EVOLUTION OF WATER RESOURCES "MANAGEMENT" IN THE 20TH CENTURY IN THE U.S.

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INTRODUCTION

Who was making decisions on water resources issues in the 1940s? Engineers. There was an almost complete absence of economists, biologists, political scientists, wildlife specialists, etc. While in the United States (U.S.) Navy in WW II, I discovered there was something more in life than physics, chemistry, and mathematics; namely, human beings and institutional behavior. Ergo, I took a detour from my long-range goal of direct involvement in water resources management to obtain a degree in sociology and economics. After a stint working in a steel mill, the next step was Berkeley to obtain a degree in civil engineering with a concentration in "water." Already having a degree, I was spared sitting in large classes for the standard degree requirements. A time sequence of courses was required for the engineering degree. This enabled me to take courses along the way in economics, pedology, soil classification, and public health.

Having completed the rigors of civil engineering at Berkeley with $5 in my pocket (confirming my capacity for financial planning), I hitchhiked to Northern California to begin my professional career in 1953 with the California Division of Water Resources (DWR), working on the California Water Plan (CWP). (At that time the division was part of the state highway department! It did not become the Department of Water Resources, with Harvey Banks as first director, until 1956.) At that time the CWP was part of "big project dreaming," e.g., North American Water and Power Alliance (NAWAPA) and Grand Canal. From DWR I went to Bechtel Corporation in Southern California, and then to Harvard in the first group of water resources fellows. The Harvard stint spawned some productive, interesting, and long-standing relationships, particularly with Maynard Hufschmidt. As well, it turned my professional focus toward the analysis, planning, and institutional aspects of water resources management. The work on water, involving hydrologic, economic, and institutional aspects, such as in establishing the Delaware River Basin Commission, led to broader issues of multimedia environmental quality management, to coastal resources management, and the effort to integrate economics, technology, ecology, and institutions.

TRENDS IN WATER RESOURCES MANAGEMENT

From my point of view, at least four significant positive trends have occurred in the water resources field over roughly the last half century. Incipient actions perhaps began with the Mississippi flood of 1927, the Flood Control Act of 1936, and the Natural Resources Committee in the late 1930s and early 1940s. Activities proliferated after WWII, beginning in the late 1940s with President Truman's Water Resources Commission (the Cooke Commission) and Bureau of the Budget and federal interagency activities. Perhaps then a logical focus is the last half of this century. Along with the positive trends noted hereafter, I will suggest two problems/issues which have been inadequately tackled.

Positive Trends

From Supply Management to Demand Management

A shift has occurred from supply management to greater consideration of managing demands in attempting to improve the efficiency and reduce the costs, or reduce the increase in costs, of water resources management. For decades, certainly during the period before I was in engineering school and for a decade or two after, water resources planning and development meant looking only for alternatives to increase supply. Water demands were considered to be water "requirements," and were referred to as such in the engineering and planning literature and in practice. The implication was that "these amounts **had** to be supplied." Thus, the current unit use or trend in unit use in industrial activities, households, and agricultural operations was multiplied by the number of units of activity to derive the "water requirement." The resulting water required would be met by increasing supply. There was no, or certainly little, attempt to investigate what variables actually affected water use by various types of activities.

The change in focus began in the 1960s. Empirical studies of water use in industrial plants demonstrated that unit water intake and waste water – quantity and quality – were a function of many variables such as: nature of production processes, raw materials, product mix and product specifications; cost of energy; cost of water recirculation; water intake prices/costs; waste water discharge costs/prices (effluent or sewer charges); costs of solid waste disposal, including sludge; capital availability to plant; availability of technological and cost information; and other constraints imposed on individual plants, e.g., gaseous discharge controls, restrictions on water recirculation, as in canning and freezing (see, for example, Bower 1966). Empirical studies of residential water use, ala Howe and Linaweaver (1967), found that the price of water intake (including sewer charges reflected therein) and educational programs with respect to water conservation measures could have, depending on their intensity, significant effects on unit residential water intake, and hence on unit residential waste water discharge. "Demand management" has even made inroads in agricultural operations, basically where sales of water rights provide an incentive to improve irrigation efficiency. For example, some farmers have found they could maintain output with less water by changing irrigation methods after having sold part of their water right, thereby increasing total net revenue. The shift to including demand management in development of electric power utility systems, stimulated by Southern California Edison's move in the 1970s, reflects the same trend.

Evolution of Orientation

Management of water quality received scant attention until the 1960s, despite the Federal Water Pollution Act of 1948. A pioneering effort to focus attention on water quality aspects was the work of Kneese (1961). This in turn generated seminal work on regional water quality management by Kneese (1964) and DHEW (1966). The next step was the move from a focus on a single medium to consideration simultaneously of multimedia – water, air, and land – and the interrelations among them. This multimedia framework was exemplified in analysis of single industrial plants (Russell 1973, and Russell and Vaughan 1976), and of regional residuals in environmental quality management, represented by an exploratory study (Bower, et al., 1968) and a much more detailed and sophisticated analytical study (Spofford, Russell, and Kelly, 1976). Subsequently, several Environmental Protection Agency (EPA) studies adopted this framework, as did studies in other countries, such as Australia, the Netherlands, and China, the last as reflected in Walter Spofford's work under the aegis of Resources for the Future (RFF).

Although the broadening of the orientation represents a major step forward, two limitations have yet to be overcome. One is the fact that studies, such as that of Spofford, et al., are static studies, i.e., based on conditions at one point in time. It was sufficiently difficult to put together a multimedia analysis of a very complicated area for one set of conditions. The difficulties are multiplied several fold if one wishes to construct the analysis in the context of planning for management over time. The second limitation is that the DHEW and Spofford, et al., studies focused on the residuals aspect of water resources management. Water resources were considered only in that context rather than in the "real world" context of dynamic multipurpose water resources management, e.g., with respect to demands for hydroelectric energy generation, flood damage reduction, irrigation, fish and wildlife habitat over time. The problem is illustrated by considering the difficulty of combining the detailed and sophisticated simulation study of water use in the Delaware River Basin upstream of the Delaware Estuary (Hufschmidt and Fiering, 1966), with the sophisticated simulation studies of DHEW (1966) and Spofford, et al., (1976) of the Delaware Estuary.

Staffing

A significant improvement in staffing has taken place in the last two or three decades. When I went to work for the California Division of Water Resources in 1953, the staff consisted of several hundred engineers, one or two economists, no water quality professionals, no biologists (ecology was not yet recognized), no political scientists, and no land use planners. This parochial view of the talents required to do a reasonable job of analyzing the many dimensions of water resources management gradually eroded, with some institutions moving to include economists in particular political scientists, wildlife specialists, and ecologists. The Corps of Engineers was probably a leader among the federal water agencies in this move. The best example of a water resources management agency with a full complement of staff for the job is the South Florida Water Management District (WMD), which is staffed with engineers, economists, system analysts, ecologists, and fisheries and wildlife experts.

The South Florida District is a rare exception with respect to staffing. Many water agencies, such as water resources management, water quality management (pollution control), and coastal resources management, do not have the range of expertise required. Part of that situation reflects lack of financial resources plus the lack of recognition of what is involved in water resources management. In this respect the South Florida WMD is in the enviable position of having an external – outside the normal budgetary process – source of financing.

From a Deterministic World to a Stochastic World

Up to the time of, and continuing for some period beyond my civil engineering training, it was a deterministic world, with respect to hydrology (as well as other aspects of civil engineering, e.g., the analysis of structures, the analysis of transportation). Federal, state, and local water agencies used the "historic trace" of hydrologic events in their analysis and planning of water resources developments, regardless of how limited the "period of record." A classic example of this approach is the Colorado River Compact, which was signed in 1922 and allocated water based on the 30-35 years of record available, which reflected a wet period in the Southwest. Thus, more water was allocated than existed.

When we arrived at Harvard in the fall of 1956 for the first year of the Harvard Water Resources Program, that was still the basic approach. Recognizing the fundamental limitation of that approach, i.e., the probability of the exact same sequence of hydrologic events being repeated in the future being close to zero, several of us who had not been exposed to, and grounded in, probabilistic theory and methods in our training, asked the August professors if there weren't a more rational way of developing hydrologic sequences for use in analysis and planning. Harold Thomas responded to the challenge, which led to the Harvard work on synthetic hydrology (Thomas, 1962). The basic approach involved developing Monte Carlo methods for generating equally likely sequences of hydrologic events, based on the moments of the distribution of events in the period of record. Of course this approach does not solve the problem of a limited period of record. However, it enables the best use of whatever data are available.

Thomas was careful to point out that Hurst, in 1927, had used the shuffling of a deck of cards to generate alternative sequences of annual flows. Although a significant improvement over simply using the historic trace, the "card deck" method meant that there would be no annual flows greater than the highest flow in the period, nor lower than the lowest flow in the period. Yet even this improved approach was ignored. The Harvard effort stimulated various other efforts, such as the James, et al., (1969) analysis of management of water quality in the Potomac Estuary. However, widespread application of the approach does not appear to have occurred (Fiering, 1997), although it is applicable in other contexts as well, e.g., hurricane and nor-easter storm patterns.

Little Forward Movement

Regulating Public Entities in Water Quality Management

In water quality management, regulation has focused virtually exclusively on private sector activities and urban outfalls. Despite the fact that the worst polluters in the U.S. are Department of Energy (DOE) and the Department of Defense (DOD) (e.g., Hanford, Rocky Flats Arsenal, and Savannah's nuclear energy-related operation), the failure to deal with these public sector activities has spawned several of the worst Superfund sites in the U.S. The Tennessee Valley Authority (TVA) and the Unites States Forest Service (USFS), while not quite at the DOE-DOD level, still discharge excessive amounts of undesired materials from their activities. For years the EPA has battled TVA coal-fired plants and is still doing so (see Stout, 1999). The Forest Service has contributed to sedimentation from logging operations in the Columbia Basin, and hence to the reduction in salmon, by failure to enforce sediment reduction practices on private contractors logging national forest areas. The National Park Service has failed to maintain water quality in Bright Angel Creek in the Grand Canyon. "Water polluted" signs exist along its banks, which was not the case prior to the mid-1970s .

Very little attention has been paid by researchers and practitioners to this "government regulating government" problem. Perusal of the literature turns up very few references relating to the problem. The most difficult situation is when the regulatory agency is at the same government level as the "offending" public agency, e. g., federal regulatory agency vs. federal agency, state regulatory agency vs. state agency. It is easier, and actions have been taken, for a higher level regulatory agency to regulate a lower level public agency. One factor compounding the problem is the existence of many POPOs; publicly owned, privately operated activities, ala Hanford and some other DOE installations. A POPO is a perfect "setup" for "passing the buck."

Water Resources Management as a Continuous Process

I have found that many government agencies responsible for water resources management, including water quality management and coastal resources management, have little understanding of water resources management as a **continuous** process. That is, such management involves a set of tasks, i.e., analysis, planning, design, construction, operation, monitoring, and feeding back of information. These tasks must be carried out over time, by whatever agencies are responsible for one or more of these tasks. This must be done in a dynamic context, such as changing economic and social conditions, changing demands, increased knowledge of behavior of ecosystems and of user behavior, and changing governmental policies in the water resources sector and in other sectors. The management problem is analogous to that of a utility, such as a power company (prior to deregulation). To make sure the light goes on when one pushes the switch, the utility has to have staff sections on analysis and planning, design, construction, operation, and maintenance. The separation of analysis/planning from implementation, as in the river basin planning commission period through Section 208 of the Water Pollution Control Act Amendments of 1972, has spawned a legacy inconsistent with the necessary continuous, adaptive management, a legacy which has been, and is, difficult to overcome.

IN SUM

Positive trends in water resources management in the last half century include: a shift from essentially a supply only orientation to inclusion of demand management; broadening the scope to recognize the interrelations among the three environmental media of water, land, and air; broadening agency staff competencies to include economists, biologists/ecologists, political scientists, and wildlife specialists; and a shift from a deterministic world to a stochastic world. Two areas currently needing much attention include: regulation of public agencies by public agencies, including the development of incentives to induce more efficient and more socially desired behavior, recognizing that few public agencies respond to economic incentives; and increased recognition that management is a continuous task along with the staffing to "back up" that recognition.

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