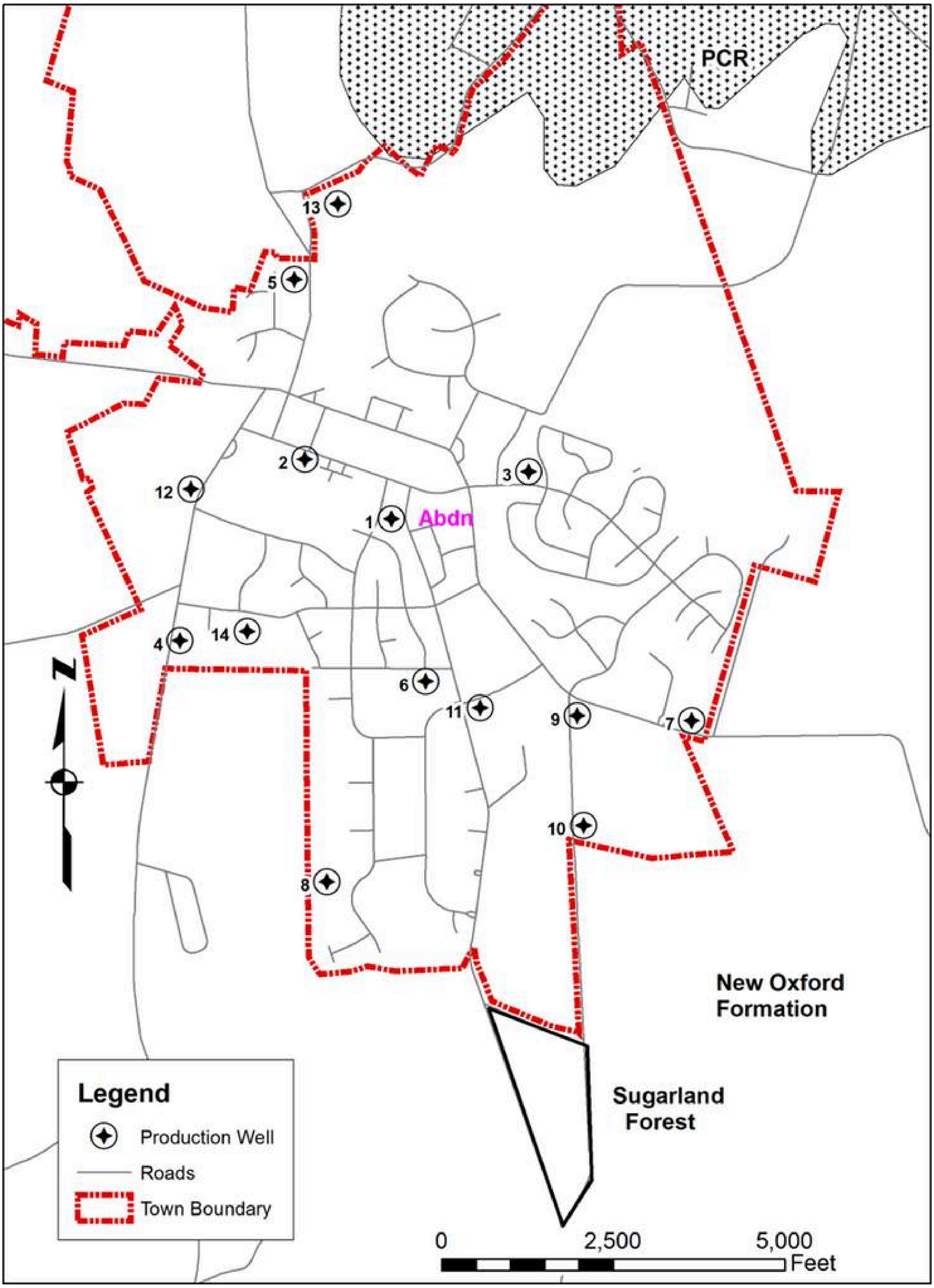


Figure 1. Map showing the locations of the Town of Poolesville's production wells. Reproduced from Hammond (2021)

SSP&A (2001) completed a water supply system evaluation for Poolesville that estimated water demand and minimum sustained yields, and developed a groundwater flow model for the water system. Adjustments were made for the effects of climate change on water demand, but not on well yields. No attempts were made to demonstrate the influence of well interference.

Susan Petro

The estimates of individual well yields were similar to those in the Hammond (1999, 2018 and 2021) studies, except that wells 9 and 10 were mis-identified, Table 1. Wells 9(1), Willard, and 10(1), Hughes Road, were tested in 1999 and ultimately abandoned, possibly due to potential bacterial contamination in well 9(1) and impacts to other users by well 10(1). Wells 9(2), Powell, and 10 (2), Cahoon, were tested in 2004. As a result of those tests potential impacts to six domestic wells were identified and those wells were replaced. Wells 9(2) and 10(2) were placed in full service in 2007, at which time pumping of those wells caused unreasonable impacts to domestic wells in the Sugarland Forest community. The impacts were mitigated by drilling deeper replacement wells.

For this evaluation, Hammond (2024), the reliable yields were adjusted based on the demonstrated drought yields (9/2000) of wells 2-8, long-term testing of wells 9 and 10, and 2 and 12, and evaluation of individual tests of wells 11, 13 and 14. The total of the individual yields is 750 gpm (771,400 gpd avg / 1,080,000 gpd max); however, this does not include the watershed limitations for Horsepen Branch (293,000 gpd avg) and Russell Branch (126,000 gpd avg) that result in a reduction of 76,600 gpd avg to 694,800 gpd avg / 972,720 gpd max (675.5 gpm), Fig. 2. This result neglects the effects of climate change, increased interference during severe droughts, and unreasonable biological impairment and reduced streamflow in Horsepen Branch and Russell Branch, which are issues to be discussed below.

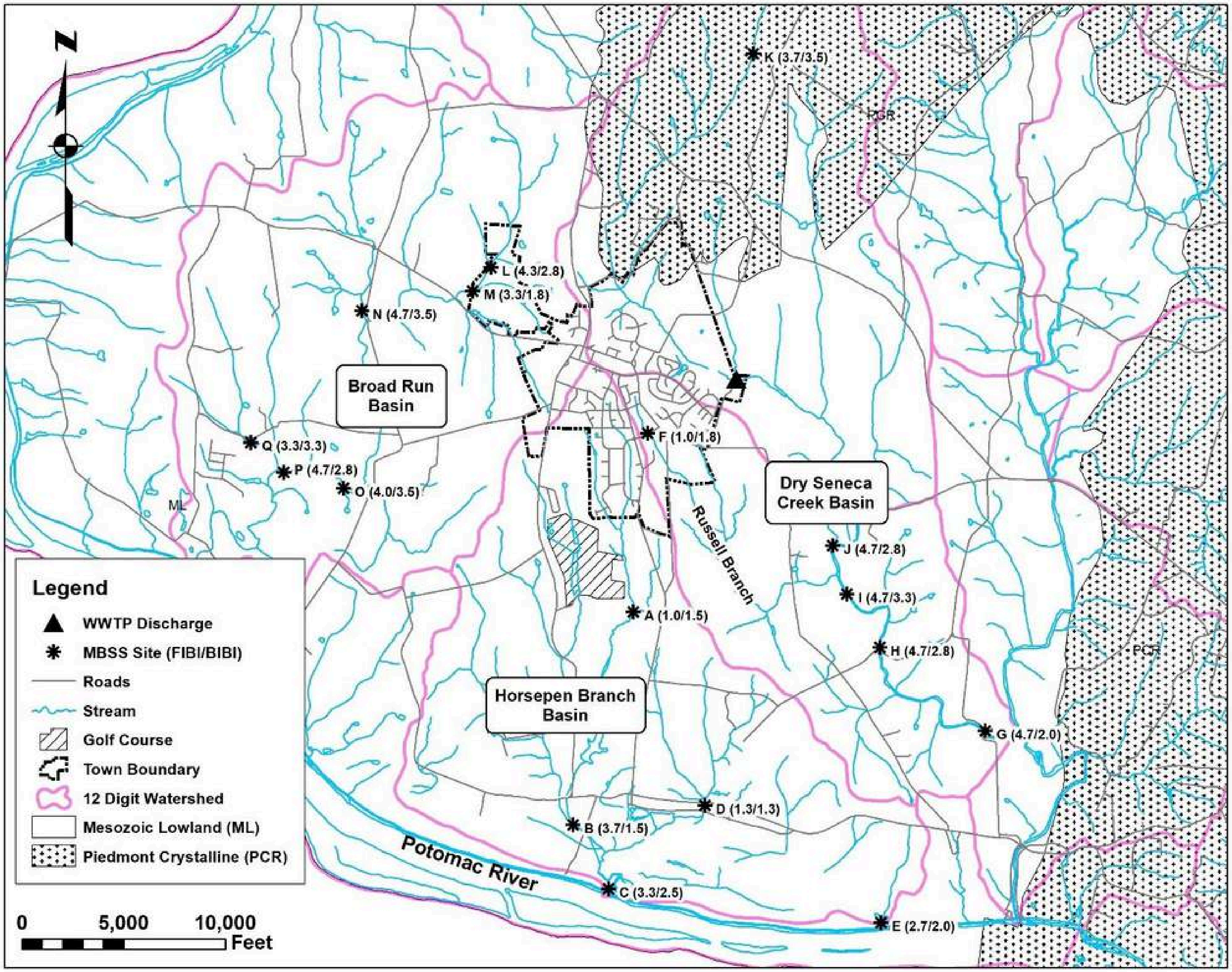


Figure 1. Map of the Dry Seneca Creek, Horsepen Branch and Broad Run watersheds in the vicinity of Poolesville, including MBSS sites with FIBI and BIBI scores. Reproduced from Hammond (2022).

Table 1. Comparison of estimated yields of Poolesville's public supply wells (1999-2024).

Well	Name	Hammond 1999	9/2000 21 h/d	Hammond 2021	SSPA 2021	Hammond 2024	Comment
2+		100	86	100	80	88	O-N 2009, 105 gpm 24h/d, drought corr. 95 gpm
3		60	55	-	40	55	Test Data Erratic
4+		35	30	37	35	37	+ Wells 2, 4, 6, 8, 11 & 14 are in Horsepen Branch. The watershed was over-allocated (293,000 gpd avg) in 1999 to meet existing water demand (public health).
5		100	85	94	90	85	
6+		130	77	113	100	77	Damaged-dewatering reservoir unit
7*		55	39	37	30	28	Damaged - Yield declined to 28 gpm
8+		60	57	60	50	57	
9(1)	Willard	47		-	-	-	Never placed in service
10(1)	Hughes Road	69		-	-	-	Never placed in service
9(2)*	Powell	-		108	47	147	Drought correcttion 147 gpm total. *Wells 7, 9, 10 limited to 126 gpm (Water Balance)
10(2)*	Cahoon	-		61	off-line		
11+	Rabenales	-		-	50	50	Potential interference with wells 6, 9 & 10
12	Schraf	-		43	45	43	O-D 2009 43 gpm, 24 h/d, wet. D-2018 55 gpm, 11.3 h/d (equivalent to 93 gpm 24 h/d). Potential Interference with well 2.
13	Elgin	-		-	50	40	
14+	Westerly	-		-	30	21	Potential interference with well 4

The SSP&A groundwater flow model used drawdowns to the first water-bearing zones rather than the drawdowns to the much shallower first reservoir units. Table 2 provides the results of extrapolating to Q90 Sa (reservoir unit, limestone or sandstone, Hammond, 2021) and to Q90 1st Wbz (Water bearing zone, 1st water strike, or 1st water bearing fracture). It demonstrates that the extrapolated total yield to the 1st Wbz (1740-1772 gpm) is nearly twice that of the extrapolated total yield to the 1st reservoir unit (952-980). This would indicate that there could be substantial error in the capture zones of the groundwater flow model.

Friends of Ten Mile Creek and Little Seneca Reservoir

Table 2. Comparison of estimated yields of Poolesville's public supply wells, when extrapolating to 1st reservoir unit versus 1st primary water bearing zone.

Well No.	name	Depth	Rate	Test Date	Climate	50W4C W/L	swl	Primary wbz	reservoir unit S_A	S_{90}	Q_{90} S_A	Adj Drought	9/00 21h/d	Comment	Q_{90} 1st Wbz
2		450	98.5(V)	Sep-69	Avg	Avg Est	38	224	112	119	93	83	86	O-N 2009, 105 gpm, drought corr. 95 gpm. Potential Interference with well 12.	154
3		285	100	Nov-72	Dry?	Dry Est	12	220	32	58	55	55	55	Test Data Erratic	222
4		600	48	Jun-77	Avg	Avg Est	24	228	68	68-167	48-20	45-19	30	Potential interference with well 14	48-16
5		500	120-129	Mar-80	Wet	35	26	345	105	140	93	80	85		283
6		500	225	Jun-85	Wet	35.5	16	180	180-220	274	148	127	77	Damaged-dewatering reservoir unit	148
7		700	50	May-92	Avg	36.5	3	432	230	225	49	46	39	Damaged - Yield declined to 28 gpm	67
8		500	80	Feb-94	Wet	38.5	18	215	170	236	58	50	56		95
9(2)	Powell	800	225	Jun-01	Avg	38.5	42	220	180	228	141	121	-	J-F 2004 45d Test, Well 9 - 120 gpm, Well 10 61 gpm. Wet (50W 4c =32.5 ft). Drought correcttion 147 gpm total. Wells 7, 9, 10 limited to 126 gpm (Water Balance)	217
10(2)	Cahoon	762	80	May-01	Avg	39	26	321	210	320	53	50	-		80
11	Rabanales	1200	200	Oct-01	Avg	39.5	58	618	205	500	82	81	-	Potential interference with wells 6, 9 & 10	162
12	Schraf	500	175	Oct-05	Wet	34	25	190	105	192	96	81	-	O-D 2009 43 gpm, 24 h/d, wet. D-2018 55 gpm, 11.3 h/d (equivalent to 93 gpm 24 h/d). Potential Interference with well 2.	173
13	Elgin	500	100	Aug-04	Wet	35	11	211	105	280	38	33	-		75
14	Jameson	700	50	Dec-02	Avg	39	18	218	118	228	26	24	-	Potential interference with well 4	48

The Appendix contains semi-log graphs of the step tests and aquifer tests of wells 2-14, as well the water level and water use data for well 6.

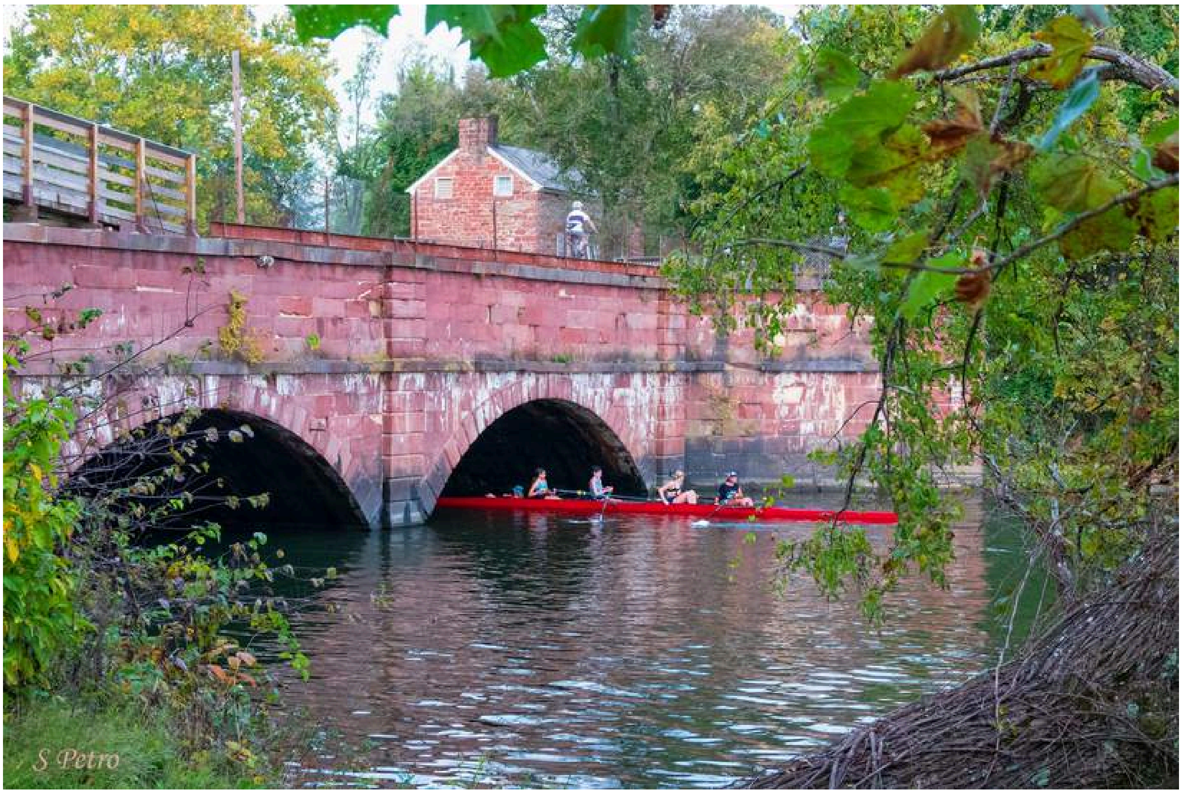
POTENTIAL IMPACTS OF CLIMATE CHANGE, POTOMAC RIVER WATERSHED

Table 3 contains Potomac River basin-wide averages of annual precipitation, evapotranspiration, stormflow, and baseflow for the base scenario and 18 climate change scenarios, Ahmed et al. (2013), for the upper portion of the Potomac watershed, upstream of the USGS gage on the Potomac River at Little Falls near Washington, D.C. The average precipitation increases in the Potomac River basin in nine out of the 18 climate change scenarios, and evapotranspiration increases in all climate change scenarios due to elevated temperatures.

The average annual baseflow decreases (by 3% to 33%) within the basin in 16 out of the 18 scenarios. For those seven scenarios where precipitation increases, as suggested by most other studies of northeast USA, the precipitation then largely cancels out losses due to evapotranspiration, with average baseflow, or effective recharge, changing by 88% to 104% in 2040 due to climate change relative to the base period of 1988-1999. In addition, storm flows change by 93% to 120%, while total streamflow changes by 90% to 111%, indicating that climate change will have slightly less impact on the reservoirs and simple intakes of the small to medium sized communities of central Maryland. A review of Washington DC annual precipitation (dcaprecip) and temperature (dcatemps) data from 1871 to 2023 at the present Reagan National Airport, suggest that the number of applicable scenarios can be reduced.

Figure 3 is a graph of the temperature (dcatemps) indicating there is a substantial increase in the temperature (5.5°F or 3.1°C) over the period of record. From the linear equation for the temperature data the R2 value is 0.6839. A regression analysis produced a P-value of 0.0122. The relatively high R2 and low P-value indicates that the solution explains much of the variation in the data and is statistically significant.

The 2nd order polynomial also provides a good fit to\the data (R2 = 0.689), but the P-value requires a special analysis program that is not available. The ICPRB models project the impacts of climate change from the base period of 1988-1999 to 2040. Projecting the dcatemps data to 2040 produces increases of 0.9 and 1.1°C for the linear and 2nd order polynomial solutions, respectively. While the dcatemps data may not be representative of the entire Potomac River basin upstream of Little Falls, the rate of change may be similar to the regional trend.



Susan Petro

To address the heat island effects at Reagan Airport, the Maryland State temperature data, compiled from 11 stations from the Eastern Shore to Garrett County, NOAA NCEI (2024), were reviewed. This indicated that the temperature change in that data set, when projected from 1900 to 2020 is 2.5°F, Fig. 4, or the same as that due to climate change in Washington D.C. Projecting the Maryland Statewide data to 2040 produces increases of 0.6 and 1.3°C for the linear and 2nd order polynomial solutions, respectively. While the absolute projected temperature in Washington D.C. would reflect both climate change and heat island effects, the rate of change is similar to the Maryland Statewide data and can be used to approximate the increase in temperature due to climate change.

In the case of the dcaprecip rainfall data, Fig 5, both the linear and second order polynomial equations produce the only solutions extrapolated to 2040 that are within the range of prediction of the ICPRB models, however, the R2 results are very low (0.0387 and 0.0065) and a regression analysis produced a high P-value (0.3213). This indicates that the result explains little of the variation in the data and is not statistically significant. The same results were obtained for the Maryland Statewide precipitation data, Fig. 6, with low R2 values of 0.0445 and 0.0528, although the P-value is 0.017.

Great Falls, Hurricane Ida ~ Susan Petro

Table 3. Basin-wide mean annual water budget for the base scenario and for the 18 climate change scenarios. Reproduced from Ahmed et al. (2013). Tables 3-1, 3-2 and 5-1.

Scenario	Temperature change	Precipitation	Evapo transpiration	Stormflow	Baseflow	Total stream flow	Precipitation	Evapo transpiration	Stormflow	Baseflow	Total stream flow	Rank
	(□C)	(inches)	(inches)	(inches)	(inches)	(inches)	(percent)	(percent)	(percent)	(percent)	(percent)	
Base	0.00	42.2	27.3	6.4	8.6	15.0						
B_A1B	1.2	42.2	29.0	5.9	7.5	13.4	100%	106%	93%	87%	89%	8
B_A2	0.8	41.7	28.5	5.8	7.5	13.3	99%	104%	90%	88%	89%	9
B_B1	0.7	45.0	28.5	7.7	8.9	16.6	107%	105%	120%	104%	111%	1
C3.0_A1B	1.3	44.0	29.2	6.7	8.2	14.9	104%	107%	104%	96%	99%	5
C3.0_A2	1.4	43.7	29.2	6.5	8.1	14.6	103%	107%	102%	94%	98%	6
C3.0_B1	1.1	41.0	28.5	5.3	7.3	12.6	97%	105%	83%	85%	84%	11
C3.5_A1B	1.6	38.2	28.9	4.0	5.7	9.7	91%	106%	63%	66%	65%	17
C3.5_A2	1.6	39.6	28.7	4.7	6.4	11.1	94%	105%	74%	75%	74%	13
C3.5_B1	0.9	41.3	28.7	5.6	7.2	12.8	98%	105%	87%	84%	86%	10
I_A1B	2.3	38.9	29.5	3.8	5.9	9.7	92%	108%	59%	68%	65%	18
I_A2	2.1	39.1	29.2	4.1	6.0	10.1	93%	107%	64%	70%	67%	15
I_B1	1.8	38.6	28.9	4.0	5.9	9.9	91%	106%	62%	69%	66%	16
M_A1B	2.2	42.1	29.9	5.3	7.1	12.4	100%	110%	83%	83%	83%	12
M_A2	1.8	39.8	29.0	4.5	6.5	11.0	94%	106%	70%	76%	73%	14
M_B1	1.6	42.8	29.4	6.0	7.5	13.5	101%	108%	93%	88%	90%	7
N_A1B	1.7	45.5	30.2	7.0	8.3	15.3	108%	111%	109%	97%	102%	4
N_A2	1.6	46.1	30.2	7.4	8.6	15.9	109%	111%	115%	100%	106%	2
N_B1	1.2	45.1	29.5	7.3	8.3	15.6	107%	108%	113%	97%	104%	3
Average	1.5	41.9	29.2	5.6	7.3	12.9	99%	107%	88%	85%	86%	

GCM Acronym	GCM Abbreviation	Institution/Model	Country
NCAR-CCSM3_0	N	National Center for Atmospheric Research	USA
BCC-BCM2.0	B	Bjerknes Centre for Climate Research	Norway
CSIRO-Mk3.0	C3.0	Commonwealth Scientific and Industrial Research Organisation	Australia
CSIRO-Mk3.5	C3.5	Commonwealth Scientific and Industrial Research Organisation	Australia
INM-CM3.0	I	Institute for Numerical Mathematics	Russia
MIROC3.2(medres)	M	National Institute for Environmental Studies	Japan

Emission Scenario Acronym	Emission Scenario Description
A2	High population growth, slow economic development and slow technological change
A1B	Very rapid economic growth and technological change, population peak mid-century, balance of energy sources
B1	Similar to A1B, but change toward service and information economy

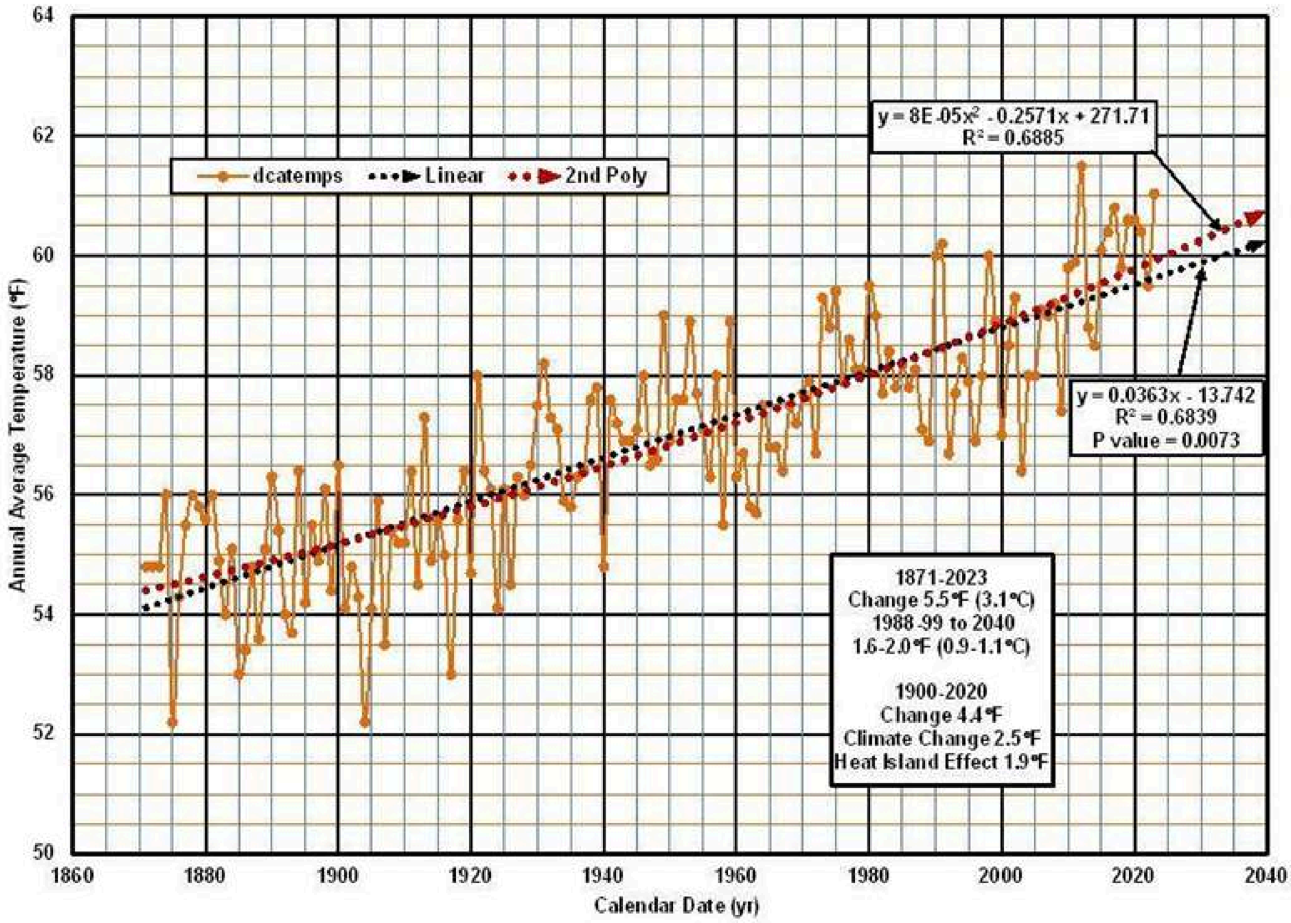


Figure 3. Annual average temperature (dcatemps) at the Reagan National Airport from 1871 to 2023, with data projected to 2040.

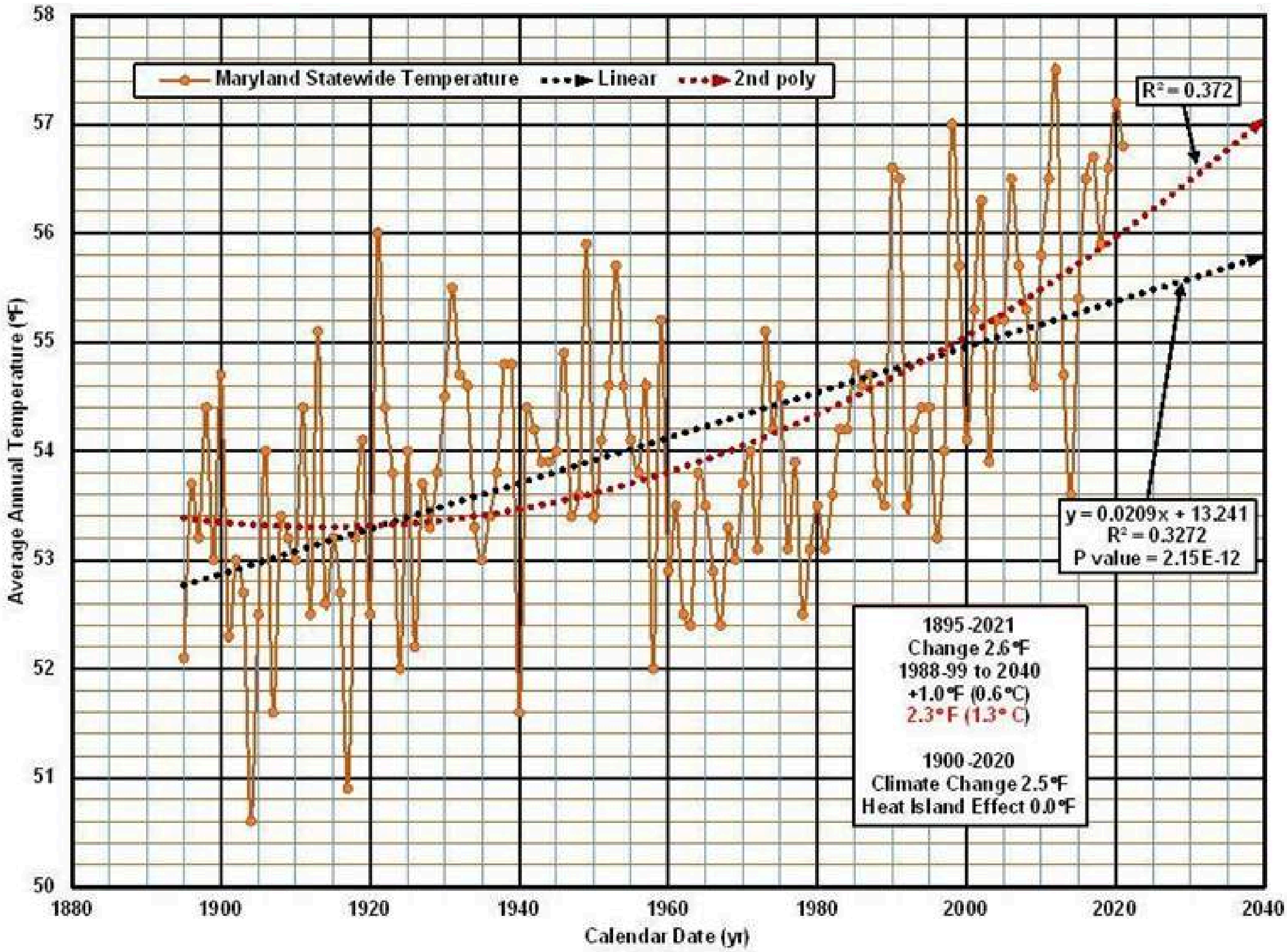


Figure 4. Maryland Statewide annual average temperature Airport from 1895 to 2021, with data projected to 2040.

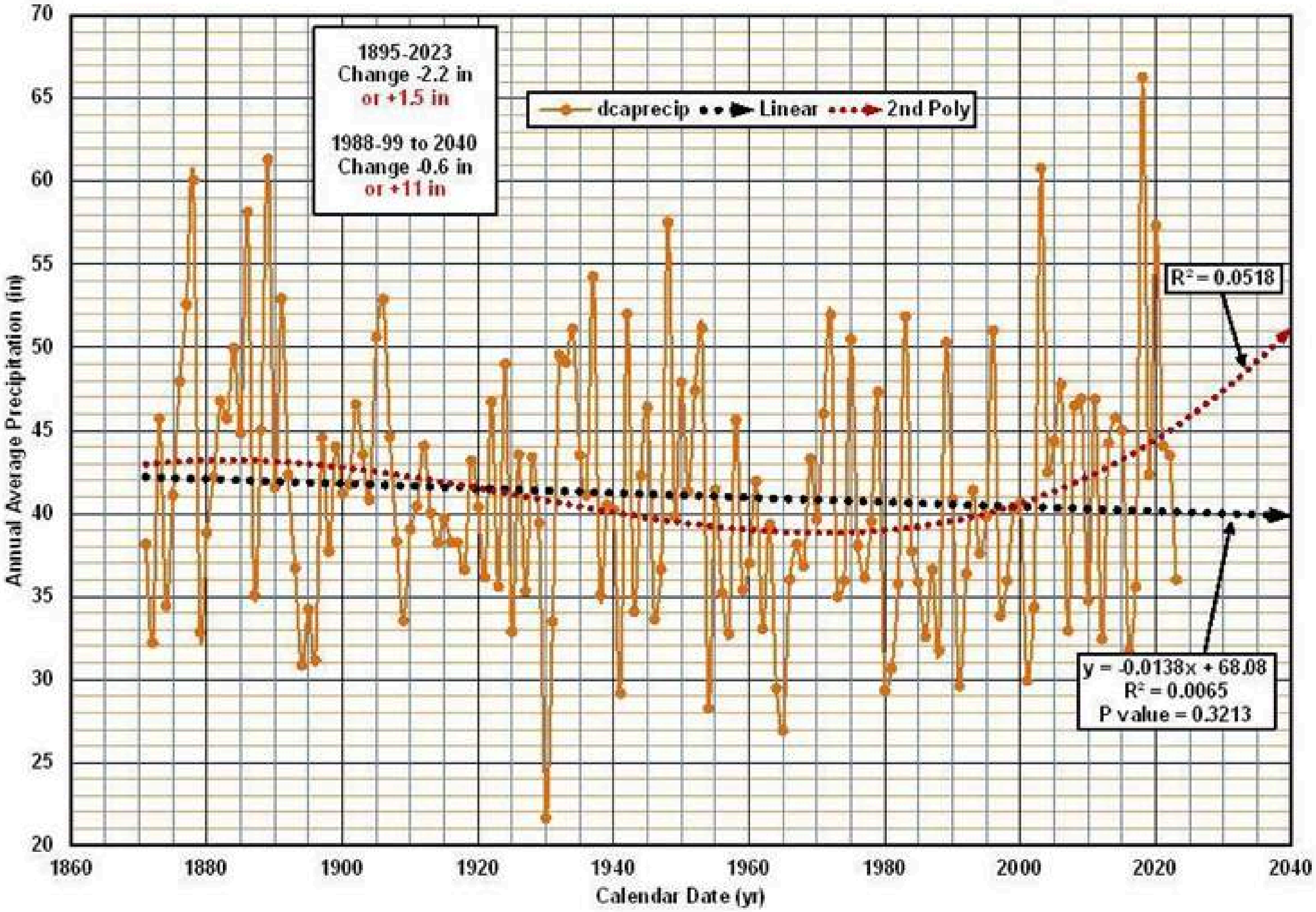


Figure 5. Annual average precipitation (dcaprecip) at the Reagan National Airport from 1871 to 2023, with data projected to 2040.

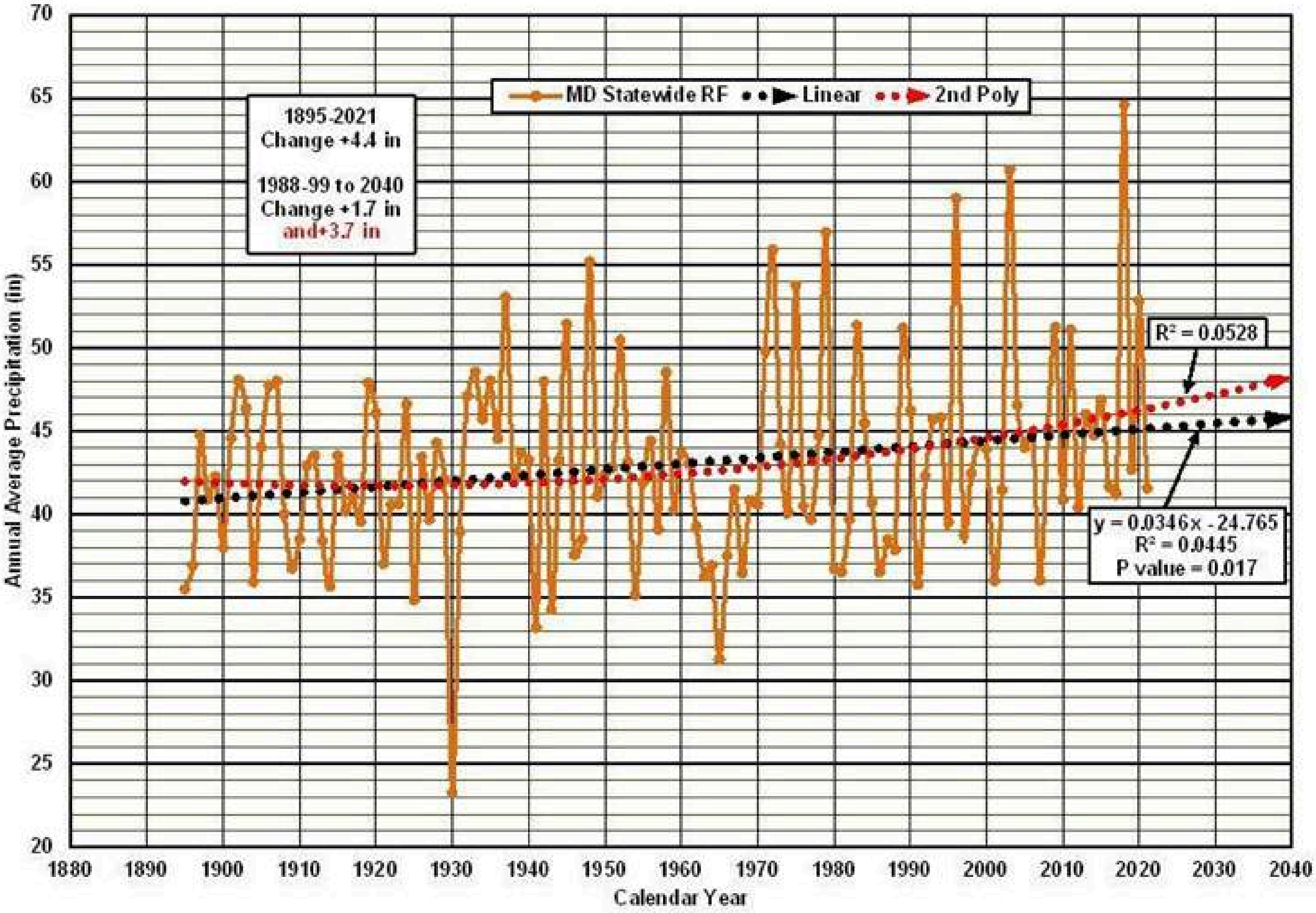


Figure 6. Maryland Statewide annual average precipitation from 1895 to 2021, with data projected to 2040.

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While the dcaprecip data is not useful, the dcatemps data might help narrow the number of climate change scenarios, by selecting those near the projected increase in 2040 of 0.9-1.1°C. There are seven ICPRB scenarios between increases of 0.7°C and 1.3°C (to account for potential error and include the Maryland Statewide results) from the base period (1988-1999) to 2040. They are B_A1B, B_A2, B_B1, C3.0_A1B, C3.0_B1, C3.5_B1, and N_B1, which have 87%, 88%, 104% 96%, 85%, 84%, and 97%, respectively, (average of 91.6%) of the average baseflow for the base period (8.6 in/yr), This indicates that the average annual baseflow in the study area will be reduced by about 0.7 in/yr. Since climate change will cause a multi decade stress on the groundwater system, then the baseflow in any year would be reduced by the same amount, including any drought. For example, baseflow analyses have been calculated by MDE for two watersheds in the in the Potomac River basin, Monocacy River at Jug Bridge (gage # 01643000) and Monocacy River at Bridgeport (gage # 01639000) in Frederick County and Seneca Creek at Dawsonville (gage # 01645000) in Montgomery County, Table 4.

Lee Langstaff

Table 4. Baseflow analyses of partial records (return years 1 to 22) of streamflow at the Monocacy River gages at Bridgeport and Jug Bridge, and the Seneca Creek gage at Dawsonville.

Monocacy River at Bridgeport			
1943-2023	Baseflow in/yr	Record 82 yr	
Year	6.4 Avg	Rank	
1954	2.97	1	Drought of Record
1969	3.33	2	1-in-41 drought
1965	3.39	3	
1981	3.53	4	
1959	3.68	5	
2023	3.70	6	1-in-14 drought
2001	3.99	7	
1966	4.05	8	1-in-10 drought
2002	4.21	9	
1988	4.33	10	
1963	4.46	11	
1944	4.57	12	
1999	4.59	13	
1962	4.61	14	
1968	4.61	15	
1947	4.61	16	
1946	4.69	17	
1980	4.76	18	
1955	4.79	19	
1960	4.89	20	
1964	5.03	21	
2007	5.07	22	

Monocacy River at Jug Bridge			
1930-2023	Baseflow in/yr	Record 94 yr	
Year	8.8 Avg	Rank	
1931	2.90	1	Drought of Record
2002	4.29	2	1-in-47 drought
1954	4.41	3	
1969	4.54	4	
1959	4.64	5	
1981	4.79	6	
1966	4.82	7	
1965	4.92	8	
1963	4.99	9	1-in-10 drought
2023	5.01	10	1-in-9 drought
1930	5.03	11	
1941	5.79	12	
2001	5.87	13	
1999	6.08	14	
1947	6.23	15	
1938	6.37	16	
1968	6.41	17	
1985	6.53	18	
2017	6.66	19	
1932	6.70	20	
1988	6.71	21	
1944	6.72	22	

Seneca Creek at Dawsonville			
1931-2023	Baseflow in/yr	Record 93 yr	
Year	10.5 Avg	Rank	
1931	2.56	1	Drought of Record
1959	5.04	2	1-in-46 drought
1969	5.31	3	
1954	5.36	4	
1963	5.40	5	
1932	5.65	6	
1966	5.67	7	
1955	5.69	8	
1981	5.70	9	1-in-10 drought
1941	5.93	10	
1947	6.05	11	
1986	6.16	12	
1965	6.36	13	
1944	6.63	14	
2002	6.66	15	
1985	6.90	16	
1957	6.99	17	
1942	7.22	18	
1977	7.23	19	
1962	7.34	20	
1968	7.35	21	
1960	7.64	22	

During the period of record (1930-2023) at the Monocacy River Jug Bridge gage, the average baseflow is 8.8 in/yr, the record low year (1-in-94 yr return) was 1931 (2.9 in/yr), the second lowest year (1-in-47 yr return) was 2002 (4.3 in/yr). Subtracting 0.7 in from the 1-in-10 yr drought (1963) baseflow of 5.0 in/yr equals 4.3 in/yr (14% decline) indicating that climate change could cause a nearly 50-yr drought to occur at a 10-yr interval. During the period of record (1943-2023) at the Monocacy River Bridgeport gage, the average baseflow is 6.4 in/yr, the record low year (1-in-81 yr return) was 1954 (3.0 in/yr), the second lowest year (1-in-40 yr return) was 1969 (3.3 in/yr).

Subtracting 0.7 in/yr from the 1-in-10 yr drought (1966) baseflow of 4.0 in/yr equals 3.3 in/yr (17.5% decline) indicating that climate change could cause a 41-yr drought to occur at a 10-yr interval. Similar results were obtained with the data from the Seneca Creek gage. During the period of record (1931-2021) at the Seneca Creek gage, the average baseflow is 10.5 in/yr, the record low year (1-in-91 yr return) was 1931 (2.6 in/yr), and the second lowest year (1-in-46 yr return) was 1959 (5.0 in/yr). Subtracting 0.9 in from the 1-in-10 yr drought (1981) baseflow of 5.7 in/yr equals 4.8 in/yr (16% decline), again indicating that climate change could cause a nearly 50-yr drought to occur at a 10-yr interval.

Furthermore, Table 5 indicated that during the peak demand months of July and August, baseflow could be changed by an average of +11% to -43% (-11% average) relative to the base period.

Hammond (2021) described a review that was completed by MDE in 2004 of production and monitoring records collected during the 1998-2002 drought from 97 wells and 2 springs of municipal purveyors, and a few golf courses in the fractured rock areas of central Maryland. That study indicated that the average maximum drought production was only 54% of the estimated yields using the techniques then in common use, but 83% of the estimates made by the methods subsequently developed in the Hammond (2018) study.

This suggests that errors in estimating the reliable yields of public supply fractured rock wells from aquifer test data may have as great or greater effect than those caused by climate change. This provides a good reason for using operational data to establish the reliable yields of public supply wells in fractured rock aquifers.

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Table 5. Basin-wide mean monthly inflow to groundwater storage (recharge) for the 18 climate change scenarios (inches and percentage of baseflow). Reproduced from Ahmed et al. (2013), Table 5-2.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total annual
Base	1.31	1.28	1.69	0.67	0.81	0.42	0.44	0.34	0.44	0.46	0.70	0.90	9.46
B_A1B	1.21	0.86	1.75	0.65	0.83	0.47	0.33	0.34	0.36	0.38	0.51	0.72	8.41
	92%	*68%*	*103%*	*96%*	*103%*	*111%*	*75%*	*100%*	*82%*	*83%*	*73%*	*80%*	89%
B_A2	1.23	0.96	1.73	0.58	0.77	0.40	0.42	0.34	0.33	0.39	0.54	0.81	8.49
	94%	*75%*	*102%*	*87%*	*95%*	*94%*	*95%*	*98%*	*75%*	*84%*	*77%*	*90%*	90%
B_B1	1.74	1.11	1.87	0.53	0.80	0.50	0.45	0.41	0.35	0.43	0.60	1.05	9.84
	133%	87%	111%	79%	99%	117%	103%	119%	79%	94%	86%	117%	104%
C3.0_A1B	1.35	1.19	1.59	0.71	0.72	0.43	0.35	0.27	0.50	0.34	0.62	1.15	9.19
	103%	93%	94%	105%	89%	101%	79%	78%	114%	73%	89%	128%	97%
C3.0_A2	1.25	1.19	1.69	0.65	0.83	0.40	0.36	0.33	0.31	0.34	0.66	1.01	9.03
	95%	93%	100%	96%	103%	95%	83%	96%	71%	74%	96%	113%	95%
C3.0_B1	1.15	0.99	1.36	0.68	0.77	0.42	0.36	0.27	0.32	0.37	0.61	0.91	8.22
	88%	78%	80%	100%	95%	99%	82%	79%	74%	81%	88%	101%	87%
C3.5_A1B	1.27	0.92	1.22	0.55	0.56	0.38	0.31	0.28	0.23	0.13	0.33	0.68	6.87
	97%	72%	72%	81%	69%	89%	70%	82%	52%	29%	47%	76%	73%
C3.5_A2	1.06	0.94	1.36	0.63	0.59	0.31	0.26	0.22	0.34	0.25	0.46	0.56	6.99
	81%	74%	80%	94%	73%	74%	59%	65%	77%	55%	66%	62%	74%
C3.5_B1	1.27	0.96	1.16	0.57	0.63	0.34	0.28	0.17	0.37	0.26	0.32	0.56	6.90
	97%	76%	68%	85%	78%	81%	64%	50%	84%	55%	47%	62%	73%
I_A1B	1.43	0.98	1.36	0.58	0.72	0.36	0.27	0.30	0.29	0.36	0.53	0.94	8.12
	109%	77%	80%	86%	89%	85%	61%	86%	66%	79%	77%	104%	86%
I_A2	1.17	1.00	1.25	0.63	0.71	0.32	0.31	0.22	0.27	0.31	0.51	0.76	7.46
	89%	79%	74%	94%	88%	76%	71%	64%	61%	67%	73%	84%	79%
I_B1	1.33	0.99	1.46	0.71	0.86	0.41	0.39	0.26	0.28	0.34	0.60	0.91	8.53
	101%	78%	86%	106%	106%	96%	88%	75%	63%	74%	87%	101%	90%
M_A1B	1.29	1.09	1.69	0.63	0.72	0.41	0.46	0.39	0.50	0.41	0.69	1.04	9.32
	99%	85%	100%	93%	90%	98%	105%	112%	113%	89%	99%	116%	99%
M_A2	1.34	1.14	1.64	0.60	0.80	0.42	0.47	0.40	0.55	0.48	0.75	0.99	9.56
	102%	89%	97%	89%	99%	98%	106%	116%	124%	104%	107%	111%	101%
M_B1	1.24	1.05	1.70	0.60	0.77	0.43	0.48	0.38	0.47	0.47	0.78	0.93	9.31
	94%	83%	101%	90%	95%	101%	110%	110%	108%	103%	112%	104%	98%
N_A1B	1.29	1.09	1.69	0.63	0.72	0.41	0.46	0.39	0.50	0.41	0.69	1.04	9.32
	99%	85%	100%	93%	90%	98%	105%	112%	113%	89%	99%	116%	99%
N_A2	1.34	1.14	1.64	0.60	0.80	0.42	0.47	0.40	0.55	0.48	0.75	0.99	9.56
	102%	89%	97%	89%	99%	98%	106%	116%	124%	104%	107%	111%	101%
N_B1	1.24	1.05	1.70	0.60	0.77	0.43	0.48	0.38	0.47	0.47	0.78	0.93	9.31
	94%	83%	101%	90%	95%	101%	110%	110%	108%	103%	112%	104%	98%

WATER APPROPRIATION AND USE PERMIT HISTORY

Otten (1981) indicated that, prior to 1969, water supplies in Poolesville were taken from individual domestic wells and springs. Due to contamination from on-site septic systems, a central water supply required by the State was developed for the town in 1970. By 1977 wells 1-4 were completed with a total tested yield of 298 gpm; however, the total yield had declined to 267 gpm and 172 gpm during the spring and fall of 1978. That decline was attributed to well interference not evident during individual testing of each of the wells.

Well 5 was completed in 1980, followed by well 6 in 1985. The annual average permitted water use was increased from 260,000 gpd to 580,000 gpd in 1986, an increase of 320,000 gpd (222 gpm), apparently based solely on the tested yield of well 6 (225 gpm). Recinos, 1996 (Kamber Engineers) noted a dramatic decline in the yield of well 6 from its tested rate of 225 gpm to 80 gpm, which was attributed to dewatering of a major water-bearing zone at 230-310 ft. It is unclear if any actions were taken to correct the problems with well 6. Wells 7 and 8 were added to the permit in 1991 and 1994, respectively, without a change in the yearly allocation.

In 1999, the estimated existing annual average demand of 480,000 gpd avg was far less than the current permitted amount of 580,000 gpd avg. The requested use at that time was for two additional proposed wells, 9(1) and 10(1) to supply existing demand only, so a reduction in the current permitted amount seemed appropriate. Although the present wells at that time probably could supply the existing demand, the town still wanted one or more additional wells as security against future water shortages. To simplify matters administratively, wells 9(1) and 10(1) were processed under a permit application (MO70G107/1) separate from that for the existing wells (MO70G007/10), for the amounts of 100,000 gpd avg / 150,000 gpd max. Once a decision has been made by the Water Management Administration (WMA) concerning wells 9(1) and 10(1), then appropriate changes were to be made to MO70G007/10 for the existing wells. The proposed wells were never placed in service, probably due to problems associated with the wells: bacteria – well 9(1) and unreasonable impacts – well 10(1).

The Administration received correspondence from Chester (later Kamber) Engineering (email from Scott Recinos) concerning the proposed appropriations for withdrawals from existing and proposed municipal supply wells for the Town of Poolesville. The main issues raised were how much water will be needed to serve a projected population of 5500 people, how much water could be allocated from each of the four watersheds in the town, and whether the existing and proposed wells could supply the proposed allocations.

The various Chester Water & Sewer Plan documents indicated a range of per capita use from 75 (1981) to 110 (1991) gpcd. The highest value included a major leak that could not be quantified from available WMA data. The next highest value (101 gpcd) was included in the Water & Sewer Plan, but was based on unreliable population data. For example, the estimated population for 2000 of 4450 was considerably lower than the Census data of 5100. If the census data were considered, then the per capita use would have been 88 gpcd. The WMA used 100 gpcd from water conservation guidance plan documents for the Poolesville permits, which produced an annual average demand of 550,000 gpd for the system, to be supplied by wells 2-10. With the additions of wells 12 and 13, the water use permit was increased to the present 650,000 gpd avg to serve a population of 6500. Wells 11 and 14 were added to the Horsepen Branch permit without any increase in the amount appropriated.

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WATER APPROPRIATION AND USE PERMITS

The reasonableness of the amounts requested, the impacts to the resource, and impacts to other users of the resource

- Reasonableness of Amount Requested (Water Demand)

Amounts requested for municipal water supplies are based on estimated water demand. Poolesville has repeatedly requested and MDE has approved amounts that substantially exceeded the water used during the maximum 12-year permit periods.

In 1986, the permitted annual average use (gpd avg) was increased from 260,000 gpd avg to 580,000 gpd avg and appeared to be based on the estimated yield of well 6 (225 gpm). The use was to meet the needs from some undefined future growth at the time. The maximum reported use under that permit was 453,000 gpd avg in 1998, or 127,000 gpd avg less than the permitted use. A slight adjustment to the permit was made reducing the use to 550,000 gpd avg at 100 gpcd in about 2000 to supply a future total population of 5500 people included in the town's comprehensive plan. The period of such plans are usually 20 years, which was not considered when issuing the 12-year permit.

In about 2008-2009, the total appropriation from multiple permits was increased to 650,000 gpd avg to supply a population of 6500. The town had identified future growth in the 2006 Capacity Management Plan to consist of 415 new connections at the proposed developments of: Winchester (98 homes), Brightwell Crossing (177 homes), Jamison (19 townhomes and 60 single-family homes), 59 residential infill lots, and three commercial properties (24.55 EDUs).The maximum reported use under those permits was 548,000 gpd avg in 2020, or 102,000 gpd avg less than the permitted use, after the nominal 12-year permit period. It was also less than the permitted use from 45 years ago by 32,000 gpd avg.

Table 6. Poolesville water use and population data, baseflow from the Seneca Creek gage at Dawsonville, and dca precipitation and temperature data (Reagan Airport), for the period 2000, 2007-2020.

Year	Water Use	Ratio	Month of Max Use	Housing Units	97% Occupancy	Occupant per unit	Population	Use	Population TOP/SSPA 2024	Occupants per unit	Use
	gpd avg	max:avg						gpcd			gpcd
2010	410,430	1.24	Jun	1,663	1,602	3.05	4,883	84.1			
2011	396,048	1.29	Jun	1,648	1,599	3.02	4,828	82.0			
2012	439,198	1.30	Aug	1,691	1,640	3.02	4,954	88.7			
2013	468,406	1.22	Sept	1,727	1,675	3.02	5,059	92.6			
2014	438,319	1.33	Jan	1,767	1,714	3.02	5,176	84.7			
2015	500,928	1.22	Aug	1,802	1,748	3.02	5,279	94.9			
2016	461,659	1.24	Jun	1,822	1,767	3.02	5,337	86.5			
2017	469,502	1.12	Dec	1,845	1,790	3.02	5,405	86.9			
2018	510,432	1.17	Jul	1,864	1,808	3.02	5,460	93.5	5571	2.99	91.6
2019	505,039	1.13	Sept	1,885	1,828	3.02	5,522	91.5	5638	2.99	89.6
2020	548,034	1.27	Jul	1,915	1,861	3.11	5,784	94.8	5800	3.03	94.5
2021	515,998	1.26	Jan	1,958	1,903	3.10	5,901	87.4	5921	3.02	87.1
2022	541,275	1.08	Jul	1,984	1,928	3.10	5,982	90.5	6005	3.03	90.1
2023	564,875	1.16	Jun	1,984	1,928	3,10	5,982	94.4	6005	3.03	94.1
Average	468,000	1.23	N/A								
2018-2023	530,942	1.19	N/A			3.07	5,772	92.0		3.01	91.2
2010-2017	448,061	1.23	N/A			3.02	5,115	87.5			

Table 6 provides data for the period 2010 to 2023 for Poolesville's water use, and the ratio between maximum month and annual average use. The per capita use (gpcd) is calculated from the water use and population statistics. The town's population data in 2010 and 2020 is taken from the US Census reports for 2010 and 2020, with a combination of the Town's housing unit records and, adjusted Census Bureau estimated data for the remaining years. SSP&A (2021) assumed a current demand of 521,000 gpd avg (average use 2018-2020), a population of 5800 (89.8 gpcd), based on the 2020 census of 5742 and with the addition of 14 new homes. It was then assumed that a population of 700 at 100 gpcd was added to bring the total population to 6500. This produced an estimated demand of 591,000 gpd avg. To that total was added 10% for a drought (consistent with MDE studies) and 4,621 gpd avg (0.9% of current demand) for 30 days at 100 °F, producing a final demand of 654,621 gpd avg. The estimated maximum monthly use was based on the greatest recorded ratio of 1.33 between maximum month and annual use; however, that high use was recorded during January 2014 and was likely related to a significant system leak. This produced a monthly use of 864,633 gpd to which was added 55,000 gpd for 30 days at 100 °F, for a maximum monthly use of 919,633 gpd max. The Town and SSP&A recently submitted updated information that increases the per capita use from 89.8 gpcd to 91.2 gpcd. Not considered in that evaluation is that the Census data for 2010 and 2020 indicate that the occupancy rate for Poolesville housing is 97%, which was used in the present study to adjust the population data submitted by the Town and SSP&A for the period 2018-2023.

Using the averages for the period 2018-2023, to account for the variations in the water use, the existing average population is 5772 residents and the reported average water use is 530,942 gpd avg. Adding 728 people at 100 gpcd, for a population of 6500, produces a total of 603,742 gpd avg. Then adding 10% for drought and 5434 gpd avg for 30 days at 100 °F, produces a total estimated demand of 669,550 gpd avg or 103 gpcd for a population of 6500. Since most of the increase during a drought occurs due to outdoor summertime use, the increase in the maximum monthly use would likely be substantially more than 10%. The average maximum to average ratio in Table 6 is 1.23 to 1, a period that does not include a significant drought. If it increased only by 15%, the ratio becomes 1.4:1 (consistent with MDE studies). Using that ratio produces a monthly demand of 937,370 gpd. Adding 66,114 gpd for 30 days at 100 °F due to climate change, produces a maximum monthly demand of 1,003,484 gpd max, increasing the maximum month to annual average ratio to 1.5:1. The ability of the well system to meet these demands will be discussed in the section on groundwater availability.

• Reasonableness of Impacts to the Resource (Water Balance)

The water balance methods used by MDE were first introduced circa 1984. The present WMA water balance methods reflect the policies in place when the last major change to the Water Appropriation or Use Permit regulations was promulgated in 1988. The present technical methods were developed between 1991 and 1994, using the stream-aquifer studies of Willey and Achmad (1986) and Otten, et.al (1988). Other applicable studies are Gerhart and Lazorchick (1984), Gerhart and Lazorchick (1988), and Plank, et al. (1995). The assumptions for the existing WMA methods are as follows:

1) Withdrawals are limited to lands owned or controlled by a permittee. For municipal water supplies, this has included the municipal water service area or Community Planning Area.

2) Allocations are determined on a watershed basis, with basins greater than 2 sq. mi. being protected.

3) The 1-in-10-year baseflow or effective drought-year recharge is applied to the areas owned or controlled by the permittee.

4) Losses due to impermeable surfaces are deducted from the effective recharge rate.

5) The calculated 7-Q-10 value for the watershed is subtracted from the effective recharge, to provide additional protection for baseflow.

6) Withdrawals are equally distributed throughout the watershed.

7) ½ of the watershed involves consumptive uses (i.e., as municipal water supplies) and ½ non-consumptive uses (e.g., subdivisions on individual wells and septic systems).

There are limitations to the WMA water balance methods that could lead to unreasonable impacts. The 1-in-10-year drought is only a moderately severe drought. Potential impacts would be greater during more severe droughts. Conversely, WMA uses the drought of record when evaluating surface water withdrawals. Using yearly average (drought) baseflow values may not account for seasonal effects during a drought. A watershed may be fully developed by consumptive uses, which would greatly increase impacts relative to a basin that is developed with ½ of the demand supplied by non-consumptive uses. Withdrawals may not be evenly distributed throughout a watershed, causing a portion of the basin to dry up, although the WMA criteria were met.

Until late 2000, baseflow or effective recharge was derived from a few regional MGS studies. Hammond (1999) derived the following water balance for the 626-acre Poolesville water service area within the Horsepen Branch watershed. Based on values derived by Bachman, et.al. (1998) for the Seneca Creek basin, the estimated annual average effective recharge rate was 625 gpd/ac (8.4 in/yr) in the water service area. It was estimated that the effective drought year recharge rate in the Piedmont areas of Maryland was about 52-63% of the average year rate. The 7Q10 value of 68 gpd/ac (0.9 in/yr) at the Seneca Creek gaging station indicated that the drought year recharge in the basin is moderately low.

The Town of Poolesville (Water Use Permittee) was then advised on May 11, 1999 that the preliminary water balance analysis indicated that there was not enough ground water available for the proposed uses in the Horsepen Branch watershed. The Town, however, was advised that permittees have been allowed to over-appropriate waters in a watershed, where public health and safety is an issue, as long as it causes no unreasonable impacts and the permittee is prepared to adjust its use to accommodate future users.

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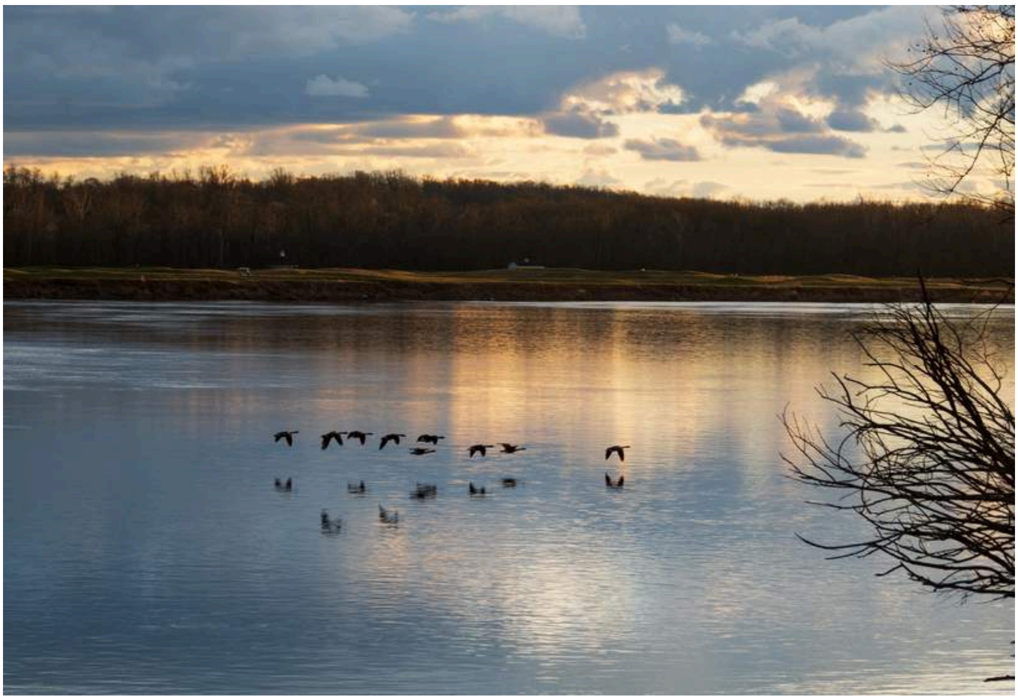
Using a ratio of the range of 7Q10 and drought year baseflow values for various watersheds in the Maryland Piedmont, it was estimated that the effective drought year recharge for the Seneca Creek basin was 56% of the average effective recharge, or 350 gpd/ac (4.7 in/yr). For the 626-acre water service area, the estimated effective drought recharge was 219,100 gpd avg. When an amount equal to the 7Q10 (14,600 gpd) was subtracted, to protect base flow, from the effective drought year recharge or the amount of ground water available in the water service area was 176,500 gpd avg, or 282 gpd/ac/avg. When 10% was deducted for losses due to impermeable surfaces, the amount of water available for use by Poolesville was 159,000 gpd avg.

While the water balance analysis indicated that 159,000 gpd avg of groundwater in the Horsepen Branch watershed was available for the town's use, a permit of 293,000 gpd avg from wells 2, 4, 6 and 8 was ultimately issued to support existing water demand and reflected the reported water use in 2000. SSP&A recalculated the water balance indicating that 132,000 gpd avg was available for the town's use. The lower amount is primarily related to a smaller service area of 519 acres derived using computer assisted mapping techniques versus 626 acres derived by MDE using manual mapping methods.



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In late 2000, MDE adapted a baseflow analysis program of Rutledge (1993) that was then used to analyze baseflow from 26 long-term (30 years with at least one major drought), unregulated (with one exception) stream gaging stations, which was ultimately expanded to 37 stations by 2011, including data from the 2001-2002 drought, if available. Included was Seneca Creek at Dawsonville which had an average base flow of 9.6 in/yr, a 1-in-10-year (drought) baseflow of 5.7 in/yr, and a 7Q10 of 0.9 in/yr. This average was somewhat higher than that calculated by Bachman et al. (1998), 8.4 in/yr, which was likely due to the lowest minima method used in that investigation.

The Seneca Creek gage is located in the Piedmont crystalline (PCR) hydrogeomorphic region (HGMR), while the Poolesville wells and town area are located in the Mesozoic lowland (ML) HGMR. Only one Maryland stream gage is located in the ML HGMR, which is on the Monocacy River at Bridgeport (Carroll County). That site has an average baseflow of 6.1 in/yr, a 1-in-10 drought baseflow of 4.0 in/yr and a 7Q10 of 0.1 in/yr. Since there has been more than 20 years of data collected at both sites after the last MDE analyses, they were recalculated through 2023 for the present investigation, Table 4. The baseflow analyses for the Monocacy River at Jug Bridge were added to demonstrate that the drought of 2023 in central Maryland only affected the Frederick Valley and Monocacy River watershed.

The baseflow analyses indicate that Poolesville was just outside of the drought area; however, a comparison with information from the interactive U.S. Drought Monitor (USDM) website suggested otherwise. That data indicated that central Maryland (and Poolesville) was in a moderate drought from April to September 2023, including a severe drought from mid-June to mid-July, 2023, Figure 5. Some of the numeric inputs to the USDM include precipitation, streamflow, reservoir levels, temperature and evaporative demand, soil moisture and vegetation health. It is not a statistical model; but a convergence of evidence approach that blends those physical indicators, field observations and local insight from a network of more than 450 experts. The USDM provides a regional perspective, but is not recommended for use to derive local conditions, with the possible exception of the effects of drought on water shortages. In this case, baseflow analysis indicates that Seneca Creek was not in a drought during the year of 2023.

Baseflow analysis provides a direct statistical measure of annual effective recharge, which can provide an explanation for the differing results of the baseflow analysis when compared to the seasonal USDM data for 2023. The difference between the baseflow and the USDM data could be that Poolesville was in an agricultural drought in 2013, but not a water supply drought.

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Figure 7. U.S. Drought Monitor (USDM) record for the Northeast region on June 20, 2023.

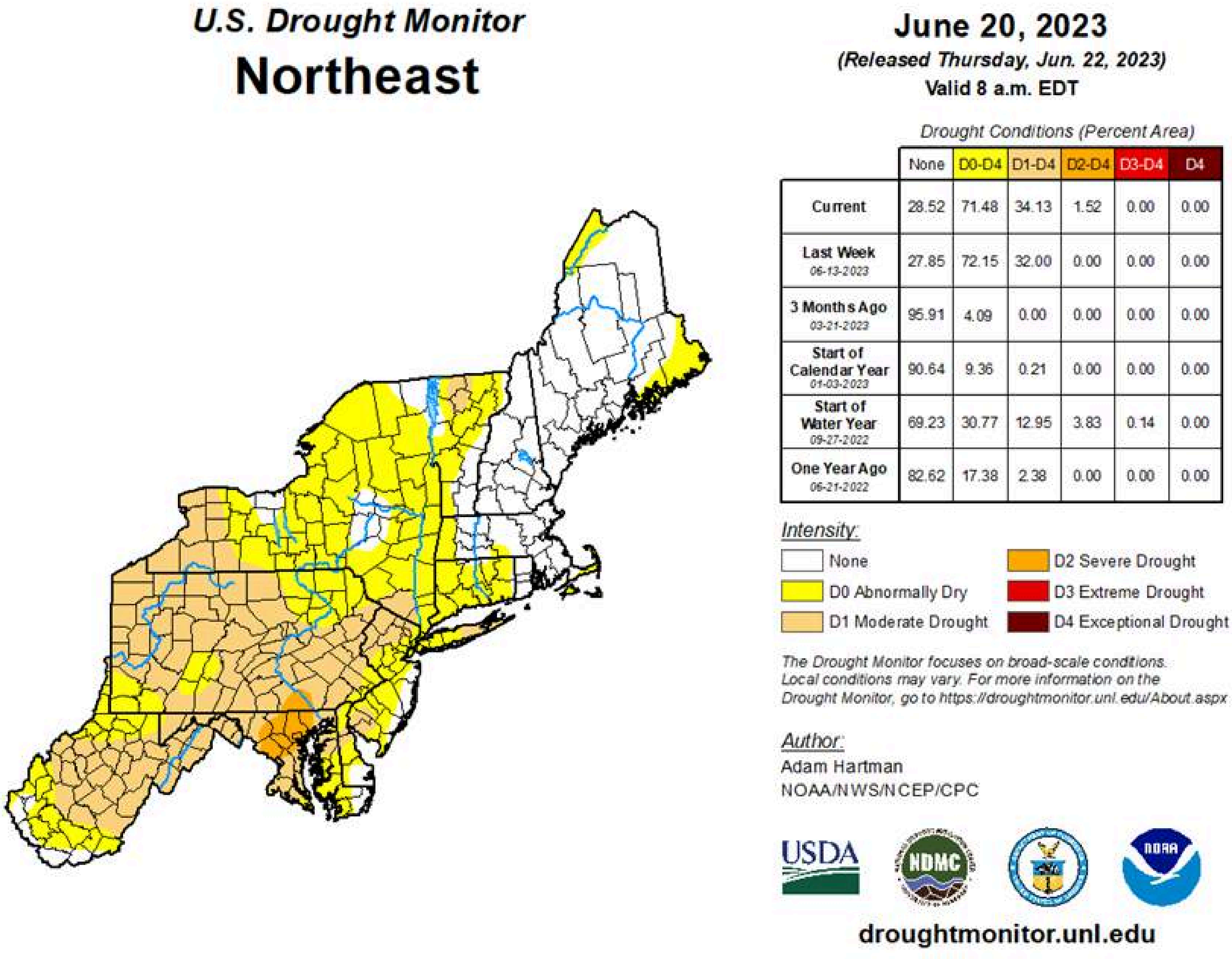

Table 7. provides a comparison of the hydrological characteristics of the Monocacy River (Bridgeport) and Seneca Creek (Dawsonville) watersheds. The results of that analysis are that rainfall and EVT for both basins are nearly identical. The difference (RF-EVT) is a measure of total streamflow and they are also nearly identical. There, however, is a big difference between the baseflows, as the baseflow index (baseflow/total streamflow) for the Monocacy River Bridgeport site is 0.38, while the index for the Seneca Creek Dawsonville site is 0.65. This may be due to differences in permeabilities of the shallow portions of each aquifer type. The New Oxford Formation and Gettysburg Shale of the ML tend to weather to low permeability clays, while the shallow portion of the crystalline rock aquifers of the Seneca Creek basin are more permeable, highly weathered clays, siltstones and sandstones.

The Poolesville New Oxford Formation is an extension of the ML Manassas Sandstone in the Culpepper basin in northern Virginia and is now classified as the Poolesville member of the Manassas Sandstone. Upstream of the Monocacy River station at Bridgeport, the Gettysburg Shale is the major lithologic unit in that watershed and the classification of the New Oxford Formation remains unchanged. To see if the Gettysburg Shale was a primary factor in the low baseflow measured at that station, the baseflows of streams underlain by ML Manassas Sandstone units in the Occoquan River basin, immediately across the Potomac River from Poolesville, were analyzed. The results are shown in Table 8.

For comparisons the Monocacy River Bridgeport and Seneca Creek Dawsonville baseflows were analyzed for the same periods of record as each of the Occoquan River gaging stations contained in the Bachman et al. (1998) study.

Two stations in Bull Run (Catharpin and Clifton) provide fairly good matches to the Monocacy River Bridgeport data and all 5 sites have lower baseflow (67 to 94%) than that of the Monocacy River gage site and approximately ½ of that at the Seneca Creek gage. Also, the median baseflow at the ML stations is 58-68% of the average baseflow which is typical streams with highly variable flows. Conversely, the median baseflow at the Seneca Creek station is 88-95% of the average baseflow which would indicate more constant flows in that stream. Finally, the baseflow index (% of total flow) at the ML stations (30-38%) is about ½ of the index (65%) at the Seneca Creek station. The higher the index, the more recharge is generally available for capture by groundwater withdrawals.

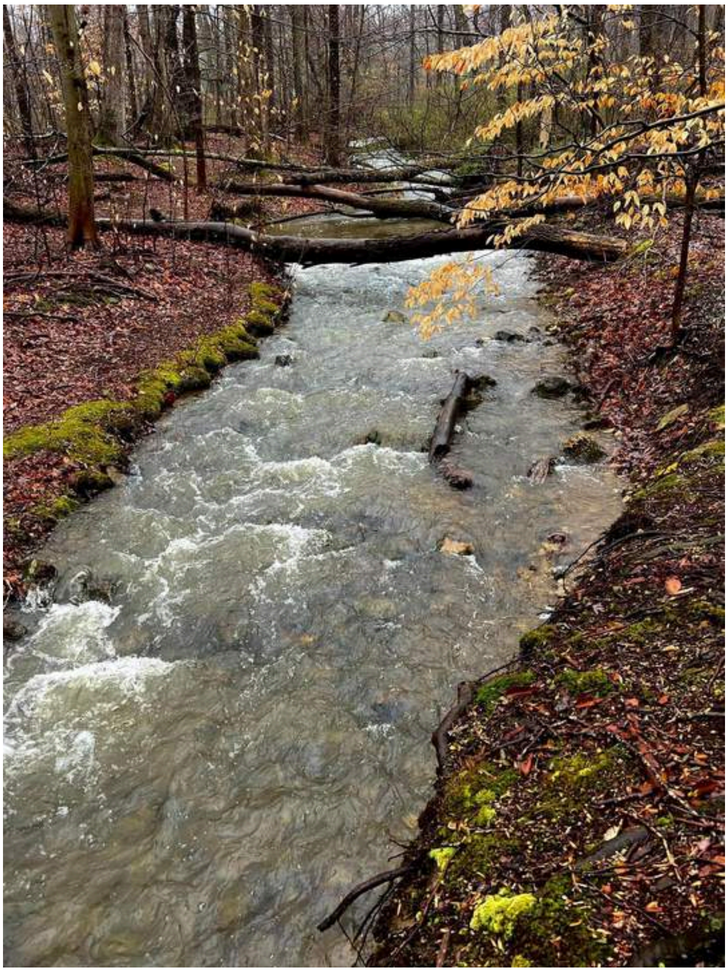

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Table 7. Hydrological characteristics above the Monocacy River Bridgeport (ML) and Seneca Creek Dawsonville (PCR) stream gage sites.

All values = in/yr, except as noted						
Site	RF[1]	EVT%RF[1]	EVT	RF-EVT	Streamflow	Baseflow
Monocacy Bridgeport	43.6	63.0	27.5	16.1	16.8	6.4
Seneca Davidsonville	43.9	62.7	27.5	16.4	16.1	10.5

[1]ESTIMATION OF EVAPOTRANSPIRATION ACROSS THE CONTERMINOUS UNITED STATES USING A REGRESSION WITH CLIMATE AND LAND-COVER DATA
Ward E. Sanford and David L. Selnick
JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION
Vol. 49, No. 1 February 2013

This analysis indicates that the flow data at the Monocacy River (Bridgeport) stream gage is more representative of the effective recharge in the Poolesville service area. Using the drainage area in Horesepen Branch of 519 acres derived by SSP&A, a 1-10-year (drought) baseflow of 4.05 in/yr, a 7Q10 of 0.1 in/yr, and 10% loss to impervious surfaces, the revised estimate of groundwater available in Horsepen Branch is 137,300 gpd avg or slightly higher than the SSP&A estimate of 132,000 gpd avg. Hammond (2022) indicated that the upper portion of Horsepen Branch (site A, 774 acres, 0.3 mi west of the junction of Budd and Hughes Roads) was biologically impaired on 7/9/2008 (summer sample) due to groundwater withdrawals (reducing flow by about 50%) and development (20.3% urban land use) within the town's boundaries. The Fish Index of Biotic Integrity (FIBI) was 1.0, while the Benthic Index of Biotic Integrity (BIBI) was 1.5. Both were well below the accepted scores when there are less than three samples at a sample site (FIBI-2.50 and BIBI-2.65).

As the over-allocation in Horsepen Branch is no longer needed to meet the previous existing demand and there is not a public health issue, the permitted use for the watershed could be reduced to some value between the water balance of 137,300 gpd avg derived in this investigation and the average reported use of 185,000 gpd avg during the permit period of 2008 to 2020, and also potentially adjusted for the effects of climate change. The reduction could be counter-balanced by increased appropriations in the Broad Run and Seneca Creek watersheds. For Russell Branch, samples were collected on 7/9/2001 (summer sample) at the Tom Fox Road crossing. The FIBI was 1.0 and the BIBI was 1.75. The stream was dry, but in addition to the town's groundwater withdrawals, the small drainage area (76 acres) and the start of the 2001-2002 drought have to be considered as mitigating factors. Additional stream sampling should be considered for both Horsepen Branch and Russell Branch. In the case of Russell Branch, larger drainage area (probably at least 1 mi2) should be sampled.

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Table 8. Baseflow and rainfall records for Mesozoic Lowland (ML) stations in the Monocacy River at Bridgeport and stations in the Occoquan River basin, and the Piedmont Crystalline (PCR) station in Seneca Creek at Dawsonville

Mesozoic Lowland (ML) and Seneca Creek (PCR) Baseflow Data												
Number	Name	Drainage	ML	Rainfall	Period of	Rutledge (1993) program			Monocacy		Seneca Creek Index 65.3%	
		sq.mi.	%	in/yr	Record	Index	Baseflow (in/yr)		Bridgeport (in/yr)		Dawsonville (in/yr)	
						%	Average	Median	Average	Median	Average	Median
16390	Monocacy R (Bridgeport)	173	E95+	43.5	1972-1996	37.9	7.0	4.6	7.0	4.6	11.3	10.1
16567	Occoquan R (Manassas)	343	67.7	43.3	1969-1980	33.5	5.7	3.8	7.0	4.7	11.9	11.3
1656725	Bull Run (Catharpin)	25.8	95.0	43.1	1970-1986	37.4	6.5	4.2	6.9	4.5	11.2	10.3
165696	Cub Run	49.9	95.7	42.8	1973-1986	30.3	4.5	2.6	6.7	4.3	10.6	9.5
1657415	Bull Run (Clifton)	185	80.0	43.0	1973-1983	37.0	6.0	4.1	6.7	4.4	11.0	10.2
16561	Cedar Run	155	71.1	43	1973-1998	34.8	4.8	2.8	6.9	4.4	10.9	9.6

Reasonableness of Impacts to Other Users of the Resource (Well Interference)

Poolesville has a relatively long history of interference with private wells by withdrawals from its public water supply wells. Early instances of impacts to the private wells are poorly documented. A Washington Post article of November 16, 1973 indicated that 10 to 15 families on private wells may have been impacted by two new town wells drilled to 300 ft. An official of the Department of Natural Resources was quoted as indicating as many as 75 other families could be affected. It appears that the impacts may have been related to operation of wells 1 and 2, since the state delayed approving a permit to operate a third well. No record could be found concerning the resolution of the problem.

A Frederick Post article (11/16/74) indicated 6 or 7 wells went dry due to pumping of Well 3. The town denied responsibility and homeowners were to pay for hookups. A chart in MDE files indicates that 14 wells went dry or turned muddy between August and October 1974. On September 4, 1974 the town proposed monitoring a 109 ft hand dug well near the school. There was a drawdown of 4-10 ft at about 500 ft from the pumping well. There was a moratorium on new connections. Developers may have already paid for taps. MDE memos indicated that well 4 might cause nearby house wells to be impacted and required monitoring of those wells. Six wells were impacted and a water line was extended to those homes. It was indicated that those homeowners could pay to be hooked up to the public water supply, although there is no known record of any actions taken in the matter. There were drawdowns of 70 ft and 82 ft in two domestic wells 1600 ft from well 6 during that 1985 test. No record could be found about actions taken to mitigate those potential impacts.

Comprehensive monitoring of private wells has been required since the completion of wells 9 and 10, which led to the town having to replace about a dozen wells near town and the Sugarland Forest community due to impacts caused by pumping of wells 9 and 10. Another 5 were replaced due to withdrawals from well 12. In addition to 2 wells replaced along Beallsville Road, due to impacts related to well 13, there was a complaint of impacts to wetlands and a stream on a neighboring farm. Potential impacts caused by wells 11 and 14 cannot be determined, since those wells have not been placed in service.

Estimate of groundwater available for the use by Poolesville

To estimate the groundwater available for use by Poolesville, a number of factors have to be considered. These are the aquifer tests results, available operational data, damage to wells 6 and 7, well interference during droughts, operational efficiency, drought year demand, limits caused by water balances in the Horsepen Branch and Russell Branch watersheds, and the effects due to climate change.

The estimated 90-d yields are a total of 859-887 gpm based on the MDE method of extrapolating to the first reservoir unit and or about twice those amounts (1740-1772 gpm) when using the depth to the 1st Mwbz as an operating target. When the individual test yields are adjusted for a drought, the MDE estimated yields are 767-793 gpm and those when extrapolating to the 1st Mwbz are 1556-1584 gpm. Using the available operational and test data, the total estimated yield in this evaluation is 750 gpm, which includes interference testing between wells 2 and 12, and 9 and 10, but not well 11 with wells 6, 9 and 10, and 14 with well 4, and includes the damage to wells 6 and 7 due to dewatering of reservoir units. The estimate does not include operational efficiency, additional well interference during droughts, watershed limitations and effects of climate change. The SSP&A estimate is 747 gpm, if the estimated yield in the present evaluation is used for wells 9 and 10. This close agreement between this evaluation and that of SSP&A, is AAP&A used the Hammond (1999) estimates for wells 2-8, and wells 9 and 10 were mis-identified, so the estimates from the Hammond (2021) report were used for those wells; i.e., the corrected SSP&A estimates are essentially the results of the Hammond (1999, 2021) studies.

The operational data indicate that the wells are operated best at full capacity; however, under certain situations this may not be possible. Recinos (1996) indicated that the wells were to be operated 16 h/d, which would have reduced the yields to about 77% of full capacity, Hammond (2001). From June 1 to June 10, 1999, the wells were operated 24 h/d, but that was too early in the drought, so pumping had to be reduced and water restrictions imposed due to potentially declining well yields. During September 2001, the wells were safely operated 21h/d or about 92% of capacity. The regional water table in September 2001 was about the same as the water table during July of the severe 2002 drought, so the September 2001 data were used to estimate the reliable drought yields of wells 2-8. Wells 9 and 10 are limited by water balance, so the wells would have to be operated at less than 92% capacity.

The total estimated yield from wells 11, 12, 13 and 14, not considering well interference, is 154 gpm. At 92% capacity for those wells, the total yield of the system (well 2-14) would be reduced by 12 gpm to 738 gpm. Long-term tests (45-60 days) were conducted to show potential interference between wells 9 and 10 (Jan-Feb 2004), wells 5 and 13 (Oct-Nov 2009), and wells 2 and 12 (Oct-Nov 2009). No tests have been conducted for other wells that may interfere (wells 4 and 14, and well 11 with wells 6, 9 and 10).

All the tests were conducted under average climatic conditions. Interference is likely to increase during a drought when limited or no recharge is available, but there is no simple way to demonstrate to what degree that it would occur. A complex numerical model may be useful to demonstrate what the well yields might be during droughts. In this respect, the model prepared by SSP&A might work, if drawdowns are extended to the reservoir units, the effects of lack of summertime recharge, and a horizontally anisotropic aquifer and a relatively impermeable crystalline rock aquifer barrier north of Poolesville are assumed.

The water balance limits withdrawals to 293,000 gpd avg in Horsepen Branch and 115,000 gpd avg in Russell Branch, as part of the total appropriation of 650,000 gpd avg. The appropriation in Horsepen Branch is over-allocated by 155,700 gpd avg, which was originally designed to provide water for the existing use in 1999. This is a primary reason that the watershed is severely biologically impaired, even at the lower withdrawal rate of 185,000 gpd avg in 2008 when the biological stream survey was conducted.

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When the decision to issue that permit was made, the town was notified that adjustments may be needed, if unreasonable impacts occurred. If the Horsepen Branch appropriation was reduced by the over-allocation to 137,300 gpd avg, the result would be total appropriations of 512,700 gpd avg. This would be insufficient for the town's use. Part of restoration of the stream could be made by increasing withdrawals from the Seneca Creek and Broad Run watersheds, which have a water balance excess capacity of 143,100 gpd avg. This would produce a total potential allocation of 655,600 gpd avg

Using the 2018-2023 data, the estimated existing average demand for the period is 530,942 gpd avg for an average population of 5772. Adding 10% for drought demand and 4778 gpd avg for 30 days at 100 °F, produces an estimated exiting water demand of 588,814 gpd avg. so it is possible to supply the estimated existing water demand based on the water balance calculations and reallocation of appropriations by the individual watersheds. Since this could take some time, a phased reduction in withdrawals from Horsepen Branch should be considered. Obtaining easements within the Horsepen Branch from owners outside the Poolesville town limits could be another option that has been approved by MDE in the past for other water use permittees.

Finally, the impacts of climate change on the water system and flows within the watersheds need to be considered. Using the seven applicable ICPRB scenarios in the section on climate change, the average reduction in baseflow (effective recharge to the wells) is 8.4%, while the average reduction in baseflow at three stream gages on the Monocacy River and Seneca Creek is 16% during a severe drought. When this factor is applied to the reliable average individual yields during a drought year (771,400 gpd avg) the result is a reliable system yield of 648,000 gpd avg, which does not include limitations due to the water balance (discussed below) and additional unidentified well interference during a drought.

The total estimated maximum yield of the wells (2, 4, 6, 8, 11 and 14) is 330 gpm. A reduction of 16% produces 277 gpm, which is close to the permitted overallocation of 269 gpm (388,000 gpd max). The total yield in the Russell Branch watershed (wells 7, 9 and 10) is 175 gpm. A reduction of 16% equals 147 gpm, but the use in that watershed is limited to 126 gpm. The remaining wells (3, 5, 12 and 13) have a total estimated yield of 223 gpm, which if reduced by 16%, produces a yield of 187 gpm. The total adjusted system drought yield, including the effects of climate change is then 582 gpm or 838,080 gpd max. At the max:avg ratio of 1.5:1, the average total yield would be 566,400 gpd avg, which would be insufficient to meet the average 2018-2023 demand of 603,742 gpd avg.

Juvenile cormorants, Sycamore Landing - Susan Petro

Susan Petro

During a drought, mandatory water restrictions would likely be required to successfully address the 6.2% deficit in groundwater availability. In practice, mandatory summertime water restrictions may be required; however, this would reduce annual demand by about 10%.

A reduction of effective recharge by climate change could also cause increased well interference and additional degradation of the biological habitat of Horsepen Branch and possibly Russell Branch.

The frequency of droughts is expected to increase, such that a severe drought (1-in-10 recurrence) could occur on a five-year interval.

Susan Petro

Should the ICPRB predictions prove reliable, under average climatic conditions, the reduction of annual average effective recharge due to climate change (8.4%) would be balanced by a similar reduction in the drought demand (10%). In addition, the estimated yields of wells 3,5,12 and 13 may increase by about 45 gpm (increase of 20% based on the Hammond, 2021, study). **Under average conditions, the water system can provide water for the 2018-2023 average population of 5772; however, this is only possible due to the substantial overallocation (108 gpm avg) and degradation of the stream in the Horsepen Branch watershed.**

At a population of 6500, the water demand would be 609,176 gpd avg under average climatic conditions, while the wells could produce 640 gpm (permitted limits in the Horsepen and Russell Brach watersheds of 269 gpm and 126 gpm, respectively and as much as a non-drought yield of 268 gpm from the remaining wells, or a total of 663 gpm (954,720 gpd max and 681,943 gpd avg (ratio 1.4:1). Again, this does not consider the over-allocation of 155,700 gpd avg in Horsepen Branch.

The 2018-2023 water demand (530,942 gpd avg) was adjusted by adding 728 people at 100 gpcd, for a total population of 6500, 10% for drought correction and 5434 gpd avg for 30 days @ 100 °F produces a total estimate demand of 669,550 gpd and 1,003,484 gpd max (max:avg ratio of 1.5:1). With a drought system yield adjusted for climate change of 838,080 gpd max, there would be a deficit of 16.5%. Severe mandatory water restrictions would likely be required to address such a problem.

"At a population of 6500, water restrictions may be required under average climatic conditions and severe water restrictions may be required during droughts. The water supply system could then be at high risk during severe and extreme droughts. "

The water supply system could then be at higher risk during severe and extreme droughts. Careful monitoring of system production and periodic evaluations are needed to verify the effects of climate change on well yields. Additional biological surveys of Horsepen Branch and Russell Branch should be performed to better determine the degree of stream degradation and what adjustments may be required to the permitted withdrawal amounts.

Montgomery Countryside Alliance
PROMOTING & PROTECTING RURAL MONTGOMERY COUNTY

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APPENDIX

Results of Step-test and Aquifer Tests of Poolesville’s Public Water Supply Wells

Shown are semi-log plots (log time versus linear drawdown) of the various aquifer tests conducted on the Poolesville’s public water supply wells. Breaks in the drawdown data (deviations from type curves) were used to estimate the depths to reservoir units. Drawdowns from type curves are extrapolated to 90 days and the calculated specific drawdown is applied to the drawdown to the reservoir unit to determine a well’s estimated yield, which is then adjusted for a drought yield using a method developed by MDE. These methods are discussed fully in Hammond (2021).

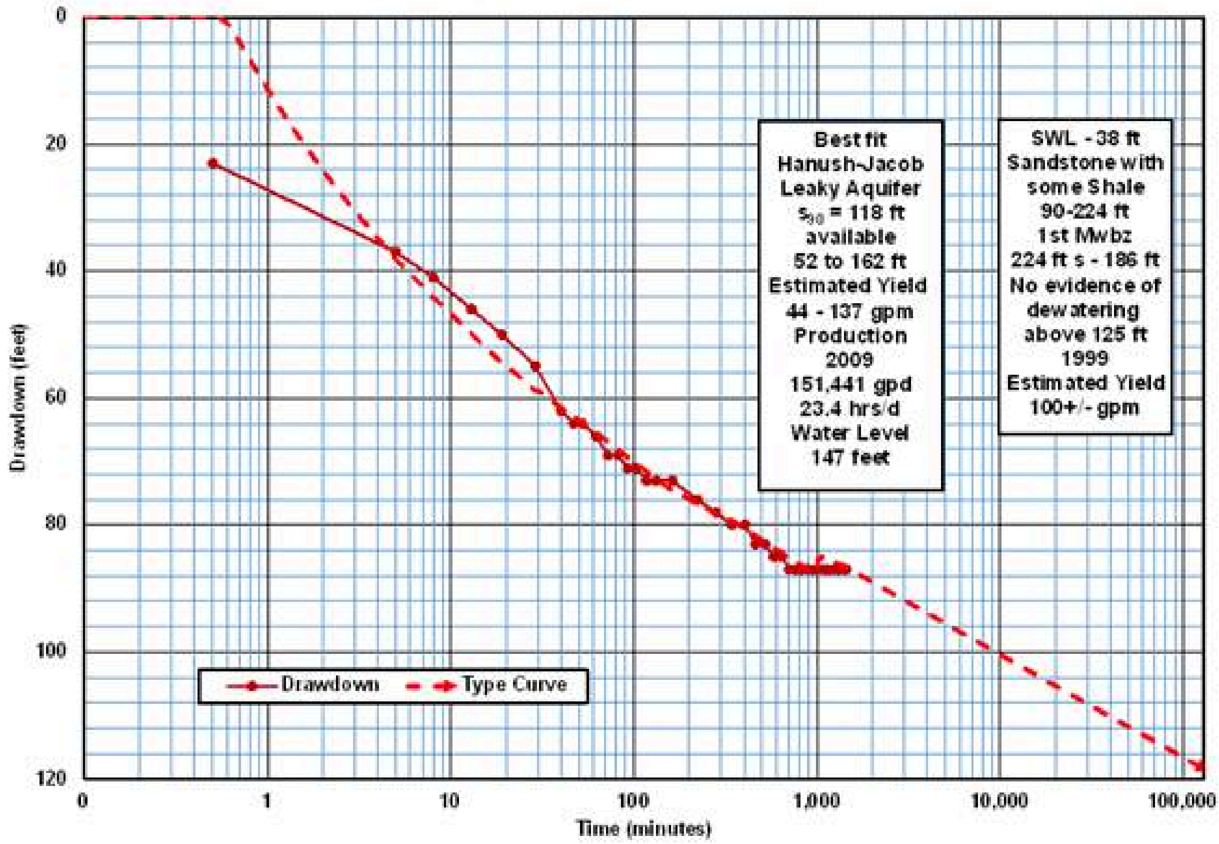

Figure A-1. Poolesville well 2 – Semi-log plot of drawdowns from a 24-h, variable rate, aquifer test, Hantush leaky aquifer solution

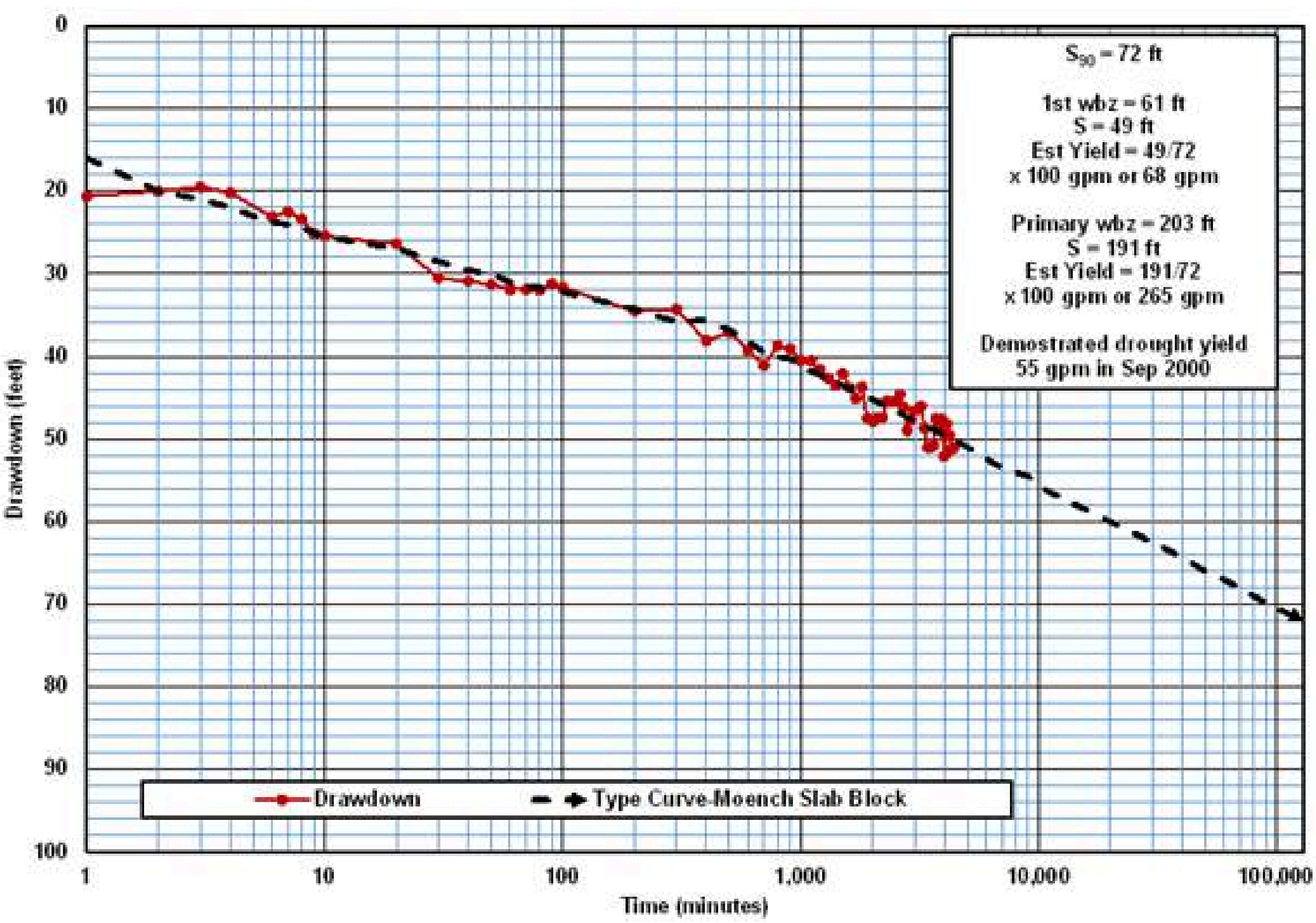

Figure A-2. Poolesville well 3 – Semi-log plot of drawdowns from a 73-h, 100 gpm, aquifer test, Moench dual porosity w/slab blocks solution.

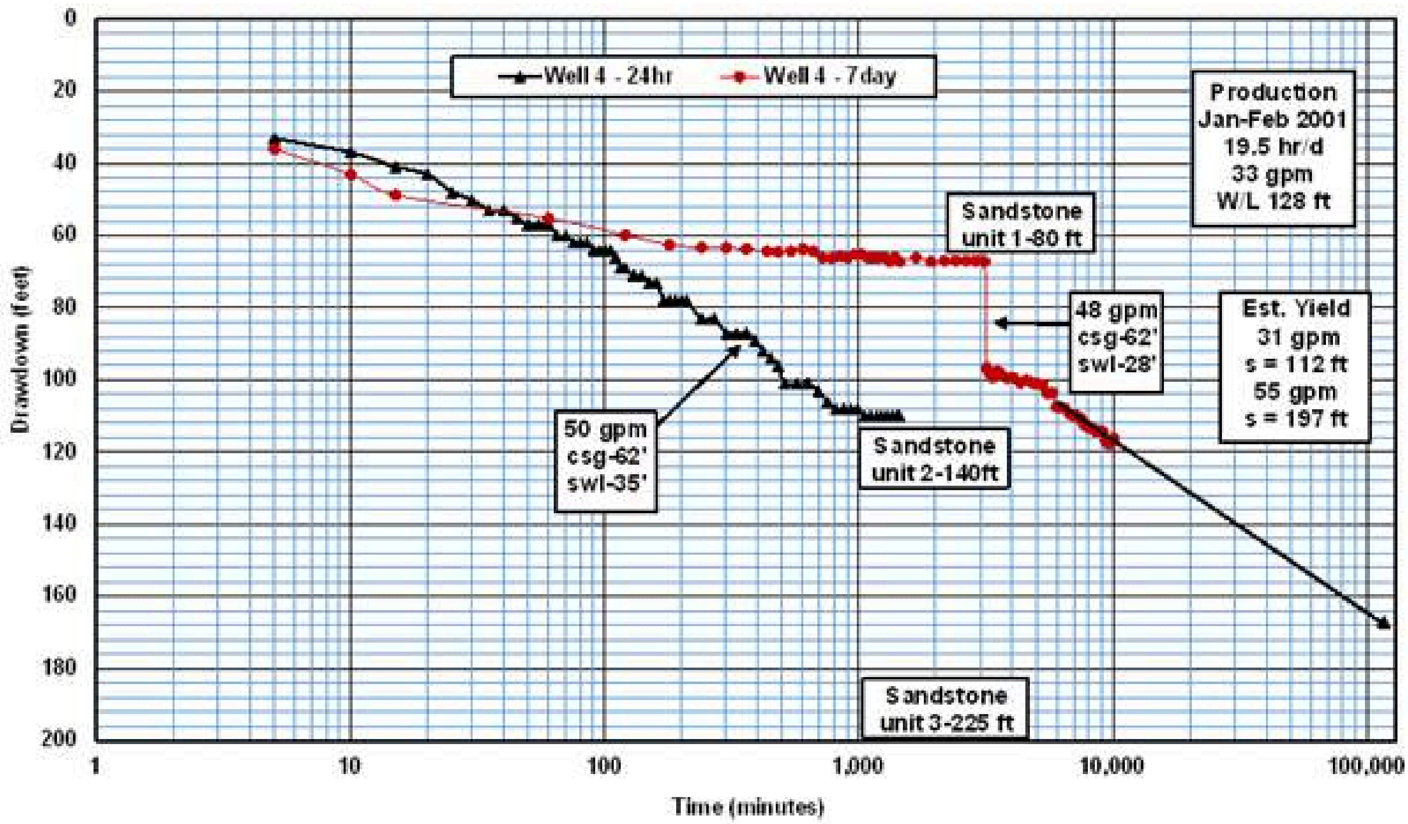

Figure A-3. Poolesville well 4 – Semi-log plot of drawdowns from 24-h, 50 gpm and 7-d, 48 gpm aquifer tests

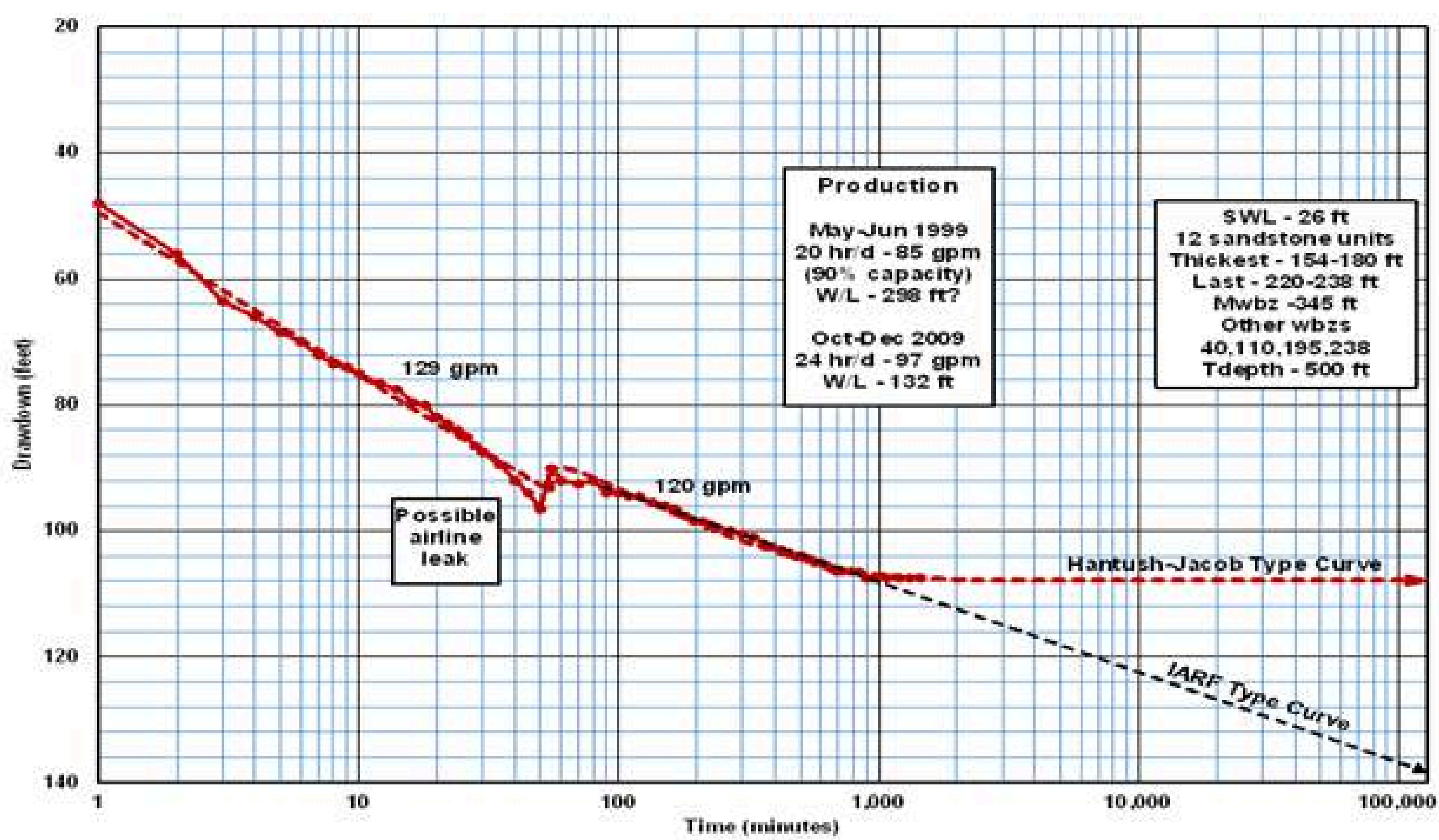

Figure A-4. Poolesville well 5 – Semi-log plot of drawdowns from a 24-h, variable rate aquifer test, Hantush-Jacob and IARF solutions.

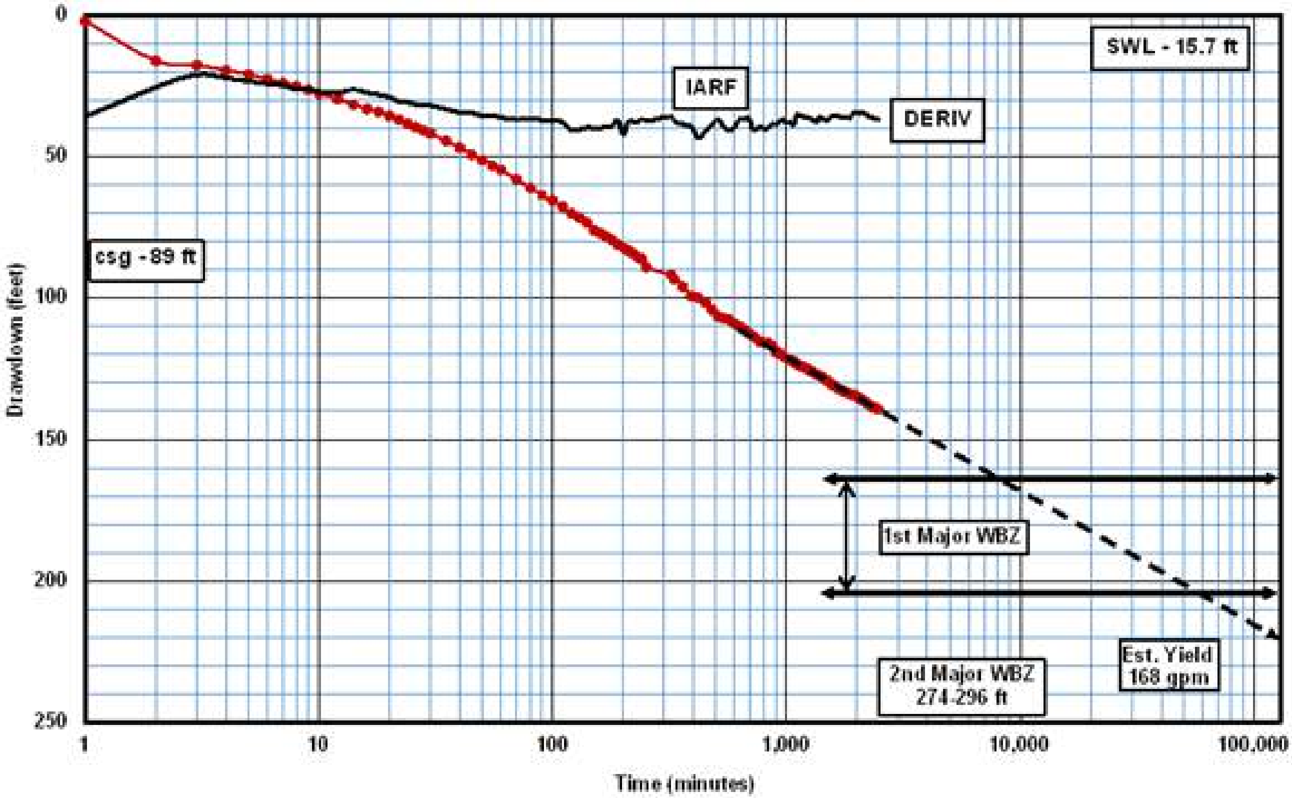

Figure A-5. Poolesville well 6 – Semi-log plot of the water levels and the adjusted logarithmic derivatives from a 72-h, 225 gpm pumping test, estimated yield based on 90-d extrapolation from an IARF segment.

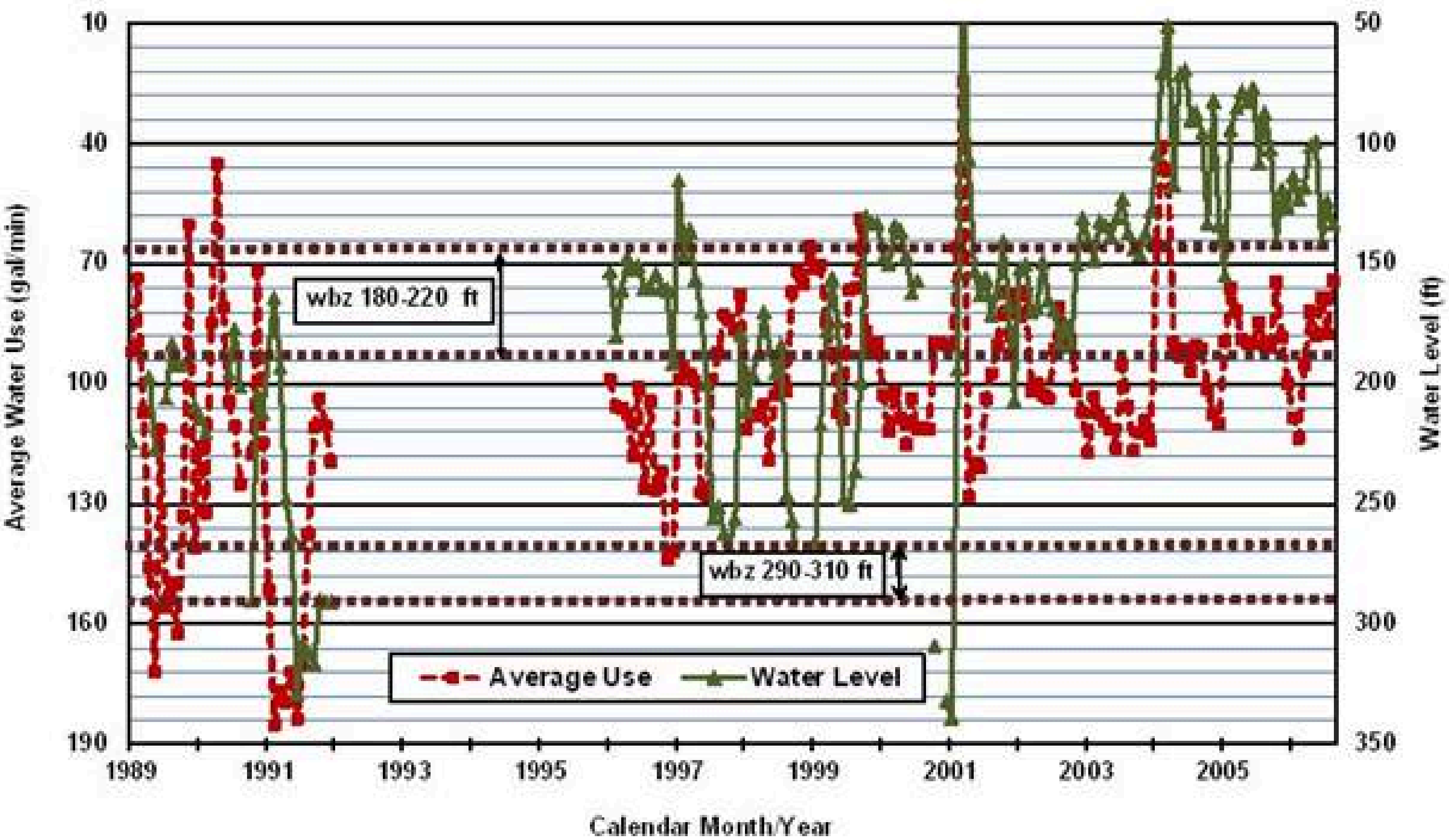

Figure A-6. Poolesville well 6 – Water use and water level data

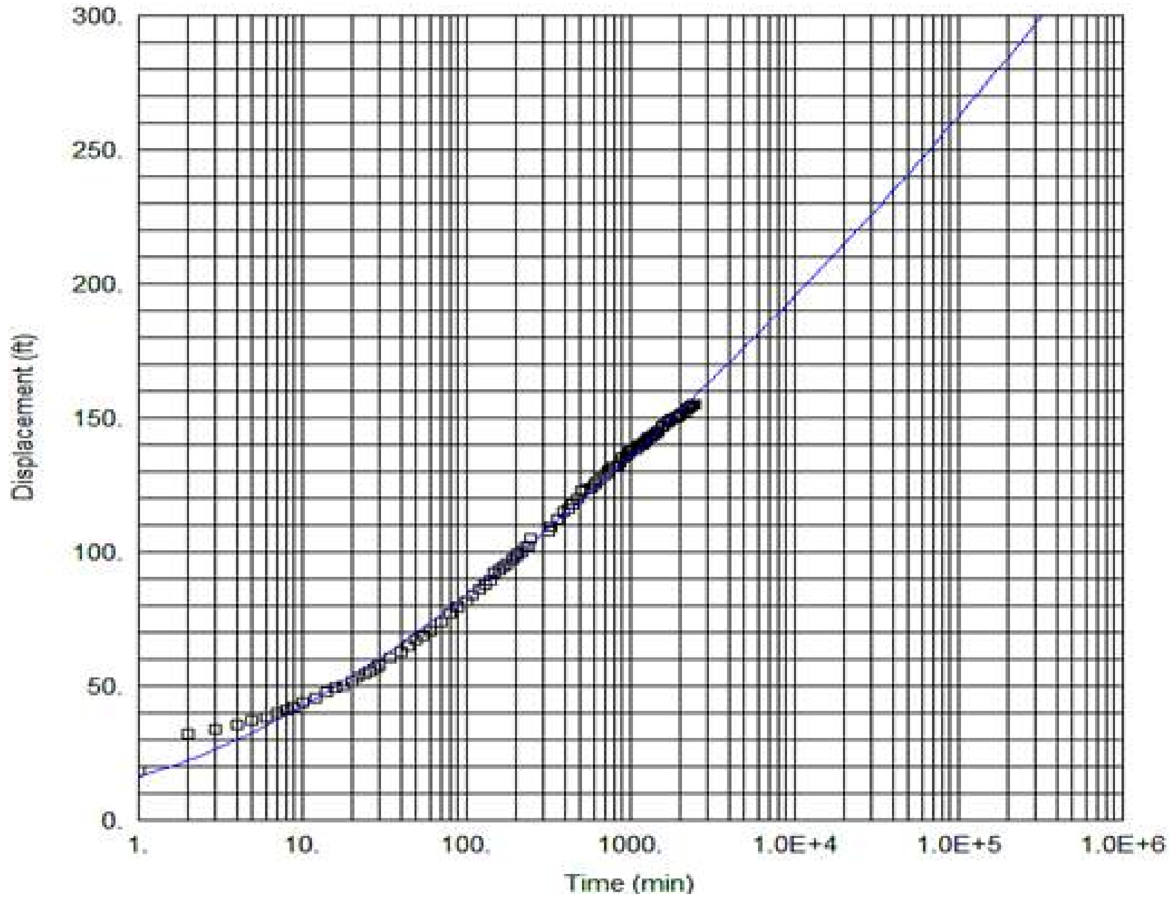

Figure A-7. Poolesville well 6, 225 gpm well, Barker solution, 90-day extraoplated estimated yield 148 gpm.

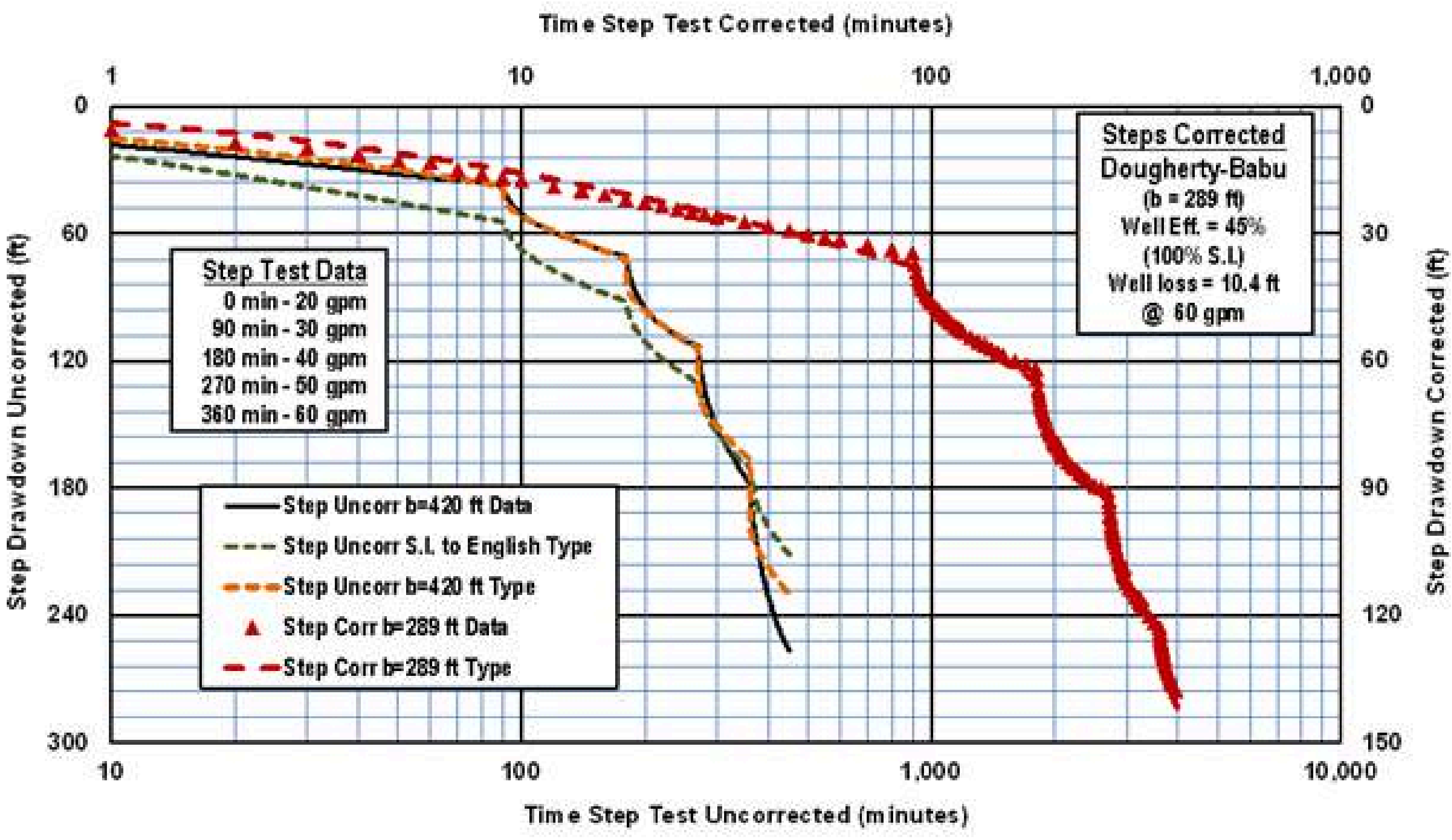

Figure A-8. Semi-log plot of drawdown from step-drawdown test of Poolesville well 7. Data is both uncorrected and corrected for aquifer thickness b of 289 ft. S.I. type curve converted to English units for uncorrected data.

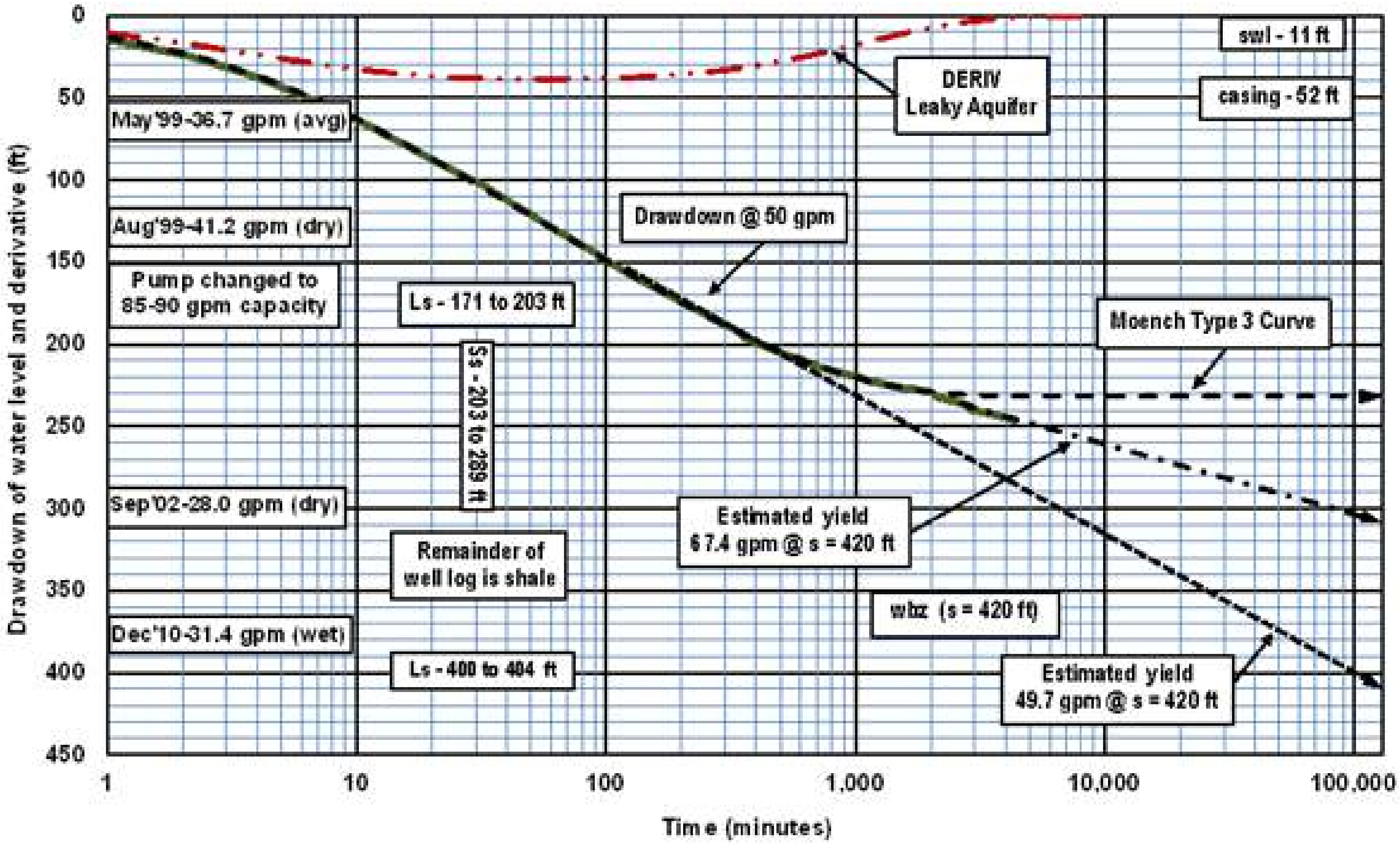

Figure A-9. Semi-log plot of drawdown and its logarithmic derivative from the 2011 72-h, 50 gpm test of Poolesville well 7 showing the best fit of the Moench leaky aquifer solution to the data (with lithologic description).

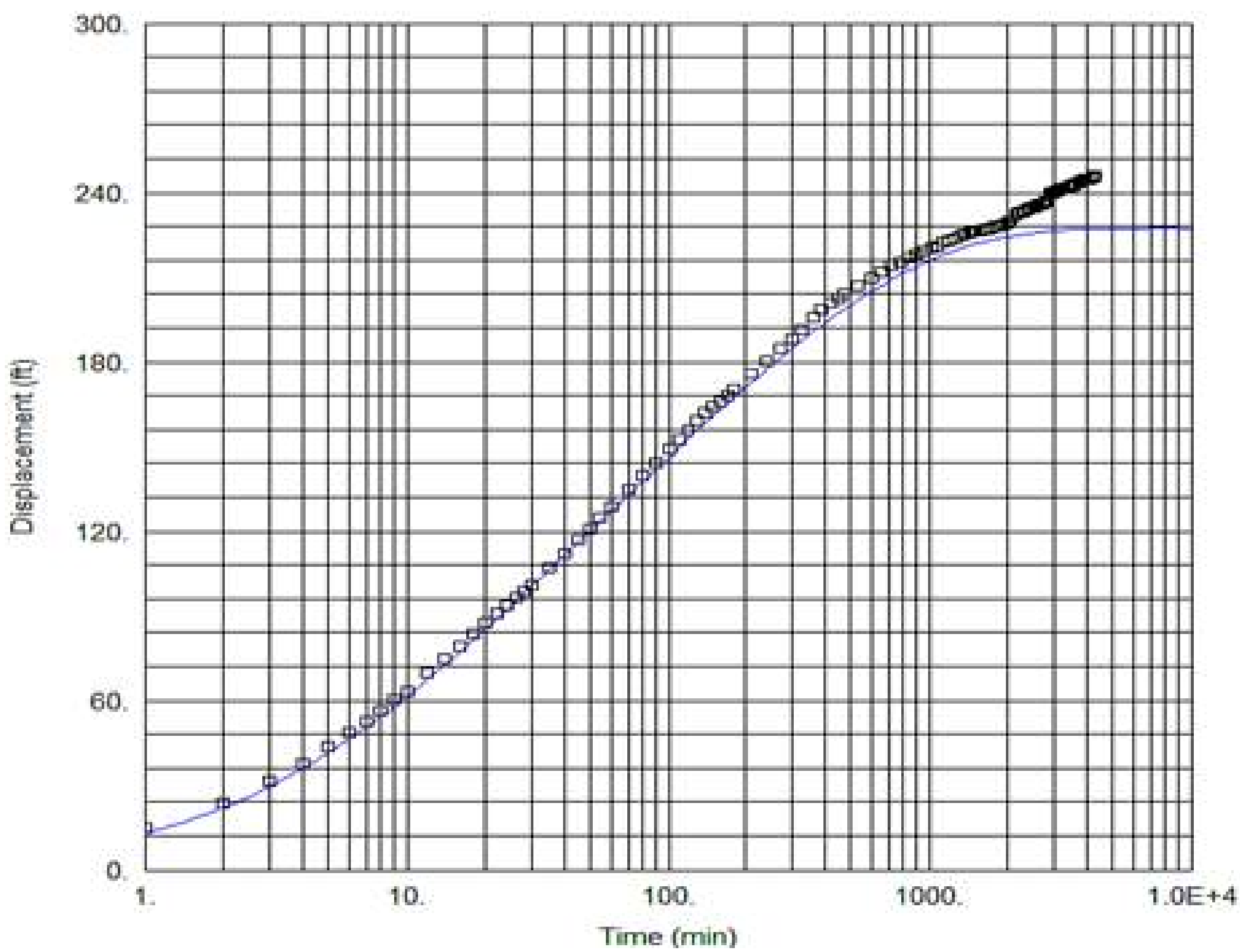

Figure A-10. Poolesville well 7, 72-h, 50-gpm test. 49 gpm simulated using Moench leaky aquifer solution.

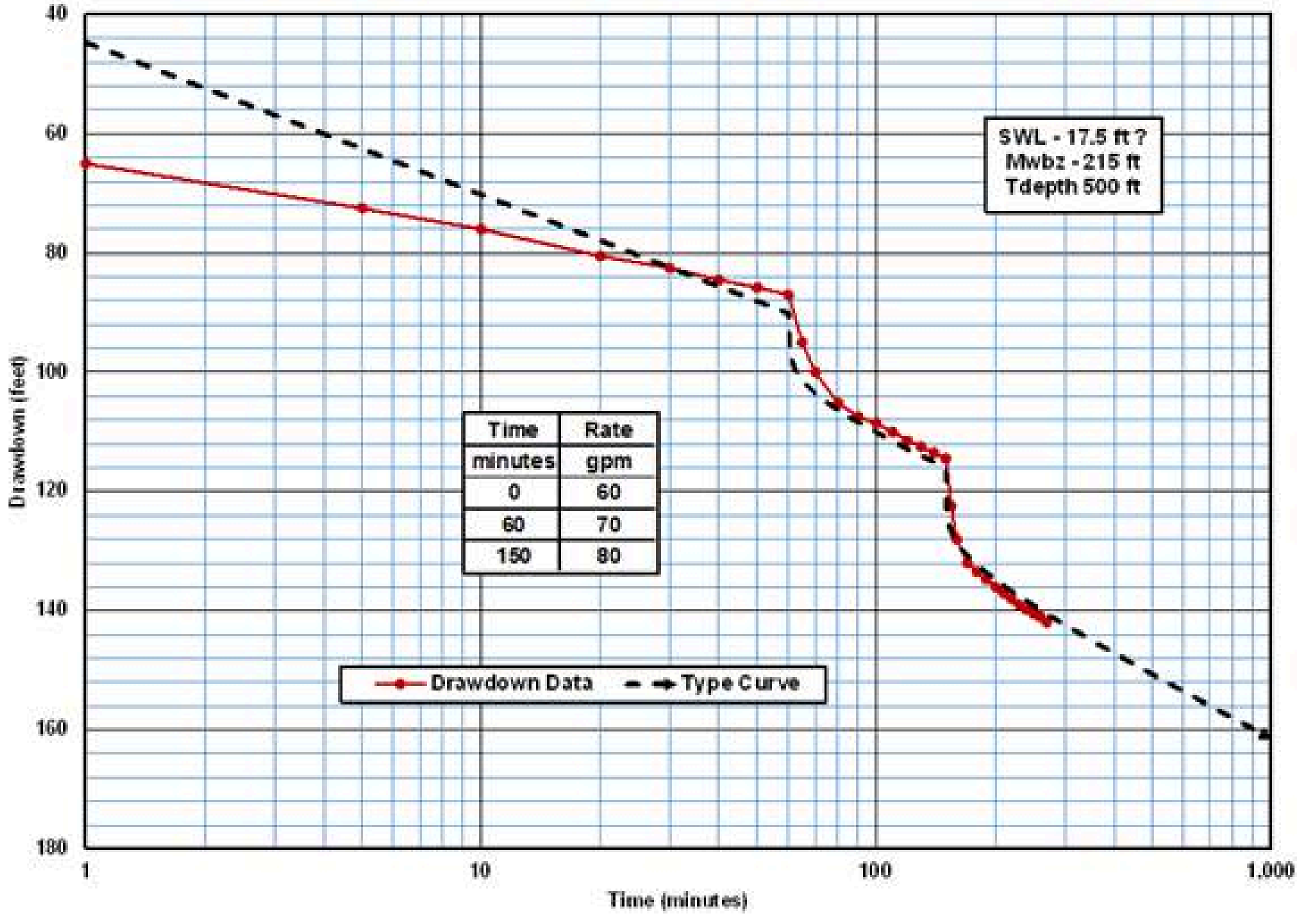

Figure A-11. Poolesville well 8 – Semi-log plot of drawdowns from a step-drawdown test, Hantush-Jacob leaky aquifer solution.

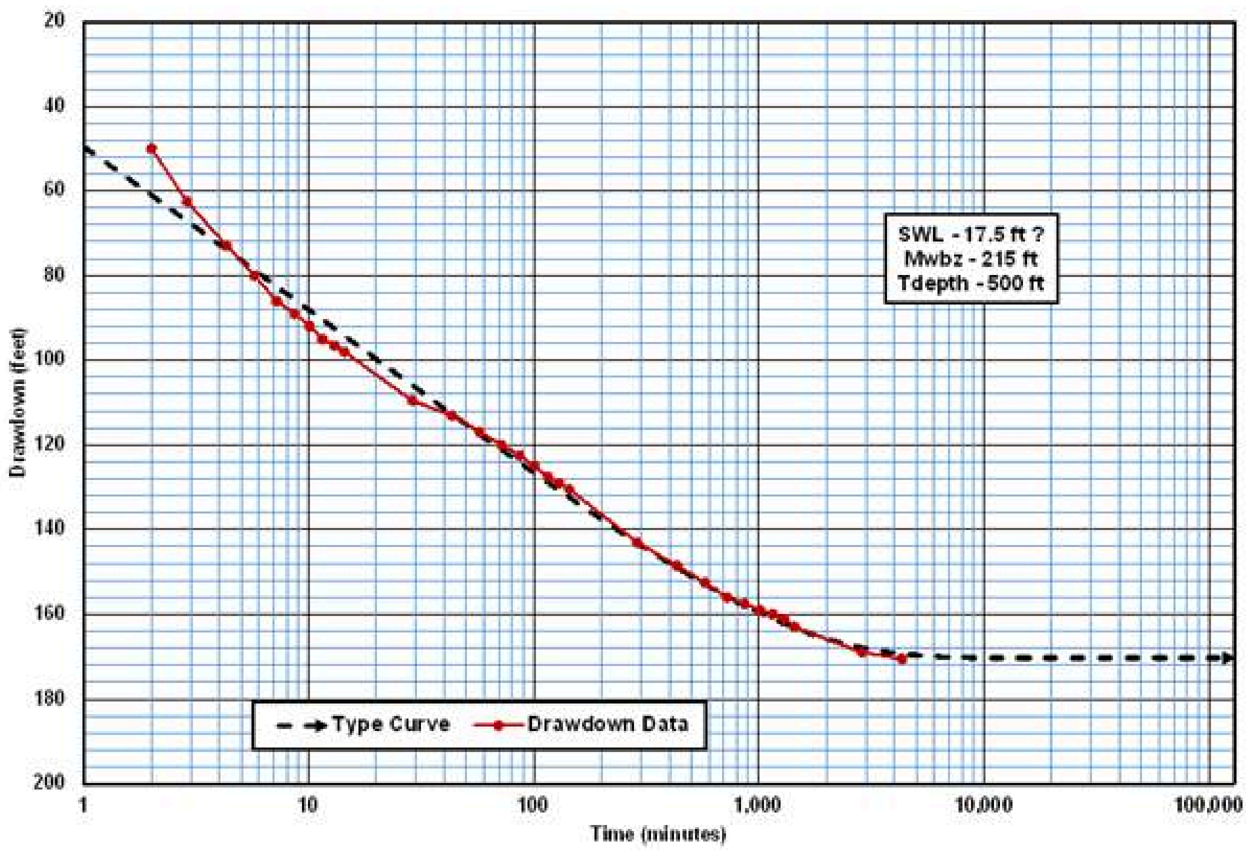

Figure A-12. Poolesville well 8– Semi-log plot of drawdowns from 72-h, 80 gpm aquifer test, Hantush-Jacob leaky aquifer solution.

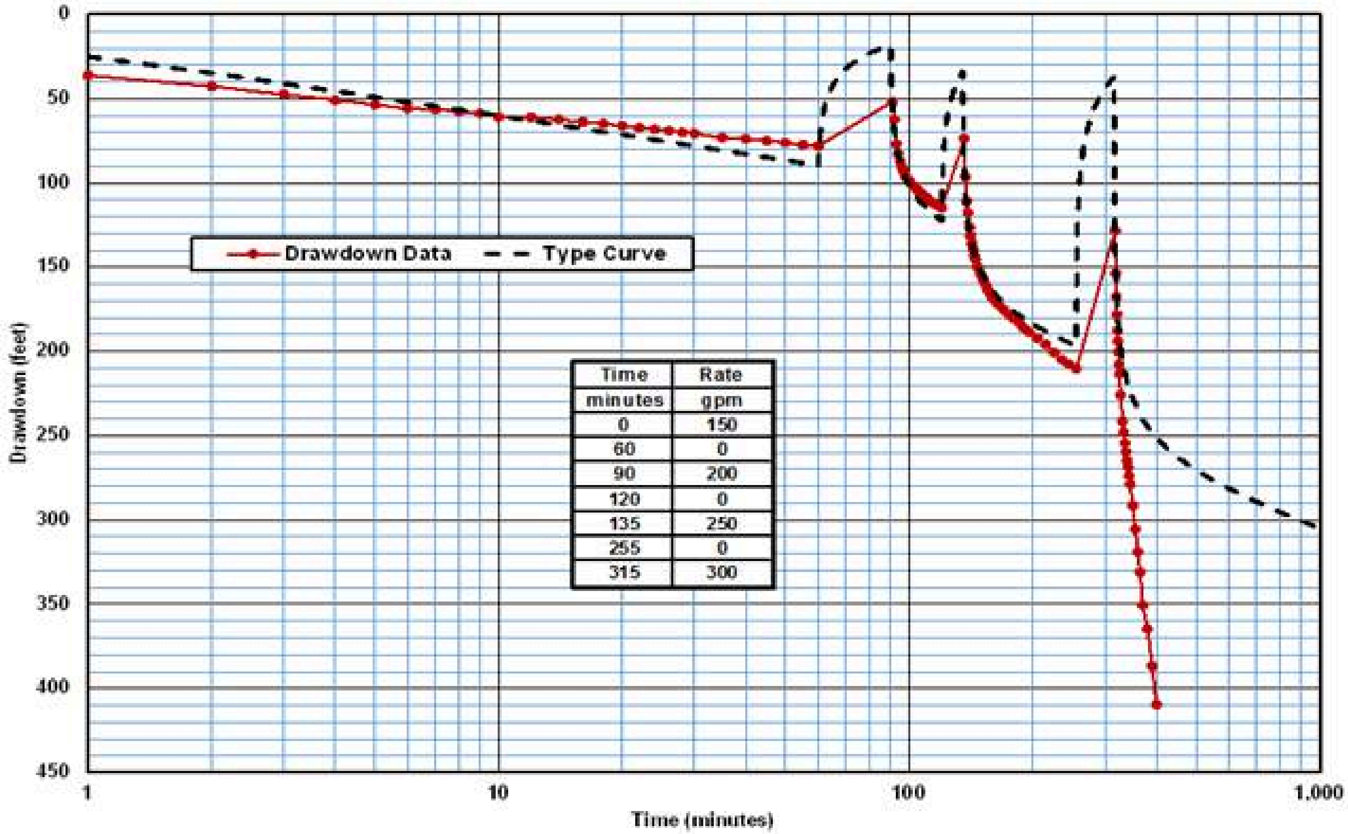

Figure A-13. Poolesville (Powell) well 9 – Semi-log plot of drawdowns from steps 1–3 of a multi-rate test, Hantush-Jacob leaky aquifer solution.

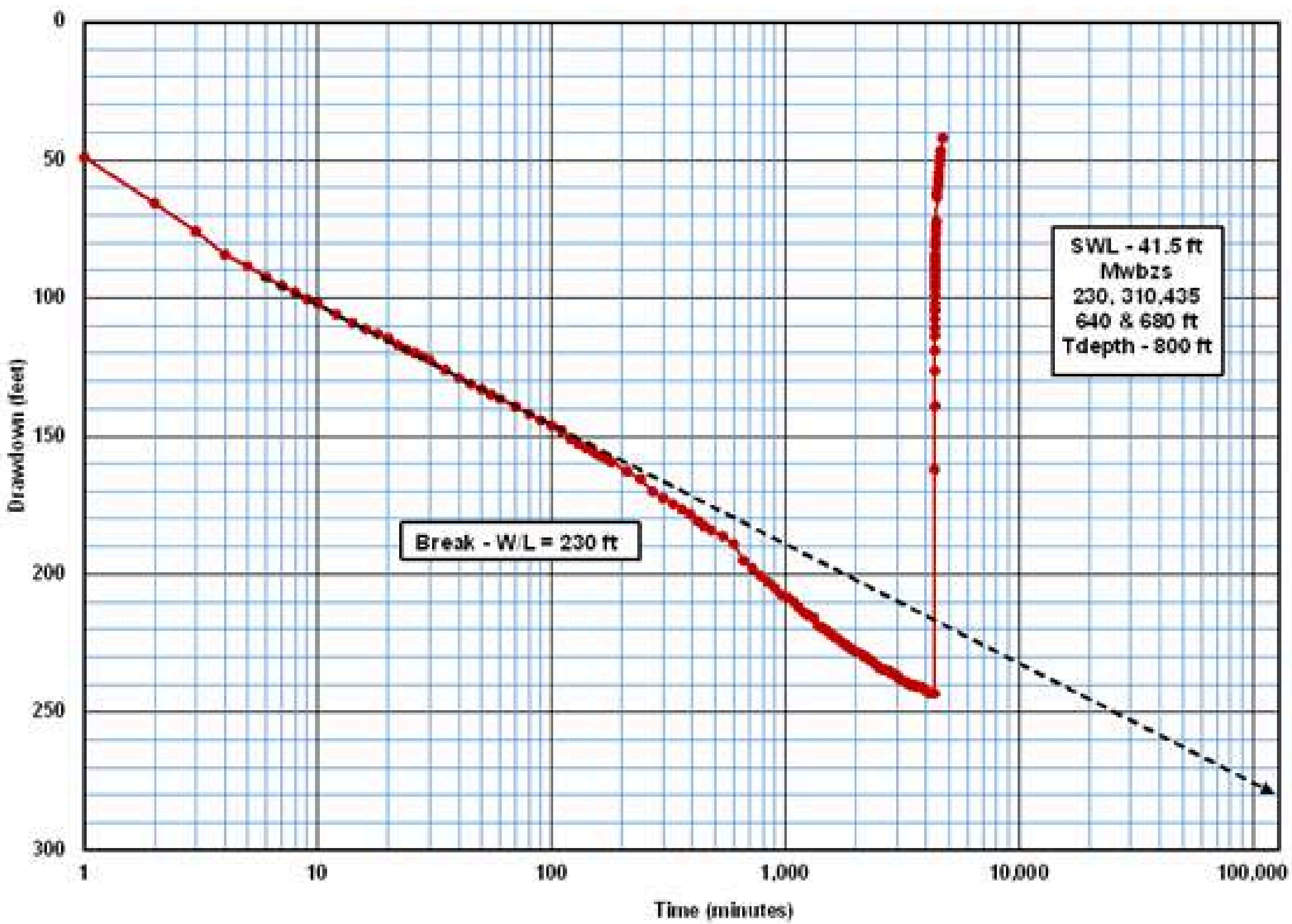

Figure A-14. Poolesville (Powell) well 9 – Semi-log plot of drawdowns from 72-h, 225 gpm aquifer test, 0-600 min Hantush-Jacob solution

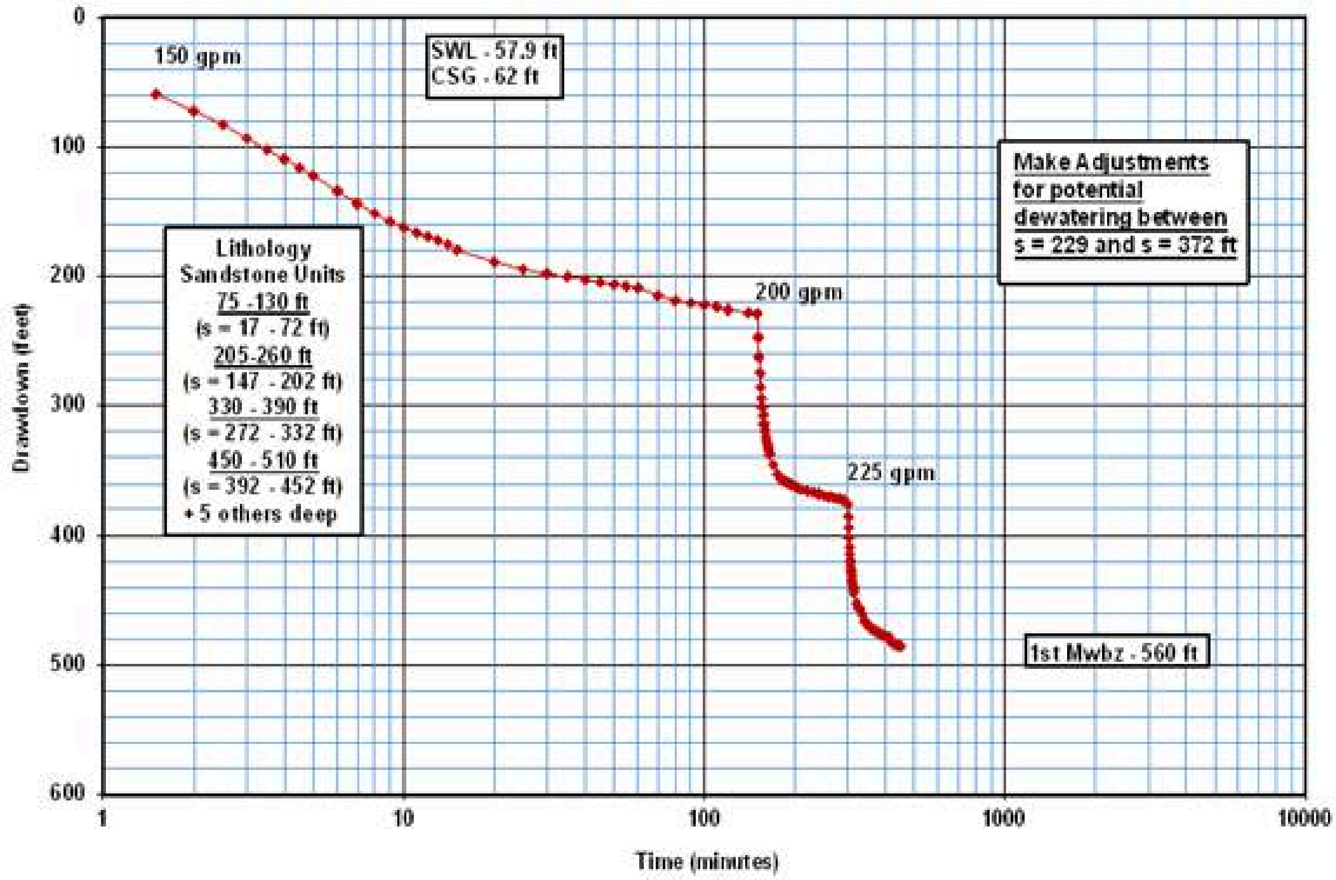

Figure A-17. Poolesville (Rabanales) well 11 – Semi-log plot of drawdowns from a step-drawdown test.

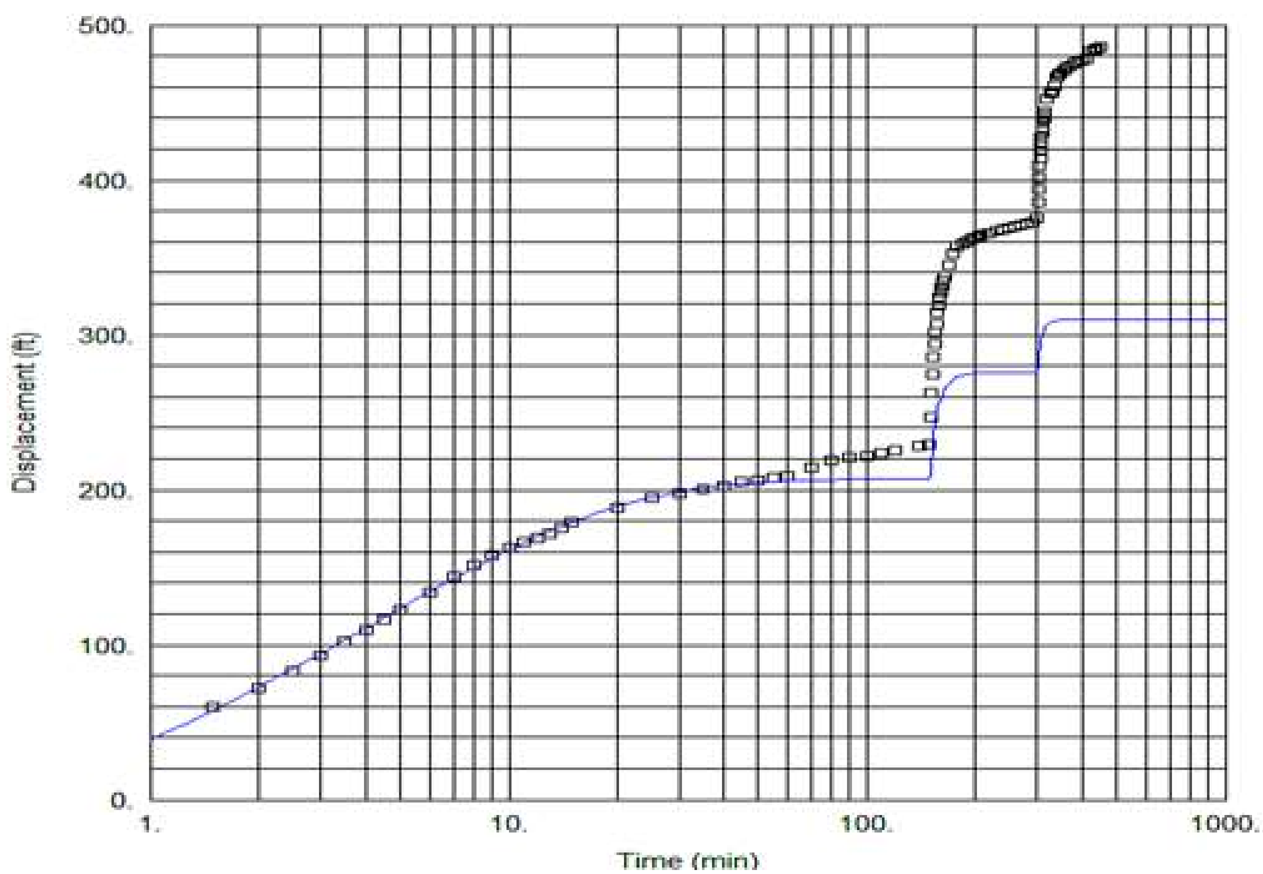

Figure A-18. Poolesville (Rabanales) well 11 – Semi-log plot of drawdowns step-drawdown test 0-50 min, Hantush leaky aquifer solution

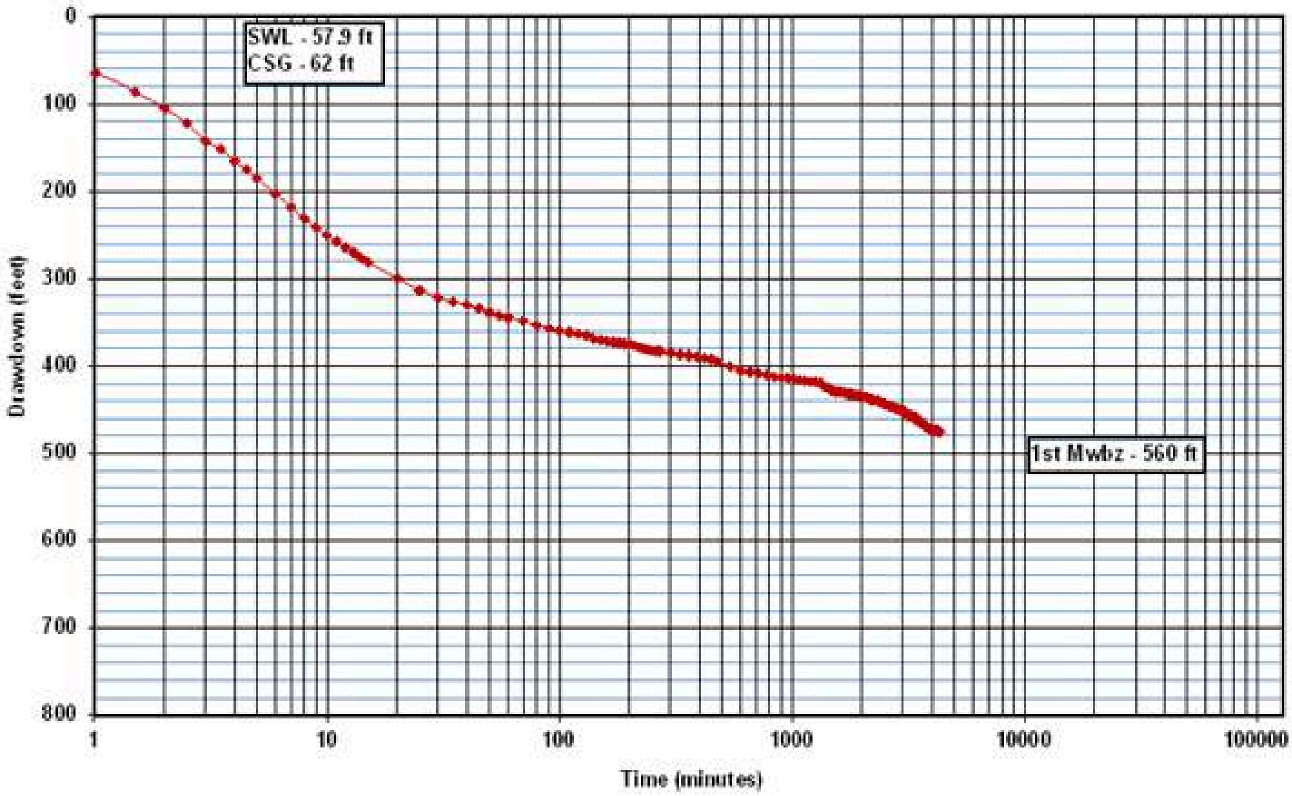

Figure A-19. Poolesville (Rabanales) well 11– Semi-log plot of drawdowns from 72-h, 200 gpm aquifer test.

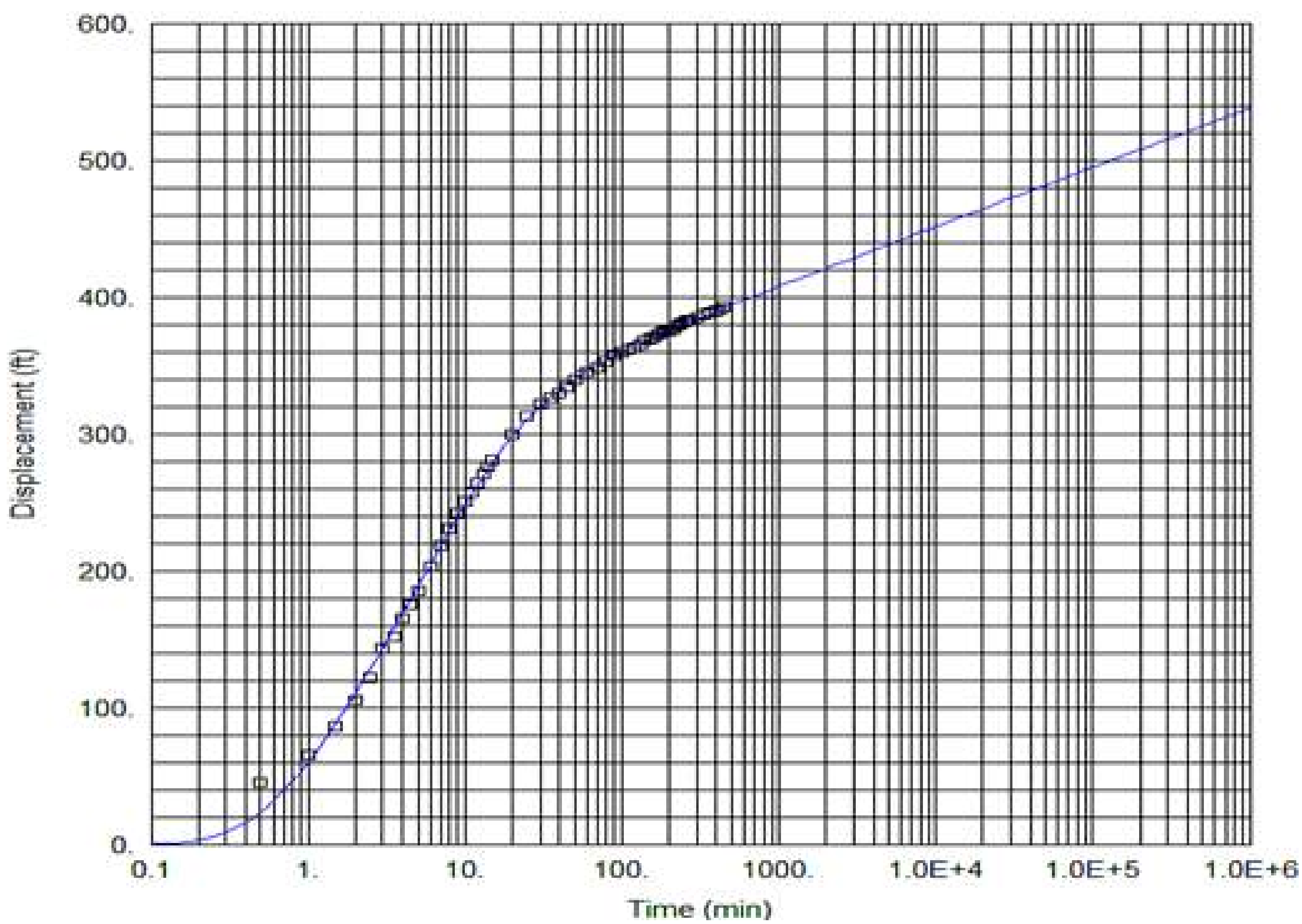

Figure A-20. Poolesville (Rabanales) well 11– Semi-log plot of drawdowns from 72-h, 200 gpm aquifer test, Neuman-Witherspoon two aquifer solution.

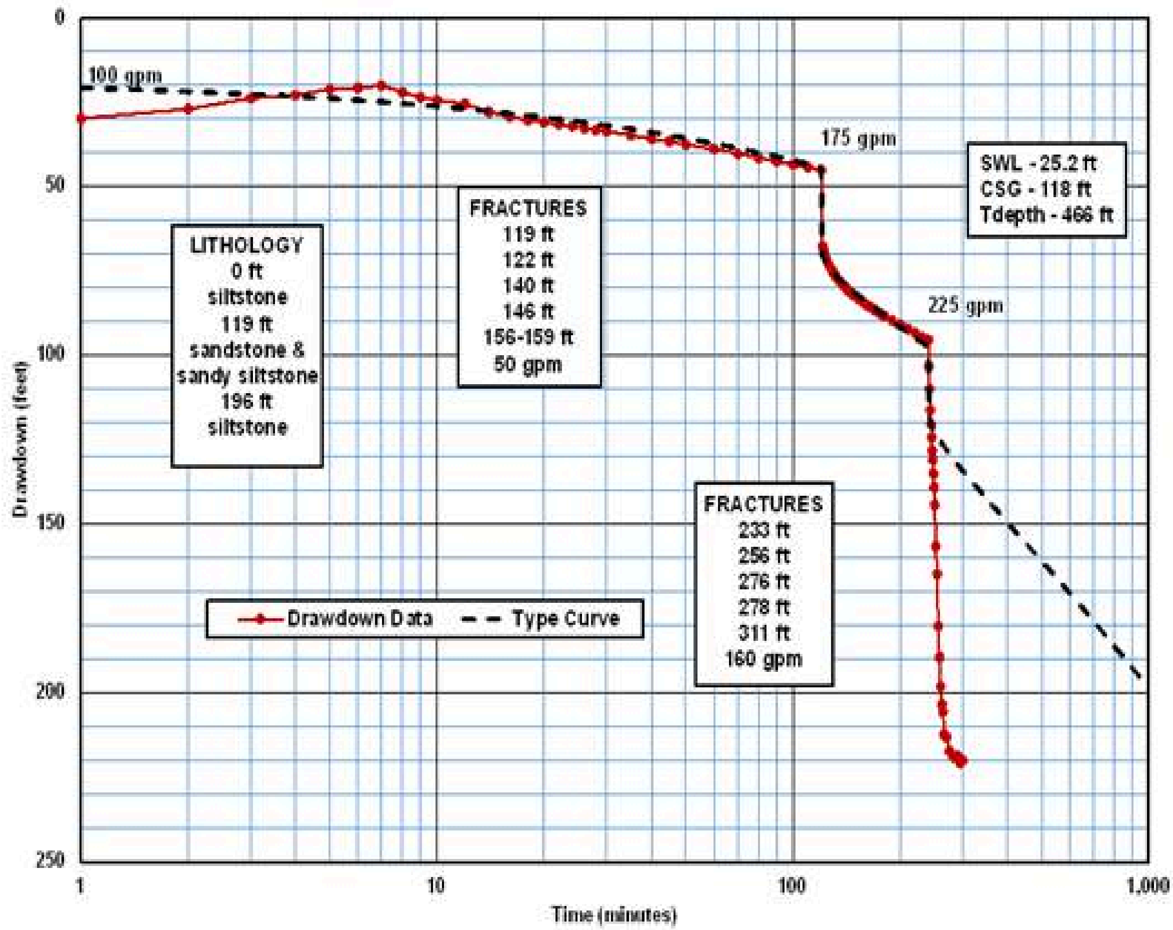

Figure A-21. Poolesville (Schraf) well 12 – Semi-log plot of drawdowns from a step- drawdown test, Dougherty-Babu double porosity solution.

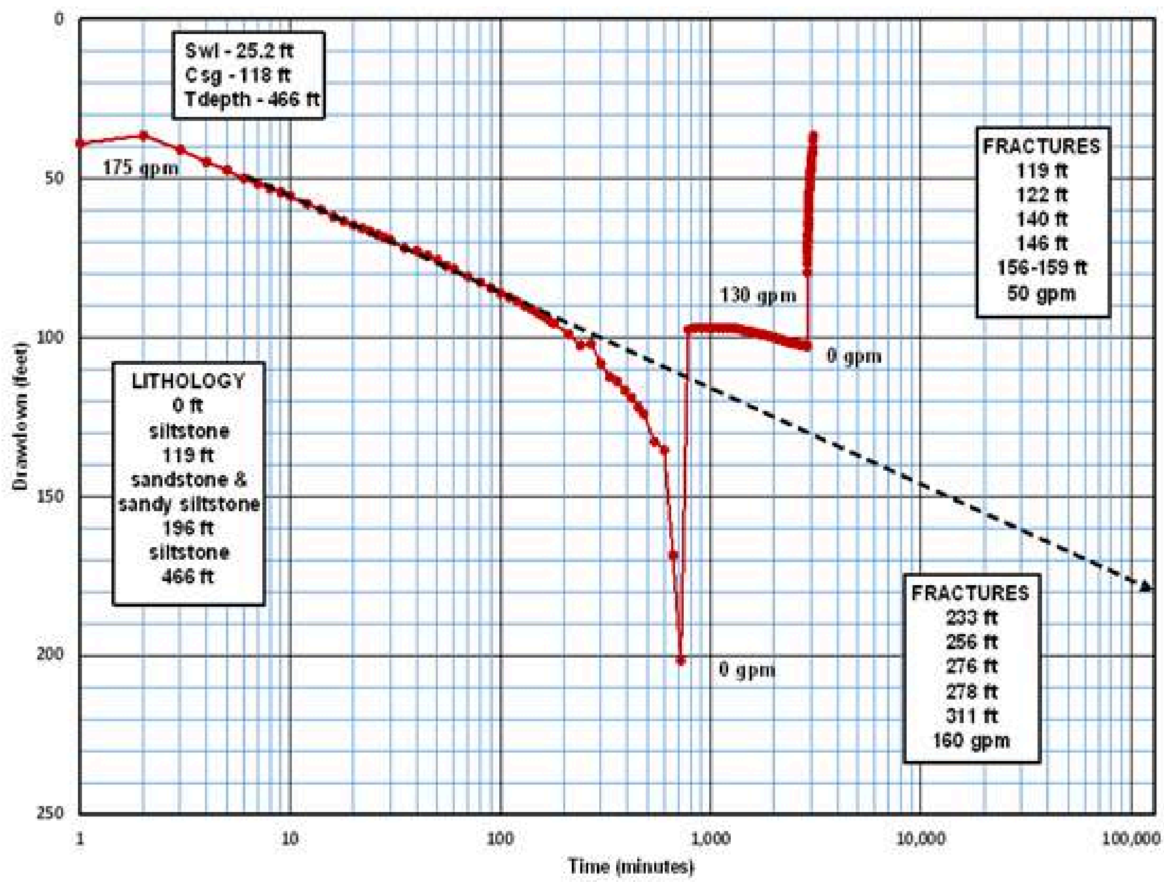

Figure A-22. Poolesville (Schraf) well 12 – Semi-log plot of drawdowns from 48-h, variable rate aquifer test, with estimated yield of 94 gpm based on 90-d extrapolation from an IARF solution, 2-180 min.

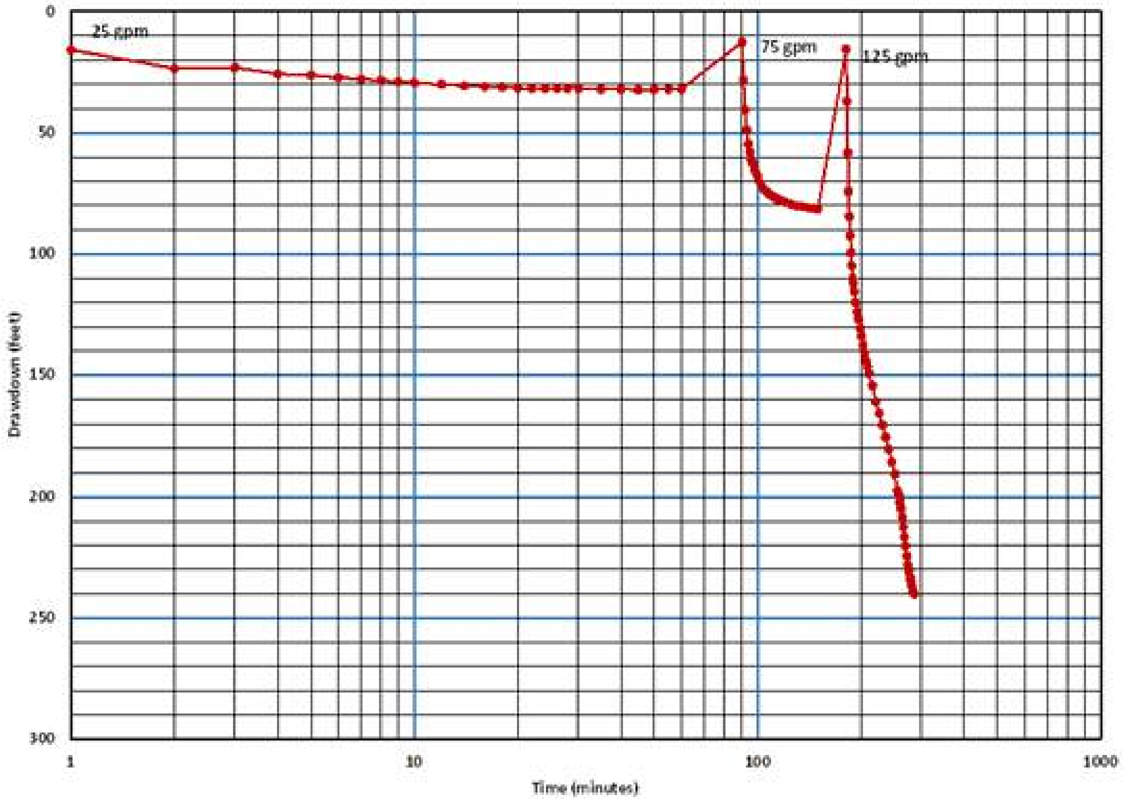

Figure A-23. Poolesville (Elgin) well 13. Semi-log plot of drawdowns from a step- drawdown test

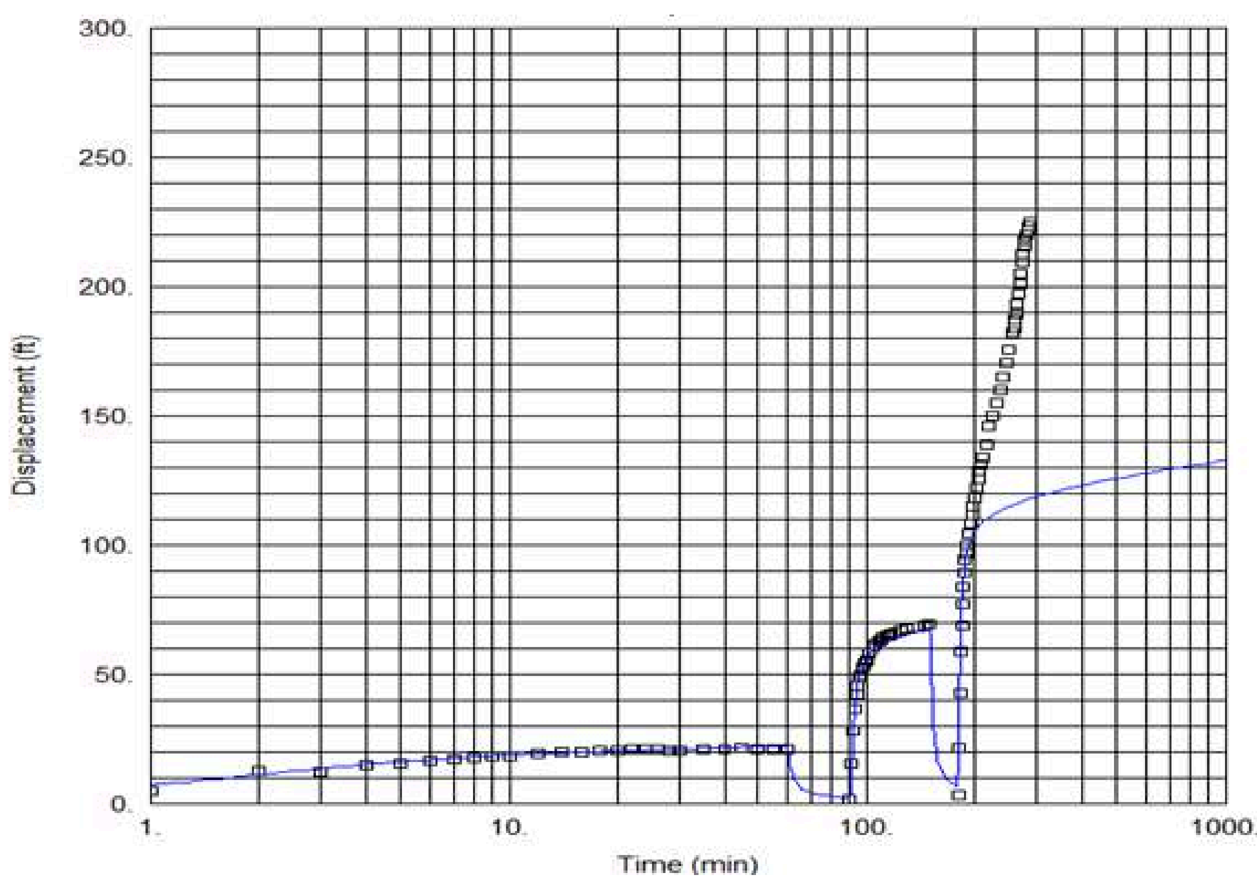

Figure A-24. Poolesville well 13. Semi-log plot of drawdowns from a step- drawdown test, Dougherty-Babu double porosity solution, 0-150 min.

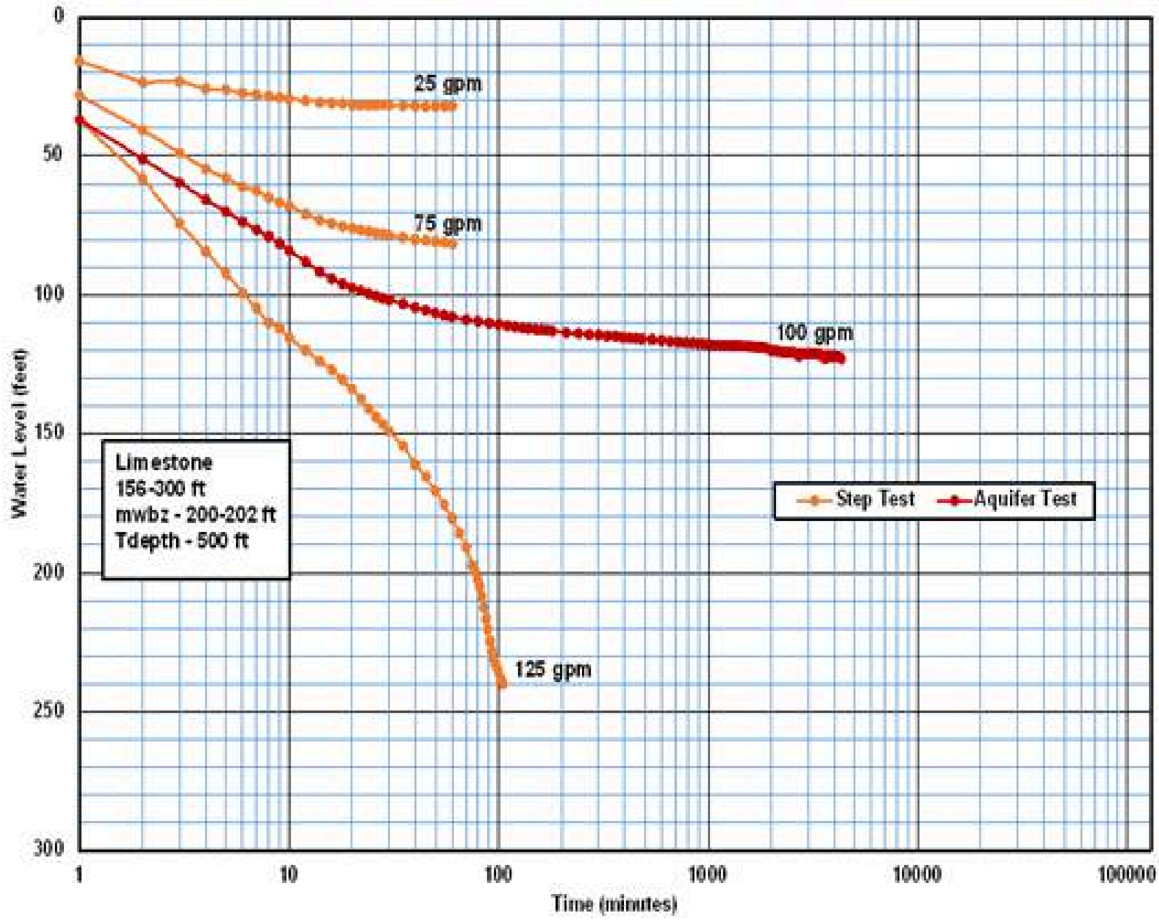

Figure A-25. Poolesville Well 13. Semi-log plot of 100 gpm 72h aquifer test and the drawdown portions of a step test (25 gpm, 75 gpm and 125 gpm steps)

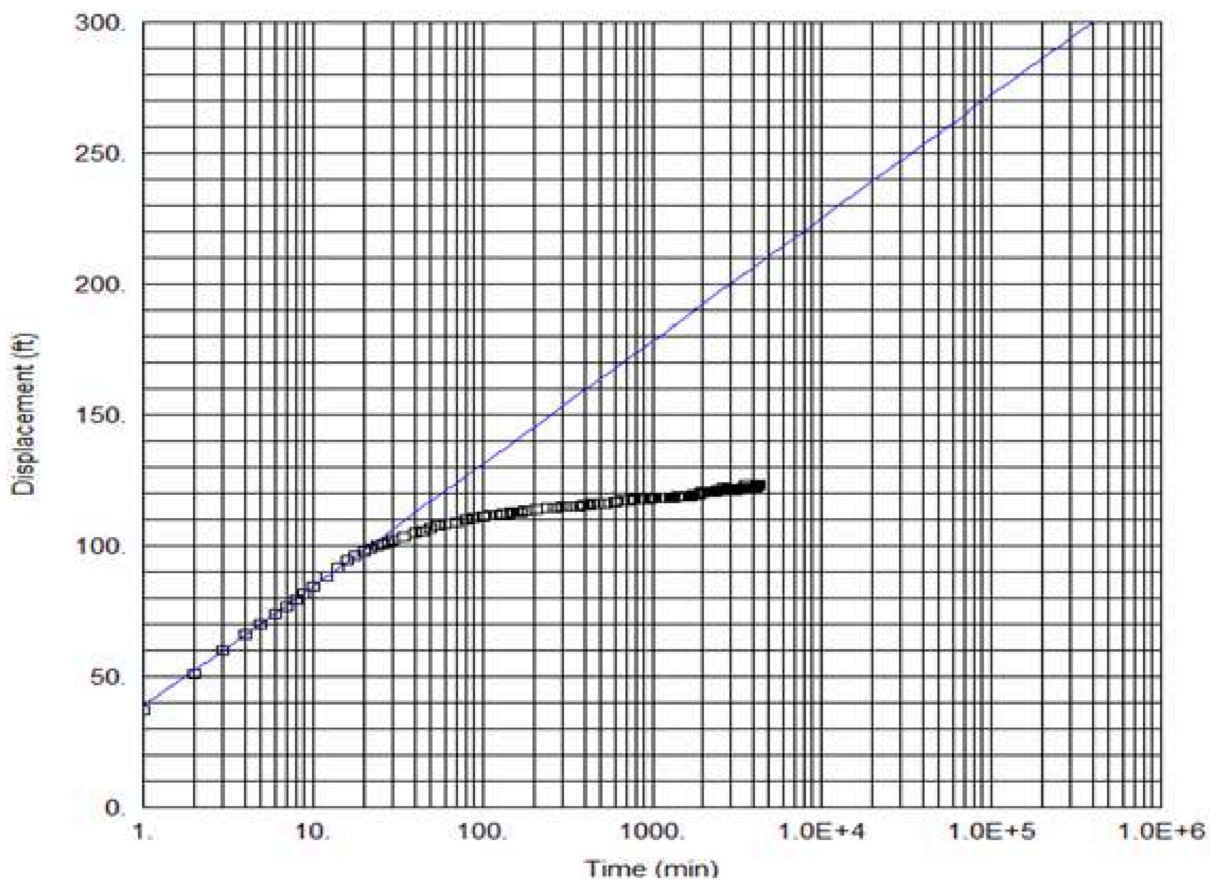

Figure A-26. Poolesville Well 13. Semi-log plot of 100 gpm, 72h aquifer test. Extrapolated drawdown using Theis solution for 0-20 min

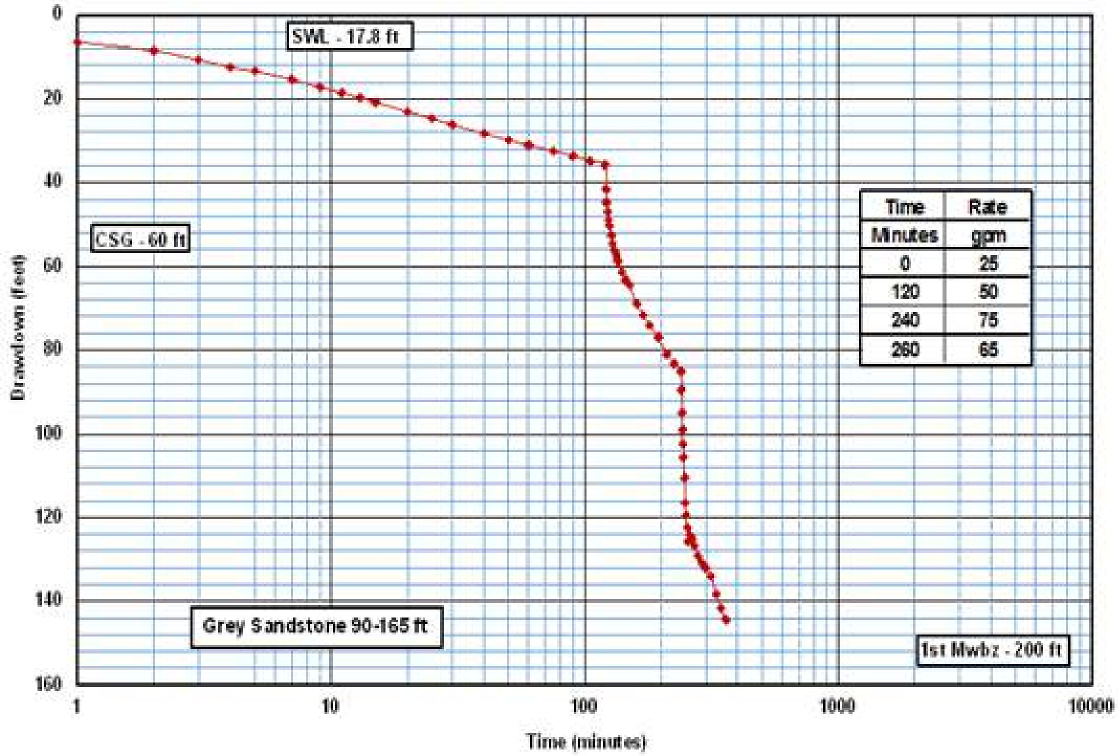

Figure A-27. Poolesville (Jamison) well 14. Semi-log plot of drawdowns from a step-drawdown test

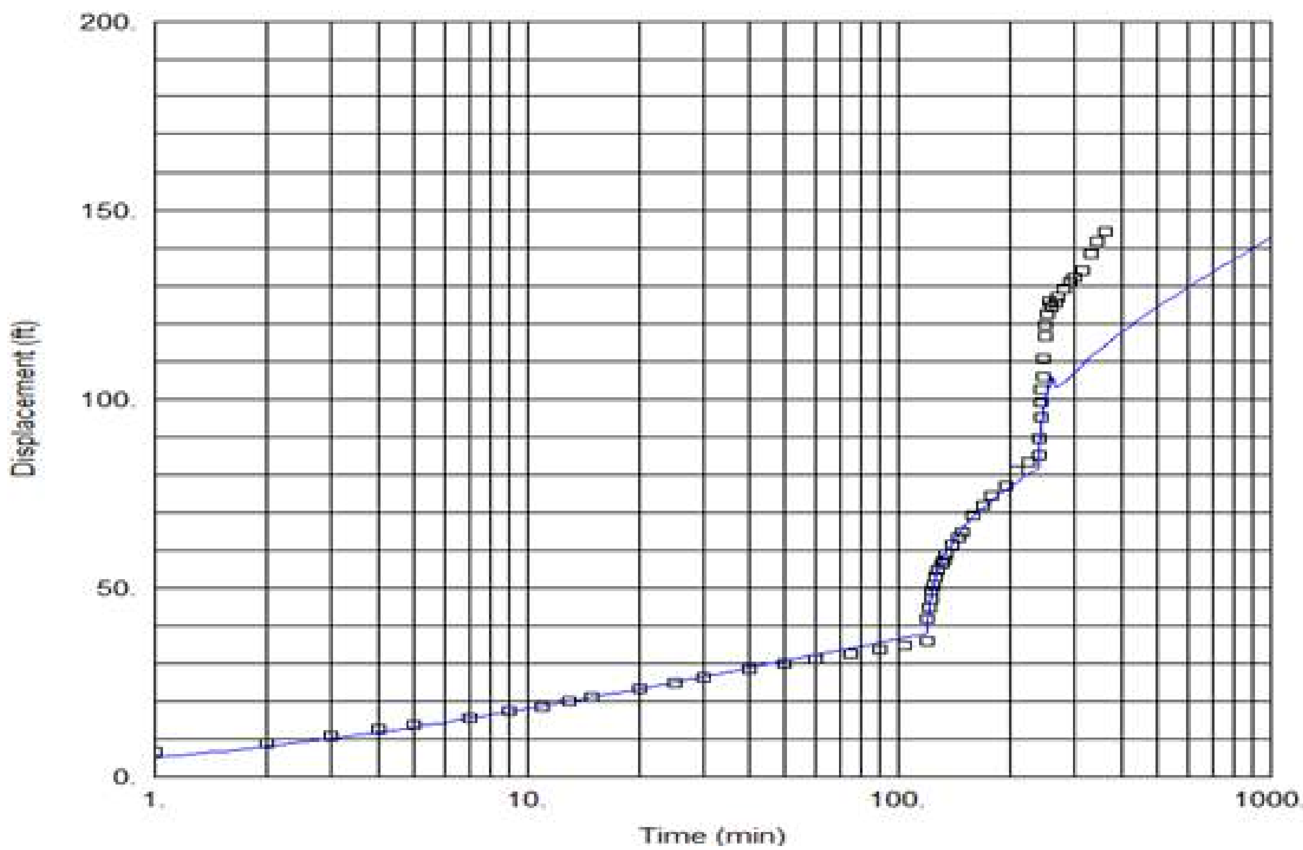

Figure A-28. Poolesville (Jamison) well 14. Semi-log plot of drawdowns from a step-drawdown test, Dougherty-Babu double porosity solution, 0-240 mi

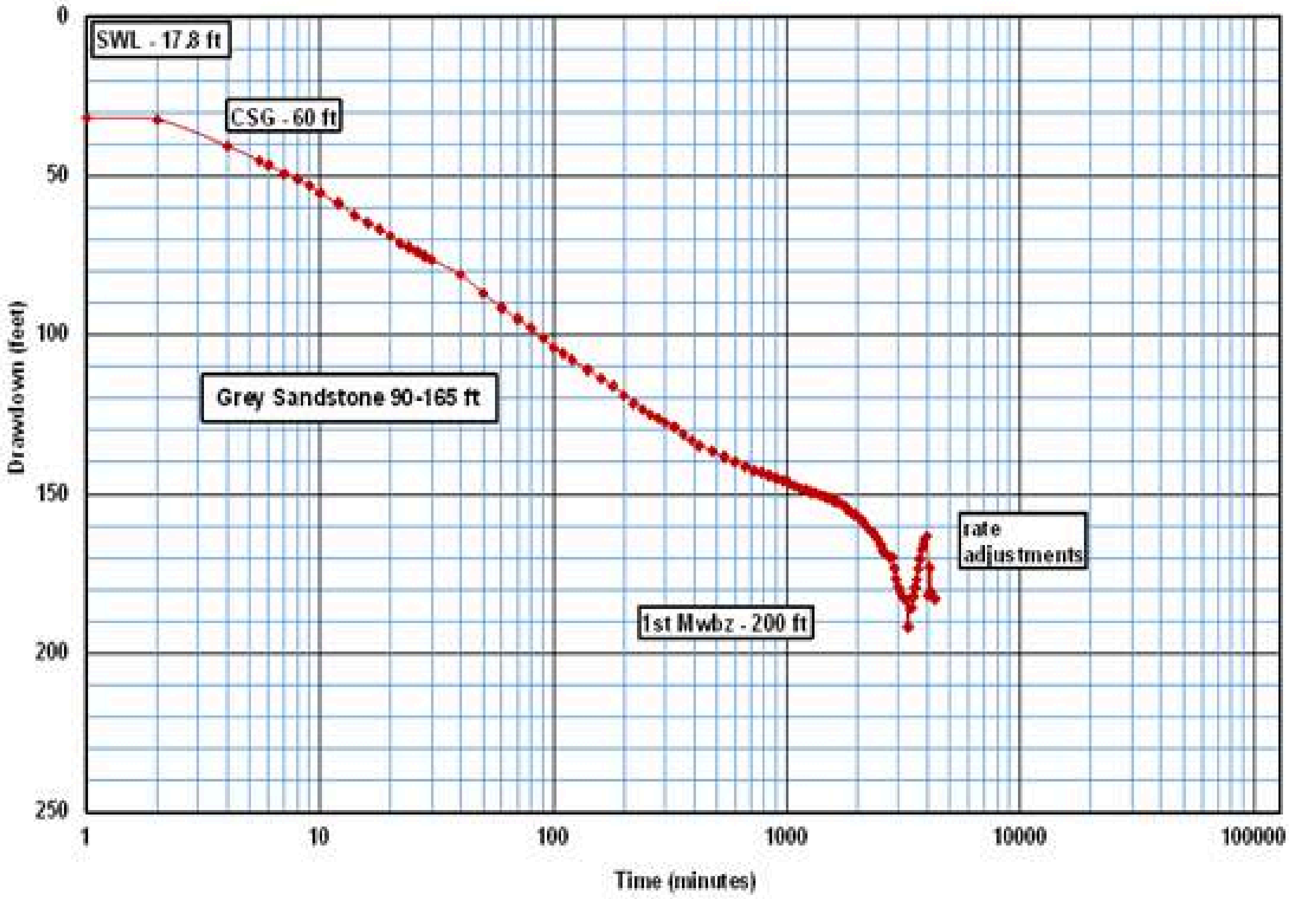

Figure A-29. Poolesville Well 14. Semi-log plot of 50 gpm, 72h aquifer test

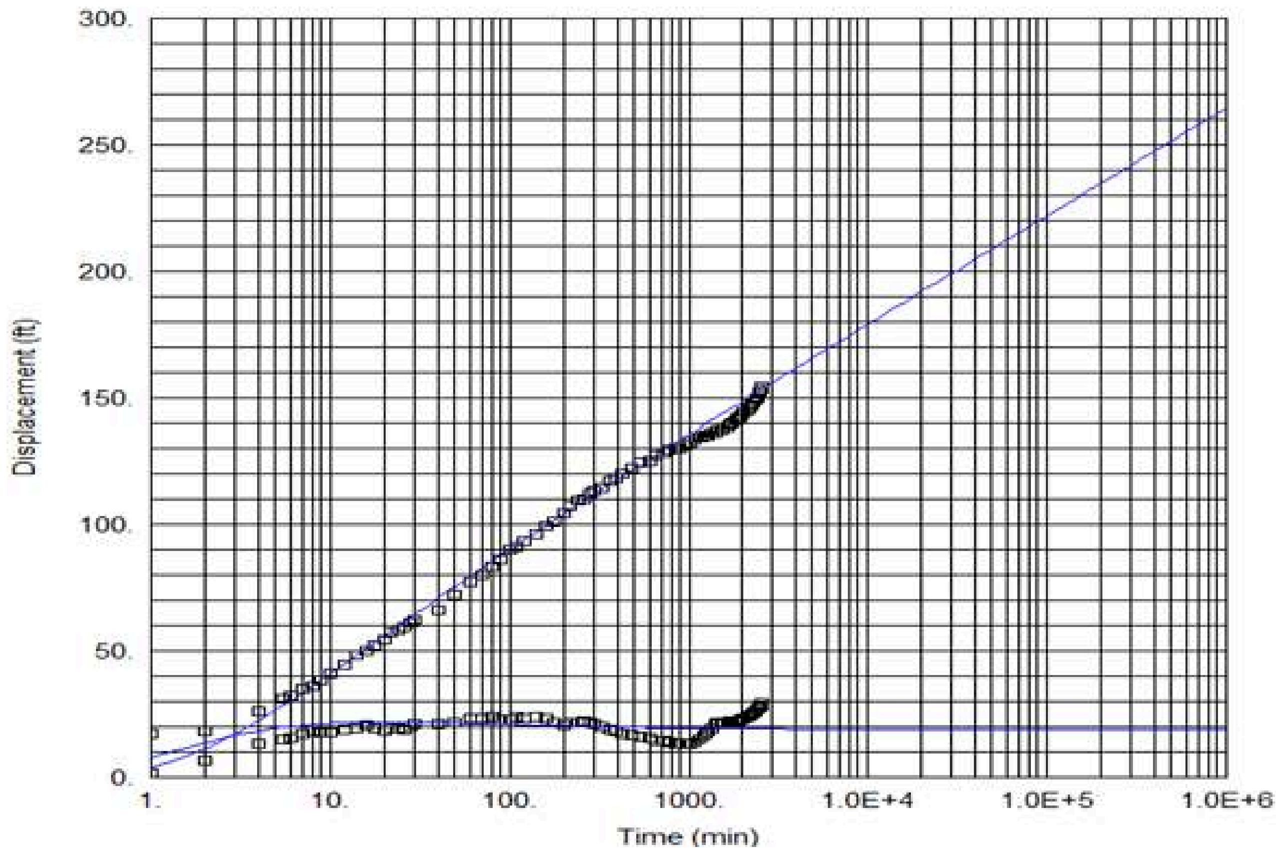

Figure A-30. Poolesville Well 14. Semi-log plot of 1st 44h of 50 gpm aquifer test. Extrapolated drawdown made using Hantush solution with aquitard storage 0-800 min