Carroll County
225 North Center St. • Westminster, MD 21157

Carroll County Water Demands and Availability

July 30, 2009

6531-001-200

MALCOLM PIRNIE

Carroll County Water Demands and Availability
ADDENDUM
July 30th, 2009

The Carroll County Water Demands and Availability Report, originally dated April 17, 2009, has been revised based on corrections to input data and calculations and a refinement of the Water Balance Assessment Tool. This current re-issue of the report, date July 30th, 2009 reflects the resulting changes in the final output from the Water Balance Assessment Tool. The net result of all of the changes is a 1.6 mgd increase in County-wide Buildout demand (30.5 mgd) which is 5.5% higher than was listed in the April 17, 2009 report (28.9 mgd).

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Acronyms Used in the Report

BLI	Buildable Land Inventory
DGA	Designated Growth Area
DNR	Department of Natural Resources
GIS	Geographical Information System
HUC	hydrologic unit code
LUD	Land Use Designation
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
SSA	sewer service area
WRE	Water Resources Element
WSA	water service area
WWTP	wastewater treatment plant

Units Used in the Report

gpd	gallons per day
mgd	million gallons per day

1. Introduction

As part of its present Comprehensive Plan update, Carroll County is in the process of evaluating its water resources through the 2006 state mandated Water Resources Element (WRE). The WRE is an important piece of the County's Comprehensive Plan and is meant to assess the adequacy of its present and future water supply, wastewater infrastructure, and potential impact on water resources. A water balance approach[1] has been recommended for the assessment by several Maryland agencies, including the Department of Planning (MDP), Department of the Environment (MDE)[2], and the Department of Natural Resources (DNR), as well as by the Governor's Advisory Committee on the Management and Protection of the State's Water Resources[3]. At the County's request, Malcolm Pirnie, Inc. performed a water balance of water resources in Carroll County based on existing and future buildout conditions.

1.1. Purpose

The purpose of the water balance is to evaluate the existing and future demands relative to the amount of water resources that may be available for usage without significant impact to the environment. This report provides a description of the methodology used in the water balance (Section 2), a discussion of watershed-specific results (Section 3), and a discussion and conclusions regarding county-wide results (Section 4).

1.2. Limitations

For the purposes of this study, the water balance approach is limited to evaluations which provide an indication of the availability of both ground- and surface water for appropriation while maintaining sufficient reserve flows to prevent unreasonable impacts.

The methodology used in the water balance approach included estimates of existing and projected buildout water demands based largely on values reported to the MDE for larger withdrawals above 10,000 gallons per day (gpd) as required under current regulations and population/household-based estimates for smaller demands. As such non-residential/ domestic withdrawals may be under-estimated by this method due to "larger" private withdrawals approaching, but not exceeding, the 10,000 gpd reporting limit.

The water balance approach does not address the engineering or socioeconomic aspects of developing water resources in the County. Although certain regulatory requirements are explicitly addressed (*e.g.*, maintaining minimum instream flows), the approach does not explicitly consider the permitting requirements or regulatory feasibility of developing the total water availability.

As well as evaluating all of Carroll County, a separate water balance was evaluated for each of nine MDE eight-digit hydrologic unit watersheds within the county. Each water balance was limited to areas within the boundaries of Carroll County. The watershed areas upstream and downstream of the county were removed from the analysis in order to avoid basing demand estimates on water resources that might also be claimed by adjacent jurisdictions. One implication of this approach is that it does not consider extra-County water resources that might be available to communities that straddle the County line, such as Mount Airy.

2. Methodology

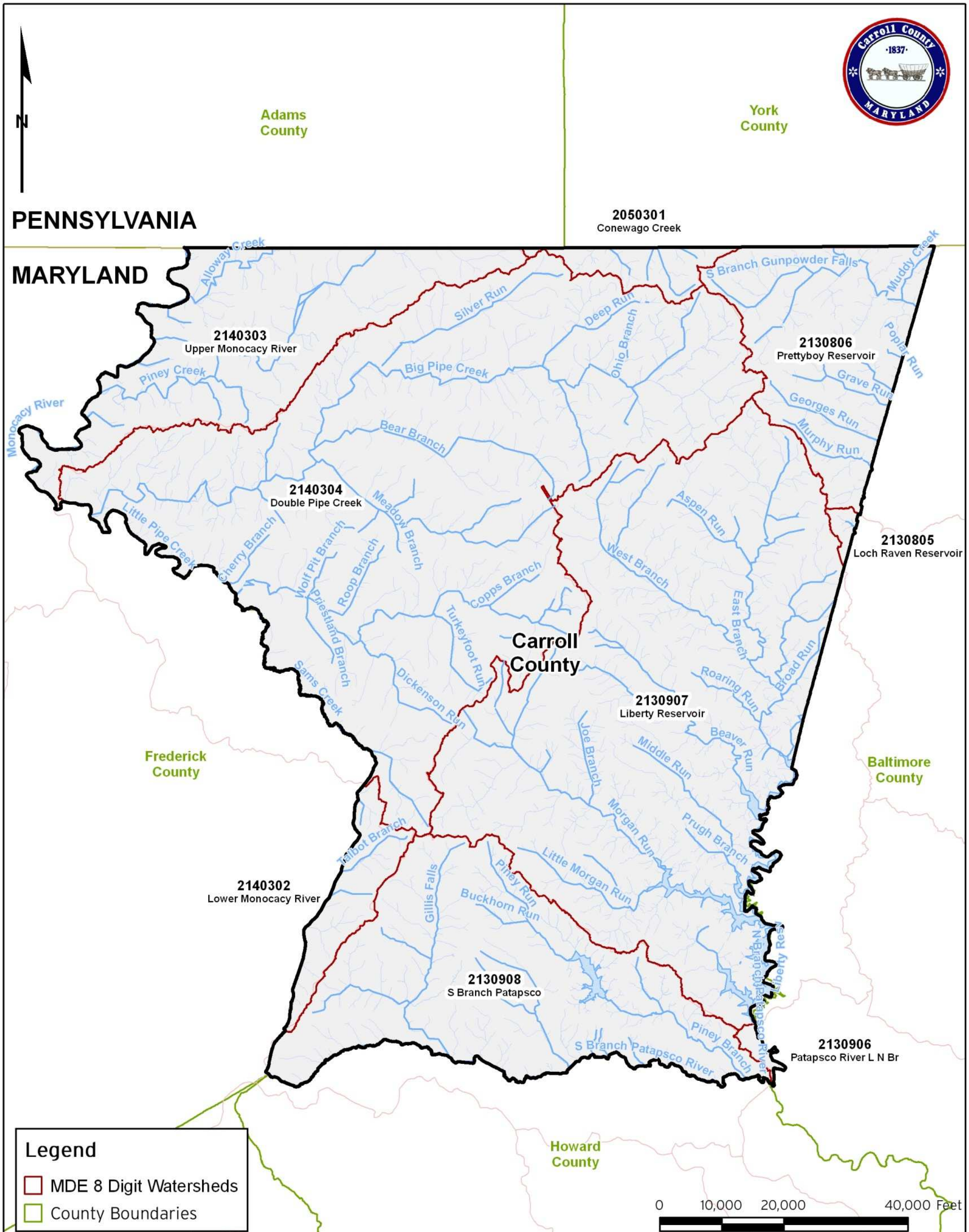
2.1. General Approach

The water resources of Carroll County were evaluated using a water balance approach to estimate existing and future water demands and availability. The methodology for the water balance was based on the approach outlined in the WRE Guidance Document[1] and detailed in the MDE's evaluation of the Catoctin watershed[2]. Malcolm Pirnie, Inc. developed a water balance assessment tool, using MS-Excel and Geographic Information System (GIS) data analyses, to assess the water resources of Carroll County. Overall, the water balance assessment tool consisted of an evaluation of the county's water demands, wastewater returns and discharges, and a consideration of available water resources in the county on a watershed-by-watershed basis.

For the purposes of this study, individual watersheds were defined using the MDE eight-digit hydrologic unit code (HUC) boundaries. There are nine such watersheds in Carroll County (Figure 2-1):

1. *Conewago Creek (02050301),*
2. *Double Pipe Creek (02140304),*
3. *Liberty Reservoir (02130907),*
4. *Loch Raven Reservoir (02130805),*
5. *Lower Monocacy River (02140302),*
6. *Patapsco River Lower North Branch (02130906),*
7. *Prettyboy Reservoir (02130806),*
8. *South Branch of the Patapsco River (02130908), and*
9. *Upper Monocacy River (02140303).*

The boundaries of all the watersheds listed above extend beyond the borders of Carroll and include areas that normally drain into the County or along its border. However, the assessment was limited to evaluating only those water demands, wastewater returns and available water resources located within Carroll County to avoid basing demand estimates on water resources that might also be claimed by adjacent jurisdictions.



MALCOLM PIRNIE

CARROLL COUNTY, MD
WATER DEMANDS AND AVAILABILITY

Carroll County Watersheds

Jul 2009

Figure 2-1

2.1.1. Data Sources

Multiple data sources were used in the water balance assessment of Carroll County:

- *MDE Hydrologic Unit Code Boundary Shapefile*[*] – including spatial boundaries of MDE 8-Digit watershed units, MDE-8 watershed digit code, and MDE 8-Digit watershed name;
- *MDE Permitted Allocations Database* – including water permit numbers, withdrawal location, average monthly allocation, and maximum monthly allocation;
- *MDE Reported Usage Database* – including water permit numbers, monthly reported usage for Jan 2000- Dec 2007 inclusive;
- *Carroll County Address Shapefile* – including locations of residential and non-residential address points limited to those locations outside of the water service areas;
- *2000 U.S. Census Bureau Data Shapefile* – including census block boundaries, census block population, and number of households in the census block;
- *2008 County Buildable Land Inventory (BLI) Zoning Shapefile* – including parcel centroid location, estimated number of additional lots where a building may be permitted in municipalities according to zoning constraints
- *2008 County BLI Land Use Designations Shapefile* – including parcel centroid location, estimated number of additional lots where a building may be permitted in unincorporated portions of the County according by land use designation constraints
- *2008 County Commercial/Industrial Water & Sewer Service Area Table* – including County estimates of existing and planned commercial/industrial zoning acreages within existing, priority, and future Carroll County water and sewer service areas;
- *2008 County Water & Sewer Service Area Shapefiles* – including water and sewer service area boundaries of existing, priority, and (expected) future conditions;
- *USGS Hydrogeomorphic Regions in the Chesapeake Bay Watershed Shapefile* – including hydrogeomorphic region boundaries, names and codes; and
- *USGS Land Use Raster* – including agricultural land use types and boundaries.

2.1.2. Specific Adaptations to the Basic Methodology

As mentioned above, the water balance methodology was based on the approach outlined in the WRE Guidance Document[1] and detailed in the MDE's evaluation of the Catoctin Creek watershed[2]. MDE's report on its evaluation of the Catoctin watershed did not include a comprehensive discussion of all source data and methods used in the analyses. Therefore, specific assumptions and changes were made in developing the present

[*] A shapefile is a common geospatial vector data format used to represent spatial features and their attributes developed by ESRI.

methodology which may have deviated from the Catoctin Creek study approach. Also, newer and/or county-specific datasets were incorporated into the analysis. The following are specific adaptations to the basic approach outlined in the Catoctin Creek watershed evaluation:

- Self-supplied residential water demands were estimated based on the number of households in the current address database provided by the County. It was assumed that the water demands for all households outside of the service areas were self-supplied by groundwater wells and that each household consisted of a single family with an average day water demand of 250 gallons per day (gpd). Households from the County address database were used as the basis for self-supplied residential demands because the Census 2000 data is nearly ten years old and may not be as representative of the current population;

- The present methodology incorporates septic returns to groundwater in order to determine the final groundwater availability. These returns were included because a significant portion of the groundwater demands are likely to be returned via septic systems. Based on published literature values[3,4,5,6,7], the average return rate assumed for domestic use is approximately 80%.

- Future demands for serviced and self-supplied residences were evaluated based on the number of additional households estimated at buildout in the County's Buildable Land Inventory (BLI). The BLI was developed by the County's Planning Department to provide a reasonable estimate of the remaining locations in the County where a building permit would likely be issued according to an analysis of geospatial constraints, such as zoning, avoidance of floodplains, and other factors that may limit development. The BLI was considered to constitute the best source of available data representing potential population growth through the planning horizon while also providing the spatial resolution necessary for analyses at the subwatershed level.

- The analysis of surface water availability included in the present analysis was generally based on MDE's approach in the Catoctin Creek analysis. However, MDE did not explicitly describe its methodology for determining the storage-safe yield curves. For the purposes of the present methodology, equivalent storage-safe yield curves were developed for each subwatershed by estimating using the worst drought on record for the gauges used in the groundwater availability calculations. Depending on the watershed, the worst drought of record occurred in either 1966-1967 or 2002-2003. The method is described in detail in Section 2.4 below.

2.1.3. Water Balance Assessment Tool

A water balance assessment tool was developed to provide quantitative estimates of water demands and availability for each watershed in the County under various scenarios. The water balance assessment tool consisted of a series of Microsoft Excel spreadsheets incorporating the data listed in Section 2.1.1 above and a series of calculations based on the methodology and assumptions discussed in the remainder of Section 2. The assumptions and variables driving the calculations were compiled onto a central dashboard (Figure 2-2) to provide flexibility and convenience to the tool.

Three scenarios were modeled using the water balance assessment tool: “reported”, “permitted”, and “buildout”. The reported scenario was an estimate of current source water usage in Carroll County largely based on 2007 withdrawal volumes reported to MDE. The permitted scenario was an estimate of the maximum source water withdrawals in the County currently permitted by MDE on a daily average basis. The Buildout scenario was an estimate of projected future source water usage and availability when the service areas have been expanded to the expected Future Service Area boundaries. It should be noted that the expected future service areas do not include the County’s “no plan” service areas associated the Designated Growth Area (DGA) boundaries. Major assumptions include household, commercial, and industrial water use rates and future commercial. The methodology, assumptions, and variable inputs used to model each scenario are discussed in the remainder of Section 2.

2.2. Water Demands

As discussed above, water demands in Carroll County were estimated under three separate scenarios: Reported, Permitted, and Buildout. For each scenario, demands were estimated by usage type:

- Demands met through municipal service areas supplies:
  - Residential
  - Commercial
  - Industrial

- Demands met through private water supplies:
  - Residential
  - Industrial/commercial
  - quarries
  - Agriculture

Demands were also estimated by source: groundwater (wells) versus surface water (intakes). Estimates of demand were disaggregated by both watershed and by service area. MDE water allocations and reported withdrawals can be found in Table B-1 of Appendix B.

WATER AVAILABILITY

FLOWBY - SEASONAL EVALUATION BASIS

Basis	ANNUAL
Month	JUN
Period	1

FUTURE - BUILD OUT SCENARIO

GROWTH RATES

Industrial/Commercial	25	%
Agricultural	0	%
Relative Perviousness	100	%

WATER DEMAND

GENERAL

Appropriation Basis	AVG	
Self Supplied Basis	2009 Well Data	
Individual Water Demand	80	gpd/per
Household Water Demand	250	gpd/hh
Unallocated GW Percentage	100	%
WSA Proportion Basis	ALLOCATION	

COMMERCIAL/INDUSTRIAL

Serviced Commercial use rate	700	gpd/ac
Serviced Industrial use rate	800	gpd/ac

AGRICULTURAL

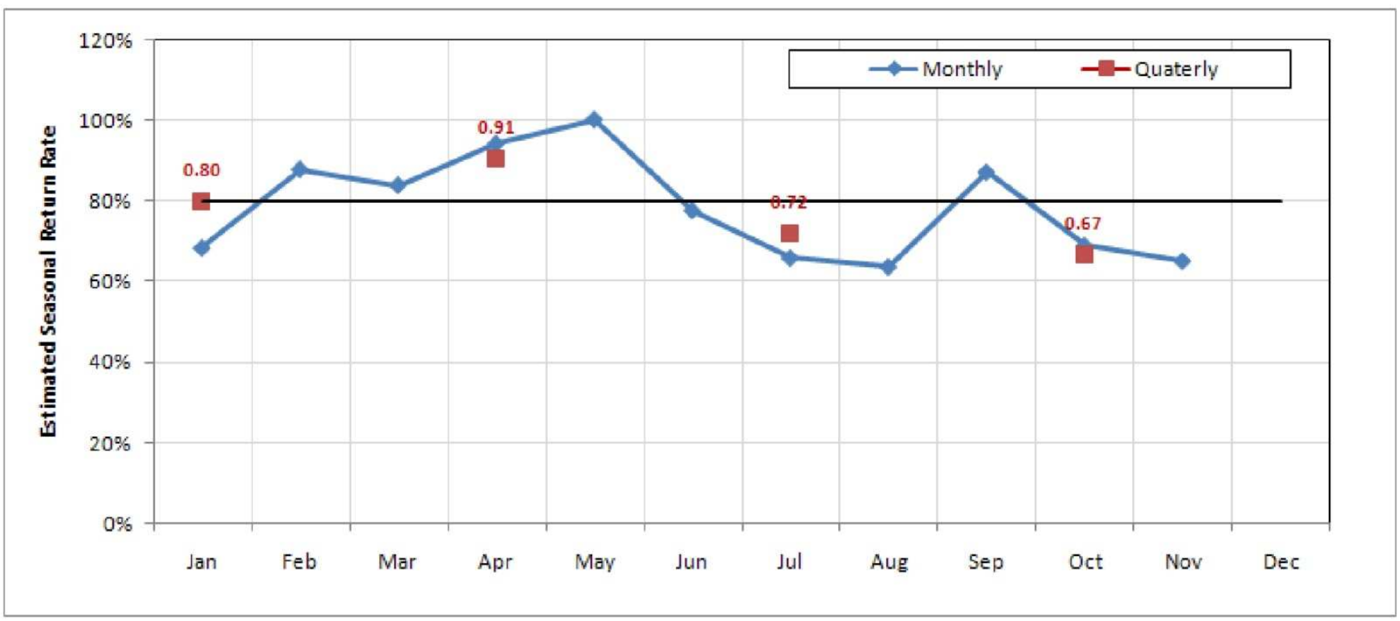
Basis	MDE

WATER RETURNS ON

RETURN SWITCHES

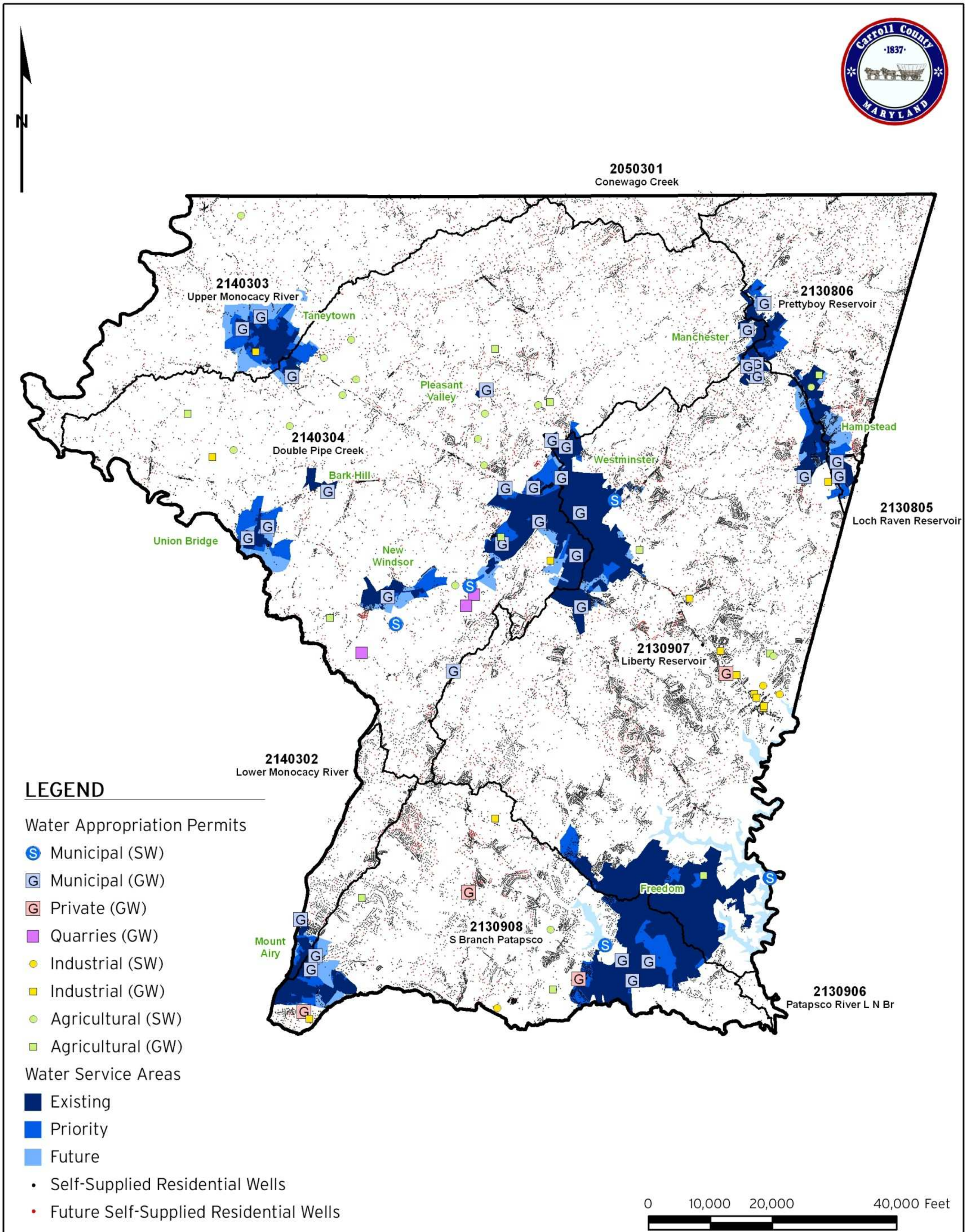
Sewer Returns	ON
Septic Returns	ON
Agriculture Returns	OFF
Quarry Returns	ON

WWTP Return Rate	80	%
Com/Ind Return Rate	80	%
Septic Return Rate	80	%
Quarry Return Rate	95	%
Agricultural Runoff Rate	5	%
Agricultural Recharge Rate	10	%



Notes:

- *Bramble Hills WSA merged with Westminster WSA for simplicity*
- Average return rates estimates based on Dec 2008 CMP Worksheet data
- Seasonal return rate estimates based on reported 2008 DMR data



MALCOLM PIRNIE	CARROLL COUNTY, MD WATER DEMANDS AND AVAILABILITY	Water Service Areas & Allocation Permit Locations	Jul 2009 Figure 2-3

2.2.1. Reported Scenario Demands

The reported scenario was developed to estimate existing water demands in Carroll County and was based on multiple data sources. Water Service Area (WSA) demands were estimated from the 2007 withdrawals reported to the MDE for municipal water supply (MDE use code 101)*. There are currently nine WSAs in Carroll County (Figure 2-3):

1. Bark Hill,
2. Freedom/Sykesville,
3. Hampstead,
4. Manchester,
5. Mount Airy,
6. New Windsor,
7. Taneytown,
8. Union Bridge, and
9. Westminster†.

Existing demands for commercial and industrial water uses within the service areas were evaluated based on County-provided acreage estimates multiplied by assumed use rates: 700 gpd/acre for commercial land use and 800 gpd/acre of industrial land use. It was assumed that residential demands made up the remainder of the service area demands so that:

Service Area Residential Demands = TSA – CSA – ISA *(Eqn 2.1)*

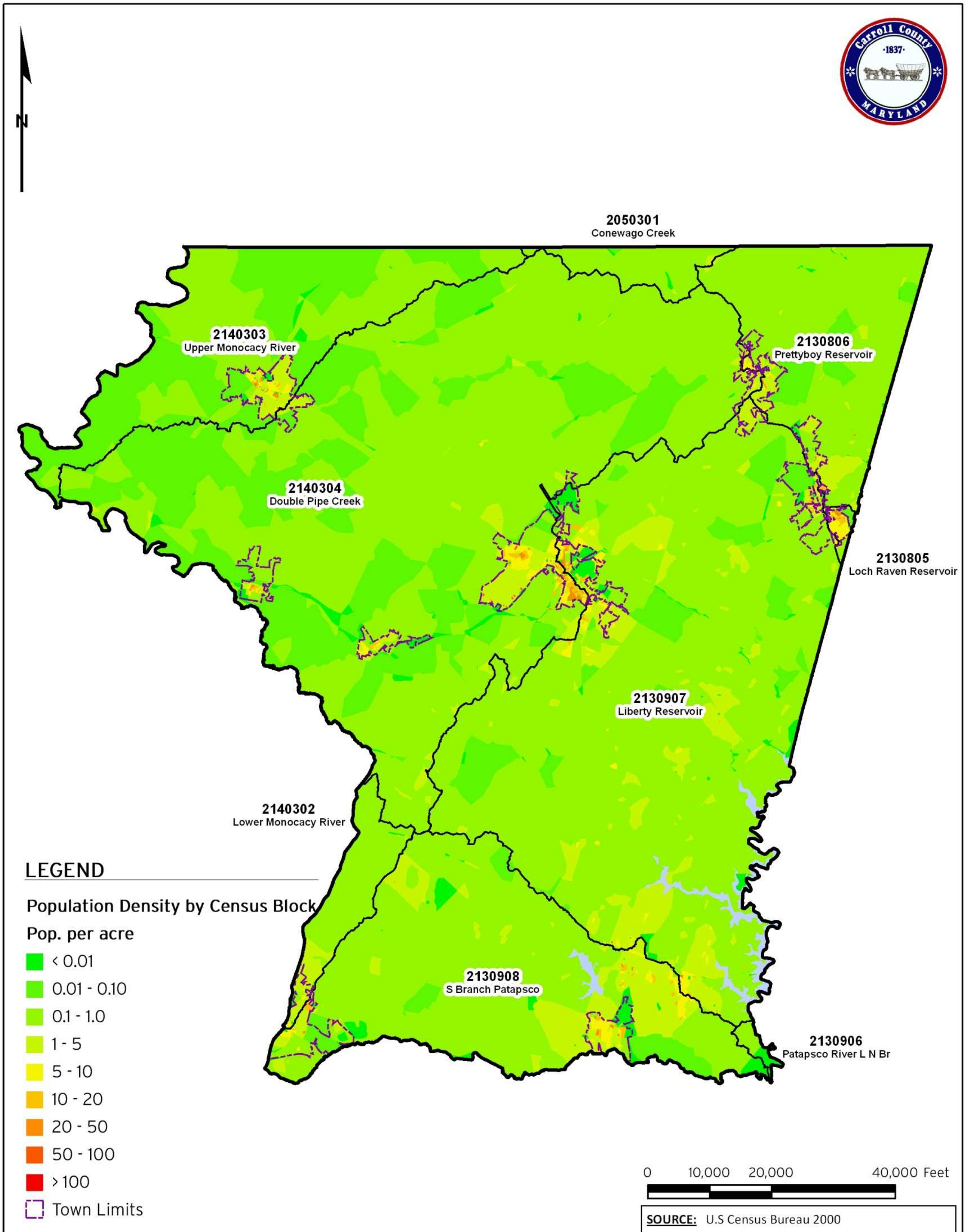
Where: TSA = Total Service Area Demands

CSA = Commercial Service Area Demands

ISA = Industrial Service Area Demands

MDE regulations stipulate that only those entities with water withdrawals above 10,000 gpd are required to obtain a water appropriation permit and report monthly withdrawal volumes. Virtually all self-supplied single-family households do not require withdrawals above the 10,000 gpd reporting requirement. Consequently, self-supplied residential demands were approximated from population estimates. Two population estimates were considered for use in the water balance – 2000 data from the US Census Bureau (Figure 2-4) and the current (Dec 2008) County address location database (Figure 2-3). The 2000

* For consistency of the analysis, the use code for the county well in the Pleasant Valley Water Service Area (CL1995G053) was changed from private water supply (MDE use code 102) to municipal water supply.
† The Bramble Hills WSA was considered to be sufficiently small to merge it with the neighboring Westminster sewer service area in the analysis



MALCOLM PIRNIE	CARROLL COUNTY, MD WATER DEMANDS AND AVAILABILITY	2000 Population Density by Census Block	Jul 2009 Figure 2-4

Census data include both population and household counts. Although direct counts of population are likely to produce more accurate estimates of demand than household counts because of the required implicit assumption of the number of people per household associated with household count data, the Census 2000 data is nearly ten years old and was considered to be out of date for estimates of existing demands. Therefore, the newer 2008 County address location database was used to estimate self-supplied residential demands. It was assumed that each residential address location outside of the existing service area, as determined by GIS analysis, had an inhabited single-family dwelling with an average water demand of 250 gpd supplied by a groundwater well. The 2000 Census Data indicate that Carroll County has an average occupation rate of approximately 2.9 persons per household and average published literature values of per capita demands are approximately 80 gpd[2,8]. Because both the occupancy and per capita demand rates are estimates, the calculated household demand rate was rounded up from 232 gpd to 250 gpd as a factor of safety since no one knows what the precise occupancy or per capita demand rates will be several decades into the future.

Non-residential demands were estimated based on usage volumes reported to the MDE in 2007 and categorized by MDE use code (Table 2-1:) in order to apply differing estimates of buildout growth and return. Non-residential demand categories used in the evaluation included industrial, agricultural, and quarries. USGS estimates of agricultural demands were also considered during the course of the analysis (Table A-2) because the USGS figures include estimates of unreported withdrawals under 10,000 gpd. However, county staff familiar with local agricultural practices indicated that the USGS figures typically over-estimated agricultural demands (1.21 mgd) compared to the reported MDE withdrawals (0.48 mgd).

As well as being categorized by demand type, water demands were also categorized by source: surface- versus groundwater. Reported 2007 withdrawals to the MDE included explicit information on whether the appropriation was a surface water source or a groundwater source, whereas estimates of self-supplied demands were assumed to be met by groundwater wells.

2.2.2. Permitted Scenario Demands

Maximum average day withdrawals permitted by MDE were estimated, as part of the Permitted scenario, using the approach described above for existing demands. Residential, commercial, and industrial allocations within service areas were estimated using the same relative ratios determined by the existing demands.

Because demands for self-supplied single-family residences are typically too small to require a permit, self-supplied residential “allocations” were estimated using the same methods and per-household use rate (250 gpd) as described above.

Table 2-1:
Carroll County MDE Water Appropriations by Use

CODE	USE DESCRIPTION	CATEGORY	COUNT
101	Municipal Water Supply	Municipal	38*
102	Private Water Supplier	Private	--*
103	Commercial (drinking/sanitary)	Industrial	7
104	Institutional (drinking/sanitary)	Industrial	3
105	Recreational (drinking/sanitary)	Industrial	--
106	Industrial (drinking/sanitary)	Industrial	1
107	Subdivisions w/ Individual Wells (till buildout)	Private	--
108	Trailer Park/Apartment Bldg/Condo	Private	4
109	Residential Heat Pump	Industrial	--
110	Sewage Treatment Plant (all uses)	Industrial	--
111	Livestock Watering	Agricultural	1
112	Farm Potable Supplies (migrant labor camp, etc.)	Agricultural	--
113	Mining Operations (Potable)	Industrial	--
201	Irrigation (Undefined)	Agricultural	--
202	Agricultural Irrigation	Agricultural	12
203	Golf Course (Irrigation)	Agricultural	8
204	Lawns and Parks (Irrigation)	Industrial	--
205	Nurseries (Plant Watering)	Agricultural	7
302	Food Processing	Industrial	--
303	Indust Wash/Sep/Gnd Wat Cleanup NOT Sand/Grvl(309)	Industrial	1
304	Mine Construction and Dewatering	Quarries	4†
305	Commercial Heating and Cooling Water	Industrial	1
306	Industrial Heating and Cooling Water	Industrial	--
307	Commercial Washing Processes	Industrial	--
308	Laboratories	Industrial	--
309	Sand and Gravel Washing	Quarries	--
310	Product Manufacturing	Industrial	--
311	Fossil Fueled Power Generation	Industrial	--
312	Nuclear Power Generation	Industrial	--
313	Hydroelectric Power Generation	Industrial	--
314	Geothermal Power Generation	Industrial	--
315	Industrial - undefined	Industrial	1
316	Commercial - undefined	Industrial	--
317	Mining Operations -undefined (exam. Dust suppress)	Quarries	--
318	Aquaculture	Agricultural	--
401	Hydrostatic Testing and Fire Protection	Industrial	1
		TOTAL	89

* The County's Pleasant Valley permit [CL1995G053] was to be a considered a municipal supply.

† A permit for the Maryland Materials quarry was inferred since it has a National Pollution Discharge Elimination (NPDES) Permit. Groundwater withdrawals were assumed to be proportional to reported discharges at the Quarry.

2.2.3. Buildout Scenario Demands

Buildout scenario demands were estimated for the same categories as above; however, the approach for estimating future buildout demands was significantly different from the approach for estimating reported and permitted demands. Residential demands within each service area were estimated by adding estimates of additional demands associated with population growth inside the service areas and annexation of adjacent areas to the existing demands (as determined in Section 2.2.1). Population growth inside the expanded future water service areas was estimated using the 2008 BLI zoning GIS data to determine the number of developable residential lots along within the expanded buildout water service areas with the assumption that each lot would contain a single-family dwelling. Similarly, population growth due to the annexation of existing households into the future water service areas was estimated using the County address location GIS data. The additional number of households was multiplied by the assumed average household demand rate (250 gpd) and added to the existing residential demands. Buildout commercial and industrial demands were estimated by determining the planned commercially and industrially zoned area acreages for each service area at buildout and multiplying by the assumed average 700 and 800 gpd/acre use rates, respectively.

Because the water balance approach is most correctly performed by summing withdrawals (where the water is removed from the natural environment) rather than direct demands, withdrawals associated with the total service area demands (i.e. residential, commercial, and industrial) were apportioned to the watersheds using the following method. Existing allocations for each service area were tabulated by both service area and watershed. Planned water resource projects explicitly discussed in the Carroll County's September 2007 *Master Plan for Water and Sewerage*[9], were also added to the table. Buildout service area source water allocation ratios were projected for each watershed by dividing each watershed's contributing buildout allocation to a given service area by the total buildout allocation associated with that service area. (For example, Taneytown currently has a 0.10 mgd allocation in the Double Pipe Creek watershed (18%) and a 0.48 mgd allocation in the Upper Monocacy River watershed (82%). Given the planned 1.15 mgd intake on Big Pipe Creek, the total buildout allocation ratios between source watersheds would change to 72 percent in the Double Pipe Creek watershed and 28 percent in the Upper Monocacy watershed.) Implicit in this method is the assumption that future buildout demands will be met by withdrawals from the same (scaled) combination of sources (by watershed and well versus surface water intake) as are currently allocated, taking into account planned allocations. Service area demands were similarly apportioned to groundwater and surface water sources using the combined existing and planned allocation ratios. Tabulations of the calculations are discussed below in Section 3 and presented in Appendices B and C.

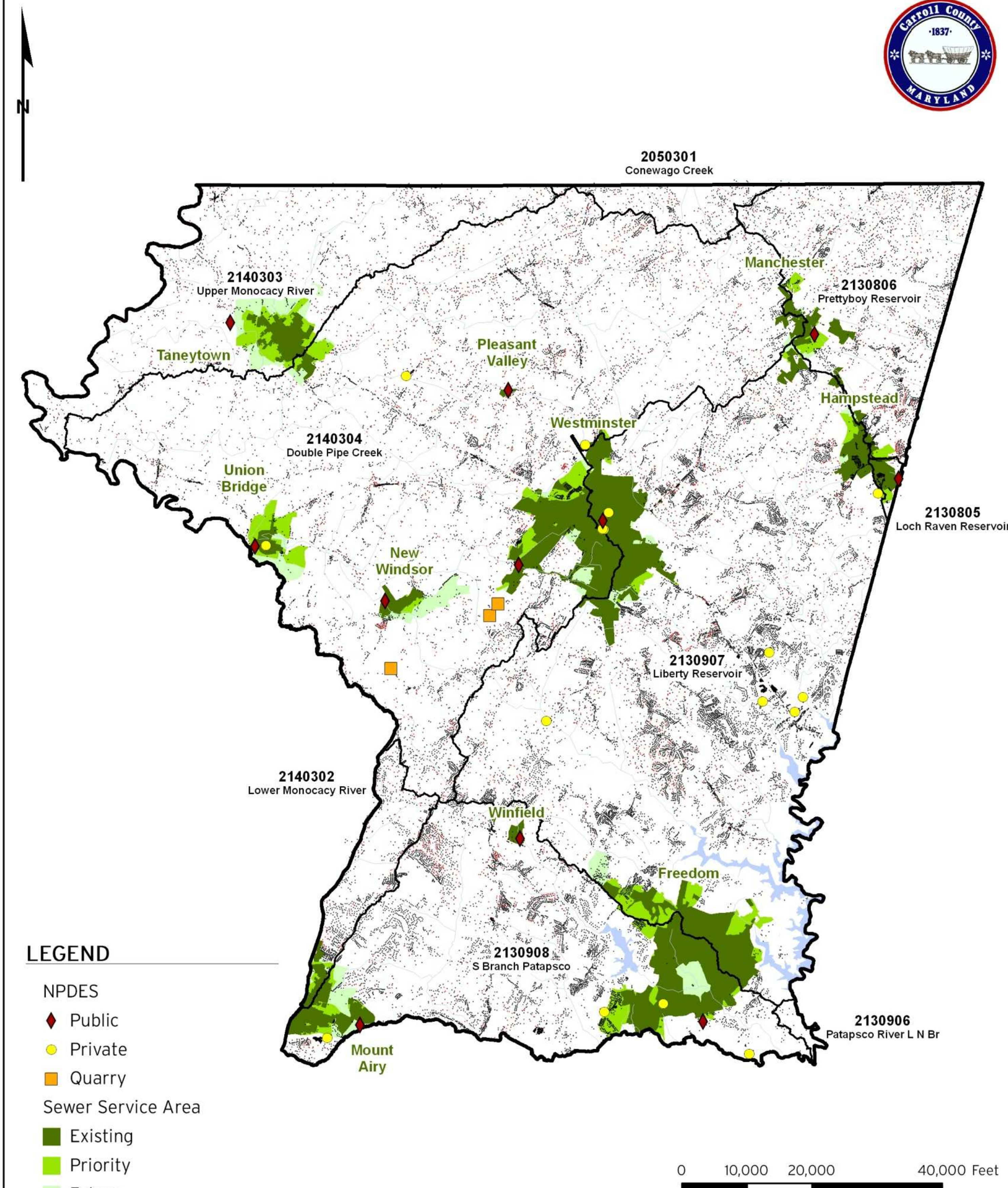
Buildout self-supplied residential demands were estimated by adding the additional demands associated with population growth outside the service areas and subtracting the demand reductions associated with annexation into the service areas. Population growth was estimated using the BLI land use designation GIS data to determine the number of developable residential lots outside the service areas with the assumption that each lot would contain a single-family dwelling. Similarly, the population reduction of self-supplied residents due to annexation was estimated using the county address location GIS data. The net household change at buildout was multiplied by the assumed average household use rate (250 gpd).

Future buildout commercial and industrial demands outside of the service areas were estimated by multiplying existing demands by a total growth rate of 25 percent (i.e. future demands = existing demands x 1.25) based on County estimates of buildout conditions. The 25% growth rate was based on extrapolated (2005-2040) estimates from Carroll County prepared for the Baltimore Metropolitan Council[10]. Quarry demands were assumed to grow proportionately with industry. Although some conversion of agricultural demands into non-agricultural uses might occur as part of buildout changes, agricultural demands were conservatively assumed to remain constant. This assumption is supported by the fact that USGS estimates of agricultural demands in Carroll County have been relatively stable (between 1 and 1.4 mgd) since 1985[5].

2.3. Water Returns

An assessment of water returns was included in the water balance assessment in order to provide an estimate of the net quantitative withdrawals in the County and in each watershed. Unless otherwise noted below, the same methodology for each of the three scenarios (existing, full allocation, future buildout) was used to determine returns. Returns from the wastewater treatment plants in each of the sewer service areas (SSA) were determined by a similar process as future withdrawals. There were ten sewer service areas considered in the analysis (Figure 2-5):

1. Freedom/Sykesville,
2. Hampstead,
3. Manchester,
4. Mount Airy,
5. New Windsor,
6. Pleasant Valley
7. Taneytown,
8. Union Bridge,
9. Westminster, and
10. Winfield.



NOTE: Discharge permits were inferred for the two Medford Quarries (CL1997G026 and CL1970G005), located in the Liberty Reservoir watershed.

MALCOLM PIRNIE	CARROLL COUNTY, MD WATER DEMANDS AND AVAILABILITY	Sewer Service Areas & NPDES Permit Locations	Jul 2009 Figure 2-5

The quantity of wastewater treatment plant (WWTP) returns was estimated by multiplying estimated withdrawals by a return factor. A return factor of 80% was estimated by comparing MDE reported withdrawals to the County's most recent (Dec 2008) Capacity Management Plan (CMP) worksheet wastewater discharge data (excluding inflow and infiltration (I/I)) into service area wastewater collection systems[*]. From a water balance perspective, I/I flows should not be included in the quantitative water balance assessment because these flows are typically due to undesirable leaks in the collection system and ideally will be reduced to a minimum in future years. A relative comparison of 2007 monthly discharges from municipal wastewater treatment plants was used to estimate seasonal variations in returns (Figure 2-6). Relative to the rest of the year, wastewater returns rates were lowest in the summer months due to consumptive use associated with residential landscape irrigation.

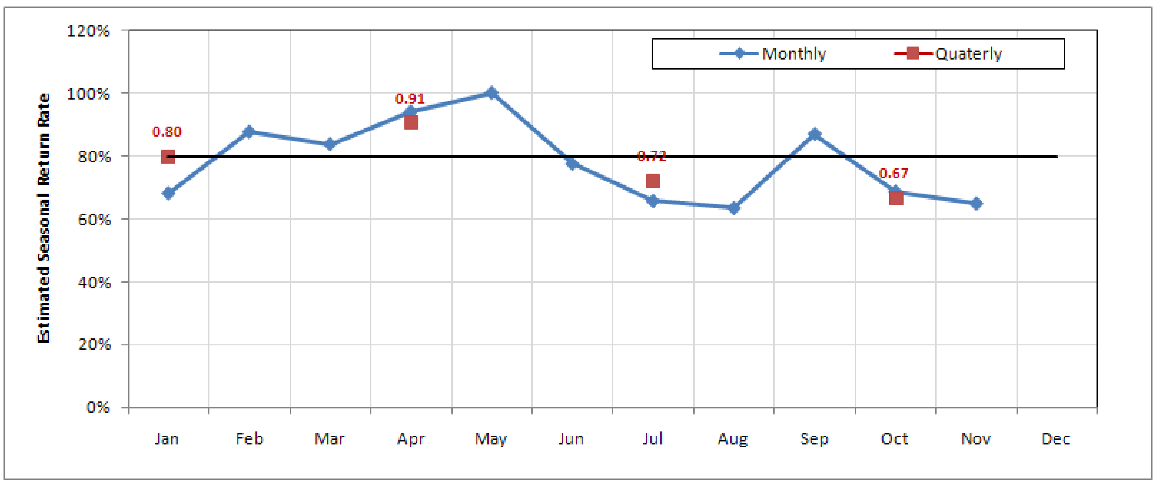


Figure 2-6: Seasonal variations in 2007 municipal WWTP returns

Direct discharges for existing large commercial and industrial water users were estimated using average values reported to the MDE as part of its state National Pollutant Discharge Elimination System (NPDES) permit program in 2007. Direct discharges for the commercial and industrial water users under the full allocation and buildout scenarios were estimated by assuming an 80% return rate for *self-supplied* commercial and industrial users with a withdrawal permit.

The most recent values for total freshwater consumptive use in Maryland[4,6,7] are approximately 10%, which correspond to return rates of 90%. National estimates of domestic-commercial freshwater consumptive use were estimated at 19%, while state

[*] The analysis excluded Mount Airy withdrawals and discharges because Mount Airy straddles Carroll and Frederick Counties so that available withdrawal and discharge data were not comparable.

estimates of domestic consumptive use in Maryland were approximately 10%[6]. The Advisory Committee on the Management and Protection of the State's Water Resources assumed septic system return rates in the Monocacy River watershed, which includes portions of Carroll County, were approximately 80%[3]. Specifically, the Monocacy River Watershed Pilot Study (appended to the May 2004 Advisory Committee report) assumed that homes on individual wells and septic systems were returning 80% of the water they take from their wells to the surficial aquifer as recharge. The Advisory Committee value of 80% was chosen for this WRE analysis as it was the more conservative of the two values and was more specific to the study area.

Septic system discharges were estimated using a GIS analysis of the County's address location database joined with spatial information on land use. Residential parcels outside of the SSAs were assumed to have a single family dwelling unit with an average return rate of 200 gpd (250 gpd withdrawal times an 80% return rate). Similarly, self-supplied non-residential entities outside of the SSAs and without a water withdrawal permit (i.e. withdrawals under 10,000 gpd), such as churches, schools, and small businesses, were assumed to have an average septic return rate of 200 gpd. Under buildout conditions, the number of residential and non-residential septic units was estimated by adding the anticipated number of units outside of the future SSA boundaries, including both projected and existing units, and by subtracting the number of existing septic units annexed into the future SSAs.

Agricultural returns were estimated by assuming a runoff rate of 5% and a recharge rate of 10% for a total return rate of 15%; however, agricultural returns were not used in the default settings for the overall water balance calculations.

Quarry returns were estimated separately from commercial and industrial demands to account for the much higher assumed return rate of 95% (because quarries typically have very little consumptive water use) multiplied by scenario withdrawals.

Returns were also categorized by surface water versus groundwater returns. All returns associated with NPDES permits including those given to municipal WWTPs, commercial and industrial direct discharges, and quarry discharges, are returned as surface water. Groundwater returns were estimated based on the septic returns.

2.4. Water Resources

Water resources were quantitatively evaluated in all nine of the County's MDE eight-digit watersheds. The net potential quantitative impacts to county water resources due to water demands and returns under existing, full allocation use, and future buildout scenarios were determined by using the methodology outlined in the two preceding sections.

2.4.1. Groundwater Availability

Groundwater availability in each watershed was estimated using the methodology outlined in the MDE guidance for the water balance portion of the WRE[1,2]. The ten-year recurrence interval (Q1-in-10) flows were used as the recommended conservative estimate of expected groundwater flows. The groundwater availability was then estimated as the Q1-in-10 groundwater flows minus a minimum amount for reserved for base flow to streams. The MDE recommended minimum reserve flow is the 7Q10 flow (the lowest flow occurring over a seven day period with a recurrence interval of ten years). Therefore, the MDE-recommended groundwater availability was determined using the following formula:

$$GW_A = ([Q1\text{-}in\text{-}10] - [7Q10]) \times Area \times 74.346 \qquad \text{(eqn. 2-1)}$$

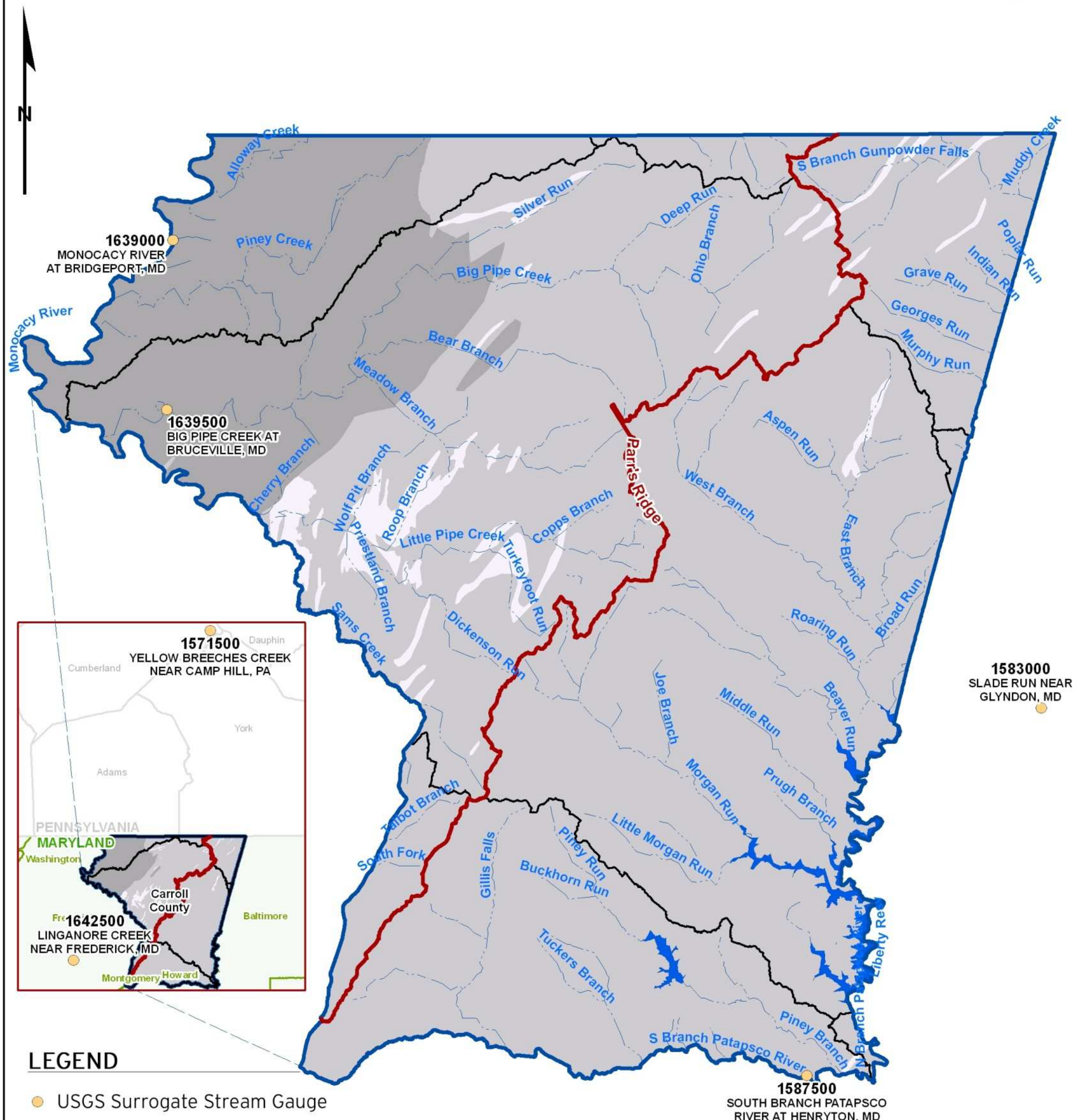
where:

where:	$[GW_A]$	=	groundwater availability for a given area
	[Q1-in-10]	=	the effective recharge during a 1 in 10 year drought in inches per year from column seven of Table A-3;
	[7Q10]	=	the 7-day 10-year low flow in inches per year from column sixteen of Table A-3;
	Area	=	the analysis area in acres; and
	74.346	=	a conversion factor changing acre-inches per year to gpd

In order to determine the groundwater availability of each watershed, the watersheds were divided into hydrogeomorphic regions to account for differing recharge rates associated with different hydrogeologic conditions present throughout the county. There are three hydrogeomorphic regions in Carroll County: Mesozoic Lowlands, Piedmont Carbonate, and Piedmont Crystalline[11]. Each hydrogeomorphic region in each watershed was assigned a surrogate USGS streamflow gauge according to the recommended MDE methodology[1] (Figure 2-7). Groundwater availability in each watershed was estimated by areally proportioning groundwater availability in each of the hydrogeomorphic regions. It was assumed that there would be no net change in groundwater recharge rates relative to existing conditions at buildout due to regulatory requirements for maintaining pre-development recharge rates[12].

Estimates of surplus groundwater remaining for allocation in each watershed were determined by subtracting groundwater demands from the groundwater availability in each scenario.

Hydrogeomorphic Region	2050301 Conewago Creek	2140304 Double Pipe Creek	2130907 Liberty Reservoir	2130805 Loch Raven Reservoir	2140302 Lower Monocacy River	2130906 Patapsco River L N Br	2130806 Prettyboy Reservoir	2130908 S Branch Patapsco	2140303 Upper Monocacy River
ML	--	1639000	--	--	--	--	--	--	1639000
PCA	--	1571500	1571500	--	--	1571500	1571500	1571500	1571500
PCR	1583000	1639500	1583000	1583000	1642500	1587500	1583000	1587500	1639500



LEGEND

USGS Surrogate Stream Gauge

Hydrogeomorphic Region

Mesozoic Lowlands (ML)

Piedmont Carbonate (PCA)

Piedmont Crystalline (PCR)

0 10,000 20,000 40,000 Feet

MALCOLM PIRNIE

CARROLL COUNTY, MD
WATER DEMANDS AND AVAILABILITY

Hydrogeomorphic Regions & Surrogate Gauge Locations

Jul 2009

Figure 2-7

2.4.2. Surface Water Availability

Minimum flows in a stream, known as "flowbys", are required by Maryland regulations[13] in order to protect streams from impacts due to surface water appropriations. Flowby requirements for streams in Maryland are typically developed using the Maryland Most Common Flow Method[2,14,15], which consists of determining the fifteenth percentile (85% exceedance) of monthly flows (Q15) based on an analysis of daily values over the historical record of a gauge adjusted to the drainage area of interest. The resulting monthly flowby values were grouped into annual averages. The water balance assessment tool can also calculate seasonal flowby values in quarterly or biannual groupings given a water year starting on a chosen month. The same surrogate gauges that were used to estimate groundwater availability were used to estimate the flowbys for each watershed.

The method discussed below was used to estimate the total theoretical amount of usable reservoir storage required to sustain a total surface water requirement, consisting of a given demand and the required flowby, for each watershed.

Required usable storage estimates were based on an analysis of the worst drought in the period of record for each stream gauge. For a given demand, the required usable storage capacity of a reservoir was estimated iteratively by using a simple mass balance over the period of record:

$$V_{i+1} = V_i + inflow_i - Y - spillage_i \quad | \; i=1 \text{ to } n \qquad \text{(eqn. 2-2)}$$

where:

i	=	subscript indicating the sequential day in the period of record
n	=	the number of days in the period of record
V	=	reservoir storage volume in inches;
inflow	=	inflow normalized by gauge area in inches;
Y	=	yield (flowby + demand) in inches;
spillage	=	a term to ensure that the storage volume does not exceed the specified usable storage capacity of the reservoir in inches
	=	$max(0, Vi + inflow - Y - capacity)$

When recursively applied over the period of record, the mass balance equation produced a theoretical storage history for the specified constant yield value (Figure 2-8). For a given gauge and a set of yield values, the storage capacity was iteratively selected until the minimum storage volume (*V*) for the entire period of record was less than 1% of the capacity (as shown in Sept 2002 in Figure 2-8), indicating the usable reservoir capacity had been estimated. The reservoir volume, inflow, and yield terms in equation 2-2 were normalized by contributing watershed area in order to combine multiple gauges in different hydrogeomorphic regions. This method uses the worst drought on record to determine the required storage capacity to meet a demand and flowby requirement, ignores the effects of direct precipitation and evaporation, and assumes no dead storage volume. The worst drought on record varied between watersheds, but either occurred in one of two periods - 1966-1967 or 2002-2003.

For each gauge, the set of yield values and resulting required usable storage capacity values were tabulated to produce a curve over a wide range of yield values (Figure 2-9) encompassing likely withdrawal requirements in addition to the required flowby.

An average storage-yield curve was estimated for each watershed (Figure 2-10) in the county by areally proportioning the estimated yield values to given reservoir volumes by hydrogeomorphic region (Figure 2-7). The resulting plots in Figure 2-10 were then used to determine the theoretical total usable storage required to meet surface water demands and flowbys in each watershed.

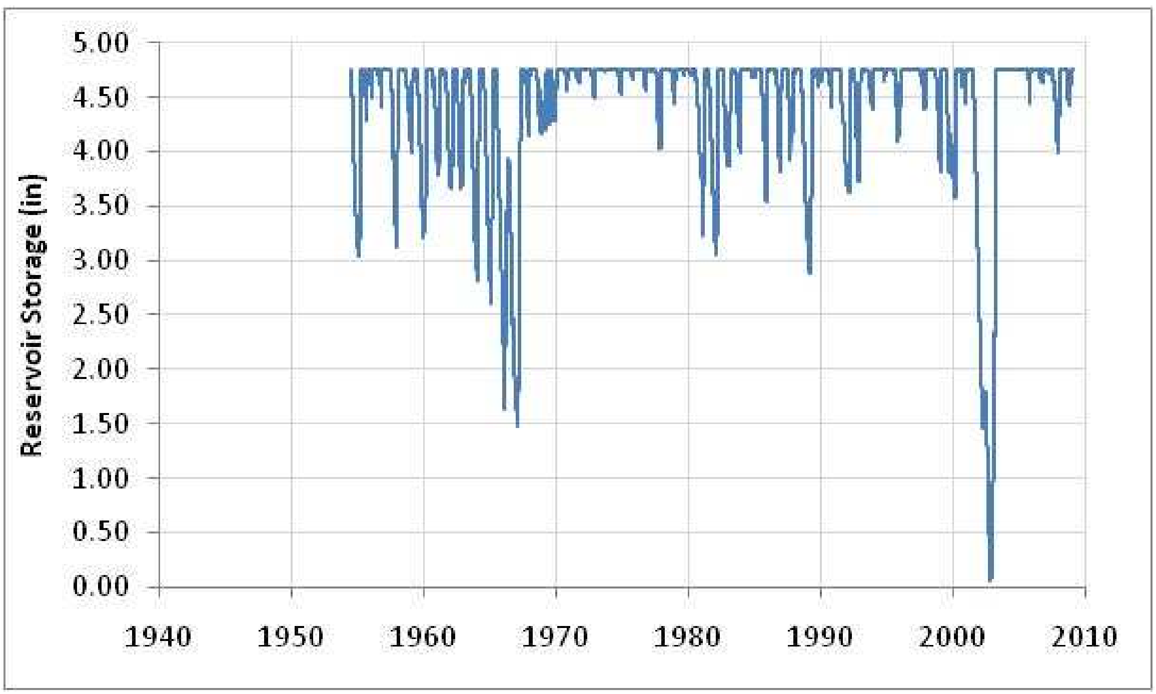


Figure 2-8: Typical curve of estimated reservoir volume over the period of record

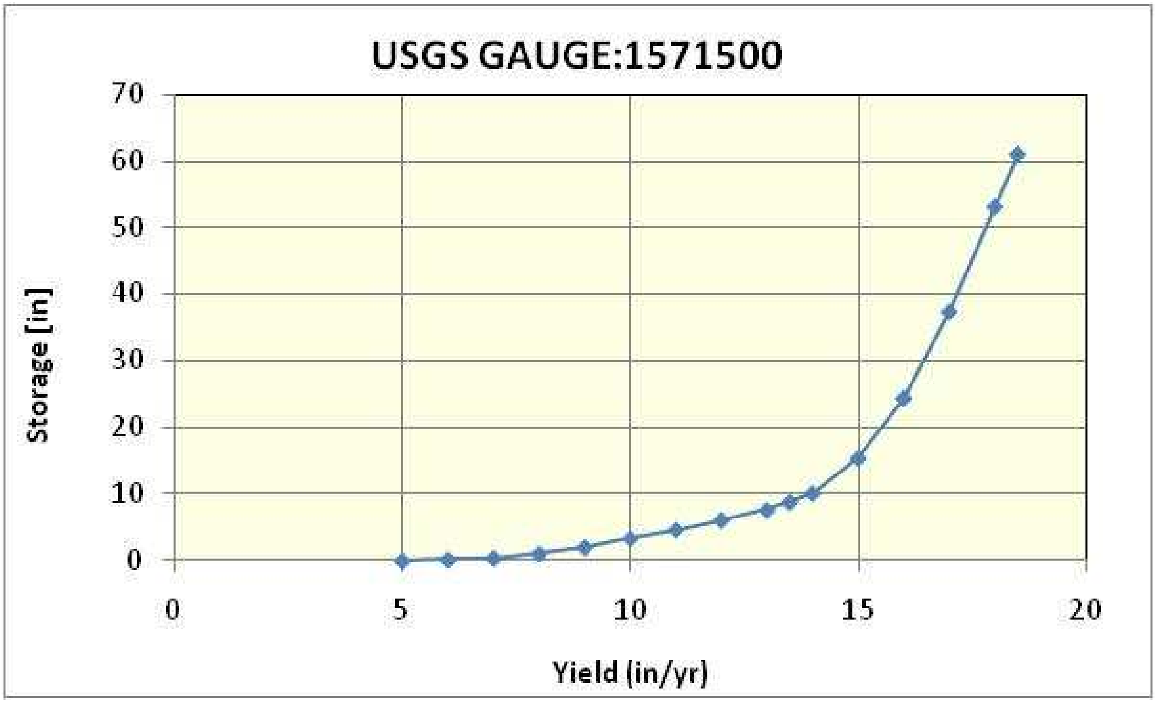


Figure 2-9: Estimated storage-yield curve for USGS gauge 1571500

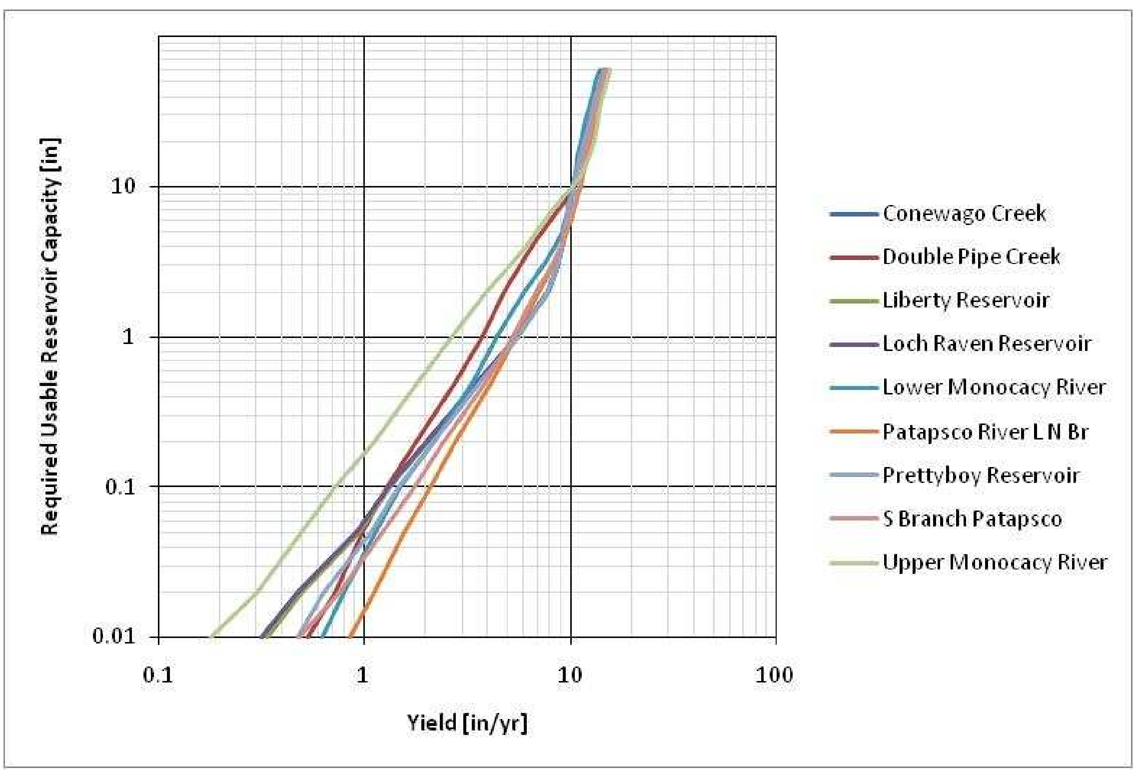


Figure 2-10: Estimated storage-yield curves by watershed

3. Results by Watershed

A brief discussion of water balance assessment results relating to each watershed is presented below, whereas County-wide results are discussed in Section 4. Numerical results of the water balance analysis are tabulated in Appendix B and presented graphically in Appendix C. Results are based on the assumptions outlined in the preceding section and summarized in Table B-1. Estimates of reservoir volumes presented in this section represent the total usable storage that would theoretically be required to meet the total surface water demands in the given watershed as well as estimated flowby requirements.

3.1. Conewago Creek [02050301]

The Conewago Creek watershed, located in the northern portion of the County, is one of the smaller 8-digit MDE watershed areas in the County (5.42 square miles). Conewago Creek is part of the Lower Susquehanna sub-basin and flows northward into Pennsylvania. The watershed does not include any of the county's WSAs. Estimates determined using the water balance assessment tool are summarized in Table 3-1and presented in Table B-3.1.

Table 3-1:
Conewago Creek Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	0	0	0
GW	Groundwater	86,500	86,500	130,500
	Total	**86,500**	**86,500**	**130,500**
RETURNS				
	WWTP	0	0	0
	Septic	71,000	71,000	91,800
	Total	**71,000**	**71,000**	**104,400**
WATER RESOURCES				
SW	Flowby	1,692,436	1,692,436	1,692,436
SW	Storage	NA	NA	NA
GW	Availability	1,392,239	1,392,239	1,392,239
GW	Surplus	1,376,739	1,376,739	1,366,139

Annual average demands in the watershed are approximately 0.09 mgd, all of which is for self-supplied residential groundwater use. Demands were projected to grow to 0.13 mgd at buildout. Similarly, septic returns were estimated to increase from 0.07 mgd to 0.10 mgd at buildout.

Groundwater availability in the Carroll County portion of Conewago watershed was estimated to be approximately 1.4 mgd. Therefore, given the present level of analysis, water resources in the Conewago Creek watershed are available in sufficient quantities that they could be developed to meet projected buildout demands.

3.2. Double Pipe Creek [02140304]

The Double Pipe Creek watershed is located in the northwest portion of the County and is the largest 8-digit MDE watershed area in the County, with an area of approximately 164 square miles. Double Pipe Creek is a major tributary in the Monocacy River sub-basin. The watershed includes the Union Bridge, New Windsor, Bark Hill, and Pleasant Valley WSAs, and portions of the Westminster and Taneytown WSAs. Estimates determined using the water balance assessment tool are summarized in Table 3-2 and presented in Table B-3.2.

Table 3-2:
Double Pipe Creek Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	139,907	792,300	1,352,061
GW	Groundwater	5,887,204	7,254,300	8,839,668
	Total	**6,027,110**	**8,046,600**	**10,191,729**
RETURNS				
	WWTP	2,553,821	3,327,290	4,017,641
	Septic	1,491,200	1,491,200	2,157,600
	Total	**5,785,821**	**6,664,090**	**9,463,363**
WATER RESOURCES				
SW	Flowby	37,707,072	37,707,072	37,707,072
SW	Storage	5,029	5,254	5,447
GW	Availability	32,171,059	32,171,059	32,171,059
GW	Surplus	27,800,855	26,433,759	25,825,391

Annual average existing demands in the watershed are approximately 6.0 mgd, mostly for residential use (49%) and quarry dewatering (41%). Approximately 8.0 mgd have been allocated, so that 75% of the total permitted water appropriation is currently being used. Demands were estimated to increase to 10.2 mgd at buildout indicating a possible need for approximately 2.1 mgd of additional appropriations in the watershed. Much of the estimated growth in demand is expected to occur due to increased self-supplied residential demands (1.1 mgd) which do not currently require a permit.

Existing surface water withdrawals were projected to increase from 0.14 mgd to 1.4 mgd at buildout conditions, which is above the current total surface water allocation of 0.73 mgd in the watershed. In order to continuously meet the future demand rate given the estimated 37.7 mgd flowby requirement, it would be necessary to develop a total usable reservoir storage capacity of approximately 5.4 billion gallons in the watershed.

Groundwater withdrawals were estimated to increase from 5.8 mgd to 8.8 mgd at buildout conditions, which is above the current total allocation of 7.3 mgd in the watershed. Estimated groundwater withdrawals in each scenario are significantly below estimated availability with a calculated surplus of 25.8 mgd given buildout demands.

Water returns in the watershed are largely comprised of municipal WWTP returns (2.6 mgd, 44%), quarry discharges (1.7 mgd, 30%), and septic returns (1.5 mgd, 26%). Total returns are projected to increase from the existing rate of 5.8 mgd to a buildout rate of 9.5 mgd.

Given the present level of analysis, water resources in the Double Pipe Creek watershed are available in sufficient quantities that they could be developed to meet projected buildout demands.

3.3. **Liberty Reservoir** [02130907]

The Liberty Reservoir watershed is the second largest in the County, with an approximate area of 136 square miles and is located in the eastern portion of the County. Liberty Reservoir is the major water feature in the watershed and serves as a major water source for the Freedom/Sykesville WSA and for the City of Baltimore. The watershed includes portions of the Freedom/Sykesville, Hampstead, Manchester, and Westminster WSAs. Estimates determined using the water balance assessment tool are summarized in Table 3-3 and presented in Table B-3.3.

Table 3-3:
Liberty Reservoir Watershed Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	4,318,319	6,764,900	5,977,392
GW	Groundwater	5,595,895	5,892,400	8,074,285
	Total	**9,914,214**	**12,657,300**	**14,051,678**
RETURNS				
	WWTP	231,770	296,310	262,554
	Septic	2,770,600	2,770,600	3,664,400
	Total	**4,153,673**	**4,403,670**	**5,792,080**
WATER RESOURCES				
SW	Flowby	42,672,450	42,672,450	42,672,450
SW	Storage	3,534	3,868	3,760
GW	Availability	35,012,921	35,012,921	35,012,921
GW	Surplus	32,292,226	31,995,721	30,961,636

Annual average existing demands in the watershed are approximately 9.9 mgd, mostly residential use (83%). Approximately 12.7 mgd have been allocated, so that 78% of the total permitted water appropriation is currently being used. Demands were predicted to increase to 14.1 mgd at buildout.

Surface water withdrawals were estimated to increase from an existing 4.3 mgd to 6.0 mgd at buildout, which is above the current allocation of 6.8 mgd. In order to continuously meet the future demand rate given the estimated 42.7 mgd flowby requirement, it would be necessary to develop a total usable reservoir storage capacity of approximately 3.8 billion gallons in the watershed.

Groundwater withdrawals were projected to increase from 5.6 mgd to 8.1 mgd, which was also above the current allocation of 5.9 mgd. Estimated groundwater withdrawals in each scenario are significantly below the total availability with a calculated surplus of 31.0 mgd given buildout demands and returns.

Water returns in the watershed are largely comprised of septic returns (2.8 mgd, 67%) and industry discharges (1.0 mgd, 25%). Municipal WWTP returns are largely returned to adjacent watersheds so that municipal returns only account for approximately 5.6% (0.23 mgd) of the total returns despite relatively large municipal demands in the watershed. Water returns are projected to increase to 5.8 mgd at buildout.

Given the present level of analysis, water resources in the Liberty Reservoir watershed are available in sufficient quantities that they could be developed to meet projected buildout demands.

3.4. Loch Raven Reservoir [02130805]

A small portion of the Loch Raven Reservoir watershed is located in eastern Carroll County. The Loch Raven Reservoir watershed has an area of only 0.93 square miles in Carroll County and is a part of the Gunpowder-Patapsco sub-basin. Portions of the Hampstead WSA are located in the Loch Raven Reservoir watershed. Estimates determined using the water balance assessment tool are summarized in Table 3-4 and presented in Table B-3.4.

Table 3-4:
Loch Raven Reservoir Watershed Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	0	0	0
GW	Groundwater	326,105	355,250	705,166
	Total	**326,105**	**355,250**	**705,166**
RETURNS				
	WWTP	367,719	464,000	592,550
	Septic	3,400	3,400	45,600
	Total	**371,319**	**467,600**	**640,950**
WATER RESOURCES				
SW	Flowby	288,987	288,987	288,987
SW	Storage	NA	NA	NA
GW	Availability	237,727	237,727	237,727
GW	Surplus	-84,778	-113,923	-419,039

Annual average existing demands in the watershed are approximately 0.33 mgd, mostly for serviced residential use (77%) and self-supplied residential use (18%). Approximately 0.36 mgd have been allocated, so that the total permitted water appropriation permitted is currently being used. Demands were projected to increase to 0.71 mgd at buildout indicating a likely need for additional permits in the watershed.

Water withdrawals in the County are currently from groundwater sources only and are anticipated to remain so at buildout.

Groundwater availability in the Carroll County portion of the Loch Raven Reservoir Watershed was estimated to be approximately 0.24 mgd resulting in existing and buildout shortfalls of 0.085 mgd and 0.42 mgd, respectively.

Without a more detailed evaluation or expansion of the analysis area, the water resources in the Carroll County portion of the Loch Raven watershed would not be sufficient to meet buildout groundwater demands. Future water demands in this watershed would have to be met using water from outside the small Carroll County portion of the watershed.

3.5. Lower Monocacy River [02140302]

The Lower Monocacy River watershed is located in the southwest portion of Carroll County and has an approximate area of 8.5 square miles within the County. The County portion of the watershed includes the headwaters of Linganore Creek. The watershed includes part of the Mount Airy WSA. Estimates determined using the water balance assessment tool are summarized in Table 3-5 and presented in Table B-3.5.

Table 3-5:
Lower Monocacy River Watershed Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	0	0	0
GW	Groundwater	313,202	332,250	314,072
	Total	**313,202**	**332,250**	**314,072**
RETURNS				
	WWTP	0	0	0
	Septic	192,200	192,200	222,600
	Total	**196,800**	**196,800**	**244,000**
WATER RESOURCES				
SW	Flowby	2,057,587	2,057,587	2,057,587
SW	Storage	NA	NA	NA
GW	Availability	1,665,118	1,665,118	1,665,118
GW	Surplus	1,548,717	1,529,668	1,595,046

Annual average existing demands in the watershed are approximately 0.31 mgd, for self-supplied residential (82%) and municipal supply (18%). Approximately, 0.33 mgd have been allocated, so that 94% of the total permitted water appropriation is currently being used. Demands were projected to remain relatively constant at buildout; however since demands are within 10% of the allocation. Municipal withdrawals in the watershed are anticipated to be reduced from 0.058 mgd to 0.008 mgd due to the proposed 3.8 mgd Gillis Falls Reservoir, which is to be located in the South Branch Patapsco River watershed. Self-supplied residential demands are expected to increase from the current demands of 0.25 mgd to projected buildout demands of 0.305 mgd.

There are currently no surface water withdrawal appropriations in the watershed, nor are any such appropriations anticipated at buildout. Groundwater demands are projected to remain relatively constant at 0.31 mgd, which is near the current allocation of 0.33 mgd indicating a possible need for additional appropriation permits.

Based on the evaluation of water usage in the watershed, the only water returns in the watershed originate from septic systems at approximately 0.19 mgd. Returns are projected to increase to 0.22 mgd under buildout conditions.

Groundwater availability in the Carroll County portion of the Lower Monocacy River watershed was estimated to be approximately 1.67 mgd, resulting in existing and buildout surpluses of 1.55 mgd and 1.60 mgd, respectively.

Given the present level of analysis, water resources in the Lower Monocacy River watershed are available in sufficient quantities that they could be developed to meet projected buildout demands.

3.6. Patapsco River Lower North Branch [02130906]

A small portion of the Lower North Branch Patapsco River watershed is located in the southeast corner of Carroll County. The watershed has an area of 0.88 square miles in Carroll County and is a part of the Gunpowder-Patapsco sub-basin. The Liberty Reservoir watershed is immediately upstream of the Lower North Branch of the Patapsco River watershed. There are no WSAs in the watershed. Estimates determined using the water balance assessment tool are summarized in Table 3-6 and presented in Table B-3.6.

Annual average existing demands in the watershed are approximately 5,250 gpd for self-supplied residential use. There are currently no permitted allocations in the watershed. Demands were projected to increase to 15,250 gpd for self-supplied residential uses at buildout conditions.

Table 3-6:
Patapsco River L N Br Watershed Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	0	0	0
GW	Groundwater	5,250	5,250	15,250
	Total	**5,250**	**5,250**	**15,250**
RETURNS				
	WWTP	0	0	0
	Septic	3,200	3,200	10,600
	Total	**3,200**	**3,200**	**12,200**
WATER RESOURCES				
SW	Flowby	276,398	276,398	276,398
SW	Storage	NA	NA	NA
GW	Availability	209,640	209,640	209,640
GW	Surplus	207,590	207,590	206,590

Water withdrawals in the County are currently from groundwater sources only and are anticipated to remain so at buildout. The current estimate of septic returns was 3,200 gpd and was projected to increase to approximately 12,000 gpd under buildout conditions.

Groundwater availability in the Carroll County portion of the Lower North Branch of the Patapsco River watershed was estimated to be approximately 0.210 mgd resulting in a calculated buildout surplus of approximately 0.207 mgd.

Given the present level of analysis, water resources in the Patapsco River Lower North Branch watershed are available in sufficient quantities that they could be developed to meet projected buildout demands.

3.7. Prettyboy Reservoir [02130806]

The Prettyboy Reservoir watershed is located in the northeast corner of the County and has an area of approximately 32.9 square miles. The Prettyboy Reservoir watershed is part of the Gunpowder-Patapsco sub-basin and generally flows eastward into Baltimore County. The watershed includes portions of the Hampstead and Manchester WSAs. Estimates determined using the water balance assessment tool are summarized in Table 3-7 and presented in Table B-3.7.

Table 3-7:
Prettyboy Reservoir Watershed Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	12,268	22,000	12,268
GW	Groundwater	876,583	1,112,650	1,260,141
	Total	**888,851**	**1,134,650**	**1,272,409**
RETURNS				
	WWTP	240,661	457,360	375,293
	Septic	587,600	587,600	804,800
	Total	**840,061**	**1,056,760**	**1,280,293**
WATER RESOURCES				
SW	Flowby	10,431,070	10,431,070	10,431,070
SW	Storage	720	721	720
GW	Availability	8,411,515	8,411,515	8,411,515
GW	Surplus	8,134,332	7,898,265	8,056,375

Annual average existing demands in the watershed are approximately 0.89 mgd, mostly for self-supplied residential use (83%) and municipal residential uses (9.3%). Approximately 1.13 mgd have been allocated in the watershed, so that 78% of the total permitted water appropriation is currently being used. Demands were projected to increase to 1.28 mgd at buildout conditions indicating a possible need for additional appropriations in the watershed, although much of the estimated growth in demand is expected to occur due to increased self-supplied residential demands which do not currently require a permit.

Existing surface water withdrawals were estimated to remain relatively constant at approximately 12,000 gpd from existing to buildout conditions, which is less than the current surface water allocation of 22,000 gpd. Given the estimated flowby of 10 mgd, a total theoretical usable reservoir storage capacity of approximately 720 million gallons would be required to meet buildout demands.

Groundwater withdrawals were projected to increase from 0.88 mgd to 1.26 mgd at buildout conditions, which is above the current total groundwater approximate allocation of 1.11 mgd. Projected groundwater withdrawals in each scenario are significantly below total estimated availability with a calculated surplus of 8.06 mgd given buildout demands and groundwater returns.

The majority of water returns in the watershed currently consist of septic returns (approximately 0.6 mgd, 70%) and municipal WWTP returns (approximately 0.24 mgd, 29%). Future returns are projected to increase to 1.28 mgd.

Given the present level of analysis, water resources in the Prettyboy Reservoir watershed are available in sufficient quantities that they could be developed to meet projected buildout demands.

3.8. South Branch Patapsco [02130908]

The South Branch Patapsco River watershed is located in the southern portion of the County and has an area of approximately 60.52 square miles. The South Branch of the Patapsco River is a major tributary in Gunpowder-Patapsco sub-basin and flows eastward along the County's southern border into the Lower North Branch of the Patapsco River watershed. The watershed includes portions of the Freedom/Sykesville and Mount Airy WSAs. Estimates determined using the water balance assessment tool are summarized in Table 3-8 and presented in Table B-3.8.

Table 3-8:
S Branch Patapsco Watershed Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	53,660	3,441,100	635,530
GW	Groundwater	1,784,294	2,392,500	2,173,533
	Total	**1,837,954**	**5,833,600**	**2,809,063**
RETURNS				
	WWTP	1,988,161	6,745,000	3,683,066
	Septic	1,071,600	1,071,600	1,440,400
	Total	**3,080,163**	**7,902,842**	**5,295,578**
WATER RESOURCES				
SW	Flowby	18,109,302	18,109,302	18,109,302
SW	Storage	1,497	2,232	1,610
GW	Availability	14,398,786	14,398,786	14,398,786
GW	Surplus	13,706,492	13,098,286	13,813,453

Annual average existing demands in the watershed are approximately 1.8 mgd, mostly for self-supplied residential use (79%) and municipal residential uses (6.8%). Approximately 5.8 mgd of appropriations have been allocated in the watershed, so that approximately 32% of the total permitted water appropriation is currently being used (including self-supplied residential withdrawals which do not require a permit). Demands were estimated to increase to 2.8 mgd at buildout conditions indicating that existing permits may be sufficient to meet projected demands.

Existing surface water withdrawals were predicted to increase significantly from an existing 0.05 mgd to buildout 0.64 mgd, which is less than the current allocation of 3.44 mgd. Given the estimated flowby of 18.1 mgd, a total theoretical usable reservoir storage capacity of approximately 1.60 billion gallons would be required to meet buildout condition demands.

Groundwater withdrawals were predicted to increase from 1.78 mgd to 2.17 mgd at buildout conditions, which are below the current total groundwater allocation of 2.39 mgd. Most of the growth includes self-supplied residential demands which do not currently require an appropriation permit. Projected groundwater withdrawals in each scenario are significantly below estimated availability with a calculated surplus of approximately 14 mgd given buildout demands and groundwater returns.

The majority of water returns in the watershed (3.1 mgd) currently consist of municipal WWTP returns (approximately 2.0 mgd, 65%) and septic returns (approximately 1.1 mgd, 35%). Future returns are projected to increase to 5.3 mgd under buildout conditions.

Given the present level of analysis, water resources in the South Branch Patapsco River watershed are available in sufficient quantities that they could be developed to meet projected buildout demands.

3.9. **Upper Monocacy River** [02140303]

The Upper Monocacy watershed is located in northwestern corner of the County and has an area of approximately 42 square miles. The Monocacy River flows southward through the watershed along the western edge of the County to the confluence with Double Pipe Creek. The watershed includes a portion of the Taneytown WSA. Estimates determined using the water balance assessment tool are summarized in Table 3-9 and presented in Table B-3.9.

Annual average existing demands in the watershed are approximately 0.76 mgd, mostly for municipal residential uses (44%) and self-supplied residential use (36%). Approximately 0.97 mgd of appropriations have been allocated in the watershed, so that approximately 78% of the total permitted water appropriation is currently being used (including self-supplied residential withdrawals which do not require a permit). Demands were estimated to increase to 1.02 mgd at buildout conditions indicating that additional permits will be required to meet projected demands.

Table 3-9:
Upper Monocacy River Watershed Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	707	10,000	707
GW	Groundwater	755,765	958,750	1,018,860
	Total	**756,471**	**968,750**	**1,019,567**
RETURNS				
	WWTP	407,055	466,400	1,390,885
	Septic	238,800	238,800	364,000
	Total	**651,855**	**826,400**	**1,904,050**
WATER RESOURCES				
SW	Flowby	5,581,106	5,581,106	5,581,106
SW	Storage	683	686	683
GW	Availability	7,919,973	7,919,973	7,919,973
GW	Surplus	7,409,009	7,206,023	7,352,513

Existing surface water withdrawals are currently a minor source of water (707 gpd) and are projected to remain so at buildout conditions. The required flowby for the Upper Monocacy watershed was estimated to be 5.6 mgd.

Groundwater withdrawals were predicted to increase from 0.76 mgd to 1.02 mgd at buildout conditions, which is above the current total groundwater allocation of 0.96 mgd. Most of the growth in demand includes self-supplied residential demands which do not currently require an appropriation permit. Projected groundwater withdrawals in each scenario are significantly below estimated availability with a calculated surplus of approximately 7.4 mgd given buildout demands and groundwater returns.

The majority of water returns in the watershed (0.65 mgd) currently consist of municipal WWTP returns (approximately 0.41 mgd, 62%) and septic returns (approximately 0.24 mgd, 37%). Future returns are projected to increase to 1.9 mgd under buildout conditions.

Given the present level of analysis, water resources in the Upper Monocacy River watershed are available in sufficient quantities that they could be developed to meet projected buildout demands.

4. County-Wide Results

A discussion of water balance assessment results relating to the County as a whole is presented below, whereas results relating to the individual watersheds are discussed in Section 3 above. Numerical results of the water balance analysis are tabulated in Appendix B and presented graphically in Appendix C. Results are based on the assumptions outlined in the preceding section, summarized in Table 4-1, and presented in Table B-10.

Table 4-1:
Carroll County Water Balance Assessment Results Summary

		Reported	Permitted	Buildout
DEMANDS				
SW	Surface Water	4,524,860	11,030,300	7,977,958
GW	Groundwater	15,630,797	18,389,850	22,531,475
	Total	**20,155,657**	**29,420,150**	**30,509,433**
RETURNS				
	WWTP	5,789,187	11,756,360	10,321,989
	Septic	6,429,600	6,429,600	8,801,800
	Total	**15,153,891**	**21,592,362**	**24,736,914**
WATER RESOURCES				
SW	Flowby	118,816,408	118,816,408	118,816,408
SW	Storage	11,463	12,761	12,220
GW	Availability	101,418,979	101,418,979	101,418,979
GW	Surplus	92,391,182	89,632,129	88,758,104

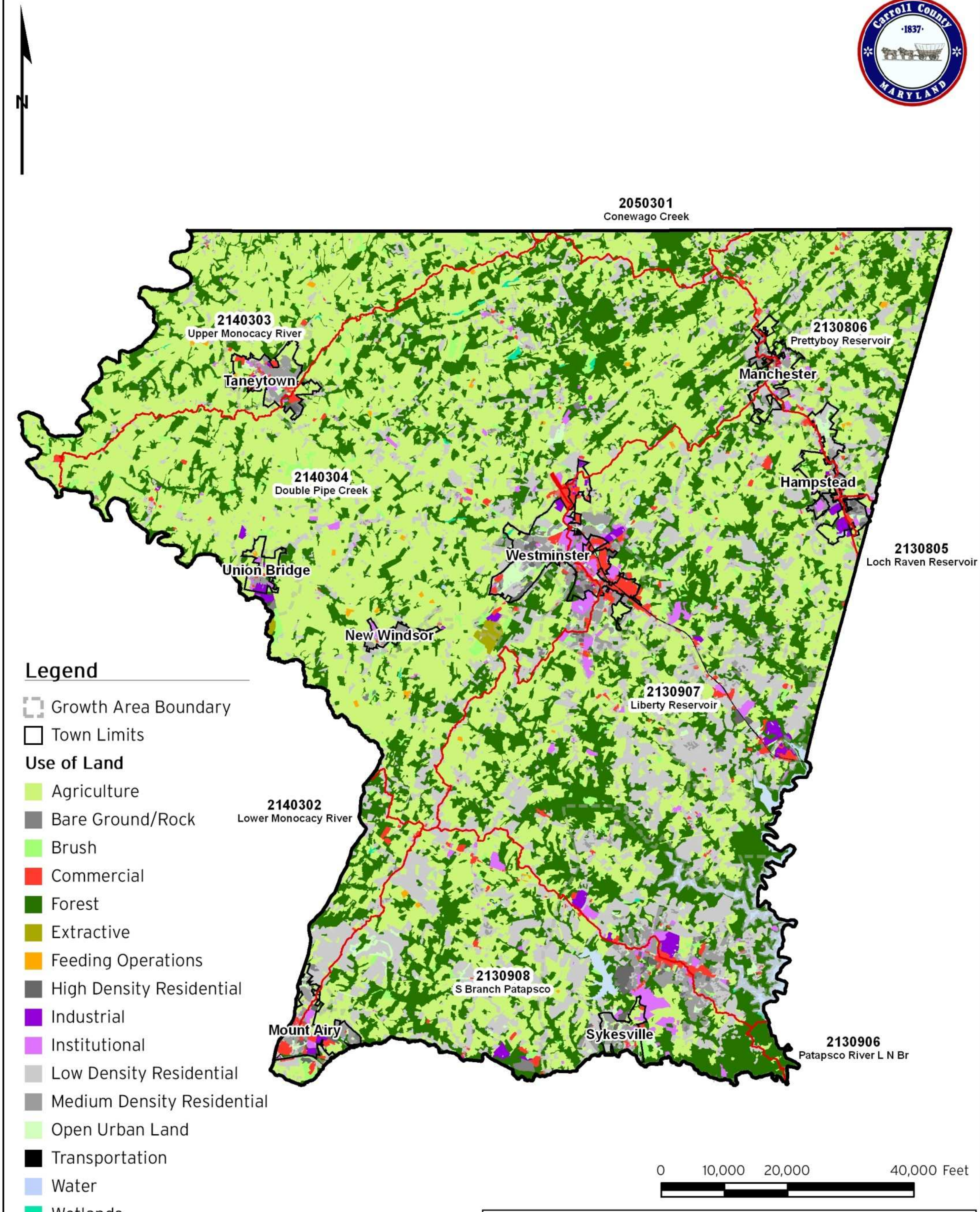
4.1. Land Use

Current use of the land in the County is presented in Figure 4-1 and summarized in Table 4-2. The use of the land in the County is largely devoted to agricultural (50%) and residential (17%) uses along with a considerable amount of forested lands (26%). Designated Growth Areas in the County include Freedom/Sykesville, the Cities of Taneytown, and Westminster, and the Towns of Hampstead, Manchester, Mount Airy, New Windsor, and Union Bridge.

Table 4-2:
Existing Land Use in Carroll County

Use of Land	Sq Mi	Acres	Percent of Total
Bare Ground/Rock	1.1	675	0.2
Brush	6.5	4,132	1.4
Forest	116.9	74,835	25.9
Wetlands	0.4	241	0.1
Water	5.2	3,301	1.1
Agriculture	224.0	143,381	49.5
Feeding Operations	0.6	410	0.1
Extractive	0.6	392	0.1
Low Density Residential	65.6	42,007	14.5
Medium Density Residential	11.0	7,023	2.4
High Density Residential	2.2	1,397	0.5
Open Urban Land	3.3	2,131	0.7
Commercial	6.5	4,145	1.4
Institutional	5.8	3,681	1.3
Industrial	2.4	1,507	0.5
Transportation	0.4	228	0.1
CARROLL COUNTY	**452.3**	**289,487**	**100.0**

Source: 2007 MDP Land Use/Land Classification Data



SOURCE: 2007 Maryland Department of Planning Land Use/Land Classification Data

MALCOLM PIRNIE	CARROLL COUNTY, MD WATER DEMANDS AND AVAILABILITY	Existing Use of Land	Jul 2009 Figure 4-1

4.2. Water Demands

4.2.1. Reported Scenario

Annual average existing demands in the County are approximately 20.2 mgd. The majority of the existing freshwater demands in the County are associated with residential uses, including 6.5 mgd (32%) for municipally supplied residential demands and 8.3 mgd (41%) for self-supplied residential demands. Estimated water demands associated with each WSA are categorized by watershed in Table B-4.

Other demands in the county include municipally supplied commercial (0.4%) and industrial demands (3.2%), self-supplied industrial/commercial demands (8.0%), and agricultural demands (2.4%). The dewatering of quarries accounts for approximately 12% of the existing water demands in the County. Currently, the largest individual withdrawals in the County (with existing usage over 0.5 mgd) are related to surface water intakes serving municipal supplies and private quarries. The larger individual industrial uses include the S&G Concrete Co. (0.32 mgd), Black & Decker Inc. (0.22 mgd), and Congoleum Corp. (0.22 mgd) facilities (Table A-1). Water demands associated with agricultural and other non-domestic uses approaching, but not exceeding, the MDE 10,000 gpd reporting threshold, may be underestimated as mentioned in Section 1.2.

The majority of average water demands are mostly being met by groundwater wells (78%) compared to surface water sources (22%). A significant portion of the groundwater demand is from self-supplied domestic users who do not require a water appropriation permit, given that their individual household demands are well below the 10,000 gpd threshold. Current surface water withdrawals constitute a larger portion (4.1 mgd, 56%) of the total source supply (7.3 mgd) when only examining withdrawals subject to an MDE appropriation permit.

4.2.2. Permitted Scenario

There are approximately 21 mgd of existing appropriations in the County in addition to an approximate average of 8 mgd of self-supplied withdrawals for a total allocation of 29 mgd. The largest type of allocations in the County (40%) is municipal supply to the WSAs. Water appropriations associated with each WSA are categorized by watershed and source type (*i.e.* groundwater versus surface water) in Table B-4. Private appropriations in the county include self-supplied industrial/commercial entities (6.4%), quarry and mining operators (11.2%) and agricultural users (4.0%). The largest individual appropriations in the County include those mentioned above in Section 4.2.1 in addition to several emergency sources for municipal supply with conditions on their use.

Current water appropriations are evenly divided between surface water (50%) and groundwater (50%) sources. Existing groundwater usage is 15.6 mgd (85%) compared to the current average limit of 18.4 mgd for groundwater appropriations, while existing surface water usage is only 4.5 mgd (41%) compared to the current limit of 11.0 mgd for surface water appropriations.

4.2.3. Buildout Scenario

Water demands under buildout conditions were projected using the methodology discussed in Section 2. Annual average projected buildout demands in the County are approximately 30.5 mgd. The majority of the existing demands (74%) are associated with residential uses, including 10.3 mgd (34%) for municipally supplied residential demands and 12.2 mgd (40%) for self-supplied residential demands. Projected buildout water demands associated with each WSA are categorized by watershed in Table B-4.

Other projected buildout demands in the county include municipally supplied commercial (0.9%) and industrial demands (7.1%), self-supplied industrial/commercial demands (6.6%), and agricultural demands (1.6%). The dewatering of quarries is projected to account for approximately 10% of the buildout demands in the County.

Estimates of existing demands and projections of buildout demands by use type (Figure 4-2) and by source type (Figure 4-3) determined in the water balance evaluation are presented below.

4.3. Wastewater Returns

Wastewater returns and other effluents in the county are currently estimated to be 15.2 mgd. Septic systems (44%) and municipal WWTPs (38%) are estimated to contribute the large majority of wastewater discharges in the County. Quarry and direct industrial discharges account for 12% and 7%, respectively. Significant volumes of water may be currently transferred between watersheds due to the distribution of WSA supply sources relative to WWTPs discharge locations. The two most extreme cases of this in the County are approximately 3.8 mgd *out* of the Liberty Reservoir watershed and 1.8 mgd *into* the South Branch Patapsco watershed. However, less than 0.1 mgd is estimated to be transferred between the County and adjacent jurisdictions by WSAs/SSAs that straddle the County line, such as Mount Airy.

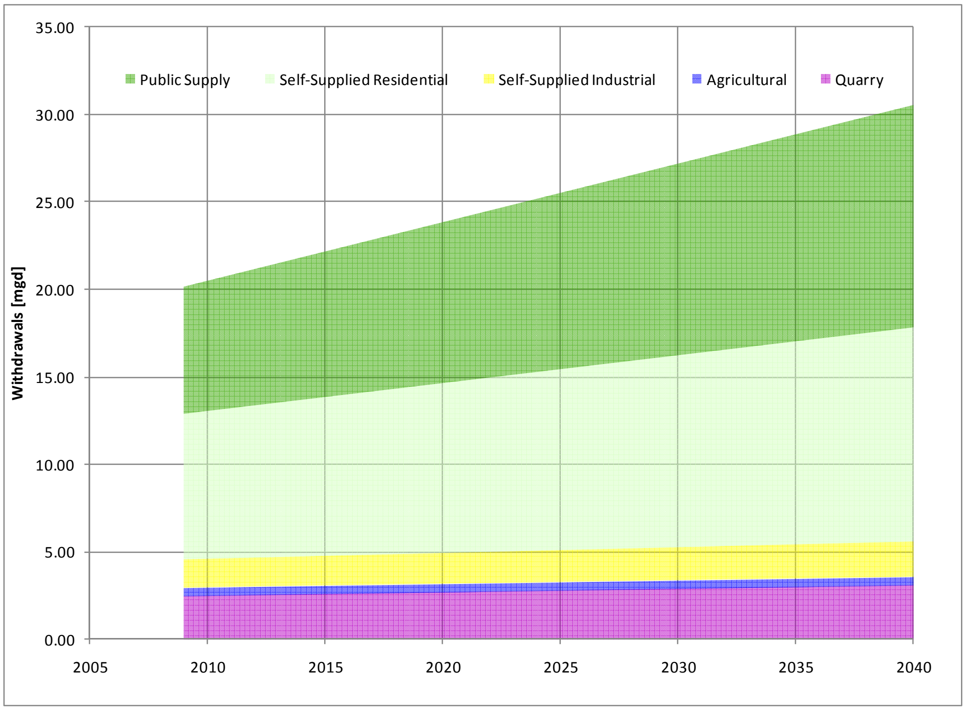


Figure 4-2: Projected Buildout Demands by Use Type

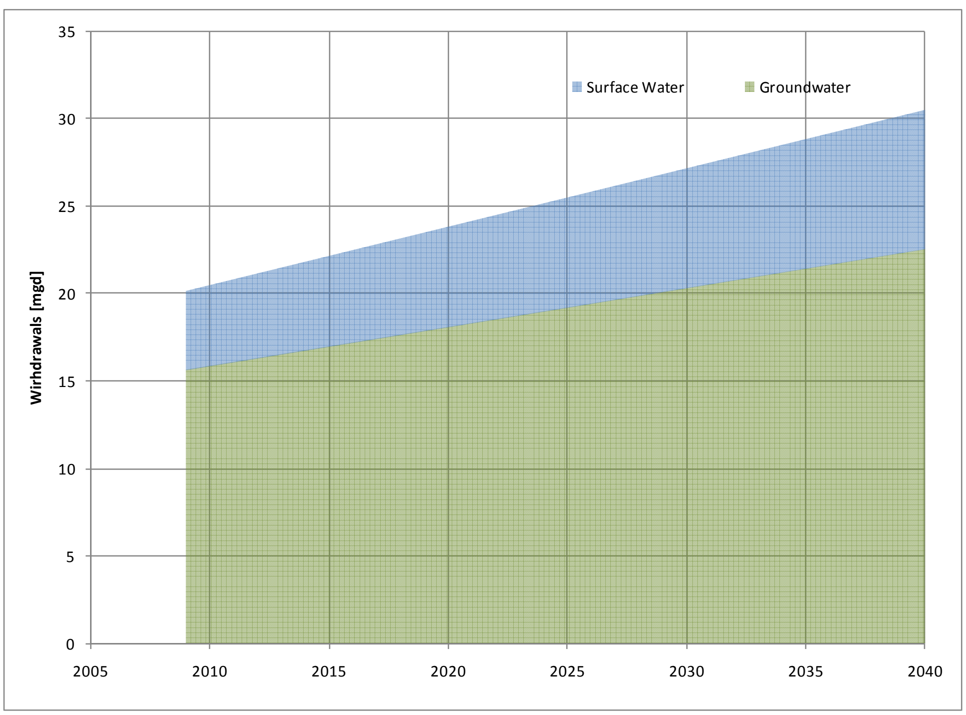


Figure 4-3: Projected Buildout Demands by Source Type

Total returns are projected to increase to 24.7 mgd at buildout. The relative contributions of returns types are predicted to remain similar to existing conditions, with approximately 40% originating from septic systems, 42% originating from Municipal WWTPs, and 12% originating from quarries. Assuming that any increases in SSA capacity will be due to plant upgrades and expansions that do not significantly change the proportion of returns by watershed, inter-watershed transfers are projected to increase to 5.4 mgd *out* of the Liberty Reservoir watershed and 3.1 mgd *into* the South Branch Patapsco watershed.

4.4. Water Resources

4.4.1. Groundwater Resources

Groundwater availability was estimated in the County by comparing conservative estimates of annual recharge (Q1-in-10) flow while allowing a reserve baseflow (7Q10) according to MDE guidance, as discussed in Section 2.4. The County-wide estimated ten-year recurrence interval recharge rate for Carroll County is approximately 5.8 inches per year while the reserve baseflow is approximately 1.1 inches/year, which results in a County-wide groundwater availability of approximately 101 mgd. With estimated existing and projected buildout groundwater demands of 15-23 mgd and total projected demands of 30 mgd, groundwater resources in the County are theoretically more than adequate to meet existing and buildout demands. However, groundwater resources are not likely to be evenly distributed throughout the County. The hydraulic properties of the County's major aquifers vary spatially and areas with higher transmissivity and storativity may not necessarily coincide with demands. Furthermore, given that the major source aquifers in the County are composed of fractured rock, groundwater exploration to find productive locations may be quite difficult. For example, "the City of Westminster in Carroll County has recovered only one mgd from the twelve mgd theoretically available in the surrounding groundwater basin after twenty years of exploration"[2]. Fractured rock aquifers are also more susceptible to seasonal variations in precipitation, due to relatively low aquifer storativity values in the Maryland Piedmont Region, leaving groundwater sources vulnerable to drought conditions. Many self-supplied residential wells in the fractured-rock area of Maryland went dry in the 1999 and 2002 droughts[16]. A detailed study of groundwater resources and availability in the fractured-rock area of Maryland, including Carroll County, is slated to begin sometime this year (2009) through funding and support from MDE, DNR and the USGS. The results of this study should provide results that will be useful for water resources planning in the County.

4.4.2. Surface Water

Estimates of surface water availability can be more difficult to quantify than groundwater availability as surface water flows are typically more variable and ephemeral. In order to address this issue, usable storage capacity volumes required to meet given demands were estimated using the method outlined in Section 2.4.2. Based on the analysis, the County would theoretically require as much as 12 billion gallons of usable storage capacity to meet projected buildout demands of 8.0 mgd and the estimated flowby of 119 mgd. The usable storage capacity is based on the respective worst drought in the period of record of each watershed, during in either one of the 1966-1967 or 2002-2003 drought events. In addition, the required usable storage capacity estimates are based on the entire drainage area of the County. Because the largest component of the required flows from storage are associated with natural flow preservation (*i.e.* meeting flowby requirements), site-specific reservoirs with smaller contributing areas could be more efficient and require smaller storage volumes. In other words, the amount of storage required to meet average projected buildout demands is over-estimated by the MDE method outlined in Section 2.4.2. Analyses of site-specific reservoir configurations and operating rules would be required to further refine and improve estimates of required storage to meet demands while maintaining flowby requirements.

The majority of surface water supply currently available to the County is through appropriations or agreements for Piney Run Reservoir (3.3 mgd), Liberty Reservoir (4.2 mgd) and Cranberry Reservoir plus Cranberry Branch and Hull Creek (2.0 mgd), which have a total average day appropriation of 9.5 mgd, which is less than the projected buildout surface water demands of 9.9 mgd. Furthermore, the spatial distribution of buildout surface water demands does not necessarily coincide with the locations of these existing appropriations, indicating the likely need for additional surface water appropriations at buildout.

4.4.3. Potential Effects Related to Climate Change

Recent drought experiences across the country lend support to predictions for increasing drought and an increasing probability of experiencing threshold level events in the middle latitudes of North America. All across the country, the southeast and the Mid-Atlantic regions, lake and reservoir levels dropped to dangerously low levels during the last decade. Significant, if not record-setting drought conditions developed twice this decade in the Mid-Atlantic region. A multi-year drought occurred in 2001-2002 that redefined river yields and supplies across the region. Paleoclimatology studies show that severe drought periods occurred prior to the 20th century when streamflow monitoring began in the region.

A rather dire climate picture was included in the Maryland Commission on Climate Change “Climate Action Plan - Interim Report to Governor and Maryland General

Assembly"[17]. In this report it was stated that: "*The Chesapeake Bay has already warmed by about 2°F and continued warming will make our extensive efforts to restore its health that much more difficult. Examination of the detail of the global models used by the IPCC shows that, if GHG emissions continue to grow on the present trajectory, air temperatures will increase in Maryland more than the global average, resulting in average winter temperature increasing by about 8°F by the end of the century. While this might be welcomed by some, average summer temperature would also increase by about 7°F and the number of days with temperatures greater than 90°F is likely to quadruple, with 25 or more 100°F days…. Precipitation during the winter and spring is likely to increase 10-15%, coming mostly in heavy rainfall events, but the summers and falls are likely to be drier as increased evaporation depletes soil moisture*." A future that looks like this would include longer growing seasons, higher evaporation rates and higher water demands for domestic, industrial and agricultural users. Perhaps of more concern is the possibility of more severe drought and flooding events, both of which could significantly affect the quantity and quality of Carroll County's water resources.

Climate change research efforts and data analyses too numerous to list have been undertaken in recent years. However, an important publication released earlier this year (2009) by the federal government was entitled "Climate Change and Water Resources Management: A Federal Perspective" [18]. This interagency report was prepared by the U.S. Geological Survey, U.S. Army Corps of Engineers, Bureau of Reclamation, and National Oceanic and Atmospheric Administration. Two key points made in this report are as follows:

- "*Climate change could affect all sectors of water resources management, since it may require changed design and operational assumptions about resource supplies, system demands or performance requirements, and operational constraints. The assumption of temporal stationarity in hydroclimatic variables should be evaluated along with all other assumptions*."

- "*Current expectations about future climate may indicate a need to supplement historical climate information. Planning assumptions might instead be related to projections of future temperature and precipitation. This can be accomplished using a multitude of approaches; a best approach has yet to be determined*."

Considering that Carroll County is looking out decades into the future toward a build-out condition, and with the possibility of reduced safe yield when considering pre-20th century history and potential climate change effects, future water supply needs may be greater than currently anticipated. The science has not yet progressed to the point of being able to quantify how groundwater levels, streamflow patterns or drought severity will change in the Mid-Atlantic region as a result of current climate change trends. However, a prudent approach is to be pro-active in planning for future water needs and to consider a diverse suite of water sources to improve supply reliability in the event of severe drought or other climate-induced changes in water availability. Carroll County may wish to consider moving more in the direction of integrated water resources planning to integrate and balance all possible water resources to sustain water demands far into the future. Integrated water resources planning is gaining momentum in this country and, as summarized below, offers a number of significant improvements over traditional water supply planning approaches:

- Comprehensive and diverse evaluation criteria (not just least-cost solution)
- Considers supply reliability (not just current capacity)
- Demand can be modified (not just supply options)
- Embraces uncertainty with planning for multiple possible future scenarios

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