Water Supply/Demand Status Report

for the

Delaware River Basin

September 2005

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Delaware River Basin Commission

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Executive Summary

This report endeavors to answer the following question: *"Can the water resources of the Delaware River Basin support anticipated future water demands?"* The approach taken to answer this question has been to evaluate current water demand, forecast future demand and evaluate both against an assessment of ground and surface water availability. Sources and demands were evaluated for the Basin as a whole and for eight sub-basins to provide a better regional assessment. For water supply planning purposes it is essential to study water demands under dry climate conditions as well as more normal conditions. Estimates of demand under these two scenarios were obtained by using water use data from the years 1995 (dry year demand) and 1996 (wet year demand). Several different thresholds for water availability were calculated for both ground and surface sources; the adequacy of water availability was then evaluated by comparing these thresholds against annual average and peak month water demands. In addition to assessing current demands, water use projections have been made for the years 2020 and 2040 to enable an assessment of possible future supply and demand conditions. While it is expected to further refine these forecasts in additional studies, they provide a useful indication of major trends and water use patterns in the Basin.

The findings of this study conclude that, *at the Basin and sub-basin scale*, water availability generally is adequate to meet current and projected future water demands. However, this analysis does not allow similar claims to me made at the smaller watershed scale, where localized water availability and distribution problems often complicate the issue and alternative methods of analysis are required. Although surface water demands have been assessed against minimum stream flows from the Basin's 1960's drought of record, a more robust assessment of supply adequacy under similar multi-year drought conditions and current operating rules can only be obtained from detailed reservoir modeling efforts which are beyond the scope of this report.

The major findings and recommendations of this study are summarized below.

- The majority (92%) of water used in the Delaware River Basin is sourced from surface waters.
- The dominant use sectors are power generation (thermoelectric), public water supply and industrial use. Collectively they account for 91% of withdrawals and 72% of consumptive water use in the Basin (excluding two major exports from the Basin).
- *At the Basin-wide scale*, water availability is adequate to meet current and future water demands under dry climate conditions.
- Based on the eight sub-basins defined in this report, results indicate that *at the sub-basin scale,* water availability will be adequate to meet current and projected future water demands under dry climate conditions. However, two sub-basins – the Upper Estuary and Lower Central – are identified for which current and/or future withdrawals exceed one of the benchmarks of availability.
- This study reinforces the fact that current and comprehensive water use records are essential for proper assessment, planning and management of water resources.
- Water use data for the agricultural sector is very sparse due to inadequate reporting in three of the Basin states. Surrogate information has been used to generate demand data for this study; better reporting would enable a more accurate assessment and would better enable agricultural interests to be provided for in allocation and water resource management decisions.
- Demand projections for the thermoelectric power industry need to be further refined and verified. The projected growth in water demand for this sector accounts for 92% of total water demand increase forecast by 2040.
- Instream flow needs for ecosystem protection are an emerging issue. A methodology needs to be established for quantifying these needs and incorporating them into future assessments of supply and demand.
- Errors and uncertainty are associated with the assumptions used in this report. Changes to these assumptions and their effects on projections of demand should be tested through sensitivity analysis.

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Purpose Statement

This report provides an overview of current and future water demands relative to water availability in the Delaware River Basin. The development of this report has been driven, in part, by objectives in Key Result Area 1 (Sustainable Water Use and Supply) of the Water Resources Plan for the Delaware River Basin: A Common Vision for a Common Resource (DRBC, 2004). One of the desired results of the plan is to have: *an adequate and reliable supply of suitable quality water to sustain human and ecological needs through 2030*. Specifically, the Plan states the need to: *ensure supplies for projected public, and self-supplied domestic, commercial, industrial, agricultural and power generation demands through 2030*. This report provides an important first step towards developing the detailed demand projections and supply estimates necessary to underpin sound water resources planning in the Delaware River Basin.

In recent years the basin states have addressed water supply and demand issues through the development of state-wide water plans, ground water protection areas and other regional programs to protect or enhance water supplies. These efforts are ongoing and are referenced in this report where specific management programs impact water supply and demand in the Delaware River Basin.

This study is the most recent in a series of steps, over many years, to address the question of future water supply adequacy for the Delaware River Basin as a whole. It provides updated water demand projections by traditional water use sector, as well as several measures of source water availability. Water supply and demand estimates have been aggregated for eight designated sub-basins consistent with delineations in the Basin Plan. It should be noted that the methods and findings of this report are not necessarily suited for disaggregation to evaluate the water supply needs of a particular localized area or distribution system. These, and other limitations of this study, are discussed below.

Study Limitations

Evaluating and managing water supply has become increasing complex in the Basin due, in part, to the evolving definition of "Water Supply". This term includes the traditional off-stream water demands for sectors such as public water supply, commercial, industrial, irrigation, and power generation uses. It has also come to include water for salinity control, boating recreation, and maintenance of aquatic habitat. True water supply adequacy can only be assessed once the needs of all these potential water uses are recognized and quantified.

This report compares aggregate supply to aggregate off-stream demands on a sub-basin basis; it does not explicitly account for reservoir operating rules, instream flow requirements, infrastructure capacities or future conservation measures.

From a regulatory perspective (as set out in the Delaware River Basin Commission Water Code) as well as from practical experience, the drought of record period 1961 to 1967 should be used as the basis for determining dependable Basin water supply. However, while the 1961-1967 criterion is applicable to the interstate management of the Basin's reservoirs, other more intense and localized droughts may provide the design criterion for local water supply systems. Such was the case for New Castle County, Delaware during the drought of 2002. As in this case, analysis of individual state, county, municipal, or watershed supply adequacy is generally led by state or local organizations, or by water purveyors. While an evaluation based on the multi-year (1961-1967) drought of record was not expressly performed as part of this study, stream flow statistics derived from the lowest flows during that period are shown as part of the analysis for comparative purposes.

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Report Overview

Section I of this report provides an overview of the Delaware River Basin, describing its size, location, physical characteristics and major geologic and hydrologic features. **Section II** offers history and background of water resources development in the Basin, which was largely shaped by the US Supreme Court Decree of 1954 that apportioned water of the Delaware River among New York City and the down basin states and also helped establish the Delaware River Basin Commission. **Section III** introduces the aims and objectives of the supply/demand study and provides a brief description of the methodology used (additional details of the methodology can be found in the appendices at the back of this report). **Section IV** discusses both surface and ground water availability in the basin. There is an inventory of the reservoirs in the basin, an analysis of surface water availability based on streamflow records and an assessment of ground water availability under different climate conditions, based on studies undertaken by the USGS. **Section V** presents an analysis of current and projected water demands for the Basin and its sub-basins. This section brings together results of previous water use studies with new analysis based on more recently available water use data and supporting information sources such as the 2000 Census data and the 2002 Agricultural Census. **Section VI** provides a resource assessment bringing together the elements of supply (section IV) and demand (section V). As with all the analysis in this report, it is expressed from both a Basin-wide and sub-basin perspective. **Section VII** concludes the report with several recommendations; some reflect specific findings of the supply/demand study and some are recommendations for future work to improve the utility and accuracy of this report.

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I. Introduction to the Delaware River Basin

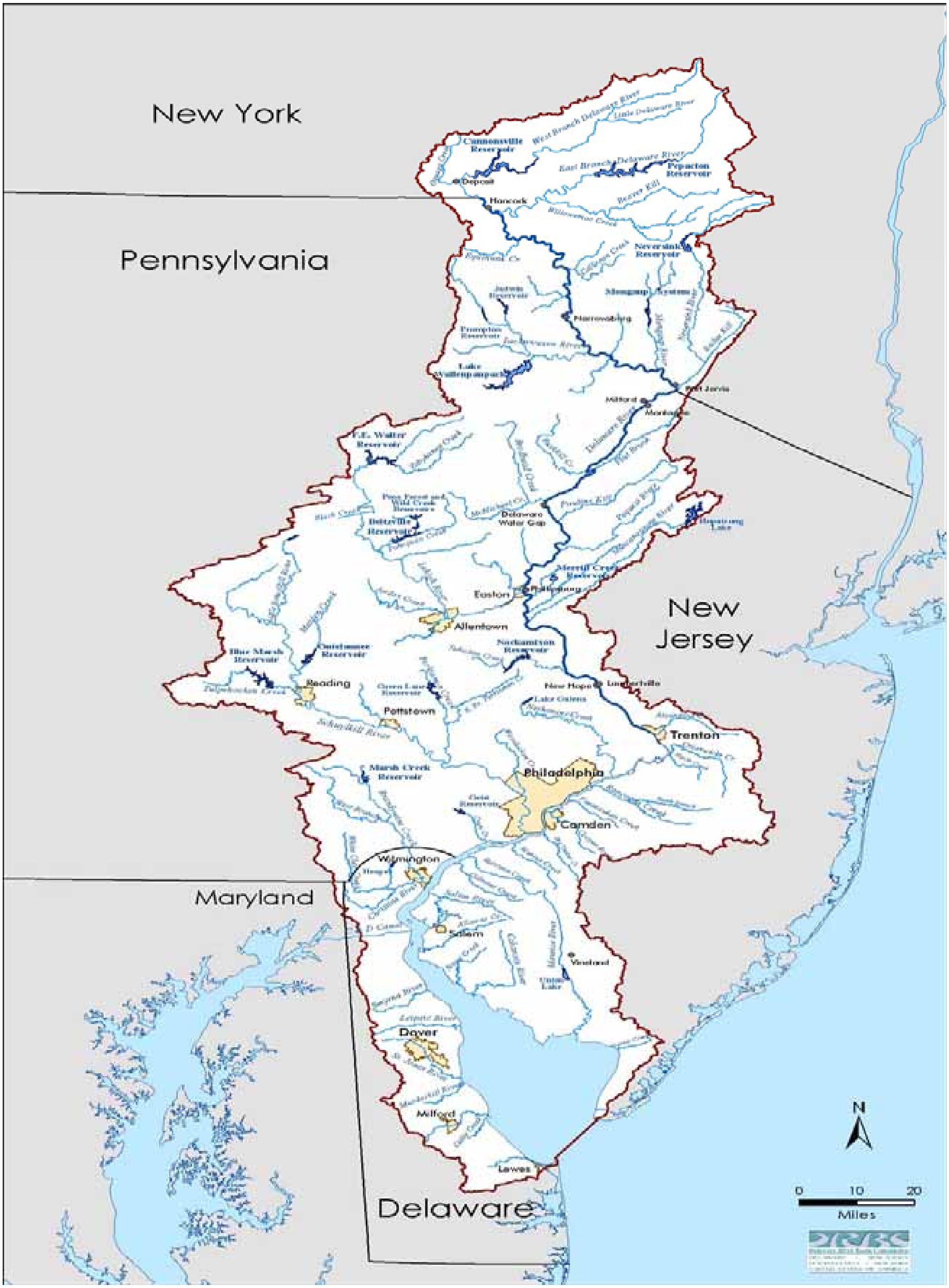
1.1 Overview of the Delaware River Basin

Stretching approximately 330 miles from headwaters to mouth, the Delaware River and its tributaries drain a 12,765 square-mile land area in the northeastern United States. A map of the Delaware River Basin is shown in Figure 1.1. Encompassed within the drainage basin are 2,363 square miles in southeastern New York, 6,422 square miles in eastern Pennsylvania, 2,969 square miles in western New Jersey, 1004 square miles in Delaware, and 8 square miles in Maryland. The area of Delaware Bay adds 782 square miles of water surface to the Delaware River system. On the basis of its physical characteristics, the Basin divides into the Upper, Central, Lower and Bay Regions.

The highlands of the southern Catskill and Pocono Mountains are the dominating characteristics of the Upper Region. Here is found the Basin's maximum elevation of 4,200 feet. Geologically, the region is part of the "hard" rock area where bedrock is resistant to erosion. It is almost completely forested, with mixed hardwoods predominating, and almost totally glaciated. The region exhibits the characteristics of a plateau of flat-lying rocks cut by narrow valleys that have been deeply carved by the river and its tributaries. The Central Region extends from an upper limit generally marked by the Valley and Ridge physiographic province, with its pattern of parallel ridges running northeast to southwest, to a lower limit marked by the Fall Line, where there is a sharp drop of 250 to 350 feet in elevation to the Atlantic Coastal Plain. The Fall Line forms an irregular south-facing escarpment between the undulating plateau and the Coastal Plain: it lies along a line passing through Trenton, New Jersey and Wilmington, Delaware. The Central Region also lies in the "hard" rock area. About a third of the region is forested, and rich soils support agricultural activities in many areas of the region. The Lower Region covers the area from the Fall Line to the Capes of Delaware Bay. Physiographically, the region is the emerged part of the Coastal Plain, a gently sloping surface extending 125 to 175 miles southeasterly from the Fall Line to the Continental Shelf. Geologically, the region is a "soft" rock area composed of overlapping beds of unconsolidated or semi-consolidated clay, silt, sand and gravel; the Delaware Bay is the Region's most marked feature. About one-third of the region is wooded with about equal divisions between soft and hard woods. The soil supports a variety of agricultural activities.

Starting in the Upper Region, on the western slopes of the Catskill Mountains, the Delaware River first emerges as the southwesterly-flowing East Branch and West Branch which join at Hancock, NY. From that point the river flows southeastward to Port Jervis, dividing Pennsylvania and New York. In this stretch it receives the flows from three important tributaries: the Lackawaxen, Mongaup and Neversink. Turning southwestward at Port Jervis, the River enters the Central Region where it becomes the dividing line between New Jersey and Pennsylvania. Here it flows in a narrow valley between the Shawmgunk Mountains on the east and the Appalachian Plateau on the west. Near Stroudsburg it cuts to the southeast through the Blue Mountain-Kittatinny Mountain Ridge at the Delaware Water Gap. Such important tributaries as the Bush Kill, Brodhead Creek and Flatbrook join the River just above the Water Gap. Following a southern course the Delaware is joined by the Lehigh, Paulins Kill, Beaver Brook, Pequest and Musconetcong below the Water Gap. At Trenton the River comes into the Lower Region and enters the tidal estuary. Turning southwest, its course parallels the Fall line to Wilmington. In this reach it receives the flows of the Neshaminy, Schuylkill, Rancocas and Christina tributaries. Just below Wilmington the River turns seaward and flows to Liston Point where it enters the Delaware Bay.

Figure 1.1 The Delaware River Basin (DRB)



II. Water Supply Background and the Delaware River Basin Commission (DRBC)

2.1 Definition of "Water Supply"

Water supply has traditionally been defined as: *"…the operation, maintenance, and construction of public water supply systems, including production, acquisition, and distribution of water to general public or to other public or private utilities, for residential, commercial, and industrial use"*[1]. However, its meaning as viewed from the perspective of river basin management extends beyond this strict definition. Water supply on a river basin scale refers more to the integration of multiple, competing uses and the balance of such demands with the careful planning for the use of the regional resource. This balance must also fit within the context of present State and DRBC regulations, with the goals of wise management and conservation of water supply, water quality protection and enhancement and resource education and stewardship.

2.2 Delaware River Basin Commission

2.2.1 The Delaware River Basin Compact

The DRBC compact was enacted in 1961 jointly by Delaware, New Jersey, New York, Pennsylvania and the Federal government. It was the first time in U.S. history that the federal government and a group of states had joined together as equal partners in a river basin planning, development, and regulatory agency. The members of the Commission are the governors of the four basin states (Pennsylvania, Delaware, New York, and New Jersey) and a federal member appointed by the President of the United States.

At the time the Commission was founded, powers and duties within the watershed were exercised by some 43 state agencies, 14 interstate agencies, and 19 federal agencies. The Compact consolidated this by creating a regional body with the legal authority to coordinate the development and control of the river system.

2.2.2 Rules of Practice and Procedure

The Commission's Rules of Practice and Procedure govern the adoption and revision of its Comprehensive Plan, Water Resources Program, exercising of the Commission's authority pursuant to the provisions of Article 3.8 (project review) and other actions of the Commission mandated or authorized by the Compact.

2.2.3 Water Code

The Commission's Water Code pertains to three general Articles: i.) Delaware River Basin Commission Policies, ii.) Conservation, Development and Utilization of Water Resources and iii.) Water Quality Standards for the Delaware River Basin. For example, the Water Code provides for the following:

- Formula for Reductions in Diversions, Releases and Flow Objectives during Drought
- Flow Objectives for Salinity Control During Drought Periods
- Priority of Use for Existing Lower Basin Reservoirs During Drought
- Conservation Releases
- Definition of Existing Water Quality in the Delaware River
- Upper Delaware Scenic & Recreational River
- Middle Delaware Scenic and Recreational River
- Stream Quality Objectives in all Zones of the Delaware River Estuary
- Toxicity Standards for the protection of Aquatic Life in the Delaware River Estuary

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[1] http://www.researchcouncil.org/2003compare/glossary.htm

- Identification of Carcinogens for the Delaware River Estuary
- Identification of Systemic Toxicants for the Delaware River Estuary

2.2.4 Comprehensive Water Resources Plan for the Delaware River Basin

In September 2004, the Governors of the four Basin States and federal agency representatives signed a resolution supporting the implementation of the Water Resources Plan for the Delaware River Basin (hereinafter referred to as the Basin Plan). The purpose of the plan is to provide a unifying framework for addressing water resources issues and problems in the Delaware River Basin. The Basin Plan emphasizes an integrated approach which aims to consider all aspects of the water resource in decision-making. The plan is divided into five Key Result Areas (KRAs), the first of which is *Sustainable Water Use and Supply* which has a strong focus on water demand and supply issues. One objective under this KRA is to *ensure supplies for projected public, and self-supplied domestic, commercial, industrial, agricultural and power generation demands through 2030*. This report provides an important first step towards developing the detailed demand projections and supply estimates necessary to underpin sound water resources planning.

Another significant component of KRA 1 in the Basin Plan is the development of instream flow requirements for the Basin. This is driven by the recognition that aquatic ecosystems needs represent a demand on water resources in addition to off-stream water demands (such as power, industrial and public water supply requirements). In essence, the question to be answered is how much water can be withdrawn and consumed without adversely impacting aquatic life. Instream flow requirements are yet to be determined, but as they are quantified it will be necessary to incorporate them into water supply and demand assessments.

2.3 The U.S. Supreme Court Decree of 1954

The Supreme Court Decree of 1954 (which amended the original 1931 decree) apportioned water of the Delaware River Basin between New York City and the down basin states.

During the drafting of the Compact, its relationship to the 1954 amended Decree was a topic of debate. Although the Compact gives the DRBC power over new diversions and flow releases unrelated to the decree, it strictly limits the Commission in Decree related matters. The final compact language effectively froze the diversions and flow releases authorized by the 1954 Supreme Court Decree. This protected New York City's 800 mgd diversion and removed its liability to future arbitration unless the Decree itself was modified. Section 3.3 of the Compact gives the Commission authority to make adjustments to the Decree formula only if there is unanimous consent of the five Decree parties (the four Basin States and New York City). During a declared emergency not limited to drought, the formula may be temporarily modified with the unanimous consent of the Commissioners. This structure allows the Decree Parties to negotiate through the Commission and to avoid further litigation over the use of the Basin's waters.

The 1954 Amended Decree contained the following diversion allowances and release requirements:

<u>Neversink Only:</u>

- Diversion allowance: 440 mgd maximum
- Release requirements: releases of 61 cfs required when flow at Montague dropped below 1,740 cfs, or flow at Trenton, NJ dropped below 3,400 cfs

<u>Neversink and Pepacton:</u>

- Diversion allowance: 490 mgd maximum

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- Release requirements: releases required to meet a target of 1,525 cfs at Montague

Neversink, Pepacton, and Cannonsville:

- Diversion allowance: 800 mgd maximum
- Release requirements: releases required to meet a target of 1,750 cfs at Montague
- Excess releases (described below)

Delaware & Raritan (D&R) Canal Diversion (New Jersey):

- 100 mgd maximum

The Amended Decree did not provide for minimum conservation releases from the three reservoirs. They were subsequently negotiated by New York State and New York City. They have since been modified through agreement by the Decree Parties and codified by DRBC docket D-77-20 CP and a series of revisions to that document, the latest of which is D-77-20 CP (Revision 7), approved on April 21, 2004. This modification established flow targets on the tailwaters below each reservoir and increased the amount of water allocated specifically for fishery protection.

2.4 "Good-Faith" Recommendations/Drought Operating Plans

The drought of the 1960's was more severe than that of the 1930's on which the 1954 decree formula was based. Subsequent negotiations by the parties to the decree led to what is known as the "Good Faith" recommendations.

Through the adoption of several "good-faith" recommendations in 1983, the DRBC formalized its drought operating procedures so as to equitably share water between upstream and downstream users during periods of shortage. The two most important provisions were (1) a rule curve for determining drought warnings and emergencies based upon the combined storage in the three New York City reservoirs and (2) a schedule of phased reductions in diversions, releases, flow objectives, and salinity control.

The current drought operating plan is intended to provide reliable water supplies for essential uses during a drought equal in severity to the 1960's drought of record while sustaining river flows to meet the Estuary's salinity standard and protect water supply intakes. Response to a drought more severe than that of the 1960s is to be negotiated separately, depending upon its severity. Under normal conditions (as defined by the reservoir operating rule curves), provisions of the 1954 Amended Decree apply. During the different stages of drought, the rules in the following table apply.

Table 2.1 Interstate Operation Formulas during Periods of Drought.

Interstate Operation Formula for Reductions In Diversions, Releases and Flow Objectives During Periods of Drought Table Reflects Temporary Operations as of March 2003 based on Docket D-77-20 CP and its Revisions				
NYC Storage Condition	NYC Diversion (mgd)	NJ Diversion (mgd)	Montague Flow Objective (cfs)	Trenton Flow Objective (cfs)
Normal	800	100	1,750	3,000
Drought Watch	680	100	1,655	2,700
Drought Warning	560	70	1,550	2,700
Drought	520	65	1100 - 1,650*	2,500 - 2,900*
Severe Drought (to be negotiated based upon conditions).				

*Varies with time of year and location of salt front in Delaware Estuary.

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The drought operating procedures have been employed eleven times since their adoption in 1983. While the Basin has only experienced two additional drought emergencies (in 1985 and 2001), DRBC has periodically declared drought warnings. In all instances, drought warning or emergency declarations were terminated by the DRBC once conditions returned to normal, as specified in the rule curve and operating procedures.

In addition to the above "Basinwide" operating plan, which is triggered by New York City Delaware Basin reservoir storage, the DRBC adopted a "Lower Basin" operating plan in 1988. This plan is triggered by storage levels in Beltzville and Blue Marsh Reservoirs and controls the Trenton flow target and the New Jersey D&R canal diversion. If both plans are triggered simultaneously, the plan producing the most stringent conditions for the Trenton target and New Jersey diversion applies.

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III. Study Purpose, Methodology and Data Sources

3.1 Study Purpose

The key purpose of this study is to answer the question: *"Can the water resources of the Delaware River basin support anticipated future water demands?"* This study assesses current and future water demands and evaluates them against an assessment of ground and surface water availability.

Although the question can be stated in simple terms, water resources planning is complex, technical, data intensive and frequently complicated by, among other factors, the issue of scale. Furthermore, planning for future conditions, especially several decades from the present, involves dealing with uncertainty and risk. However, responsible water management requires that we address these issues, if we are to *ensure supplies for projected public, and self-supplied domestic, commercial, industrial, agricultural and power generation demands through 2030*, as set out in the Basin Plan. This study will get us closer to answering the question posed above, even if it raises other, more complex, questions in the process.

The objectives of this study include an assessment of current and future water demands for key water using sectors in the Basin to the year 2040. These are compared against an assessment of ground and surface water availability under various benchmark conditions. The analysis quantifies the following:

- Withdrawals and consumptive use
- Dry year and Wet year demand
- Peak month and average annualized demand
- Surface and ground water supply

This report should not be regarded as a definitive and precise forecast of future uses. The assessment of supply and demand has been undertaken at the Basin-wide scale and also for those sub-basins delineated in the Basin Plan (see Section 2.2.4). Further refinement, particularly on a geographic basis, will be necessary for detailed watershed assessments. This report serves as a generalized summary of sources, demands and projections which will assist in prioritizing ongoing water supply planning efforts.

3.2 Methodology

This report builds on earlier DRBC water use and supply assessments, specifically those consumptive use estimates generated by DRBC staff in November 2000, in support of a study entitled "Strategy for the Resolution of Interstate Flow Management Issues in the Delaware River Basin"[2]. These estimates were documented in a report hereinafter referred to as the *Consumptive Use Report*. Since the development of that report, more recent water use data, census data, and information related to specific use sectors have become available and this study has incorporated the newer data where appropriate.

This report presents an inventory of the utilization of surface and ground water supplies in the basin, along with current and projected water withdrawals and consumptive use for the years 2020 and 2040, by water use sector and source type (ground or surface supply). Sources and demands are evaluated on a sub-basin basis, given normal and dry climate conditions and average month and peak month water demands. Water demand projections are primarily based on an extrapolation of past trends in water use and were compared against available water supply. Resource assessments were also made on both the sub-basin and basin level, and used to develop recommendations regarding

[2] Full Title: Preliminary Consumptive Water Use Estimates for the Delaware River Basin For 1996 including Projections for 2020 and 2040.

future use and development of water supply. A detailed methodology describing the assessment and projection of water demand is found in Appendix I.

3.2.1 Demand Forecasting Model

Data analysis for this study required significant use of GIS, Microsoft Access and Microsoft Excel software. The core of the forecasting model was built using a multi-layer spreadsheet format in Microsoft Excel. A key component of the model is the ability to enable different forecast scenarios to be developed and saved in order to compare different future water use patterns. In its current form the forecast model output reflects the most likely forecast conditions based primarily on an extrapolation of past trends and the reasoned judgment of water resources staff at DRBC. The past is not necessarily a reliable predictor of the future but, in the absence of alternative information, it is often the most useful (and least contentious) starting point for estimating future demands. Other scenarios have been developed that reflect alternative growth patterns and these can be easily tested to see their impact on the supply demand balance. The scenario-based approach is advocated as it provides a tool for water resources planners to look at not just one set of forecast assumptions, but rather a range of assumptions that lead to alternative water demand outcomes. Policy decisions can then be made with the objective of reaching the most desirable outcome.

3.2.2 Delineation of Delaware River Basin into Sub-basins

This report provides an assessment of supply and demand at both the Basin-wide and sub-basin scale. The sub-basin delineations are generally consistent with those developed for the purpose of the Basin Plan. The delineation of the 10 Basin Plan sub-basins represents an effort to capture regional water resources issues throughout the Basin. Where possible, the Basin Plan sub-basins have been developed based on a merging of the 21 sub-basins used for the modeling of consumptive use in the Basin and defined in the DRBC's Water Resources Program. It should be noted that in the Upper Basin the newly defined sub-basins are not a simple aggregation of the old and, because the consumptive use estimates, which serve as a basis for demand projections in this report, are based on the older sub-basins, it has been necessary to combine the 3 upper Basin sub-basins into one unit. See figure 3.1.

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3.2.3 Alternative Climate Conditions

Available water supplies and demands are inherently dependant on climate and must be quantified relative to a specific climate condition. Complete water use datasets for the Basin were readily available for the years 1995 and 1996. These years were also used in the Consumptive Use Report as a basis from which to perform consumptive use projections. Precipitation values were used to characterize climate conditions in these years. A probability of precipitation exceedence was calculated for each year using areal averages above Montague and above Trenton and probability curves from the Army Corps' Drought Atlas. The results are shown in table 3.1.

Table 3.1 Precipitation statistics for 1995 and 1996 in the Delaware River Basin.

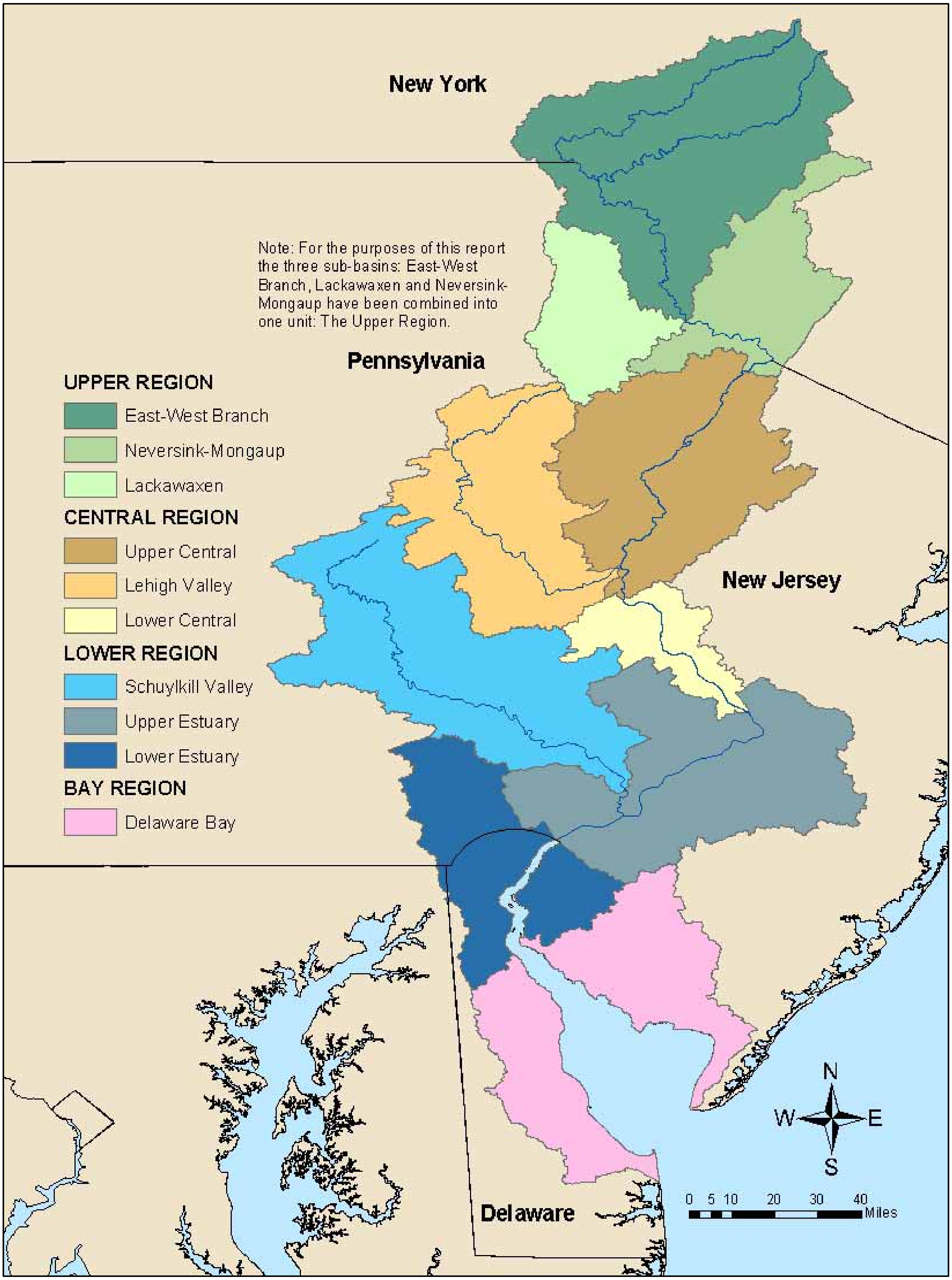
Calendar Year	Above Montague (5 stations)		Above Trenton (75 stations)	
	Precip	*Prob-exceed*	*Precip*	*Prob-exceed*
1995	38.90"	0.72	40.44"	0.68
1996	56.33"	0.04	62.04"	0.02
Average	43.18"	-	43.97"	-

In summary, table 3.1 shows that 1995 was a drier than average year and 1996 was exceptionally wet.

3.2.4 Basis for Water Use Assessment and Demand Projections

Water withdrawal records stored in DRBC databases were analyzed for the years 1995 and 1996. These are the most recent years for which complete and reliable records exist Basin-wide. Water withdrawal records were analyzed to obtain information on surface water withdrawals, ground water

Figure 3.1 Delaware River Basin (DRB) sub-basin delineations



withdrawals and total withdrawals for eleven use categories (sectors). Consumptive use values were determined by applying either a generic coefficient for each use sector (e.g., agriculture: 90% consumptive), or by applying a site-specific consumptive use factor based on DRBC docket information or other reporting (see Appendix II for further information on calculation of consumptive use by various sectors).

Water use projections are included in this report for the years 2020 and 2040. The projections are based, in part, on assumptions made in the DRBC Consumptive Use report and have been updated based on more recent information where this was available (see Appendix 1 for further information). Because the previous Consumptive Use report forecasts only a total consumptive use per sub-basin, per sector, the same growth factors were applied to both surface water and ground water withdrawals for the purposes of this study

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IV. Water Availability

The Delaware River Basin has one major importation of water from the Octoraro Reservoir in the Susquehanna River Basin amounting to approximately 30mgd. All other sources are from ground and surface waters located within the Basin.

4.1 Surface Water Supply

4.1.1 Reservoir Storage in the Basin

The Delaware River Basin has 19 major water supply reservoirs with a total water supply storage capacity of over 414 billion gallons. Table 4.1 shows a listing of these reservoirs, their purpose, location and capacity.

4.1.2 Consumptive Use Replacement

The replacement of consumptive use during dry conditions has long been an important component of DRBC policy, particularly as it relates to water evaporated by thermoelectric power generators. The Commission has required the development of storage for compensating releases as a condition for approval of new power generating facilities and their continued operation under drought conditions.

Merrill Creek Reservoir, constructed in 1989, is an example of a public-private partnership initiated in response to an anticipated increase in water demand from the power generating sector. This off-stream reservoir project was developed to eliminate the need for power generating facilities to curtail operations during low-flow conditions.

The reservoir is a pumped storage system designed to provide water to offset the consumptive use of post-Compact power plants during drought warning and drought events, although it makes a small conservation release at all times. When either a Lower Basin or a basin-wide drought watch, drought warning, or drought condition exists and flows at Trenton would otherwise fall below 3,000 cfs, Merrill Creek makes an additional release equal to that day's total consumptive use from the power plants owned by the major energy utilities and by those water utilities that purchased storage in the reservoir. Because there is surplus storage in the reservoir, the owner companies have thus far made voluntary releases for pre-Compact units as well.

Water is pumped from the Delaware River to refill storage in the reservoir as necessary, except when additional releases are being made or when the pumping would cause the flows at Trenton to fall below specified levels. These levels depend on the time of year and the position of the salt front in the Delaware Estuary; the farther upstream the salt front encroaches, the less pumping is permitted.

As discussed in section 5.7, the majority of increases in water use in the Basin over the next 40 years are expected to be associated with new electric generation facilities. Substantial capacity in Merrill Creek is currently unused and is thus available for future purchase as makeup water for new facilities.

At other locations in the Basin, in addition to consumptive makeup for electrical generation, water is released from storage in order to offset consumptive use through public water supply, and through exportation in cases in which water is not returned within the same watershed from which it was withdrawn. For example, water is released from Marsh Creek reservoir to make up for water withdrawn to serve Downingtown, and West Chester, Pennsylvania, in order to protect flows and ensure supply to downstream users, particularly the State of Delaware, during dry periods. The releases from Marsh Creek are not made on an exact equivalent consumptive use basis, but constitute a pre-set compensation release.

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Table 4.1 Reservoirs in the Delaware River Basin: capacity, location and purpose.

RESERVOIR	PURPOSE[1]	STORAGE (MG)		LOCATION
		WS/WSA/P (total usable)	**FL**	**STREAM, COUNTY, STATE**
PRIMARILY WATER SUPPLY RESERVOIRS				
Penn Forest	WS	6,510	-	Wild Creek; Carbon Co., PA
Wild Creek	WS	3,910	-	Wild Creek; Carbon Co., PA
Still Creek	WS	2,701	-	Still Creek; Schuylkill Co., PA
Ontelaunee	WS	3,793	-	Martins Creek; Berks Co., PA
Green Lane	WS	4,376	-	Perkiomen Creek; Montgomery Co., PA
Geist	WS	3,512	-	Crum Creek; Delaware Co., PA
Edgar Hoopes	WS	2,199	-	Tributary of Red Clay Creek; New Castle Co., DE
Union Lake	WS	3,177	-	Maurice River; Cumberland Co., NJ
Hopatcong	WS[2]	5,995	-	Musconetcong River; Sussex, Morris Co., NJ
Nockamixon	WS[3]	11,990	-	Tohickon Creek; Bucks Co., PA
Subtotal:		*48,164*		
NEW YORK CITY RESERVOIRS, WATER SUPPLY AND FLOW AUGMENTATION				
Cannonsville	WS, WSA	98,400	-	West Branch Delaware River; Delaware Co., NY
Neversink	WS, WSA	35,581	-	Neversink River; Sullivan Co., NY
Pepacton	WS, WSA	147,926	-	East Branch Delaware River; Delaware Co., NY
Subtotal:		*281,907*		
HYDROELECTRIC POWER GENERATION RESERVOIRS				
Lake Wallenpaupack	P	29,813	-	Wallenpaupack Creek; Wayne Co., PA
Mongaup System	P	15,314	-	Mongaup River; Sullivan Co., NY
Subtotal:		*45,127*		
MULTIPURPOSE OR FLOOD LOSS REDUCTION RESERVOIRS				
Prompton	FL	none	6,614	W. Branch Lackawaxen River; Wayne Co., PA
Beltzville	WSA, FL	12,978	8,797	Pohopoco Creek; Carbon Co., PA
Marsh Creek	WS,WSA,FL[5]	4,040	1,160	Marsh Creek; Chester Co., PA
Chambers Lake (Hibernia Dam)	WS,WSA	383	-	Birch Run; Chester Co., PA
Blue Marsh	WSA,FL	4,757	10,554	Tulpehocken Creek; Berks Co., PA
Lake Galena	WS,FL	1,629	1,127	N. Branch Neshaminy Creek; Bucks Co., PA
Francis E. Walter	FL	none	35,190	Lehigh River; Luzerne, Carbon Co., PA
Jadwin	FL	none	7,983	Dyberry Creek; Wayne Co., PA
Merrill Creek	WSA	15,640	-	Merrill Creek; Hunterdon Co., NJ
Subtotal:		*39,427*	*71,425*	
Total Storage		**414,625**		

[1] Purposes

WS-Water supply primarily for local use.

WSA- Water supply primarily for flow augmentation to replace consumptive uses and meet instream needs.

FL- Flood loss reduction.

(Many of these reservoirs are also designed to enhance fish and wildlife habitat and increase recreational opportunities).

P- Hydroelectric Power Generation

[2] Used for water supply only on an emergency basis.

[3] Used for flow maintenance during drought emergencies.

[4] Authorized storage; 28,200 acre-feet to spillway crest.

[5] Used for flow maintenance in Brandywine Creek.

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The flow target on the main stem of the Delaware River at Trenton, NJ, and releases from storage to maintain the flow target during dry conditions, have also provided a means of compensation for consumptive use and any exportation of water in the industrialized lower half of the Basin. Releases are made from lower basin reservoirs to maintain the target flow, with a portion of the storage in two of these reservoirs having been purchased by the DRBC for this purpose. The storage has been financed through a surface water charging program in which surface users pay for the volume of water withdrawn and consumed. The flow target at Trenton, NJ serves to replace new consumptive use occurring between Montague, NJ and Trenton. Although consumptive use in the tidal reach of the river downstream of Trenton is not replaced on a gallon for gallon basis (see Appendix VI, figure VI-1), the Trenton target increases during drought operations as chloride levels increase in the estuary, so as to repel advance of the salt front. The releases to maintain these higher targets and to meet the DRBC estuary chloride standard of 180 mg/l (as a 30 day average) at River Mile 98 serve to offset the effects of increased consumptive use during dry conditions.

4.1.3 Surface Water Storage and Availability Calculations

Storage facilities increase the reliability of a surface source, although by no means do they provide a guarantee of availability. In the absence of storage, surface water availability is less reliable. However, if a substantial history of flow records exist a probabilistic assessment of available streamflow can be made. The best source of streamflow data resides with the USGS who collect data through a vast monitoring network and maintain a nationwide database available for access online (http://waterdata.usgs.gov/nwis/).

Streamflow datasets, collected by the USGS, were analyzed using a Microsoft® Excel spreadsheet program developed by DRBC staff. This program enables automated downloading of USGS data directly into a template file structure which analyzes the data generating numerous descriptive statistics and plots including low-flow recurrence intervals and flow exceedence values. A total of 146 gauging stations were identified in the Delaware River Basin having greater than 10 years of daily flow records available. As part of this analysis, two separate surface water benchmarks were established for each sub-basin based on the streamflow datasets, namely "low flow" and "drought" flow values. The low flow value was calculated as the 95% exceedence flow as determined by a flow duration curve value. The drought flow value was determined by identifying the lowest 7-day average flow during the drought of record period 1961 to 1967. As directed by the DRBC Water Code, the drought of record period 1961 to 1967 has been used as a conservative surface water availability baseline against which to assess water demands. Of the total number of gauging stations analyzed in this study, approximately half (77) were operational during the drought of record period. Relationships between the low flow values and drought flow value were developed for the 77 stations and extrapolated to the 146 stations to provide comparable benchmarks. More detail on the analysis to develop surface water benchmark statistics can be found in Appendix VII. The results of this analysis are documented in Appendix III along with contributing drainage area to the gauge and other data, in order to produce estimates of flow per square mile (cfs/sq. mi).

Streamflow stations were grouped by sub-basin and the median value for each of these two streamflow benchmarks was calculated. Values were determined for each sub-basin and for the Delaware River Basin as a whole. A weakness of this approach is that, in several of the sub-basins, flow regimes in the mainstem are being combined with tributary flows. In this analysis, the sub-basin area approach fails to take account of the fact that, as the mainstem Delaware River nears the Bay, flows are related not just to conditions in the sub-basin, but on total drainage area above the gauge. This, as well as other short-comings of using such a method to determine average streamflow, must be recognized; however this approach still provides a screening level analysis which can be refined in future efforts.

Table 4.2 Median values of 95% flow exceedence and drought of record flow for gauged streams in the DRB.

Sub-basin	95% Exceedence (cfs/sqmi)	1960's drought of record low flow (7-day avg) (cfs/sqmi)
Upper Region	0.1496	0.1797
Upper Central	0.2432	0.1731
Lehigh Valley	0.3729	0.1658
Lower Central	0.1953	0.0976
Schuylkill Valley	0.3165	0.1841
Upper Estuary	0.3601	0.1964
Lower Estuary	0.2888	0.0874
Delaware Bay	0.2713	0.0401
Delaware River Basin	**0.2710**	**0.2032**

In section 6 of this report, streamflow benchmark values are calculated by multiplying these flows (low flow and drought of records flow) by the drainage area of each sub-basin to provide a benchmark for evaluating current and future surface withdrawals.

4.2 Ground Water Storage

4.2.1 Physiographic provinces/generalized geology

The basin can be divided into seven generalized geologic provinces. They include, from north to south: Appalachian Plateaus, Catskill, Valley and Ridge, New England Upland, Piedmont Uplands and Lowlands and the Coastal Plain. Figure 4.1 provides a map of the generalized geologic provinces and identifies the two key areas of groundwater concern in the Basin.

4.2.2 "Safe yield"

The definition of safe or dependable yield is generally held to be the yield from a water system that is available continuously throughout a repetition of the most severe drought of record, without causing undesirable effects. Actual statistics used for the estimate of safe yield differ widely, especially as they pertain to protection of designated high quality surface waters, ground water protected areas, and critical areas, etc. Two primary methods (thresholds) to estimate safe yield are as follows:

4.2.2.1 Base flow Recurrence Intervals

Base flow, or that part of stream discharge from ground water seeping into the stream, is typically measured in terms of frequency analyses conducted using flow statistics from gaged streams. The recurrence interval statistic is one measure that can be equated to a quantity and used as a planning threshold in determination of withdrawal limits. The appropriate magnitude of the recurrence interval to use as a planning threshold for safe yield is a matter of considerable debate. One application of this method, which uses the 1 in 25-year base flow recurrence interval, currently serves as the basis for the Southeastern Pennsylvania Ground Water Protected Area (GWPA) and is described in section 4.2.3.2.

4.2.2.2 Percentage of Average Annual Recharge

As detailed in the 1995 New Jersey Water Supply Plan, the New Jersey Department of Environmental Protection (NJDEP) uses 20% of the average annual recharge as the basis for estimating the safe yield of ground water sources in the State. Estimates of annual recharge for the geologic formations in New Jersey were made by the New Jersey Geological Survey (NJGS).

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4.2.3 Critical/Protected Areas

Two major critical or protected areas relative to ground water supply exist in the basin: Potomac-Raritan-Magothy (PRM) Aquifer - Critical Area No. 2 in south-central New Jersey and the Ground Water Protected Area in southeastern Pennsylvania (see figure 4.1). New or expanded withdrawals in both of these critical areas are carefully managed and subject to specific regulations which serve to allocate the resource on the basis of a sustainable long-term yield.

4.2.3.1 Potomac-Raritan-Magothy (PRM) Aquifer: Critical Area No. 2

The State of New Jersey has designated two areas of water supply concern. These are areas where water usage poses a significant threat to the long-term integrity of a water supply source. Critical Area No. 2 was declared in 1994 and includes portions of Burlington, Camden, Gloucester, Atlantic, Cumberland, Salem, Monmouth and Ocean Counties. Water allocations from the Potomac-Raritan-Magothy aquifer system were reduced an average of 22 percent within this region. Critical Area No. 2 represents an area of 910.4 square miles within the Delaware River Basin, or approximately 7% of the basin. Since Critical Area No. 2 was established, NJDEP has reduced and/or limited allocations, and as a result, water levels in many locations within the critical area have rebounded or are showing improvement.

4.2.3.2 Ground Water Protected Area (GWPA)

Based on an assessment of available water resources in relation to current and projected uses, it was established that ground water withdrawals in portions of Berks, Bucks, Chester and Montgomery Counties in Pennsylvania exceeded, or threatened soon to exceed, the sustainable yields of local ground water basins. Significant portions of the southeastern Pennsylvania area experienced total ground water withdrawals which approached or exceeded the dry period annual recharge rates for the respective formations. Since 1975, major ground water withdrawals in the region (exceeding 100,000 gallons per day) have increased by over 13 million gallons per day, and additional quantities have been taken by the cumulative effect of small withdrawals. Lowered water tables, and fluctuations in ground water levels during dry periods, periodically interfered with and in some cases cut off normal access to ground water resources by users in the area, particularly residential users reliant on individual domestic wells. Due to these circumstances, the GWPA was established in 1980 and uses the 1 in 25-year baseflow recurrence as its basis for regulation of ground water. The 1 in 25-year baseflow occurrence is used essentially as the "safe yield" for the GWPA. Withdrawal limits are specified for each of the 76 sub-basins within the protected area and new or expanded withdrawals are managed in accordance with those withdrawal limits. The GWPA represents an area of 1,200 square miles within the Delaware River Basin, or approximately 10% of the basin.

Since the GWPA was established, the number of ground water interference claims has declined, despite the occurrence of droughts in 1995, 1998, 1999, 2001 and 2002, and public water suppliers as well as industrial and commercial entities have maintained their level of ground water use without significant impacts to other users or nearby water resources. Much of the GWPA has also benefited from increased interconnections sourced from surface water supplies, further relieving the stress on local ground water sources.

4.2.4 Contaminated Aquifers

In addition to those aquifers that are designated protected, or critical within the basin, there are also aquifers that exhibit poor water quality and are generally not available as a source for water supply. Ground water may have been either impacted by contamination due to releases in urbanized and/or industrial areas of the basin, or may exhibit natural contamination, for instance excessive concentrations of metals, or sulfate. Extensively farmed areas may also have contaminated ground water sources with arsenic, nitrate and/or pesticides. It is estimated that as a percentage of basin-wide ground water supply, sources that are contaminated are not significant. However, some areas in the

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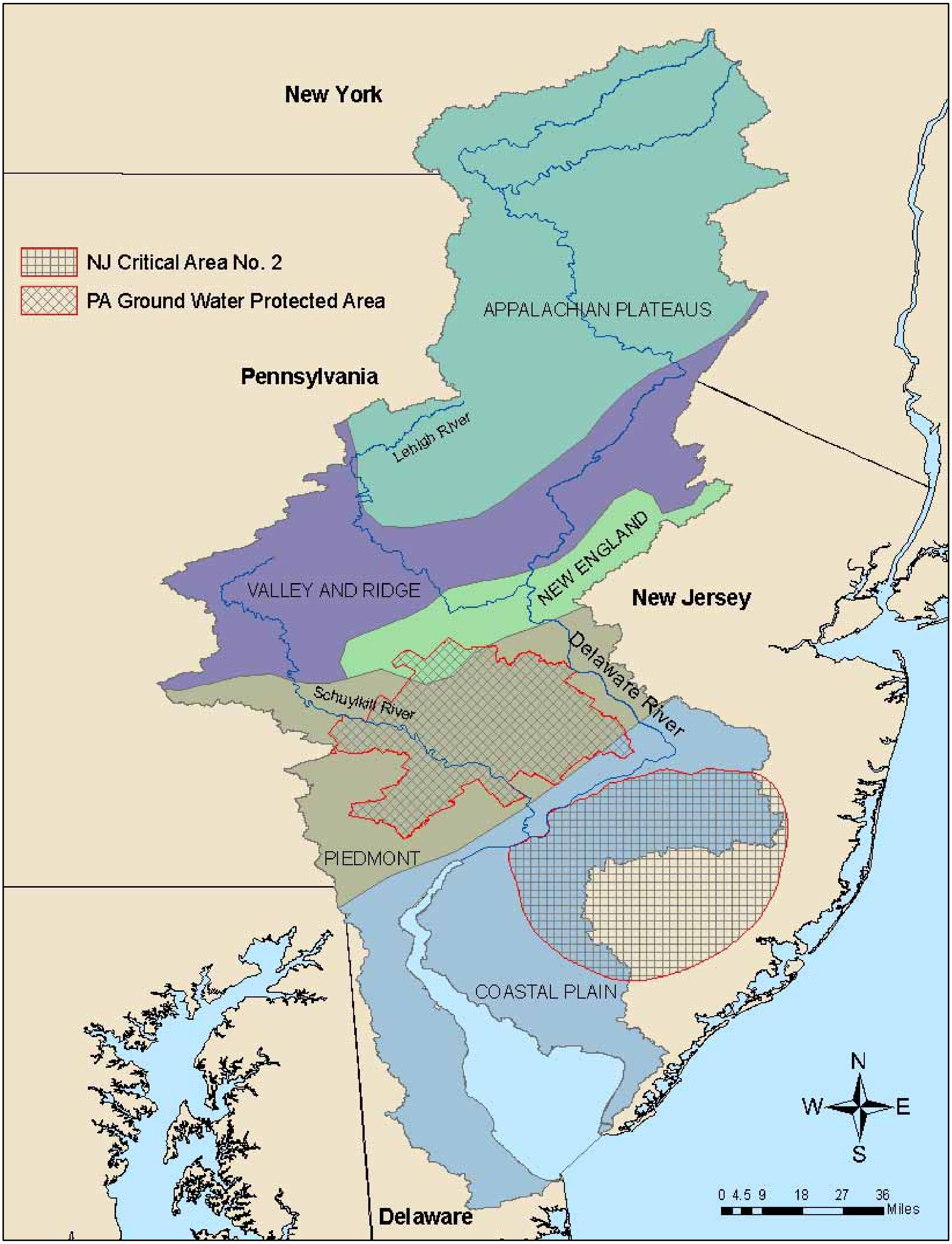
Figure 4.1 Generalized geologic provinces in the Delaware River Basin



County pipeline project (surface water intake in Delran, New Jersey) serves much of Gloucester County, NJ, in order to reduce stress on Critical Area No. 2, and prevent natural chloride concentrations from impacting existing ground water supplies.

4.2.5 Ground Water Storage/Yield

During 2003 / 2004 the DRBC and USGS partners in the Basin contracted to undertake a GIS based groundwater availability study for the entire Delaware River Basin. The assessment was conducted on a modified HUC 10/11 watershed designation which broke the Basin into 147 watersheds with a median size of 82 square miles; 90% of watersheds fell into a range of 40-160 square miles. Two separate approaches were taken to developing groundwater availability: one for the fractured-rock aquifers and one for the Coastal Plain regions.

4.2.6 Surface Water Storage and Availability Calculations

USGS estimates of annual base flow for ten (10) streamflow-measurement stations throughout the basin were used to estimate the ground water contribution to base flow of the generalized physiographic provinces in the basin. The hydrograph separation procedure was used to separate the surface-runoff and base flow or ground water discharge components of streamflow. A normal frequency distribution was used to estimate the annual base flow for the 2, 5, 10, 25 and 50 year recurrence intervals at each of the streamflow measurement stations. These data were then aggregated for each of the major Basin Plan sub-basins, and along with an area derived from a GIS coverage of the sub-basins, a total base flow was estimated for each respective subbasin, and is presented in Table 4.2, below. Normal base flow represents the 2-year recurrence interval, drought represents the 25-year recurrence interval, and 20% normal represents 20% of the 2-year recurrence interval. The 910.4 square mile extent of the PRM Aquifer: Critical Area No. 2 was assigned a zero base flow component, to conservatively account for future protection of this resource. As more information becomes available as a result of the joint DRBC/USGS study of groundwater availability in the Delaware River Basin it will be used to refine these estimates.

Table 4.2 Baseflow recurrence intervals for DRB sub-basins.

DRB Sub-basin	Area (sq mi)	Base flow (mgd/sq mi)			Base flow (mgd)		
		Normal	Drought	20% normal	Normal	Drought	20% normal
Upper Region	3429.5	0.861	0.548	0.172	2,971.7	1,912.6	594.3
Upper Central	1,537.4	0.883	0.579	0.177	1,106.5	560.4	221.3
Lehigh Valley	1,360.7	0.883	0.579	0.177	995.5	522.2	199.1
Lower Central	449.0	0.810	0.400	0.162	177.0	96.0	35.4
Schuylkill Valley	1,894.8	0.810	0.400	0.162	978.1	460.5	195.6
Upper Estuary*	1,744.3	0.311	0.174	0.062	586.0	341.7	117.2
Lower Estuary*	1,004.1	0.311	0.174	0.062	619.7	359.8	123.9
Delaware Bay*	1,430.2	0.718	0.431	0.144	907.0	544.4	181.4
DRB Totals	**12,850.0**				**8,341.5**	**4,797.6**	**1,668.3**

* Actual baseflow values cannot be calculated from baseflow multiplied by area in the above table as certain portions of these sub-basins were assigned zero baseflow as they are part of the NJ Critical Area 2.

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V. Analysis of Current and Projected Water Demands

Unless otherwise stated, all demands have been analyzed in units of million gallons per day (mgd)

5.1 Existing Surface and Ground Water Demands

5.1.1 Uses by Sector

In the Delaware River Basin the predominant source of water supply is surface water. Approximately 92% of total water withdrawals are from surface sources, with the remainder coming from ground water. This is shown in Table 5.1, which also shows how different use sectors rely on surface and ground water.

Table 5.1 1995 DRB Water Use by Sector and Withdrawal Type

Sector	Total Use (MGD)	% SW (by vol.)	% GW (by vol.)
Agriculture	66.5	39.9	60.1
Commercial / Institutional	11.3	12.0	88.0
Public Water Supply	946.8	69.9	30.1
Domestic (residential wells)	83.7	0.0	100.0
Mining	126.8	46.3	53.7
Non-Agricultural Irrigation	7.5	63.8	36.2
Industrial	983.8	90.7	9.3
Hydropower	334.5	100.0	0.0
Thermoelectric Power	5,089.2	99.9	0.1
Ski	1.25	99.1	0.9
Other	39.6	65.7	34.3
Basin (weighted) Total	**7,690.8**	**92.2**	**7.8**

5.2 Effects of Climate and Peaking factors on Demand

For water supply planning purposes it is essential to study water demands under dry climate conditions, in addition to more normal conditions. Similarly, it is important to consider peak demand as well as average demand. The month of July is the peak month for total withdrawals (aggregate of all sectors) and has been used in this analysis; note that for some sectors (e.g., ski related use) July is not the peak month. A detailed tabulation of annualized and peak month demands (expressed as mgd), by use sector and by sub-basin, is given in Appendix IV. Summarized in Table 5.3 below are the peak month withdrawal and consumptive use values, based on 1995 (dry year) and 1996 (wet) water use records.

Table 5.3 indicates a minimal difference in peak month total *withdrawals* between different climate conditions (less than 1%); however, in terms of *consumptive use* the total difference is approximately 30%. Several influencing factors need to be understood to explain these statistics. Although net withdrawals are similar, some use sectors show large changes. Unsurprisingly, water use for irrigation (both agriculture and non-agriculture) show withdrawals to increase by around 100% in the dry year peak month compared to the wet year peak month. Industrial use shows a withdrawal increase of approximately 20%; however this is three times the magnitude of the increase in irrigation needs. In terms of consumptive use, total irrigation demand explains approximately 65% of the total increase in consumptive use in the dry year. It is interesting to note that water use for power generation (for both hydro and thermo generation) actually showed a decrease in the dry year peak month. For hydropower this is likely to be explained simply by there being less streamflow available for power generation. This could also impact thermo power operations depending on the nature of the cooling processes. Consumptive water use actually increased for thermoelectric generation (by 4%), while withdrawals declined (by 5%), which suggests that facilities with evaporative cooling towers, rather

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than once-through cooling loops, may have been responsible for additional power generation demands that typically accompany dry (and hot) years.

Table 5.3 Peak Month Withdrawals and Consumptive Uses by Sector.

All values in MGD (unless otherwise indicated)	Peak Withdrawals				Peak Consumptive Use			
	1995 (dry)	1996 (wet)	Difference	Diff as % of wet	1995 (dry)	1996 (wet)	Difference	Diff as % of wet
Agriculture	186.5	93.5	93.1	99.6%	167.9	84.1	83.8	99.6%
Commercial / Institutional	13.9	12.0	1.9	16.0%	1.4	1.2	0.2	16.0%
Public Water Supply	1,057.3	959.7	97.5	10.2%	224.7	204.0	20.7	10.2%
Domestic	89.5	6.3	83.2	1,320.4%	18.4	1.3	17.1	1,277.2%
Mining	113.5	103.5	10.0	9.6%	17.0	15.5	1.5	9.6%
Non-Ag. Irrigation	17.8	8.3	9.5	114.4%	16.0	7.5	8.5	114.4%
Industrial	1,174.1	893.9	280.2	31.3%	55.6	46.5	9.2	19.7%
Hydro-power	322.8	446.7	-123.9	-27.7%	0.0	0.0	-	-
Thermo-power	5,973.4	6,272.9	-299.5	-4.8%	85.4	82.1	3.3	4.1%
Ski	0.0	0.0	-	-	0.0	0.0	-	-
Other	19.6	9.4	10.2	108.6%	0.5	0.2	0.4	213.4%
Totals	**8,968.4**	**8,806.2**	**162.2**	**1.8%**	**587.1**	**442.4**	**144.7**	**32.7%**

It should be recognized that not all differences between water use observed in a dry and wet year can be explained solely on the basis of climate, especially when the analysis is based on only one year of data representing each climate condition. In the case of industrial and power generation facilities (which represent some of the largest point withdrawals in the Basin) it is not uncommon for operational (rather than demand-related) requirements to cause units to temporarily come on and off-line distorting trends in water use in the short term. This was demonstrated by operational issues at the Salem, NJ nuclear generating station during the period July 1995 to July 1997. This facility has a total average withdrawal of approximately 2.5 billion gallons per day; hence operational issues can drastically influence basin-wide water use trends. For the purposes of this report adjustments were made to the withdrawal figures for the Salem facility to reflect more typical operating conditions.

Based on this analysis of wet versus dry year water demands, the following discussion will focus on dry year (1995) water demands to provide a conservative baseline against which to forecast future demands and compare supply availability. Similar quantitative analysis for 1996 (wet) demands can be found in Appendix IV.

5.3 Uses by Sub-basin

Tables 5.4a and 5.4b show how ground water and surface water are currently used, and are projected to be used, in each of the sub-basins. The projections show how the reliance on these sources is expected to change through the forecast period to 2040. Table 5.4a shows total withdrawals for each of the sub-basins, while Table 5.4b shows consumptive use estimates for these sub-basins.

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Table 5.4a Water Withdrawals estimates by source for the DRB sub-basins

Total Withdrawals (all values MGD)	1995		2020		2040	
	GW	SW	GW	SW	GW	SW
Upper Region	19.1	194.2	21.6	195.2	28.6	196.4
Upper Central	85.7	452.2	90.4	592.4	113.6	712.9
Lehigh Valley	58.2	207.8	61.6	219.8	75.8	231.9
Lower Central	14.5	163.9	16.0	183.5	20.5	201.5
Schuylkill Valley	103.1	562.6	105.4	748.3	126.1	909.9
Upper Estuary	176.0	1,859.3	180.8	2,496.3	214.8	3,027.2
Lower Estuary	50.5	3,586.5	60.5	5,056.7	86.9	6,285.1
Delaware Bay	89.7	67.2	92.5	65.7	108.2	64.4
Total Withdrawals	597.0	7,093.8	628.9	9,557.9	774.5	11,629.3
	7,690.8		**10,186.8**		**12,403.8**	

Table 5.4b Consumptive Use estimates by source for the DRB sub-basins

Consumptive Use (all values MGD)	1995		2020		2040	
	GW	SW	GW	SW	GW	SW
Upper Region	2.6	1.0	2.9	1.1	3.6	1.2
Upper Central	13.5	9.3	13.5	11.4	15.5	13.4
Lehigh Valley	7.1	9.1	7.9	10.6	9.7	12.1
Lower Central	1.7	29.2	1.9	35.6	2.4	41.1
Schuylkill Valley	13.8	51.3	14.4	65.0	16.8	77.1
Upper Estuary	22.8	56.2	23.7	61.5	26.4	65.9
Lower Estuary	11.1	41.0	11.6	51.0	13.8	59.7
Delaware Bay	29.0	16.7	26.2	15.3	25.1	14.1
Total Withdrawals	101.7	213.7	102.2	251.6	113.3	284.6
	315.3		**353.8**		**397.9**	

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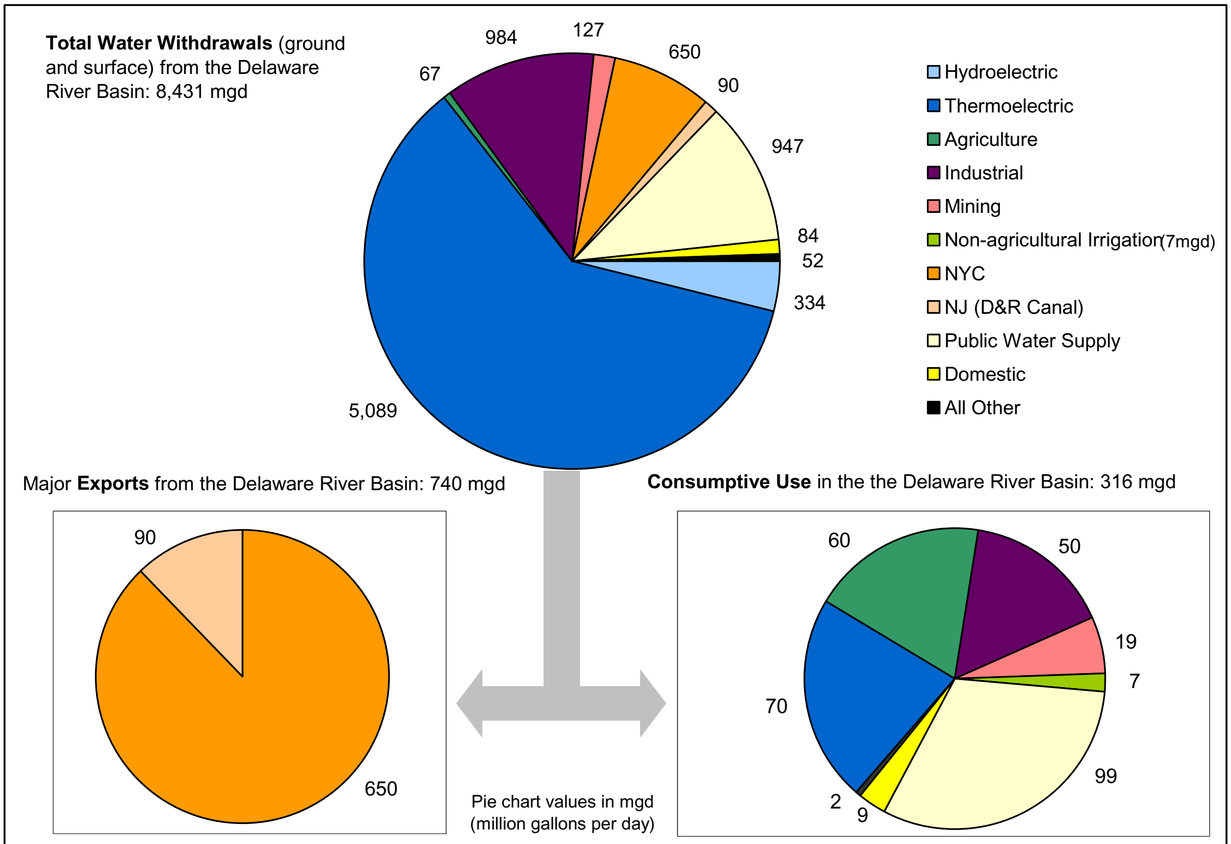
5.4 Total Withdrawals Consumptive Use & Delaware River Basin Exports

Water management in the Delaware River Basin is influenced heavily by the export of significant quantities of water, primarily to augment supplies for New York City and northeastern New Jersey. Due to the nature of these exports and the reservoir system that has been built to accommodate them, they are often modeled and assessed separately from in-Basin water use. Figure 5.1 puts these exports into perspective with total water withdrawals and consumptive water use within the Delaware River Basin, based on an assessment of 1995 data.

Figure 5.1 shows that, in terms of water withdrawals, the thermoelectric power sector (hereinafter referred to as the power sector) is the most significant in the Basin – accounting for over 60% of total withdrawals, including exports. It should be noted that the majority of these withdrawals take place in the lower portions of the Basin, especially the Estuary. The relevance of the location of some of the biggest water users in the power sector is explored more fully in section 5.6.

Figure 5.1 Withdrawals, Consumptive Use and Major Exports from the Delaware River Basin



The two sectors of industry and public water supply each account for slightly over 10% of total withdrawals. Exports from the Basin account for nearly 9% of total withdrawals. The two hydropower facilities in the Basin account for nearly 4% of withdrawals, but return all the water withdrawn for use downstream. The other categories combined account for the remaining 5% of withdrawals.

Although it is useful to consider relative water withdrawals in the Basin, it is often more important to examine consumptive uses. The significance of consumptive use is that it measures how much of the withdrawal volume is not directly returned to the river basin for downstream users, or to meet ecological flow needs. The methodology for the calculation of consumptive use is described in Appendix II; the quantity of consumptive use by sector for the entire Basin is shown in Figure 5.1. This analysis shows that water use for public supplies is the largest sector, accounting for one third of total consumptive use. Also dominant in this assessment are the sectors of power, agriculture (due to the generally high consumptive use coefficients associated with irrigation processes) and industry accounting for 23%, 20% and 16% of total consumptive use, respectively. The sum of all other uses accounts for the remaining 8%. As hydropower production is entirely non-consumptive it does not feature in this analysis. A detailed breakdown of total withdrawals and consumptive use by sector for each of the eight sub-basins can be found in Appendix IV.

Figure 5.1 also shows the magnitude of the two major exports from the Delaware River Basin. The largest is the diversion from the upper basin reservoir system to New York City (NYC). As established by the 1954 Supreme Court decree, a maximum of 800 mgd (as an annual average) can be taken, under normal operating conditions. The Delaware and Raritan Canal serves as a diversion conduit for the New Jersey Water Supply Authority which is allowed to export a maximum of 100

mgd (as a daily maximum), under normal operating conditions, to the Raritan River Basin. Appendix V shows a history of monthly diversions from these two Basin exports. Of note is the trend in the NYC export from the late 1980's onwards which shows that water exports have reduced from their peak values in large part due to wide ranging conservation efforts by the City.

5.5 Consumptive Use and Equivalent Impact Factor

As seen in figure 5.1 the majority of water withdrawn in the Delaware River Basin is for thermoelectric power generation, accounting for slightly over 60% of total withdrawals and 22% of total consumptive use. However it is important to note that the majority of these withdrawals take place in the Delaware Estuary (see Figure 5.2) which benefits from drainage from the majority of the Basin and supports the highest flows.

One of DRBC's primary concerns in managing consumptive water use in the Basin is to ensure that there is sufficient flow in the mainstem of the river entering the estuary to prevent the "salt line" from traveling beyond its safe range and affecting water supply intakes. As salt-laced water moves upstream, it may lead to higher water treatment costs for water suppliers and may also lead to higher corrosion control costs for industries along the river. The DRBC monitors the location of the 7-day average 250 parts per million chloride concentration, which is known as the "salt line".
For the purposes of managing the salt line, any withdrawal below river mile 38 (the mouth of the Cohansey River) has been determined to have no discernable effect on chloride movement. Between river miles 38 and 92.4 (the mouth of the Schuylkill River) an *equivalent impact factor* (EIF) curve has been developed to reflect the impact of consumptive use (relative to impacts above river mile 92.4) in this part of the estuary. At locations between river miles 92.4 and the gauge at Montague, NJ, all consumptive use is considered to have an equal impact on the salt front. The relationship between river mile and equivalent impact factor is shown in Appendix VI.

Table 5.5 and corresponding Figure 5.2 show the magnitude of withdrawals and consumptive use at each power generating facility in the Basin. The table shows absolute consumptive use and also the equivalent consumptive use for the six facilities that are affected by the equivalent impact factor. Total average consumptive use for the power generating sector, in 1995, is 69.4mgd; when corrected for EIF consumptive use is 53.3mgd. The Limerick, PA nuclear generating facility has the largest consumptive use in the Basin; it is situated on the Schuylkill River and therefore has an EIF of 1.0. The next three largest facilities, in terms of consumptive use, are all situated in the Estuary, between river miles 38 and 92.4, and have their absolute consumptive use values reduced when adjusted for the EIF.

A similar analysis was undertaken for industrial facilities that are subject to the EIF. Appendix VI shows a list of the facilities that are affected and the impact of the EIF on consumptive use values. In summary, this analysis shows that 12 industrial facilities are subject to an EIF and have a combined absolute consumptive use (in 1995) of 12.7mgd. When adjusted for EIF their combined consumptive use is 8.7mgd. To put these figures in a Basin-wide perspective, in 1995, absolute consumptive use and EIF-adjusted consumptive use was 50.0mgd and 46.0mgd, respectively.

It should be noted that the demand forecasts included in this report use absolute consumptive use figures and not those adjusted for EIF. This is because the forecast methodologies are based on generalized growth factors. Inclusion of EIF considerations require forecasts to be made at the individual facility level which is beyond the scope of this study.

Figure 5.2 Location of power generating facilities in the Delaware River Basin

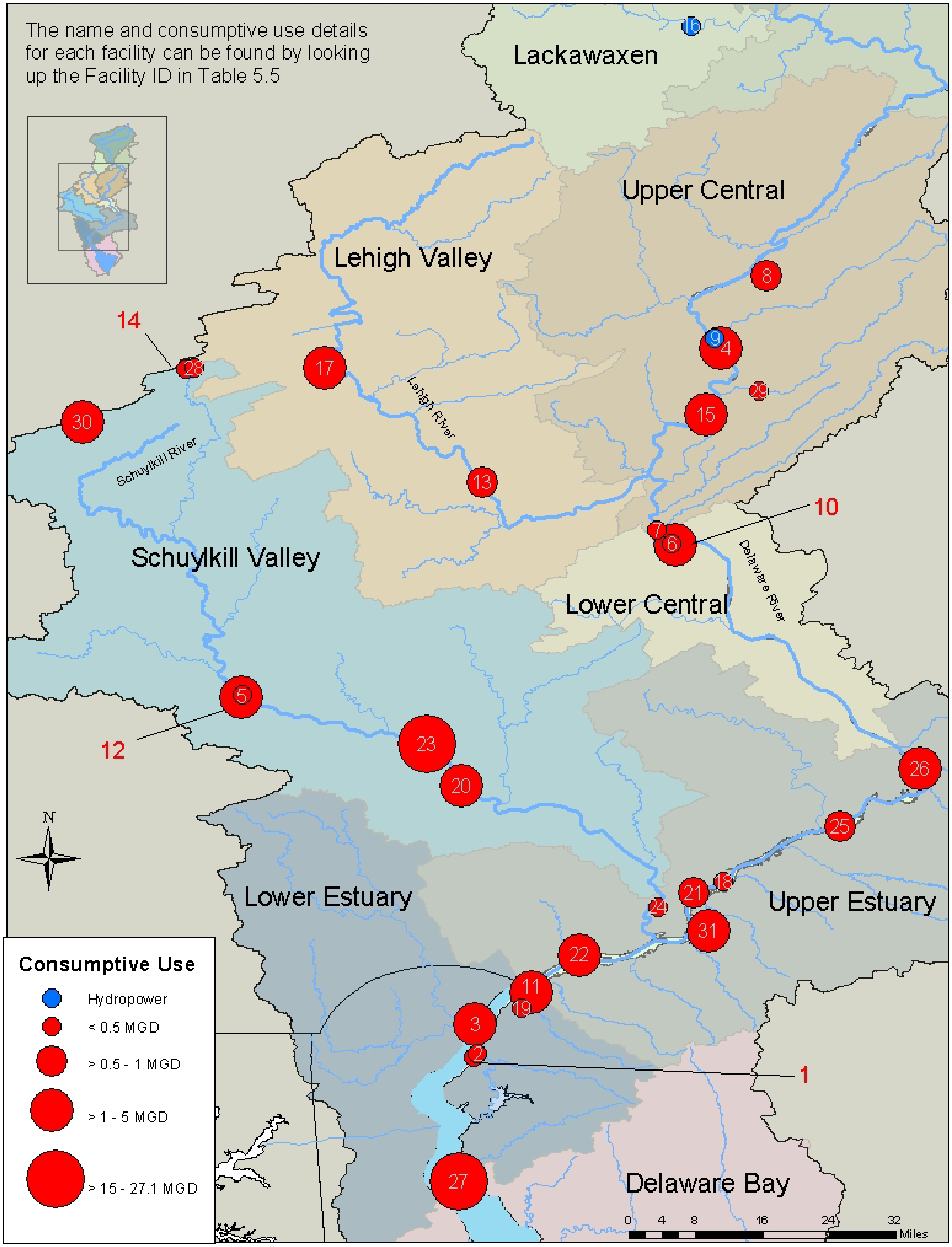


Table 5.5 Withdrawals and Consumptive Water Use by Power Generation Facilities in the Delaware River Basin (based on 1995 average demands).

MAP ID	Site Name	Withdrawal (MGD)	Consumptive Use (MGD)	Consumptive Use (MGD) (adjusted for EIF)*	% of absolute consumptive use	Cumul. % of absolute consumptive use
23	Exelon - Limerick Unit	35.6	27.1	27.1	38.9	39
27	PSE&G Co - Salem & Hope Creek	2,473.4	15.3	**2.3**	22.0	61
22	Exelon - Eddystone Unit	716.1	4.3	**3.6**	6.1	67
3	Conectiv - Hay Road	537.8	4.1	**2.4**	5.9	73
26	PSE&G Co - Mercer Station	461.4	2.9	2.9	4.2	77
31	Wheelabrator Gloucester Co. Lp	16.3	1.6	1.6	2.3	80
10	Reliant Energy Gilbert (1-3)	15.1	1.5	1.5	2.2	82
4	Reliant Energy - Portland	219.7	1.5	1.5	2.1	84
11	Logan Generating Company, Lp	1.4	1.4	**1.0**	2.0	86
15	P P & L - Martins Creek	58.3	1.4	1.4	2.0	88
20	Exelon - Cromby	223.0	1.3	1.3	1.9	90
5	Reliant Energy - Titus (SW Withdrawal)	12.9	1.1	1.1	1.6	91
30	Wheelabrator Frackville Energy Co. Inc	1.7	1.1	1.1	1.6	93
17	Panther Creek Partners	1.0	1.0	1.0	1.5	94
8	Reliant Energy - Yards Creek	7.2	0.7	0.7	1.0	95
25	PSE&G Co - Burlington Station	85.5	0.6	0.6	0.8	96
13	Northampton Generating - Lehigh River	0.6	0.6	0.6	0.8	97
21	Exelon - Delaware Unit	75.4	0.5	0.5	0.7	98
1	Conectiv - Deepwater Station	103.3	0.4	**0.2**	0.6	98
2	Chambers Cogen - Carneys Point	3.1	0.3	**0.2**	0.5	99
24	Exelon - Schuylkill Unit	36.8	0.3	0.3	0.4	99
29	Warren Energy Resource Co. Lp	0.2	0.1	0.1	0.2	99
18	Peco Energy Co / Richmond	1.3	0.1	0.1	0.2	100
7	Reliant Energy Gilbert (8)	1.2	0.1	0.1	0.2	100
14	Northeastern Power - Silverbrook Mine	0.1	0.1	0.1	0.2	100
19	Pedricktown Cogen / Conectiv	0.5	0.0	0.0	0.1	100
12	Reliant Energy - Titus (Wells)	0.2	0.0	0.0	0.0	100
28	Tractebel Electricity & Gas	0.1	0.0	0.0	0.0	100
6	Reliant Energy - Gilbert	0.0	0.0	0.0	0.0	100
9	Great Bear Hydropower,Inc.	145.4	0.0	0.0	0.0	100
16	P P & L - Wallenpaupack	189.0	0.0	0.0	0.0	100
	TOTAL:	**5,423.6**	**69.4**	**53.3**		

* Red = Change in consumptive use based on EIF considerations; black = not influenced by EIF

5.6 Sensitivity Testing of Consumptive Use Estimates

In this study, the assessment of consumptive use has largely been based on estimated, sector-wide coefficients and these coefficients are known to be uncertain.

As noted in section 5.5, estimates of consumptive use for the power and industry sectors have been based on site-specific information, where available, and this has provided a more accurate estimation than a generic sector-wide assumption. A rudimentary sensitivity analysis shows that the assessment remains highly sensitive to the 10% consumptive use estimate for public water supply and domestic use. For example, a 1-percentage point change in this assumption equates to a 3.4% change in overall consumptive use, equivalent to a value of 10.7mgd.

It is recommended that a Monte-Carlo Simulation or Multivariate Sensitivity Simulation (MVSS) be carried out on the estimation of consumptive use, to test the sensitivity of the assumptions simultaneously.

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5.7 Current and Forecast Water Use by Sector

Water demand forecasts have been developed for the years 2020 and 2040, projected from a base year of 1995 for dry year demands (and 1996 for wet year demands). Figures 5.3(a-i) and 5.4(a-i) illustrate, by use sector, both current and projected demands for the dry year scenario, for each sub-basin (and the Delaware River Basin as a whole). Figure 5.3 shows withdrawals and figure 5.4 shows consumptive water use. No attempt has been made to forecast demand from the two major exports from the Basin and these are not included in the following analysis which summarizes major use patterns and trends in each sub-basin:

Upper Region (3,430 sq mi):
Hydropower accounts for 96% of withdrawals in this sub-basin, with total withdrawals not projected to increase significantly by 2040. With respect to withdrawals, the Upper Region shows the smallest increase of all sub-basins. The majority of consumptive water use is for public water supply needs, domestic uses (residential dwellings with their own wells) and agriculture. Following past trends, population growth is expected to result in increased consumptive use for PWS and domestic use, which will offset a marginal decrease in the agricultural sector, such that net consumptive use in this sub-basin is projected to increase by 34%.

Upper Central (1,537 sq mi):
In the Upper Central sub-basin, water withdrawals are projected to increase by over 50% between the base year and 2040. Almost all of this increase is attributable to growth in water demand by the power sector and therefore the most likely source of this increase is from surface water. In terms of consumptive use, agricultural water demand is projected to decrease by one third, but this will be more than offset by increases in PWS, domestic use and particularly power generation.

Lehigh Valley (1,361 sq mi):
Public water supply and industrial use are the dominant use types in this sub-basin in the base year (1995), accounting for approximately 65% and 27% of withdrawals respectively. Withdrawals for industrial uses have declined dramatically in the Lehigh Valley during the 1990's, mostly as a result of the loss of heavy industry in the region, and are not forecast to expand by 2040. Increases are projected in the Lehigh Valley for the PWS, domestic use and power sectors, such that net withdrawals and consumptive use will increase by 16% and 34% respectively.

Lower Central (449 sq mi):
Similar to the Lehigh Valley, water use in the Lower Central sub-basin is dominated by industrial and public water supply uses. About 17% of withdrawals in the base year (1995) are for power generation needs, although this sector is forecast to increase its demand such that it will account for around 23% of total demand by 2040. Consumptive water use patterns show that the power sector has the greatest use with the projected increase accounting for around 55% of total consumptive use in 2040. Agricultural water use in the Lower Central sub-basin is expected to decline over the forecast period, reflecting the continuation of past trends which show a decrease in land area devoted to agricultural production. The Lower Central sub-basin includes the Point Pleasant diversion which, from an intake on the Pennsylvania side of the mainstem Delaware River, sends water via pipelines and instream flow augmentation across southeastern Pennsylvania and into the Schuylkill Valley sub-basin. The project has been operational since 1989 and serves the dual-purpose of supplying consumptive use make up water to the nuclear generating facility at Limerick, PA and providing water to the Forest Park water treatment facility which treats water for both North Wales and North Penn Water Authorities. The diversion has enabled the two water purveyors, once solely reliant on ground water sources, to meet increasing demand without further stressing groundwater in the region, as encouraged through DRBC's Ground Water Protected Area program. Currently, the capacity of the withdrawal is approximately 90mgd; in 1995 the East Branch serving the Limerick facility had an

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Figure 5.3 Total Water use (Dry Year) - 1995, 2020 and 2040 projected water demand by sector

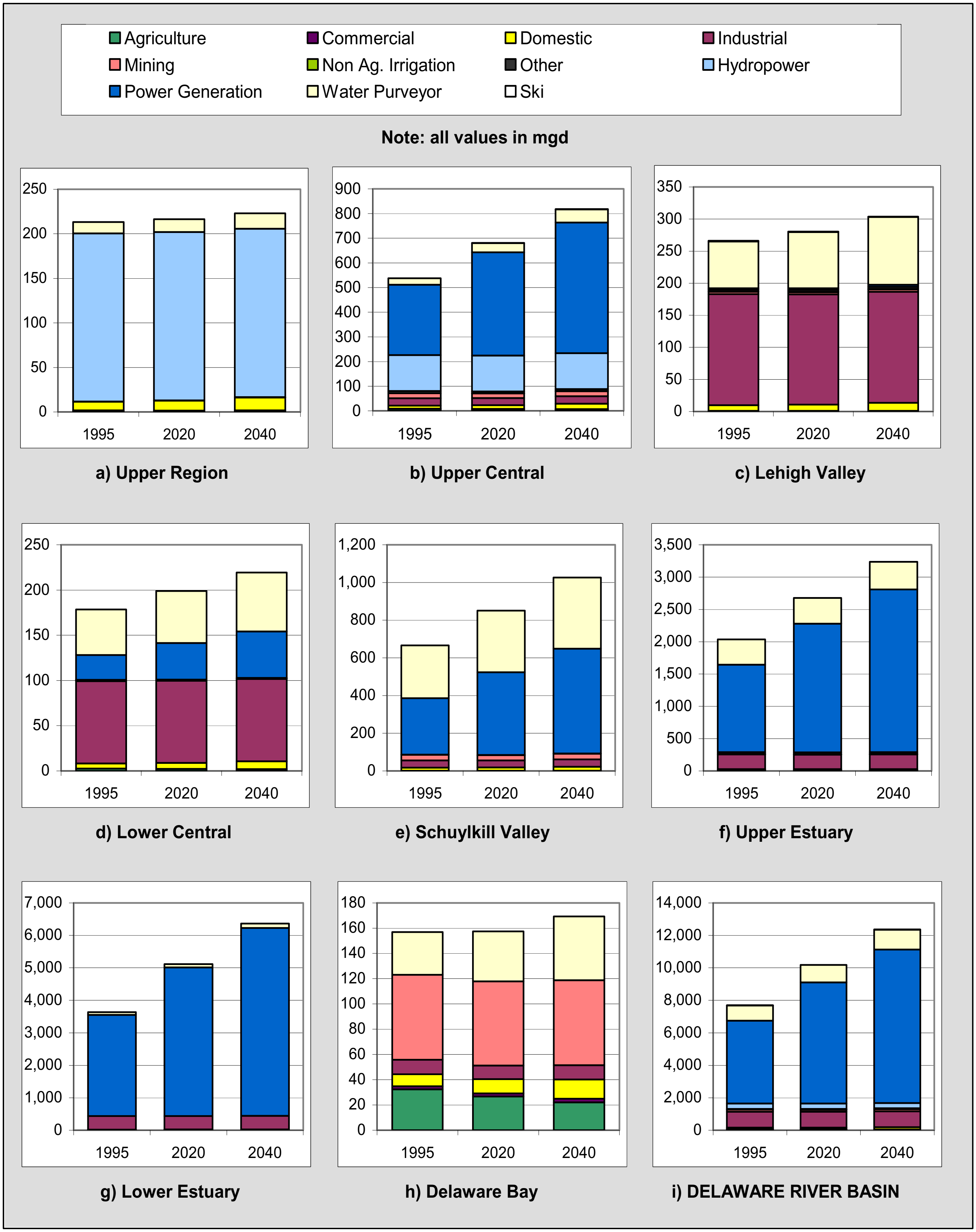
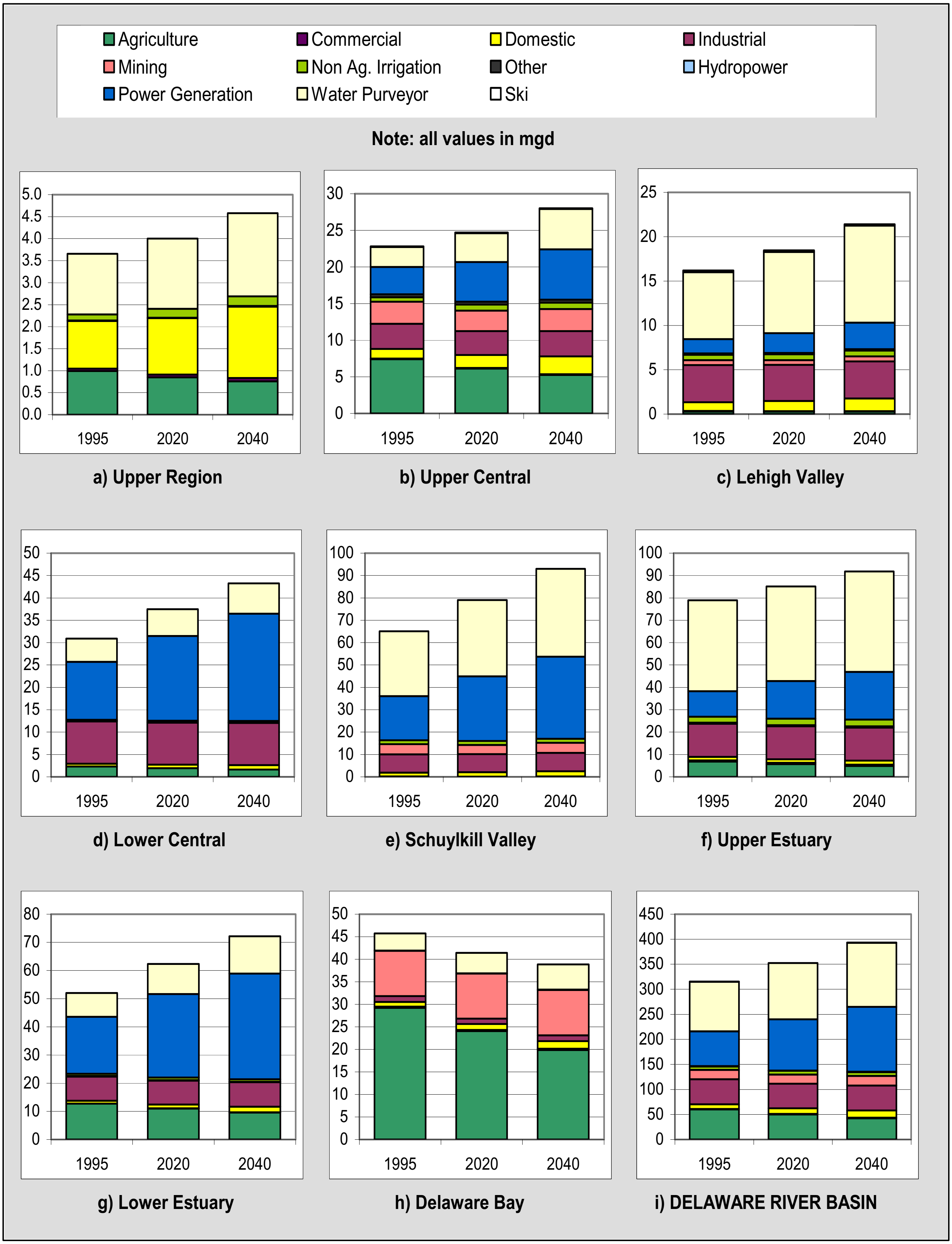


Figure 5.4 Consumptive Water Use (Dry Year) - 1995, 2020 and 2040 projected water demand by sector



average throughput of approximately 24mgd (peak month: 42mgd) and the North Branch conveyed an average of 9mgd (peak month: 24mgd) for public water supply purposes.

Schuylkill Valley (1,894 sq mi):
In the base year, public water supply and power generation each account for around 40% of withdrawals. Mining and industry each make up half of the remainder. It should be noted that this does not include the withdrawals related to the Point Pleasant diversion which occur in the Lower Central sub-basin but are discharged in the Schuylkill Valley. In this sub-basin, only power generation shows significant growth by 2040, with both withdrawals and consumptive use increasing by a factor of around 1.5 by the end of the forecast period. The forecasts do not detail where new facilities would be located, or whether existing facilities could be expanded. The feasibility of increasing power generation through large surface water withdrawals in this sub-basin should be examined in greater detail.

Upper Estuary (1,744 sq mi):
Withdrawals in the Upper Estuary are dominated by the power sector, accounting for 75% of the total in the base year. However, power facilities in this region are not highly consumptive in nature and therefore (in 1995) represent only 15% of total consumptive use, whereas public water supply accounts for over 50%. Demand for water for public water supply and for power generation is expected to grow throughout the forecast period; by 2040 public water supply will still account for around 50% of consumptive use with the power sector accounting for approximately 25%.

Lower Estuary (1,004 sq mi):
As with the Upper Estuary, most of the water (91%) in this sub-basin is withdrawn to meet power generation needs. Due to the increasingly saline nature of water in the mainstem as it nears the Bay there are far fewer withdrawals for public water supply purposes in the Lower Estuary. In terms of consumptive water use, 40% is for power generation processes, nearly 25% is for agriculture and the remainder is divided evenly between public water supply and industrial uses. A predicted growth in power generation drives the increase in demand in this sub-basin – a projected 73% increase in total withdrawals (and 34% in total consumptive use) by 2040. Relative to the power sector, demand for water by industry and public water supply is not forecast to change significantly by 2040. Consumptive water demand for agriculture shows a decrease of approximately 28% across the forecast period.

Delaware Bay (1,430 sq mi):
Withdrawals for mining purposes account for nearly 50% of the total in this sub-basin, followed by public water supply, agriculture and industry in that order. Due to the highly consumptive nature of agricultural water use it accounts for nearly two-thirds of total consumptive use in the base year, followed by mining, public water supply and industrial uses. Withdrawals for public water supply are expected to increase in this region by a factor of approximately 1.6, but a projected decrease in the number of irrigated acres for agricultural production means that *this is the only sub-basin where total consumptive use is expected to fall by the end of the forecast period.* This highlights the fact that when an increase in demand is forecast for certain sectors (e.g., public water supply) the potential that it will replace existing uses must be factored into the assessment to determine whether, on net balance, withdrawals and consumptive use will increase or decrease.

Relative to other sectors, the consumptive nature of water use for mining and mineral extraction processes is not well understood in the Delaware River Basin. The assessment methodology for this study assumes a consumptive use of 15% of withdrawals for these uses; further study of this sector and improvements to this estimate will help to quantify more accurately consumptive water use, particularly in this sub-basin where significant mining activity occurs.

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Delaware River Basin (12,850 sq mi):
Between the base year and 2040, net withdrawals in the Delaware River Basin are projected to increase by 61% and consumptive use by 27%. The projections suggest that thermoelectric power generation will be the sector responsible for the greatest increase in water demand, accounting for 95% of the total increase in withdrawals and 90% of the increase in consumptive use. Although projections for this sector have been recently revised by DRBC staff (and found to be consistent with regional growth projections for energy demand) a special focus should be placed on future water demand for this sector. Specifically, the forecast growth in the Upper Central and Schuylkill sub-basins should be carefully examined as the projected increase in consumptive use in these regions could have a significant water resources impact.

Table 5.6 summarizes the net change in withdrawals and consumptive use for each sector between the baseline (1995) and final forecast period (2040). This provides a simple assessment of the rates at which sectors are growing and therefore may help guide future prioritization efforts. To minimize adverse effects on water resources, attention should be directed to those sectors with the greatest potential for growth.

Table 5.6 Net Changes in withdrawals / consumptive use base year - 2040

Sector	Change in water use
Agriculture	-26.3%
Commercial / Institutional	17.3%
Domestic (residential wells)	65.8%
Non-Agricultural Irrigation	16.4%
Thermoelectric Power	85.6%
Public Water Supply	33.4%
Basin Total (withdrawal / consumptive use)	**61.3% / 26.8%**

The sectors of industry, mining, hydropower, ski and other are not featured in the above table as their water use was not forecast in this study. Values for these sectors were held constant through the forecast period.

In the forecast assumptions the consumptive use factor (or coefficient) for each sector was not varied over time which explains why each sector only has one value for both changes in withdrawals and consumptive use in the table 5.6. A more sophisticated analysis could attempt to model changes in consumptive use factors which could, for example, arise from technological advances in the power sector, or development of more efficient irrigation methods. For the Basin total, the difference between the two figures reflects the fact that sectors with a lower than average consumptive use are forecast to grow at greater rates.

Water demand for the domestic use category is projected to grow by over 65% between the base year and year 2040, whereas public water supply is expected to grow by around half this amount. It is probable that the forecasting method has over-estimated the growth in domestic demand as it is likely that in those areas with highest growth rates (often rural areas where residents may currently be served by individual wells) development will bring with it public water supply systems to meet demand. This issue arises due to no data being available from the year 2000 census on how each household obtains its water supply; 1990 percentages of households on wells were applied to updated population numbers from the 2000 census. An alternative forecasting methodology would be to assume a switch to pubic water supply for the fastest growing and more densely populated sub-basins. In terms of overall impact on projected water demand, identical consumptive use factors have been assumed for public water supply and the domestic sector and therefore there is no discrepancy with total projected use values; however, some of the projected increase in domestic use may be met instead by the public water supply sector.

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VI. Resource Assessment

The resource assessment section of this report is comprised of two parts; the first takes a Basin-wide perspective and the second discusses the results for individual sub-basins. Benchmark values have been established for the supply-side evaluation as described in section IV. For the surface water assessment, consumptive use values have been used to represent the demand-side component. This reflects the fact that upstream discharges frequently contribute flow to downstream withdrawals; in other words, surface waters are typically reused several times as water flows downstream, with the exception of the consumptive use portion which is not returned. Consumptive use is not the only consideration, as water needs to be available to sustain the full withdrawal quantity; however, due to the inherent reuse process, it is more feasible to compare consumptive use than total surface water withdrawals with the supply availability benchmarks. For ground water, total withdrawal volumes are used in the comparison with available supply. This is appropriate as discharges originating as ground water withdrawals are typically not returned directly to the ground water system.

6.1 Delaware River Basin

Based on the findings of this study, water availability is adequate to meet current and projected future water demands under dry climate conditions, *at the Basin-wide scale.*

6.1.1 Surface Water Assessment

The largest increase in water use is projected for the thermoelectric power generating sector, which is primarily sourced from surface supplies and, based on a linear extrapolation of recent trends, is projected to consume 130 mgd by 2040 (increasing from 70 mgd in 1995). Consumptive water demands increase the frequency and duration of low flows; however, the release of water from upstream reservoirs to meet flow requirements, or simply offset consumptive demands, helps to reduce the negative impacts. Since there is substantial reserve available in some Basin reservoirs (e.g., Merrill Creek) to offset additional consumptive use, it appears that, basin-wide, surface water resources will be adequate to meet surface water demands in 2040.

Current average and peak-month surface water consumptive use in the Delaware River Basin is significantly less than the 95% exceedence (low flow) value which is based on a 0.294 cfs/square mile median, low flow, contribution from the drainage area of the entire basin (see Appendix VII for an explanation of the methodology). Compared to drought flows, current peak-month consumptive demands are approximately 25% of the 1960's drought low flow value. By the year 2040, peak and average projected consumptive surface water use in the Delaware River Basin is still approximately one-fifth of the 95% exceedence value. In 2040 peak-month demands are still projected to be less than one-half drought low-flow values. However, it is important to note this projection represents a basin-wide generalized average, and does not specifically account for the location of future withdrawals, which, considering the increased use projected for the power sector, is a critical variable for assessment of overall basin water supply. Similarly, the analysis does not factor in future reserve of storage which may provide releases to augment streamflow.

6.1.2 Ground Water Assessment

With respect to ground water availability, when averaged over the entire Delaware River Basin, existing (1995) and projected (2040) peak-month withdrawals account for approximately 8% and 10% respectively, of the average (1 in 2 year) base flow recurrence value. These existing and projected withdrawal rates equate to approximately 15% to 18% respectively, of the 25-year base flow recurrence – the threshold currently used in the Ground Water Protected Area (GWPA) of Southeastern Pennsylvania (see section 4.2.3.2). Existing and projected peak-month withdrawals for the basin are approximately 42% and 53% of the most conservative planning threshold currently applied in the basin, defined by New Jersey as 20% of the average annual recharge (equivalent to the average base flow recurrence). Based on the overall basin assessment of ground water yield and

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Figure 6.1 Consumptive Surface Water Withdrawals (Dry Year): Average and peak month (July) values

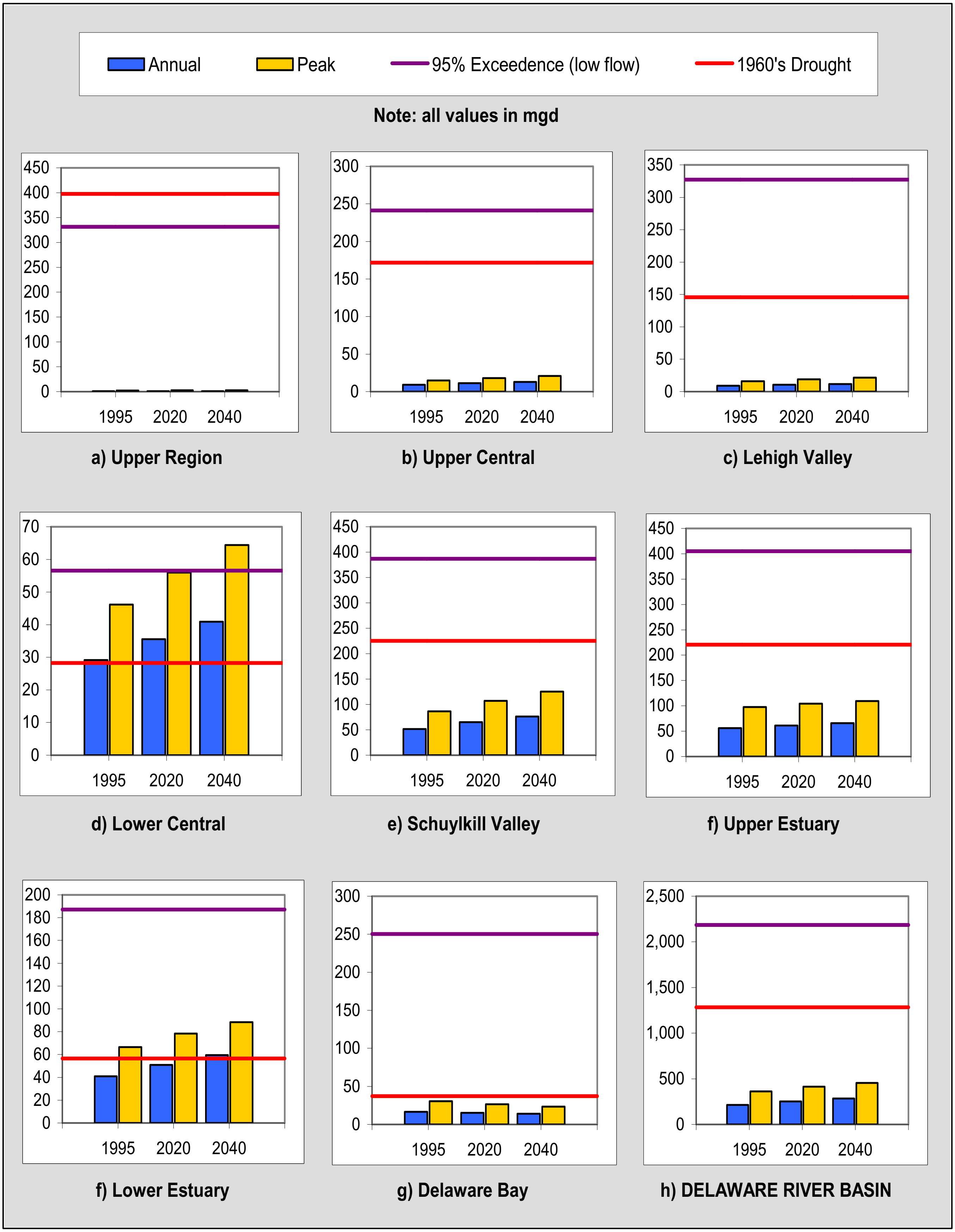
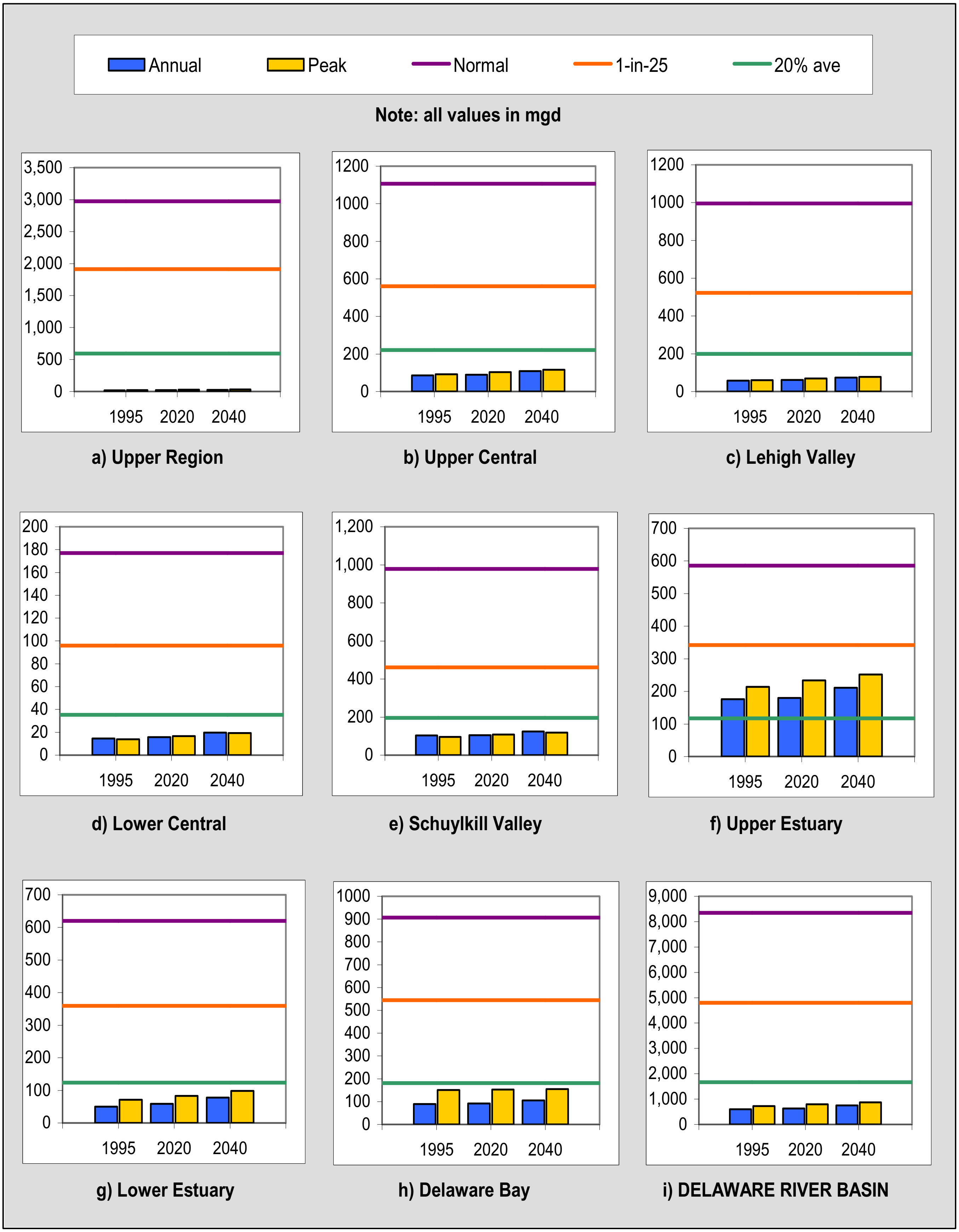


Figure 6.2 Ground Water Withdrawals (Dry Year): Average and peak month (July) values



demand, ground water resources generally are adequate to meet water supply demands in the Delaware River Basin through the year 2040. Comparing total withdrawal volumes, rather than consumptive use or net withdrawals (withdrawals minus artificial groundwater recharge), against these benchmark availability estimates provides for a more conservative water resources planning assumption.

It is important to note that an overall estimation of ground water availability, based on the geology and area of the basin (or sub-basin), does not readily translate into an assurance of ground water supplies to all areas to meet current and projected demands. The controlling factor in estimating potential shortfalls is the *distribution* of such sources to the areas of demand. As such, while projected peak-month ground water demand for 2040 represents just over 50% of the most conservative threshold for supplies in the basin, this is not necessarily equivalent to the statement that all ground water demands will be met, since at the local level, ground water supply challenges associated with poor geology and/or natural or anthropogenic contamination may exist.

6.2 Individual Sub-basins

Based on the eight sub-basins defined in this report, the results of this analysis indicate that at the sub-basin scale water availability generally will be adequate to meet current and projected future dry-climate demands. However, two sub-basins are identified for which current and/or future withdrawals exceed one of the benchmarks of availability; the significance of these specific findings is included in the discussion below.

6.1.1 Surface Water Assessment

For all sub-basins with the exception of the Lower Central region, consumptive surface water demand under peak-month, dry climate conditions is currently less than or equal to one-third of the 95% exceedence flow value. The projections show that in 2040 peak month consumptive demands will still be less than or equal to 40% of this benchmark value. For the Lower Central sub-basin (see figure 6.1d), current demands are less than the 95% exceedence value, but in 2020 peak-month consumptive demands are projected to equal it. In 2040 they are projected to reach 114% of this benchmark value.

When measured against the drought of record low flow period, demands in two of the eight sub-basins currently exceed this benchmark; these sub-basins are the Lower Central and Lower Estuary. By 2020, peak consumptive demands in the Lower Central are forecast to be more than double the drought of record benchmark; in the Lower Estuary sub-basin consumptive demands will be 150% of the benchmark value.

An assessment of supply and demand over a large scale, such as an entire Basin or even sub-basin, necessarily requires broad assumptions and analysis methods. The method chosen for comparing surface water supply and demand on a sub-basin basis has constraints but, consistent with the intent of this report, will still provide a screening tool for more sophisticated analysis. Of the sub-basin summaries shown in figure 6.1, the Upper Region, Lehigh Valley and Schuylkill Valley sub-basins most accurately depict the water supply versus demand status. This is because these sub-basins are either isolated from the mainstem Delaware River, or represent its headwaters. Therefore, the method of determining flow exceedence statistics is not distorted by the influence of drainage areas external to the sub-basin. For example (see figure 3.1), the Lehigh Valley represents a single isolated watershed, whereas the Lower Central sub-basin is divided by the mainstem Delaware River. Thus, actual flows in the Lower Central sub-basin are a function not only of drainage area in the sub-basin, but also of drainage from a significant portion of the Basin to the north. Therefore, actual flows are influenced by an external drainage area which is not accounted for in the calculation of the exceedence values. Hence, the flow exceedence values calculated for this sub-basin (and others with

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similar characteristics) do not serve as a strong basis for a relative measurement of stress; actual benchmark availability statistics for this sub-basin would be higher than shown.

Many large withdrawals situated in the middle to lower basin are located on the main stem of the Delaware River and benefit from the drainage area above their respective points of withdrawals, which could include drainage from as much as three or four additional sub-basins. In ongoing evaluations of the availability of surface water, it is critical to perform the analysis based on the location of any new or expanded withdrawals, and the contributing drainage area supporting flow to that point of withdrawal.

It is clear that power generation accounts for the largest total use, and this is primarily sourced from surface water. The siting of future power generating facilities bears directly on the potential for specific sub-basin stress, as does the location and capacity of reserve storage to offset such use.

6.1.2 Ground Water Assessment

For all sub-basins with the exception of Upper Estuary, peak-month ground water demands throughout the projection period are all less than the most conservative planning threshold (20% of the average annual recharge). Of these sub-basins the Delaware Bay is closest to reaching this benchmark value by 2040 (see figure 6.2.h). For the Upper Estuary both average and peak-month current demands exceed this ground water availability threshold and withdrawals are projected to increase by around 20% by 2040. Current peak-month demand is 63% of the 1-in-25 year baseflow recurrence. For comparison, sub-basins in the Ground Water Protected Area (GWPA) are designated "potentially stressed" when withdrawals reach 75% of the 1-in-25 year baseflow recurrence. This sub-basin contains a well-developed portion of the GWPA in Pennsylvania and a significant portion of the Critical Area No. 2 in New Jersey. The total area under these ground water protection programs amounts to two-thirds (1,150 square miles) of the total area of this sub-basin. While both areas afford the potential for limited ground water development given that projected withdrawals are within the respective regulatory criteria, those areas will remain restricted in terms of supply and continue to be managed in an effort to continue mitigation of ground water resources.

Finally, it is important to note that this analysis does not provide for evaluation of supply and demand at the smaller watershed scale, where localized water availability and distribution problems often complicate the issue.

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VII. Recommendations

This section concludes the report with six key recommendations that will assist in managing the water resources of the Delaware River Basin. Some of these recommendations are specific to the findings of this study and point to geographic areas and water using sectors that require greater attention. Other recommendations indicate where analysis methods, assumptions and water use data – which are the foundations of a water supply and demand assessment – need to be improved to give water resources managers more confidence in the results.

7.1 Improve the Collection and Management of Water Use Data

Reliable and uniform information on the sources and use of water resources in the Delaware River Basin is essential for proper assessment, planning and management of water resources. Data collection and management problems have prevented a more recent assessment of basin-wide water use, although more up-to-date information exists for some portions of the Basin. However, it is not possible to reliably evaluate significant management programs, such as the GWPA in southeastern Pennsylvania in the absence of current and comprehensive water use data. Over the past 10 years, data management has not been a priority and has not received the necessary resources. Such problems are widely acknowledged and are being addressed and it is hoped that more current and accurate assessments will be possible in the future.

7.2 Address Key Areas of Uncertainty

Error and uncertainty exist in almost all water resources datasets. However, this study has highlighted several areas where extra effort to verify assumptions and methodologies could lead to more accurate determinations of supply and demand:

- *Consumptive Use Factor Estimate: Mining.* Relative to other sectors, the consumptive nature of water use for mining and mineral extraction processes is not well understood in the Delaware River Basin. The assessment methodology for this study assumes a consumptive use of 15% of withdrawals for these uses; further study of this sector and refinements to this figure will help to more accurately quantify consumptive water use.
- *Consumptive Use Factor Estimate: Agriculture.* Consumptive use for this sector is better understood than for mining activities but estimates often vary (USGS estimates consumptive use to equal 40-100% of withdrawals[3]).
- *Methodology for determining surface water availability.* Aggregation of demands and surface water availability at the sub-basin scale has several shortcomings. In ongoing evaluations of the availability of surface water, it is critical to perform the analysis based on the location of any new or expanded withdrawals, and the contributing drainage area supporting flow to that point of withdrawal.

7.3 Focus on Most Stressed Sub-basins

As noted in Section VI – Resource Assessment, the sub-basins in which current and projected demands have exceeded, or are approaching, the most conservative benchmarks for ground water and surface water supply are the Upper Estuary and Lower Central. For the Lower Central sub-basin, it may be beneficial to explore alternative measures of assessing surface water availability before concluding that this sub-basin is under stress. It is recommended that the Upper Estuary sub-basin be given a high priority for a more focused evaluation of ground and surface water supplies and projected demand through the year 2040. This recommendation extends to the adjacent Schuylkill Valley sub-basin which has among the highest consumptive use of all sub-basins and contains a significant portion of the Ground Water Protected Area. It should be noted that an important limitation affecting the assessment of both surface and ground water availability to meet demand, is

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[3] Solley, Wayne B. Estimated use of water in the United States in 1995

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the actual location and magnitude of the existing or projected withdrawal along with any existing or potential storage to help offset the effects of the withdrawal. In general, as the size of the study area decreases, it becomes more feasible to develop accurate water budgets, distribution system models and demand projection to assist water resources planning efforts.

7.4 Mitigate Consumptive Use Impacts

The management of consumptive use has long been a key component of DRBC policy, particularly as it relates to use by the thermoelectric power generators. This report highlights the sectors with the largest consumptive use (as a proportion of total consumptive use in the Basin) and recommends that efforts are focused on these sectors to mitigate their impacts. DRBC currently has two main mechanisms to help offset the impacts of consumptive use:

- *A Surface water charging program.* This program collects revenue from surface water users to create, support and rehabilitate storage facilities to provide releases for offsetting consumptive use and large withdrawals.
- *Passby flow requirements.* Docket decisions on surface water allocations often contain a requirement designed to protect low-flows. These decisions require that withdrawals are curtailed, or stopped altogether, under specified flow conditions.

As shown in figure 5.1, the sectors accounting for the greatest proportion of consumptive use are Public Water Supply, thermoelectric power generation, agriculture and industry; collectively they account for nearly 90% of total consumptive use and therefore efforts to reduce use by these sectors would have the largest effect Basin-wide. Although irrigation demand is small at the Basin-wide scale, this sector should also receive attention as it has a high consumptive use *factor (*90%*)*. Therefore, efforts to reduce the magnitude of consumptive use related to such uses will have a beneficial local impact, even if they do not have an effect at the Basin-wide, or regional scale. Methods exist to reduce the magnitude of consumptive use associated with all the use sectors listed above and should be explored; where reduction in consumptive use is not technically or economically feasible, actions to offset or compensate for the consumptive use, such as releases from storage, should be implemented.

7.5 Improve Demand Projections for the Power Sector

Between the base year and the year 2040 the majority (92%) of total increased water demands in the Delaware River Basin are projected to be for thermoelectric power generation. Such significant growth potential warrants further investigation as to where these increases are most likely to occur and if the growth can be accommodated. Within the confines of this study it was not possible to generate growth factors for individual sub-basins; instead a Basin-wide growth factor was developed and applied uniformly for each sub-basin. A key recommendation for future work is to assemble a group of experts from the power generating industry and task them with developing regional demand estimates. Such planning used to be coordinated through the Delaware River Basin Electric Utilities Group who issued Master Citing Studies which projected major water-related electric generating projects 10-15 year ahead. Since deregulation of the industry, this group has disbanded; the last master citing study was conducted in 1989. Another aspect to consider is the relationship between increased generating capacity and increased water demand. The assumption in this study has been that the relationship is fixed; however, new cooling technologies may require less water to be withdrawn and consumed per megawatt of electricity generation.

7.6 Develop and Integrate Instream Flow Criteria

An assessment of freshwater instream flow needs is required to enable water resources management decisions to restore or maintain healthy aquatic ecosystems. Despite the importance of natural hydrologic variation in aquatic, wetland and riparian ecosystems, most ecosystem management and restoration efforts have focused on the known or perceived hydrologic requirements of only one, or at most a few, target aquatic species, potentially neglecting the needs of other species and ecosystem

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processes and functions in general. More progressive approaches move away from a simplistic standard setting approach, typically focused on low flows, and provide for an assessment and understanding of the full range of flow issues (quantity, timing, duration, frequency and rate-of-change of flows). It should be noted that in the Upper Basin debate over instream flow needs has been ongoing as a result of the operation of the New York City water supply reservoirs. An interim Fishery Management Plan is in place to provide minimum flow targets, during normal and drought conditions, for the reservoir tail-waters. Discussions continue toward development of a long-term flexible reservoir release program.

Freshwater instream flow needs to protect aquatic habitat for all areas of the basin still remain to be quantified. The actual instream flow needs may prove to be a considerable fraction of the normal flow, and may bear significantly on the evaluation of the adequacy of existing surface water and ground water sources to meet projected demand. Consistent with objectives in the Basin Plan, instream flow needs need to be better defined and then fully integrated within water resources assessments to complete the picture of supply and demand.

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Appendices

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Appendix I - Demand Forecasting Methodology

Overview:
Water demand projections were made by generating growth factors for each of the eleven water using sectors identified in this study. It is important to note that some projection assumptions (and therefore growth factors) are sub-basin specific. In other words, for a given water use sector, each sub-basin may have a different growth factor. For other sectors, the lack of sufficient data (or sufficient analytical resources and staff time to develop sub-basin specific factors) means that a generic basin-wide growth factor has been used. In all cases the analysis shows results at the sub-basin scale even when growth factors are non-sub-basin specific. Another point to note about the sector categorization is that the term "self-supplied" is implied for all sectors except public water supply. For example, the Industry sector captures all industrial facilities having their own well or surface source of water (self-supplied). There may be additional industrial facilities in the Basin who receive water from a water purveyor; such uses (which tend to be small) are included in the public water supply sector.

Sector Specific Assumptions:
The following section discusses the assumptions used to develop growth factors for each water use sector. Some sectors have been forecast using growth factors developed in the Consumptive Use report, in these cases a detailed methodology for those factors is not provided here; the reader is referred back to that original report.

Agriculture
In the Delaware River Basin, water use for the agricultural sector is not well understood. Although water use for this sector should be monitored and reported, few records exist in DRBC and state databases, especially for Delaware, New York and Pennsylvania. For New Jersey data are reasonably reliable and have been used as a basis from which to extrapolate for the other three Basin states. Therefore, this required an additional step in order to develop base year water use data for the entire Basin. The approach made use of data obtained from the US Census of Agriculture[1]; specifically, data on farmed lands (acres per county) and the percentage of irrigated acres (available only at the state level).. From these two datasets an area of *irrigated acres of farmland* was estimated for each of the Basin counties. Water use coefficients (measured in MG/irrigated acre) for agricultural irrigation were generated using the data from New Jersey; coefficients were calculated by dividing known withdrawals by estimated irrigated acreage. Separate coefficients were generated for a northern and southern portion of the Basin reflecting differences in climate and irrigation demand in these two regions. The regions were established in accordance with the methodology developed in the Consumptive Use report and the reader is referred to that document for further information, including a map of the two regions.

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1 Data were obtained from:

http://www.nass.usda.gov/census/census97/county/farms/index.htm
http://www.nass.usda.gov/census/census97/fris/tbl02.txt

Once Basin-wide base year water use estimates had been generated, further information was obtained from the US Census of Agriculture (http://www.nass.usda.gov/census/) to provide the basis for generating the growth factors. Using information from past censuses (1987 – 2002) on *acres in farmland*, a linear trend was developed and extrapolated to give growth rates for the forecast years (2020 and 2040). As no assumptions were made about changes in the efficiency of irrigation practices over the forecast period (i.e., these were held constant), the growth factors could be applied directly to provide estimates of future water demand. The forecast driver of acres in farmland was chosen in preference to irrigated acres (which show different trends) as the irrigated acreage data was only available as a state-wide figure and not on a county by county basis. If data collection efforts allow, historical county level irrigation data could be used to develop a more accurate forecast driver as water use should more closely correlate with irrigated acres than total farmed acres.

Commercial and Institutional

Growth factors for this sector were taken directly from the Consumptive Use report; the reader is referred to that document for more information.

Public Water Supply

To clarify any confusion, the term public water supply (PWS) is used in this report to refer to any water distribution system that serves the public. The owners of the system may be a public entity (typically referred to as municipal systems) or private (also known as investor owned systems).

Public water supply systems provide water to the public in their residences, but also may supply industries, businesses and some irrigation needs. Because of the mixed end uses of this sector, a true forecast driver of demand would need to reflect some weighted values of population change, expected economic activity and employment in key sectors. These factors are too complex to model in this assessment, but could be investigated further in future work. For the purposes of this study, population growth was used as the sole driver of demand.

Population data at the census block-group level was obtained for the Basin for the years 1990 and 2000. GIS techniques were used to clip census block groups to sub-basin boundaries to get a more accurate estimate of population using watershed boundaries. Using watershed boundaries is not only more applicable for water resources assessments, but has the added benefit that the boundaries do not change over time. Political boundaries do occasionally change and using these can lead to complications when comparing datasets from different census years.

Three alternative growth scenarios were developed based on the census population datasets. One scenario projects population growth based on extrapolating a linear trend relationship between the two census years. The second scenario assumes the relationship between the two census years to be best described by an exponential curve. A third set of population projections were developed by calculating the mid-point between these two

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scenarios. The three scenarios show different population numbers; table I-1 shows how population growth would occur (for total Basin population) according to each scenario.

Table I-1 DRB Population Totals based on alternative projection methods

1990	2000	2020	2040	Projection Type
7,322,093	7,758,465	8,629,188	9,501,911	Linear projection
		8,824,340 (2.3%)	10,272,514 (8.1%)	Exponential projection
		8,726,764 (1.1%)	9,887,212 (4.1%)	Mid-Point projection

Note: Population totals for 2020 and 2040 are based on a summation of individual sub-basin populations that have been individually forecast and are not calculated directly from total basin population figures. The figures in parenthesis show how divergent the projections are by showing the percentage difference relative to the linear projection line.

In order to verify these projection scenarios they were compared to population projections developed by the Delaware Valley Regional Planning Commission (DVRPC). The DVRPC covers a 9 county area all of which are in (or partially in) the Delaware River basin. Figure I-1 shows a comparison of the DVRPC population projections versus the three DRBC population projections. Figure I-1 was developed to verify the population projection methods against other published methods. Therefore total county area population figures have been used in this evaluation.

Figure I-1 shows good agreement between the DVRPC methodology and the techniques used to forecast population in this study. The mid-point forecast fits closely to the DVRPC projections ($r^2 = 0.998$). It should be noted that although these methods show close agreement for the 9-county area in aggregate, the projection methods do not show consistent agreement for each county. The projection methods used in this study, which rely solely on the past to be a predictor of the future, do not take into account practical limits to population growth such as those areas which may already be approaching build-out conditions.

As the mid-point forecast method showed greatest agreement with other published data, this method of developing population projections was chosen to generate growth factors for public water supply and for the domestic water use sector.

<u>Domestic</u>

This is an estimate the water use by those who obtain their water supply from individual residential wells, rather than from a water purveyor. Because no water use records are collected by households with individual wells the use by this sector is based on an estimate derived from surrogate data. Primarily the data sources used are state estimates of per capita residential water use and population data from the US Census. Estimates for this sector were updated in this report from those presented in the Consumptive Use report due to the availability of new Census data from the year 2000. In previous census years information has been collected on the source of each household's water supply (domestic well versus water purveyor). In 2000, no information was gathered on this

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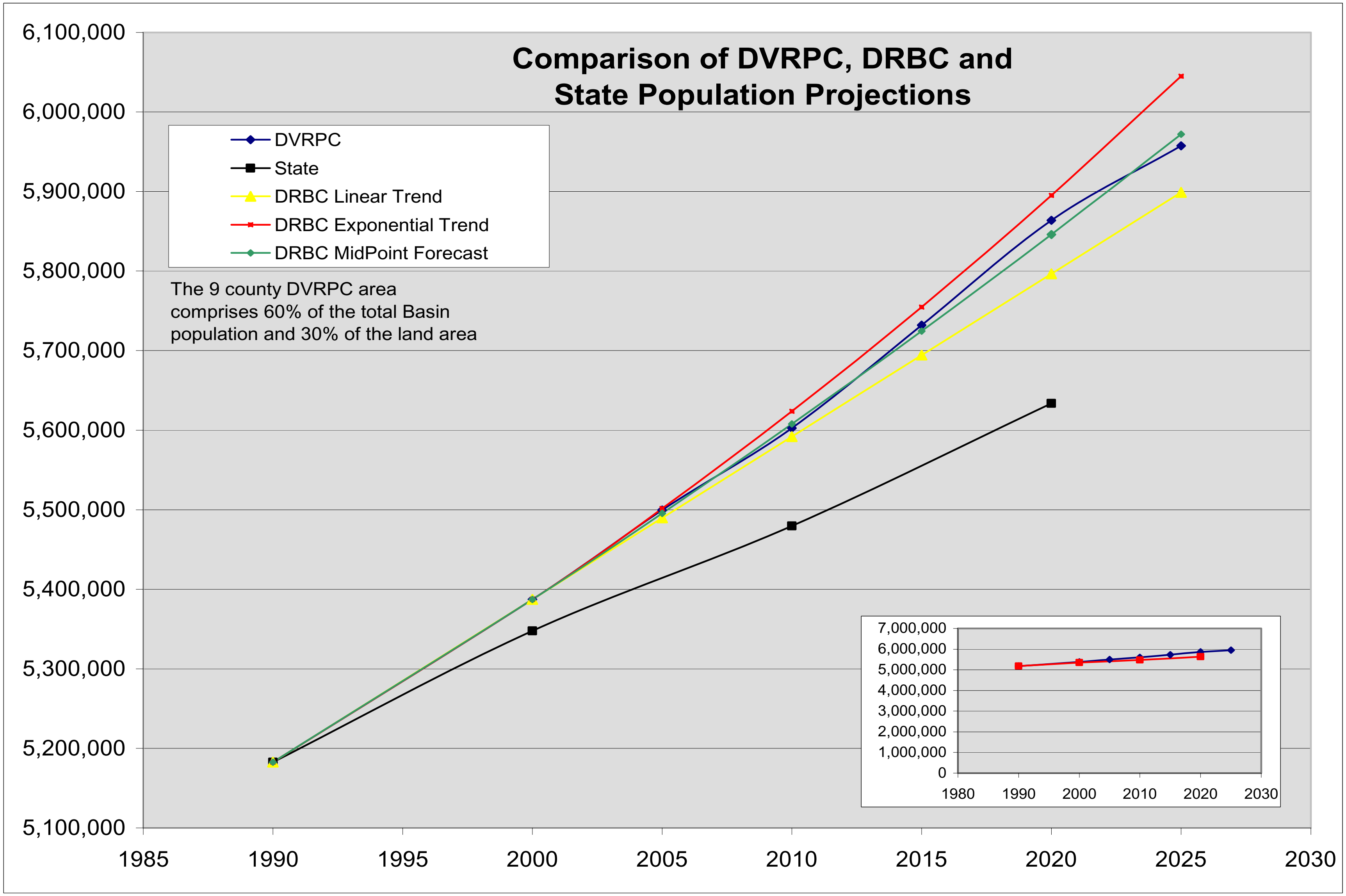
Figure I-1 Comparison of DVRPC, DRBC and State Population Projections



Also shown in Figure I-1 are state projections for the selected counties in the DVRPC area. State projections for Pennsylvania have not been updated based on US Census 2000 data, therefore year 2000 estimates for Pennsylvania counties have projected values for year 2000. New Jersey projections have been updated based on US Census 2000 data.

issue and therefore 1990 data is the most recent year for which reliable data exist. The approach to revising these estimates was to apply the proportion of domestic wells in 1990 (by census block group) to year 2000 block group data, thereby generating new totals for the number of households (and therefore population) on domestic wells. Estimates for the base years of 1995 and 1996 were made by interpolating along a linear relationship between the census years.

The key driver for determining future demand for this sector is population growth. Projections were made using the same growth factors for population as used and described in the section on Public Water Supply.

Mining

Water use for the mining sector is not well understood in the Delaware River Basin. No attempt has been made to forecast demands for this sector; a zero growth factor has been applied, resulting in water use for the forecast years being equal to base year values.

Non Agricultural Irrigation

Growth factors for this sector were taken directly from the Consumptive Use report; the reader is referred to that document for more information.

Industry

Industrial water use encompasses a vast range of activities, from large-scale heavy industry, such as steel making, to hi-tech component manufacturing. The diverse nature of water needs for industry adds to the complexity of the forecasting for this sector. A possible approach would be to use Standard Industrial Classification (SIC) or the newer North America Industry Classification System (NACIS) for which per unit (or per employee) water use coefficients could be derived (and have already been derived in other studies[2] in conjunction with economic growth estimates for these sub-sectors. However, the water use data are not currently broken down by any such classification system. Such an analysis would require significant resources and analytical effort and was not possible for this study (nor was it attempted in the Consumptive Use study). For the purposes of this report a zero-growth factor has been applied to this sector, resulting in water use for the forecast years being equal to base year values. Given recent trends, i.e., the decline in traditional heavy industry and hence a decline in water use for the industrial sector in the Basin, the zero-growth scenario may represent a conservative planning estimate.

Hydroelectric Power

Only two hydroelectric power facilities (subject to DRBC review and monitoring programs) are located in the Basin. No attempt has been made to forecast demands for this sector; a zero growth factor has been applied, resulting in water use for the forecast years being equal to base year values.

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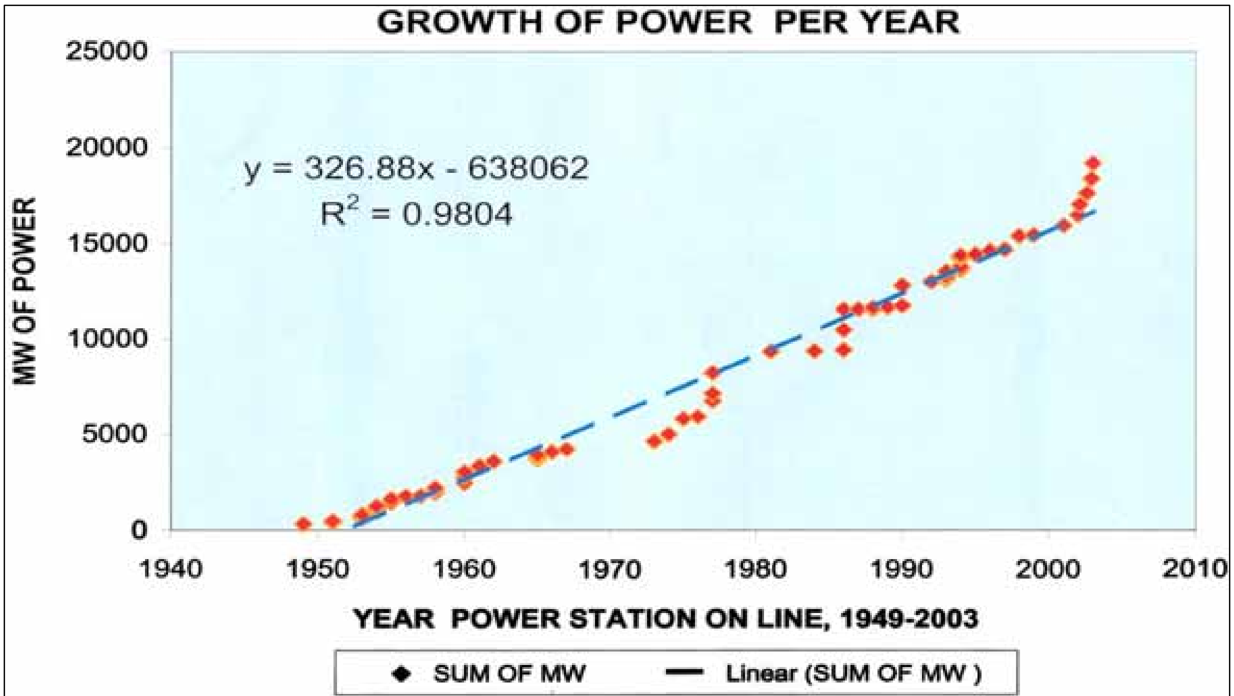
[2] Regional Water Demand by Sector, Greater Vancouver Regional District, Policy and Planning Department, Regional Utility Planning, Burnaby, B.C., September 1999, Table 19-Regional Significant End Uses (1997)

Thermoelectric Power

The original forecast methodology and assumptions used to produce the Consumptive Use report indicated that water demand for thermoelectric power generation will triple between the base year and 2040. Such significant growth potential led DRBC staff to reassess water use trends for the thermoelectric power sector, to determine whether increases of this magnitude are feasible. Figure I-2 shows the results of previous analytical work to examine the rate of growth in water demand for the power sector.

Figure I-2 Time series analysis estimating growth rate of power generation in the DRB



The regression analysis shown in Figure I-2 was the key driver in developing previous water demand forecasts for the power sector. However, this method may have resulted in an over-estimated growth rate for water demand as it does not consider the retirement of existing facilities.

As part of the updated staff analysis, a regression equation was developed by analyzing actual annual water use records for thermoelectric power generation from (1990 to 2001). The new (linear) regression equation (as shown in Figure I-3) was then used to forecast future demand. Additional information on power generation demands was obtained from the Energy Information Administration (EIA) http://www.eia.doe.gov, part of the US Department of Energy (DoE). This additional information includes a projection (to 2025) of growth in net Electricity Generating Capacity (new construction minus retired facilities). The revised analysis produces a forecast scenario for this study that is driven by the regression equation. Figure I-3 shows both the regression equation and the EIA projections; these two independent data sources project similar rates of growth (at least to 2025). The EIA projections provide a useful verification that the projected growth rates are plausible.

It should be noted that the EIA forecasts are based on data specific to the Mid-Atlantic Area Council which comprises the electricity generating facilities located in Pennsylvania, New Jersey and Maryland. For the growth rates defined by the EIA projections to be considered relevant for the Delaware River Basin it would have to be assumed that the relative mix of power generating sources in the Basin (i.e., coal, nuclear, etc) would not be significantly different from that of the Mid-Atlantic Area. This assumption has not been verified.

Ski

No attempt has been made to forecast demands for this sector; a zero growth factor has been applied, resulting in water use for the forecast years being equal to base year values.

Other

Withdrawals that could not be assigned to a water use sector were place in this category. No attempt has been made to forecast demands for this sector; a zero growth factor has been applied, resulting in water use for the forecast years being equal to base year values.

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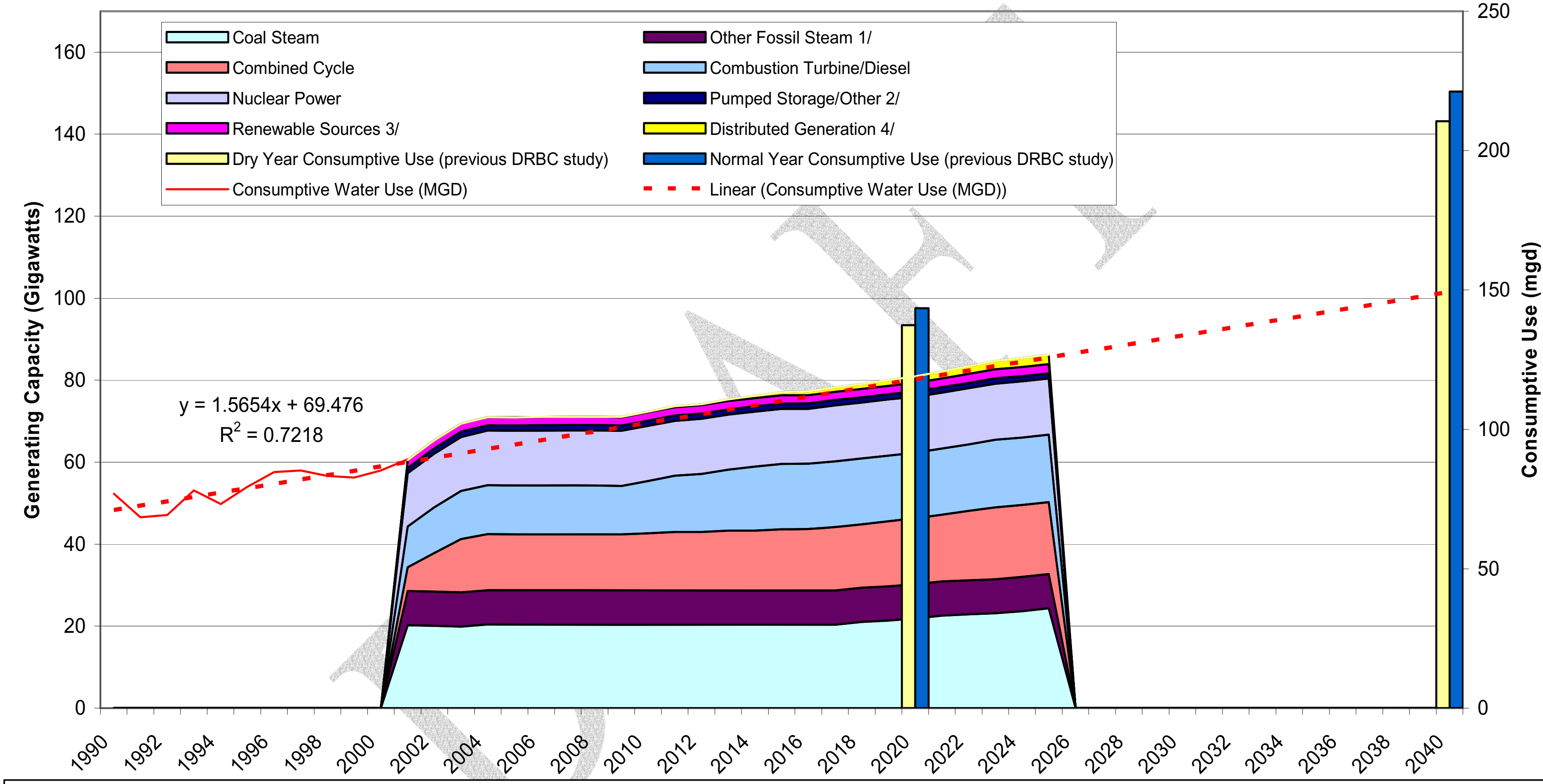
Figure I-3. Thermoelectric Power Generation & Water Demand Projections



1/ Includes oil-, gas-, and dual-fired capacity.
2/ Other includes methane, propane gas, and blast furnace gas for utilities; and hydrogen, sulfur, batteries, chemicals, fish oil, and spent sulfite liquor.
3/ Includes conventional hydroelectric, geothermal, wood, wood waste, municipal solid waste, other biomass, solar thermal, photovoltaics, and wind power.
4/ Primarily peak-load capacity fueled by natural gas.
Sources: 2002 (except for prices and nonutility data): Energy Information Administration (EIA), Annual Energy Review 2001, DOE/EIA-0384(2001) (Washington, DC, October 2002).

Known water use (1990-2000) is shown by the solid red line. Projections used in this report are based on an extrapolation of the linear regression Consumptive Use estimates shown above (blue and yellow bars) reflect previous DRBC projections of water demand for this sector.

Appendix II - Consumptive Use Estimates

Estimates of consumptive use for each use sector have been obtained from several sources. The sectors and their consumptive use factors are shown in Table II-1.

Table II-1 Consumptive Use factors by sector

Use Sector	Consumptive Use (% of total withdrawal)
Agriculture[1]	90%
Mining[2]	15%
Power (thermoelectric)[3]	Site-specific calculation
Power (hydroelectric)[4]	0%
Commercial/Institutional[5]	10%
Golf / Irrigation[1]	90%
Public Water Supply[6]	10%
Domestic[6]	10%
Ski[7]	22%
Industrial[3]	Site-specific calculation
Other[8]	5%

The information in Table II-1 is primarily obtained from engineering and hydrologic reports accompanying DRBC docket applications. Consumptive use information was supplemented with data from the DRBC surface water supply charging program. In addition, data on consumptive use factors by water use category was confirmed with published information from the USGS, DRBC staff investigations and various State Water Use reports, further detail is given below.

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Explanation of Notes in Table II-1

1. A sector-wide assumption, taken from: Measuring and Estimating Consumptive Use of the Great Lakes Water. Great Lakes Commission, 2003.
http://www.glc.org/wateruse/wrmdss/finalreport/pdf/CU_Briefing.pdf See also:
http://www.ers.usda.gov/Briefing/WaterUse/Questions/qa2.htm

2. A sector-wide assumption consistent with the range of consumptive use coefficients documented in the USGS report: Estimated Use of Water in the United States in 1995

3. For both the thermoelectric power and industrial sectors, site-specific consumptive use information was applied to each withdrawal value based on DRBC docket applications. There are two main drivers for applying this greater level of accuracy to these sectors:
- Thermoelectric power and industrial use combined account for approximately three quarters of total withdrawals in the Delaware River Basin.
- Cooling methods and industrial processes can vary greatly in their individual consumptive use characteristics depending on the type of systems employed. Illustrating this, a review of Delaware River Basin water users from these two sectors revealed that consumptive use percentages ranged from 0.37% to 100%

4. Zero consumptive use assumed. Evaporation from reservoirs created as a result of the construction of hydroelectric power generating facilities has not been considered in this report.

5. This sector has been assigned a consumptive use factor equivalent to that used for the public water supply sector.
6. A sector-wide value has been applied based on assumptions used in previous DRBC studies, including the Consumptive Use report. The 10% value is often quoted but infrequently referenced. A review of available literature on the subject revealed no definitive reference for this value; however, its use has been justified by (unpublished) DRBC staff investigations developed specifically for the purpose of this study.
7. Previous DRBC studies (as documented in the Consumptive Use report) support the use of this sector-wide assumption.
8. Sector-wide assumption based on a weighted average the consumptive use factors of other sectors.

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Appendix III Results from analysis of 146 USGS gauging stations in the Delaware River Basin

Station	Station Name	State / Del Riv.	Record Period	Ave Daily Flow (cfs)	Min Flow (cfs)	Min Flow Date	Max Flow (cfs)	Max Flow Date	Flow Exceedence values			Drainage Area (sq mile)	Ave Flow (cfs / sq mile	Low flow (95% E) (cfs / sq mile)	lowest 7-day ave. flow - drought of record (cfs / sq
									10% E (cfs)	50% E (cfs)	95% E (cfs)				
01413500	East Br Delaware R At Margaretville NY	DR	1938 - 2002	305.9	6.0	9/25/1964	11,300.0	1/19/1996	694.0	168.0	20.0	163.0	1.877	0.123	0.166
01417000	East Branch Delaware River At Downsville NY	DR	1942 - 2002	304.1	0.6	10/10/1954	17,700.0	3/22/1948	784.3	67.0	7.1	372.0	0.818	0.019	0.129
01417500	East Br Delaware River At Harvard NY	DR	1978 - 2002	320.2	32.0	9/26/1985	10,800.0	5/30/1984	639.0	158.0	76.0	458.0	0.699	0.166	#N/A
01420980	E Br Delaware River Abv Read Cr At Fishs Eddy NY	DR	1914 - 2002	1,355.1	68.0	8/28/1949	38,600.0	3/18/1936	3,060.0	731.0	174.0	766.0	1.769	0.227	0.188
01421000	East Br Delaware R At Fishs Eddy NY	DR	1914 - 2000	1,367.4	68.0	8/28/1949	38,600.0	3/18/1936	3,100.0	740.0	176.0	784.0	1.744	0.224	0.184
01421900	W Br Delaware River Upstream From Delhi NY	DR	1997 - 2002	222.4	8.1	9/13/2001	3,860.0	1/9/1998	532.0	120.0	13.0	134.0	1.659	0.097	0.164
01423000	West Branch Delaware River At Walton NY	DR	1951 - 2002	577.4	13.0	9/27/1964	16,000.0	3/15/1986	1,330.0	310.0	38.0	332.0	1.739	0.114	0.166
01425000	West Br Delaware River At Stilesville NY	DR	1953 - 2002	615.6	7.2	2/8/1966	14,800.0	3/16/1986	1,500.0	327.5	15.0	456.0	1.350	0.033	0.136
01426500	West Branch Delaware River At Hale Eddy NY	DR	1914 - 2002	937.1	18.0	10/20/1963	24,500.0	3/22/1948	2,120.0	520.0	86.0	595.0	1.575	0.145	0.121
01427510	Delaware River At Callicoon NY	DR	1976 - 2002	2,626.4	312.0	8/23/1985	54,800.0	3/15/1986	5,990.0	1,390.0	683.1	1,820.0	1.443	0.375	#N/A
01428500	Delaware R Above Lackawaxen R Nr Barryville NY	DR	1941 - 2002	3,215.7	126.0	9/4/1953	85,000.0	8/19/1955	7,180.0	1,700.0	596.0	2,020.0	1.592	0.295	0.159
01434000	Delaware River At Port Jervis NY	DR	1905 - 2002	5,161.7	175.0	9/23/1908	163,000.0	8/19/1955	11,200.0	3,060.0	929.7	3,070.0	1.681	0.303	0.136
01438500	Delaware River At Montague NJ	DR	1940 - 2001	5,670.1	412.0	8/23/1954	187,000.0	8/19/1955	12,000.0	3,400.0	1,340.0	3,480.0	1.629	0.385	0.166
01440200	Delaware River Near Delaware Water Gap PA	DR	1965 - 1995	6,262.3	580.0	7/8/1965	96,000.0	3/16/1986	13,100.0	3,850.0	1,680.0	3,850.0	1.627	0.436	#N/A
01446500	Delaware River At Belvidere NJ	DR	1923 - 2001	7,816.6	610.0	8/25/1954	184,000.0	8/19/1955	16,600.0	5,000.0	1,570.0	4,535.0	1.724	0.346	0.166
01457500	Delaware River At Riegelsville NJ	DR	1907 - 1970	10,831.2	906.0	9/20/1908	228,000.0	3/19/1936	23,000.0	7,170.0	1,990.0	6,328.0	1.712	0.314	0.226
01463500	Delaware River At Trenton NJ	DR	1913 - 2001	11,625.8	1,240.0	7/10/1965	279,000.0	8/20/1955	24,500.0	7,830.0	2,440.0	6,780.0	1.715	0.360	0.183
01414000	Platte Kill At Dunraven NY	NY	1997 - 2002	59.9	1.9	9/10/1997	1,070.0	1/9/1998	141.0	36.0	3.3	34.9	1.716	0.095	#N/A
01414500	Mill Brook Near Dunraven NY	NY	1938 - 2002	54.7	1.2	9/26/1939	2,080.0	1/19/1996	120.0	32.0	3.9	25.2	2.171	0.155	0.198
01415000	Tremper Kill Near Andes NY	NY	1938 - 2002	58.1	0.6	9/23/1964	1,830.0	3/22/1948	133.0	33.0	3.4	33.2	1.751	0.102	0.114
01420500	Beaver Kill At Cooks Falls NY	NY	1915 - 2002	557.4	23.0	9/25/1964	16,700.0	1/19/1996	1,230.0	320.0	61.0	241.0	2.313	0.253	0.398
01422500	Little Delaware River Near Delhi NY	NY	1998 - 2002	89.4	2.1	9/13/2001	1,120.0	1/9/1998	205.5	50.0	4.0	49.8	1.795	0.080	0.191
01425675	Oquaga Creek Near North Sanford NY	NY	1970 - 1980	9.1	0.1	8/19/1971	237.0	3/5/1979	21.0	4.7	0.5	4.7	1.947	0.107	#N/A
01426000	Oquaga Creek At Deposit NY	NY	1941 - 1972	109.0	0.9	8/4/1955	3,460.0	3/10/1964	254.0	50.0	3.7	67.6	1.612	0.055	0.111
01427500	Callicoon Creek At Callicoon NY	NY	1941 - 1981	176.8	4.6	7/31/1965	5,550.0	8/17/1947	401.0	86.0	12.0	110.0	1.608	0.109	0.136
01428000	Tenmile River At Tusten NY	NY	1947 - 1972	64.7	1.1	11/16/1964	3,340.0	8/19/1955	155.0	32.0	3.9	45.6	1.419	0.086	0.145
01433500	Mongaup River Near Mongaup NY	NY	1940 - 1994	344.4	9.4	9/1/1958	12,300.0	8/19/1955	713.0	282.0	28.0	200.0	1.722	0.140	0.225
01434017	East Br Neversink River Nr Claryville NY	NY	1992 - 2002	68.0	5.9	9/1/1993	1,220.0	1/8/1998	128.0	43.0	9.9	22.9	2.968	0.432	#N/A
01434021	W Br Neversink R At Winnisook L Nr Frost Valley NY	NY	1991 - 2002	2.4	0.1	8/8/1991	76.0	5/10/1998	4.5	1.1	0.2	0.8	3.086	0.273	#N/A
01434025	Biscuit Bk Above Pigeon Bk At Frost Valley NY	NY	1984 - 2002	10.2	0.3	9/8/1991	431.0	4/4/1987	20.0	6.0	0.9	3.7	2.742	0.228	#N/A
01434092	Shelter Creek Below Dry Creek Nr Frost Valley NY	NY	1993 - 2002	1.9	0.0	9/10/2002	52.0	1/19/1996	4.0	1.1	0.1	0.6	3.068	0.177	#N/A
01434498	West Branch Neversink R At ClaryvillLE	NY	1992 - 2002	103.4	6.8	10/6/1998	3,100.0	1/19/1996	195.3	62.0	12.0	33.8	3.060	0.355	#N/A
01435000	Neversink River Near Claryville NY	NY	1952 - 2002	187.5	7.5	9/25/1964	6,090.0	2/20/1981	371.0	114.0	22.0	66.6	2.816	0.330	0.556
01436000	Neversink River At Neversink NY	NY	1942 - 2002	90.6	0.0	10/28/1954	5,800.0	12/30/1948	236.0	27.0	4.8	92.6	0.979	0.052	0.572
01436500	Neversink River At Woodbourne NY	NY	1978 - 1992	79.9	17.0	3/14/1989	3,020.0	5/30/1984	118.0	58.0	28.0	113.0	0.707	0.248	0.496
01436690	Neversink River At Bridgeville NY	NY	1993 - 2002	195.6	25.0	1/19/2002	4,170.0	4/17/1993	366.8	119.0	51.0	171.0	1.144	0.298	#N/A
01437500	Neversink River At Godeffroy NY	NY	1938 - 2002	470.5	32.0	8/17/1965	15,900.0	8/19/1955	1,010.0	290.0	83.0	307.0	1.532	0.270	0.339
0142400103	Trout Creek Near Trout Creek NY	NY	1997 - 2002	32.5	0.4	8/12/1997	500.0	1/24/1999	86.0	17.0	1.1	20.2	1.610	0.054	#N/A
0143400680	E Br Neversink R Northeast Of Denning NY	NY	1991 - 2002	29.5	2.1	8/8/1991	701.0	10/21/1995	54.0	18.0	3.9	8.9	3.307	0.437	#N/A
01428750	West Branch Lackawaxen River Near Aldenville, PA	PA	1987 - 2002	77.4	4.0	8/6/1999	1,600.0	1/19/1996	173.7	41.0	7.7	40.6	1.907	0.190	#N/A
01429000	West Branch Lackawaxen River At Prompton, PA	PA	1945 - 2002	107.5	0.0	8/25/1960	2,440.0	8/19/1955	246.0	58.0	10.0	59.7	1.801	0.168	0.218
01429500	Dyberry Creek Near Honesdale, PA	PA	1944 - 2002	112.7	1.2	7/29/1970	5,880.0	7/10/1952	250.0	56.0	7.0	64.6	1.745	0.108	0.170
01430000	Lackawaxen River Near Honesdale, PA	PA	1986 - 2002	280.8	9.6	9/17/1991	6,280.0	3/15/1986	615.2	160.0	23.0	164.0	1.712	0.140	0.159
01431500	Lackawaxen River At Hawley, PA	PA	1939 - 2002	491.2	14.0	8/13/1999	28,100.0	5/23/1942	1,130.0	250.0	40.0	290.0	1.694	0.138	0.131
01432000	Wallenpaupack Creek At Wilsonville, PA	PA	1910 - 2002	365.9	0.0	11/17/2002	9,650.0	5/25/1996	915.0	240.0	0.0	228.0	1.605	0.000	0.000
01439500	Bush Kill At Shoemakers, PA	PA	1909 - 1946	235.2	4.0	9/26/1932	4,170.0	3/18/1936	510.2	170.0	20.9	117.0	2.010	0.179	0.145
01440400	Brodhead Creek Near Analomink, PA	PA	1958 - 2002	134.2	5.1	8/13/1999	6,070.0	7/28/1969	291.0	84.0	12.0	65.9	2.036	0.182	0.197
01442500	Brodhead Creek At Minisink Hills, PA	PA	1951 - 2002	553.8	30.0	9/27/1964	30,500.0	8/19/1955	1,190.0	346.0	72.0	259.0	2.138	0.278	0.274
01447500	Lehigh River At Stoddartsville, PA	PA	1944 - 2002	187.4	7.0	9/27/1964	18,900.0	8/19/1955	387.0	127.0	23.0	91.7	2.044	0.251	0.087
01447680	Tunkhannock Creek Near Long Pond, PA	PA	1966 - 2002	44.0	1.4	8/12/1999	643.0	4/6/1984	89.0	31.0	7.6	20.0	2.201	0.380	#N/A

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Appendix III (cont'd) Results from analysis of 146 USGS gauging stations in the Delaware River Basin

Station	Station Name	State / Del Riv.	Record Period	Ave Daily Flow (cfs)	Min Flow (cfs)	Min Flow Date	Max Flow (cfs)	Max Flow Date	Flow Exceedence values			Drainage Area (sq mile)	Ave Flow (cfs / sq mile	Low flow (95% E) (cfs / sq mile)	lowest 7-day ave. flow - drought of record (cfs / sq mile)
									10% E (cfs)	50% E (cfs)	95% E (cfs)				
01447720	Tobyhanna Creek Near Blakeslee, PA	PA	1962 - 2002	261.4	21.0	9/4/1999	5,540.0	4/6/1984	527.0	177.0	44.0	118.0	2.215	0.373	#N/A
01447800	Lehigh R Bl Francis E Walter Res Nr White Haven PA	PA	1958 - 2002	619.6	22.0	7/23/1965	11,000.0	1/29/1996	1,315.0	411.0	74.0	290.0	2.136	0.255	0.141
01449000	Lehigh River At Lehighton, PA	PA	1983 - 2002	1,273.2	104.0	8/30/1999	15,100.0	4/16/1983	2,610.0	877.0	223.0	591.0	2.154	0.377	#N/A
01449360	Pohopoco Creek At Kresgeville, PA	PA	1967 - 2002	101.1	9.9	8/7/1999	1,550.0	4/16/1983	199.0	73.0	22.0	49.9	2.025	0.441	#N/A
01449500	Wild Creek At Hatchery, PA	PA	1941 - 1978	35.5	1.0	8/5/1958	812.0	5/23/1942	71.0	29.0	4.0	16.8	2.112	0.238	0.101
01449800	Pohopoco Cr Bl Beltzville Dam Nr Parryville, PA	PA	1968 - 2002	163.4	9.5	10/12/1993	1,470.0	4/15/1993	367.0	103.0	30.0	96.4	1.695	0.311	#N/A
01450500	Aquashicola Creek At Palmerton, PA	PA	1940 - 2002	150.2	9.1	9/15/1964	4,680.0	7/10/1945	301.0	99.0	26.0	76.7	1.959	0.339	0.183
01451000	Lehigh River At Walnutport, PA	PA	1947 - 2002	1,847.2	134.0	9/18/1964	62,400.0	8/19/1955	3,830.0	1,290.0	325.0	889.0	2.078	0.366	0.151
01451500	Little Lehigh Creek Near Allentown, PA	PA	1946 - 2002	99.3	23.0	12/24/1965	4,050.0	7/7/1984	170.0	77.0	34.0	80.8	1.229	0.421	0.371
01451650	Little Lehigh Creek At Tenth St. Br. At Allentown	PA	1987 - 2002	120.4	23.0	8/7/1999	5,200.0	9/9/1987	200.0	94.0	46.0	98.2	1.226	0.468	#N/A
01451800	Jordan Creek Near Schnecksville, PA	PA	1967 - 2002	92.0	0.5	8/7/1999	2,800.0	9/9/1987	204.0	48.0	7.2	53.0	1.737	0.136	#N/A
01452000	Jordan Creek At Allentown, PA	PA	1945 - 2002	114.6	0.0	9/11/1966	6,650.0	9/9/1987	249.0	60.0	7.5	75.8	1.512	0.099	0.025
01452500	Monocacy Creek At Bethlehem, PA	PA	1949 - 2002	53.1	5.2	1/1/1966	1,200.0	1/26/1978	96.0	41.0	17.0	44.5	1.192	0.382	0.427
01453000	Lehigh River At Bethlehem, PA	PA	1910 - 2002	2,352.6	160.0	10/15/1910	70,400.0	8/19/1955	4,690.0	1,670.0	510.0	1,279.0	1.839	0.399	0.207
01454700	Lehigh River At Glendon, PA	PA	1967 - 2002	2,814.9	330.0	2/1/1981	44,300.0	6/23/1972	5,520.0	2,060.0	720.0	1,359.0	2.071	0.530	#N/A
01459500	Tohickon Creek Near Pipersville, PA	PA	1936 - 2002	148.6	0.1	10/6/1941	6,820.0	9/12/1960	352.0	41.0	3.0	97.4	1.526	0.031	0.012
01464645	Nb Neshaminy Cr Bl Lake Galena Nr New Britain, PA	PA	1986 - 2002	28.7	3.1	12/30/1989	1,040.0	9/17/1999	51.0	23.0	4.2	16.2	1.773	0.259	#N/A
01464720	Nb Neshaminy Creek At Chalfont, PA	PA	1991 - 2002	40.2	2.3	8/18/1991	3,300.0	10/19/1996	80.0	15.0	4.7	31.5	1.276	0.149	#N/A
01465500	Neshaminy Creek Near Langhorne, PA	PA	1935 - 2002	297.0	2.9	9/8/1957	27,300.0	8/19/1955	575.0	140.0	23.0	210.0	1.414	0.110	0.090
01465770	Poquessing Creek At Trevose Road, Phila., PA	PA	1965 - 1980	7.6	0.1	8/31/1966	277.0	1/21/1979	12.0	3.8	1.0	5.1	1.494	0.197	#N/A
01465798	Poquessing Creek At Grant Ave. At Philadelphia, PA	PA	1966 - 2002	32.3	0.2	8/3/1999	2,490.0	9/16/1999	61.0	12.0	3.3	21.4	1.508	0.154	#N/A
01467042	Pennypack Creek At Pine Road, At Philadelphia, PA	PA	1965 - 1980	68.8	6.8	9/11/1966	1,830.0	1/21/1979	119.0	44.0	14.0	37.9	1.816	0.369	#N/A
01467048	Pennypack Cr At Lower Rhawn St Bdg, Phila., PA	PA	1966 - 1993	92.0	8.4	9/12/1966	3,040.0	9/27/1985	174.0	50.0	18.0	49.8	1.846	0.361	#N/A
01467087	Frankford Creek At Castor Ave, Philadelphia, PA	PA	1983 - 2002	40.4	0.4	9/25/2002	3,140.0	9/16/1999	78.0	16.0	5.0	30.4	1.330	0.164	#N/A
01467500	Schuylkill River At Pottsville, PA	PA	1944 - 1968	98.5	13.0	11/23/1964	2,660.0	7/19/1945	200.9	65.0	23.0	53.4	1.844	0.431	0.618
01468500	Schuylkill River At Landingville, PA	PA	1974 - 2002	273.7	32.0	1/24/1981	4,660.0	4/16/1983	530.0	194.0	65.0	133.0	2.058	0.489	#N/A
01469500	Little Schuylkill River At Tamaqua, PA	PA	1920 - 2002	84.6	2.9	9/2/1966	3,600.0	9/30/1924	180.0	51.0	9.3	42.9	1.973	0.217	0.233
01470500	Schuylkill River At Berne, PA	PA	1948 - 2002	708.5	40.0	9/2/1949	26,000.0	6/23/1972	1,470.0	449.0	125.0	355.0	1.996	0.352	0.251
01470720	Maiden Creek Tributary At Lenhartsville, PA	PA	1966 - 1980	12.6	0.0	9/2/1966	740.0	6/22/1972	30.0	5.9	1.0	7.5	1.693	0.134	#N/A
01470779	Tulpehocken Creek Near Bernville, PA	PA	1975 - 2002	105.7	15.0	9/8/2002	2,140.0	1/26/1978	177.0	82.0	33.0	66.5	1.589	0.496	#N/A
01470853	Furnace Creek At Robesonia, PA	PA	1983 - 2002	6.6	0.1	9/11/1983	139.0	12/5/1993	13.0	4.5	1.1	4.2	1.581	0.263	#N/A
01470960	Tulpehocken Cr At Blue Marsh Damsite Near Reading	PA	1966 - 2002	272.2	23.0	9/13/1966	11,000.0	6/23/1972	535.0	175.0	54.0	175.0	1.555	0.309	#N/A
01471000	Tulpehocken Creek Near Reading, PA	PA	1951 - 2002	311.6	27.0	9/24/1991	12,000.0	6/23/1972	607.0	210.0	65.0	211.0	1.477	0.308	0.156
01471510	Schuylkill River At Reading, PA	PA	1978 - 2002	1,566.7	180.0	12/26/1980	24,700.0	1/25/1979	3,190.0	1,050.0	315.0	880.0	1.780	0.358	#N/A
01471980	Manatawny Creek Near Pottstown, PA	PA	1975 - 2002	127.8	11.0	8/7/1999	3,010.0	7/7/1984	238.4	82.0	28.0	85.5	1.495	0.327	#N/A
01472000	Schuylkill River At Pottstown, PA	PA	1928 - 2002	1,892.4	175.0	9/19/1932	71,200.0	6/23/1972	3,810.0	1,280.0	382.0	1,147.0	1.650	0.333	0.179
01472157	French Creek Near Phoenixville, PA	PA	1969 - 2002	87.0	7.1	8/7/1999	4,530.0	6/22/1972	167.0	55.0	16.0	59.1	1.472	0.271	#N/A
01472174	Pickering Creek Near Chester Springs, PA	PA	1968 - 1982	10.3	1.0	9/2/1969	500.0	1/26/1978	16.0	6.5	2.3	6.0	1.717	0.385	#N/A
01472198	Perkiomen Creek At East Greenville, PA	PA	1982 - 2002	59.9	4.2	8/24/1985	2,800.0	1/19/1996	112.0	36.0	12.0	38.0	1.575	0.316	#N/A
01472199	West Branch Perkiomen Creek At Hillegass, PA	PA	1982 - 2002	37.0	3.0	8/7/1999	1,760.0	1/19/1996	72.0	23.0	6.6	23.0	1.609	0.287	#N/A
01472620	East Branch Perkiomen Creek Near Dublin, PA	PA	1984 - 2002	31.6	0.0	9/24/2002	528.0	9/16/1999	62.0	26.0	0.1	4.1	7.814	0.027	#N/A
01472810	East Branch Perkiomen Creek Near Schwenksville, PA	PA	1992 - 2002	122.1	3.5	9/25/2002	6,020.0	1/19/1996	193.0	72.0	42.0	58.7	2.080	0.716	#N/A
01473000	Perkiomen Creek At Graterford, PA	PA	1915 - 2002	400.0	3.8	6/25/1921	18,600.0	7/9/1935	818.9	174.0	40.0	279.0	1.434	0.143	0.179
01473120	Skippack Creek Near Collegeville, PA	PA	1967 - 1993	79.0	0.7	10/3/1968	6,600.0	9/13/1971	142.0	28.0	4.5	53.7	1.472	0.084	#N/A
01473169	Valley Creek At Pa Turnpike Br Near Valley Forge	PA	1983 - 2002	31.4	7.4	7/13/1999	2,020.0	9/16/1999	51.0	23.0	12.0	20.8	1.511	0.577	#N/A
01473950	Wissahickon Cr At Bells Mill Rd, Phila., PA	PA	1966 - 1980	85.7	7.9	8/29/1966	2,390.0	12/21/1973	146.0	51.0	17.0	53.6	1.600	0.317	#N/A
01474000	Wissahickon Creek At Mouth, Philadelphia, PA	PA	1966 - 2002	103.6	8.8	8/30/1995	5,560.0	9/16/1999	178.0	60.0	24.0	64.0	1.619	0.375	#N/A
01474500	Schuylkill River At Philadelphia, PA	PA	1932 - 2002	2,715.9	0.6	9/2/1966	93,400.0	6/23/1972	5,820.0	1,670.0	289.0	1,893.0	1.435	0.153	0.010
01475510	Darby Creek Near Darby, PA	PA	1965 - 1989	64.9	8.6	9/17/1986	1,770.0	9/13/1971	107.0	45.0	17.0	37.4	1.735	0.455	#N/A

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Appendix III (cont'd) Results from analysis of 146 USGS gauging stations in the Delaware River Basin

Station	Station Name	State / Del Riv.	Record Period	Ave Daily Flow (cfs)	Min Flow (cfs)	Min Flow Date	Max Flow (cfs)	Max Flow Date	Flow Exceedence values 10% E (cfs)	50% E (cfs)	95% E (cfs)	Drainage Area (sq mile)	Ave Flow (cfs / sq mile	Low flow (95% E) (cfs / sq mile)	lowest 7-day ave. flow - drought of record (cfs / sq mile)
01475530	Cobbs Cr At U.S. Hghwy No. 1 At Philadelphia, PA	PA	1965 - 1980	7.4	0.9	9/10/1966	310.0	8/23/1974	12.0	4.5	1.8	4.8	1.558	0.377	#N/A
01475550	Cobbs Creek At Darby, PA	PA	1964 - 1984	30.6	0.0	6/12/1966	1,150.0	7/28/1969	57.0	14.0	1.1	22.0	1.393	0.050	#N/A
01475850	Crum Creek Near Newtown Square, PA	PA	1982 - 2002	22.4	0.6	8/8/1991	1,610.0	9/16/1999	38.0	15.0	4.3	15.8	1.420	0.272	#N/A
01477000	Chester Creek Near Chester, PA	PA	1932 - 2002	90.3	5.8	8/11/2002	6,510.0	9/13/1971	154.0	60.0	22.0	61.1	1.478	0.360	0.131
01479820	Red Clay Creek Near Kennett Square, PA	PA	1988 - 2002	37.2	0.9	9/4/1995	1,820.0	9/16/1999	59.0	26.0	9.9	28.3	1.313	0.349	#N/A
01480300	West Branch Brandywine Creek Near Honey Brook, PA	PA	1961 - 2002	26.0	1.0	8/22/2002	2,520.0	6/22/1972	40.0	15.0	5.4	18.7	1.391	0.289	0.160
01480500	West Branch Brandywine Creek At Coatesville, PA	PA	1970 - 2002	62.1	3.0	8/23/2002	3,400.0	6/22/1972	110.0	41.0	12.0	45.8	1.357	0.262	#N/A
01480617	West Branch Brandywine Creek At Modena, PA	PA	1970 - 2002	83.7	7.4	8/23/2002	4,010.0	6/22/1972	144.0	55.0	21.0	55.0	1.522	0.382	#N/A
01480675	Marsh Creek Near Glenmoore, PA	PA	1967 - 2002	12.4	0.2	8/22/2002	444.0	6/22/1972	24.0	7.5	1.5	8.6	1.445	0.175	#N/A
01480685	Marsh Creek Near Downingtown, PA	PA	1974 - 2001	29.7	0.2	9/7/1999	462.0	6/18/1982	66.0	15.0	3.7	20.3	1.461	0.182	#N/A
01480700	East Branch Brandywine Creek Near Downingtown, PA	PA	1966 - 2002	89.3	7.2	9/12/1966	3,220.0	6/22/1972	170.0	57.0	21.0	60.6	1.473	0.347	#N/A
01480870	East Branch Brandywine Creek Below Downingtown, PA	PA	1973 - 2002	142.8	19.0	9/14/2002	3,080.0	9/16/1999	272.0	93.0	36.0	89.9	1.588	0.400	#N/A
01481000	Brandywine Creek At Chadds Ford, PA	PA	1963 - 2002	411.9	33.0	8/22/2002	10,600.0	1/26/1978	774.0	283.0	100.0	287.0	1.435	0.348	#N/A
01411456	Little Ease Rn Nr Clayton NJ	NJ	1989 - 2001	10.3	0.4	9/19/2001	111.0	9/20/1989	23.0	7.0	1.0	9.8	1.051	0.102	#N/A
01411500	Maurice River At Norma NJ	NJ	1933 - 2001	162.7	23.0	9/13/1966	5,260.0	9/2/1940	280.0	142.0	56.0	112.0	1.453	0.500	0.205
01412000	Menantico Creek Near Millville NJ	NJ	1932 - 1956	37.9	1.4	8/18/1936	847.0	8/20/1939	62.0	33.0	13.0	23.2	1.635	0.560	#N/A
01412500	West Branch Cohansey River At Seeley NJ	NJ	1952 - 1966	1.8	0.0	7/27/1966	95.0	9/12/1960	2.6	1.6	0.7	2.6	0.706	0.271	#N/A
01412800	Cohansey River At Seeley NJ	NJ	1978 - 1987	36.3	12.0	8/21/1987	2,150.0	6/21/1983	53.0	28.0	17.0	28.0	1.295	0.607	#N/A
01440000	Flat Brook Near Flatbrookville NJ	NJ	1924 - 2001	110.3	4.1	9/11/1966	6,310.0	8/19/1955	236.0	71.0	13.0	64.0	1.724	0.203	0.188
01443500	Paulins Kill At Blairstown NJ	NJ	1978 - 2001	205.3	11.0	8/13/1999	2,700.0	1/25/1979	421.0	138.0	28.0	126.0	1.630	0.222	0.183
01443900	Yards Creek Near Blairstown NJ	NJ	1967 - 2001	10.7	0.0	6/19/1970	225.0	1/18/1977	24.0	4.8	1.0	5.3	2.010	0.180	#N/A
01445000	Pequest River At Huntsville NJ	NJ	1940 - 1961	46.9	1.6	8/6/1955	481.0	8/20/1955	102.0	35.0	4.4	31.0	1.512	0.142	#N/A
01445500	Pequest River At Pequest NJ	NJ	1922 - 2001	156.9	12.0	8/21/1965	2,040.0	1/25/1979	329.0	111.0	28.0	106.0	1.480	0.264	0.189
01446000	Beaver Brook Near Belvidere NJ	NJ	1923 - 1960	52.4	1.2	8/4/1955	1,370.0	3/12/1936	115.1	35.0	4.3	36.7	1.429	0.117	#N/A
01455500	Musconetcong River At Outlet Of Lake Hopatcong NJ	NJ	1929 - 2002	43.6	0.0	8/23/1967	731.0	8/20/1955	103.0	29.0	5.6	25.3	1.722	0.221	0.332
01456000	Musconetcong R Nr Hackettstown NJ	NJ	1922 - 1972	118.8	5.3	8/24/1957	1,760.0	8/20/1955	254.0	85.0	20.0	68.9	1.724	0.290	0.232
01457000	Musconetcong River Near Bloomsbury NJ	NJ	1922 - 2001	238.9	27.0	9/8/1966	3,190.0	9/20/1989	460.0	184.0	65.0	141.0	1.694	0.461	0.262
01463620	Assunpink Creek Near Clarksville NJ	NJ	1973 - 2002	48.0	1.0	9/6/1995	832.0	2/26/1979	98.0	32.0	7.1	34.3	1.400	0.207	#N/A
01464000	Assunpink Creek At Trenton NJ	NJ	1924 - 2001	133.8	4.0	9/2/1929	4,050.0	7/21/1975	275.0	87.0	25.0	90.6	1.477	0.276	0.177
01464500	Crosswicks Creek At Extonville NJ	NJ	1953 - 2001	136.3	8.7	8/4/1999	3,930.0	8/28/1971	252.0	93.0	33.0	81.5	1.672	0.405	0.221
01465850	South Branch Rancocas Creek At Vincentown NJ	NJ	1962 - 1974	94.5	3.1	8/9/1966	981.0	11/9/1972	193.0	72.0	15.0	64.5	1.466	0.233	#N/A
01466500	Mcdonalds Branch In Lebanon State Forest NJ	NJ	1954 - 2001	2.1	0.5	10/13/1995	20.0	2/28/1958	3.6	1.8	1.0	2.4	0.914	0.426	0.426
01467000	North Branch Rancocas Creek At Pemberton NJ	NJ	1922 - 2001	170.1	9.0	9/29/1932	1,690.0	8/21/1939	310.0	140.0	51.0	118.0	1.441	0.432	0.356
01467081	South Branch Pennsauken Creek At Cherry Hill NJ	NJ	1978 - 2001	18.5	2.2	8/12/1999	551.0	7/5/1989	36.0	9.4	4.1	9.0	2.057	0.457	#N/A
01467150	Cooper River At Haddonfield NJ	NJ	1964 - 2001	33.1	1.2	6/27/1964	1,510.0	8/28/1971	57.0	22.0	8.5	17.0	1.948	0.500	#N/A
01475000	Mantua Creek At Pitman NJ	NJ	1942 - 1975	11.6	2.6	7/17/1966	470.0	8/27/1971	17.0	10.0	6.0	6.1	1.909	0.992	0.496
01477120	Raccoon Creek Near Swedesboro NJ	NJ	1967 - 2001	39.5	6.6	8/4/1999	1,260.0	8/28/1971	65.7	29.0	13.0	26.9	1.468	0.483	#N/A
01482500	Salem River At Woodstown NJ	NJ	1942 - 1984	19.2	0.0	9/30/1981	912.0	11/25/1950	34.0	12.0	3.0	14.6	1.313	0.205	0.068
01477800	Shellpot Creek At Wilmington, DE	DE	1946 - 2002	10.0	0.1	10/4/1968	1,480.0	9/16/1999	18.0	2.9	0.6	7.5	1.339	0.075	0.000
01478000	Christina River At Coochs Bridge, DE	DE	1944 - 2002	28.6	0.2	8/28/1966	2,650.0	9/16/1999	48.0	13.0	3.0	20.5	1.395	0.146	0.049
01479000	White Clay Creek Near Newark, DE	DE	1960 - 2002	116.1	5.0	9/10/1966	8,220.0	9/16/1999	195.0	76.0	25.0	89.1	1.303	0.281	0.079
01480000	Red Clay Creek At Wooddale, DE	DE	1944 - 2002	62.3	4.5	9/4/1966	3,440.0	9/16/1999	107.0	43.0	16.0	47.0	1.326	0.340	0.128
01480015	Red Clay Creek Near Stanton, DE	DE	1989 - 2002	67.6	7.0	9/12/1995	4,300.0	9/16/1999	111.8	46.0	18.0	52.4	1.290	0.344	#N/A
01481500	Brandywine Creek At Wilmington, DE	DE	1947 - 2002	473.3	35.0	8/23/2002	14,300.0	6/23/1972	877.7	330.0	109.0	314.0	1.507	0.347	0.191
01483200	Blackbird Creek At Blackbird, DE	DE	1957 - 2002	4.7	0.0	10/6/1968	397.0	9/16/1999	9.7	2.7	0.3	3.9	1.224	0.078	0.000
01483700	St Jones River At Dover, DE	DE	1958 - 2002	37.4	0.0	5/10/1961	1,460.0	9/13/1960	84.0	20.0	2.1	31.9	1.172	0.066	0.031
01484100	Beaverdam Branch At Houston, DE	DE	1959 - 2002	3.6	0.0	7/28/1977	98.0	5/30/1984	6.6	2.7	0.6	2.8	1.272	0.212	0.000
													Basin Average (cfs):	**0.307**	-
													Basin Median (cfs):	**0.281**	-
													St. Dev (cfs):	**0.170**	-

Note: #N/A = flow gauge not operational during drought of record / insufficient period of record.

Appendix IV. Table IV-1 Water Demand by Sector and by Sub-Basin 1995 (Dry Year)

WITHDRAWALS	Annual											
GROUNDWATER	1995											
	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.61	0.52	9.76	0.00	0.09	0.05	0.00	0.00	0.00	8.05	0.00	**19.07**
Upper Central	4.87	0.51	11.88	23.26	20.11	0.02	8.30	0.00	0.24	16.54	0.01	**85.74**
Lehigh Valley	0.19	0.43	8.76	18.73	3.64	0.23	0.00	0.00	1.04	25.18	0.00	**58.19**
Lower Central	0.00	0.00	5.69	2.88	0.94	0.03	0.00	0.00	0.01	5.01	0.00	**14.55**
Schuylkill Valley	0.02	1.23	15.63	13.39	29.79	1.12	0.03	0.00	1.35	40.58	0.00	**103.15**
Upper Estuary	3.57	4.59	14.08	11.38	3.44	1.10	4.43	0.00	0.00	133.41	0.00	**176.01**
Lower Estuary	6.99	0.29	8.33	10.08	1.33	0.09	0.82	0.00	0.46	22.13	0.00	**50.53**
Delaware Bay	23.70	2.40	9.50	11.47	8.71	0.07	0.00	0.00	0.00	33.86	0.00	**89.71**
	39.95	**9.97**	**83.65**	**91.20**	**68.05**	**2.71**	**13.59**	**0.00**	**3.09**	**284.75**	**0.01**	**596.97**

WITHDRAWALS	Annual											
SURFACE WATER	1995											
	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.49	0.00	0.00	0.00	0.00	0.10	0.00	189.04	0.00	4.61	0.00	**194.25**
Upper Central	3.37	0.23	0.00	7.07	0.00	0.65	0.00	145.41	285.25	9.80	0.42	**452.22**
Lehigh Valley	0.15	0.21	0.00	154.46	0.07	0.43	3.26	0.00	0.63	47.81	0.78	**207.80**
Lower Central	2.57	0.00	0.00	88.17	0.07	0.25	0.00	0.00	27.56	45.31	0.00	**163.93**
Schuylkill Valley	0.02	0.00	0.00	25.04	0.02	0.86	0.00	0.00	297.77	238.88	0.03	**562.61**
Upper Estuary	3.99	0.92	0.00	216.57	0.08	1.74	22.76	0.00	1,357.37	255.86	0.00	**1,859.29**
Lower Estuary	7.18	0.00	0.00	401.26	0.00	0.73	0.00	0.00	3,117.58	59.73	0.00	**3,586.47**
Delaware Bay	8.78	0.00	0.00	0.00	58.47	0.00	0.00	0.00	0.00	0.00	0.00	**67.24**
	26.55	**1.36**	**0.00**	**892.57**	**58.70**	**4.77**	**26.01**	**334.45**	**5,086.15**	**662.01**	**1.24**	**7,093.82**

WITHDRAWALS	Annual											
TOTAL	1995											
	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	1.10	0.52	9.76	0.00	0.09	0.15	0.00	189.04	0.00	12.66	0.00	**213.32**
Upper Central	8.24	0.74	11.88	30.33	20.11	0.67	8.30	145.41	285.49	26.34	0.43	**537.96**
Lehigh Valley	0.34	0.64	8.76	173.19	3.71	0.66	3.26	0.00	1.66	72.99	0.78	**265.99**
Lower Central	2.57	0.00	5.69	91.06	1.00	0.28	0.00	0.00	27.56	50.32	0.00	**178.48**
Schuylkill Valley	0.04	1.23	15.63	38.43	29.81	1.98	0.03	0.00	299.12	279.45	0.03	**665.76**
Upper Estuary	7.57	5.51	14.08	227.95	3.52	2.84	27.19	0.00	1,357.37	389.28	0.00	**2,035.31**
Lower Estuary	14.17	0.29	8.33	411.33	1.33	0.82	0.82	0.00	3,118.04	81.86	0.00	**3,637.01**
Delaware Bay	32.48	2.40	9.50	11.47	67.18	0.07	0.00	0.00	0.00	33.86	0.00	**156.96**
	66.51	**11.33**	**83.65**	**983.76**	**126.76**	**7.47**	**39.60**	**334.45**	**5,089.24**	**946.76**	**1.25**	**7,690.78**

CONSUMPTIVE	Annual											
GROUNDWATER	1995											
	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.55	0.05	1.08	0.00	0.01	0.04	0.00	0.00	0.00	0.89	0.00	**2.63**
Upper Central	4.38	0.05	1.32	2.42	3.02	0.02	0.41	0.00	0.15	1.75	0.00	**13.52**
Lehigh Valley	0.17	0.04	0.97	1.51	0.55	0.21	0.00	0.00	1.04	2.58	0.00	**7.07**
Lower Central	0.00	0.00	0.63	0.42	0.14	0.02	0.00	0.00	0.00	0.51	0.00	**1.73**
Schuylkill Valley	0.02	0.12	1.74	1.40	4.47	1.01	0.00	0.00	0.82	4.21	0.00	**13.80**
Upper Estuary	3.22	0.46	1.56	1.69	0.52	0.99	0.00	0.00	0.00	14.37	0.00	**22.80**
Lower Estuary	6.29	0.03	0.92	1.14	0.20	0.08	0.04	0.00	0.05	2.31	0.00	**11.07**
Delaware Bay	21.33	0.24	1.05	1.28	1.31	0.06	0.00	0.00	0.00	3.77	0.00	**29.05**
	35.96	**1.00**	**9.28**	**9.87**	**10.21**	**2.44**	**0.46**	**0.00**	**2.06**	**30.40**	**0.00**	**101.67**

CONSUMPTIVE	Annual											
SURFACE WATER	1995											
	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.44	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.49	0.00	**1.02**
Upper Central	3.03	0.02	0.00	1.02	0.00	0.58	0.00	0.00	3.56	0.98	0.09	**9.29**
Lehigh Valley	0.14	0.02	0.00	2.69	0.01	0.39	0.16	0.00	0.57	4.98	0.17	**9.12**
Lower Central	2.31	0.00	0.00	9.01	0.01	0.23	0.00	0.00	12.91	4.71	0.00	**29.18**
Schuylkill Valley	0.02	0.00	0.00	6.78	0.00	0.78	0.00	0.00	18.95	24.74	0.01	**51.27**
Upper Estuary	3.59	0.09	0.00	13.13	0.01	1.56	0.00	0.00	11.44	26.33	0.00	**56.16**
Lower Estuary	6.46	0.00	0.00	7.51	0.00	0.66	0.00	0.00	20.16	6.16	0.00	**40.96**
Delaware Bay	7.90	0.00	0.00	0.00	8.77	0.00	0.00	0.00	0.00	0.00	0.00	**16.67**
	23.90	**0.14**	**0.00**	**40.13**	**8.81**	**4.29**	**0.17**	**0.00**	**67.59**	**68.38**	**0.27**	**213.67**

CONSUMPTIVE	Annual											
TOTAL	1995											
	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.99	0.05	1.08	0.00	0.01	0.14	0.00	0.00	0.00	1.38	0.00	**3.66**
Upper Central	7.42	0.07	1.32	3.44	3.02	0.60	0.41	0.00	3.70	2.73	0.10	**22.81**
Lehigh Valley	0.30	0.06	0.97	4.20	0.56	0.60	0.16	0.00	1.60	7.56	0.17	**16.19**
Lower Central	2.31	0.00	0.63	9.43	0.15	0.25	0.00	0.00	12.91	5.22	0.00	**30.91**
Schuylkill Valley	0.04	0.12	1.74	8.18	4.47	1.78	0.00	0.00	19.78	28.95	0.01	**65.07**
Upper Estuary	6.81	0.55	1.56	14.81	0.53	2.55	0.01	0.00	11.44	40.69	0.00	**78.96**
Lower Estuary	12.75	0.03	0.92	8.65	0.20	0.74	0.04	0.00	20.21	8.48	0.00	**52.03**
Delaware Bay	29.23	0.24	1.05	1.28	10.08	0.06	0.00	0.00	0.00	3.77	0.00	**45.71**
	59.86	**1.13**	**9.28**	**50.00**	**19.01**	**6.73**	**0.63**	**0.00**	**69.65**	**98.79**	**0.27**	**315.35**

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All Figures in mgd (million gallons per day)

Appendix IV. Table IV-2 Water Demand by Sector and by Sub-Basin 2020 (Dry Year)

WITHDRAWALS GROUNDWATER — Annual 2020

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.52	0.63	11.17	0.00	0.09	0.07	0.00	0.00	0.00	8.80	0.00	**21.27**
Upper Central	3.97	0.62	15.42	21.47	18.55	0.03	7.55	0.00	0.33	21.24	0.01	**89.17**
Lehigh Valley	0.18	0.39	9.95	17.17	3.37	0.25	0.00	0.00	1.38	28.52	0.00	**61.21**
Lower Central	0.00	0.00	6.66	2.69	0.88	0.03	0.00	0.00	0.01	5.55	0.00	**15.83**
Schuylkill Valley	0.02	1.18	17.12	12.48	27.12	1.06	0.03	0.00	1.80	44.10	0.00	**104.91**
Upper Estuary	2.98	4.55	14.15	10.43	3.26	1.27	3.94	0.00	0.00	139.33	0.00	**179.92**
Lower Estuary	6.15	0.34	11.53	9.39	1.20	0.11	0.78	0.00	0.63	28.56	0.00	**58.69**
Delaware Bay	19.52	2.45	11.38	10.68	8.17	0.09	0.00	0.00	0.00	39.39	0.00	**91.69**
	33.34	**10.17**	**97.37**	**84.32**	**62.65**	**2.91**	**12.30**	**0.00**	**4.15**	**315.48**	**0.01**	**622.69**

WITHDRAWALS SURFACE WATER — Annual 2020

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.43	0.00	0.00	0.00	0.00	0.16	0.00	189.04	0.00	5.51	0.00	**195.14**
Upper Central	2.83	0.31	0.00	7.07	0.00	0.91	0.00	145.41	418.49	16.01	0.42	**591.47**
Lehigh Valley	0.15	0.21	0.00	154.46	0.07	0.48	3.26	0.00	0.92	58.84	0.78	**219.17**
Lower Central	2.16	0.00	0.00	88.17	0.07	0.28	0.00	0.00	40.43	51.91	0.00	**183.02**
Schuylkill Valley	0.02	0.00	0.00	25.04	0.02	0.87	0.00	0.00	436.85	283.36	0.03	**746.19**
Upper Estuary	3.35	0.98	0.00	216.57	0.08	1.99	22.76	0.00	1,991.38	259.16	0.00	**2,496.28**
Lower Estuary	6.10	0.00	0.00	401.26	0.00	0.83	0.00	0.00	4,573.76	73.80	0.00	**5,055.74**
Delaware Bay	7.22	0.00	0.00	0.00	58.47	0.00	0.00	0.00	0.00	0.00	0.00	**65.69**
	22.26	**1.50**	**0.00**	**892.57**	**58.70**	**5.53**	**26.01**	**334.45**	**7,461.83**	**748.60**	**1.24**	**9,552.70**

WITHDRAWALS TOTAL — Annual 2020

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.95	0.63	11.17	0.00	0.09	0.23	0.00	189.04	0.00	14.31	0.00	**216.41**
Upper Central	6.81	0.93	15.42	28.54	18.55	0.94	7.55	145.41	418.82	37.25	0.43	**680.65**
Lehigh Valley	0.32	0.61	9.95	171.63	3.44	0.73	3.26	0.00	2.31	87.36	0.78	**280.38**
Lower Central	2.16	0.00	6.66	90.87	0.95	0.31	0.00	0.00	40.43	57.47	0.00	**198.85**
Schuylkill Valley	0.04	1.18	17.12	37.52	27.13	1.93	0.03	0.00	438.65	327.46	0.03	**851.10**
Upper Estuary	6.34	5.53	14.15	227.00	3.34	3.26	26.70	0.00	1,991.38	398.49	0.00	**2,676.20**
Lower Estuary	12.25	0.34	11.53	410.65	1.20	0.94	0.78	0.00	4,574.39	102.36	0.00	**5,114.43**
Delaware Bay	26.74	2.45	11.38	10.68	66.64	0.09	0.00	0.00	0.00	39.39	0.00	**157.37**
	55.61	**11.68**	**97.37**	**976.89**	**121.35**	**8.43**	**38.31**	**334.45**	**7,465.98**	**1,064.08**	**1.24**	**10,175.40**

CONSUMPTIVE GROUNDWATER — Annual 2020

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.46	0.06	1.28	0.00	0.01	0.06	0.00	0.00	0.00	1.01	0.00	**2.90**
Upper Central	3.58	0.06	1.76	2.24	2.78	0.02	0.38	0.00	0.20	2.34	0.00	**13.37**
Lehigh Valley	0.16	0.04	1.14	1.39	0.51	0.23	0.00	0.00	1.38	3.04	0.00	**7.89**
Lower Central	0.00	0.00	0.76	0.39	0.13	0.03	0.00	0.00	0.00	0.59	0.00	**1.91**
Schuylkill Valley	0.02	0.12	1.96	1.31	4.07	0.95	0.00	0.00	1.11	4.78	0.00	**14.31**
Upper Estuary	2.69	0.46	1.62	1.54	0.49	1.14	0.00	0.00	0.00	15.63	0.00	**23.56**
Lower Estuary	5.53	0.03	1.32	1.06	0.18	0.10	0.04	0.00	0.07	3.10	0.00	**11.42**
Delaware Bay	17.57	0.25	1.30	1.19	1.23	0.08	0.00	0.00	0.00	4.54	0.00	**26.15**
	30.01	**1.02**	**11.14**	**9.12**	**9.40**	**2.61**	**0.42**	**0.00**	**2.76**	**35.03**	**0.00**	**101.51**

CONSUMPTIVE SURFACE WATER — Annual 2020

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.39	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.58	0.00	**1.11**
Upper Central	2.55	0.03	0.00	1.02	0.00	0.82	0.00	0.00	5.22	1.61	0.09	**11.34**
Lehigh Valley	0.13	0.02	0.00	2.69	0.01	0.43	0.16	0.00	0.83	6.13	0.17	**10.57**
Lower Central	1.95	0.00	0.00	9.01	0.01	0.25	0.00	0.00	18.94	5.40	0.00	**35.56**
Schuylkill Valley	0.02	0.00	0.00	6.78	0.00	0.79	0.00	0.00	27.81	29.34	0.01	**64.74**
Upper Estuary	3.02	0.10	0.00	13.13	0.01	1.79	0.00	0.00	16.78	26.67	0.00	**61.50**
Lower Estuary	5.49	0.00	0.00	7.51	0.00	0.75	0.00	0.00	29.58	7.61	0.00	**50.94**
Delaware Bay	6.50	0.00	0.00	0.00	8.77	0.00	0.00	0.00	0.00	0.00	0.00	**15.27**
	20.04	**0.15**	**0.00**	**40.13**	**8.81**	**4.97**	**0.17**	**0.00**	**99.16**	**77.33**	**0.27**	**251.03**

CONSUMPTIVE TOTAL — Annual 2020

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.85	0.06	1.28	0.00	0.01	0.20	0.00	0.00	0.00	1.59	0.00	**4.00**
Upper Central	6.13	0.09	1.76	3.26	2.78	0.85	0.38	0.00	5.42	3.95	0.09	**24.71**
Lehigh Valley	0.29	0.06	1.14	4.08	0.52	0.66	0.16	0.00	2.21	9.17	0.17	**18.46**
Lower Central	1.95	0.00	0.76	9.40	0.14	0.28	0.00	0.00	18.95	5.99	0.00	**37.47**
Schuylkill Valley	0.04	0.12	1.96	8.09	4.07	1.74	0.00	0.00	28.91	34.12	0.01	**79.05**
Upper Estuary	5.70	0.55	1.62	14.67	0.50	2.94	0.01	0.00	16.78	42.30	0.00	**85.07**
Lower Estuary	11.02	0.03	1.32	8.57	0.18	0.84	0.04	0.00	29.65	10.71	0.00	**62.36**
Delaware Bay	24.07	0.25	1.30	1.19	10.00	0.08	0.00	0.00	0.00	4.54	0.00	**41.42**
	50.05	**1.17**	**11.14**	**49.26**	**18.20**	**7.59**	**0.59**	**0.00**	**101.92**	**112.36**	**0.27**	**352.54**

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All Figures in mgd (million gallons per day)

Appendix IV. Table IV-3 Water Demand by Sector and by Sub-Basin 2004 (Dry Year)

WITHDRAWALS Annual
GROUNDWATER 2040

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.46	0.80	14.60	0.00	0.09	0.08	0.00	0.00	0.00	11.00	0.00	**27.03**
Upper Central	3.45	0.78	21.93	23.26	20.11	0.03	8.30	0.00	0.45	30.00	0.01	**108.31**
Lehigh Valley	0.18	0.45	12.66	18.73	3.64	0.25	0.00	0.00	1.92	36.39	0.00	**74.22**
Lower Central	0.00	0.00	8.73	2.88	0.94	0.03	0.00	0.00	0.01	7.07	0.00	**19.66**
Schuylkill Valley	0.02	1.29	21.19	13.39	29.79	1.13	0.03	0.00	2.50	55.00	0.00	**124.36**
Upper Estuary	2.53	5.10	16.50	11.38	3.44	1.32	4.43	0.00	0.00	166.51	0.00	**211.21**
Lower Estuary	5.49	0.40	18.20	10.08	1.33	0.11	0.82	0.00	0.86	40.91	0.00	**78.21**
Delaware Bay	16.14	2.87	15.19	11.47	8.71	0.10	0.00	0.00	0.00	50.39	0.00	**104.88**
	28.27	**11.69**	**128.99**	**91.20**	**68.05**	**3.06**	**13.59**	**0.00**	**5.74**	**397.26**	**0.01**	**747.86**

WITHDRAWALS Annual
SURFACE WATER 2040

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.38	0.00	0.00	0.00	0.00	0.17	0.00	189.04	0.00	6.45	0.00	**196.03**
Upper Central	2.39	0.35	0.00	7.07	0.00	0.94	0.00	145.41	529.52	23.13	0.42	**709.23**
Lehigh Valley	0.14	0.21	0.00	154.46	0.07	0.48	3.26	0.00	1.17	69.09	0.78	**229.66**
Lower Central	1.83	0.00	0.00	88.17	0.07	0.28	0.00	0.00	51.15	58.27	0.00	**199.77**
Schuylkill Valley	0.02	0.00	0.00	25.04	0.02	0.88	0.00	0.00	552.76	323.79	0.03	**902.53**
Upper Estuary	2.82	1.03	0.00	216.57	0.08	2.06	22.76	0.00	2,519.72	262.00	0.00	**3,027.04**
Lower Estuary	5.20	0.00	0.00	401.26	0.00	0.84	0.00	0.00	5,787.24	87.16	0.00	**6,281.70**
Delaware Bay	5.92	0.00	0.00	0.00	58.47	0.00	0.00	0.00	0.00	0.00	0.00	**64.39**
	18.69	**1.60**	**0.00**	**892.57**	**58.70**	**5.64**	**26.01**	**334.45**	**9,441.56**	**829.89**	**1.24**	**11,610.35**

WITHDRAWALS Annual
TOTAL 2040

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.84	0.80	14.60	0.00	0.09	0.24	0.00	189.04	0.00	17.45	0.00	**223.06**
Upper Central	5.83	1.14	21.93	30.33	20.11	0.97	8.30	145.41	529.97	53.12	0.43	**817.54**
Lehigh Valley	0.32	0.66	12.66	173.19	3.71	0.73	3.26	0.00	3.09	105.48	0.78	**303.88**
Lower Central	1.83	0.00	8.73	91.06	1.00	0.31	0.00	0.00	51.16	65.35	0.00	**219.43**
Schuylkill Valley	0.04	1.29	21.19	38.43	29.81	2.01	0.03	0.00	555.26	378.79	0.03	**1,026.89**
Upper Estuary	5.35	6.13	16.50	227.95	3.52	3.38	27.19	0.00	2,519.72	428.50	0.00	**3,238.25**
Lower Estuary	10.69	0.40	18.20	411.33	1.33	0.96	0.82	0.00	5,788.10	128.07	0.00	**6,359.90**
Delaware Bay	22.06	2.87	15.19	11.47	67.18	0.10	0.00	0.00	0.00	50.39	0.00	**169.26**
	46.96	**13.29**	**128.99**	**983.76**	**126.76**	**8.70**	**39.60**	**334.45**	**9,447.30**	**1,227.15**	**1.25**	**12,358.21**

CONSUMPTIVE Annual
GROUNDWATER 2040

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.42	0.08	1.62	0.00	0.01	0.07	0.00	0.00	0.00	1.22	0.00	**3.42**
Upper Central	3.10	0.08	2.43	2.42	3.02	0.03	0.41	0.00	0.27	3.18	0.00	**14.95**
Lehigh Valley	0.16	0.04	1.41	1.51	0.55	0.23	0.00	0.00	1.92	3.73	0.00	**9.55**
Lower Central	0.00	0.00	0.97	0.42	0.14	0.03	0.00	0.00	0.01	0.73	0.00	**2.29**
Schuylkill Valley	0.02	0.13	2.35	1.40	4.47	1.02	0.00	0.00	1.53	5.71	0.00	**16.63**
Upper Estuary	2.28	0.51	1.83	1.69	0.52	1.19	0.00	0.00	0.00	17.97	0.00	**25.98**
Lower Estuary	4.94	0.04	2.02	1.14	0.20	0.10	0.04	0.00	0.09	4.27	0.00	**12.84**
Delaware Bay	14.52	0.29	1.69	1.28	1.31	0.09	0.00	0.00	0.00	5.58	0.00	**24.76**
	25.44	**1.17**	**14.32**	**9.87**	**10.21**	**2.75**	**0.46**	**0.00**	**3.82**	**42.38**	**0.00**	**110.42**

CONSUMPTIVE Annual
SURFACE WATER 2040

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.34	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.67	0.00	**1.16**
Upper Central	2.15	0.04	0.00	1.02	0.00	0.84	0.00	0.00	6.60	2.32	0.09	**13.06**
Lehigh Valley	0.13	0.02	0.00	2.69	0.01	0.43	0.16	0.00	1.05	7.19	0.17	**11.86**
Lower Central	1.64	0.00	0.00	9.01	0.01	0.25	0.00	0.00	23.97	6.06	0.00	**40.95**
Schuylkill Valley	0.02	0.00	0.00	6.78	0.00	0.79	0.00	0.00	35.18	33.53	0.01	**76.31**
Upper Estuary	2.54	0.10	0.00	13.13	0.01	1.85	0.00	0.00	21.24	26.96	0.00	**65.84**
Lower Estuary	4.68	0.00	0.00	7.51	0.00	0.76	0.00	0.00	37.43	8.98	0.00	**59.36**
Delaware Bay	5.33	0.00	0.00	0.00	8.77	0.00	0.00	0.00	0.00	0.00	0.00	**14.10**
	16.82	**0.16**	**0.00**	**40.13**	**8.81**	**5.08**	**0.17**	**0.00**	**125.47**	**85.72**	**0.27**	**282.63**

CONSUMPTIVE Annual
TOTAL 2040

	AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.76	0.08	1.62	0.00	0.01	0.22	0.00	0.00	0.00	1.89	0.00	**4.58**
Upper Central	5.25	0.11	2.43	3.44	3.02	0.87	0.41	0.00	6.87	5.50	0.10	**28.01**
Lehigh Valley	0.29	0.07	1.41	4.20	0.56	0.66	0.16	0.00	2.97	10.93	0.17	**21.41**
Lower Central	1.64	0.00	0.97	9.43	0.15	0.28	0.00	0.00	23.97	6.79	0.00	**43.24**
Schuylkill Valley	0.04	0.13	2.35	8.18	4.47	1.81	0.00	0.00	36.71	39.24	0.01	**92.94**
Upper Estuary	4.82	0.61	1.83	14.81	0.53	3.04	0.01	0.00	21.24	44.93	0.00	**91.82**
Lower Estuary	9.62	0.04	2.02	8.65	0.20	0.86	0.04	0.00	37.52	13.25	0.00	**72.20**
Delaware Bay	19.85	0.29	1.69	1.28	10.08	0.09	0.00	0.00	0.00	5.58	0.00	**38.86**
	42.26	**1.33**	**14.32**	**50.00**	**19.01**	**7.83**	**0.63**	**0.00**	**129.29**	**128.11**	**0.27**	**393.05**

All Figures in mgd (million gallons per day)

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Appendix IV. **Table IV-4 Water Demand by Sector and by Sub-Basin 1995 (Normal Year)**

WITHDRAWALS GROUNDWATER	Annual 1996 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.37	0.53	9.85	0.00	0.09	0.04	0.00	0.00	0.00	7.98	0.00	**18.85**
Upper Central	2.84	0.59	12.06	23.71	22.53	0.03	0.01	0.00	0.23	16.17	0.01	**78.18**
Lehigh Valley	0.11	0.45	8.84	17.87	3.29	0.14	0.00	0.00	0.95	25.57	0.00	**57.22**
Lower Central	1.35	0.00	5.75	3.00	1.84	0.01	0.00	0.00	0.00	4.58	0.00	**16.53**
Schuylkill Valley	0.01	1.45	15.75	13.00	34.09	0.80	0.07	0.00	1.39	40.46	0.00	**107.03**
Upper Estuary	2.11	4.61	14.13	12.48	3.92	0.61	2.49	0.00	0.00	115.39	0.00	**155.74**
Lower Estuary	4.72	0.30	8.48	10.22	0.09	0.05	0.00	0.00	0.72	20.83	0.00	**45.40**
Delaware Bay	14.13	2.19	9.61	11.50	9.47	0.02	0.00	0.00	0.00	32.07	0.00	**79.00**
	25.65	**10.12**	**84.47**	**91.79**	**75.31**	**1.70**	**2.57**	**0.00**	**3.29**	**263.05**	**0.01**	**557.96**

WITHDRAWALS SURFACE WATER	Annual 1996 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.28	0.00	0.00	0.00	0.00	0.06	0.00	393.32	0.00	4.61	0.00	**398.27**
Upper Central	2.07	0.12	0.00	7.02	0.00	0.52	0.00	145.41	393.59	9.47	0.38	**558.58**
Lehigh Valley	0.09	0.23	0.00	55.21	0.04	0.18	3.26	0.00	1.24	47.18	0.55	**107.98**
Lower Central	0.16	0.00	0.00	67.80	0.06	0.20	0.00	0.00	24.22	44.30	0.00	**136.75**
Schuylkill Valley	0.01	0.00	0.00	27.27	0.02	0.56	0.00	0.00	231.01	217.53	0.03	**476.42**
Upper Estuary	2.04	0.68	0.00	119.82	1.68	1.02	12.25	0.00	1,460.62	271.27	0.00	**1,869.38**
Lower Estuary	2.86	0.00	0.00	435.43	0.00	0.29	0.00	0.00	3,225.69	55.22	0.00	**3,719.50**
Delaware Bay	3.40	0.00	0.00	0.00	40.18	0.00	0.00	0.00	0.00	0.00	0.00	**43.58**
	10.91	**1.03**	**0.00**	**712.56**	**41.98**	**2.83**	**15.50**	**538.73**	**5,336.38**	**649.59**	**0.97**	**7,310.46**

WITHDRAWALS TOTAL	Annual 1996 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.65	0.53	9.85	0.00	0.09	0.10	0.00	393.32	0.00	12.59	0.00	**417.12**
Upper Central	4.91	0.71	12.06	30.73	22.53	0.55	0.01	145.41	393.82	25.64	0.39	**636.76**
Lehigh Valley	0.20	0.68	8.84	73.08	3.33	0.32	3.26	0.00	2.19	72.76	0.55	**165.20**
Lower Central	1.51	0.00	5.75	70.80	1.90	0.21	0.00	0.00	24.23	48.88	0.00	**153.28**
Schuylkill Valley	0.02	1.45	15.75	40.27	34.11	1.36	0.07	0.00	232.40	257.99	0.03	**583.45**
Upper Estuary	4.15	5.29	14.13	132.30	5.59	1.63	14.74	0.00	1,460.62	386.66	0.00	**2,025.12**
Lower Estuary	7.58	0.30	8.48	445.65	0.09	0.34	0.00	0.00	3,226.41	76.05	0.00	**3,764.91**
Delaware Bay	17.53	2.19	9.61	11.50	49.65	0.02	0.00	0.00	0.00	32.07	0.00	**122.58**
	36.55	**11.15**	**84.47**	**804.34**	**117.28**	**4.54**	**18.08**	**538.73**	**5,339.67**	**912.63**	**0.98**	**7,868.42**

CONSUMPTIVE GROUNDWATER	Annual 1996 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.33	0.05	0.68	0.00	0.01	0.03	0.00	0.00	0.00	0.87	0.00	**1.98**
Upper Central	2.56	0.06	0.83	2.44	3.38	0.03	0.00	0.00	0.14	1.63	0.00	**11.07**
Lehigh Valley	0.10	0.04	0.61	1.39	0.49	0.13	0.00	0.00	0.95	2.61	0.00	**6.32**
Lower Central	1.22	0.00	0.40	0.45	0.28	0.01	0.00	0.00	0.00	0.47	0.00	**2.82**
Schuylkill Valley	0.01	0.15	1.09	1.38	5.11	0.72	0.00	0.00	0.84	4.08	0.00	**13.37**
Upper Estuary	1.90	0.46	0.97	1.98	0.59	0.55	0.00	0.00	0.00	11.99	0.00	**18.45**
Lower Estuary	4.25	0.03	0.58	1.39	0.01	0.05	0.00	0.00	0.15	2.11	0.00	**8.58**
Delaware Bay	12.72	0.22	0.66	1.37	1.42	0.02	0.00	0.00	0.00	3.51	0.00	**19.91**
	23.08	**1.01**	**5.82**	**10.40**	**11.30**	**1.53**	**0.01**	**0.00**	**2.07**	**27.27**	**0.00**	**82.50**

CONSUMPTIVE SURFACE WATER	Annual 1996 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.25	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.48	0.00	**0.79**
Upper Central	1.86	0.01	0.00	0.83	0.00	0.47	0.00	0.00	4.08	0.95	0.08	**8.28**
Lehigh Valley	0.08	0.02	0.00	0.97	0.01	0.16	0.16	0.00	1.12	4.82	0.12	**7.45**
Lower Central	0.14	0.00	0.00	6.95	0.01	0.18	0.00	0.00	14.00	4.52	0.00	**25.81**
Schuylkill Valley	0.01	0.00	0.00	7.65	0.00	0.50	0.00	0.00	18.37	22.09	0.01	**48.62**
Upper Estuary	1.84	0.07	0.00	10.36	0.25	0.92	0.00	0.00	11.84	27.32	0.00	**52.59**
Lower Estuary	2.57	0.00	0.00	7.81	0.00	0.26	0.00	0.00	20.88	5.67	0.00	**37.20**
Delaware Bay	3.06	0.00	0.00	0.00	6.03	0.00	0.00	0.00	0.00	0.00	0.00	**9.09**
	9.82	**0.10**	**0.00**	**34.56**	**6.30**	**2.55**	**0.17**	**0.00**	**70.28**	**65.84**	**0.21**	**189.83**

CONSUMPTIVE TOTAL	Annual 1996 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.58	0.05	0.68	0.00	0.01	0.09	0.00	0.00	0.00	1.35	0.00	**2.77**
Upper Central	4.42	0.07	0.83	3.26	3.38	0.50	0.00	0.00	4.22	2.58	0.09	**19.35**
Lehigh Valley	0.18	0.07	0.61	2.36	0.50	0.29	0.16	0.00	2.06	7.42	0.12	**13.78**
Lower Central	1.36	0.00	0.40	7.40	0.28	0.19	0.00	0.00	14.00	4.99	0.00	**28.63**
Schuylkill Valley	0.02	0.15	1.09	9.02	5.12	1.22	0.00	0.00	19.20	26.17	0.01	**61.99**
Upper Estuary	3.74	0.53	0.97	12.34	0.84	1.47	0.01	0.00	11.84	39.31	0.00	**71.04**
Lower Estuary	6.82	0.03	0.58	9.20	0.01	0.31	0.00	0.00	21.03	7.78	0.00	**45.77**
Delaware Bay	15.78	0.22	0.66	1.37	7.45	0.02	0.00	0.00	0.00	3.51	0.00	**29.00**
	32.90	**1.11**	**5.82**	**44.96**	**17.59**	**4.08**	**0.17**	**0.00**	**72.36**	**93.12**	**0.22**	**272.33**

All Figures in mgd (million gallons per day)

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Appendix IV. Table IV-5 Water Demand by Sector and by Sub-Basin 2020 (Normal Year)

WITHDRAWALS GROUNDWATER	Annual 2020 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.32	0.63	11.22	0.00	0.09	0.05	0.00	0.00	0.00	8.75	0.00	**21.06**
Upper Central	2.38	0.72	15.58	21.75	20.69	0.04	0.01	0.00	0.31	20.73	0.01	**82.23**
Lehigh Valley	0.11	0.42	9.98	16.47	3.05	0.16	0.00	0.00	1.25	28.77	0.00	**60.22**
Lower Central	1.14	0.00	6.69	2.70	1.52	0.01	0.00	0.00	0.01	5.20	0.00	**17.26**
Schuylkill Valley	0.01	1.42	17.14	11.52	31.52	0.78	0.06	0.00	1.87	44.02	0.00	**108.36**
Upper Estuary	1.75	4.56	14.12	11.47	3.65	0.71	2.16	0.00	0.00	120.43	0.00	**158.84**
Lower Estuary	4.09	0.34	11.71	9.34	0.08	0.06	0.00	0.00	0.98	27.06	0.00	**53.66**
Delaware Bay	11.55	2.25	11.46	10.68	8.70	0.02	0.00	0.00	0.00	37.23	0.00	**81.88**
	21.36	**10.35**	**97.91**	**83.92**	**69.30**	**1.84**	**2.23**	**0.00**	**4.43**	**292.17**	**0.01**	**583.51**

WITHDRAWALS SURFACE WATER	Annual 2020 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.24	0.00	0.00	0.00	0.00	0.09	0.00	393.32	0.00	5.52	0.00	**399.17**
Upper Central	1.74	0.16	0.00	7.02	0.00	0.74	0.00	145.41	577.43	15.54	0.38	**748.43**
Lehigh Valley	0.08	0.23	0.00	55.21	0.04	0.20	3.26	0.00	1.82	58.07	0.55	**119.46**
Lower Central	0.13	0.00	0.00	67.80	0.06	0.23	0.00	0.00	35.54	50.94	0.00	**154.70**
Schuylkill Valley	0.01	0.00	0.00	27.27	0.02	0.56	0.00	0.00	338.91	258.04	0.03	**624.84**
Upper Estuary	1.71	0.72	0.00	119.82	1.68	1.18	12.25	0.00	2,142.86	275.54	0.00	**2,555.76**
Lower Estuary	2.42	0.00	0.00	435.43	0.00	0.34	0.00	0.00	4,732.37	68.42	0.00	**5,238.98**
Delaware Bay	2.80	0.00	0.00	0.00	40.18	0.00	0.00	0.00	0.00	0.00	0.00	**42.98**
	9.15	**1.11**	**0.00**	**712.56**	**41.98**	**3.34**	**15.50**	**538.73**	**7,828.93**	**732.05**	**0.97**	**9,884.32**

WITHDRAWALS TOTAL	Annual 2020 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.56	0.64	11.22	0.00	0.09	0.15	0.00	393.32	0.00	14.26	0.00	**420.23**
Upper Central	4.12	0.88	15.58	28.77	20.69	0.79	0.01	145.41	577.74	36.27	0.39	**830.66**
Lehigh Valley	0.19	0.65	9.98	71.68	3.10	0.36	3.26	0.00	3.08	86.83	0.55	**179.68**
Lower Central	1.27	0.00	6.69	70.51	1.58	0.23	0.00	0.00	35.54	56.14	0.00	**171.96**
Schuylkill Valley	0.02	1.42	17.14	38.78	31.54	1.35	0.06	0.00	340.78	302.06	0.03	**733.19**
Upper Estuary	3.47	5.28	14.12	131.28	5.33	1.89	14.41	0.00	2,142.86	395.96	0.00	**2,714.60**
Lower Estuary	6.51	0.34	11.71	444.77	0.08	0.40	0.00	0.00	4,733.35	95.47	0.00	**5,292.64**
Delaware Bay	14.35	2.25	11.46	10.68	48.88	0.02	0.00	0.00	0.00	37.23	0.00	**124.86**
	30.50	**11.46**	**97.91**	**796.48**	**111.27**	**5.18**	**17.73**	**538.73**	**7,833.36**	**1,024.22**	**0.98**	**10,467.83**

CONSUMPTIVE GROUNDWATER	Annual 2020 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.29	0.06	0.81	0.00	0.01	0.05	0.00	0.00	0.00	0.99	0.00	**2.21**
Upper Central	2.14	0.07	1.12	2.24	3.10	0.04	0.00	0.00	0.19	2.18	0.00	**11.09**
Lehigh Valley	0.10	0.04	0.72	1.28	0.46	0.14	0.00	0.00	1.25	3.06	0.00	**7.06**
Lower Central	1.02	0.00	0.48	0.41	0.23	0.01	0.00	0.00	0.00	0.56	0.00	**2.71**
Schuylkill Valley	0.01	0.14	1.23	1.23	4.73	0.70	0.00	0.00	1.13	4.62	0.00	**13.79**
Upper Estuary	1.58	0.46	1.02	1.83	0.55	0.64	0.00	0.00	0.00	13.00	0.00	**19.07**
Lower Estuary	3.68	0.03	0.84	1.26	0.01	0.06	0.00	0.00	0.20	2.86	0.00	**8.95**
Delaware Bay	10.40	0.22	0.82	1.27	1.30	0.02	0.00	0.00	0.00	4.22	0.00	**18.26**
	19.22	**1.03**	**7.05**	**9.50**	**10.39**	**1.66**	**0.01**	**0.00**	**2.77**	**31.49**	**0.00**	**83.13**

CONSUMPTIVE SURFACE WATER	Annual 2020 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.22	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.58	0.00	**0.88**
Upper Central	1.56	0.02	0.00	0.83	0.00	0.67	0.00	0.00	5.99	1.55	0.08	**10.70**
Lehigh Valley	0.08	0.02	0.00	0.97	0.01	0.18	0.16	0.00	1.64	5.93	0.12	**9.10**
Lower Central	0.12	0.00	0.00	6.95	0.01	0.20	0.00	0.00	20.54	5.19	0.00	**33.02**
Schuylkill Valley	0.01	0.00	0.00	7.65	0.00	0.51	0.00	0.00	26.95	26.21	0.01	**61.32**
Upper Estuary	1.54	0.07	0.00	10.36	0.25	1.06	0.00	0.00	17.37	27.75	0.00	**58.41**
Lower Estuary	2.18	0.00	0.00	7.81	0.00	0.30	0.00	0.00	30.63	7.02	0.00	**47.95**
Delaware Bay	2.52	0.00	0.00	0.00	6.03	0.00	0.00	0.00	0.00	0.00	0.00	**8.55**
	8.23	**0.11**	**0.00**	**34.56**	**6.30**	**3.01**	**0.17**	**0.00**	**103.11**	**74.22**	**0.21**	**229.92**

CONSUMPTIVE TOTAL	Annual 2020 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.51	0.06	0.81	0.00	0.01	0.13	0.00	0.00	0.00	1.56	0.00	**3.09**
Upper Central	3.71	0.09	1.12	3.06	3.10	0.71	0.00	0.00	6.18	3.73	0.09	**21.79**
Lehigh Valley	0.18	0.07	0.72	2.25	0.46	0.32	0.16	0.00	2.89	8.99	0.12	**16.16**
Lower Central	1.14	0.00	0.48	7.36	0.24	0.21	0.00	0.00	20.54	5.76	0.00	**35.73**
Schuylkill Valley	0.02	0.14	1.23	8.87	4.73	1.21	0.00	0.00	28.07	30.83	0.01	**75.12**
Upper Estuary	3.12	0.53	1.02	12.18	0.80	1.70	0.01	0.00	17.37	40.75	0.00	**77.48**
Lower Estuary	5.86	0.03	0.84	9.07	0.01	0.36	0.00	0.00	30.83	9.88	0.00	**56.89**
Delaware Bay	12.92	0.22	0.82	1.27	7.33	0.02	0.00	0.00	0.00	4.22	0.00	**26.80**
	27.45	**1.15**	**7.05**	**44.06**	**16.69**	**4.66**	**0.17**	**0.00**	**105.88**	**105.72**	**0.21**	**313.05**

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All Figures in mgd (million gallons per day)

Appendix IV. Table IV-6 Water Demand by Sector and by Sub-Basin 2004 (Normal Year)

WITHDRAWALS GROUNDWATER	Annual 2040 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.28	0.81	14.77	0.00	0.09	0.06	0.00	0.00	0.00	10.93	0.00	**26.94**
Upper Central	2.01	0.90	22.30	23.71	22.53	0.05	0.01	0.00	0.43	29.39	0.01	**101.33**
Lehigh Valley	0.11	0.47	12.77	17.87	3.29	0.16	0.00	0.00	1.76	36.95	0.00	**73.37**
Lower Central	0.96	0.00	8.83	3.00	1.84	0.01	0.00	0.00	0.01	6.80	0.00	**21.44**
Schuylkill Valley	0.01	1.52	21.35	13.00	34.09	0.80	0.07	0.00	2.58	54.84	0.00	**128.27**
Upper Estuary	1.49	5.11	16.57	12.48	3.92	0.75	2.49	0.00	0.00	143.68	0.00	**186.49**
Lower Estuary	3.65	0.41	18.67	10.22	0.09	0.07	0.00	0.00	1.33	39.75	0.00	**74.19**
Delaware Bay	9.61	2.62	15.38	11.50	9.47	0.03	0.00	0.00	0.00	47.87	0.00	**96.48**
	18.13	**11.85**	**130.64**	**91.79**	**75.31**	**1.91**	**2.57**	**0.00**	**6.11**	**370.19**	**0.01**	**708.51**

WITHDRAWALS SURFACE WATER	Annual 2040 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.21	0.00	0.00	0.00	0.00	0.10	0.00	393.32	0.00	6.46	0.00	**400.09**
Upper Central	1.46	0.18	0.00	7.02	0.00	0.76	0.00	145.41	730.63	22.51	0.38	**908.36**
Lehigh Valley	0.08	0.23	0.00	55.21	0.04	0.20	3.26	0.00	2.30	68.18	0.55	**130.06**
Lower Central	0.11	0.00	0.00	67.80	0.06	0.23	0.00	0.00	44.97	57.34	0.00	**170.51**
Schuylkill Valley	0.01	0.00	0.00	27.27	0.02	0.57	0.00	0.00	428.82	294.86	0.03	**751.58**
Upper Estuary	1.44	0.76	0.00	119.82	1.68	1.22	12.25	0.00	2,711.40	279.21	0.00	**3,127.77**
Lower Estuary	2.06	0.00	0.00	435.43	0.00	0.34	0.00	0.00	5,987.94	80.97	0.00	**6,506.74**
Delaware Bay	2.30	0.00	0.00	0.00	40.18	0.00	0.00	0.00	0.00	0.00	0.00	**42.48**
	7.68	**1.17**	**0.00**	**712.56**	**41.98**	**3.42**	**15.50**	**538.73**	**9,906.06**	**809.52**	**0.97**	**12,037.59**

WITHDRAWALS TOTAL	Annual 2040 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.49	0.82	14.77	0.00	0.09	0.16	0.00	393.32	0.00	17.39	0.00	**427.03**
Upper Central	3.47	1.08	22.30	30.73	22.53	0.81	0.01	145.41	731.07	51.89	0.39	**1,009.70**
Lehigh Valley	0.19	0.70	12.77	73.08	3.33	0.36	3.26	0.00	4.06	105.13	0.55	**203.43**
Lower Central	1.07	0.00	8.83	70.80	1.90	0.23	0.00	0.00	44.98	64.14	0.00	**191.95**
Schuylkill Valley	0.02	1.52	21.35	40.27	34.11	1.36	0.07	0.00	431.40	349.70	0.03	**879.85**
Upper Estuary	2.94	5.87	16.57	132.30	5.59	1.97	14.74	0.00	2,711.40	422.88	0.00	**3,314.26**
Lower Estuary	5.72	0.41	18.67	445.65	0.09	0.41	0.00	0.00	5,989.27	120.72	0.00	**6,580.93**
Delaware Bay	11.91	2.62	15.38	11.50	49.65	0.03	0.00	0.00	0.00	47.87	0.00	**138.95**
	25.81	**13.02**	**130.64**	**804.34**	**117.28**	**5.32**	**18.08**	**538.73**	**9,912.17**	**1,179.72**	**0.98**	**12,746.10**

CONSUMPTIVE GROUNDWATER	Annual 2040 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.25	0.08	1.02	0.00	0.01	0.05	0.00	0.00	0.00	1.18	0.00	**2.60**
Upper Central	1.81	0.09	1.54	2.44	3.38	0.04	0.00	0.00	0.27	2.97	0.00	**12.54**
Lehigh Valley	0.10	0.05	0.88	1.39	0.49	0.14	0.00	0.00	1.76	3.77	0.00	**8.58**
Lower Central	0.87	0.00	0.61	0.45	0.28	0.01	0.00	0.00	0.00	0.71	0.00	**2.91**
Schuylkill Valley	0.01	0.15	1.47	1.38	5.11	0.72	0.00	0.00	1.55	5.52	0.00	**15.92**
Upper Estuary	1.34	0.51	1.14	1.98	0.59	0.67	0.00	0.00	0.00	14.95	0.00	**21.19**
Lower Estuary	3.29	0.04	1.29	1.39	0.01	0.06	0.00	0.00	0.27	4.02	0.00	**10.37**
Delaware Bay	8.65	0.26	1.06	1.37	1.42	0.02	0.00	0.00	0.00	5.21	0.00	**18.00**
	16.32	**1.18**	**9.00**	**10.40**	**11.30**	**1.72**	**0.01**	**0.00**	**3.85**	**38.33**	**0.00**	**92.11**

CONSUMPTIVE SURFACE WATER	Annual 2040 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.19	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.67	0.00	**0.95**
Upper Central	1.32	0.02	0.00	0.83	0.00	0.69	0.00	0.00	7.58	2.25	0.08	**12.75**
Lehigh Valley	0.07	0.02	0.00	0.97	0.01	0.18	0.16	0.00	2.07	6.96	0.12	**10.57**
Lower Central	0.10	0.00	0.00	6.95	0.01	0.20	0.00	0.00	25.99	5.84	0.00	**39.09**
Schuylkill Valley	0.01	0.00	0.00	7.65	0.00	0.51	0.00	0.00	34.09	29.95	0.01	**72.21**
Upper Estuary	1.30	0.08	0.00	10.36	0.25	1.10	0.00	0.00	21.98	28.13	0.00	**63.19**
Lower Estuary	1.85	0.00	0.00	7.81	0.00	0.31	0.00	0.00	38.76	8.30	0.00	**57.03**
Delaware Bay	2.07	0.00	0.00	0.00	6.03	0.00	0.00	0.00	0.00	0.00	0.00	**8.09**
	6.91	**0.12**	**0.00**	**34.56**	**6.30**	**3.08**	**0.17**	**0.00**	**130.47**	**82.09**	**0.21**	**263.90**

CONSUMPTIVE TOTAL	Annual 2040 AG	COMM_IND	DOMESTIC	IND	MINING	NON_AG_IRR	OTHER	PWR_HYDRO	PWR_THERMO	PWS	SKI	Totals
Upper Region	0.44	0.08	1.02	0.00	0.01	0.14	0.00	0.00	0.00	1.86	0.00	**3.56**
Upper Central	3.13	0.11	1.54	3.26	3.38	0.73	0.00	0.00	7.84	5.22	0.09	**25.29**
Lehigh Valley	0.17	0.07	0.88	2.36	0.50	0.32	0.16	0.00	3.83	10.73	0.12	**19.14**
Lower Central	0.97	0.00	0.61	7.40	0.28	0.21	0.00	0.00	25.99	6.54	0.00	**42.01**
Schuylkill Valley	0.02	0.15	1.47	9.02	5.12	1.23	0.00	0.00	35.65	35.47	0.01	**88.14**
Upper Estuary	2.64	0.59	1.14	12.34	0.84	1.77	0.01	0.00	21.98	43.07	0.00	**84.37**
Lower Estuary	5.14	0.04	1.29	9.20	0.01	0.37	0.00	0.00	39.03	12.32	0.00	**67.41**
Delaware Bay	10.71	0.26	1.06	1.37	7.45	0.02	0.00	0.00	0.00	5.21	0.00	**26.09**
	23.23	**1.30**	**9.00**	**44.96**	**17.59**	**4.79**	**0.17**	**0.00**	**134.32**	**120.42**	**0.22**	**356.01**

All Figures in mgd (million gallons per day)

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Figure IV-1 Total Water use (Normal Year) - 1996, 2020 and 2040 forecast demand by sector

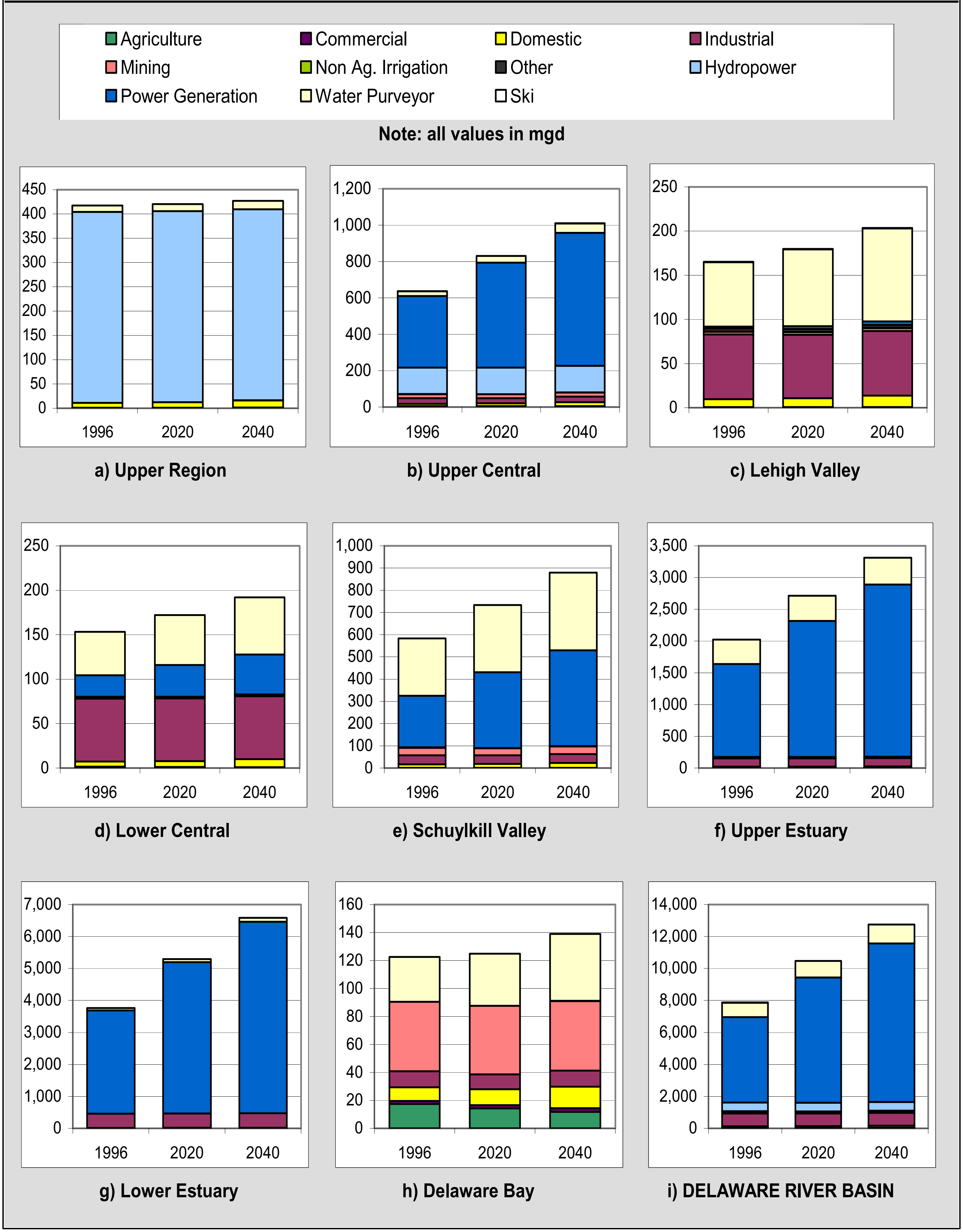
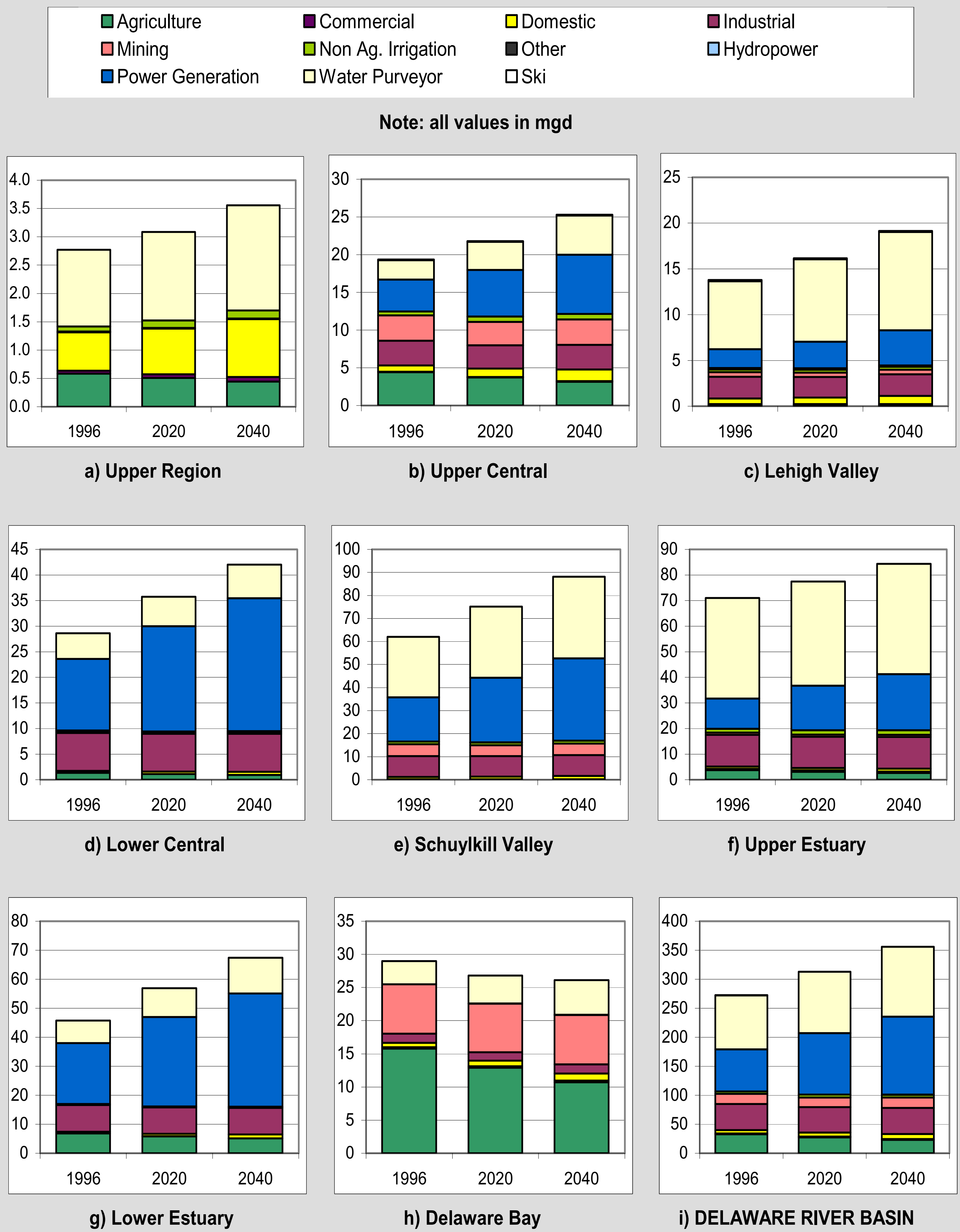


Figure IV-2 Consumptive Water Use (Normal Year) - 1996, 2020 and 2040 forecast demand by sector



All Figures in mgd (million gallons per day)

Figure IV-3 Consumptive Surface Water Withdrawals (Normal Year): Annual and Peak Month (July) values

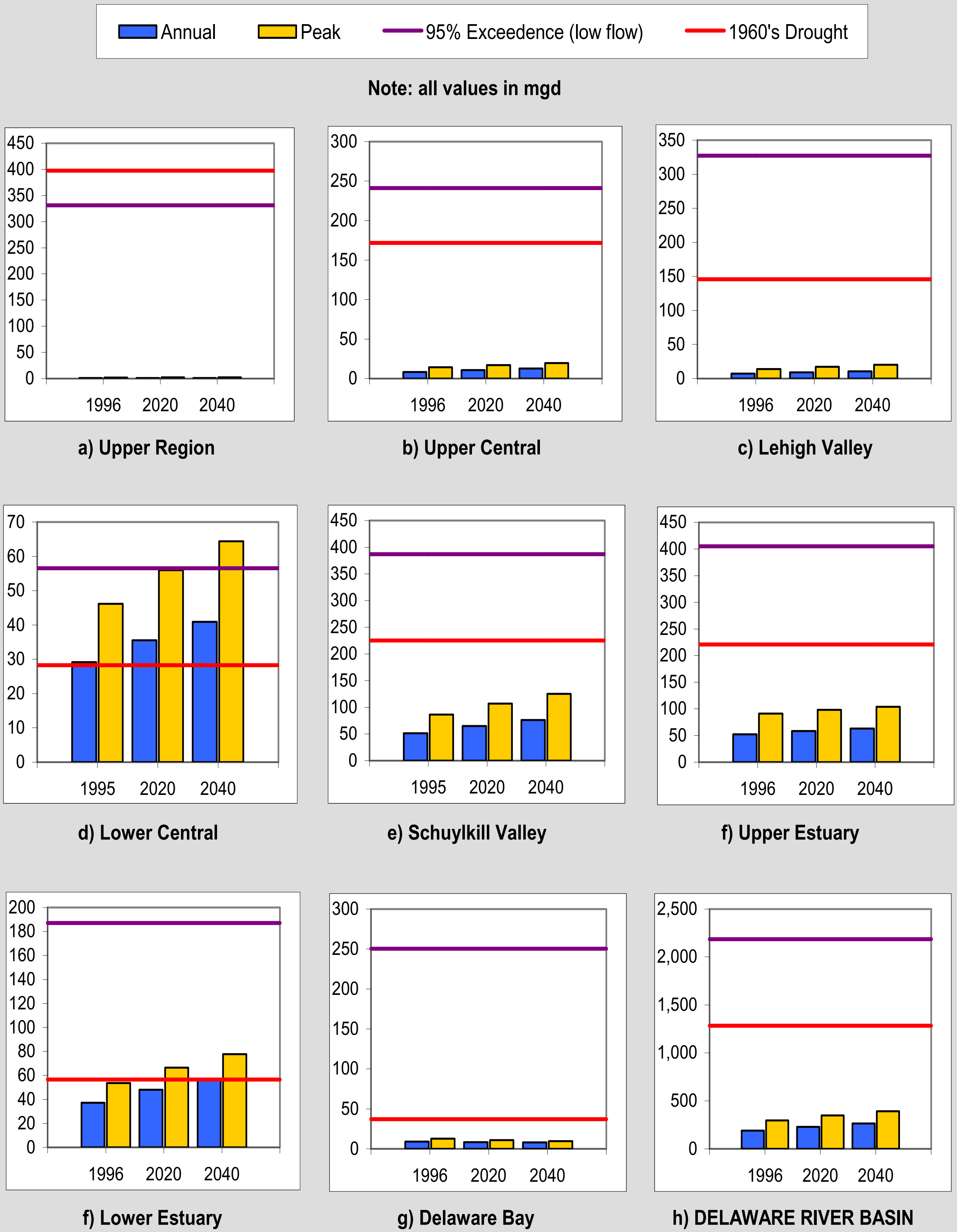
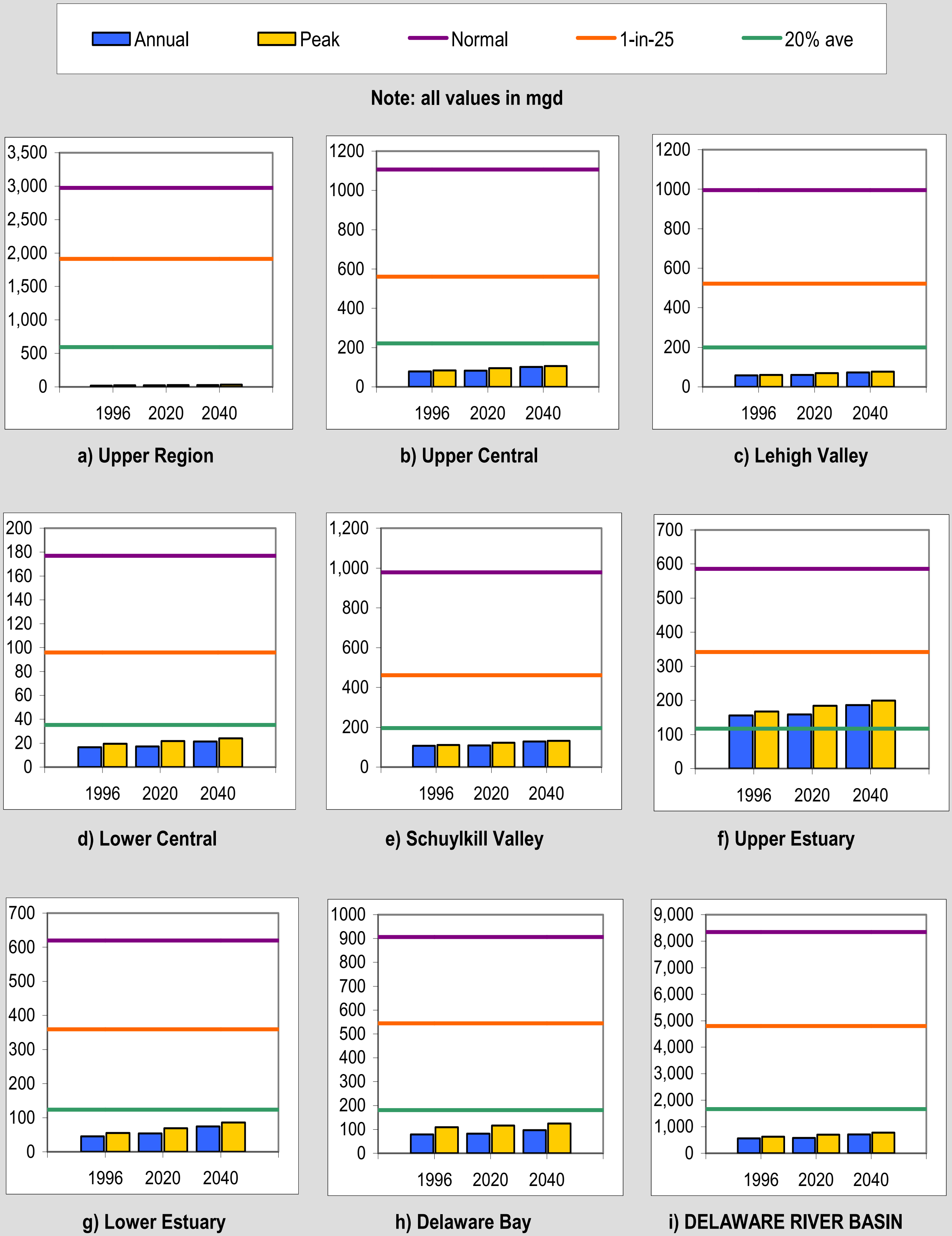
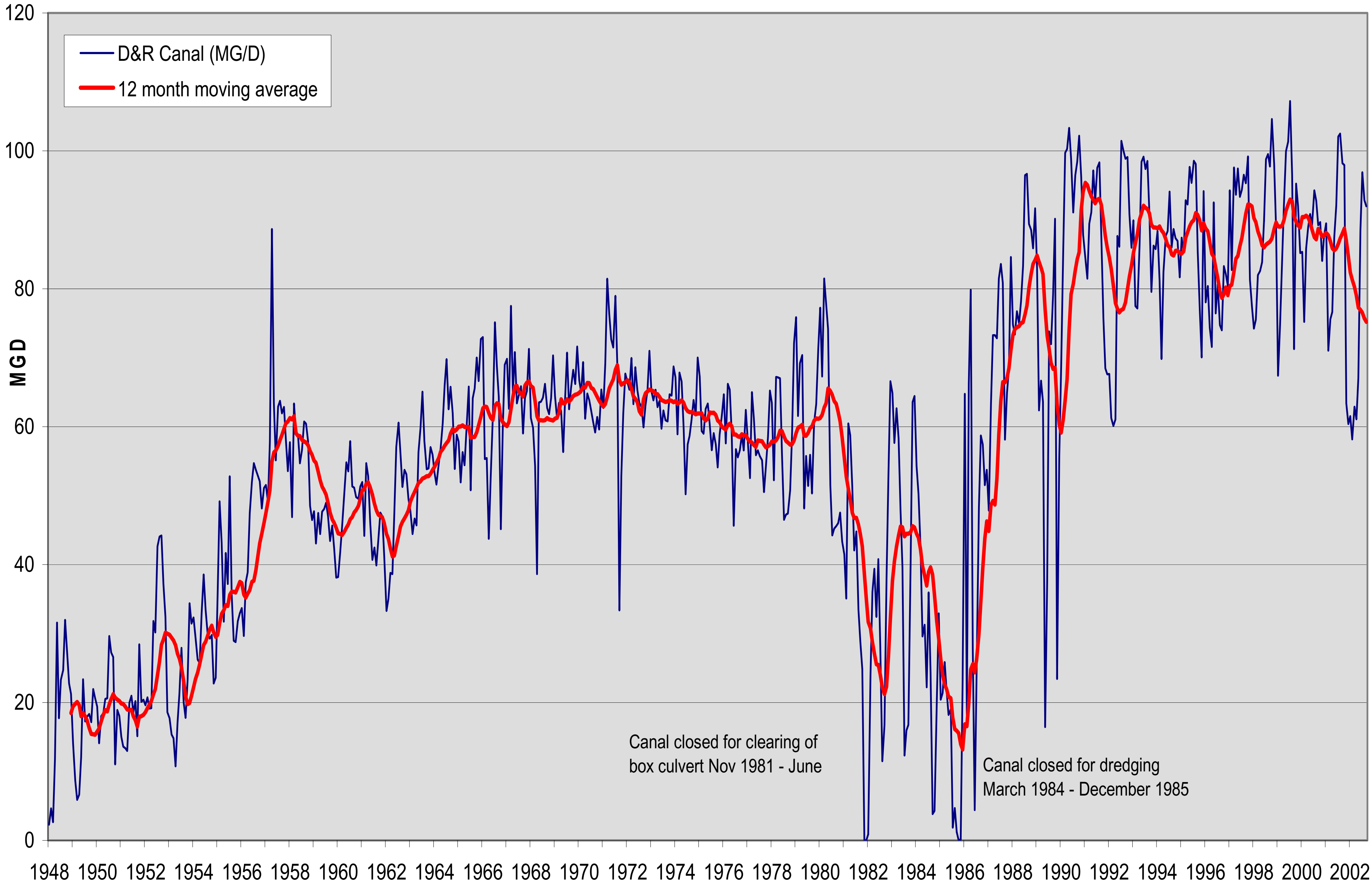


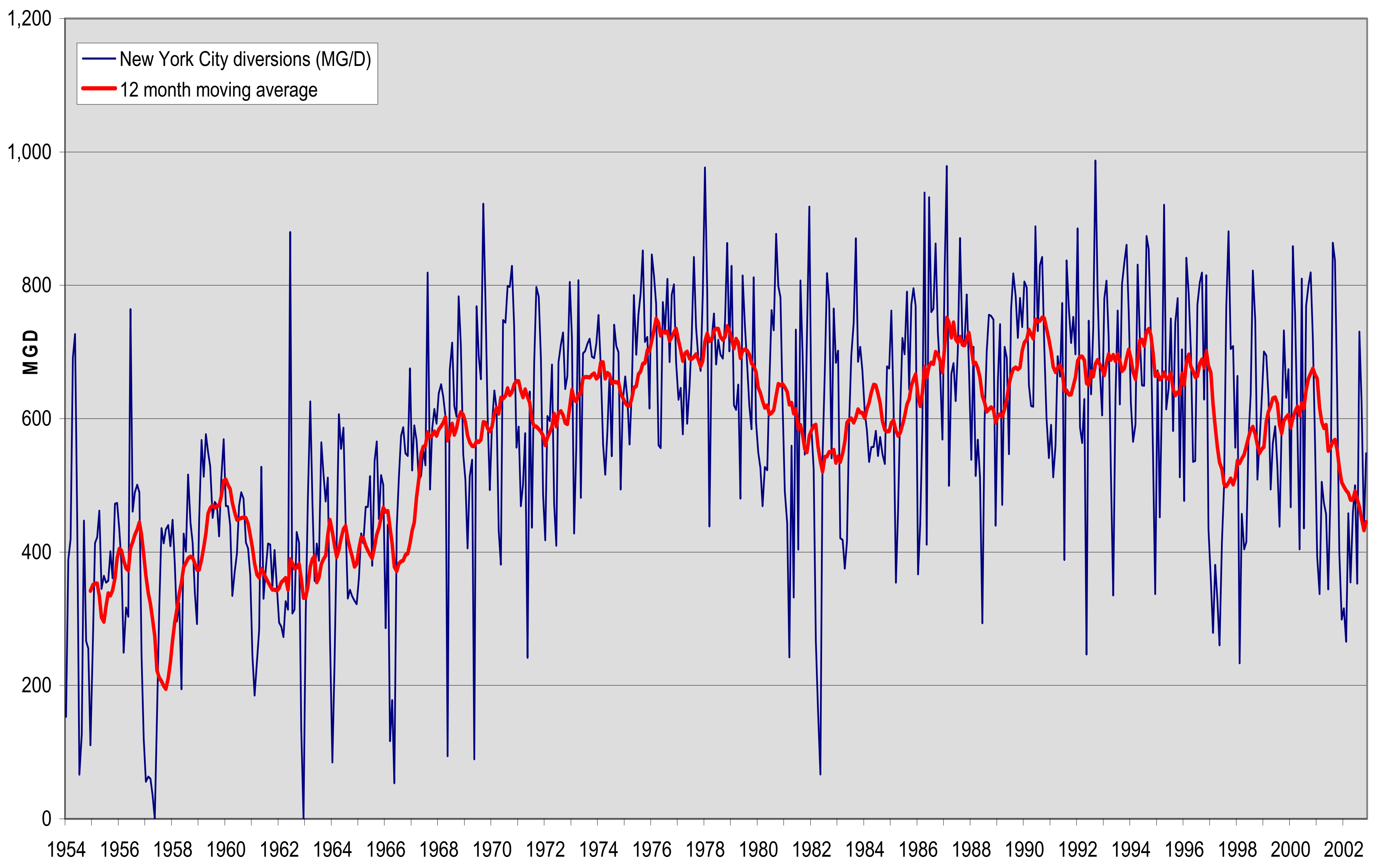
Figure IV-4 Ground Water Withdrawals (Normal Year): Annual and Peak Month (July) values



Appendix V. Figure V-1: Exports to Northeastern New Jersey via the Delaware & Raritan (D&R) Canal 1948 - 2002



Appendix V (cont'd). Figure V-2 Exports to New York City from Delaware River Basin 1954 - 2002



Appendix VI – Equivalent Impact Factor

The importance of the Equivalent Impact Factor (EIF) on consumptive use in the Delaware River Basin is explained in section 5.6 of the main report. Table VI-1 shows listing of industrial facilities in the Basin that are subject to EIF considerations and the impact of the EIF factor on consumptive use values. Figure VI-1 shows the relationship between river mile and EIF.

Table VI-1 Impact of EIF on consumptive use at industrial facilities (1995)

Site Name	Withdrawal (MGD)	Consumptive (MGD)	Consumptive (MGD) (adjusted for equivalent impact factor)	% of absolute consumptive use	Cumul. % of absolute consumptive use
Valero Refining Corp-Nj	8.5	2.4	2.2	18.9	19
Sun Refining- Delaware River	8.8	2.2	1.6	17.5	36
Star Enterprise	218.1	2.2	0.8	17.2	54
E.I. Dupont De Nemours & Co.	16.7	1.7	1.5	13.7	67
E.I. Dupont De Nemours & Co.	35.6	1.4	0.7	11.2	78
BP Oil Inc - Delaware River Div	91.4	1.2	0.9	9.7	88
E. I. Dupont-Edgemoor	6.8	0.7	0.4	5.6	94
Scott Paper Co - Delaware River	14.9	0.6	0.5	4.7	98
General Chemical Corp	17.2	0.1	0.1	0.7	99
Citisteel	0.6	0.1	0.0	0.5	100
SPI Polyols	5.4	0.1	0.0	0.4	100
Essex Industrial Chemical	0.0	0.0	0.0	0.0	100
TOTALS	**423.9**	**12.7**	**8.7**		

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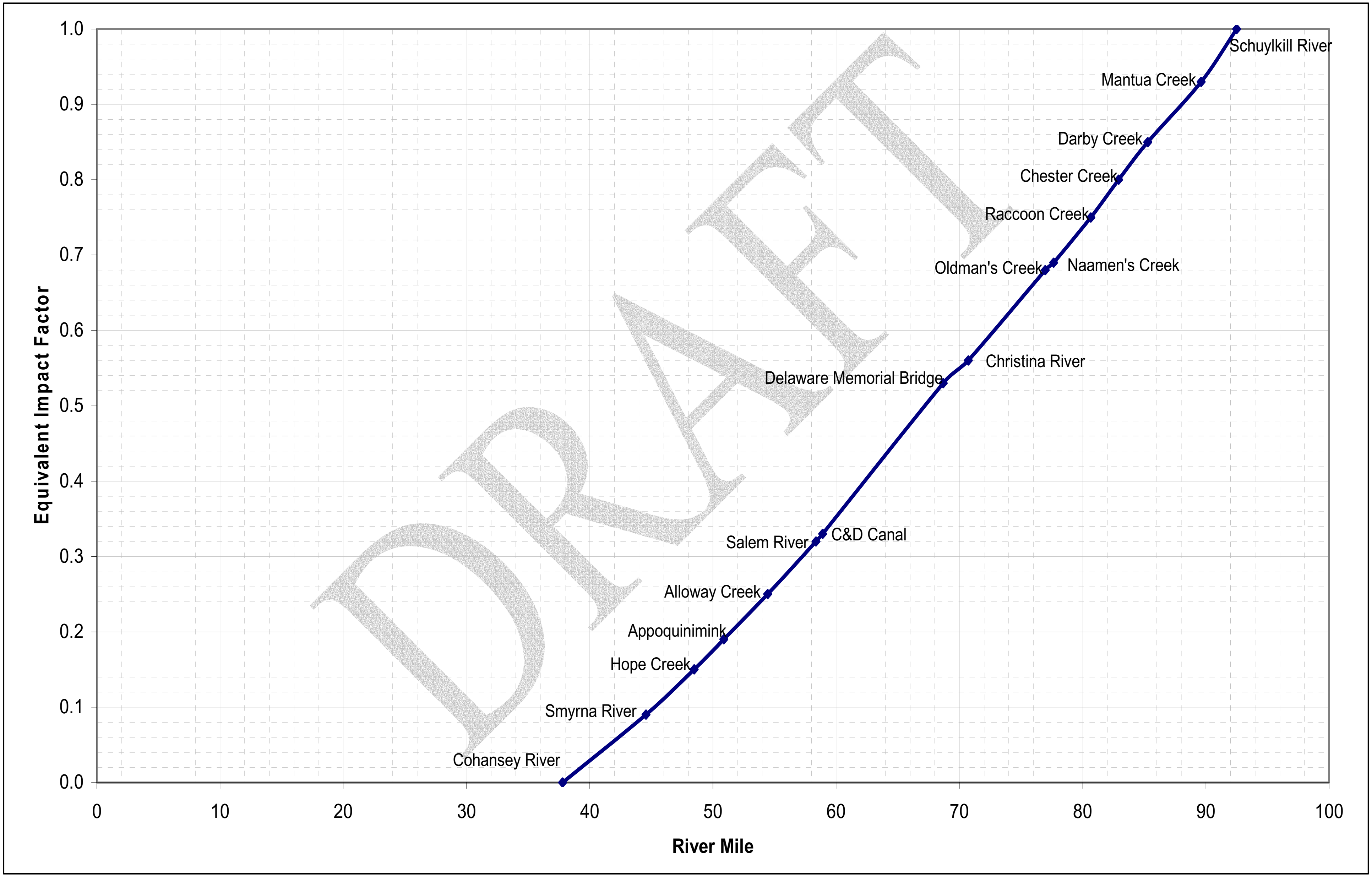
Figure VI-1 Relationship between River Mile and Equivalent Impact Factor



Appendix VII – Determining Surface Water Availability Statistics

Surface water availability statistics have been calculated to provide a benchmark against which to evaluate water demands. The approach taken in this study has been to aggregate consumptive surface water demands (for each sub-basin) for comparison against streamflow exceedence values. Consumptive use values have been used in this analysis as some of the largest surface water withdrawals in the Basin (e.g., those used for cooling purposes) typically discharge the majority of the volume withdrawn.

The following is step-by-step explanation of how surface water benchmark values were derived for each of the sub-basins.

- Analysis performed on data obtained from the USGS website for each suitable gage in the Basin (total of 107) using a spreadsheet program to obtain the 95% exceedence value from a flow duration curve. The 95% exceedence values is the flow value which is exceeded for 95% of the period of record. Therefore this is considered a low-flow value. USGS data are provided in cubic feet per second (cfs) and were converted into million gallons per day (mgd) so that they were comparable with water demand estimates.
- Information was obtained on the contributing drainage area for each gage
- A calculation was made to determine a value of mgd / square mile of drainage for each gage (representing low flow conditions).
- The results (one for each gage) were grouped by sub-basins
- From the grouped data the median low flow/sq. mile value was calculated
- The area of each sub-basin was calculated
- This area (in square miles) was multiplied by the median value for low flow/sq. mile to generate the benchmark against which to evaluate (consumptive) surface water withdrawals

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