League of Women Voters of the
National Capital Area
Water Supply Task Force

Drinking Water Supply in the Washington, D.C. Metropolitan Area: Prospects and Options for the 21st Century

February, 1999

League of Women Voters of the National Capital Area

Water Supply Task Force

Published by: League of Women Voters of the National Capital Area
Washington, D.C.

Copyright: © February 1999, The League of Women Voters of the National Capital Area

Reproduction of this publication for educational or other non-commercial purposes is authorized without prior written permission from the copyright holder provided the source is fully acknowledged. Reproduction of this publication or resale or other commercial purposes is prohibited without prior written permission of the copyright holder.

Citation: League of Women Voters of the National Capital Area, Water Supply Task Force, February 1999, *Drinking Water Supply in the Washington, D.C. Metropolitan Area: Prospects and Options for the 21st Century*. (Washington, D.C.: League of Women Voters of the National Capital Area)

Information: As of January 2012, copies of this report and of its executive summary may be found on the world wide web at http://www.joyhecht.net/professional.html. For further information, please contact:

Dr. Joy E. Hecht, chair
Water Supply Task Force
1-202-494-1162
jhecht@alum.mit.edu

Table of Contents

List of Tables

List of Figures

List of Acronyms

AWWA	American Water Works Association
bg	billion gallons
ccf	hundred cubic feet
COG	Council of Governments
D.C. WASA	District of Columbia Water and Sewer Authority
EWTP	Experimental Water Treatment Plant
FCWA	Fairfax County Water Authority
ICPRB	Interstate Commission on the Potomac River Basin
LCSA	Loudoun County Sanitation Authority
LFAA	Low Flow Allocation Agreement
mgd	million gallons per day
MWCOG	Metropolitan Washington Council of Governments
UOSA	Upper Occoquan Sewage Authority
USGS	United States Geological Survey
WAD	Washington Aqueduct Division of the U.S. Army Corps of Engineers
WASA	Water and Sewer Authority
WSSC	Washington Suburban Sanitary Commission

ACKNOWLEDGMENTS

This report was made possible by the generous cooperation and support of many individuals and organizations. Water supply professionals in the region who generously contributed their time and expertise include Paul Bender (WASA), David Binning (FCWA), Ed Halley (O'Brien and Gere), Dale Hammas (LCSA), Tom Jacobus (WAD), Chuck Murray (WSSC), George Papadapolous (WASA), Pete Peterson (WAD) and Jim Warfield (FCWA). Karl Berger of COG came to as many meetings as his growing family would allow, and was generous with his time on the phone and in email when he couldn't be with us. Officers and staff of the National Capital Area and the National Leagues have brought us together, provided meeting space, assisted us in disseminating this report, and provided a dozen other services which have made it easier for us to focus on getting the study done.

Finally, this study never would have happened without the continual flow of information, suggestions, data, corrections, criticism, advice, sarcastic edits, and even occasional awe from Roland Steiner and Erik Hagen of ICPRB. Thanks, guys, we never could have done it without your help. And we promise, we'll return all the books we borrowed!

MEMBERS OF THE WATER SUPPLY TASK FORCE

Co-Chairs:	Joy E. Hecht, Arlington
	Robert R. Perry, Falls Church
Members:	Geri Albers, Washington, D.C.
	June Duke, Washington, D.C.
	Marcia Finnerty, Arlington
	Myles Glasgow, Washington, D.C.
	Anne Gregory, Arlington
	Mary Nightlinger, Fairfax
	Jean Packard, Fairfax
	Dick Smith, Arlington
	George Stryker, Prince George's County
	Newell Trask, Loudoun County
Participants:	Karl Berger, MWCOG
	Erik Hagen, ICPRB
	Roland C. Steiner, ICPRB

Executive Summary

The Washington, D.C. region has expanded dramatically in population and geographic area in the past few decades. This report addresses the availability of water to meet the long run needs of the region as it continues to grow. The supply of water varies both seasonally and from year to year, while demand has grown steadily with the growth of the region's population. Projections by the Interstate Commission on the Potomac River Basin (ICPRB) indicate that demand could exceed supply early in the 21st century in the event of severe drought. This report explains how this could occur and discusses several strategies which may enable the region to avoid water shortages in case of drought.

Background

In 1997, the region's water system supplied an average of 468 million gallons per day (mgd). Over 96% of this was provided by three major suppliers; Fairfax County Water Authority serving most of northern Virginia, the Washington Aqueduct serving the District of Columbia, Arlington, and Falls Church, and the Washington Suburban Sanitary Commission serving most of the Maryland suburbs. In addition, smaller water companies serve a few other jurisdictions across the region.

About 75% of the region's water comes from the Potomac River, and the remainder from the Patuxent and Occoquan Rivers. A severe drought in 1966, when flows on the Potomac briefly dropped to below today's production levels, led the region to begin collaborating on drought management. In 1978, the Low Flow Allocation Agreement was signed, specifying how water will be allocated among the three major suppliers in case of drought. In the 1980s, two dams were completed whose reservoirs store water for release into the Potomac in case of drought. The agreement and the dams were expected to ensure that the region could handle a severe drought without excessively inconveniencing its population.

Demand and Supply Projections

The region's three major water companies are mandated to assess the supply and demand for water every 5 years. The 1995 study, prepared by the ICPRB, provides the information on demand and supply on which much of this report is based.

Demand projections

The ICPRB uses a relatively simple model to project water demand. It considers three types of water users; single family homes, multifamily buildings, and employees. The study estimates "water use factors," coefficients indicating the average quantity of water consumed by each type of user in each jurisdiction. Demand for water is calculated as the number of users in each category multiplied by the water use factor for that category and jurisdiction. The projections of the number of users are based on population projections provided by the local jurisdictions to the Metropolitan Washington Council of Governments (COG). The ICPRB model assumes that the water use factors will remain constant throughout the period of concern; that is, consumption per user will not change in the future.

In addition to the water known to be consumed by households or employees, some water is not accounted for. This unaccounted for water is attributable to leaks, faulty water meters, pipe maintenance, and fire fighting. The ICPRB estimates unaccounted water from historic records. Factoring in unaccounted-for water, the total water demand for each year in the future is estimated as single family use

+ multifamily use + employee use + unaccounted retail water + unaccounted wholesale water.

Supply projections

Water supply projections are based on historical records of both the free-flowing Potomac River and the inflow and outflow for the reservoirs which currently serve the system. They also take into account an "environmental flow-by" at Little Falls Dam of 100 (mgd) to protect aquatic life. To determine when supply might exceed demand, the ICRPB simulated a recurrence of the so-called "drought of record" which occurred in 1930-31, whose probability in any given year is 1 to 2 per cent. It is important to bear in mind that although this probability is fairly low, such a drought could occur at any time.

Comparison of supply and demand

ICPRB projections indicate that under a reocurrence of the drought of record, demand would exceed supply in 2035. That is, by 2035 population would be high enough to exhaust the water supply in the reservoirs; before that year, existing water storage systems could meet water demand even if the worst drought on record were to reoccur. This projection assumes that water in the Savage River Reservoir, which is designated for diluting polluted water rather than for consumption, would be made available in case of drought. Without that source, the reservoirs could be depleted by 2025.

In practice, the adequacy of water supply would be constrained well before existing storage systems are depleted. Experience with water shortages is limited; however in the past one water supplier made plans to impose water use restrictions if storage dropped to 40% of reservoir capacity. The ICPRB projections indicate that under the drought of record, storage levels could be reduced to 40% as soon as 2015 with the Savage River Reservoir and 2005 without it. Thus, although an actual deficit in the supply does not occur in the projections until 2025 or 2035, heightened concern and the imposition of water use restrictions could occur much sooner. These projections require us to address the problem now.

Strategies to Prevent Water Shortages

The present study identifies several strategies for responding to the prospect of future water shortages. These are conservation, identification of new water sources, reducing waste in the water distribution system, managing growth in the metropolitan area, and reclaiming treated waste water.

Conservation

Water conservation involves a combination of measures to reduce water consumption or slow its growth relative to projected needs. Water prices can be structured to create a financial incentive for households, manufacturers, and commercial enterprises to reduce consumption. In commercial and industrial establishments, process changes can offer cost-effective reductions in water demand. Regulatory policy can require technologies to reduce water use; for example, building codes often require low-flow toilets and shower heads in new construction. All of these measures are accompanied by education efforts to encourage households and businesses to reduce water use. Demand reduction may also include use restrictions when extreme conditions occur. Rather than build a supply system adequate to allow lawn-watering during droughts, for example, a community can consciously choose to sacrifice lawns when a drought occurs and invest resources elsewhere.

New sources

Potential new sources of water include surface or ground water from within the Potomac basin and transfer of water from outside the basin. One way to increase water supply during droughts would be to construct one or more additional reservoirs on currently free-flowing reaches of the Potomac and its tributaries. Although this option has been routine in the past, today it would likely face intense opposition and practical difficulties in the Washington area. There has been widespread development both in the valleys that would be flooded and along potential shorelines in much of the basin. In more remote areas, there would be intense opposition to impounding free-flowing streams in scenic areas. Ground water might be obtained from wells in the coastal plain of southern Maryland. Previous studies have indicated that these might offer a maximum yield of 100 mgd, but this would be available under drought conditions only and not as a sustainable supply. The transfer of water from outside the Potomac basin, a strategy commonly used in the western United States, would face enormous difficulties and seems unlikely.

Reducing unaccounted-for water

The water utilities consider unaccounted-for water to be the difference between their production or purchase and the quantity paid for by final consumers. Some of these losses are attributable to unmetered uses, such as fire fighting, flushing pipes during routine maintenance, and use in public buildings and parks. Others are due to to illegal hookups or inaccurate meters. Still others are due to actual physical losses from leaky pipes and similar problems. Total unaccounted-for water for the three main suppliers in the Washington area ranges from 10 to 28%. In contrast, the American Water Works Association considers a 10% loss to be acceptable in a well-run system. The incentive to reduce these losses depends in part on whether the cost of doing so is less than the cost of producing additional water. Both the actual losses and the means of detecting and reporting them differ among the utilities. Therefore, detailed studies of unaccounted-for water leading to a concerted reduction effort may be justified.

Growth management

Growth management could limit the increase in regional population and hence the demand for water. Environmentalists will recognize in this approach the principle of limiting growth to the natural carrying capacity of the area. Sentiment for limiting growth fluctuates over time; right now the tools for doing so are more readily available in Maryland than in Virginia. Nationwide, there is a movement to concentrate new development in higher density mixed-use centers where infrastructure, including water and sewer lines, already exists. This results in substantial savings in water use through smaller lawns to be watered, smaller houses, fewer miles of pipes that may be susceptible to leaks, and less water used during flushing. While growth controls may be desirable, they are not a likely strategy for reducing water demand, since they go far beyond the relatively narrow infrastructure concerns of water supply.

Reuse of waste water

The recycling and reuse of treated waste water is common throughout the country where surface water is the raw water source. This option is already in use in the Washington, D.C. area at the Upper Occoquan Sewage Authority (UOSA) treatment plant in Centreville, Virginia. The Fairfax County Water Authority withdraws raw water from the Occoquan downstream from the UOSA plant, treats it by conventional methods, and converts it into potable water delivered to its customers. The reuse of effluent from the Blue Plains treatment plant on the Potomac estuary downstream from Washington may offer a similar opportunity. As much as 200 to 300 mgd might be pumped upstream and discharged into the Potomac above the intake used to supply Washington. This would ensure a supply of water to the Washington Aqueduct and permit higher withdrawals from the river by other users. The major concern is with this strategy is clearly its health implications. Technical experts feel that the resulting water can be potable; however, the treatment required may make it costly.

Conclusions

Drinking water shortages may confront the Washington metropolitan area early in the 21st century. This is not a problem which can be put off while the region's jurisdictions cope with more immediate problems. While this report does not identify clear choices among the options for preventing water shortages, we can make a number of useful observations:

- Water conservation offers both short- and long-term ways for reducing water use. These should be considered irrespective of our approach to water supply.

- Exploiting new water sources through construction of new reservoirs or building large-scale ground-water extraction facilities may face serious difficulties due to increased population in the areas affected and large-scale land-use changes in recent years.

- Reducing waste in the distribution systems is a financially viable way to save water where losses are great and the cost of producing additional water exceeds that of finding and fixing leaks.

- Growth management could lead to reduced demand for water in the region; however, the scope of growth management efforts goes far beyond the issues considered in this report.

- Reclamation of waste water from the Blue Plains plant is a technical option which warrants additional evaluation with current data.

More thorough technical and financial analyses of all the options are needed in order to make informed decisions about how to address projected water shortages. Concurrently, there must be broad public discussion of the region's water supply issues involving all interested stakeholders. As we approach the 21st century, public policy questions like this one are no longer the purview of water systems engineers alone; they must be addressed by everyone who has a stake in the outcome.

1. INTRODUCTION: THE PROBLEM

The Washington, D.C. region has expanded dramatically in population and geographic area in the past few decades. Such growth generates new challenges in many areas, from land use to transportation, from housing to environmental quality. This study addresses one challenge in particular, the availability of water to meet the long run needs of the region as it continues to grow. Our interest in this issue is broad in scope and far-reaching in time scale. We are concerned, not with the ability of local public authorities to withdraw, treat, and distribute water from the region's rivers and underground sources, but with the capacity of those water sources to slake the region's thirst if growth continues as projected in the twenty first century.

The geographic scope of this study is set by the area served by the three major water suppliers in the region:

- the Fairfax County Water Authority (FCWA), producing drinking water for Fairfax County and portions of neighboring jurisdictions;
- the Washington Aqueduct Division of the Army Corps of Engineers (WAD), whose Dalecarlia and McMillan treatment plants provide water to Washington, D.C., Arlington, and Falls Church (which in turn sells water to parts of Fairfax County); and ,
- the Washington Suburban Sanitary Commission (WSSC), treating water for Montgomery and Prince George's counties.

As the urban area grows, the three suppliers are likely to serve new communities. We are, therefore, considering the areas which they expect to serve, rather than only those which they now serve.

Rather than defining *a priori* the time horizon of interest to us, we looked at projections of supply of and demand for water published by the Interstate Commission on the Potomac River Basin (ICPRB) to determine at what point the availability of water might become a constraint in the region (Mullusky et al, 1996). The analysis of water supply is based on the flow of water in the region's rivers. Reservoirs allow us to save water in periods of high flow in order to use it during periods of seasonal low flow and high demand, or longer-term drought. The analysis of demand is based on local jurisdictions' population projections and average water use in each jurisdiction by households of different types.

The ICPRB projections focus on the supply available under drought conditions rather than on water available in an average rainfall year. Two drought benchmarks are used in the ICPRB work. One is the so-called "drought of record," the worst drought to have occurred in the century during which data have been kept on flows in the region's rivers. In that drought, which occurred in 1930-31, the average monthly flow in the Potomac dropped below 554 million gallons per day (mgd).[1] The second benchmark was in 1966, when the lowest one-day flow on record occurred, 388 mgd. Flows only stayed near that level for a few days, however, so this event was less severe than the earlier drought (Mullusky et al, p. 46). In contrast with these levels, the average annual flow between 1959 and 1994 was 7,730 mgd. The drought of record, therefore, involves dramatically lower flows than we typically experience. About 75% of the region's water comes directly from the Potomac, so these decreases are crucial for water supply.

The second benchmark has been used only in internal ICPRB work so far.[2] Published assessments of water supply and demand ask in what year a reoccurrence of the drought of record could cause the region's reservoirs to run out of available water altogether; that is, when will population have

1 Information provided by Erik Hagen, ICPRB.

grown enough that the reservoirs will be empty were the drought of record to occur. In practice, however, if the reservoirs were to drop to 40% of their maximum capacity, it would be appropriate to introduce water use restrictions, in order to prevent storage from going any lower. This is obviously more likely than a total depletion of the reservoirs, and could therefore occur sooner than the water shortages resulting from a reoccurrence of the drought of record. The ICPRB study indicates that by 2035, regional demand for water could deplete the reservoirs were the drought of record to reoccur. Of more immediate concern, a reoccurrence of that drought could bring the reservoirs to below 40% of capacity as soon as 2005 under ICPRB projections (Mullusky et al, p. 52).

The strategies available to respond to the possibility of water shortages can take years or decades to come on line. Moreover, the farther in advance the problems are considered, the greater the range of choices available and the lower the cost of implementing some of them. The time is ripe, therefore, for the citizens of the Washington area to begin assessing the options, so as to head off serious water problems before they occur.

This study first presents the region's water situation, and then considers several options for how to respond to the challenges ahead of us. Chapter 2 provides general background on the region's water supply system. Chapter 3 reviews the ICPRB projections of water supply and demand. Chapter 4 considers five options for responding to anticipated shortages:

- water conservation, use restrictions, and related techniques to reduce demand per consumer;
- identifying new sources of water which could increase supply, including new reservoirs, new sources of ground water, or interbasin transfers;
- reducing losses or leakage from the distribution systems;
- managing growth in the region so as to reduce demand by reducing the number of consumers or the consumption per household; and
- reclaiming treated wastewater from the Blue Plains Waste Water Treatment Plant for reuse within the region.

Chapter 5 draws initial conclusions and calls for more in-depth analysis and comparison of strategies for managing long-run water supply and demand.

Our objective in conducting this study, and particularly in assessing the options for addressing water supply issues, is to develop an initial sense of the magnitude of the problem and the feasibility and relative cost-effectiveness of the solutions. We do not expect to arrive at even preliminary conclusions about which is the best option. We do, however, hope to raise awareness of the problem and the possible solutions and make a case for additional investigation of the alternatives. We hope that this study will be the start both of a more thorough and better grounded analysis of the options and, even more importantly, of a wide-ranging public debate which will lead to a choice among them.

2Information provided by Roland Steiner and Erik Hagen, ICPRB.

2. Background: The Region's Water Supply System

Over 96% of the drinking water in the Washington metropolitan area is furnished by three major suppliers; the Washington Aqueduct Division of the Army Corps of Engineers, the Fairfax County Water Authority, and the Washington Suburban Sanitary Commission. Water provided by the three suppliers is either furnished directly to the public or sold to smaller suppliers for resale through their distribution systems. In addition to the three major companies, a small proportion of water is treated by local government authorities in Rockville, the City of Manassas, the City of Fairfax and smaller surrounding jurisdictions. Figure 1 shows the area served by each supplier and the locations of their water intakes and treatment plants. Figure 2 shows all of the regional water suppliers and the interconnections among their distribution systems.

Washington Aqueduct Division (WAD)

The Washington Aqueduct Division of the Army Corps of Engineers (WAD or "the Aqueduct") furnishes treated water to the District of Columbia's Water and Sewer Authority (WASA), the Arlington County Department of Public Works and the Falls Church Department of Public Utilities. Falls Church distributes water to users in a large section of Fairfax County and in the town of Vienna. WAD also directly supplies water to federal facilities including National Airport, Ft. Myer, and Arlington Cemetery. WAD provided water to over 350,000 households in 1995.

The Aqueduct withdraws most of its raw water from the Potomac River through two conduits at Great Falls and the remainder, less than 10%, from a pumping station at Little Falls. The Little Falls pumping station is used mainly to meet demand during periods of low river flow, when the effectiveness of the gravity-dependent conduits from Great Falls is limited. All raw water must pass through the Dalecarlia Reservoir and is then pumped to either the Dalecarlia or the McMillan treatment plants. From the treatment plants it is fed to the three distribution systems.

Fairfax County Water Authority (FCWA)

The Fairfax County Water Authority serves its own county directly and wholesales water to the Virginia-American Water Company for distribution to Alexandria and Dale City. FCWA also provides water under contract to the Prince William County Service Authority and the Loudoun County Sanitation Authority. The Authority takes water from the Potomac through an intake 18 miles upstream of Chain Bridge and from a reservoir it manages on the Occoquan River. FCWA provided water to about 385,000 households in 1995.

Washington Suburban Sanitary Commission (WSSC)

The Washington Suburban Sanitary Commission provides treated water to Prince George's County, Montgomery County and a small part of Howard County in Maryland. It is currently negotiating to provide water to Charles County as well. WSSC withdraws water from the Patuxent River, managed in two reservoirs, and from an intake on the Potomac River fourteen miles above Chain Bridge. WSSC provided water to almost 550,000 households in 1995.

Figure 1. Map of the Regional Water System

Figure 2. Interconnections among the Regional Water Suppliers

Table 1 shows the average daily water withdrawal in millions of gallons per day by each of the three water companies for the years 1995 through 1997. As we can see from the table, about 75% of the region's water, or some 387 mgd, comes from the Potomac. The annual average daily demand from all sources is about 480 mgd now; it is projected to rise to 623 mgd by 2020 (Mullusky et al, pp. 46-47).

Table 1. Average Daily Water Withdrawal (mgd)

	1995	**1996**	**1997**
WAD			
Great Falls intake	174	172	145
Little Falls intake	12	11	31
Total	187	183	176
FCWA			
Potomac	72	63	71
Occoquan	48	51	56
Total	119	114	127
WSSC			
Potomac	121	116	116
Patuxent	46	46	49
Total	167	161	165
Overall Total	**473**	**458**	**468**

Source: ICPRB unpublished data, provided by Erik Hagen. Columns do not total due to rounding error.

Drought Management

The drought of 1966 reduced flow on the Potomac to 388 mgd for a single day, leading to a recognition that better management of river flows and withdrawals was essential to guarantee adequate water supplies to the metropolitan area. The legal rights to water in the Potomac River basin became an increasing concern. While those who wanted water in the past had generally been able to use it without adverse impact on others, it was clear that in the future unrestricted demand would outstrip supply. This led to the development of a series of regional water resource agreements.

The first agreement to cooperate on water resource management in the Washington area was the Potomac River Low Flow Allocation Agreement (LFAA) signed in 1978 by the U.S. Army Corps of Engineers (for WAD), the District of Columbia, the State of Maryland, WSSC, the Commonwealth of Virginia, and the Fairfax County Water Authority. In case of low flow on the river, the LFAA binds the three water utilities to allocate available water in proportion to the average of their winter demand over the previous five years. It directs WAD to declare alert, restriction, and emergency stages of flow and establishes an unbiased moderator to resolve disputes and enforce the agreement.

In the 1980s, two dams were completed whose reservoirs store water for release into the Potomac in case of low flow. The Bloomington Dam (now named Jennings Randolph) on the North Branch of the Potomac was completed in 1982, and the Little Seneca Reservoir in Montgomery County was completed in the mid-1980s. The three main Washington area water suppliers participate in the construction, operation, and maintenance costs of the dams. In return, they are guaranteed a supply of water in case of drought.

In July 1982 the Corps of Engineers, FCWA, WSSC, the District of Columbia and ICPRB entered into a second cooperative agreement for water resource management, the Water Supply Coordination Agreement. This document designated ICPRB as the coordinator of water resources in times of low flow. In times of drought, the water system will be operated according to procedures developed, administered, and routinely tested by ICPRB, which coordinate the use of the Patuxent and Occoquan Reservoirs with management of the Potomac waters. This regional management ensures that WSSC and FCWA will make maximal use of the reservoirs under their control, so that WAD, which does not manage any reservoirs of its own, will have use of the Potomac.

The 1982 agreement also provides that in April 1990 and each fifth year thereafter the signatories will review and evaluate the adequacy of the available water supplies to meet the demand of the Washington metropolitan area over the subsequent twenty years. If the review finds that water supply will be inadequate, the parties must identify additional sources of supply, which will also be allocated according to the terms of the LFAA. The costs of constructing, operating and maintaining new water sources will be allocated among the suppliers in accordance with cost allocation formulae in the agreement as well.

3. Projections of supply and demand

The parties to the regional agreements have committed to forecast demand for and availability of water in the Washington metropolitan area every five years. Their 1995 report, prepared by ICPRB (Mullusky et al, 1996), provides the analysis of regional water supply which underlies much of this report. The ICPRB study is the most detailed assessment available of the demand for water over the next twenty five years, and is therefore the basis for this report. If we want to rely on their results, we must have some appreciation of how they are obtained. This section provides a simple explanation of the main components of the ICPRB water demand and supply analysis. It then compares supply and demand projections to identify when we might expect to experience water shortages. Finally, it suggests a number of features of their model which may be open to question, and which may call for further refinement in subsequent iterations of their study.

3.a Methodology for ICPRB Water Demand Forecasts

The ICPRB report uses a relatively simple model to project water demand to 2020. It is based on several independent variables:

- Number of households

Data on the number of households in each jurisdiction in the region are projected to 2020, based on population projections which the local jurisdictions in the region provide to the Metropolitan Washington Council of Governments (COG) (MWCOG 1994). Households in the service region are then subdivided according to whether they live in single family or multifamily buildings.

- Number of employees

The number of people working in each jurisdiction is similarly projected to 2020, again based on projections which the local jurisdictions provide to COG.

- Water use factors

"Water use factors" indicate the quantity of water consumed each day per household or per employee. In suburban jurisdictions, water use is higher for single-family households than for multi-family households, presumably because of the water consumed watering lawns. To reflect this difference, there are two different household water use factors. No distinctions are made among types of employment in estimating water consumption per employee; each jurisdiction has only one employee water use factor. There is considerable variation across jurisdictions in these water use factors, as can be seen in Table 2, which shows the 1995 range for each of the three use categories.

To calculate the total quantity of water used by each category of users in each year, the number of users in that year is multiplied by the appropriate water use factor. Thus:

water use in single family buildings = number of households x single family use factor;
water use in multifamily buildings = number of households x multifamily use factor; and
water use by employees = number of employees x employee use factor.

The water use factors are constant throughout the period of the projections. That is, the ICPRB study assumes that consumption per household or per employee will not change in the future. Therefore the projections of increased water use result only from growth in the number of households or the number of employees.

User category	**Range of water use factors in gallons per day**
Households in single-family buildings	200 - 350 (all but one jurisdiction out of 18 are under 262)
Households in multi-family buildings	122 - 280 (all but three jurisdictions out of 18 are under 200)
Employees	30 - 102 (all but two jurisdictions out of 19 are under 53. Data for Lorton Correctional Facility are not included in this table because they appear to be calculated differently from municipal data.)

- Unaccounted-for water

In addition to metered consumption, some water is not accounted for. Unaccounted water use is the difference between the quantity of water which leaves the water treatment plants and the amount which is billed to the customers. Most unaccounted water use is attributed to leakage from the wholesale distribution systems (between the water treatment plant and the distributor), leakage from the retail distribution systems (the network of pipes serving retail customers), faulty water meters at the retail level, pipe maintenance and firefighting. Two different coefficients are estimated for unaccounted water use, one for the wholesale distribution system and the other for the retail system. These coefficients are expressed as a percentage of total water use, and are estimated based on historical records from the retail customers, the wholesale customers, and the water companies.

Taking into account these four input variables, total water use for each year in the future is then estimated as:

single family use + multifamily use + employee use + unaccounted retail water + unaccounted wholesale water

The ICPRB study makes one refinement to this model in order to look at the impact on water use of changes in building codes to require water conservation. Such measures were introduced in Maryland in 1990 (WSSC, April 1998). This year was therefore used as a cut-off date to analyze the difference between water consumption in suburban homes built through 1989 and consumption in those built in 1990 or later. Contrary to expectations, the analysis found that water use was higher in new single-family homes than in old ones, while it was lower in new multi-family homes than in old ones. ICPRB is interested in analyzing this issue further, with larger samples than were possible initially.

3.b Methodology for ICPRB Supply Projections

The ICPRB study uses a number of different methods and assumptions to project the available supply of water into the future. The projections used in this report to assess when the region could encounter water shortages are based on a simulation model which takes into account how the region's reservoirs are actually managed. Without going into the details of how available supply is projected, a few points should be noted.

Projections of available water are based on the so-called "drought of record," which occurred in 1930-31. That is, the projections indicate how much water would be available if that drought were to occur again. While the data series on flows in the river is relatively short, it provides the only information available about how low the river might get, and is therefore used to estimate how much water might be available in the future.

The earliest hydrological record on the Potomac begins in 1898, when data began to be collected on flows past Point of Rocks, Maryland. Based on the verified data, which date only as far back as 1929, experts estimate the probability of the drought of record occurring in any one year at 1- 2%. This represents the approximate likelihood of water supply being as low as the ICPRB's projections in any given year. It is important to bear in mind, of course, that such a drought could occur in any year. The fairly low probability of it occurring must not lull us into feeling that such a possibility is distant; in fact, such a drought is just as likely to occur next year or in five years as it is to occur in 2030.

The supply modeling process takes into account several key timing issues. First, demand for water fluctuates seasonally, as does natural flow. In general, demand is higher than average from June through September, and lower than average in the other months. This fluctuation is greater in suburban areas, where more water is used for watering lawns than in the city. During a drought the fluctuation becomes even greater than usual, particularly at the end of the summer when increasing numbers of people decide to water their lawns. Second, in considering the severity of a drought, the model must consider not only how low the flow drops on the river, but also for how many days the flows are low. Thus although the lowest flows in the 1966 drought were lower than those of 1930-31, the 1930-31 drought was more serious because it lasted considerably longer. Flows are analyzed for a single day, as well as by monthly and annual averages; each measure serves different purposes in drought management planning.

Projections of water supply also take into account that we cannot use all the water in the river, lest we destroy the aquatic ecosystems dependent on the river's flow. In 1981, the Maryland Department of Natural Resources (DNR) analyzed how much water must always remain in the river in order to protect species other than ourselves (Maryland DNR, 1981). This so-called "environmental flow-by" was set at 100 million gallons per day over Little Falls Dam and 300 mgd from Great Falls to Little Falls Dam. All ICPRB estimates of available water in case of drought begin by subtracting off 100 mgd, to ensure that in planning for water management in case of drought we plan for aquatic as well as human life.

3.c Comparison of Demand and Supply

Table 3 shows the average daily demand for water averaged over the year, including the environmental flow-by, in millions of gallons per day. Water demand up to 2020 is calculated using the ICPRB model; demand from 2025 to 2050 is extrapolated from the earlier data. The table also shows how much water will be remaining and available in the reservoirs at that level of demand. As mentioned above, this is under the "drought of record" assumption.

As the table shows, the Washington metropolitan area could expect to run out of stored water for the first time were the drought of record to recur in 2035. This calculation is generous, because it includes the water stored in the Savage River Reservoir, which was built to dilute mine acids rather than for drinking water supply; without relying on Savage, the target year would be 2025. This does not mean that we *will necessarily* run out of water in 2035 (or 2025). Rather, the target year is the first time at which, were we to have a serious drought, our existing water storage system would not be sufficient to meet the projected demand. If our 1-2% probability for the drought of record is correct, this means that there is a 1-2% chance of exhausting the water supply available from the reservoirs in 2025-2035. Before that time, existing water storage systems could meet water demand even if the worst drought on record were to recur.

While a reoccurrence of the drought of record would not deplete the reservoirs until 2025-2035 under these projections, water supply managers are not likely to let their reservoirs empty completely. During the mild drought of 1977, FCWA found that the water storage system in the Occoquan Reservoir would become stressed once it was dropped to about 40% of its capacity. While no absolute water deficits would be experienced at that level of supply, FCWA considered imposing serious water restrictions in its service areas when supply dropped that low in 1977. Based on this judgment by FCWA managers, ICPRB now anticipates that when any of the reservoirs in the system drop to as low as 40% of capacity, the region's water companies will implement water restrictions or other emergency measures to reduce demand.[3] While short-term water resource restrictions are routinely applied in many parts of the country, and have been in effect in Loudoun County this year, they serve as a loud warning that water supply may be a serious problem, and tend to galvanize public attention to the issue. In planning for long-run water supply, therefore, it is important to anticipate when such measures might come into effect as well as when we might experience real water deficits.

To project when we might drop to 40% of reservoir capacity, ICPRB staff have made some adjustments to the data in their 1995 study. They estimate the total supply of water directly available to the region's water companies at some 35.1 billion gallons. Unlike the totals in the ICPRB report (e.g. pp. 47 and 49), this figure excludes the 16.6 billion gallons (bg) of reserves which must remain in Jennings Randolph Lake in order to protect water quality and it excludes 6.5 bg of water in the Savage River Reservoir.[4] With these assumptions, under a reoccurrence of the drought of record, water storage would drop to 40% of capacity, or 14 billion gallons, in about 2005, as shown in Table 3. If the Savage River water is available, this risk is pushed back to 2015.

This, then, is the anticipated water shortage which this study considers. In terms of the time required to develop new water supply options, 2015 is not far off and 2005 is frighteningly close. Fortunately, the risk which could occur as soon as 2005 is of water restrictions rather than the reservoirs running dry; they would not be depleted in case of a drought of record until 2035. Nevertheless, it is clearly time to initiate public discussion of the strategies available to address this problem.

Table 3: Available Water Storage, With and Without Savage River

Forecast Year	Demand including flow-by, in mgd	All water remaining in reservoirs, in mg	Water remaining without Savage, in mg
1990	552.9	23,900	17,400
1995	583.5	23,400	16,900

3Personal communication, Roland Steiner and Erik Hagen, ICPRB.

4Personal communication, Roland Steiner and Erik Hagen, ICPRB.

2000	618.2	22,300	15,800
2005	650.1	20,300	**13,800**
2010	678.9	17,700	11,200
2015	706.0	14,100	7,600
2020	732.1	10,400	3,900
2025	757.6	6,900	400
2030	782.3	3,400	-3,100
2035	806.6	**-200**	-6,700
2040	830.3	-3,200	-9,700
2045	853.8	-6,700	-13,200
2050	877.8	-10,700	-17,200

3.d Questions on the Demand and Supply Forecasts

While the ICPRB forecasts are the best available, they do raise a number of questions. We are not suggesting that these questions in any way invalidate the ICPRB projections. However, we do recommend that the water companies and the ICPRB consider addressing them in the design of the 2000 water demand and supply study.

- It may be possible to improve some of the population and employment projections provided by the local jurisdictions to COG. It would be useful for COG to investigate how they are being done, and perhaps to provide technical assistance if some jurisdictions' projections are found to include significant error. Since both the jurisdictions themselves and COG depend on these projections for a wide range of uses beyond the analysis of water demand, improving them may generate benefits far beyond strengthening the next ICPRB water analysis.

- Projections of water use by single-family households are not explicitly related to lot size, although that is probably a significant factor in use. The single-family use coefficients do reflect differences in lot size across jurisdiction, since a different coefficient is calculated for each jurisdiction. However, if we are interested in projecting how changes in zoning or introduction of other growth management techniques affect water demand, it would be useful to be able explicitly to relate water use to lot size. Coefficients based on lot size could be determined by analyzing a sample of single-family home water billing records from across the region, and relating water use to size of the lot on which the home is built. The resulting coefficients could then be applied to project water use for single-family homes throughout the region.

- The ICPRB model assumes that water use per household and employee will be the same in the future as it is now. "All else being equal," this may well be a reasonable assumption. However, it may be interesting to consider as well the impact on quantity used of such conservation strategies as increasing water prices and the water-conserving technologies mandated by the Federal Energy Policy Act of 1992.

- A related concern is that the ICPRB report does not allow for water use restrictions which may decrease demand in times of drought. In actuality, as a drought progresses water use will drop sharply as water use restrictions are imposed. This means that projected demand in time of drought will be significantly lower than projected demand in an ordinary rainfall year, pushing back the time when water shortages would occur in case of a drought of record. It may be appropriate to incorporate this in the next water supply and demand study.

- The ICPRB study assumes that almost all of the water storage in the region will be available for water supply in the event of a drought. The issue of the Savage River Reservoir has been mentioned above. That reservoir is designed to dilute water coming from upstream which has been rendered unduly acidic because of mine outflows. Recent improvements in upstream water quality mean that the river is less acidic than in the past, so it may be plausible to seek to use that reservoir in case of emergency. However, similar issues arise with respect to Jennings Randolph Reservoir. The total capacity of Jennings Randolph is about 42.7 bg, of which 13.4 bg are allocated to water supply, 16.6 bg are reserved for diluting the river's flow in order to protect water quality, 11.8 bg are kept empty to reserve space in case of upstream floods, and 0.9 bg are expected to be filled with sediment over time. The 1995 ICPRB study assumes that 30 bg are available for water supply; this includes both the water supply and the water quality allocations. However the ICPRB does not have the legal authority to release the water quality allocation in order to provide drinking water; it is under the authority of the Army Corps of Engineers and is explicitly designated for other purposes. While it might be possible to reallocate it to drinking water supply in case of drought, this should not be simply assumed. This issue should be reexamined and discussed explicitly in the next study.

- The 100 mgd flow-by which is reserved to preserve aquatic ecosystems may require review. This flow-by level was recommended by Maryland's Department of Natural Resources (Maryland DNR 1981). While a thorough review of that study is beyond the scope of this report (and the knowledge of its authors), it does raise several questions. The DNR study analyzed how key fish species respond to changes in their habitats and how available habitat is affected by decreased flow. Their model was not calibrated for flows less than 300 mgd, however, and was built for the study of rivers less complex than the Potomac (Maryland DNR, pp. 8-9). Consequently, the DNR flow-by recommendations are based not on the model, but on the drought of 1966, when flow averaged 119 mgd below Little Falls for two weeks. While fish mortality was observed at the time, it is believed to have had no long-term impact on the fisheries (DNR pp. 97, 117, etc.).

  The DNR study recommends 100 mgd as a minimum daily environmental flow-by below Little Falls Dam and 300 mgd between Little Falls Dam and Great Falls. These recommendations are only for daily flow, not average flow over a longer period. The report also recommends that after the completion of the Bloomington Dam a monthly flow schedule be established to complement the 100 mgd daily minimum. This was never done; the 100 mgd figure alone has been used since the completion of the DNR study. We therefore recommend that the preparation of the 2000 water supply and demand analysis include an independent expert review of the flow-by rates and the establishment of monthly flow-by levels as recommended in 1981.

- The ICPRB report assumes that the total storage capacities of the region's reservoirs will not change in the future. While reservoir siltation is quite low, it is not zero. It may be appropriate to consider whether siltation may in fact reduce storage capacity sufficiently by 2025 or 2035 that this should be factored into the supply analysis. The bathymetric survey of Jennings Randolph now underway through ICPRB should provide data which will indicate whether this issue warrants further concern in the 2000 study.

4. What to do about shortages?

The ICPRB study suggests that if the drought of record were to recur, there would be absolute water shortages by 2035, but water use restrictions might be necessary as soon as 2005. This chapter reviews several strategies for responding to these possibilities:

- reducing water demand through the introduction of incentives and regulations which lead to lower consumption;
- identifying new sources of water from reservoirs, ground water, or interbasin transfers;
- reducing waste in the water distribution systems, in order to make more of the treated water available for consumption;
- managing growth in the Washington area in order to reduce demand for water; and
- reclaiming treated wastewater so that it can be reused within the region.

This chapter does an initial scoping of the potential of each of these options to contribute in a cost-effective way to alleviating possible future water shortages. We explain how each option would work, assess whether or how much it might reduce demand or increase supply of water, provide available information about the costs involved, and consider issues such as technical risk, implications for public health and the environment, and political feasibility.

Because this study has been prepared based on limited data and studies, it has not been possible fully to assess and compare the five options which we have identified. Our aim in considering them is not to identify the most feasible or cost-effective strategy for preventing water shortages in the coming decades. Rather, it is to launch a discussion of possible strategies, and provide an initial base for identifying areas in which additional work is desirable in order to map out appropriate responses to the challenges of water supply in the region.

4.a Water conservation

Water is used for many purposes, ranging from the fundamental needs for life support, to productive activities like manufacturing and agriculture, to recreational uses like swimming pools and golf courses. The quantity actually essential to sustain life is small; about two liters per person per day. The challenge when we consider water conservation is to identify strategies to reduce our other uses of water, preferably without harming our quality of life.

A combination of tools is generally used to reduce actual water use or slow down the growth in consumption relative to predicted trends. Water prices can be structured so as to create a financial incentive for households, manufacturers, and commercial enterprises to reduce consumption. In commercial and industrial establishments, process changes may reduce water demand and even be cost-effective for the firm in only a few years; the policy strategy here is to help firms identify such "win-win" opportunities. Regulatory tools can require the use of technologies which reduce water consumption; for example, building codes often require use of low-flow toilets and shower heads in new construction. All of these tools are accompanied by public education efforts to encourage both households and businesses to reduce water use. Finally, the demand-reduction toolkit includes the application of use restrictions when extreme conditions occur. This can be an accepted part of the package; rather than building a supply system adequate to allow lawn-watering in drought, for example, a community can make a conscious choice to sacrifice lawns when a drought occurs and invest their resources elsewhere.

Critics of water conservation sometimes argue that it is not cost effective in an area with growing population, because it simply postpones investments in future water supply sources rather than permanently eliminating the need for them. This argument is flawed, for several reasons. The costs and benefits of conservation must be analyzed just as would be the costs and benefits of increasing supply, and whichever option is most cost-effective (and in other respects appropriate) should be selected. Thus if it costs less to reduce demand than to increase supply, it will be a more appropriate solution than seeking new water sources (Drury and Skeel, p. 229). Moreover, even if additional supply investments will be needed in the future, postponing them allows the region to use the required resources for other socially desired aims in the interim, rather than tying them up in water supply infrastructure.

Critics of conservation strategies also argue that they will reduce revenue and profits to the water companies. This is true if the utilities plan, invest, produce, and set prices based on pre-conservation demand and revenue assumptions. However, when conservation is fully integrated into the utility's planning process, production and investments will be planned based on lower demand projections, and prices will be set accordingly, so conservation will not lead to losses (Drury and Skeel, p. 228). This is the conclusion of a recent WSSC study of water use in the Maryland suburbs, conducted in response to revenue decreases associated with declines in both total and per capita consumption through the 1990s. The study recommends that WSSC anticipate further decreases in consumption, thereby not incurring operating costs which they might not be able to recover from water sales (WSSC 1998, p. 13).

Water Pricing

Water pricing systems which encourage conservation typically have several components. One is a fixed charge levied on all customers irrespective of how much they consume. The second is a charge per unit of water consumed. This will be a progressive charge; that is, the price per gallon of water increases with the amount of water consumed. Thus a certain basic level of consumption will be quite cheap. Beyond that, the price will increase, much as federal income tax rates go up when a household moves into a higher tax bracket. Such a pricing scheme is designed to make it increasingly expensive for households to increase their water consumption, reflecting the fact that it is increasingly difficult to provide more and more water. The third component of the water prices may be an increase in rates during the peak season, designed to reduce fluctuations in water use and thus decrease the need to invest in productive capacity which is only used for a short time each year.

Research suggests that such pricing strategies are effective in reducing water consumption. Drury and Skeel (1997) cite a number of studies of this issue, and also discuss their own experience in Seattle, where water consumption was reduced by about 6% in response to price changes. They also compare Seattle and Tacoma, which consumed water at about the same rate at the start of the study. In Seattle, the fixed charge for water was set at a low \$2.50 per month, but they set a fairly high peak use rate use of \$2.27 per hundred cubic feet (ccf). Tacoma, in contrast, set a higher fixed charge of \$7.68 and a lower peak use rate of \$0.74 ccf. After a few years average household costs were nearly the same in the two cities, but Tacoma's daily household consumption was 21% higher than Seattle's.

In suburban Maryland, WSSC has found that their highly progressive price structure is a significant factor in the drop in consumption observed in the 1990s. WSSC shifted from a 100-step progressive pricing structure to a somewhat simpler 16-step system, and subsequently raised the prices in each step. After this they observed significant decreases in consumption, particularly in high-rise and garden apartment buildings. While they expect that a number of factors contributed to those declines, they observe a strong correlation between cumulative per-unit increases in water prices and decreases in per-unit production (WSSC 1998, Attachment 2 p. 7).

"Win-win" Conservation Opportunities

In many situations, investments in water conservation can pay off in a short enough time frame that large consumers will find it in their financial interest to make them. For industry, it can be cost-effective to alter manufacturing processes in order not only to reduce water use, but also to reclaim valuable raw materials which would have otherwise disappeared down the drain. This industrial water conservation also has reduced the costs for treatment or disposal of industrial wastes and has increased company profits. Some manufacturing processes use tremendous amounts of water and subsequently produce large quantities of toxic wastes which are difficult to store and treat. This leads to large expenditures on compliance with state and federal regulations. By reducing water use and altering manufacturing processes, some companies will be able to save substantial amounts of money.

Similar experiences may be found in the residential sector. The WSSC study, in considering why water use decreased by 6-8% in apartment buildings, noted that private firms are working with building managers to help them reduce water use. The firms' payment takes the form of a share of the savings on the water bills (WSSC 1998, p. iii). The fact that firms will enter this line of work with no payment other than a share of the reduced water bills indicates that the savings are financially significant for all of the participants.

Water-Conserving Technologies

Technological options such as low-flow toilets and shower heads can offer easy ways to reduce water use. The Federal Energy Policy Act of 1992 only allows the manufacture and sale of low-flow plumbing fixtures in the United States, and many jurisdictions now require them in their building codes as well. When built into new homes or offices (as opposed to retrofitting existing properties not otherwise being renovated) these fixtures should allow reduced water use at no additional cost.

Other technologies may also offer useful opportunities to save water at a larger scale. One interesting option is the collection and reuse of graywater - that is, water which has been used for purposes which leave it unpotable, but perfectly appropriate for lawns, industrial purposes, or other non-consuming uses. Such systems are sometimes set up in complexes such as hotels associated with golf courses, or in municipal parks. They require investment in a second collection and distribution system, and therefore can have significant start-up costs; however the payback period may be short enough to make them financially interesting as well. The potential for reuse of graywater in Texas has been sufficient to lead that state's Board of Plumbing Examiners to propose guidelines for the development of such systems (Texas Water Resources Institute 1998).

Landscape Design

Landscape design in areas such as office parks, golf courses, or subdivisions can have significant impacts on the need for irrigation water. Such techniques as use of native plants and careful placement of plantings can as much as halve the amount of water needed to create a pleasant landscape (Sakrison 1997, p. 194). In addition to promoting water conservation, careful landscape design can also deter erosion, provide habitat for native wildlife, encourage infiltration of stormwater, and reduce runoff.

Public Education

Any water conservation strategy must be accompanied by public education. Such a program would target different water users in different ways, based on their water use patterns. Household users would benefit from information about the importance of water conservation, tips on how to use water, and how much they could save on their water bills. Home designers, builders, engineers and landscape architects may need technical information about how to design for less water use. Industrial, commercial and government enterprises might require assistance in designing individual strategies for how each plant could reduce its water use and perhaps save money at the same time.

Water Use Restrictions

One component of a conservation strategy is the public acceptance of water use restrictions in case of drought. Such restrictions typically include bans on lawn watering, filling swimming pools, and other non-essential uses of water. While they may always be brought into effect with or without a conservation-based water supply strategy, public opinion may need to shift for such restrictions to be viewed as normal. Otherwise, the introduction of water use restrictions may be viewed as a signal that it is essential to plan for increases in supply.

Costs and Time Frame

The cost of a conservation-based water supply strategy will vary substantially depending on which tools are used and the opportunities for cost-effective water savings. Some conservation tools will permit financial savings, and indeed should be used whether or not conservation is a public policy objective. Others may require no initial cost, and will have a modest pay-off over time; these may include the building code changes to require low-flow toilets and showers in new constructions. Still other water conservation tools may involve significant initial costs, and may not pay off quickly; however they may still be cost-effective strategies for closing the gap between water supply and demand.

The time frame in which conservation tools will have a significant impact on water consumption will also vary greatly depending on the choice of tools and the rapidity with which they are implemented. Such strategies as the use of low-flow plumbing fixtures in new construction will only reduce water use at the rate that new structures replace old ones with the higher-volume plumbing systems. The same goes for changes in landscaping and strategies which are only implemented with new developments. Other tools lead to faster decreases in consumption, especially to the extent that the public sector is willing to require them or pay for the requisite investments. Thus if significant decreases in water use are desired quickly, tax credits could be given to those who retrofit existing plumbing systems or factories which change their manufacturing processes to use less water. Rapid investments in conservation may be less cost-effective than slower gradual ones, but may still be warranted if the alternative is more expensive investments in increased water supply.

4.b Identifying new sources of water

Increases in the supply of water to the Washington metropolitan area could come from three sources. Within the Potomac River Basin, water is available from surface sources or underground. By managing surface water with reservoirs, managers can provide water during the critical dry season when demand peaks and supply reaches its lowest levels. Ground water is available in parts of the Potomac Basin; however, the supply is relatively limited. Transfer of water from outside the basin, a strategy commonly used in the western United States, is the third possibility; however it seems unlikely.

Surface Water

Many municipalities use reservoirs to buffer the seasonal variation in surface streams used for water supply. Typically, runoff to streams, lakes, and reservoirs is highest in the late fall, winter, and early spring when vegetation is not transpiring and is lowest in late spring, summer and early fall. Reservoirs are allowed to fill during the periods of high runoff, then drawn down when stream flows are at their lowest. In this way, water use in the municipality is not limited by seasonal variations in surface-water flows.

The Washington area uses more water in the summer and early fall than is available from the free-flowing Potomac River in the driest of years. The reservoirs on the adjacent Occoquan and Patuxent Rivers are routinely used to even out the seasonal variations in free-flowing surface water. In addition, Jennings Randolph Reservoir and Little Seneca Creek provide additional storage that until now has not been needed. One means of avoiding future water deficits would be the construction of new reservoirs on what are currently free flowing reaches of the Potomac River and its tributaries. There are, however, major difficulties and likely intense opposition to the use of this alternative.

In the 1950s, in response to burgeoning growth and a congressional resolution, the U.S. Army Corps of Engineers identified 16 major multipurpose reservoir sites in the Potomac basin (U.S. Army 1963). All but one of the sites are upstream from Washington. The Bloomington site is the only one which was utilized for a reservoir; this facility, later renamed Jennings Randolph, was completed in 1982. In 1974, the consulting firm of Black and Veatch identified 21 more potential sites within the Washington metropolitan area (Black and Veatch, 1974). Most of these were small (<10bg capacity) and all but one required that inflow be augmented by pumping from the mainstem of the Potomac.

These previously identified sites, with yields ranging from 30 to 900 mgd, would form the logical starting point for any effort now to augment water supplies by construction of additional reservoirs. Reservoirs constructed on these previously identified sites would have yields that range from 20 to 900 mgd. Though it is beyond the scope of this study to formally evaluate each of them, we note some of the issues that might arise were they to be pursued.

The largest of the sites identified in the past is in Seneca, Maryland. This would be a major impoundment with a yield of 900 mgd on the mainstem of the Potomac adjacent to Loudoun, Montgomery, and Frederick Counties. The effects of construction of this dam are so great, including flooding of the Chesapeake and Ohio National Historic Park, and the level of current development along the potential shoreline so extensive, that it seems an unlikely option given the increased populations of those suburban counties.

All of the sites considered for pumped storage are along streams that are highly valued for their scenic and aesthetic qualities and are bordered by low to moderate density residential development. Goose Creek and Catoctin Creek in Virginia, along which 8 of the sites are located, are state scenic rivers. During the dry months, these reservoirs would be drawn down substantially, since there would be no inflow from pumping from the Potomac River. This would result in unsightly, muddy shorelines for much of the year (U.S. Army 1983).

The Royal Glenn site (WV), Brocks Gap (VA), Savage II (MD), and Mount Storm (WV), are located on distant upstream tributaries in mountainous, timbered areas. Some of the flooded land would be in national or state forests, so public recreation and tourism would be affected. The free-flowing South Branch of the Potomac, where the Royal Glenn site is located, is heavily used for white water canoeing, a use that would be lost. The Brocks Gap site is in Rockingham County which has adopted a land use policy calling for agricultural uses only on lands administered by the County. The Savage II site is largely within a Maryland state forest. The river supports excellent cold water fishing which would be lost within the reach affected by the reservoir.

The Verona (VA), and Six Bridges (MD) sites, and a series of three sites near Chambersburg (PA) are within broad, relatively open valleys heavily used for agriculture as well as residential developments. One of the sites near Chambersburg would require relocation of a town. The Verona and Six Bridges sites were authorized for Phase I architectural engineering and design in 1974. Both faced substantial public opposition and shortly thereafter the states of Virginia and Maryland withdrew their support. The Verona site would face intense opposition were it proposed now. (Woodley, 1998)

Licking Creek (MD/PA), Town Creek (MD), Sideling Hill (MD), Tonoloway Creek (MD/PA), North Mountain (VA/WV), Little Capacon (WV), and Opequon (VA) are close to the main stem of the Potomac both north and south of the river. The floodplains are narrow and the topography rugged to gently rolling. Maps of these areas show many roads alongside or leading to the streams suggesting there has been considerable residential development. New waste water treatment plants have been located in the valleys of Licking Creek and Opequon Creek.

As this discussion suggests, a wide range of factors could constrain use of the reservoir sites previously identified. Indeed, the reservoir option may come to be seen as presenting so many difficulties that it will not be adopted. A 1983 U.S. Army Corps of Engineers report makes it clear that opinion about reservoirs had changed drastically since 1963 (U.S. Army 1983). Free flowing streams were coming to be regarded as healthier than impounded streams. The scenic, aesthetic, and recreational values of free flowing streams were seen as equal to if not greater than those of reservoirs. In addition, population growth and development at the sites and in their vicinity would create strong opposition, increase costs, and raise many additional problems.

The decision to pursue new surface water sources should be based on more complete information and analysis than is now available. If additional reservoir capacity is to be an option for future water supply, the selection process needs to be restarted from the beginning. New sites hitherto not considered might emerge from such a process. In the current climate, the process would have to be quite different from those of past studies. The location of sensitive and controversial public facilities such as reservoirs requires the involvement of all stakeholders: public officials from the Washington area and upstream communities, water purveyors, land owners, industry groups such as farmers and real estate developers, environmental groups, and ordinary citizens. Moreover, the screening, appraisal, and selection of sites must be transparent, so that all parties can see exactly how decisions are made.

The costs of additional reservoirs would also have to be reestimated from scratch. Current estimates have relied on the figures for the increase in construction costs from 1963 as published in the Engineering News Record. Other factors such as possible disproportionate increases in land costs and the costs of screening and environmental studies now required have not been factored in.

Estimated costs in previous studies range over a wide interval depending on size, topography, and other specifics of a site. The most realistic numbers are probably for Jennings Randolph, for which actual costs are available, and for the Verona site for which two years of Phase I architectural engineering and design studies were completed. The following table gives construction costs for these structures in 1998 dollars. More refined cost estimates would serve little purpose at this time.

The time needed to bring new reservoirs on line is long. The Bloomington (now Jennings Randolph) Reservoir was first proposed by the Corps of Engineers in 1963; construction was completed in 1982. Given the lengthy public process and environmental studies which would be required now, twenty to thirty years would appear to be a realistic time frame for the implementation of the reservoir option.

Table 4. Costs of Reservoir Construction

Site	Safe Yield (mgd)	Cost/mgd (1998$M)
Jennings Randolph	155	1.6
Verona	125	2.2

Groundwater

In 1983, the Corps of Engineers published a study of possible groundwater sources for the Washington area that focused on the coastal plain aquifers of southern Maryland (U.S. Army 1983). These aquifers are part of a wedge of unconsolidated sands, silts, and clays that range in thickness from 0 above Chain Bridge to over 2000 feet in southern Prince George's County. The area of study lies within a 30-mile radius of Washington to the southeast.

The United States Geological Survey (USGS) conducted a digital simulation of the groundwater system in this area to assess the effects of pumping from these aquifers at various rates (Fleck, 1982). Hypothetical well fields were located at sites where there would be the least interference with existing ground-water pumpage. The Corps concluded that use of ground water from the coastal plain aquifers at rates up to 100 mgd would be feasible. Because it would take a relatively long time for the aquifers to be recharged to their initial conditions, pumping at this rate was seen as a contingency source for drought years only and not as a sustained source of water. It would also be possible to pump at lower rates with shorter recovery times.

If ground water from southern Maryland is to be considered as a future water source for the Washington area, even as a drought contingency only, the 1983 study needs to be updated. The USGS has been collecting data on the coastal plain aquifers since then, so a new simulation can be better calibrated. Increased usage by local municipalities since the early 1980s could change the conclusions.

The Corps of Engineers drew up plans with costs for typical systems that included four well fields, transmission mains, pumping stations and a water treatment facility near Largo in Prince George's County. They estimated the costs for such systems at from 1.2 to 1.3 million dollars per mgd of supply; these costs convert to 1.9 to 2.1 million dollars per mgd in 1998 dollars.

A large ground-water collection system has not been built in the Washington, D.C. area before, so estimates of the time it would take are speculative. Transmission mains would follow existing highways, so rights-of-way and environmental studies for them would be expedited. We might estimate 3 to 5 years for feasibility studies, 3 to 5 years for environmental studies and public input, and 3 to 5 years for construction.

Interbasin Transfers

During the late 1970s, there were extensive studies of the regional water supply which resulted in the present regional water management system and signing of the Low Flow Allocation Agreement. One of the options considered then was an interbasin transfer from the Shenandoah River. The scheme was to pump Shenandoah water over the mountains into Bull Run and thus to the Occoquan Reservoir. Part of the rationale for such a system was the wish to bypass the regulatory function of the State of Maryland, which controls access to the Potomac. Since the proposal to impound the Shendandoah River in the vicinity of Staunton, Virginia, for the benefit of the Washington area met with intense public opposition in the 1970s, it seems highly unlikely that a plan to export water from the valley completely would fare any better.

4.c Reducing unaccounted-for water

The assessment of future water needs for the Washington metropolitan area must consider the cost-effectiveness of reducing water loss in the distribution systems and how much water could be reclaimed through such actions. The water utilities consider unaccounted-for water to be the difference between their production or purchase and the quantity paid for by final consumers. These losses are of several types. Some is attributable to known unmetered uses, such as fire fighting and flushing pipes during routine maintenance. Other losses are due to unmetered connections such as public buildings and parks, to illegal hookups, or to inaccurate meters. A third cause of unaccounted-for water is actual physical losses in the system, due to reservoir seepage and evaporation, leaky pipes, and other physical leaks. The American Water Works Association (AWWA) considers 10% loss from a combination of these sources to be acceptable in a well-run water supply system.

Water companies' concern about unaccounted-for water usually stem from concerns about unexplained revenue shortfalls. Their efforts to track the unaccounted-for water are focused on identifying ways of recapturing lost revenue. For this reason they are often most interested in meter issues, since finding and correcting them will increase revenue; however, this will not directly reduce consumption.

From the perspective of long-run water supply problems, it is the physical losses in the systems which are of particular importance. By reducing these losses, it would be possible to satisfy more demand from the water already piped out of the Potomac. However, under current cost structures, it is often more expensive to find and fix the leaks than to pump and treat additional water. At present, when the supply in the rivers is not constrained and producing additional water is cheap, the water companies do not usually devote that much attention to fixing leaks. (The District of Columbia is an exception; it is discussed below.) In the future, however, when companies are confronting water shortages and considering major investments in new sources, the investments required to reduce physical leakage may become cost-effective as the costs of alternatives will have risen far beyond their current levels. This suggests that this could be a useful strategy for reducing water use in the future, but is not likely to have significant impacts in the short run.

The determination of how much water loss is acceptable must be made for each distribution system based on the cost of reducing losses versus the cost of the water lost. The jurisdictions in the Washington area vary substantially in their rates of unaccounted for water, as shown in the table below. These figures combine all of the elements of unaccounted for water, and do not disaggregate physical water loss from accounting losses. Moreover, these figures combine the losses between wholesalers like WAD and the distributors with those between the distributors and the end users. Moreover, the methods for estimating unaccounted-for water may differ across jurisdictions, so these data are not totally reliable. However, they do suggest that this is a significant issue in most parts of the region, which may call for further examination.

The District of Columbia shows particularly high rates and quantities of unaccounted-for water. Because of the age of the distribution system and the inadequate maintenance in recent years, it is clear that a significant portion of this is physical rather than accounting loss. In response, WASA now has in place an excellent system for determining physical water loss. The city has been divided into about 100 districts. Water consumption is estimated in each district over a 24-hour period with all valves closed except one. A pitometer tube, which is a hydraulic instrument that measures flow, is inserted into the pipe line at the open valve. The flow of water to that district can then be accurately measured. Readings taken during the night usually record the lowest flow. Customers who use large amounts of water during the night can be identified and either shut off for a short period or measured at their meter. This procedure allows for a very accurate calculation of unaccounted-for water. If the night flow is larger than expected, it is usually possible to identify the location of the flow by listening devices or other methods and a decision made as to what further action should be taken to locate and repair the leaks. WAD expects to sell water to its customers at an average rate of $0.675 per 1000 gallons in FY 2000; at this rate, the physical losses of water are great enough that it is cost-effective to invest in repairing the leaks.

WSSC reports its unaccounted-for water at 18%. Their recent study on water accountability (WSSC 1998) focuses primarily on water meter problems, in an effort to recapture the associated lost revenue. WSSC's production of water costs only $0.17 per 1000 gallons, according to their own data (personal communication, WSSC staff). At this rate, it is not profitable to spend much time finding and repairing leaks in the system.

The Fairfax County Water Authority has a relatively new system compared to the other systems in the metro area. Still, they have an active program to repair and replace water mains scheduling 10-15 projects per year costing approximately $1 million, in order to prevent physical leakages from becoming a significant problem.

If all the area water systems adopted as standard operating procedure a program of leak detection and repair, they might be able to reduce water consumption by as much as 5%. ICPRB estimates that the average annual demand for the suppliers in 2020 will be 622 mgd. If this can be reduced 5% by leak detection programs, over 30 mgd could be saved.

Water Supply Company	Jurisdiction	Unaccounted for water (mgd)	Total use of water (mgd)	Share not accounted for
WAD	DC	38.84	137.64	28.2%
	Arlington	3.86	25.71	15.0%
	Falls Church & Vienna	1.7	15.49	11.0%
	National Airport	0.2	0.55	36.4%
	Pentagon, Ft. Myers	0.36	1.27	28.3%
FCWA	Direct Service area	8.36	75.96	11.0%
	Alexandria	1.98	17.99	11.0%
	Dale City	0.48	4.36	11.0%
	Loudoun County	2.26	7.86	28.8%
	Prince William County – east	1.59	10.23	15.5%
	Prince William County – west	0.87	5.63	15.5%
	Herndon	0.51	2.5	20.4%
	Dulles Airport	0.06	0.56	10.7%

	Ft. Belvoir	0.25	2.26	11.1%
	Lorton	0.19	1.77	10.7%
WSSC	Montgomery County	16.12	89.58	18.0%
	Prince George's County	14.75	81.97	18.0%
	Andrews AFB	0.32	1.79	18.0%

4.d Growth management

The close relationship between population, land use, and water demand is obvious. Where there is growth in residential populations, job centers and industry, there is increased water use. Growth management might affect water demand in three ways. Growth controls which keep the total regional population down could minimize the number of new households and employees using water. Development controls which concentrate houses and commercial development on small lots may reduce water use by reducing watering of lawns. Economic development strategies which discourage the introduction of water-intensive economic activities may also reduce water use. This section considers each of those approaches in turn.

Growth Control

One option for balancing water demand and supply in the future is to limit development to that which can be served by the water supply available within the region. Environmentalists will recognize in this approach the principle of limiting growth to the natural carrying capacity of the area. The availability of adequate water could restrict new development regardless of zoning or other property rights. This scenario could prevail by default if the region does not provide any significant increases in water supply.

On the other hand, the jurisdictions of the region may decide to limit their growth by their land use plans and regulations and in so doing reduce the future demand for water. There are very noticeable pendulum swings between times when government policies favor controlling growth and times when promoting maximum growth is the governing sentiment. The 1990s have been years of growth promotion, but recently the pendulum seems to be swinging back.

Maryland has historically offered a more agreeable climate than Virginia for setting limits and instituting controls. Montgomery County has an adequate public facilities ordinance, a greenbelt area and a transferable development rights system. An adequate public facilities ordinance requires that new development must be in step with the provision of the public facilities needed to support it. Transferable development rights (TDRs) allow a landowner to sell the development rights to his or her land separately from the land itself and requires a developer to own the required number of development rights before s/he builds. Downzonings are a first step in creating a TDR system.

Virginia, both in its political bodies and its courts, provides a more difficult climate for land use controls. There is a historic predilection in the Commonwealth for supporting property rights against regulation, and the development industry is a powerful political force locally and in Richmond. Moreover the local jurisdictions are relatively weak with the state reserving most powers to itself. Counties must be granted special enabling legislation from the state government to do many of the things that would be decided locally elsewhere.

Nevertheless, several jurisdictions in the region are currently making efforts to restrain their development. Overwhelmed by infrastructure costs, Prince William County has downzoned a portion of the county and is now going to court to defend its action against developer and landowner suits. Loudoun County, the fastest growing jurisdiction in the Washington area, has recently amended its comprehensive plan to eliminate 100,000 residences and associated commercial development. However, these restrictions apply to residences and commercial development to be built after 2020-2030, so they would have little effect on the water demand projections of concern in this report.

Development controls to reduce sprawl

Land use patterns do not affect water demand as powerfully as growth limitations, but they make a difference. While growth control has been out of favor until recently, the implications of sprawl for both fiscal and environmental health have come to be widely understood. Movements seem to be gathering strength nationwide to prevent further urban encroachment onto undeveloped land and concentrate new development in downtown urban areas. Local policies have aimed at channeling growth into higher density mixed-use development centers where infrastructure exists. The hope is to reduce the spread of houses on large lots onto more and more open land.

Mixing homes, work places, and shopping and concentrating them on comparatively small footprints has clear advantages for transportation and other infrastructure and for the environment. The effects on water use are less obvious, but they do exist. Townhouses have significantly less lawn and garden to water than the average suburban house. The same saving occurs when office buildings are sited on tight urban lots rather than in campus settings. The miles of water mains needed to serve the same amount of development if it were arranged in the usual sprawl patterns are reduced to a much more efficient system. This allows significant savings in water needed to flush pipes, and offers less opportunities for losses due to leaks.

The links between development patterns and water use have been examined in a study of eighteen jurisdictions in suburban Seattle (Sakrison 1997). The study looked at summertime daily mean water use for twelve different types of housing and lot patterns. It found that water use in small or medium houses on streets arranged in grids was about half that of conventional suburban properties on curved streets or cul-de-sacs. Larger suburban estate homes consumed from two to four times the amount of the conventional suburban properties. The author does not investigate what it is about the home designs that leads to the differences; presumably it has to do with lawn size, the need to flush more feet of pipe per home, and possibly larger household size in the bigger properties.

Targeted Economic Development

In some parts of the country, the choice of economic development strategy may have a significant impact on water demand. In rural areas, in particular, strategies which shift the local economy away from irrigated agriculture and towards other kinds of economic activity could significantly reduce water demand. This form of growth management offers less potential in the Washington area, however. Water use on the job accounts for less than 25% of the total for the region (Mullusky et al, Appendix J). More importantly, however, until very recently there has been little or no high-water-use economic activity in the region; the chip plant recently completed in Manassas is the major exception. There may therefore be little opportunity to reduce water demand in the Washington area through an economic development strategy which encourages low-water-use activities.

Conclusion

While growth management may be desirable in the Washington region from a number of perspectives, it doesn't seem likely to be the most effective strategy for reducing water demand. The growth management process goes far beyond relatively narrow infrastructure-related goals like water supply. Moreover, it is highly political and subject to frequent fluctuations in the political climate. If a growth management process is already getting underway motivated by a broader set of concerns, then being part of it and working to ensure that reducing water demand is part of it would be valuable. However water demand issues alone are not likely to be sufficient to launch a program of such broad scope.

4.e Recycle/reuse treated water

The recycling and reuse of treated wastewater is common throughout the country where surface water is the raw water source. Typically this involves placing drinking water supply intakes downstream from the outflow of a sewage treatment plant. Treated water flows into the river, is diluted by the background flow, and is then picked back up in the water supply intakes. This can greatly increase the available supply of water. This strategy is already in use on the Occoquan Reservoir, where FCWA treats a mixture of highly treated effluent from the Upper Occoquan Sewage Authority (UOSA) plant and surface water and has experienced no known problems. The option for consideration now is the highly treated effluent from the Wastewater Treatment Plant at Blue Plains, which could be picked up by WAD along with other water from the Potomac.

Proposal to recycle Blue Plains effluent

The idea of recycling Blue Plains effluent was tested at the Potomac Estuary Experimental Water Treatment Plant (EWTP), constructed and operated at Blue Plains between 1980 and 1983 (Montgomery Engineers 1983; US Army Corps of Engineers 1983). The plant was built in order to assess the feasibility of using the Potomac estuary as a supplementary water source in times of extreme drought. It treated a blend of water, half of which came from the river and the other half from Blue Plains effluent. The objective of the experimental plant was to analyze the treatment of the highly concentrated and polluted estuary water which could occur in case of a severe drought. Its use of Blue Plains water was essentially to emulate the water quality which could occur naturally at the upstream end of the Potomac estuary near Chain Bridge. However, this analysis also lets us consider the safety of using Blue Plains effluent as a source of raw water, an idea which may receive more attention now than when the EWTP was built, because of the success of the UOSA and other wastewater reuse systems. Reuse of Blue Plains could significantly reduce the Washington Aqueduct's need to withdraw "natural" water from the Potomac, in essence allowing WAD customers to keep reusing the same water.

The actual configuration of the water reuse system was left open in the EWTP analysis. The experimental plant, which treated 1 mgd, was located directly adjacent to Blue Plains. The focus of the study was largely on the feasibility of treating the water to safe levels. Consequently, the actual configuration of a full-sized (200 mgd) system was left open, since construction was not anticipated in the foreseeable future. One open question concerned whether the treated water would discharged back into the river to dilute the flow past the WAD intakes, or channeled directly into the WAD distribution system without further treatment. Another question concerned where the treatment plant would be located; near Blue Plains, like the EWTP, or near Chain Bridge.

The reuse of Blue Plains effluent would provide a significant source of supply for WAD. The total effluent flow from Blue Plains averages about 330 mgd annually; monthly averages range above or below the annual average by about 50 mgd (ICPRB unpublished data). Total WAD water production averaged 186 mgd in 1994, with monthly averages ranging from 165 to 213 mgd[5] (Mullusky et al,

5Blue Plains serves the WSSC jurisdictions, and only some WAD jurisdictions; this explains the

Appendix A). Thus the entire Washington Aqueduct Division (WAD) demand could be met with Blue Plains effluent. This would permit higher withdrawals from the Potomac by the other water suppliers with intakes above Great Falls, including FCWA, the City of Rockville, the Town of Leesburg, and WSSC, since the flow would not be needed to supply WAD.

Health considerations

The major concern about this strategy clearly relates to its health implications; whether the quality of Blue Plains discharges is sufficient to protect the public health. When the EWTP was built, the assumption was that even if technical experts were convinced of the safety of the approach, public opinion would require much greater assurance than technically necessary. (This assumption may no longer hold, now that wastewater is already being reused on the Occoquan with very little public attention or concern.) Consequently, the EWTP was designed to meet water quality standards which exceeded EPA standards in a number of respects, including standards on a number of pollutants not regulated by EPA.

The EWTP tested a number of different treatment processes, two of which were found to produce water of acceptable quality to be used as raw water, though it was not necessarily potable (Army Corps of Engineers 1983, pp. F-15-17). The two processes differed in several respects, of which perhaps the most important was that the second relied on ozonation rather than chlorine for final disinfection; ozonation is a technology receiving considerable attention today, and is likely to be used in all new treatment plants in the future. The second process was found to produce significantly better water in terms of levels of fecal coliforms, manganese, and odor; however both processes met the standards set for the EWTP tests.

The effluent limitations presently permitted at Blue Plains reveal a water that is, in general, of better quality than the present river water. In the case of suspended solids, the 7 mg/L effluent limitation is about half the suspended solids currently found on average in the river water, and the other parameters routinely sampled are of equally high quality. This further suggests that reusing Blue Plains effluent may be a viable strategy for supplying water to the region.

The experience of the UOSA treatment plant in Centreville, Virginia may also aid in alleviating public health concerns. The UOSA plant treats sanitary sewage, discharging the treated effluent into the Occoquan Reservoir. The FCWA withdraws raw water from the Occoquan downstream from the UOSA plant, treats it by conventional methods, and converts it into potable water delivered to over one million of its customers. This has been done with no health problems, and without public concern or opposition. Indeed, FCWA has been able to reduce water intake from the Potomac far more than planned, because of success of reusing UOSA water. This experience suggests that the same might be the case with the reuse of Blue Plains effluent as well.

Costs

It is difficult to estimate the costs of a system to reuse Blue Plains effluent based on available data. The Montgomery Engineers study estimated the cost of a scaled-up version of the EWTP, which could treat 200 mgd of mixed effluent and estuary water. However, because of the many unknowns in the system configuration, their estimates do not include water intakes or associated pumping system, finished water pumping or reservoirs, treated water distribution system, land purchase, or site preparation.

The Montgomery Engineers study estimated costs of the two processes mentioned above, and compared them with costs in a conventional treatment plant. Their results are summarized in Table 6.

---

excess of flows out of Blue Plains over WAD production.

Treatment Configuration	Capital Cost (millions of $1983)	Annual O&M (millions of $1983)	Total cost in cents/1000 gallons
First Process (with chlorine)	122.30	12.57	34.32
Second Process (with ozonation)	174.14	15.94	47.62
Conventional Water Treatment Plant	n/a	n/a	19.00

While this does not provide us with complete information by any means, it does show that this system would be significantly more expensive than conventional water treatment was in 1983. If all water treatment is likely to require ozonation in the future, the difference might be less significant, however.

Legal and regulatory considerations

The reuse of Blue Plains effluent to supply WAD with raw water could lead to a need to rethink some aspects of the Water Supply Coordination Agreement. That agreement calls for a water management strategy in which under drought conditions FCWA and WSSC will rely first on the Occoquan and Patuxent Reservoirs before they access water from the Potomac. This reserves more Potomac water for WAD, reflecting the fact that the Virginia and Maryland companies have access to sources other than the Potomac, whereas WAD does not.

Were it possible for WAD to reuse Blue Plains effluent, the Aqueduct might need little or no additional water from the Potomac, at least at current flow and use levels. To the extent that this is the case, it may no longer make sense to require FCWA and WSSC to meet most of their water needs from the Occoquan and Patuxent rather than the Potomac in case of severe drought. For this reason, serious evaluation of effluent reuse on the Potomac should include consideration of possible changes in the water management agreements which it might entail.

5. Conclusions

This study has made it clear that drinking water supply is not a long-run concern which can be put on a back burner while the region's jurisdictions focus on more immediate problems. At current population growth rates, a severe drought could lead to water restrictions only six years from now, and to depletion of the region's reservoirs in 2025. Given the long lead time required to implement most solutions to the problem, the time to assess our choices is now, not in the next century.

We have presented a broad overview of the major strategies available for responding to these water shortages. The scope of this assessment and the depth of the available data do not allow us to identify which of these approaches, or what combination of approaches, may be the most effective. However we can make a few points which have a bearing on the viability and potential effectiveness of the options considered.

Water conservation probably offers some fairly rapid strategies for reducing water use through win-win modifications of residential, commercial, and industrial facilities. These should be considered irrespective of our approach to water supply, since they can be profitable even were there no concern about water conservation. Regulatory approaches such as building code requirements will also save water at little or no cost; however their impact will be very gradual as old inefficient structures are replaced with new ones. Other changes which reduce water use faster will require public or private sector investment. They will therefore call for broad changes in attitudes and behavior by many individuals and firms. While this could be the most cost-effective and environmentally conservative way to address water problems, it may also be harder to bring about than larger-scale technological fixes like finding new supplies of water.

Exploiting new water sources through construction of new reservoirs or building large-scale groundwater extraction facilities is the strategy which has been followed in the past. Such approaches to providing water depend on reliable technology more than on the compliance of many individuals, and may therefore seem simpler to introduce - especially to decision-makers who are engineers by background. However, as population density increases throughout the region, and as environmental concerns gain increasing legitimacy, it may no longer be realistic to make the large-scale changes in land use required by these strategies.

Reducing waste in the distribution systems is a financially viable way to save water where losses are great and the cost of producing additional water exceeds that of finding and fixing leaks. In the short run this is only viable in the District of Columbia. It may become an option elsewhere in the future, as the cost of new water production rises with scarcity. As long as its viability is not the result of increased losses in the Maryland and Virginia distribution networks, this could eventually be a helpful way to make somewhat more water available without investing in new sources.

Growth management could lead to reduced demand for water in the region. However, the scope of growth management efforts goes far beyond the issues with which we are concerned here; we cannot expect water issues to trigger a growth management movement. To the extent that such movements are gaining momentum locally or regionally, it is essential to ensure that water supply issues form part of the discussion, but we should not expect growth management alone to solve the water problems we have identified.

Reclamation of the waste water from Blue Plains looks like a technical option which warrants re-evaluation with current data. Such reclamation is already practiced on the Occoquan and is common elsewhere in the country, suggesting that it is safe and the associated public health concerns can be managed. Environmentally it might be more acceptable than construction of new dams and reservoirs. Further investigation of the viability of this option would be a good idea.

Where do we go from here?

Two steps are needed next. These can be undertaken simultaneously, and to some extent jointly. First, a much more thorough technical and financial analysis of all of the options we have discussed is essential, in order to develop the kinds of data which would allow a more rigorous comparison of their costs and benefits. For each option, we would like more precise information on several issues:

- What does the strategy entail; what kinds of conservation tools are we considering, which new reservoirs should be considered, etc.?
- How much additional water could be made available through each tool?
- In what time frame could that water be made available?
- What are the per unit costs of the water conserved or supplied with each tool, including both investments and operating costs?
- Who will pay for the new tools? Will they affect new users or the whole region? Will the cost be up-front or borne once the water is available?
- What are the environmental impacts of the proposed tools?
- What are the social impacts of the proposed tools; do they call for significant behavioral changes?
- Will specific groups be particularly impacted by the tools, e.g. communities displaced?

The second step is to launch a broad public discussion of the region's water supply issues, involving all interested stakeholders. As we approach the 21st century it is essential to recognize that these are not merely technical decisions to be made by water company engineers. Rather, they are broad policy issues that are inextricably linked to the growth of our communities and the protection of our environment. They must be raised in the context of debates on urban growth and growth management, environmental protection, conservation of rivers in their natural form, transportation planning, and other difficult policy questions. The public discussion of these issues may parallel, provide input to, and benefit from the technical analysis of the options available to address them. Ultimately our choices must be based not only on technical and financial understanding, but also on the vision of the community as a whole concerning which risks we are willing to take and which costs we are willing to bear.

References

(Note: Most of these documents are available in the library of the Interstate Commission on the Potomac River Basin, Rockville MD.)

American Water Works Association, 1997, *Conference Proceedings of Water Resource Management: Preparing for the 21st Century.* August 10-13, 1997, Seattle, Washington.

Black and Veatch Consulting Engineers, 1974, "Water Supply Study for Washington Metropolitan Area" Prepared for the Fairfax County Water Authority, The Government of the District of Columbia, and the Washington Suburban Sanitary Commission, Kansas City, Missouri.

Drury, Kim and Tim Skeel, "Conservation as a Water Resource: Quantified Accomplishments." In American Water Works Association, 1997, pp. 225-231.

Fleck, William B., 1982, "Digital simulation of ground-water flow in part of southern Maryland." U.S. Geological Survey, Open-file Report, Towson, Maryland.

Maryland Department of Natural Resources, 1981, "Potomac River Environmental Flow-By Study." Submitted to the U..S. Army Corps of Engineers in Fulfillment of the Requirements of Article 2.c of the Potomac River Low Flow Allocation Agreement. Annapolis, Maryland

Metropolitan Washington Council of Governments, 1994, "Cooperative Forecasting: Round 5 Technical Report - October 1994." Washington, D.C.

J. M. Montgomery, Consulting Engineers, Inc., 1983, "Operation, Maintenance and Performance Evaluation of the Potomac Estuary Experimental Water Treatment Plant." Prepared for the U.S. Army Corps of Engineers, Baltimore District.

Mullusky, Mary G., Stuart S. Schwartz, and Roland C. Steiner, 1996, "1995 Water demand forecast and resource availability for the Washington Metropolitan Area." Interstate Commission on the Potomac River Basin, Rockville, Maryland, Report No. 95-6.

Sakrison, Rodney G., "Water Use in Compact Communities: The Effect of New Urbanism, Growth Management and Conservation Measures on Residential Water Demands." In American Water Works Association, 1997, pp. 181-195.

Texas Water Resources Institute Newsletter, 1998, available on the worldwide web at: http://twri.tamu.edu/twripubs/WtrSavrs/v1n3/article-9.html

U.S. Army Corps of Engineers, 1963, "Potomac River Basin Report." Baltimore, Maryland.

U.S. Army Corps of Engineers, 1983, "Metropolitan Washington Area Water Supply Study, Appendix F, Structural Alternatives." Department of the Army, Baltimore District, Baltimore, Maryland.

Washington Suburban Sanitary Commission, April 1998, "Final Report: Phase I, Water Accountability Task Force."

Washington Suburban Sanitary Commission, Office of Budget and Financial Planning, December 2, 1997, "Water Consumption Report for Fiscal Years 1995 through 1997."

Woodley, John Paul, Jr. (Secretary of Natural Resources, Commonwealth of Virginia), letter to Newell Trask concerning the Verona site, September 22, 1998.

Yingling, Ronald K. (Project Manager, WSSC Water Accountability Task Force), Memo to Timothy Hirrel (Planning Manager, WSSC Water Resources Planning Section) re "Water Production Analysis," September 10, 1997, revised March 13, 1998.