METROPOLITAN WASHINGTON AREA WATER SUPPLY

Paul W. Eastman,*

Abstract: In 1982, after thirty years of planning and controversy about adequate public water supply for the rapidly growing interstate metropolitan area of Washington, DC, and the Maryland and Virginia suburbs, local, state and federal agencies adopted cooperative agreements which will satisfy expected requirements well into the 21st Century. The agreements provided for coordinated state-of-the-art drought management operations by the three major regional water utilities of their intakes in the largely unregulated Potomac River as well as local and upstream reservoirs. Various solutions were proposed over the years but never implemented because of social, political, and environmental objections which were overcome by the largely non-structural cooperative operations plan adopted in 1982.

Introduction

The North Branch or mainstream headwater of the Potomac River rises in the Appalachian Highlands of the East Central United States (Fig. 1). The river flows 620 km (385 mi) in a great loop to its mouth in Chesapeake Bay. The free-flowing portion of the Potomac cuts through a hill and valley region, where it is joined first by the South Branch, and then also from the south by the largest tributary, the Shenandoah River. Several smaller tributaries join the Potomac, for example the Monocacy River from the north, as it flows through the Piedmont Plateau to Great Falls, a short distance above the District of Columbia (DC). From this point, where the Potomac breaks over the fall line into the coastal plain, it becomes a freshwater tidal river. The more than 160 km (100 mi) of tidewater gradually becomes brackish and then saline so that the lower portion is a true estuary.

The drainage area of the Potomac and its tributaries is approximately 38,000 km^2 (14,670 mi^2), encompassing parts of the four states of Maryland, Pennsylvania, Virginia and West Virginia, and the 179 km^2 (69 mi^2) of the District of Columbia (DC). The DC is the center of the Washington Metropolitan Area (WMA), upstream of which the watershed of the free-flowing Potomac covers about 28,500 km^2 (11,000 mi^2). The WMA contains about three-quarters of the nearly four million population in the entire basin.

*Executive Director, Interstate Commission on the Potomac River Basin, 6110 Executive Blvd, Suite 300, Rockville, MD 20852.

The U.S. Army Corps of Engineers' Washington Aqueduct Division (COE WAD), the Washington Suburban Sanitary Commission (WSSC), and the Fairfax County Water Authority (FCWA) are the three major water utilities in the WMA (Fig. 1). The WAD has supplied water to DC since 1863 and now also to the Virginia suburbs of Arlington County and Falls Church. It serves about 1,200,000 people, including transients and commuters, from two water filtration plants supplied from the Potomac River by a gravity intake at Great Falls about 10 miles upstream from the DC and a pumping plant intake near the DC boundary with Maryland.

The WSSC, created by the Maryland State Legislature in 1918, serves most of the about 1,300,000 people in the Maryland suburban counties of Montgomery and Prince Georges. It's sources of supply are a filtration plant and two reservoirs on the Patuxent River northeast of the DC and a filtration plant and intake completed in 1951 on the Potomac River upstream from the WAD intakes.

The third major water utility, the FCWA, was created in 1957 by Fairfax County, the largest of the Virginia counties in the WMA. The FCWA initially acquired and integrated numerous small well-water systems and in the mid-1960's acquired water treatment facilities and a reservoir on Occoquan Creek, a tributary of the Potomac estuary downstream from DC, from a private water company. In 1982 it completed a filtration plant and intake in the Potomac River upstream from both the WSSC and WAD intakes. The FCWA now serves more than 700,000 people in the Virginia suburbs of Fairfax County and Prince William County.

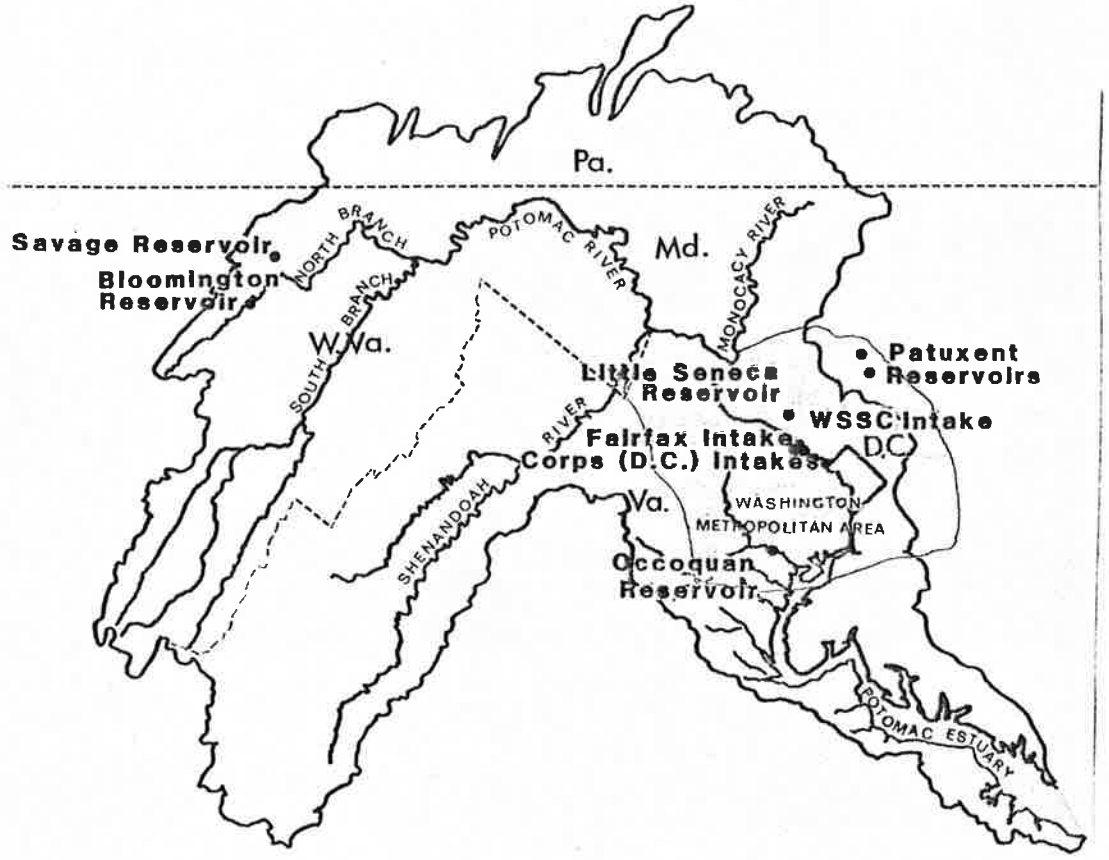

FIGURE 1. MAJOR TRIBUTARIES AND WATER SUPPLY FACILITIES OF THE POTOMAC RIVER BASIN.

The Problem

With the rapid growth in the WMA, especially beginning with World War II, and the exploitation of major reservoir storage sites within the suburban counties (the Patuxent and Occoquan reservoirs), the Potomac River had become increasingly the source of water supply to support the growth. Between 1930 and 1960, when the comprehensive water and related resources planning recommendations by the COE and others began to be released, the Potomac Basin population doubled, increasing from about 1.4 million to 3 million, as compared with a national growth rate of 45 percent. WMA population grew from about 670,000 to 2 million in the same thirty-year period and the high growth rate was expected to continue into the next century (Potomac Basin Center, 1969).

The Potomac was and is a fickle river. The annual average flow is over 26 x 10^6 m^3/d (7 bgd) and the extremes have ranged from over 1135 x 10^6 m^3/d (300 bgd) to less than 1.9 x 10^6 m^3/d (500 mgd). A historical record lowest one-day flow of 1.47 x 10^6 m^3/d (388 mgd) in 1966 became the measure for describing the WMA water supply problem.

Proposed Basin Comprehensive Solutions

Solving the WMA water supply problem was only one aspect of the comprehensive planning objectives for the Potomac Basin in the 1960's. Maximum development of water storage sites for multiple purposes, including the relatively new purposes for federal projects of recreation and flow augmentation for improving water quality, expanded the range and magnitude of alternative solutions which were considered and recommended. Initially at least, WMA water supply seemed to be almost incidental to the other purposes to be served.

Prior to the 1950's the COE had made several planning studies of the Potomac Basin with emphasis on flood control and hydropower generation, but implementation of reservoir recommendations was not attempted as the result of a review after World War II.

In 1956, following a drought, a series of Congressional resolutions directed the COE to prepare a comprehensive plan for control of floods and development and conservation of the Potomac Basin's water and related resources, including recreation, municipal water supply and pollution abatement. The Water Supply Act of 1958 authorized the COE to include municipal and industrial water supply in its reservoirs, the costs to be reimbursed by the beneficiaries. Even more important, as a result of heightened Congressional interest in water pollution, the 1961 amendments to the Federal Water Pollution Control Act authorized the COE to include storage in reservoirs for regulation of streamflow for the purpose of water quality control, except that the flow regulation was not to be a substitute for adequate treatment or other controls at the pollution sources. This provision specified that the costs were to be nonreimbursable if the benefits were widespread or national in scope, which was especially significant to the Potomac Basin comprehensive study.

The COE first studied the Potomac North Branch and the District Engineer's report was released in 1961 (COE, 1961). The major

recommended project, Bloomington Reservoir, was authorized the following year. The North Branch report was prepared and released separately because the sub-basin was considered to be geographically and culturally a separate entity, the coal mining depression had turned the area into a chronically depressed area, and substantial public support was expected. Maryland especially wanted Bloomington reservoir for both the benefits in the western Maryland portion of the North Branch, i.e., flood control, amelioration of the mine acid drainage by storage and flow augmentation, recreation, and to increase minimum flows for water supply for Maryland's downstream riparian counties, including those in the WMA. Maryland created the Maryland Potomac Water Authority, composed of primarily riparian county elected officials, to guarantee reimbursement of the nonfederal share of the water supply storage in Bloomington. Congress subsequently began to appropriate funds for construction of Bloomington in 1973 and it finally was completed in 1981, the only major COE reservoir to be built in the entire Potomac basin. A much smaller reservoir in the North Branch Sub-basin, the Savage River Reservoir, was started in the early 1930's under the Public Works Administration program, was completed by the COE in the 1950's, and is operated conjunctively with Bloomington Reservoir by the Upper Potomac River Commission primarily to provide a dependable flow for an industry which is the major employer in the chronically depressed sub-basin.

In 1963 the COE District Engineer released the Potomac River Basin Report, the complete development plan (COE, 1963). The most controversial recommendations were for sixteen major reservoirs in the basin above the WMA, all with benefits for recreation and low flow augmentation for water quality improvement and water supply, but only four with flood control benefits. Bloomington, which had been previously recommended, was one of the sixteen. Other recommendations were included, of which only slightly less controversial were the proposed 418 small watershed multiple-purpose reservoirs. According to the COE, the plan would have provided for: (1) generally all water supply and water quality control needs to the year 2010; (2) flood damage reductions of about 63 percent and (3) recreation opportunities for up to about 16 million visitor days per year. The COE plan would have regulated the Potomac by 2010 to provide a dependable flow over Great Falls into the estuary at the DC of about 11.4 x 10^6 m^3/d (3 bgd) or 42 percent of the average annual flow.

The Controversy Mounts

Opposition was immediate, widespread and strong. At one hearing in Washington, DC, on the report in September, 1963, which close to a thousand people attended, most of the audience was antagonistic, especially to the 16 major reservoirs (ICPRB, 1963). Typically at this hearing and at the many that followed, the opposition pointed out that a reservoir on the Potomac mainstem would destroy a long and valuable part of the historic Chesapeake and Ohio Canal (now a National Historical Park), and it and the others would inundate thousands of acres of the basin's attractive natural environment and valuable agricultural lands, displace hundreds of families from properties contributing hundreds of thousands of dollars in real estate taxes, and create artificial lakes subject to drawdowns that would periodically expose large areas of unsightly mudbanks.

"The heaviest guns of the opposition" were voiced by Anthony Wayne Smith, President and General Counsel of the National Parks Association at the hearing in 1963. He continued to be the major and most influential spokesman for national conservation and environmental organizations in opposition to any major reservoirs in the Potomac Basin.

President Lyndon Johnson responded to the public controversy about the 1963 COE report by directing the Department of Interior (DOI) to coordinate a new interdepartmental study. A year later in 1965 the Governors of the basin states and the President of the DC Council established a Potomac River Basin Advisory Committee (PRBAC) to coordinate the views of the members on all matters affecting the Potomac watershed and to develop new institutional arrangements (ICPRB, 1965). The Interstate Commission on the Potomac River Basin (ICPRB), with the same member states and DC, had been created by an interstate compact approved by Congress in 1940 only to investigate water quality problems and coordinate pollution control activities. ICPRB had proposed amendments to the compact in 1959, one of which was to broaden its investigatory and coordination authority to include all water resources matters, but they were not approved by all of the states until 1968 and by Congress for DC and the federal government until 1970 (ICPRB, 1970). However, most PRBAC members were also ICPRB Commissioners.

A New Federal Comprehensive Approach

The Federal InterDepartmental Task Force on the Potomac, chaired by a DOI Assistant Secretary issued its Potomac Interim Report to the President in 1966 which included input from the PRBAC (FITFP, 1966). It also contained a number of recreational and scenic recommendations which added fuel to the controversy, especially the proposed establishment of a Potomac Valley Park consisting of the river and adjacent lands from the WMA upstream for about 290 km (180 mi) to Cumberland, MD.

Relative to solution of the water supply problems, the report noted four long-range possibilities: diversion of water from the Susquehanna River; desalination of salt water; reclamation of wastewater; and the utilization of the upper estuary as an additional emergency source for the WMA. To take care of the immediate need for a 20-year margin of safety, the report recommended construction of three upper basin tributary reservoirs which, together with the authorized Bloomington reservoir and the smaller existing nearby Savage Reservoir, would satisfy WMA demands through 1980.

A series of other reports spawned by the Federal Interdepartmental Task Force followed the Interim Report (Potomac Basin Center, 1969). They included recommendations concerning landscape preservation, recreation, and upper basin sediment and erosion control, but commented only generally, if at all, on basin or WMA water supply problems. During the same period other studies specifically relating to WMA water supply were conducted independently of the Federal Interdepartmental Task Force. One, sponsored by the National Parks Association in 1968, concluded that the use of freshwater from the upper estuary portion of the Potomac could satisfy future WMA emergency water supply supplemental requirements during low flow periods (Fosdick, 1968). Many individuals

and organizations which opposed previous and subsequent proposals for construction of upper basin reservoirs used the recommendations in that report to support their arguments.

Meanwhile, the Chief of the COE revised the recommendations in the 1963 District Engineer's report and in 1968 testified before the Congress that only six reservoirs were capable of servicing water supply and related needs and that they were compatible with scenic and recreational values (PBC, 1969 and COE, 1970). He recommended that Sixes Bridge in MD and PA on the Monocacy River and Verona in the upper Shenandoah sub-basin of VA be given top priority. At that time the latter two projects were supported by both professional and elected officials of municipal and county governments, as necessary for economic development in the areas of the proposed projects, and also the relevant state agencies in MD and VA.

Later in 1968, the Secretary of Interior sent his final report to the President with the recommendations of the Federal Interdepartmental Task Force (USDOI, 1968). With reference to water quality, the report stated that reservoir storage to augment low flows for improvement of the quality of the upper Potomac estuary in the WMA was no longer being considered and recommended stronger enforcement of the necessary treatment of wastewater in the WMA to achieve the estuary quality goals. Relative to water supply, the report recognized that the upper estuary might be developed as a water supply source in the future but appeared to be too risky to serve as a adequate basis for planning at that time. To meet current needs, the report suggested immediate funding and construction of the authorized Bloomington project in the Potomac North Branch Sub-basin and that the six additional reservoirs recommended by the COE in 1968 be scheduled for completion to satisfy the growth of water supply demand in the WMA.

In 1965, as a result of the mid-1960's drought in the Northeast, Congress authorized the COE to develop water supply plans for affected urban areas in the region. The WMA was one of the areas included in the COE Northeastern Water Supply (NEWS) Study conducted in the late 1960's and early 1970's. The NEWS interim report on Potomac River Basin Water Supply, completed in early 1973, evaluated new alternatives for increasing WMA water supply, including high flow skimming from the Potomac and pumping to the existing reservoirs in the WMA, reuse of water from the tidal river, interbasin transfers from the Rappahannock and Susquehanna Rivers, and restricting water use during emergencies (COE, 1973). The COE again recommended the immediate construction of Verona and Sixes Bridge reservoirs. It also recommended the construction of an experimental pilot treatment plant to test the feasibility of recycling water from the upper freshwater portion of the tidal estuary.

In the Water Resources Development Act of 1974, Congress authorized another intensive study to determine solutions to the WMA water supply problem. It also authorized the Verona and Sixes Bridge reservoir projects and the construction and operation of the experimental estuary pilot treatment plant. In an unusual action, Congress directed the COE to request the National Academies of Sciences and Engineering to review and comment on the conclusions reached in both the WMA Water Supply

Study and the estuary pilot treatment plant testing program, apparently to ensure their credibility. Subsequently, after loss of any effective local, state and Congressional support for the Verona and Sixes Bridge Reservoirs and substantial progress had been made for a local solution to the WMA water supply problem, the COE terminated further consideration of the reservoir projects.

The WMA Looks for Self-Sufficiency

In the 1970's the WMA suburban water utilities (WSSC & FCWA) were engaged in planning independently for new or improved facilities to satisfy their growing populations. The WSSC was planning to construct a weir to enhance its ability to withdraw water at its existing Potomac river intake while the FCWA was planning to construct intake and treatment facilities on the Potomac to supplement its Occoquan reservoir supply. Both needed permits from the COE under the latter's authority for regulating structures, etc., in navigable waterways. Since the locations of the existing and proposed suburban utility intakes were upstream from the COE WAD intakes, the COE insisted on an agreement for limiting and allocating withdrawals when the demand would exceed expected low flows in the river. Midway in the negotiations from 1974 to 1978 for this Low Flow Allocation Agreement (LFAA), the COE insisted on a provision allowing any party to freeze the allocation formula (based on average winter water use in the previous 5 years) in 1988 or thereafter. The WSSC and FCWA service areas in the suburbs were growing while the population of the COE WAD service area, primarily the DC, was beginning to stabilize. Thus the freeze would expose the suburbs to proportionately greater deficits than the COE WAD service area in the future. The LFAA with the 1988 freeze was signed in 1978 despite objections from MD, VA, WSSC and FCWA (U.S. Dept. of Army, et. al., 1978). The utilities and the states recognized that there would be a long delay in getting COE permits if they took their objections to the federal courts.

During the same period, the WSSC conducted a study to determine how it could supplement its water supply sources within its two-county suburban jurisdiction. The study was carried out by a consultant under the direction of a task force which included county government elected officials working closely with citizens and technical advisory committees. Members of the committees and task force met regularly with the consultant, who became intimately familiar with their objectives and concerns and therefore could include them in the analysis of alternatives. The elected officials and citizens understood the technical limitations in the study and had confidence in the somewhat unusual conclusions and recommendations: (1) small peak demand shortages of seven or fewer days duration with associated water use restrictions during severe droughts would be acceptable; (2) the two-county water needs for fifteen to twenty years could be met with a small reservoir (Little Seneca) in one of the counties at a site previously considered for a Soil Conservation Service multiple-purpose small watershed project (which had support from many landowners in the area as a means of preventing objectionable higher density development of the sparsely populated rural area), or a large raw water pipeline between existing WSSC facilities on the Potomac River and the Patuxent River reservoirs on the opposite side of the two-county area; and (3) planning by WSSC

should start on both alternatives with construction of preferably the Little Seneca Reservoir project, to follow immediately (BWSTF, 1978).

The organization and conduct of the study led to widespread support by citizens and quick approval by the county governments of the study conclusions and the Little Seneca Reservoir project. The WSSC applied to the COE for a navigable waterway construction permit for the proposed project but the U.S. Environmental Protection Agency (USEPA) objected, primarily on the basis that an independent solution by one WMA utility would lead to independent solutions by the other utilities with an aggregate environmental impact much greater than that which would occur from a regional solution.

Seeking the Regional Solution

By 1977 only one of the many upper Potomac Basin reservoirs recommended to solve the WMA water supply problem was under construction (Bloomington). The others, along with a variety of alternative solutions, had been rejected for environmental and political reasons. Nevertheless, the federal, state, and WMA government agencies had learned valuable lessons which contributed to the regional cooperation that led to the innovative solution subsequently adopted. After lengthy and difficult negotiations, the Potomac LFAA was about to be signed. The MWCOG had improved and significantly revised downward regionally acceptable population forecasts. MWCOG also was developing a Water Shortage Emergency Plan to be used as necessary to manage restrictions under the LFAA. The WMA suburban utilities had adopted progressive rate schedules to encourage water conservation and building codes had been revised to require reduced water use plumbing devices in new construction. The situation was ripe for a new approach to solving the problem.

ICPRB, while working with MWCOG on water quality management planning, first developed the idea that alteration of the operations of existing Potomac river intakes and suburban reservoirs could increase the total available supply during drought periods. Based on a total regional demand forecast of 2.84×10^6 m^3/d (750 mgd) in the year 2000, the ICPRB analysis showed that the worst water supply deficit would occur during the 90 day, 50 year recurrence interval low flow in the Potomac (90-Q-50) of 2.2×10^6 m^3/d (580 mgd) as follows:

$$\begin{array}{rl} & 2.84 \times 10^6 \text{ m}^3/\text{d} \times 90 \text{ days} = 255 \times 10^6 \text{ m}^3 \text{ (67.5 bg)} \\ \text{minus} & \underline{2.2 \times 10^6 \text{ m}^3/\text{d} \times 90 \text{ days} = 200 \times 10^6 \text{ m}^3 \text{ (52.5 bg)}} \\ & \text{Deficit} = 55 \times 10^6 \text{ m}^3 \text{ (15 bg)} \end{array}$$

The storage available in the suburban reservoirs is almost 75×10^6 m^3 (20 bg), or about 20×10^6 m^3 (5 bg) greater than necessary to make up for the deficit produced by the worst Potomac low flow conditions in the historical record. ICPRB's analysis concluded that suburban reservoir yields could be increased sufficiently to eliminate future shortages during drought periods if their operations were coordinated with use of the Potomac River intakes. The MWCOG gave the concept widespread publicity and local government decision-makers supported it enthusiastically.

The COE WMA water supply study underway at the time was a convenient means for the more detailed analysis necessary to implement the concept. After many years of frustration in their planning activities, the COE quickly responded to the recommendations of the Federal, Interstate, State, Regional Advisory Committee to investigate the necessary interconnections between the suburban reservoirs and the Potomac intakes. Both raw water interconnecting pipelines and finished water interconnections (use of distribution systems and treatment facilities) were investigated. The finished water interconnection method of operation would reduce water distributed from the suburban reservoir treatment plants well below their traditional safe yields when Potomac flows were ample to supply a larger proportion of the distribution systems than previously had been the practice. The reservoir water saved could be used to increase delivery to the distribution systems at levels well above traditional safe yields during low flows in the Potomac.

The results of the distribution system modeling in the finished water interconnection study revealed that new distribution system lines were unnecessary to implement the concept. The existing distribution systems with only improvements proposed for normal, non-drought operations were sufficient to support the necessary increased use of suburban reservoirs during Potomac low-flows and of Potomac intakes during high flows. Rules were devised for the new method of operation which increased the suburban reservoir yields by 340 x 10^3 m^3/d (90 mgd), or 100%, and the increase in operating costs was negligible. The COE in its WMA water supply study called the new operating rules "reregulation" and the suburban utilities immediately agreed to implement the the rules.

Also in 1977 a severe drought in the watershed of the Occoquan Reservoir, the primary source of supply for the Virginia suburbs, caused the reservoir to fall to alarmingly low levels. County officials seriously considered closing schools and businesses. The ICPRB and others provided technical assistance and applied the technique of risk analysis to determine the risks associated with the continuation of the drought (Sheer, 1980). Based on watershed runoff simulations, a relatively slight decrease in reservoir withdrawals and associated voluntary water use restrictions reduced the risk of depleting the storage from fifteen to three percent. The quantitative assessment of risk provided a credible demonstration of the problem for both the decision-makers and the public. The public cooperation with voluntary restrictions in a politically tense atmosphere eliminated the need for more controversial mandatory restrictions which might otherwise have been necessary to save water.

Modeling of the System

In late 1977, the Department of Geography and Environmental Engineering of the Johns Hopkins University in cooperation with ICPRB, received grants from the Maryland Department of Natural Resources, the Virginia State Water Control Board, and the Maryland Water Resources Research Center (from the U.S. Office of Water Research and Technology) to investigate future operating rules for Bloomington Reservoir which would increase its yield for water supply. Early results from the

investigation showed that the yield could be increased substantially with improvements in river flow and water demand forecasting and coordinated operation of Bloomington with the downstream WMA reservoirs and river intakes. The Johns Hopkins group developed a computer model (Potomac River Interactive Simulation Model or PRISM) to simulate the operation of the upstream and downstream reservoirs and the downstream WMA river intakes (Palmer, et.al., 1980). The use of PRISM by the WMA utility managers graphically demonstrated the value of cooperative operations for eliminating future water shortages at much less cost than the previously proposed construction of additional major reservoirs or other less conventional structural solutions.

The COE quickly made use of a modified PRISM in its WRA Water Supply Study and in 1979 used the results of the PRISM modeling, the finished water interconnection study, and the new and lower demand forecasts to produce recommendations in a draft/progress report (COE, 1979). The COE emphasized the WMA cooperative solutions to the problem; specifically reregulation, a small local reservoir, and a raw water interconnection between one or both of the local reservoirs and the Potomac. The COE report noted that regional cooperation could greatly reduce cost, but recognized the difficulties in achieving the necessary regional agreements. However the local utilities decided to work cooperatively to overcome the difficulties and asked ICPRB to help.

The amendments to the ICPRB Compact approved by Congress in 1970 included a new Article III which authorized ICPRB to establish sections, composed of more than two but less than all five of the member states (including DC), to carry out special regional activities (ICPRB, 1970). With the decision in 1976 at two ad-hoc meetings of the basin states that there was no liklihood of approval of a proposed stronger State-Federal Potomac Basin Compact, the states urged ICPRB to make use of the authority to establish sections. Recommendations in a report by the Congressional Research Service in 1979 that ICPRB establish an Article III Section to deal with the interstate WMA water supply problem, and subsequent favorable testimony in hearings held by the Senate Subcommittee on Governmental Efficiency and the DC also encouraged ICPRB (DeMoncada, 1979 and U.S. Senate, 1979). As a basis for working with the WMA utilities, ICPRB formed a Section on Cooperative Operations on the Potomac (CO-OP) in late 1979, supported by a Technical Operations Committee composed of the managers of the three major WMA water utilities.

The utilities working through the MWCOG achieved the formation of a WMA Water Supply Task Force of local government officials similar to the successful Bi-County task force in the Maryland suburbs, as the means for gaining the necessary local government approvals of the regional solution and the required agreements. ICPRB CO-OP was given responsibility for combining and refining all of the techniques required for coordinated daily operations of the WMA utilities during droughts and CO-OP staff became the technical staff to the new task force.

CO-OP revised the PRISM model to develop daily operating rules to allow for the uncertainty of daily river flow forecasts, the daily variation in water use, and other characteristics of daily utility operations (Sheer, 1986). Working with the National Weather Service

CO-OP calibrated the National Weather Service River Forecast System for the Potomac Basin and incorporated risk analysis in the computer programs. CO-OP also worked together with the utilities, the Johns Hopkins group and the National Weather Service in developing demand forecast techniques for incorporation in the CO-OP model.

Using the CO-OP Model

The WMA Water Supply Task Force, composed of one elected official each from the suburban county governments and the DC, first met in early 1980 (McGarry, 1981). The Chief Executives of the member jurisdictions represented on the Task Force appointed members to a Citizens Advisory Committee which worked closely with the Task Force and a Technical Advisory Committee composed of the chief operating officers of the three WMA water utilities. The General Manager of the WSSC chaired both the Task Force and the Technical Advisory Committee. They all quickly agreed to use the COE WMA Study water demand projections which were based on the improved MWCOG population projections.

CO-OP was charged with using the refined CO-OP model to develop practical rules for coordinated daily drought-management operations of the reservoirs and river intake facilities. The CO-OP model simulations using the operating rules demonstrated that it was possible to meet the WRA water requirements, including a 380 x 10^3 m^3/d (100 mgd) flowby into the upper estuary, through the year 2000 without the additional pipeline and small reservoir recommended in the COE WRA study progress report. However, more local flexibility in the WMA was needed to reduce the risks associated with the uncertainty of river flow augmented by releases from the upstream reservoirs, the travel time for which is four to five days. A margin of safety in the upstream releases of about 380 x 10^3 m^3/d (100 mgd) was necessary to ensure adequate flow downstream, most of which would flow by the WMA intakes unused. A new small reservoir, the releases from which would be only a day's travel time from the intakes would eliminate that operational problem. The large margin of safety in the upstream reservoir releases would not be needed, reducing the unused portion of the releases from seventy percent to about ten percent and the water saved would meet water requirements through the year 2030.

The proposed small local reservoir (Little Seneca) in the Maryland suburbs, which had been recommended by both the Bi-County study and the COE WRA study progress report, was incorporated in the CO-OP model and it met all of the requirements for needed local flexibility. The costs were modest and the Task Force committees agreed that Little Seneca Reservoir should be a regional undertaking and the costs shared. They recommended that the necessary agreements be developed and implemented for (1) sharing the reimbursable water supply storage costs of both the upstream COE Bloomington Reservoir, completed in 1981, and the local Little Seneca Reservoir, construction of which had just started (completed in 1985), and (2) cooperative operation of all regional water supply facilities for drought management purposes. The Task Force members adopted the recommendations in principle in January 1982 and charged the technical advisory committee with negotiating the necessary agreements. Both WSSC, which was constructing the Little Seneca Reservoir for its own use, and Montgomery County, MD, in which it was

located, endorsed the concept of Little Seneca Reservoir as a regional facility.

First the Fish and Wildlife Service (F&WLS) and later the USEPA expressed concern about the minimum instream flow downstream from the WMA water supply intakes (the flowby) after signing of the Low Flow Allocation Agreement in 1978. They felt that the 380 x 10^3 m^3/d (100 mgd) flowby provision in the LFAA would not be sufficient to protect fish habitat. The Maryland Department of Natural Resources volunteered to carry out a study to determine desirable minimum flowbys with participation by the F&WLS and ICPRB. The study included fish habitat simulations from which it was concluded that extreme low flows for periods as short as one to two days were critical (MD DNR, 1981). CO-OP model runs demonstrated that the water supply operating rules could be revised to provide less frequent extreme low flows during periods critical to the fish habitat than those which would occur naturally, without detriment to the necessary water supply withdrawals. This satisfied the concerns of the F&WLS and the USEPA.

Several hundred simulation runs were made on the CO-OP model during the cost-sharing negotiations among the three utilities. Water shortages which would occur if coordinated operations were not achieved were allocated according to each utility's own interpretation of the Low Flow Allocation Agreement and the riparian doctrine of rights to Potomac flows. CO-OP's neutral technical support role in running the simulations was an important factor in the success of the negotiations.

WMA Cooperative Operations

The cooperative drought-management operations were designed to interfere as little as possible with normal utility operation. They begin with the determination of drought conditions which are defined by either the flow in the Potomac below 200 percent of expected withdrawals or the probability of meeting all water requirements and refilling all reservoirs by the following June below 98 percent. The National Weather Service River Forecasting System and risk analysis are used to determine the probabilities.

The utility managers and CO-OP tested the cooperative operations in a 1981 drought-management exercise using the CO-OP model to simulate historical meteorology and water demands along with the necessary interactive responses for joint operation of all reservoir, intake, treatment and distribution facilities. The exercise developed an understanding about lines of communications, enabled the participants to correct procedural problems, and provided additional assurance that the cooperative operations were practical and would provide adequate water supply for all three WMA utilities well into the future. This first drought exercise (they are repeated every year) was very helpful background for the utility managers' and their lawyers in the writing of the contracts covering the cooperative operations and the cost-sharing arrangements. Thus, despite the many complexities, including the interstate nature of the agreements, the unusual characteristics of the District of Columbia government, and the multiple responsibilities of the COE as a planner, builder, regulator and WMA water utility, eight related contracts were successfully written and signed on July 22, 1982.

After almost 30 years of planning and controversy, the problem of an adequate water supply for the WMA had been solved.

Conclusion

In the initial planning efforts, water supply was only one of several elements in federal comprehensive multiple-purpose planning for the entire Potomac Basin. Of the sixteen major upper basin reservoirs proposed, only one in a remote, chronically depressed area was built. Others along with less conventional proposals arising from subsequent federally-dominated planning efforts were never implemented due to a variety of social, environmental and political objections.

Beginning late in the 1970's, frustrated by the previous failures, pressured by federal regulatory requirements into regional cooperation with the Potomac River as the vital linkage, and provided with new techniques of water resources systems analysis employing computer simulation, hydrologic modeling and risk analysis, the three major WMA water utilities, working closely with elected government officials and interested citizens, solved their problem with an innovative, largely non-structural solution. The estimated savings are more than $200 million as compared with previously proposed, predominantly structural solutions. The environmental benefits from improved capability for management of minimum flows to protect fish habitat and the recreational opportunities provided by the small, new local reservoir counterbalance any negative environmental effects. The WMA experience has been an extraordinary demonstration that largely non-structural alternatives, including better management of existing water resources facilities, can overcome many social, environmental, and political difficulties while achieving substantial cost savings.

Although the cooperative operations plan is expected to provide adequate water supply for the WMA well into the next century, the question remains as to where the WMA will go for water beyond that time. An increasingly viable option for future supplemental supply during droughts is the fresh water in the upper tidal estuary of the Potomac, a mixture of highly treated wastewater, urban runoff and low flow from the free-flowing river. As authorized in 1974, the COE built and evaluated the performance of a 3.8×10^3 m^3/d (1 mgd) pilot estuary treatment plant, the design and operation of which was reviewed by a committee of the National Research Council (NRC) of the National Academies of Science and Engineering.

The COE study concluded that the finished water produced was of acceptable quality for human consumption (Montgomery, 1983). However, unit costs using granular activated carbon (GAC) adsorption or reverse osmosis ranged from nearly 200% to over 350% of the cost of water from conventional surface water treatment plants not using GAC adsorption. Among other comments, the NRC committee questioned the sufficiency of toxicological testing to adequately evaluate the safety of treated estuary water for humans and the adequacy of the economic feasibility discussion (NRC Committee, 1984). These questions probably will be answered satisfactorily in the decades ahead. Therefore, if the WMA continues to grow, the estuary will be a feasible alternative within the WMA to the additional major upper basin reservoirs which were so strenuously opposed in the past.

Acknowledgements

Many agencies and individuals contributed to the successful solution of the WMA water supply problem. Of these, Robert S. McGarry, at the time General Manager of the Washington Suburban Sanitary Commission and Chairman of the WMA Water Supply Task Force (now Director of the Montgomery County, MD, Department of Transportation), and Daniel P. Sheer, Director of ICPRB CO-OP, especially deserve recognition. Sheer's case study report for the U.S. Geological Survey 1985 National Water Summary describes in greater detail the cooperative operations methodology (Sheer, 1986).

Appendix I. References

Bi-County Water Supply Task Force Technical Advisory Group, "Bi-County Water Supply Study: Montgomery and Prince Georges Counties, MD," Washington Suburban Sanitary Commission, Hyattsville, MD, April 1978.

Committee to Review the Potomac Estuary Experimental Water Treatment Plant Project, "The Potomac Estuary Experimental Water Treatment Plant," National Research Council, Nat'l Academy Press, Wash., DC, 1984.

DeMoncada, C., "Water Management in the Washington Metropolitan Area," Congressional Research Service, Library of Congress, March 15, 1979.

Federal Interdepartmental Task Force on the Potomac and Potomac River Basin Advisory Committee, "Potomac Interim Report to the President," U.S. Department of Interior, Jan. 1966.

Fosdick, E.R., "The Potomac River Estuary as a Supplemental Source of Municipal Water for the Washington Metropolitan Region," National Parks Ass'n, Washington, DC, Jan. 1968.

Interstate Commission on the Potomac River Basin Newsletter, Rockville, MD, Sept. 1963.

Interstate Commission on the Potomac River Basin Newsletter, Rockville, MD, June 1965.

Maryland Dept. of Natural Resources, "Potomac River Environmental Flow-By Study,", Annapolis, MD, 1981.

McGarry, R.S., "The Washington Metropolitan Water Supply Task Force," in "A 1980's View of Water Management in the Potomac River Basin," Report for the U.S. Senate Subcommittee on Governmental Efficiency and the DC, Cte on Gov't Affairs, U.S. GPO, Wash., DC, Nov. 12, 1981.

Montgomery, J.M. Cons. Engrs, "Operation, Maintenance and Performance Evaluation of the Potomac Estuary Water Treatment Plant," U.S. Army Corps of Engineers, Baltimore District, Sept. 1983.

Palmer, R.N., Wright, J.R., Smith, J.A., Cohon, J.L. and ReVelle, C.S., The Johns Hopkins Univ., "Policy Analysis of Reservoir Operation in the Potomac River Basin," Tech. Rep. 59, Water Resources Research Center, Univ. of MD, College Park, MD, 1980.

Potomac Basin Center, "The Potomac: A Summary of Basin Facts and Brief Review of Proposals of Recent Years," Washington, DC, 1969.

Sheer, D.P., "Analyzing the Risk of Drought: The Occoquan Experience," Jour. AWWA, May 1980.

Sheer, D.P. "Case Studies in Water Supply Management," National Water Summary 1985, U.S. Geological Survey, 1986 (in press).

U.S. Army Corps of Engineers, Washington District, "Potomac River Review Report, North Branch Potomac River," April 1961.

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

U.S. Army Corps of Engineers, "Report of the Chief of Engineers on the Potomac River Basin," Letter dated Feb. 26, 1969, U.S. House of Representatives Document No. 91-343, 1970.

U.S. Army Corps of Engineers, North Atlantic Div., Baltimore District, "Potomac River Basin Water Supply, An Interim Report," April 1973.

U.S. Army Corps of Engineers, Baltimore Dist., "Metropolitan Washington Area Water Supply Study for the Potomac Water Users," Draft/Progress Report, Aug. 1979.

U.S. Congress, "Interstate Commission on the Potomac River Basin Compact Amendments," P.L. 91-407, Sept. 25, 1970.

U.S. Dept. of Army, State of MD, Commonwealth of VA, DC, WSSC, and FCWA, "Potomac River Low Flow Allocation Agreement," Jan. 11, 1978.

U.S. Dept. of Interior, "The Nation's River," USDOI Official Report on the Potomac, 1968.

U.S. Senate, "DC Water Supply," Report of Hearing before the U.S. Senate Subcommittee on Governmental Efficiency and the DC, Cte on Gov't Affairs, 96th Cong., 1st Session, U.S. GPO, Wash., DC, Oct. 10, 1979.