# CRISIS DECISION-MAKING IN AMERICAN WATER DEVELOPMENT

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## INTRODUCTION

History is replete with examples of the importance of water to the well-being of civilizations. The great civilizations which occupied the valleys of the Tigris and Euphrates Rivers owed their prosperity in large part to their cultivation of the riches of those rivers, and their downfall was at least in part due to neglect of their water resources and changes in the hydrological regime.

North Africa once supplied Rome with agricultural produce far more varied and plentiful than now found there. This is traceable in part to elaborate irrigations systems which had been developed there and which were partly destroyed by war and permitted to decay.

In more recent history, we can observe the demise of the great plain of the Indus River, once the grain basket of the Indian Sub-Continent, but now the home of abject and grinding poverty. An interesting variation of the water story, the plain of the Indus has gradually become water-logged and highly saline with an average of 100,000 acres per year being lost to cultivation in the midst of one of the greatest population explosions in human history.

The Western Hemisphere presents its own examples of economic retardation traceable in part to lack of water. Northeastern Brazil and the high plateaus of Mexico would be examples.

The existence of such examples does not mean that the availability of water is sufficient to guarantee economic growth nor that it would necessarily be worthwhile to incur the expense of bringing water to those regions. Indeed, plentiful water is not, in all cases, even necessary for establishing a thriving economy, as can be seen in the success of Israel in establishing a viable economy in the face of meager water supplies. Even so, it would not be unreasonable to argue that water can and does exert a profound influence on the course of development and well-being of national economies.

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DO WE HAVE A WATER CRISIS?

To relate the foregoing observations to the contemporary U. S. scene, one can observe that, while water availability has been extremely important to the development of several major regions of the United States, the dependence of economic activity on water tends to decrease with advancing wealth and technology. Advanced irrigation farming in the Southwest can substitute investment in lined irrigation canals for water, but a peasant economy could not consider this possibility. A modern beet sugar plan can be designed to withdraw from its water source only 76 gallons per 100 pounds of sugar, whereas the average for older plants is closer to 1200 gallons. Washed coal operations are currently designed to withdraw from 1 to 1,000 gallons of water per ton.

The United States thus has a greater flexibility than ever before in conserving its water resources, greater opportunities for devoting water to the highest value uses, and a vast inventory of technology to reduce required water intake and improve water quality. Yet it is commonly thought that the country faces a water crisis which requires crash programs to avoid dire results! How much content is there in this impression?

The answer to this question might be placed in some perspective by noting that decision-making, particularly in the public sector, frequently takes place in a crisis atmosphere. In 1955 there existed a common impression of a great shortage of engineers and several programs were instituted to promote engineering education and advertise professional opportunities. Sputnik went up and we were suddenly lacking scientists, scientific education, and adequate research.

Eastern railroads declined in service to the public for years, yet it seemed to require the rather spectacular bankruptcy of the New Haven to call this to the public's attention. Social injustices of years' standing went unheeded until the situation assumed crisis proportions. Now we presumably face a crisis in water quantity and quality.

All of these situations have characteristics in common: the underlying problem had existed for some time; experts and informed laymen in each field were very much aware of the problems but the public was not well informed; some particular incident seems to trigger public awareness; those who have long term responsibility for alleviating the problem help to fan the fires of crisis in hope of gaining support to help make up for accumulated inadequacies.

Why do such crises occur? First, the public sector, both local and national, has limited funds to allocate among many programs and political support must be mustered to secure funds. The issues are complex and their understanding frequently requires data, analytical abilities, and time that the average voter cannot easily acquire, making it unlikely that the initiative would come from the public. At the same time, no institutions exist with the time and expertise required to keep particular problem areas under continuing review. Existing institutions which have the potential for so doing frequently get bogged down in day-to-day administration and develop traditional viewpoints which may mask a problem for a time and then magnify it unduly through failure to perceive the whole range of alternative solutions.

Does the United States face a crisis in the water resources area? A crisis must have two elements: there must be a present or impending shortage of water and there must be significant costs which will result from that shortage. The definition of shortage which must be used here is:

> water of the quality desired is not available in the quantity desired under the terms of availability, including price, to which users have become accustomed.

For most commodities, the market is expected to take care of such excesses of demand over supply by inducing increased supply and improved quality and through adjusted prices. It is worth recalling, however, that water has unique characteristics which frequently, though not always, take its provision outside the market place.

1. Water users frequently have impacts on each other's operations. Upstream users affect downstream availability and quality. Groundwater use affects other's pumping costs as well as stream flow.

2. Gross supplies provided by nature are irregular, probabilistic--serving to cloud property rights in the commodity and making market transfers difficult.

3. Supply systems, to be efficient, frequently must be large-scale, basin-wide, frequently requiring legal and administrative powers which are difficult to transfer to private enterprise.

Recognizing that much of our water resource supply and development falls within the scope of public authorities for the above reasons, we must seek the causes of the currently perceived excess of demand over supply and investigate just what is known about the costs of shortages when they are actually experienced.

THE DEMAND FOR WATER: IS IT REASONABLE?

Demand may conveniently be broken down into classes of uses: residential, commercial, industrial, public, and agricultural. Only residential, industrial, and agricultural demands will be mentioned here.

Residential demands represent a small percentage of national total water withdrawals, but in metropolitan areas such demands can represent a large percentage of total system output and can account for very large proportions of total investment. Contemporary urban water problems are of two major types: inadequate distribution system capacity and shortage of basic water supply. However, many of these problems arise through excessive, uneconomic demand.

The urban situations serve to illustrate an important point: uneconomic pricing of water throws a large and unnecessary burden of capital expansion on the water system. The system must stand ready to satisfy all demands without permitting an excessive pressure drop to occur. Thus systems are designed to handle the peak hourly demand rate. The following table gives results of measurements taken in a recent analysis of 34 study areas across the country.

TABLE 1. Per Capita Water Use in 34 Study Areas1/

| Period | Range | Mean |
|---|---|---|
| Average Annual | 50 to 530 | 115 gpcd |
| Maximum Day | 72 to 1450 | 300 gpcd |
| Peak Hour | 150 to 2750 | 690 gpcd |
| Ratios: | | |
| Maximum Day/Average Annual | 145 to 500 | 260% |
| Peak Hour/Average Annual | 260 to 1300 | 600% |

1/ Residential Water Use Research Project, The Johns Hopkins University, Report II, Phase 2, by F. P. Linaweaver, Jr., June 1965.

Nearly all of the excess use above the average annual is accounted for by lawn sprinkling. The "average system" must thus be designed to distribute 6 times the amount that is used on average, and most of this additional investment is attributed to lawn sprinkling.

What does this have to do with pricing? Much of the water is in fact wasted and this waste is induced by uneconomic pricing; that is, prices are set below the actual cost that additional demands impose on the system. The following table illustrates the impact of metering on residential water use.

TABLE 2. Water Use in Metered and Flat-Rate Areas[1/]
(climatically similar areas)

| | Metered Areas (10) | Flat-Rate Areas (7) |
|---|---|---|
| | (gallons/day per dwelling unit) | |
| Annual Average | | |
| Leakage and waste | 26 | 32 |
| Household | 239 | 232 |
| Sprinkling | 191 | 520 |
| Total | 456 | 784 |
| Maximum Day | 975 | 2400 |
| Peak Hour | 2420 | 5240 |
| | (Inches of water) | |
| Annual | | |
| Sprinkling | 14.9 | 47.2 |
| Potential Evapo-transpiration | 29.7 | 25.7 |
| Summer | | |
| Sprinkling | 7.4 | 27.3 |
| Potential Evapo-transpiration | 11.7 | 15.1 |

1/ Residential Water Use Research Project, The Johns Hopkins University, Report II, Phase 2, by F. P. Linaweaver, Jr., June 1965.

Metering means that users must pay for each additional unit they use. Whatever may have been the levels of prices paid, the differences of behavior under metering and flat rate are striking.

Some major urban areas which are currently experiencing basic water shortage and distribution bottlenecks still price water on a flat-rate basis. It has been more than ten years since an eminent board of consultants recommended universal metering and extensive system repairs for New York City. Yet most residential users are still not metered and the system losses through leakage amounts variously estimated from 200 to 400 million gallons per day.

One can quote Reno's experience of a few years ago as an indication that residential water usage can be substantially reduced without damage to the community. (1) After lowered lake levels had reduced the Truckee River to a trickle, a program of public information was undertaken to advertise the nature of the shortage and the kinds of steps which households and businesses might undertake to conserve water at minimum inconvenience. The result was a 20 per cent reduction in overall consumption with a great reduction in peak demands. In spite of reduced application, lawns were not adversely affected.

It is my conclusion from this and other evidence that residential demands in many places are excessive relative to what they would be if water were metered at economic prices, with a bit of consumer eudcation thrown in. Not only would short-term reductions follow, but over time more suitable adjustments of lawn acreage, shrub and tree types would be made.

What of industrial demand? The outstanding characteristic of industrial demand is the variablility of gross water use (withdrawal plus recirculation in some cases) per unit of product. The following table summarizes data collected in a survey by the National Association of Manufacturers.

Of course, not only does gross use vary a great deal within a given industry, but consumptive use and water-borne waste load also differ widely.

On the basis of this evidence and a sequence of intensive industry studies being conducted by Resources for the Future, Inc., it is clear that there exists a wide design range for plants in most industries, ranging from heavy water using design to high water conserving design. Conserving water costs money, of course, but with water supply costs continually increasing and with a rational pricing of water, industrial plants can and will adapt to lower water intake.

This adaptablility has been exhibited in new plants in various industries. An excellent example of it, combined with the <u>perils of forecasting without taking technological change and adaptation into account</u> is

TABLE 3. Ranges of Gross Water Use per Unit of Product[1/]

| | |
|---|---|
| Beet Sugar | 76 to 3200 gallons per 100 lb. sugar (withdrawal only) |
| Salt Production | 6 to 640 gallons per ton |
| Distilling | 125 to 167 gallons per proof gallon |
| Soap | 3 to 100 gallons per case |
| Detergents | 33 to 38 gallons per drum |
| Tanning | 0.2 to 64 gallons per sq. ft. |
| Petroleum Refining | 500 to 3247 gallons per bbl. of crude |
| Pulp and Paper: | |
| 1954 average | 66,400 gallons per ton of product |
| 1959 average | 57,000 gallons per ton of product |
| Steel | 3544 to 24,798 gallons per net ton |
| Coal Preparation | 1 to 1000 gallons per ton |

1/ Water in Industry, National Association of Manufacturers and the Chamber of Commerce of the United States, January 1965.

found in two forecasts for the pulp and paper industry's water withdrawal. The forecasts were made independently by Business and Defense Services Administration and Resources for the Future, Inc. In 1954 when actual withdrawal amounted to 1607 billion gallons, both organizations forecast a 1959 withdrawal of 2140 billion gallons. A Census survey covering 1959 indicated actual use was up only to 1744 bgy, an increase of 8-1/2 percent, in spite of an increase in product output of 30 percent.

The water use projections of the Senate Select Committee on National Water Resources (88th Cong., Aug. 1960) were, for all sections of the country except the West and Southwest, dominated by flow augmentation "requirements" to maintain acceptable stream quality. Combinations of secondary treatment and flow augmentation were assumed. Other quality-improving alternatives, such as in-stream reaeration and waste load redistribution, were not taken into account, nor were the wide possibilities of industrial process change for reducing waste outfall.

The point is that many of the industrial water use forecasts which have contributed to predictions of water shortage by 1980 or 2000 have not taken into account the adaptability of industrial water use in reducing water requirements and waste loads. The success of the Ohio River Sanitation Commission in achieving results in this field is a monumental example of what can be achieved on a voluntary basis.

A final observation on the demand side should be made to cover agriculture. Here I find myself in the embarrassing position of having no particular expertise while addressing experts. Several "safe" points might nonetheless be made. Irrigation represents the largest withdrawal and by the far the largest consumptive use of water in the country. At the same time, irrigation efficiency remains low in many areas. Where small river basins are involved or where groundwater is used, the impact of inefficiency in application may be localized, but in the larger basins the effects may be felt over vast areas. In all cases, inefficient use leads to pressures for the development of new sources such as long distance inter-basin diversion, often long before such needs are economically justified. Clearly there are cases where private rationality diverges from the nationwide interest. If imported water will be provided to an irrigation district at, say, $15 per acre foot while local projects designed to reduce losses will cost $20 per acre foot of water saved, the district can hardly be blamed for voting for imported water. This cannot, however, obscure the fact that currently proposed inter-basin diversions are going to cost the country at least $30 per acre foot, whoever pays the bill.

The national interest requires continuing effort to increase irrigation efficiency. A few percentage points in increased efficiency can represent sufficient water not only to provide for the future economic health of the agricultural sector but to provide water that may be necessary for continued population expansion and industrial growth. Again, a more rational pricing of water would give impetus to increasing efficiency.

The overall conclusions regarding current and prospective demands for water seem to be that:

1. under-pricing or flat-rate pricing lead to excessive use and waste in all sectors of the economy;

2. economic pricing can, over a long period, result in more efficient use through process and systems adaptation;

3. many of the extrapolations of future water requirements have greatly overstated needs by failing to take into account technological change, process and system adaptability, and some important alternatives in handling the water quality problem.

## WATER SUPPLY: HAVE WE LOOKED AT THE ALTERNATIVES?

New supplies of water are available to the United States only at increasing cost. In the development of surface supplies, most regions have already utilized the best reservoir sites. The Colorado is so highly controlled that additional reservoirs will reduce reliable flows through evaporation. Imported water from projects which can be executed within the next decade will cost at least $30 per acre-foot, as shown by the reconnaissance estimates below (uncorrected for price increases since originally made):

| | |
|---|---|
| Snake-Colorado | $31.80* |
| Modified Snake-Colorado | 34.00 |
| Sierra-Cascade | 27.00 to $38.00 |
| Yellowstone-Snake-Green | 30.00 |

(*Water Resources Center, UCLA)

These figures represent only the first step of delivery into a major reservoir or other point of the Colorado River.

Desalination is currently receiving a great deal of publicity as a new source of water. Plants have been successfully established on a commercial basis two or three places in the United States and in greater numbers abroad. Costs to date are running $1.00 and up per thousand gallons, but plants now in the engineering stage promise to reduce this to about 30 cents per thousand gallons -- $97.80 per acre-foot. These costs refer to very large scale plants in the 100 to 200 million gallons per day range which require particular circumstances for their viability: sea coast location where intake salt water and brine disposal are cheap, a market for vast amounts of electrical power (400-1500 megawatts) produced jointly with the water, and ability to use the water near at hand. Once plants of this size have been attained, present technology will have been largely exploited, and major breakthroughs appear unlikely. Potential applications of desalting appear limited.

The effective supply schedule of water depends upon water agencies' perceptions of alternatives. New York has long had its "crisis" but is only now turning to the Hudson River for water -- water of a quality far superior to that used by many major cities, including nearby Philadelphia which uses the waters of the Delaware. The last reservoir added to the New York system provides more costly water than the Hudson and, now during extreme draw-down, is providing "black water" of a quality offensive to many users. This point apparently was not anticipated by those who argued that cost differences were justified by quality differences.

Los Angeles will be importing water from Northern California at $45 to $65 per-acre foot (depending upon who does the figuring) while having a vast potential for water reuse and sewage reclamation at almost half the cost. The Whittier Narrows sewage reclamation plant produces potable water from domestic sewage at 5 cents per thousand gallons or $16.50 per-acre foot. The water is used currently as groundwater recharge. This program is capable of vast expansion in Los Angeles, but plans are moving ahead for the desalting plant mentioned earlier -- $98 water.

It seems quite likely that advanced waste treatment processes will be improved and lowered in cost in the near future. A new surge of interest and research, both public and private, is being felt in this field, promising to make water reclamation and reuse even more attractive.

Realistic supply alternatives thus are frequently ignored or given low priority in development in spite of large cost differences.

At the same time, some disadvantages have been overlooked in public discussions of alternatives.

The brine disposal problem in desalting has not been adequately analyzed. A plant producing 100 mgd from sea water will produce 20,000 tons of salt per day -- in the form of brine unless further treated. The disposal of such quantities of brine can cause change in the biological regime of the ocean along the coast. Various forms of plant and fish life were killed in the environs of the Point Loma demonstration plant. Disposal of brine at inland locations will, in some locations, require costly recharge wells which might ultimately feed back into the brackish water supply.

Large-scale importation schemes have the drawbacks of inflexibility, irreversibility and long payout periods. Given the economies of scale in building large diversion systems, it is difficult to keep demand and supply in phase. While it is necessary to build ahead of demand in a growing economy, a balance must be struck between the operating cost economies of larger systems and the premature commitment of capital. A long payout period is not to be deplored in itself, but committing oneself to projects of very long life in the midst of an era of great invention and technological change may not be the best way of handling uncertainty. Not only are there uncertainties about future technological advances, but little is known about environmental and ecological response to withdrawal of large quantities of water from rivers such as the Columbia or Snake or to the flooding of vast mountain valleys as envisioned in NAWAPA. Anyone who has observed a large reservoir gone dry can appreciate the irreversibility of such projects. These points may be summed up in the phrase "the desirability of flexibility" in water resource development.

These observations on the supply situation can be summed up in the following points:

1. additional supplies are going to cost a good deal more than we have been used to paying;

2. how high costs go will depend on our willingness to consider on the basis of cost all alternatives for augmenting supplies;

3. planners should consider the "desirability of flexibility" before committing us to large-scale, irreversible projects.

## THE COST OF WATER SHORTAGE

I trust that by now my conclusions are beginning to show: that nationally we have no shortage of water which cannot be eliminated by more efficient, less wasteful use (most easily induced by pricing water at its real national cost) and through additions to supplies from the lowest cost available sources, including water reclamation and reuse. This conclusion holds, in my mind, for all of the major water resource regions, although there may well be smaller areas for which the suggested steps would prove inadequate to maintain the growth of the existing economic structure. For such cases, it is probably worthwhile to give thought to what changes in economic structure might best exploit the natural advantages of the area.

The final step in this analysis will be to state what is known -- or rather, what is not known about the short and long term costs of failing to satisfy the demands for water.

New York provides an illustration of an area which has been forced to restrict water use during the drought. There seem to be two extreme schools of thought (both without support of cost analysis) about this situation: (1) that it is unthinkable and unreasonable to have, in an affluent society, a water system which will <u>ever</u> fall short of meeting all demands; (2) that infrequent extreme events like the drought cannot be guarded against with complete certainty and that the best way of coping may simply be an occasional belt-tightening.

To assume that any water system, particularly systems depending on surface storage, can guarantee meeting all demands with a probability equal to one at a cost anyone would be willing to pay is indeed naive.

The amount which should be invested in increasing the probability of meeting all demands depends upon the costs associated with having to restrict water use. The latter element is simply not known, and, in the absence of that information, both of the above approaches represent naive opinions. The costs imposed on New York by water restrictions have not been compiled, so we cannot tell to what extent the observed shortfall of supply really represents a problem of crisis proportion. If, as one eminent authority feels, the costs have been insifnificant, then the shortage does not imply crisis at all. The real story can only be uncovered through careful research on the problem.

The long-term impact of water shortage is also uncertain. Clearly, agriculture in arid areas requires water and without it such activity must contract. But many arid areas have great potential along lines other than agriculture, as demonstrated by the postwar industrial and commercial growth of the Southwest. It is yet to be demonstrated that water availability, within the range of conditions found in the United States, has any measurable effect on industrial location. A study currently underway at RFF indicates that those U. S. counties adjacent to navigable rivers and inland waterways experienced an average 1950-60 decade growth of 8 percent in employment; those adjacent to the Great Lakes expanded their employment 9 percent; costal areas expanded by 28 percent; while the rest of the country averaged 13 percent. Although there are local deviations from these averages, it is clear that water availability per se doesn't guarantee economic growth. (2)

CONCLUSIONS

More rational pricing of our water resources and more efficient use, combined with a fuller exploitation of existing technological alternatives on the supply side can preclude any water crisis in the forseeable future. Effective application of these steps will require revisions in our traditional thinking, from the acceptance of reclaimed water for drinking to a fresh look at the best ways of promoting the continuing economic growth of arid areas.

Public education and the production of larger numbers of broadly educated water managers are needed. Extensive research is needed not only on the technological aspects of water systems, but on the regional economic and social impact of alternative pricing and administrative controls over water. We must study carefully the implications of new legislation relating to water, such as "basins or counties of origin protective statutes" which, while aimed at securing equity, may unduely shackle our use of water resources. Legal ingenuity and creativity must be combined with careful economic analysis to facilitate transfers of water from one use to another when called for by large differences in the value of product or service produced, full account being taken of secondary impacts and the necessity of adequate compensation being paid.

It is in these areas that institutions like New Mexico State, with its Water Resources Institute, can make great contributions both to the regional and national well being. With their continuing contributions to our knowledge of water-related technology, sociology, and economics, and through the establishment and effective use of new institutions such as the River Basin Commissions provided in the Water Resources Act of 1965, we can successfully meet any challenges facing us.

REFERENCES

1. See Noel A. Clark, "The Western States Have Water Supply Problems, Too," Water and Wastes Engineering, 1966, 3, 2.

2. Bower, Blair T., "The Location Decision of Industry and Its Relationship to Water," paper given at the Conference of the Committee on the Economics of Water Resources Development, San Francisco, December 10, 1964. (Another research project on the topic is currently underway at TVA.)