A River Runs through It

An integrated system of dams gives TVA the unique ability to manage the Tennessee River's potential for a broad range of benefits.

BY JACK DAVIS, RENEE HURST, MORGAN GORANFLO JR., AND ARLAND WHITLOCK

Electricity has fueled past prosperity; the lifeblood of the future is water. Human imagination will usher forth new technologies and the promise of renewable and distributed energy generation. But water is a finite resource with a finite carrying capacity.

Historically, the Tennessee Valley has enjoyed ample water supplies—the result of precipitation from Gulf moisture pushed eastward by large frontal movements. Average annual rainfall in the region is 51 inches (130 centimeters), compared to 5 to 20 inches in the southwestern United States, about 30 inches along the northern tier states, and 40 to 45 inches in the northeast.

Even the Tennessee Valley, however, is not immune to water shortages. An extended drought from 1984 through 1988 caused municipalities to restrict water use and accept a higher rate of pollution due to the reduced assimilative capacity of the river. More recently, from 1998 through today, lower than normal rainfall has caused drought conditions across the region. For calendar year 2000, precipitation averaged 38 inches across the Valley—13 inches below normal—demonstrating again the region's dependence on large volumes of water for home use, not to mention navigation, power generation, recreation, and industrial needs.

Growing Demand

Consider how the region is growing, and the seriousness of the situation is readily apparent. About 4 million people get their drinking water from the Tennessee River and its tributaries. Likewise, numerous water-intense industries rely on steady, large-volume withdrawals. This includes TVA, which withdraws about seven billion gallons a day for thermoelectric power generation—primarily for cooling water used in the process of generating fossil and nuclear power. TVA's ability to operate its dams to meet water demands for power generation is a little-understood part of what makes the TVA system fully integrated and operationally interdependent. All this adds up to a total daily withdrawal of more than 9 billion gallons (34 billion liters) a day. Fortunately, most of this water is returned to the river where it is available for use over and over again.

Rapid growth in the amount of water used by industry is realistic given the region's advantages: its location near the population center of the United States, interstate highways crossing from east to west and north to south, an excellent rail network, major regional airlines, barge transportation, four distinct seasons and relatively mild winters, and, perhaps most important, a reliable water supply of good quality.

Water usage issues become even more alarming from a broader geographic perspective. Concerns over water supply have already hit Atlanta with a vengeance. (See "Thirst for Growth" in this issue of FORUM.) But the problems with ensuring Atlanta's water supply do not end with Atlanta. Medium-size and smaller cities, and even towns all over the country, already are struggling with tre-

mendous growth in water usage.

A fight brewing in north Georgia is symptomatic of what the region will likely be facing in the not too distant future. According to a lawsuit recently filed by the Southeastern Federal Power Customers Inc., the U.S. Army Corps of Engineers permitted a small amount of water to be removed from Lake Lanier in the 1970s under contracts with the Atlanta Regional Commission, Gwinnett County, and the cities of Cumming and Gainesville. The removal of water greatly increased over the years from about 10,000 acre-feet (12 million cubic meters) per day in 1977 to about 134,000 acre-feet per day in 1999—an increase of almost 1,200 percent. Few water sources can long support that rate of growth.

Escalating Conflict

Growth—in terms both of population and water use—is clearly the most serious issue facing water management in the next century. Our demands for ample drinking water, wastewater treatment, and industrial water supplies will bring conflict. Upstream and downstream users already are vying for increased benefits from a fixed resource. Water quality, fisheries, recreation, assimilative capacity, and other in-stream uses have taken on new value.

The entire northwest Georgia area above Atlanta is growing rapidly and exceeding the capacity of existing groundwater and surface water supplies. Similar problems are developing in the areas around Birmingham and Cullman, Alabama, and in portions of Alcorn, Tishomingo, Prentiss, Itawamba, and Lee Counties in northeast Mississippi. Each of these areas may look to the Tennessee River for additional water to supplement or replace declining groundwater supply sources or inadequate surface water resources. Not surprisingly, the state of Tennessee recently enacted legislation to require state permits for all water transfers inside and outside its boundaries. (See "Treading Political Water" in this issue of FORUM.) More such action can be anticipated as different political units realize the potential for loss of control over their water supply.

Circumstances similar to those at Lake Lanier will become more widespread. Greater pressure can be expected on TVA's tributary reservoirs for municipal water supply as the relatively small cities in these areas grow. The number of regional water systems is steadily increasing, allowing distant users to access water directly from these reservoirs, without investing in lines to return used water to source streams.

Water transfers for drinking water purposes already are taking place. For example, last year, 35 transfers took place among public water systems in Tennessee as municipal water distribution systems cross watershed boundaries to deliver safe drinking water to residential and commercial customers whose private wells failed or became contaminated.

During long-term droughts, these withdrawals will lower pool levels, reducing the amount of water available for hydropower generation, thermal cooling, navigation, assimilative capacity, recreation, and other downstream uses. They also will set the stage for conflicts over water use and supply—conflicts entwined with economic development and environmental protection and therefore all the more difficult to resolve.

While these conflicts can't be avoided, they can be minimized. The first requirement is to apply an integrated approach to river management, making every drop of available water count repeatedly as it passes downstream. A second requirement is to have an unusual degree of operating flexibility, taking full advantage of the water nature provides. The third is to take advantage of regional governance to allocate available water wisely, providing a predictable and reliable balance among competing demands. The TVA model meets all these requirements.

An Integrated Approach

There are literally thousands of dams in the United States, but virtually none are operated like TVA dams. Most reservoir projects were built for specific purposes—irrigation, hydropower production, water supply diversion, or navigation—and for the benefit of specific political jurisdictions. In contrast, TVA's 49 dams were built to provide the total benefit of the Tennessee River to the people of a seven-state region by balancing the use of the water for multiple purposes. No single activity was to be considered an end in itself. Instead, the focus was on realizing the full potential of the river.

Two primary types of dams and reservoirs were included in the design of the integrated system. The topography of the mountainous eastern Valley area was conducive for TVA to build at least one high, multipurpose dam on each of the major tributary rivers. These dams created reservoirs to provide seasonal flow regulation,

by using a wide range of pool level variations throughout the year to store and release water as needed, fluctuating on average about 30 to 40 feet (10 to 13 meters) per year.

On the Tennessee River itself, with its wider floodplain and preexisting urban developments nearby, TVA built a series of dams and reservoirs to ensure a navigable pool from Paducah, Kentucky, to Knoxville, Tennessee. These reservoirs in general do not have as much storage space for flow regulation as their tributary counterparts. Their pool levels typically fluctuate only 3 to 6 feet on an annual basis.

When TVA was created in the 1930s, the river system was operated primarily for navigation and flood control and, to the extent consistent with these purposes, for power production. Today, recreation, water quality, water supply, and other benefits also are factored into the system's operation. This expanding list of uses demonstrates the breadth of benefits that can be provided through an integrated approach, and it shows how the TVA model can uniquely adapt to changing needs and user expectations.

TVA is able to provide such a wide range of benefits and to respond to evolving social values and economic demands by operating its 49 dams as a single unit. The reservoirs and dams work together to make sure the right amount of water is available at the right place at the right time—and even at the right temperature.

A drop of water that falls as rain in the mountains of western North Carolina is used over and over as it makes the long journey to the mouth of the Tennessee River near Paducah, Kentucky—a distance of well over 800 miles (1,300 kilometers). That same drop of water is used as habitat for fish and flotation for navigation, as coolant for power plants and propellent for spinning turbines, as liquid for human consumption and carrier for industrial waste.

The wisdom of this multipurpose approach is well established. TVA's integrated water-control system transformed the Tennessee River and its tributaries into one of the most useful river systems in the world. It tamed the Tennessee's unpredictable flow, which once varied seasonally at Muscle Shoals, Alabama, a hundredfold, from little more than a trickle of about 4,600 cubic feet per second (130 cubic meters per second) to a torrent of over 460,000 cubic feet per second. It has prevented more than $4.8 billion in flood damages in the Tennessee Valley since 1936, plus more than $348 million in damages on the lower Ohio and Mississippi Rivers.

It has opened a 650-mile navigable channel that links the Tennessee Valley ports, by way of an inland waterway system, with ocean ports leading to countries around the world. And, of course, the system helped generate electric power for industrialization, rural electrification, and the development of the region. Today, TVA also manages the river system to maintain reservoir levels for recreation, provide a reliable water supply, and protect aquatic habitat, particularly downstream of its hydropower dams.

Operating Flexibility

Operating the TVA system as a single unit is not the only factor that allows TVA to provide such a wide range of benefits, however. These benefits also arise because of a key difference in the way TVA operates its dams compared with other operators. Most federal dam operators choose to be very conservative, accepting a smaller accrual of total benefits by reducing the need for the system to respond quickly to changing conditions. By contrast, TVA takes a much more aggressive approach, placing considerable responsibility on its water managers to respond to changes continuously to optimize benefits each day while protecting downstream areas, ensuring adequate reservoir levels for recreation and maintaining the integrity of the system.

Seasonal use of storage. Most federal and private reservoir projects have specific allocations for individual purposes, such as power, flood control, and water supply. Those dams used for flood control typically have been designed and constructed following one of two approaches: either a reservoir is kept empty for flood control at all times, or a designated volume—a definite layer—is reserved in the top portion of the reservoir for flood control. Other uses are not permitted to encroach on this designated volume at any time.

TVA's system, on the other hand, is built around the idea of allowing seasonal variations in the use of storage space. The same space, or designated volume, may be used for both flood reduction and other purposes at different times of the year. An optimal zone of operation has been developed for each TVA reservoir, based on many decades of experience charting demands for both water use and flood storage space throughout the year. This zone is defined by an upper boundary, called a

flood guide, and a lower boundary, called a minimum operating guide. The flood guide level is set primarily to reserve storage space for runoff from the heavy rains that typically fall in winter, but it also gives TVA the flexibility to generate low-cost electricity during wintery days. The minimum operating guide represents the storage space conserved for providing downstream minimum flows. If the reservoir level drops below this guide, water is released only to maintain minimum flows for aquatic life, water supply, navigation, and the safe operation of thermal power facilities.

Swift response to rainfall. TVA typically reserves less storage space in its reservoirs than do other federal dam owners. Most federal reservoirs have a large flood control reservation above maximum pool level—4 or 5 inches or more. Some western reservoirs can actually store more water than enters the reservoir during an entire year. In contrast, most TVA tributary storage reservoirs have only an inch of storage space at summer pool levels. Several TVA reservoirs along the main Tennessee River have a summer level that is only a few tenths of a foot below the top of the dam's gates.

While the additional storage space allows water managers elsewhere in the nation hours or even days to refine forecasts before deciding on a release rate from their dams, TVA water managers must react to storms much more quickly.

A second challenge is presented by the lack of information about the timing or volume of runoff that will be received in the future. In other locations where snowmelt is the primary source of runoff, precise measurements can be made of the depth and density of the snowpack. This gives water managers advance notice of the volume of runoff likely to occur during the spring thaw and weeks, or even months, to prepare. In contrast, most reservoir scheduling for flood control in the TVA region must be done in reaction to rainfall as it is occurring or has just occurred.

To meet these challenges, TVA's River Forecast Center is staffed around the clock, 365 days a year. Preparation, planning, and practice are watchwords, and a premium is placed on retaining experienced staff. Water managers are trained not only in flood control operations, but in all benefit areas. They are aided by rainfall reports from nearly 300 raingages and 60 streamgages strategically located throughout the Tennessee Valley, supplemented by state-of-the-art radar technology.

Engineering discretion. TVA delegates extensive responsibility to its water managers to make their best decisions, based on up-to-the-minute assessments of current and expected conditions and needs. This concept allows the accrual of benefits that would not be possible under any other scheme of operation. The majority of river and reservoir systems in the United States are scheduled in strict adherence to a prescribed set of rules and water-use allocations often approved at the national level. TVA water managers continually evaluate current and expected conditions at the local level, employing a systemwide perspective to ensure the best use of the water for all prescribed beneficiaries.

Scheduling frequency. Frequent reevaluation of conditions leads to frequent rescheduling of releases from TVA reservoirs. The storage capacity of TVA reservoirs is a critical factor. Because there is so little storage in main-river reservoirs, gate changes are often necessary with little warning.

In response to a large rainfall in 1990, for example, discharges from TVA's Wheeler Dam increased from zero at 1 a.m. to more than 300,000 cubic feet per second at midnight to regulate downstream flood stages.

Run-of-the-river reservoirs—reservoirs that have to pass on all incoming flow because of limited storage space—require more immediate decisions in response to significant changes in inflows. At run-of-the-river projects like Ocoee No. 2 Dam, for example, coordinating releases for both power and whitewater recreation requires particularly close scheduling.

The uses that TVA reservoirs serve also affect scheduling. Multipurpose dams along the main Tennessee River and tributary dams at summer pool levels must be scheduled and rescheduled frequently during rainy weather to ensure proper use of the limited flood storage space. In addition, most main-river TVA dams require frequent scheduling because power needs fluctuate greatly during the day, and the economic value of hydrogeneration changes on an hourly basis.

While these changes can be anticipated to some degree, changes in weather or other power supply costs can dramatically affect the way releases are scheduled to achieve maximum benefits. Other uses, such as recreation and thermal cooling of power plants, also require frequent adjustments in schedules to optimize water use. Meeting a downstream water re-

quirement might require changes in flow at several upstream dams over a considerable period.

Regional Governance

Every major American watershed is managed under increasingly competitive pressures for reallocations of water, and in virtually all cases, individual watershed interests and jurisdictions are trying to protect their traditional water allocations. Such a situation is certainly understandable in the absence of any coordinated effort. But rainfall and flowing streams do not recognize political and geographic boundaries, and any solution for fair public use of the water resource should address all concerned interests. Upstream and downstream interests—which increasingly face new pressures brought on by water shortages outside the drainage area—need to be coordinated.

Again, the TVA model is instructive. Prior to the creation of TVA, two schools of thought existed regarding the management of natural resources. One school argued that such vital resources could be managed effectively only by a highly centralized national government. The other school of thought argued that natural resources should be managed by individual states.

TVA demonstrated that yet a third system, a regional agency, could effectively manage large river and land systems, especially if the agency, as President Franklin Roosevelt characterized it, is "clothed with the power of government but possessed of the flexibility and initiative of a private enterprise."

TVA was headquartered not in Washington, but near the river it was to manage; and its resource management responsibilities were not constrained by political boundaries, but instead were drawn around a single ecosystem, including parts of seven states and crossing city, county, and state boundaries.

Contrast the Tennessee Valley with the Pacific Northwest, where 17 authorities and two countries make decisions about managing the Columbia River, and the advantages of a single source of regional jurisdiction are obvious. Regional governance enables TVA to efficiently and fairly distribute the benefits of the river and its tributaries, while assuring local communities of control and influence over their water resources. It also enables TVA to provide a reliable and predictable river resource that fortifies local economies and unifies the region across state and local boundaries.

The Future

The TVA river system is unique in its design and operation. Nowhere else in the world are dams, reservoirs, navigation channels, and electric systems operated as a single unit. Nowhere else do water managers have the operating flexibility to make the most efficient use of resources based on an up-to-the-minute assessment of current and expected conditions and needs. Although controversy continues regarding the issue of national oversight and decision making, most would agree that this experiment in watershed stewardship has been an unparalleled success in delivering its prescribed benefits to the Tennessee Valley region.

TVA's authorized mission is ongoing. The economic development in the Tennessee Valley is sustainable in large part because TVA's integrated system supplies reliable water and electricity without depleting the resource. The demands for other uses of the river—for navigation, flood control, recreation, fishing, aquatic habitat, waste removal, thermal cooling, and other in-stream uses—will continue to increase. The job of balancing these competing needs will fall to TVA, and the Valley's long-term economic prosperity will hinge largely on the balance achieved.

In 1999, TVA created a citizen advisory council to help with this delicate balance of public benefits. The Regional Resource Stewardship Council is advising TVA on policies, practices, and priorities in deciding how best to use the Valley's water and other resources for the benefit of the public. Its 20 members represent distributors of TVA power, industrial customers that buy electricity directly from TVA, beneficiaries of navigation and flood-control activities, and recreational and environmental interest groups. This council will play an important role in anticipating and meeting the future water challenges facing the Tennessee Valley.

Ironically, the greatest of these challenges may be the growing threat to the integrated nature of the TVA system—the unique characteristic that has made the nation's investment in TVA's dams so productive. Several scenarios—most put forth by private utilities in the Northeast and Midwest—have been discussed in recent years, including operating TVA under different authority, splitting its responsibilities with another federal agency, or even privati-

zation. Under any of these scenarios, TVA's integrated system would likely disintegrate.

Disintegration would preclude the most efficient use of the river, resulting in an immediate waste of water and money and a decline in the level of benefits the citizens of the Tennessee Valley have come to expect from the Tennessee River. Worse, the nation would lose a valuable model for dealing with its future challenges. The future of the Tennessee Valley Authority bears watching closely. Much is at stake.■

Morgan Goranflo is a senior consultant and Renee Hurst is a communications specialist for River Operations at the Tennessee Valley Authority in Knoxville, Tennessee. Arland Whitlock and Jack Davis are private consultants. Both retired from TVA River Operations in Knoxville.