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The report is based on a review of both published and unpublished conservation literature providing an annotated description of each, including reference.

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PREFACE AND ACKNOWLEDGEMENTS

Recent interest in the role of conservation in water supply planning has resulted in an urgent need for information on a wide range of issues concerning water conservation planning. The work documented in this report was conceived and planned in response to the need by the U.S. Army Engineer Institute for Water Resources (IWR) in the Spring of 1978.

This effort represents a survey of the currently available literature on water conservation measures. Information was sought from published and unpublished sources including governmental manuals, pamphlets, research reports, masters thesis, doctoral dissertations and conference proceedings--approximately 750 items were reviewed. The studies reported in this volume were selected as being representative of the major problems involved in evaluating water conservation: the technical effectiveness of available conservation measures, the evaluation of economic efficiency, and the question of social acceptability. For each source in this volume an effort was made to describe the objective(s), to report the methodology, and to summarize and critically appraise the salient findings. A word of caution is warranted. Because of this growing concern in water conservation the need for periodic revision of this annotated bibliography will become increasingly evident.

A.J. Fredrich, Director of IWR and Donald Duncan, Senior Policy specialist from the Office, Chief of Engineers provided the initial impetus for this project.

Special graditude is expressed for the eager and willing assistance of Kyle Schilling, the IWR project manager for this effort, in procuring many of the avilable but not widely known reports on water conservation. The following persons contributed significantly in the preparation of this report: Kurt Alley, John Boland, Philip Carver, Bonnie Kranzer, and John H. Sims.

DUANE D. BAUMANN
President
Planning & Management Consultants, Ltd.

Abbott, H. E., K. G. Cook, and R. B. Sleight. "Social Aspects of Urban Water Conservation." Century Research Corporation. Prepared for the Office of Water Resources Research. August 1972.

This report presents the results of a survey of the managers and the customers of 17 Eastern United States water utilities that imposed short-term water use restrictions. Almost all communities imposed the restrictions on uses of water outside and appealed for less use inside the house. The survey of customers revealed that most agreed that outside uses are least essential (only 5 to 12% of the respondents rated stoppage of various outside uses to involve "much" inconvenience compared to 41 to 54% for various inside uses). Cooperation was excellent and continued even after the emergency ended. These measures achieved from 18% to 50% reduction in water use with voluntary measures being as effective as compulsory. The report recommends voluntary measures be tried first. Most consumer respondents (80%) do not want restrictions in normal times. But half of the respondents were not willing to pay 10% more for their water to insure adequate supplies. In drought areas 75% of the respondents preferred metered to flat rates. There was strong objection (92% of the respondents) to dyeing or giving the water an unpleasant taste as a warning to consumers to save water. Estimates by respondents of the amount of water used for various purposes were wildly inaccurate, indicating that instruction from public officials on in-house water reduction should be very specific rather than call for percent reductions or for limits to a specific number of gallons per person or household. The report concludes: (1) People of the Eastern United States are quite ignorant of their water use and supplies. Most people are willing to save water in emergencies but don't know how. A continuing educational campaign by the utilities to correct this

situation is needed. (2) Emergency restriction plans should be prepared in advance (examples are given). Most respondents preferred that the declaration of emergency come from the water official (60%) than another city official (23%). But the report notes that the water official may be too busy to make a public announcement. One of the most important aspects of an emergency plan is to have all information funneled through one office to avoid confusion. Most often lacking were official announcements of the end of the emergency.

"How Cities Lose Water." The American City. November 1974. p. 98 (byline Boston Conference American Water Works Association)

Charles W. Keller is quoted as stating that if 10% of the water produced is lost or unaccounted for, the system can be rated as excellent and a loss of 20% is considered reasonable. Inaccurate water metering of input can account for a large percentage lost. In one city (unnamed), a 37% loss was reduced to 17% loss by correcting the meter measuring input. "A 1965 survey of 476 cities calculated water losses by state.... The ranking showed Wyoming with the lowest loss (1.85%) and Louisiana with the highest (27.93%)."

"Why Metering Makes Sense." The American City. April 1972. pp. 72-73.

This article describes an experience of several water utilities which changed from flat rates to commodity (metered) charges. Kingston, New York reported a 27% drop in average use (5.45 mgd 1957 to 4.0 mgd in 1960-1963) as a result of the program of universal metering. Peak demand also dropped 46% (8.0 in 1957 to 4.33 in 1962, both dry years). This reduction has continued (up to 1969). The article also discusses (and rejects) the arguments that might be used against metering. A good cartoon and sample rates are also included.

"AWWA Policy Statement on the Use of Reclaimed Wastewaters as a Water Supply Source." Journal of the American Water Works Association 63. (October 1971):609.

States that current knowledge is "not advanced sufficiently to permit direct use of treated wastewaters as a source of public water supply." However, "the Association encourages the use of reclaimed wastewaters for beneficial purposes such as industrial cooling and processing, irrigation of crops, recreation, and (within the limits of historical practice), groundwater recharge." Further research on direct reuse is urged.

Anderson, Raymond W. "Pawtucket, Rhode Island and the Drought." Journal of New England Water Works Association 81 (1967):301-303.

The City of Pawtucket Water System supplies 130,000 people--an average consumption of 17.5 mgd in 1965. During the summer of 1964 and 1965, the average consumption for the month with the greatest demand averaged just below 20 mgd with the maximum day equal to 26 mgd. During drought conditions in 1966, meetings were held with the mayor, the Water Conservation Committee, Chamber of Commerce and all businesses and industries to formulate plans for water conservation. Voluntary conservation helped but during the summer more drastic measures were needed. Two ordinances were passed: an emergency ordinance banning all use of water for watering lawns, car washing and any unnecessary use when the supply in the two reservoirs dropped below 50%; an ordinance permanently forbidding the use of water for air-conditioning without the use of cooling towers or other reclaiming methods.

When both of these ordinances were put in force, the saving was around 100 mg per month over a similar month in 1965. (3.3 mgd). (16 to 18% of expected demand for that month.)

Andrews, R. A., and M. R. Hammond. "Characteristics of Household Water Consumption in Three New Hampshire Communities." Durham, New Hampshire: Water Resources Research Center, University of New Hampshire, December 1970. Research Report #3.

This report outlines the results of a study of 361 households in Durham, Epping and Portsmouth, NH. Billing records and interviews were used to

obtain data on water use and household characteristics. Average daily per capita water use was 42, 52, and 59 gpcd for these cities with standard deviations of 22, 26, and 22 gpcd, respectively. Among the findings is that lawn watering is not a major household use of water in this area. The use of septic systems as opposed to sewers did not influence water use. Water use was found to be significantly related to the number of persons. Price was not examined as an explanatory variable.

Angeliedes, Steven P. and Eugene Bardach. "Water Banking by Local Districts Would Increase Flexibility and Reduce Waste. Discussion Paper. Berkeley: Graduate School of Public Policy, University of California, 1977. DRAFT

This paper outlines the present system of water allocation in California, discusses the waste and inflexibility involved in this system and examines

changes in the law to remove these problems. The conclusions of the paper are: (1) A free market system although fine in theory, will be hindered by institutions now in place. Realistically these institutions cannot be eliminated. The transactions cost of a free market water transfer system are not necessarily smaller. (2) An administered market system is a more incremental change from the present institutional structure. However, it does not deal adequately with the risk of losing the water right faced by the potential transferor who must initiate the transaction. Both administered and free market systems will not work well with district supplied water which accounts for the vast majority of surface supplied water in California. (3) Water banking as practiced on the state level in 1976-1977 would work well at the district level. This system should be adopted at the present time. The administered market system, unlike the free market system, is not inconsistent with local water banking but should be adopted at a later time to avoid confusion with the more important concept of water banking.

Bailey, J. R., R. J. Benoit, J. L. Dodson, J. M. Robb, and H. Wallman. "A Study of Flow Reduction and Treatment of Waste Water from Households." For the Federal Water Quality Adm., Program #11050 FKE, Contract #14-12-428. Groton, CT: General Dynamics, Electric Boat Division, December 1969. (Summarized in Water and Sewage Works 85:57-66.)

This report examines potential means of waste flow reduction. The information used in this study is gathered from an extensive literature survey and from manufacturers of reduction devices. Using this information it is estimated that for a family of four, limited flow control valves for showers

and faucets would save 24 and 2 gal/day respectively and shallow-trap (single family) toilets (3.5 vs. present 5 gal/flush) would save 30 gal/day while vacuum-flush toilets for new multi-family units would save 90 gal/day. Table IX presents costs for these and a number of other devices (both new and old construction costs). The study found that these devices and lower-use clothes washers with suds-savers, are economically justifiable for new homes with flow control devices justifiable for installation in existing houses (faucet devices only marginally so). Reuse of wash water for toilet flushing was found to be economic for new houses in areas of fair to poor soil drainage (when septic tanks are used). All other systems to reduce use or to treat wastewater on site were judged uneconomic.

A survey of the acceptability of various devices was made of plumbers, architect-engineers, equipment manufacturers and houseowners. Of note is that 82 and 86 per cent of the homeowners and architect-engineers indicated acceptance of the use of wash water for toilet flushing. Little opposition to flow-reduction devices was also found.

Baumann, Duane D. and Daniel M. Dworkin, editors. Water Reuse Practices Prospects and Problems. A report on the Proceeding of a seminar held in Indianapolis, July 20-25, 1975, U.S. Army Engineer Institute for Water Resources. Contract Nos. DACW31-75-M-1344 and DACW31-75-C-0199. January 1975.

This report presents ten papers on the subject of water reuse. Included are papers on (1) "Planning for Reuse," by the editors; (2) "Water Reuse in

the U.S. Army Corps of Engineers Urban Studies and Wastewater Management Program: An Overview" by James F. Johnson; (3) "The U.S. E.P.A. and Water Reuse, " by Paul Durand; (4) "Status of Wastewater Reuse in South Africa," by L. R. J. Van Vuuren; (5) "Selected Health Aspects of Reclaimed Wastewater in South Africa," by W. H. J. Hattingh; (6) "Economic Consideration in the Reuse of Urban Wastewater," by Jerome W. Milliman; (7) "Determinants of Professional and Public Response to Renovated Wastewater," by John H. Sims; (8) "Opportunities and Constraints in the Reuse of Wastewater," (with reference to the Chicago area), by Donald E. Natchske; (9) "Water Reuse in Agriculture, Industry and Recreation," (with reference to the Lubbock, Texas area) by James E. Bertram; and (10) "Planning for Water Reuse in Denver, Colorado," by Richard Heaton.

Baumann, Duane D., Daniel Dworkin, Scott Sebastian, Barbara Andrews and David Holtz. Planning Alternatives for Municipal Water Systems. Indianapolis: Butler University, Holcomb Research Institute. 1976.

The purpose of this book was to present issues involved in the management of municipal water systems. Topics covered included projections of demand and water supply, the balancing of supply and demand and the acceptance by the public and professional sectors of different alternatives. The book is concise, and presents a valuable summary of current and future planning alternatives for municipal water systems.

Beatty, K. M. and J. C. Pierce. "Representation and Public Involvement in Water Resource Politics: A Comparison of Six Participant Types." Water Resources Bulletin 12 (No. 5, October 1976):1005-1018.

The purpose of this article is to explore the question of whether water politics participants are in fact unrepresentative of the general public and, by distinguishing among several types of participants, to compare responsiveness levels of alternative participant groups. A ten-page questionnaire focusing on water resource policy was mailed to 1127 potential respondents. Six hundred and eighty-seven questionnaires were returned at least partially completed. The sample selection is not discussed. It is believed that there may be a systematic sample bias toward involvement in water resource policy because that was the thrust of the questionnaire.

The questionnaire obtained the following: (1) Information concerning the amount of participation in water resource policy planning by the respondent. (2) Types of planning activities participants had been involved in (six categories were derived). (3) Background variables such as age, occupation, income, and various uses of water. (4) The respondent's level of satisfaction with current water resource policy. (5) A preference ranking for seven alternative uses of water (such as agriculture, industry, recreation).

The assumption of the paper is that the representativeness of water resource policy turns on two linkages: First, how similar the general public and the participating public are in certain relevant ways and, second, how responsive policy makers are to the participating public. This paper, while realizing the importance of the second, focuses only on the first linkage.

Citizen advisory committees are the participation groups which are least representative of the general public in background characteristics. They

tend to be better educated, have higher incomes, are waterfront property owners, and heavy water users. The participation group most similar to the general public are those who sign petitions. Participants in water resource policy, regardless of the nature of this participation, tend to be more dissatisfied with water resource policy than does the general public.

A rather high degree of representativeness between all participants and non-participants was exhibited concerning the preference ranking of alternative water uses. The authors caution that this does not necessarily imply that the same agreement would exist regarding how these alternative uses should be achieved.

Bennett, J. W. "Anthropological Contributions to Water Resources Management." In Man and Water, pp. 34-81. Edited by L. D. James. Lexington, Ky: University Press of Kentucky, 1974.

In the general use category, this study is international in geographical location with emphasis on developing nations. The purpose of the study is to demonstrate the importance of anthropological considerations in water resource planning.

Two basic points are made. First, there is a correlation historically between water controls and sociopolitical organization. Thus, by examining the management of water historically, present phenomena pertaining to water management can be better understood. Second, when Western water resource planners assist developing nations, careful consideration should be given to the climate, kinship system, religious beliefs, etc. of the developing nation and the impact various water policies would have on important institutions.

Berger, B. B. "Public Health Aspects of Water Reuse for Potable Supply." Journal of the American Water Works Association 52 (May 1960):599-606.

This article reviews the biological and chemical compatibility of secondary treated effluent for reuse in municipal supply. The article concludes "A combination of current sewage and water treatment processes should, therefore not be considered adequate to convert sewage to safe drinking water." Among the areas reviewed are physical quality (appearance), the pathogenic aspects of bacteria, fungi, viruses, protozoa, and worms, and both organic and inorganic chemicals. In most cases the article notes very little is known of: (1) what is contained in treated sewage effluent and; (2) how these are removed by water treatment and; (3) what effects they might have on human health.

Berry, D. W., and G. W. Bonem. "Predicting the Municipal Demand for Water." Water Resources Research 10 (December 1974):1239-1342.

This article presents the results of a cross-sectional regression on average percapita use derived from New Mexico municipal pumpage data (gross). Percapita income was found to be a good predictor of percapita use. "Price and climatological variables were not significant in the regression, perhaps as a result of insufficiently precise data."

Bertram, James E. "Water Reuse in Agriculture, Industry and Recreation." In Planning for Water Reuse, pp. 121-126. Edited by Duane D. Baumann and Daniel M. Dworkin. Chicago: Maaroufa Press, Inc. 1978.

This article describes the effluent reuse practices in Lubbock, Texas. The wastewater has become a resource as it is being used in crop irrigation, as cooling water for the Southwestern Public Service Company, and is planned to be used in a series of lakes known as the Canyon Lakes Project. The innovative approach by the City of Lubbock is one to be monitored and results of its projects will be of utmost value in water conservation research.

Blackburn, Anne M. "Management Strategies Dealing with Drought." Journal of the American Water Works Association 70 (February 1978):51-59.

This article reviews the steps taken by the Thames Water Authority to deal with the 1976 drought in the United Kingdom. "A major regional publicity campaign on water conservation (during the drought) brought a voluntary reduction in use of 20 percent." "A pressure reduction of 25 percent throughout the (London) metropolitan water-supply distribution system was also introduced; it produced 10 percent water saving." Later all outside uses of water were banned. Sewage effluent from London was made available to grass race-course owners at no cost, but they had to pay for its transportation and spreading from tank trucks. Seventeen hour-cutoffs (per day) were imposed on Southern

Wales to achieve up to 50 percent total reductions.

One problem with these statistics, particularly the effect of pressure reduction, is the necessary guess-work involved in separating out the effect of different measures.

Bogue, Stuart H. "Trends in Water Use." Journal of the American Water Works Association 55 (1963):548-554.

The author identifies the following as water use factors: 1) size and type of community -- the larger the community the narrower the range in fluctuation of demand. Fluctuation is smaller in an industrial community than in a residential community; 2) standard of living -- as it increases so does demand and variation; 3) location of community; 4) water quality; 5) pressure; 6) sewers -- water use increases when sewers are installed; 7) metering; 8) age of community; 9) lawn sprinkling; 10) cost; 11) air conditioning. There is a correlation between family income and residential use and between home values and water used.

This article seems like a relatively naive summary of the above -- uses generalized data from Detroit Cities (area) to support the above facts and does not provide any new insights. The author also claims "there is no need to worry about the availability of water if the citizens are willing to pay the price either to import it from adjacent or distant water-rich areas, or, if feasible, to construct facilities to convert unfit waters into potable supplies." (p. 554) The author cites only two general references -- with no reference to technical reports.

Bohae, Charles E., and Raymond A. Sierka. "Effect of Water Conservation on Activated Sludge Kinetics." Journal of Water Pollution Control 50 (No. 10, 1978):2313-2326.

The authors review the literature concerned with the effectiveness and implimentation of water conservation programs, and note that the widespread application of such programs would result in marked increases in the substrate concentrations reaching activated sludge wastewater treatment processes. While reductions in wastewater flows can be expected generally to reduce the cost of wastewater collection and disposal systems, the impact on the design parameters and cost of activated sludge unit processes is not so obvious. The authors first construct a mathematical model of an activated sludge process, where influent volume and substrate concentration can be varied to simulate the impact of a water conservation program. Bench scale experiments conducted with a synthetic sewage material are then used to evaluate the coefficients of the mathematical model, and to test various hypotheses concerning the results. It is concluded that changes in substrate removal efficiencies resulting from increases in influent substrate concentrations (water conservation) range from zero to a few percent. Effluent BOD and COD concentrations, therefore, are found to change almost proportionately with influent BOD and COD concentrations. The implementation of water conservation programs, then, may make effluent concentration standards more difficult to meet, although there is no evidence that an activated sludge plant's ability to meet a mass loading discharge requirement will be impaired. Optimal aeration tank volume is found to be essentially unchanged by water conservation, reflecting the relatively constant nature of total organic loading. Finally, where reuse of the treated

wastewater is a potential consideration, attention must be given to the effect of water conservation on the salinity of the effluent. A twenty percent reduction in wastewater flow resulting from a water conservation program is found to increase effluent TDS as much as 70 mg/liter.

Boland, John J. "The Micro Approach--Computerized Models for Municipal Water Requirements." In Treatise on Urban Water Systems, pp. 295-316. Edited by Albertson et al. Fort Collins: Colorado State University, 1971.

Projected present per-capita consumption as an estimate of future consumption, although reasonable and moderately successful on the national level, fails the needs of most water suppliers. Their problems are usually intensely local. This research has several objectives -- a review and evaluation of the existing and the possible techniques for stimulating municipal water supply requirements; selection and merging of consistent techniques into a single comprehensive planning tool; and the development of a computer program to minimize the computational burden of the water supply planner. This was accomplished in two phases.

Phase one was the construction of a computer model for estimating urban water supply requirements, as a factor of chosen parameters. Some 200 parameters, including projections comprise the independent variables necessary for estimations in a large urban area. This computer model is the MAIN I system.

Phase two dealt with solutions and applications of forecasting techniques to the MAIN I system. The end result is a large model capable not only of estimating water requirements at given values of the parameters but also of estimating future values of the parameters themselves. This model and technique

are referred to as the MAIN II system.

The MAIN II system estimates water requirements by disaggregating water users into 150 user categories and then uses a variety of mathematical models or other methods to estimate water requirements separately for each category. One of the benefits of MAIN II is that it should facilitate examination of the local trends pertinent to the planning of a given supplier.

MAIN I was tested on the city of Baltimore, Maryland as well as Park Forest, Illinois and Baton Rouge, Louisiana with remarkably good results. MAIN II has subsequently been used to prepare forecasts for Baltimore, Maryland and several metropolitan areas in Louisiana.

Boland, John J. "Forecasting the Demand for Urban Water." In Municipal Water Systems, pp. 91-114. Edited by D. Holtz and S. Sebastian. Bloomington: Indiana University Press, 1978.

This paper is a state-of-the-art summary of forecasting topics. Generally, it concerns itself with long-range forecasting in urban areas. The topics covered range from traditional techniques and approaches to forecasting to studies currently in progress; from entirely general to highly specific methodologies.

Basic forecasting is classified (following Herrington 1976) into four categories: judgment methods, survey methods, extrapolations, and analytical methods. Discussions of each method including not only the strengths but the short-comings and drawbacks are given.

The paper then proceeds to consideration of several of the improved modern techniques. The MAIN II system as developed by Hittman Associates and the probabilistic approach of Whitford are each given relatively detailed treatment.

Next is presented a criterion for selecting an appropriate forecasting

method from all those available. This part of the paper is wholly theoretical. Basically it focuses attention on quantifying the results of an inaccurate forecast, associating a cost measure with error and choosing a technique which strikes the best balance between the two possible errors: overestimation and underestimation.

The concluding sections of the paper summarize work done for the Washington Suburban Sanitary Commission. These sections are relatively detailed and focus attention on the seasonal variation not only of demand but of supply, as well as the usual problems of forecasting.

Boland, John J. and C. W. Mallory. "A Systems Study of Storm Runoff Problems in a New Town." Water Resources Bulletin 6 (No. 6, 1970):980-989.

This is the report on a systems study of the use of a large number of small impounding reservoirs located throughout an urban community. The primary objective is to control storm water for water quality purposes. The study also examines treatment of the water at these reservoirs for later release for potable or subpotable uses in the community.

The study site was a watershed of some 1140 acres in the first community of the fully-planned city of Columbia, Maryland. This watershed is the drainage basin of the artificial Wilde Lake. The objectives of the study are: 1) to maintain the quality of the lake; 2) to obtain a system which could be built in the open spaces available; 3) to determine the potential use of the treated water; and 4) to determine the performance and costs of this land storage, treatment and reuse concept in comparison to other alternatives.

Having selected a design basin for the reservoirs, a system model is developed and used to evaluate the various combinations available. This model

precludes a table of net benefits for all possible combinations of storage and treatment facility locations and the various quality levels of reuse water.

Since storm water pollution control was not practiced in the area at the time of the study there were no precedents on cost data with which these ideas could be compared. Thus an engineering firm was engaged to design a system of pollution control for Lake Wilde. Costs were then compared. The quality of the treated water was comparable but not so high as that attained by the local storage system. The economic comparison of the two alternatives are given in tabular form. They consistently favor the local reservoirs.

Bollman, Frank H., and Melinda A. Merritt. "Community Response and Change in Residential Water Use to Conservation and Rationing Measures: A Case Study -- Marin Municipal Water District." Presented at the fall conference of the AWWA, San Jose, CA, October 10, 1977.

This paper presents the preliminary results of a survey of a random sample of 1,000 households in the Marin Municipal Water District as of March 17, 1977. The report presents some interesting statistics on water use. The 1976 ban on outside water use achieved a 25% reduction in water use. The rationing plan that replaced the ban achieved a total reduction of close to 63% (as of July, 1977). The rationing plan included a $10.00/cu.ft. fine for water use from 46 to 92 gal/cap/day and a $50.000/cu.ft. fine for use beyond 92 gal/cap/day. Eighty percent of the respondents rated the 46 gal/cap/day consumption level as moderately inconvenient or not convenient (as opposed to extremely inconvenient or cause of great hardshop). Eighty-eight percent gave a level of 100 gal/cap/day or less as the amount of water that they could "conveniently live with in future years when a shortage no longer existed" compared to an average pre-drought

level of 125 gal/cap/day. Also included are factor analyses of income and temperature effects. The authors imply that further studies of this and other data are forthcoming.

Bonem, G. W. "On the Marginal Cost Pricing of Municipal Water." Water Resources Research 4 (February 1968): 191-193.

This commentary discusses the implications of "third party" benefits from the improvement of community appearance through the use of water to maintain yards and gardens. Such "spillover" effects indicate that price should be set below the marginal production cost of the water. Negative spillover effects from the construction of water supply facilities are not discussed.

Boone, Sheldon. Irrigation Use and Management - June, 1978 Review Draft. Denver: Soil Conservation Service, Cooperative Irrigation Study. 1978.

The author is Chairman of the Technical Work Group for the Interagency Task Force on Irrigation Efficiencies for Colorado. This report presents the results of an interagency task force organized both to examine irrigation water use efficiency and to make policy recommendations. The results of a Soil Conservation Study on the cost of improving irrigation efficiency are presented. It is estimated that a one-time expenditure of $14.6 billion ($6.2 billion off-farm and $8.4 billion on-farm) and an annual expenditure of $0.14 billion could reduce gross diversions of 38.6 million acre-feet and net depletions (consumptive use) by 3.3 million acre-feet. Benefits from such a program are roughly estimated to be $2.4 billion per year. No estimate is made of the length of duration of these benefits. The report notes that in many cases the environmental effects of water conservation may be detrimental to wildlife dependent on "wasted" water. Not all of these changes can be attributed

to an accelerated Federal conservation program as some are expected to occur over the next 25 years in any case. The report presents a thorough discussion on irrigated agriculture both in the Eastern and Western U.S. and the Federal programs that are related to it. In the more limited discussions on institutional and implementation aspects it is noted that although the beneficial use concept is flexible enough for state agencies to implement water conservation, changes in state statutes will be necessary to implement water conservation.

Several possible definitions of water conservation are offered by the report. Those rejected are: (1) storage of excess runoff; (2) reallocation to other "important" uses and; (3) keeping a rain drop on the land where it falls to reduce erosion and to replenish soil moisture, ground water, and streamflow. The definition accepted by the report is "Water conservation means the wise use of water for all purposes in such a way that its value to society is maximized."

Bower, Blair T. "The Economics of Industrial Water Utilization." In Water Research, pp. 143-173. Edited by Allen V. Kneese and Stephen C. Smith. Baltimore: Johns Hopkins University Press, 1966.

This paper presents a very good general discussion of the issues associated with reducing water use by industry. It is noted that past projections of industrial water "needs" have ignored (1) substitution possibilities among components of industrial water utilization systems; (2) the relationship of water to other factor inputs; and (3) the impact of technological changes. In example, the paper notes that from 1954 to 1959 pulp and paper production increased 26% while the intake of water increased by only 8.5%. Similarly, from 1949 to 1959 refinery capacity for 104 petroleum refineries increased by 51%

while fresh water intake increased by only 5%

At the time of the paper (1966), water utilization costs presented only 0.1% to 3% of total industrial production costs. Of these costs, waste treatment and disposal costs dominate water costs by a ratio of from 3:1 to 6:1.

Major factors affecting water use are given as: (1) technology of the production process and final production quality requirements; (2) the quality of raw product inputs; (3) effluent controls; and (4) the cost of intake water. Many examples are cited.

Listed as possible methods of affecting industrial water use are: imposition of effluent charges or standards; significantly increasing the cost of intake water; and fixed physical limitations on the intake water supply and/or permitted discharge. The use of a "water utilization charge" is endorsed. The total amount of this charge would be based on: (1) the quantity of water intake; (2) the consumptive use of water; and (3) the waste load in the effluent. Forty-three references are cited.

Brewer, M. F. "Economics of Public Water Pricing: The California Case." In Economics and Public Policy in Water Resources Development, pp. 222-247. Edited by S. C. Smith and E. N. Castle. Ames: Iowa State University Press, 1964.

This paper discusses five possible pricing systems that could be used by regional agencies for transfering Feather River water to local retailing groups. The systems discussed are: (1) postal pricing; (2) differentiation by types of water use; (3) zonal price differentiation; (4) price variations over time; and (5) benefit pricing. These alternatives are compared on the basis of

economic efficiency, solvency for the California Water Plan and prevention of "unjust enrichment."

Brewer, Robert and Patrick H. McAuley. "An Analysis of Price/Cost Sensitivity of Water Use in Selected Manufacturing Industries." U.S. Department of Commerce: Bureau of Domestic Commerce Staff Study, June 1976.

This report describes a study of the effects of an intake water price (tax) on the amount of intake for non-contact cooling, cotton textile finishing-processing, kraft papermaking and steelmaking. The analysis in each case is conducted on a hypothetical plant that already meets the P.L. 92-500 requirement of Best Available Treatment Economically Achievable (BAT). The findings are that,with the exception of textile finishing, only very high prices of water would make reduction in intake water economical for the optimally designed plant. For the 35,000 lb/day textile mill, a price of $0.28/1000 gal. brings reduction of intake water from the BAT level of 0.57 mgd. to 0.30 mgd while a $1.32/1000 gal reduces water intake to 0.19 mgd. For a draft paper producing 1000 T/day of unbleached linear board a price of $0.75/1000 gal is needed to reduce water intake from the BAT level of 5.6 mgd to 2.1 mg. Non-contact cooling and steelmaking will not reduce intake water amounts below the BAT level as long as prices are below $1.30/1000 gal and $0.95/1000 gal respectively.

Brigham, Arthur P. "Public Education Campaigns to Cut Water Use (Waste Reduction)." Proceedings, Conference of the American Water Works Association, June 8-13, 1975, Minneapolis, Minnesota. Paper No. 8-3a.

The five-year effort of the Washington Suburban Sanitary Commission, serving a suburban area of Washington, D.C., to cut unnecessary water use is described. A handbook of water-saving and waste reduction ideas was distributed to 370,000 water users, water-saving workshops were held, slide-speaker programs were made available to civic organizations, product data on water-saving appliances were made available, and television and radio spot announcements were employed. Later steps included changes in the plumbing code to require water-saving plumbing fixtures in new or remodeled dwellings, and the distribution of toilet leak detector kits, plastic bottles for reducing flush volumes, and shower head flow reducers. Implementation of these practices and devices is claimed to have been influential in marked (6 to 17 percent) reductions in total water use during late 1973 and 1974, as compared to the same month in the previous year. No investigation of alternate or coincident causes (e.g., weather changes) is reported.

Brigham, Arthur P. "Effective Use of Communications Tools to Manage Water Demands and Wastewater Loads." Paper presented October 1976 at Conference on "Planning Alternatives for Municipal Water Systems."

The author's purpose is to describe and discuss an effective water conservation campaign in Washington, D.C. by the WSSC. The study, basically descriptive in nature concludes that "More and more public service organizations

are realizing they cannot really depend on the newspapers and the broadcasters to reach their customers with the complete truth . . . the positive side of their story." (p. 5) There are five important pressure points that are the "prime targets of today's water utility communications effort." (p. 7) They are: (1) rates which must be simply communicated and must be explained; (2) political and civic relationships; (3) customer service/education; (4) employee relationships; and (5) special projects. The study describes aspects of the water saving campaign: (1) water saving idea contest; (2) water savings and waste reduction handbook; and (3) news features. A study was made of 2,400 customer units for 6 months and was coordinated by the WSSC's public affairs office and field project engineer. "The project generally proved the water-saving effectiveness of shower flow controls, pressure-reducing valves and toilet insert devices and gave the WSSC a platform for recommending the use of these conservation devices to its customers." (p. 15) Plumbing code changes, bumper sticker, bottle kits were also mentioned. Analysis of the program's impact indicated that: (1) during the first stages of the program excluding the Bottle Kit period per capita use dropped 101.6 gal/day to 100.2. With a net savings of 117 million gpd. (2) After Bottle Kit was introduced, use dropped to 97.0 gpd with a net savings of 5.4 million gpd. This also brought about a reduction in the wastewater flow. A range of 6.1 to 17.2% decrease from months from 1972-1973 is shown. A breakdown of residents versus industry not shown and definition of customer unit is unclear, making it difficult to see exactly where the savings were. A shower control device campaign is now underway with over 300,000 distributed.

The study's statistics are extremely gross and vague and limit its usefulness. It does show a reduction in demand, however, as a result of education campaigns.

Brigham, A. P. "A Public Education Campaign to Conserve Water." Journal of the American Water Works Association 68(No. 12, 1976):665-668.

The author describes a comprehensive community water conservation program and demonstrates its effectiveness in a residential suburban Washington, D.C. area.

The projects which were included in the campaign to increase public awareness of the need for water conservation are:

(1) flyers;

(2) water-saving idea contests;

(3) workshops for property managers;

(4) speaker programs;

(5) assembly of data on water-saving appliances;

(6) T.V. and radio spot announcements; and

(7) production and distribution of home toilet leak-check kits.

Results showed a 4.42% reduction from the anticipated water use and a substantial drop in sewage flow. The article demonstrates that it is possible to mount an effective conservation campaign in a large metropolitan area.

Bruner, J. M. An Analysis of Municipal Water Demand in the Phoenix Metropolitan Area. 1969.

This dissertation includes a general discussion of municipal water with special reference to the Phoenix area along with statistical examinations of the temporal variations in water use, and several regressions explaining the effect of explanatory variables on municipal water use. Price, value of the residence and evapotranspiration were found to significantly (.05 level) affect water use.

From a time-series regression on residential billing records for Buckeye, Arizona, price elasticity estimate of -0.8 was obtained. There is reason to suspect that this estimate is too high since the new desalinization plant that caused the price rise also reduced the corrosiveness of the water allowing for the installation of recycling for evaporation coolers.

From cross-sectional studies, a price elasticity estimate of -0.27 was obtained based on a log-linear functional form. The data for this estimate consisted of samples of 20 residences each from six towns. One possible difficulty with both regression estimates is that sewer charges are not included. In many areas these charges are based on water use.

Bruvold, W. H. and H. J. Ongerth. "Public Use and Evaluation of Reclaimed Water." Journal of the American Water Works Association 66 (No. 5, 1974):294-296.

The authors' purpose is to develop insight into what the public currently thinks of various uses of recycled water. Five California communities were selected in which recycled water was being used. Five control communities were selected which resembled the "project" communities in size, location, and type of dwelling unit. A cluster sampling technique led to the selection of approximately 100 subjects in each of the ten communities. Of the 1050 originally contacted by mail, 972 participated. An hour long field interview was conducted. The major attitudinal portion of the interview consisted of 25 selected uses of recycled water. Each respondent indicated opposition or non-opposition toward each possible use in the local community. Not surprisingly, opposition to the use of recycled water rose as the use in question entailed closer personal contact. There were no significant differences in opposition between "project" and control communities. Additionally, attitudes in the five "project" communities were assessed regarding the actual recycling project in their particular community. Most responses were indifferent - indicating at least that little community polarization had developed over the recycling project.

Bruvold, William H. "Consumer Response to Urban Drought in Central California." NSF Grant # ENV77-16171 (Copies available from author at School of Public Health, University of California at Berkeley.)

The author seeks to assess consumer attitudes toward residential water conservation programs (mild, moderate and vigorous) adopted by San Francisco Bay Area districts, to evaluate the effectiveness of the water conservation programs mounted and to explore relationships between conservation behaviors and beliefs about the seriousness of drought and the necessity for continuing conservation efforts.

For the study, nine water service agencies were chosen according to stringency of the conservation programs mounted (three each of mild, moderate, and rigorous). Five census tracts were randomly selected for each study site; in turn 25 census blocks were selected randomly from those making up the tracts. Four respondents, 2 males, 2 females, 1 of each pair from 18 to 35 years, the other over 35, were chosen from each block. The total sample was approximately 900.

The data show clearly that rigorous and moderate conservation programs can be established which are very effective (in the cases examined the stated objectives were exceeded), and which are also judged to be fair and equitable by the regulated consumers. Further, and more specifically, the data show: (1) There is a certain threshhold of seriousness that the proposed conservation program must cross if it is to be effective; thus, rigorous programs are more effective in reaching their greater goals than mild ones are in reaching theirs. (2) The public feels that conservation programs should be <u>mandatory</u>, not voluntary. (3) The public wants any such program <u>enforced</u>, and strictly so.

(4) Allotments should be made on a per capita basis, not on previous use.

Two beliefs, perceived seriousness of the drought and need to continue conservation, were better predictors of conservation behaviors than were either education or income.

The study is an excellent one, although the interpretation is psychologically naive.

Bruvold, W. H. "Affective Response Toward Uses of Reclaimed Water." Journal of Applied Psychology 55 (No. 1, 1971):28-33.

The author discusses urban residential use of reclaimed water in the San Francisco area and San Diego area. His purpose is to develop scales assessing public reaction to various suggested uses of reclaimed wastewater.

Three 26-item scales, each consisting of descriptive statements regarding a particular use of reclaimed wastewater (drinking, swimming, laundry) were devised and ranked according to favorableness of each statement. These scales were then administered to 25 respondents in a San Diego suburb which had a history of water shortage and which had used reclaimed wastewater in the past. These scales were also administered to 25 respondents in a San Francisco suburb where there was neither a history of water shortage nor use of reclaimed water. Respondents were asked to check the items on the three scales which were closest to their own. The same scales were then administered to the same respondents two months later.

The test-retest reliability coefficients indicate that individual scores obtained from the two administrations were reasonably stable. The authors

try to establish construct validity of the scales by demonstrating that, as one would expect, respondents from the arid town with a history of reclaimed water use exhibited more favorable attitudes toward this process than did the respondents from the other town. Construct validity is also indicated by the fact that, as one would expect (if the instrument was valid), favorability of attitudes toward the reuse of water was inversely related to the closeness of personal contact indicated by the three suggested uses.

Given the limited objectives of the paper, it is successful.

Burns, D. R. J., J. R. Gerstle, G. J. Roussos, M. K. Whitaker and B. Wemple. "The Effect of Price on Residential Water Demand - A Comparative Use Study." University of Colorado, Boulder, CO.

This paper presents the results of a comparison of the water use of two Colorado communities: Heatherwood and Table Mesa. Elasticities were calculated by comparing water use for households with estimated house values within specific ranges. This analysis produced price elasticity estimates of -0.20 to -0.38 and -0.27 to -0.53 for in-house water use and sprinkling water use, depending on the house value class. The study also produced estimates of "income" elasticity based on estimated house value. The "income" elasticity estimates for domestic demand were 0.239 and 0.246 for Table Mesa and Heatherwood, respectively, while the estimates for the "income" elasticity for sprinkling demand were 0.31 and 0.257.

There are two possible problems with this study. First, it is difficult to guarantee that the difference in water use between the two towns is not due to some factor other than price. Secondly, since no statistical tests were conducted it is difficult to know what significance to attach to the results.

California Department of Water Resources. An Urban Water Conservation Conference, Proceedings. January 16-17, 1976, Los Angeles.

This document represents the official record of the Urban Water Conservation Conference held in Los Angeles, January 16-17, 1976. It contains the papers presented at the meetings as well as the discussion questions following the presentations. The program was divided into panels which centered on topics concerning the technological advances in urban water conservation, the uses of water outside the home, alternatives to volunteer conservation, pricing and its ramifications, conservation education and a look into the future. Although the conference primarily examines water conservation in California, the applications and scope of many presentations are nationwide. This is an excellent source of data, both general and specific and the broad range of topics discussed make it a valuable source of reference in urban water conservation.

California Department of Water Resources. The California Drought - 1976. May 1976.

This report discusses the effects of the California drought and the measures that were proposed at that time. Areas described include: agriculture (both dry-farming and irrigated), the State Water Project, the Central Valley Project, the Delta Urban areas, recreation, fish and wildlife, forestry, energy, and ground water. Of special interest are the discussions of the early planning of the conjunctive use of ground water and the water exchange with the Metropolitan Water District of Southern California. These measures proved to be very important in dealing with the drought later in 1976 and 1977.

California Department of Water Resources and U.S. Cooperative Extension Services. Agricultural Water Conservation Conference, Proceedings. June 23-24, 1976, University of California, Davis, California.

This publication contains the official recordings of the Agricultural Water Conservation Conference held at the Davis Campus of the University of California, June 23-24, 1976. An overview or perspective on water conservation is presented first, examining areas of opportunities, water quality, energy, environment, economics and policy. Approaches to water conservation are then discussed on topical issues of irrigation methods, irrigation management, water delivery systems, water pricing, and legal and institutional aspects of water conservation. Papers conceived with the implementation of water conservation in the field are then followed by a discussion of water conservation policy.

This is an excellent collection of information pertaining to agricultural water conservation. It covers all realms of the problems encountered and can be used as a specific source of data as well as a general compendium of research on this topic.

California Department of Water Resources. The California Drought 1977 An Update. 1977

This publication summarizes the overall impact in California of the drought in 1976 and adds an update to the status of drought conditions as of February 1977. A review of the weather conditions precipitating the drought is given followed by impact statements of the 1976 drought. Impacts are examined on a statewide basis as well as regional and resource impacts. Water availability in 1977 is also examined. Plans for drought management in 1977 are outlined in economic and managerial terms.

There is little actual water conservation data, as this was not the purpose of this publication. Appendix E contains information bulletins that contain information about technological appliances and their water saving properties.

The report is a concise and comprehensive survey of the drought in California and the prescribed steps needed to alleviate the pressures of the drought.

The California Governor's Drought Emergency Task Force (1978), Drought Alternative Strategies for 1978. January 1978.

This report outlines the effects of the drought on California in 1976 and 1977 and recommends actions which should be taken if the drought continues into 1978. It is anticipated that if the snowpack and rainfall of the 1977-1978 winter are as low as that of 1976-1977, the effects will be worse than in 1977 but not catastrophic. Agriculture had almost as many irrigated acres in production in 1976 and 1977 as before but with different cropping patterns and with ground water depletions averaging 4.2% and 8.4% in each of the years. Higher pumping and well-drilling costs were substantial. Agricultural losses are estimated at $800 million. Continued drought would bring further ground water depletion. Based on the 1976 and 1977 experience, municipal deficits up to 50% are considered manageable. Continued drought would necessitate water hauling (tank truckers) to many small communities but not at unmanageable proportions. Electric brownouts and blackouts can be avoided in 1978 (as they were in 1976 and 1977) but replacement of hydro water with fossil fuels is expensive. The fishes, wildlife and forestry situations have been bad and will be worse and will require special attention. In Northern California, recreation has been displaced to the delta and to Donner and Tahoe. Removal of exposed sags and temporary launch facilities are needed.

California State Department of Water Resources. "Appendix G - Device Testing - A Pilot Water Conservation Program." Bulletin 191, (March 1975).

"This Appendix contains bidding and testing procedures used in selection of water saving devices for use in the AB 380 Pilot Water Conservation Program. It also presents the performance data developed during the testing of the shower and toilet devices. The evaluation and subsequent selection of devices for the program is the subject of Appendix H of the Final Report."

California State Department of Water Resources. Water Conservation in California. Bulletin 198, (May 1976).

This report presents estimates of present water use and of potential use reduction in California from various techniques. Potential reductions include: 1.24 million acre-feet/year (MAFY) by the year 2000 from the universal application of water saving devices in households (current urban use is 5.04 million acre-feet/year) 1.20 million acre-feet/year of withdrawals from agriculture from improved farm management (primarily replacing gravity with sprinklers and drip irrigation and lining of canals and daterals), 0.20 million MAFY from leak detection, 0.20 MAFY from improved use practices for residential sprinkling and for 0.15 to 0.30 MAFY from improved commercial and govermental sprinkling. Except for some discussion of exhortation by the Department of Water Resources and changes in pricing policies there is little discussion of how these reductions might be achieved. There is no discussion at all about transfers of water rights or water banking.

Camp, R. C. "The Inelastic Demand for Residential Water: New Findings." Journal of the American Water Works Association 70 (August 1978):453-458.

This article presents the results of a multiple regression study of the determinants of residential water use. The sample consisted of 228 Mississippi households randomly selected from 10 utilities. Water use was derived from billing data. The price used was from the rate schedule at the mean level of consumption for that city. Data for other explanatory variables were obtained by interview or observation of the house characteristics. Values found to be significant (.05 level) were number of persons, lawn area to irrigate, number of clothes washers, presence of swimming pool, rainfall, price and education. The estimated price elasticity was -0.24 for the linear functional form and -0.31 for the mixed linear-logarithmic form.

Carmichael, J. "Water Recycling in Southern California." In Our Environment: The Outlook for 1980 (Part 1 of Our Environment: Water), pp. 237-255. Edited by A. J. Van Tassel. Lexington, MA: Lexington Books, 1973.

This article describes the present water industry in Southern California in detail and estimates the (average) costs of water obtained from different sources. Reclamation projects in Whittier Narrows, Santee, and Glendale-Los Angeles are examined. It is estimated that water imported from Northern California cost $57/acre-foot in 1972 and will cost $75/acre-foot in 1980 compared to $11/acre-foot for reclaimed water and $197/acre-foot for desalted seawater. The article concludes that water recycling (by ground water recharge) is "economically and practically feasible, and reclamation plants are functioning

in the area (Southern California) at present." It is noted that present and projected reclamation plants are unlikely to have a major impact on water supply. Today reclaimed water accounts for only 0.2% of water use in Southern California.

Carver, P. H. Price as a Water Utility Management Tool Under Stochastic Conditions. Johns Hopkins University, unpublished Ph.D. Dissertation. 1978.

Included in this dissertation are empirical studies of the price responsiveness of municipal water use. The two time-series studies of water use in the Washington D.C. area provide evidence that the short run response to price changes is small (price elasticity around -0.1 or less). Also included is a simulation of the effects of alternative price structures conducted for a run of the river utility which is used to estimate their impacts on economic benefits, system reliability, equity goals and administrative constraints.

The first study uses monthly water production data from 13 utilities over 6 years. Seasonal and nonseasonal uses are considered separately. Long run effects are estimated to be larger for nonseasonal (domestic) use (price elasticity -0.02 to -0.70). The long run seasonal use elasticity was not found to be significantly different from the short run.

The second study of price responsiveness uses 4 years of billing data from the Fairfax County (VA.) Water Authority. During this period an innovative rate structure was introduced. Commercial and residential users responded significantly but apartments did not. The estimated elasticities for seasonal residential use were -0.13 to -0.17 for the first year of the new price structure and -0.02 to -0.04 in the second year. The discrepancy indicates that

consumer understanding of rates may have been a problem.

The simulation results indicate that decreasing block rates offer no advantages. Block rates were inferior to uniform rates with fixed charges (rebate) on all adminstrative considerations. If block rates are employed the point at which rates increases should be set low (5 to 10 thousand gallons per month). Seasonal rates, with low summer prices to account for the low sewer costs of seasonal use, can achieve the highest level of economic benefits of any rate-making policy tested. These benefits are achieved at a considerable sacrifice of system reliability. The innovative rates adopted by the Fairfax County (VA) water authority appear to be inferior to seasonal rates.

Clark, R. M. "Cost and Pricing Relationships in Water Supply." Journal of the Environmental Engineering Division of ASCE, Vol. 102 #332, Proceedings Paper #12025:351-373.

Of interest in this article is a study of the simple correlation between price and per capita water use for 21 sections of a midwestern SMSA (not named). Elasticities in the range of -0.6 are reported depending only slightly on functional form (significantly different from zero .05 level). This methodology fails to incorporate any of the many variables other than price which affect water use. This creates a significant possibility of spurious correlation given the small sample size (21).

Clark, Robert M. and Haynes C. Goddard. "Cost and Quality of Water Supply." Journal of the American Water Works Association 69 (No. 1, January 1977): 13-15.

A statistical analysis of public water supply cost and consumption data for the Cincinnati SMSA is presented. Information was obtained from 22 separate water suppliers within the metropolitan area. The cost of water is shown to be correlated with the population served, the population density, average daily water use, and various characteristics of the source of supply. Water use, in turn, is shown to be correlated with cost.

Cline, Neil M. "The Experience/Evaluation of Water Reuse in Orange County, California." In Planning for Water Reuse, pp. 127-138. Edited by Duane D. Baumann and Daniel M. Dworkin. Chicago: Maaroufa Press, Inc. 1978.

This article summarizes the status of the water supply in Orange County, California and points out the value and efficiency for wastewater reuse. The county anticipates the provision of wastewater reclamation, reuse systems and conservation measures resulting in 30,000 acre feet/year in reclaimed water.

Cohen, Sheldon, and Harold Wallman. Demonstration of Waste Flow Reduction From Households. Groton, CT: General Dynamics, September 1974. U.S. EPA-670/2-74-071, Environmental Protection Technology Series.

This report presents the results of a demonstration project in which domestic water use reduction devices were installed in 8 single family homes. Three of these homes also had systems installed to recycle laundry and bath water for use in toilet flushing and/or lawn watering. The study concludes: (1) Significant reductions in water use can be obtained from the use of available water conservation devices (shallow trap toilets, toilet inserts, flow-reducing valves, etc.) at net cost savings. Broad-based demonstration projects such as the WSSC program should be implemented. (2) The grey water reuse system used proved "manageable and simple to use, and capable of reliable and safe operation...projected economics look marginally favorable for high user charge areas (if water and sewer costs exceed $0.57/1000 gal) and where septic systems are flow-limited." More research is recommended. (3) The extension of the wash water reuse concept to multiple family dwellings should be investigated in order to determine its potential attractiveness for water conservation and waste flow reduction. Reuse on a multiple-dwelling basis should be more economical than for a single-family dwelling.

Actual percentage reductions from the devices tested are presented (Table 1) but the authors admit that these estimates suffer from the very small number of households sampled (3 to 11).

Commission on Natural Resources Ad Hoc Committee on Water Resources. Water Conservation Research. A report to the Office of Water Research and Technology. Washington, D.C.: National Academy of Sciences, October 2, 1978 (Mimeo).

This report begins by reviewing the events or factors which have led to the current administrations emphasis on resource conservation. It then summarizes five consultant's reports which had covered topics such as, agricultural water conservation, domestic water conservation, industrial water conservation, steam-electric power water conservation and incentives and institutions for water conservation and discusses them in light of the goals of the Committee on Water Resources. The report concludes that given the limited funds available, the Committee should stress research concerned with incentives for the adoption of water conservation activities, attitudes and perceptions and on institutions and transfer of technology.

Comptroller General of the United States. More and Better Uses Could be Made of Billions of Gallons of Water by Improving Irrigation Delivery Systems. Report to the Congress of the United States, the United States General Accounting Office, September 2, 1977.

This report underscores the need for a comprehensive and coordinated effort on the part of local, state and federal governments to reduce seepage losses occurring from irrigation conveyance systems. The seepage problem is discussed and a program to reduce these problems is outlined.

Comptroller General of the United States. Municipal and Industrial Water Conservation - The Federal Government Could do More. Report to the Congress of the United States, the United States General Accounting Office, April 3, 1978.

This report justifies the need for a national approach to water conservation in terms of economic costs such as energy cost reductions, construction cost reductions and overall efficiency. Techniques and their effectiveness are outlined. Areas covered are domestic water saving devices, metering, pricing leakage control, water pressure control, educational campaigns and industrial conservation.

Recommendations are made to the Water Resources Council to take the lead in the establishment of an interagency task force of federal and non-federal agencies. This could then act as a general clearing house for water conservation for municipal and industrial water supplies. Further recommendations pertaining to the implementation of water conservation are made to the heads of various federal agencies which are related to water resources development or use.

In terms of water conservation the first section of this report is important as it presents a broad review of various water conservation techniques and their effectiveness.

Crew, M. A. and G. Roberts. "Some Problems of Pricing Under Stochastic Conditions: A Case of Seasonal Pricing for Water Supply." Water Resources Research 6 (October 1970):1272-1276.

This article presents two models of seasonal pricing: a two-period deterministic model and a one-period stochastic model. The first gives rules for investment and pricing for perfectly divisible capacity of:

$$LRMC = \frac{P_1Q_1 + P_2Q_2}{Q_1 + Q_2} \quad \text{and} \quad P_2 - P_1 = \frac{\partial TC(k)}{\partial k}$$

where LRMC is the long run marginal cost

P_1 and Q_1 are the price and quantity in period 1

P_2 and Q_2 are the price and quantity in period 2

TC(k) is the total cost of capacity

and k is the amount of capacity provided.

For the second model the solution is obtained by setting price at a level to satisfy the predetermined security constraint. This second model was found to be unsuitable for analytically solving multi-period problems.

Darr, P., S. L. Feldman, and C. Kamen. The Demand for Urban Water. Leiden, The Netherlands: Martinus Nijhoff Social Sciences Division, 1976.

A comprehensive analysis of the structure and level of urban water use in Israel is presented, based on data collected from more than thirty urban areas during the period 1962 to 1972. Aggregate water use for each urban area is correlated with an income surrogate (motorization rate) and the results contrasted with comparable results for the United States. Attempts to correlate water use with price were unsuccessful at this level, due to the complex nature of the water rate structures in use (increasing-block structure). A behavioral analysis was undertaken which attempted to explain variations in water use in terms of such variables as income, persons per dwelling unit, age of the head of the household, education, rooms per dwelling, and various cultural factors including the family's national origin. Survey methods were also used to estimate consumers' willingness to pay for water. A case study of water use in an arid environment (Eilat, on the Red Sea) is also reported, illustrating the use of both macro- and micro-data to obtain a complete description of the determinants of water use. Eilat consumers were questioned, among other things, about their ability to reduce water use in the face of higher prices/shortages.

Water use in Eilat was found to be uncorrelated with many of the socio-economic variables identified elsewhere in Israel; it depended, instead, almost entirely on the technical specifications of water-using appliances (e.g., desert coolers). The implications of these results for water use forecasting and for water tarrif design are discussed.

De Rooy, Jacob. "Price Responsiveness of the Industrial Demand for Water." Water Resources Research 10 (June 1974):403-406.

This article presents the methodology and results of a cross-section regression study of 30 large chemical manufacturing plants in northern New Jersey. Presented are the price elasticities of water used for cooling processing and steam generation (-0.894, -0.745, and -0.741, respectively) obtained by the "mixed regression" technique. Sanitary water use for employees was found to be related only to the number of employees.

Two problems exist with the methodology: the first, which is noted by the author, is the assumption that the recycling ratio is fixed. This assumption leads to the use of average rather than marginal cost as the independent price variable. Another problem is the use by the author of the "mixed regression technique." It is not clear why this method was necessary as there does not appear to be a need to estimate the 3 equations (cooling, processing and steam generation) as a simultaneous equation system. Using the ordinary least squares technique leads to lower estimates of the price elasticity of processing and steam generation (-0.354, not significantly different from zero, and -0.590, respectively). Neither of these two problems appears sufficient to dispute the contention of the author that the water price elasticity of manufacturers is less than zero but greater than -1.0.

Dunn, Dorothy F. and Thurston E. Larson. "Relationship of Domestic Water Use to Assessed Valuation, with Selected Demographic and Socioeconomic Variables." Journal of American Water Works Association 55 (1963):441-450.

The authors evaluate a number of possible factors relating to differences in domestic water use for both the water supply and waste treatment industries. Individual users seldom make large demands on the total supply, but collectively, these are usually the greatest source of revenue to the utility. The authors provide an excellent and concise literature review. A random sample was taken of 208 single family dwellings in 1958 in Kankakee, Illinois, where there had been no water restrictions. Interviews were taken and data obtained from city zoning regulations, county property valuations, and water meter readings. The data was subjected to two analyses: (1) regression-dependent variable-water use; (2) coefficient of cost. Among the results: the average use ranged from 13 to 161 gpcd and maximum month use ranged from 14 to 295 gpcd; for household water demand, the average was 148 gpd and maximum 205 gpd or 138% of the average. The study found "assessed valuation and the respective household water demand for month of maximum use to be used as the primary base for comparison of the influence of other factors for which data was obtained." (r = .46, .50, .37 of assessed valuation and other socio-economic characteristics of income, occupation and education). Water use had the highest r with occupation, (.322). Large family sizes are significantly above the reg. line of use vs assessed valuation. The second most important parameter found was to be the number in the household. "Per capita maximum month use was relatively high for 1-2-3 member households, but progressively less for households with more persons." Homes with automatic washers had higher assessed valuation, larger family size and used more water than those who had wringer washers. Similar relations were

noted in terms of shower vs. tub-only bathing facilities. Found the dishwasher to be the "most clearly Significant Water use of those appliances considered." Outdoor use was greater for larger family size and valuation but maximum use was of low significance. The study concludes: above average use demanded by assessed valuation of $10-13,000 and lower than average by valuation of less than $7,000; higher valuation ($14-17,000) had even greater demands reflecting appliances, education level, income, etc. The authors claim that individualistic domestic water use patterns differ "but slightly from the use patterns of the socio-economic group of which they are a part."

Dworkin, D. M. "Water Reuse: A Flexible and Efficient Management Alternative for Municipal Water Supply." Water Resources Research 11. (October 1974): 607-615.

"A comparison between the fixed schedule of planned expansion of water supply sources and an alternative expansion program based on a short term decision from monitoring reservoir levels, water use and streamflows and employing water reuse capacity and new source development is simulated for the Colorado Springs, Colorado municipal system. For this complex, fast-growing system with supply based on streamflows and some current reuse capacity the alternative plan postpones major new development an average of 14 years at a cost at present value of half the original planned expansion."

Ecological Analysis Incorporated. "Water Supply Study for Montgomery and Prince George's Counties, Maryland." October 1977. Washington Suburban Sanitary Commission's (Maryland) (WSSC) Water-Saving and Waste-Reduction Program (Other sources: internal memos, press releases, and personal communications with Michael P. Bork, Walter A. Klein and Arthur P. Brigham and Richard Shagogue).

On October 29, 1971, WSSC adopted as policy a water use reduction program that included an education-publicity program and studies of changes in plumbing codes and the WSSC rate structure. The plumbing code changes subsequently adopted require that all new buildings have showers with flow rates of 3.5 gpm or less, faucets with flow rates of 4 gpm or less and toilets which use 3.5 gal/flush or less. Traps with mechanical sealing devices in water closets are permitted if substantial water savings will result. All continuous flow equipment with water use exceeding 5 gpm are required to have recycling (maximum make-up water of 7,000 gal. per day).

Two studies were undertaken to promote and examine the effect of water reduction devices in individual homes (EAI, 1977, p. 414). In the first study 4,800 water reducing devices (water closet inserts, pressure-reducing valves, and flow controllers) were placed in 2,400 dwelling units (11% of the John Drainage Basin). Water use reductions in 4 apartment complexes ranged from a 16% reduction to a marked increase in use. Water reduction in single family homes ranged from 26% to 13.5%. Pressure-reducing valves (to 50 psi) installed in 83 single family homes achieved a 30 to 37% reduction in water use in combination with toilet inserts. Shower flow-control devices installed in 25 homes achieved reductions of 1.2 to 2.0%. The second project entailed

the house-to-house distribution of toilet inserts, shower flow reduction devices, dye pills for toilet leak checks and instruction booklets to virtually all single family and apartment dwelling units (215,000 and 100,000 respectively). This project is believed to have contributed in part to a 5.4 mgd reduction in total sewage flow between 1972 and 174 even though the number of connections increased by approximately 8%. A measure of the overall success of the WSSC program can be seen in the fact that from 1966 to 1970, water use per connection increased by an average of 4.5% per year but from 1970 to 1975 water use decreased at a rate of 0.8% per year (EAI, 1977, p. 3-3). This result can also be partially attributed to the effect of price changes. From 1966 to 1970 real price (deflated by the U.S. CPI) declined at an average annual rate of 2.7%. From 1970 to 1975 real price rose at an average annual rate of 9.3%

This report also contains discussion and literature review of the effectiveness of water use restrictions during a water shortage. It was concluded that for WSSC a request of no outside water use and appeals for conservation would achieve a decrease of from 11 to 39% depending on the year in question, on the degree of cooperation and on the amount of residential sprinkling on that day (Stage II). Banning all outside water use, creating a crisis atmosphere and lowering system pressure could achieve reduction of from 19 to 50% (Stage III). These measures combined with terminating service to selected large commercial and institutional uses could achieve a total reduction of from 21 to 53% (Stage IIIB). A failure of the Potomac Treatment Plant required measures similar to this latter stage (IIIB) to be implemented in July of 1977. A decrease of approximately 40% was accomplished 2 days after the treatment plant failure during a period when residential sprinkling was a large compenent of unrestricted water use.

Ellis, Willis H. "Water Transfer Problems: Law." In Water Research, pp. 233-250. Edited by Allen V. Kneese and Stephen C. Smith. Baltimore: Johns Hopkins University Press, 1966.

This paper presents a discussion of the legal problems (and their potential solutions) of transferring water use in western agriculture to other purposes such as municipal or industrial use. The paper states that in the Rio Grande basin in 1975 (projected) one acre-foot will return $50 per year is used in agriculture, $200 to $300 per year is used for recreation, and $3,000 to $4,000 per year is used for industry (from N. Wollman, The Value of Water in Alternative Uses, Albuquerque: The University of New Mexico Press. 1962, p. xvii) Other sources are given.

Ertel, M. O. and S. G. Koch. "Public Participation in Water Resources Planning: A Case Study and Literature Review." Amherst, MA: Water Resources Research Center, University of Massachusetts, 1977.

The purpose of the study, which concentrates on the northeastern United States, was: (1) to determine the effectiveness of three Citizen Advisory Groups and to determine their perception of their role in water resource planning; and (2) to bring to light some of the political, ethical, and social issues involved in public participation in water resource planning.

Questionnaires were sent to each advisory group member at time 1 and again at time 2 in order to determine attitudes about his role in planning, on water-related issues, and any changes in these attitudes which occurred over time. A major assumption of the study was that the large turnover rate in advisory group

members was unsystematic. Four functions of advisory group members were identified and ranked in order of perceived importance: (1) advice on planning process; (2) informing the public; (3) review of final plan; and (4) support for final plan. The most significant area of opinion convergence at time 2 was on the key issue of structural versus non-structural alternatives. The majority preferred the latter. This preference is explained by the prevailing national interest in non-structural alternatives.

In addition to the empirical study, a theoretical discussion of the various rationale for public participation in policy planning is provided. Public participation: (1) fosters a sense of community; (2) enhances self-development of individual citizens; (3) leads to improved policy; (4) facilitates policy implementation; and (5) fosters democracy. These rationale are then assessed critically.

Many important methodological considerations are omitted in part 1. Part 2, the theoretical treatment of public participation, contains relevant information and questions some facile assumptions.

Feldman, S. L. "Peak-Load Pricing Through Demand Metering." Journal of the American Water Works Association 67 (September, 1975):490-494.

This article presents a discussion of peak-load pricing of municipally supplied water. The article also advocates the use of a pressure sensitive "demand" meter to deal with the peak-load problem on an hourly basis. While the general discussion of peak-load pricing is good, the concepts underlying the new meter seem weak. First, the design parameter of greatest interest is maximum day use which is only weakly correlated with maximum hour use. Secondly, depending on the location of pumping stations and local service reservoirs pressure may be inversely correlated with system hourly use. Finally, research needs to be done on the willingness of consumers to take the trouble to check their meter for the current price before using water.

Feldman, S. L. A Handbook of Water Conservation Devices. NSF/RANN Grant #APR76-19369. Worcester, MA: Graduate School of Geography, Clark University, November 1977.

This handbook reviews 34 types of devices for reducing residential water use. The major classes of devices reviewed are: (1) toilets; (2) flow-limiting devices; (3) alternative plumbing systems; (4) clothes and dish washers; and (5) lawn and garden controls. For each device a general description is given, water savings are estimated and a list of manufacturers is provided. No actual tests on changes in household use are performed.

Feth, J. H. Water Facts and Figures for Planners and Managers. Washington: U.S. Geological Survey, 1973.

This publication contains a very general discussion of water use in the United States. Presented are some statistics on domestic and commercial-industrial water use.

Flack, J. Ernest. "Meeting Future Water Requirements Through Reallocation." Journal of the American Water Works Association 59 (No. 11, 1967):1340-1350.

The article discussed the scope of the water problem in the U.S. as of 1967, and examined reallocation as a method of solving the problem. Based on the findings of the Senate Select Committee on National Water Resources and those of Wollman and Garnsey in American Association for the Advancement of Science (1963) pp. 372, it was concluded that unless new sources of water were developed or consumption was drastically reduced, the projected water withdrawals for the west could not be realized in 1980.

Referring to the work done by Howe and Linaweaver and that summarized by Bain, Caves, and Margolis as well as that done by the author, he concludes that municipal water demand is relatively elastic at low prices but relatively inelastic at high prices. He argues in favor of universal metering.

In the section devoted to industrial water use, it is found that this sector's demand would be likely to remain small compared to that of irrigation. Further note is made that actual consumptive use by industry is frequently very small compared to intake.

As for consideration of reallocations and transfers, the paper is concerned with the agricultural, recreational and industrial sectors of the

arid West. This section is quite carefully presented. It is concluded that sufficient flexibility should exist in water rights as to assure that the demands of higher valued uses can be met by obtaining water from transfers as well as from additional storage or imports.

Flack, J. Ernest. "Urban Water: Multiple-Use Concepts." Journal of the American Water Works Association 63 (No. 10, 1971):644-646.

This is a very brief paper presenting an easily readable overview of the development of multiple-purpose management in urban water utilities. Single-purpose private development of water supply evolved to single-purpose public development. From this point it has been increasingly recommended that the management of water supply and sewer systems be combined. In fact, this policy has been implemented in many instances. This is a summary of guidelines for the utility managers facing such a combination. The discussion is very practical in orientation omitting mention of possible implications.

Flack, J. Ernest. "Management Alternatives for Reducing Demand." Paper presented October 1976 at the Conference on Planning Alternatives for Municipal Water Systems.

The author assesses methods of demand reduction in municipalities and cites two: (1) Technological (metering, pressure reduction, reduction of unaccounted water, water saving devices, horticultural practices, land use controls, growth controls, building and zoning codes); and (2) Socio-economic (pricing, demand or peak pricing, seasonal pricing, public education, incentives, rationing, detection of unauthorized uses and control of public uses).

In order to appraise the efficiency of these methods, one must know: (1) how well they can be expected to reduce demand; (2) the social and economic benefits; and (3) how to delineate implementation problems. "Implementation of water conservation by a water utility will permit it to: (1) reduce its cost of operation and maintenance; (2) postpone system expansion to meet future growth; (3) increase its time horizon for future water supply acquisition and development; (4) better conform to a steady-state or reduced growth rate; and (5) conserve and better utilize its scarce resources, water and energy." (p. 3-4).

Demand reductions can be implemented by structural, operational, and economic or social methods. As social means of demand reduction, the author cites: (1) public education, [In-house-use conservation is important, not that it saves that much water, but because it establishes a conservation ethic which carries over to uses that significantly affect peak demand such as lawn irrigation. Using less water and timing uses to avoid peak demand periods can be stressed through public information and education" (p. 12).] and (2) horticulture changes (types of lawns, etc.) The feasibility of these methods must be evaluated from an engineering, economic, and soci-political viewpoint. The structural alternatives "are sufficiently attractive from an economic standpoint that they warrent investigation." (p. 15)

Horticultural changes, pricing, credits, and incentives need to be justified as conservation means by attitudes and responses after their implementation. Their effectiveness is highly problematical. The article plays down importance of resident conservation but raises point of reducing peak demands.

Flack, J. E. and G. J. Roussos. "Water Consumption Under Peak-Responsibility Pricing." Journal of the American Water Works Association 70 (March 1978):121-126.

This article describes how peak responsibility pricing of water might be applied to Denver, Colorado. A numerical example is presented. Two significant problems exist in the analysis. First, no recognition is made of the problem of revenue sufficiency. Secondly, the actual application of the method presented for calculating the peak and off-peak prices can give a peak period price lower than the off-peak period price. This is contrary to economic theory.

Flack, J. Ernest and Wade P. Weakley with Duane W. Hill. Achieving Urban Water Conservation - A Handbook. Fort Collins, CO: Colorado Water Resources Research Institute, Colorado State University,1977.

This book presents an excellent overview of the potential means of reducing residential water use by methods available to water utility managers. Especially valuable are the discussions of the methods of implementation and the assessment of social and political acceptability for each conservation technique. The discussions of return flow implications are also included although these aspects are only for interbasin transfers.

The conclusion of the book is that saving of from 30 to 40% are possible through the implementation of a combination of socially acceptable and economically feasible conservation techniques. It is recommended that every utility plan of operation include metering, building code modification,

public education and leak detection. Demonstration projects for low water-use horticulture, and utility programs for the free distribution and assistance in installation of water saving devices appear to have widespread applicability. Pricing schemes and recycling systems appear to need more study before they can be widely applied in operating utility systems. Water use restrictions are effective in dealing with short-term shortages. Chapter V by Duane W. Hill describes the use of surveys for studying problems related to water.

Fox, I. K. "Policy Problems in the Field of Water Resources." In Water Research, pp. 271-290. Edited by Allen V. Kneese and Stephen C. Smith. Baltimore: Johns Hopkins University Press, 1966.

The purpose of the study is to reflect on the ideological factors that affect water resource policy. Two examples of ideology deterining policy are found in: (1) Water abundance and the development of the western United States. Two opposing views are in evidence: economic rationality (water needs are carefully assessed and met through moderate transfers, etc.) and developmental (the assumption that great projects are necessary, a psychological "boom" mentality.) (2) Waste disposal and preservation of water quality. The management view (which assumes waste disposal is a legitimate use of a waterway and maintains that the extent of this use should be determined by cost-benefit analysis) opposes the complete abatement view (which assumes that any pollution is bad and therefore should be eradicated).

Fox identifies four inherent characteristics of water projects which cause policy difficulties: (1) costs may be spread out over large numbers thus disguising the high net cost; (2) benefits aren't always reaped by those

who share in the cost; (3) substantively unrelated policies become politically enmeshed; and (4) benefits may be diffuse, making support difficult to mobilize.

Fox advises that the process of policy change itself must be studied both historically and theoretically. The article, although not conceptually sophisticated, focuses on an important area and demonstrates an awareness of the social and psychological issues involved.

Frankel, R. J. "Economics of Artificial Recharge for Municipal Water Supply." Washington: Resources for the Future, March 1967.

This paper analyzes whether or not waste water reclamation could be economically competitive with other water source systems. Also evaluated are the physical and chemical limitations of artificial recharge using municipal wastewaters; the economic tradeoffs between additional treatment prior to recharge and greater land utilization; and the break-even point for land values as a function of economies of scale. An extensive literature review is made on each of these subjects. The author concludes that "wastewater reclamation through ground water discharge is the most feasible economic solution to reclamation of municipal wastewaters today." The values presented indicate that recycling municipal wastewaters by artificial recharge can in some cases be less expensive than the conventional system of surface water supply and discharge using secondary wastewater treatment. Accumulation of total dissolved solids will, however, limit the number of times water can be recycled.

The paper, although a brief summary of an apparently much larger study, contains much useful information on the subject, even though much of the cost data is outdated. Table I presents a comparison of the estimated cost of reclaimed sewage effluent and cost of alternative supply for 17 operating facilities in 1967.

Gallagher, D. R. and R. W. Robinson. "Influence of Metering, Pricing Policies and Incentives on Water Use Efficiency." Australian Water Resources Council Technical Paper No. 19. Canberra, A.C.T., Australia, 1977.

Trends in water use in the major cities of Austrialia were reviewed, and the dependence of decisions to construct new supply capacities on water use forecasts is discussed. In particular, emphasis is placed on the relationship between water rate structures or rate levels and water use. A comprehensive review of the English-language literature on the factors affecting water use is presented. Data were collected from residential areas in Nowra, N.S.W. (Australia) and Wollongong, N.S.W. These data included water use observations and the results of consumer attitude surveys and price experiments conducted with respect to both winter and summer water use.

The price elasticity of the demand for domestic water was shown to be within the relatively inelastic range, and nearly identical to estimates obtained in U.S. studies. No significant price coefficient was obtained for summer sprinkling use. Present rate-making policy in the study area consists of a fixed annual charge, based on property value, which establishes a water use allowance. Only those customers using more water than their allowance face a commodity charge, known as an excess use charge. The authors, based on an analysis of system costs, propose a rate structure consisting of a fixed periodic charge and a uniform commodity charge for all units of water used. They argue that such a policy would promote efficiency, both in use and in supply.

Gallup Poll. "Water Quality and Public Opinion." Journal of the American Water Works Association 65 (No. 8, 1973):513-518.

The poll seeks to determine variables relevant to public opinion concerning water quality. A selected summary of a pre-1973 poll is provided. Responses were broken down by sex, race, education, occupation, geographic region, water source, income, and community size. Among the relevant results are: (1) although some minor inter-group variation existed, the vast majority of Americans were satisfied with both the quantity and quality of water available to them (82% and 70%, respectively). (2) Between 60 and 70% of the public thinks that water pollution is either somewhat of a threat or a great threat to the water supply. Only a little over 1/3 feel that their water company is meeting this challenge. (3) Approximately 55% of the respondents said that they would object to drinking recycled sewage. Forty percent said they would not object.

Gardner, B. Delworth and H. H. Fullerton. "Transfer Restrictions and Misallocations of Irrigation Water." American Journal of Agricultural Economics 50 (August 1968):556-571.

This article estimates the ceteris paribus change in the rental price of water among four companies when transfer restrictions were relaxed. Statistical evidence is presented that the real price of water rose as a result of allowing intercompany transfers (based on the intracompanies of a single firm). This is estimated to be $1.84/acre-foot. The article advocates the use of this value times the number of acre-feet as a measure of the benefits of the policy change. There are serious problems with this approach. The costs of an inefficient market result from two (or more) companies placing different marginal values (price) on the water used. How, then, can the marginal value (price) of one firm be used to calculate the efficiency loss?

Garland, Sidney B., III "Water Rationing in Okinawa." Journal of the American Water Works Association 67 (June 1975):296-297.

This article describes the turning off of water for periods of up to 24 hours for selected zones by the Okinawa Water Utility (IIWS). The utility has successfully prevented outbreaks of water-borne diseases that could result from infiltration when the pressure is low by instructing residents in disinfecting water. No estimates of the effectiveness of this conversion technique are provided by the article.

Gerlach, Luther P. and Virginia H. Hine. Lifeway Leap. Minneapolis: University of Minnesota Press, 1973.

The authors' purpose is to explore four conceptual tools or ways of interpreting change and to provide a more adaptive base for decision-making. These tools involve revolution versus developmental change, concept of systems, analysis of movements, and an evolutionary perspective on these tools. Developmental change is change that takes place within an ongoing system; one adds to it or improves it rather than replace key elements (reform). Revolutionary change is change that upsets the workable balance of a system and throws it out of an established equillibrium; it involves fundamental transformation in the structure of society and its basic institutions. The facility for developing ideas is an example of vertical thinking, while the ability to generate new ones is lateral.

The United States has instigated revolutionary change in underdeveloped countries, but is hesitant to accept such changes at home. The authors suggest that "the process of social change which we call modernization is similar, from the point of view of those experiencing it, to the process of futurization in which we are engaged. If we can agree that social upheavals, dislocations and painful conflicts are an inevitable accompaniment of constructive social change elsewhere, then perhaps we can look upon the upheaval, dislocations, and conflicts in our own society in a more positive way and stop expecting constructive change to be necessarily orderly and conflict free." (p. 148)

Five factors crucial to the growth of a movement are: organizational structure; patterns of recruitment; ideology; personal commitment; and opposition. Movements should be viewed as a part of a natural social process.

Revolutionary and developmental change are both part of the evolutionary process. Movement participants, by themselves are not the only initiators of evolutionary change. They generate a range of responses and counter-innovations that are also part of the evolutionary process. The process of evolution also operates on the socio-cultural level.

The authors present an extremely interesting set of concepts and point of view; the analysis can be tied into the conservation movement which could be labeled a radical change (depending on the methods used, etc.) The study provides valuable insights into the workings of a movement and its place in social evolution.

Gilbert, Jerome B. "The California Drought -- Out of Disaster, Better Water Management." Journal of the American Water Works Association 70 (February 1978):79-81.

This author summarizes some of the major benefits that have resulted from the California Drought. The drought brought attention to the need for comprehensive water management, consideration of multiple use projects, efficient delivery, use and recycling. It also demonstrated the need for cooperation between local, state, regional, and federal agencies in terms of regulations and water transfer. Groundwater management also appeared as an area that requires further emphasis and improvement. The more efficiently the water resource is managed the less it will cost and the fewer environmental impacts it will have in the future.

The concept of the article, benefits of drought, is an interesting one. The author points out crucial areas of water management that, if studied and improved, would greatly increase the overall efficiency of water management in California. It is a good general article for water management in California with applications for anywhere else in the United States.

Gilbert, J. B. and Associates. Water Conservation Reuse and Supply - San Francisco Bay Region. Prepared for the Association of Bay Area Governments, 1977.

This report presents a detailed program for achieving reduced water use in the Bay area. Present water use is divided into agricultural (41%), residential in-house use (22%), residential use outside the house (10%), commercial-industrial use (20%), publicly used water (3.5%) and water lost or unaccounted for (3.5%). Specific plans for conservation are proposed. Estimates are made of the cost and effectiveness of these plans. The incremental cost of conservation plans are compared with incremental cost of supply-augmentation projects. The average cost of the moderate plan for residential use is estimated at $0.04/1000 gal. The maximum residential plan has an average cost of $0.30/1000 gal while agricultural water conservation has an average cost of $0.16/1000 gal. The cost of water developed from new sources ranges from $0.10 to $0.30/1000 gal. Most of the water reuse projects envisioned in the study would be locally cost-effective only if federal subsidies were provided. Institutional and financial consideration of the plans is also discussed.

Gottlieb, M. "Urban Domestic Demand for Water: A Kansas Case Study." Land Economics 39 (May 1963):204-210.

This article presents the results of several cross-section regressions in Kansas and the United States. Estimated price elasticities ranged from -0.39 to -1.24. The regression on 12 Illinois data points found a positive price elasticity (0.27). All these estimates suffer from a lack of information concerning the standard errors of the coefficient as well as the relatively small sample sizes (18 to 34 excluding Illinois). A further difficulty with these numbers is that they are derived from data twenty to thirty years old.

Granger, G. A. "Water Conservation Through Metering." Journal of the American Water Works Association 17 (February 1955): 122-123.

This article describes the detection of leaks through a single program of universal metering. Unaccounted-for-water was reduced from 60 to 70% to 6 to 20%.

Griffith, Evan L. "Southern California's Drought Response Program." Journal of the American Water Works Association 70 (February 1978):74-78.

The article summarizes the response of the Metropolitan water district of Southern California to the drought of 1975-77. The district's system of cut backs and reallocation is outlined. By use of industry conservation, a 10% savings by July-August of 1977 was accomplished. (In Los Angeles a mandatory 20% savings was achieved.) The study concludes that the drought brought close cooperation and coordination between agencies and institutions concerned with water resources in Southern California. The public has been awakened to the problems of future water supply and costs.

The study emphasizes the need for cooperation of agencies and planning for future droughts.

Groopman, Abraham. "The Effects of the North-East Water Crisis on the New York Water Supply System." Journal of the American Water Works Association 60 (January 1968):37-47.

This article describes the activities of the New York water system in response to the 1966 drought. Based on the results in 1949-1950, it judged that "intensive appeals for voluntary conservation backed up by restrictions on the nonessential use of water could reduce consumption by 20 to 25%". In April 1965 such a campaign was instituted. Restrictions concentrated on outside uses of water. Appeals were made through the mass media, door-to-door solicitation, sound trucks, handouts of flyers and bumper stickers. The response was immediate. By the end of May, July and September water use is shown to be reduced by 120, 205, and 270 mgd (respectively) over what would have existed without the campaign. These reductions correspond to 10, 17, and 22% of the water use that would have been expected on those days. One failing of the article is that the method of computing the "probable" water use in the absence of restrictions is not presented. The article notes that water use remained 75 to 100 mgd less than it was prior to the campaign even 2 years after (mid-1967) the campaign was relaxed.

Grunewald, Orlen C., C. T. Haan, David L. Debertin, and D. I. Carey. "Rural Residential Water Demand in Kentucky: An Econometric and Simulation Analysis." Lexington: University of Kentucky Water Resources Institute. Research Report No. 88, 1975.

This paper examines residential water use in certain rural areas of Kentucky, specifically those provided with public water supply by means of connections to nearby urban areas. Data was collected from 150 such areas. The purpose of the study was to demonstrate the application of econometric demand functions to the determination of optimal pricing policies and reservoir design criteria, and to show the interaction between design criteria and optimal rate structures.

Data was collected for 150 rural residential areas, varying in size from 15 to 2064 customers. Water use date and prices were as of 1972 and were obtained from the records of the Kentucky Public Service Commission. Mean income, mean housing unit value, and mean number of persons per household were as of 1970 and were obtained from U. S. Census reports. Summer evaporation data for 1972 were obtained from Climatological Data - Kentucky. The sample was acknowledged to be non-random, as various data points were excluded for reasons including substantial non-metered consumption, substantial non-residential consumption, etc. Both linear and log-linear models are attempted. Average price is used as a surrogate for price, although all water districts sampled apparently used decreasing-block price schedules. Several regression models are presented, irrespective of the significance level of specific terms.

The authors conclude that the model which best represents rural residential water use in Kentucky is the following:

$Q = 90.92\ P^{-.92}$

Where: Q = residential water use, 1000 gallons/dwelling unit/day

P = aver. price, $/1000 gallons (1972 dollars)

They further conclude that the elasticity of residential water consumption is negative, that the demand function is hyperbolic in shape, that other factors (income, persons per dwelling unit, summer evaporation, etc.) have little effect on water use, that the demand is more elastic than has been claimed by other investigators, that an increasing block price schedule is consistent with marginal cost pricing principles and is optimal in this situation, and that pricing policies have a marked effect on reservoir capacity requirements and, hence, cost.

The study suffers from two major faults: (1) a failure to recognize the bias in empirical elasticity estimates which results from the use of average price in the regression where actual rate structures are of the decreasing-block form; and (2) a persistent confusion between costs which increase over time and costs which increase with output, and between marginal cost concepts and average cost concepts. In the first case, the authors accept an estimate of the price elasticity of demand equal to -0.92, which certainly exaggerates, perhaps substantially, the true elasticity (as a result of the average price bias). In the second instance, confusion between alternate concepts leads the authors to believe that increasing-block price schedules embody marginal cost pricing principles, which they do not, and to conclude that such schedules are in some sense optimal. Also, the existence of a hyperbolic demand function was not proved; it was only shown that the data fit a hyperbolic function more closely than a linear one. The apparent non-significance in other variables was properly attributed to a lack of variation in the data set. Characterization of data for a rural residential area is a useful addition to the literature.

Gysi, Marshall. "The Effect of Price on Long Run Water Supply Benefits and Costs." Water Resources Bulletin 7 (No. 3, 1971):521-528.

This paper is essentially a continuation of the work reported by the author in his doctoral dissertation. The data used here is unchanged from the dissertation. The objective is to apply economic concepts and discrete dynamic programming models to the problems of predicting long-term effects of various pricing policies. More precisely, the model is designed to determine optimal water supply capacity experience patterns for a hypothetical community with a given water pricing policy. The optimum path is the one which maximixes the discounted sum of future producer's and consumers' surpluses.

The policies examined are constant unit rates, decreasing and increasing block rates and summer differential rates. Price is found to be a major determinant of short-run allocation and long-run planning and conservation of water supplies. It is argued that it would be better to institute conservational pricing policies now than to force future legal strictions.

Gysi, Marshall, and Daniel P. Loucks. "Some Long-Run Effects of Water Pricing Policies." Water Resources Research 7 (No. 6, December 1971): 1371-1382.

The authors contrast the long-run effects of various rate-making policies for urban water utilities. Five types of rate structure are considered: decreasing-block rates, constant rates, flat rates, summer differential rates, and increasing-block rates. A forward moving dynamic programming model is employed to estimate the optimal size and timing of water supply capacity increases that would maximize the sum of consumers' and producers' surpluses. Each rate-making policy leads to a different stream of capacity increases and, therefore, costs, producing a different expected present value of surpluses. On the basis of various results obtained from the use of this model, a combination of the summer differential and the increasing block rate structures is identified as the desirable rate-making policy. This conclusion is based on economic benefits predicted, on minimal need for peak-period rationing, and on the authors' judgement that low consumption users should be rewarded with lower average rates.

Hanke, S. H. "Demand for Water Under Dynamic Conditions." Water Resources Research 6 (October 1970):1253-1261.

This article examines the effects of the change from flat rates to commodity (metered) charges for single family dwelling units in Boulder, Colorado using time-series data. The study found that: (1) "sprinkling demands were reduced by the introduction of meters, with actual sprinkling being greater than the calculated ideal under flat rates and less than ideal under metered rates; (2) sprinkling use not only declined with the introduction of meters but subsequently continued to decline; (3) domestic demands (in-house) were reduced 36% after meter installation and; (4) domestic demands stabilized at these lower levels. The evidence generated by the analysis demonstrates that water users do not return to their old use patterns after meters are installed, and that metering results in a permanent and significant improvement in water efficiency." These findings are well-substantiated in the article.

Hanke, S. H. "Pricing Urban Water." In Public Prices for Public Products. Edited by Selma Mushkin. Washington: The Urban Institute, 1972.

This paper presents a good general discussion of the use of pricing policy for municipal water supply. Among the pricing policies discussed are uniform, spatially differentiated and peak-responsibility. The paper also presents a discussion of the problem encountered in attempts to estimate the effect of price on water use. Thirty-four estimates of price elasticity are included (Table 12.5). For municipal or total residential water use these estimates range from -0.12 (Seidel & Baumann, 1955) to -1.24 (Gottlieb, 1952). Among the conclusions are: (1) that user fees are universally applicable to municipally supplied water; (2) the "first-rate-of-return" philosophy combined with uniform rates leads to excessive (non-optional) expansion of water supply facilities when compared to the result of peak responsibility pricing of water; and (3) water use is sensitive to changes in price, the sensitivity depends on the type of use and on the user class (domestic, commercial, etc.). The article fails to consider the effect of sewer costs when discussing optional water pricing policy. The facts that water and sewer prices are inherently related (in the absence of separate meters for sewer contributions) and that sewer costs are related to domestic in-house use only and experience late winter-early spring peak periods which interfere with some of the usefulness of water peak responsibility pricing are ignored.

Hanke, S. H. "Pricing as a Conservation Tool - An Economist Dream Come True?" In Municipal Water Systems: The Challenge for Urban Resources Management. Edited by D. Holtz and S. Sebastian. Bloomington: Indiana University Press, 1978.

The paper presents a review of the potential rate-making policies for municipally supplied water. Included are increasing-block, decreasing-block, seasonal, and marginal cost policies. A case study of applying marginal cost pricing to Adelaide, South Australia, is presented. The paper concludes:

> "The dominant rate structure in the industry, declining-block rates, is inefficient, discriminatory, and perverse in its income redistributive properties. Although many environmentalists and those in the industry view increasing block rates and innovative, seasonal rates as an economist dream come true, the economist views them as a great nightmare. These new innovations that fly under the banner of conservation encourage an uneconomic use of resources and create many cross-subsidies among consumers."

Hanke, Steve H. and John J. Boland. "Water Requirements or Water Demands." Journal of American Water Works Association 11 (1971):677-681.

The article seeks to demonstrate that a negative functional relationship exists between the quantity of water demanded and the price paid for each unit; and to demonstrate that pricing policy is a powerful tool that can be used to satisfy a variety of goals of the utility.

In Boulder, Colorado, in 1961, water meters were installed in areas previously on a flat rate basis and prices changed to 35¢/1000 gallons. Three thousand and eighty-six individual, residential connections were sampled. Flat rate aggregated data from 1955-1961 with commercial and industrial use are subtracted out. The metered rate was studied from 1962-1968 on 220 meter routes.

The domestic demand equaled the lowest quarterly demand (winter) and was assumed uniform throughout the year. The study divided the area into northern (low income) and southern routes (affluent). Upon metering, there was a 36% decrease in average residential water use and it did not tend back to original levels. Lawn sprinkling is the largest and most important component of seasonal use. This also was reduced upon metering.

Interviews were conducted of 180 persons in both areas; most were middle income and well-educated. Of those samples, 51% indicated adoption of conservation practices with the advent of metering and had further intentisifed those practices. Only 1.7% reported a drop in conservation practices after the first year.

The time series analysis of residential water use in Boulder from March 1955 to June 1968 concludes that the marginal commodity price of water to residential consumers was changed from zero (flat rate) to 35¢/1000 gal.

Sprinkling water use was separated out of domestic (in-home) use. Population, income, and climate were substantially constant throughout the study period. And, sprinkling use, corrected for weather conditions, dropped more than 50%. Some questions about the study remain: What was the flat rate? Was it substantially lower than what a consumer would pay at 35¢/1000? Perhaps this was a drastic increase thus resulting in drastic reductions--e.g., not beginning at a kind of base level subsistence.

Hanke, S. H. and R. K. Davis. "Demand Management Through Responsive Pricing." Journal of the American Water Works Association 63 (September 1971):555-560.

This article describes the use of seasonal pricing to reduce the need for new water supply facilities in Washington, D.C. Basic principles of pricing are outlined and a prospective case study of applying peak responsibility water pricing is performed. "The practical implications of such a move are that the anticipated investments in reservoir storage and system capacity to cope with growth in peak-day (water) demands can be postponed by perhaps more than 10 years." One unfortunate aspect of this analysis is the failure to consider sewer costs which might be increased by the increase in winter water use.

Hanke, S. H. and J. E. Flack. "Effects of Metering Urban Water." Journal of American Water Works Association 60 (December 1968):1359-1366.

This article presents a good summary of the theoretical aspects of metering and a review of the empirical evidence to that data (1968). The article also presents an outline of how a benefit-cost calculation could be made to assist in deciding whether to install meters.

Harnett, John S. "Effects of the California Drought on the East Bay Municipal Utility District." Journal of the American Water Works Association 70 (February 1978):69-73.

The author's purpose is to describe the effects of the drought (1975-1977 and how the East Bay Municipal Utility District responded to the phenomena. The utility serves a population of more than 1 million on an eastern side of San Francisco Bay. The area experienced the driest year ever recorded during the 1976-1977 rain year. This followed the previous year which was the third driest on record. By March 1977 the Pardee Reservoir, the only impounding reservoir, was filled to 22% capacity, 112 ft. below the spillway. Because of reduced capacity and an additional amount of water, it was at 36.5% capacity at end of Fall 1977.

On February 8th, 1977, a water rationing plan was adopted, aimed at an overall reduction of 25%, resident customers were allotted 280 gpd, industrial customers were cut 10%, commercial and public use cut 25%, apartment complexes were cut 30%, and non-residential irrigation cut by 50%. The District also adopted specific prohibitions against wasteful usage. By April 1977 further reductions were needed to aim for overall reduction of 35%. Water rates were increased and an excess use charge was established. Customer response was immediate and usage dropped in February and March. Newsletters and other publications were used to disseminate information. By June 1977, water was also pumped in from Sacramento to the Jan Joaquin Delta by merging construction of installations.

One result of this study, as the author contends, is that there will be a permanent reduction in per capita consumption mainly because of operation charges by some of the utility's largest customers and home usage charges.

The cost of water will not return to predrought rates because of lower consumption and higher costs of operation (p. 73). The author suggests that in selecting numer us options, all factors should be weighed, the public should be extensively involved, and that the program must be administered fairly and firmly. The program adopted must provide "an appeal procedure" to maintain public support. A non-drought conservation program was highly recommended as it keeps both the customers and the utility aware and ready to deal quickly with an actual drought.

This is an important article. It points out reduction of usage by 35% within just a few months. The article also points out implications of relatively permanent reductions in water usage as a result of technological change during the crisis period.

Hattingh, W. H. J. "Selected Health Aspects of Reclaimed Water in South Africa." In Planning for Water Reuse, pp. 27-36. Edited by Duane D. Baumann and Daniel M. Dworkin. Chicago: Maaroufa Press, Inc. 1978.

This article briefly summarizes the research program implemented by the National Institute for Water Research for the purpose of examining the health aspects of reclaimed wastewaters. After examining the microbiological and chemical quality the article concludes that, "reclaimed waters compare favorably" with present drinking water supplies. The article further concludes that present day technology should be capable of producing any quality of water desired.

Headley, J. Charles. "The Relation of Family Income and Use of Water for Residential and Commercial Purposes in the San Francisco-Oakland Metropolitan Area." Land Economics 39 (1963):441-449.

The author's purpose is to define the determinants of economic demand for water used for residential and commercial use and to estimate the parameters associated with these determinants as a basis for study and projection of demand for residential and commercial water. The study uses a model in which demand is a function of: price per unit, income, temperature, precipitation, and other socio-economic variables. Fourteen cities in the area were selected to be studies by a time series model and a cross-sectional model. Precipitation, temperature and price of water were assumed to be constant. General relation estimated was that water demand was a function of income. Cross-section data was obtained with 1950 and 1959 time series for each city. Data was obtained from utility records and population data from the United States Census of population for 1950 and 1960.

The results of a linear regression fit for 1950 and 1959 of residential gpcd (dependent) and median family income (independent) were that for each $100 increment in median family income, there was a 2.2 and 1.3 gallon pcd change in the same direction (1950 and 1959 respectively). "By computing the average percent change in water purchases associated with a given percent change in median income, an estimate of the income elasticity of demand . . . was derived." In 1950 it was 1.49 and 1959 it was 1.24, indicating that water purchases are very responsive to changes in income "therefore, demand for residential water with respect to income is elastic." However, inspection of data showed that actual increases in water demand were not as high as cross-sectional estimates would indicate. Residential purchases did not increase as fast as percentage

use as family income.

In the linear regression, the function did not fit as well, with less reliability in regression coefficients. The use of time series analysis significantly reduced the magnitude of the income elasticity, but these seem to be the more reasonable, varying from .00135-.4035 (2 cities). The author offers an hypothesis that "Commercially used water is not a perfect substitute for residential water and that this--the commercial segment of the market definitely requires more study and better data to explain the demand." The author then projects high, medium and low demand for water for the area to 1975 and outlines his assumptions, etc. He concludes that:

1) There is a significant positive relationship between family income and residential water purchases both cross-sectionally and over time. Thus family income is an important variable in the projection of future water demand in this area.

2) Elasticities of demand for residential water with respect to income were larger in cross-sectional analysis than in time series. These different elasticities have different uses. Cross-sectional elasticities probably vary less within a city than between cities and are best used when estimating an addition to a city or subdivision, etc. With increases in demand over time it is best to use time series elasticity.

3) The high cross-sectional elasticities "may have implications in the financing of additional water service facilities by needs of discriminatory pricing of service based on income or any of the variables for which income stands as a proxy. Price elasticity must also be considered here to assure that this action would indeed provide the added revenues." (p. 448)

The author's study makes an interesting point of income elasticity versus price elasticity and the possible implications of this are not taken into account in other studies.

Hedlund, John D. "Meeting Future Water Requirements by Water Conservation." Presented at the 1975 Winter Meeting of the American Society of Agricultural Engineers, December 15-18, 1975. Paper No. 75-2557.

This paper outlines the results of the Soil Conservation Service study for the 1975 National Water Assessment which was directed by the Water Resources Council. The finding indicates that if a program resulting in high efficiency could be implemented, gross irrigation withdrawal could be reduced by 48 million acre-feet from 1975 levels by 2000. Incidental losses could be reduced by 7.4 million acre-feet, (8 million in text), 6.2 of which is assumed to be used for crop consumptive use on newly irrigated acreage. The cost of these improvements is estimated as a one-time installation cost of $5.7 billion. A more important policy question is what would be the difference in costs between the use in 2000 under current trends and the use in 2000 if "an accelerated program of irrigation efficiency improvements" program is adopted. Such analysis is not provided. The decreases in water withdrawals and consumptive use in the year 2000 from such a program are given as 29.2 million acre-feet and 4.7 million acre-feet respectively.

Heggie, G. D. "Effects of Sprinkling Restrictions." Journal of the American Water Works Association 49 (March 1957):267-276.

This article describes the results of various types of sprinkling restrictions in the city of Detroit from 1952 to 1955 designed to reduce the peak hour. "Both the voluntary and the imposed restrictions brought about a significant drop in the maximum hour consumption but only a moderate drop in daily consumption." With a 10 a.m. to 9 p.m. sprinkling ban it was possible to lower the peak hours from 1,074 mgd to below 800 mgd. Use on the peak day was lowered from 665 to 549 mgd. Other less stringent restrictions met with less consumer resistance but also had less effect. A 2 p.m. to 9 p.m. sprinkling ban resulted in a shifting peak (peak hour 900 mgd).

Hogarty, T. F. and R. J. Macay. "The Impact of Large Temporary Rate Changes on Residential Water use." Water Resources Research 11 (December 1975): 791-794.

This article presents the results of a time series study of the effect of price on water use of less than 120 individually owned townhouses in Blacksburg, Virginia over a 2-year period. The estimates of the short run price elasticity in response to a price increase range from -1.41 to -0.50. The data indicate that the short run elasticity to a price decrease may be very low or nonexistent. This article suffers from considerable confusion concerning long run and short run effects. The results are also clouded by the very small data base.

Hollman, K. W. and W. J. Primeaux, Jr. "The Effect of Price and Other Selected Variables on Water Consumption." Prepared for the Office of Water Resources Research (July, 1973), NTIS #PB-222-264.

This report presents the results of a regression analysis of data from 402 households in 14 Mississippi towns. Data were obtained by personal interview and from inspection of water utility records. Average price at the mean consumption level for each utility is used. Variables found to be significant at the .05 level include number of persons (per residence), number of bathrooms, number of dishwashers, number of clothes washers, the existence of a swimming pool, irrigable lawn area, average maximum temperature, annual precipitation, education level, and price. When the income related variables were removed the market value of the house was found to have a significant effect ("income" elasticity 0.24 to 0.26). Price elasticity values ranged from -0.26 to -0.45 depending on the other variables included and on the functional form. One possible problem with these estimates is that sewer charges are not included. If these charges are based on water use then the price value used is incorrect.

Howe, C. W. "Savings Recommendations with Regard to Water-System Losses." Journal of the American Water Works Association 63 (May 1971):284-286.

This article examines the data on losses in municipal water systems and estimates the amount of water that could be justifiably saved solely on economic grounds. Fifty-eight percent of the cities and 79 percent of total production surveyed lost less than 15 percent of the water pumped, a level thought to be in "pretty good shape" by rule of thumb estimates. A savings function is derived from the data and it is indicated that present systems use less than the economic amount of leak detection. It is estimated that the amount that could be saved by the implementation of economically efficient levels of leak detection and repair is 2.4 million acre-feet, approximately 9 percent of current municipal system production. Based on the data presented there is no indication of any bias in the technique used to make this estimate.

Howe, C. W., and F. P. Linaweaver. "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure." Water Resources Research 3 (First Quarter, 1967):13-32.

This article presents an excellent analysis of the effect of price of water use by residential users. The data base is cross-sectional water use by household or groups of dwelling units obtained from meters installed as part of the Johns Hopkins Residential Water Use Research Project. In-house use and sprinkling uses are dealt with, separately.

The major findings are: (1) domestic (in-house) demands are relatively inelastic with respect to price ($N_p \simeq 0.2$); (2) sprinkling demands are elastic

with respect to price but less so in the west than in the east ($N_{p(east)} \simeq -1.6, N_{p(west)} \simeq -0.4$ to -0.7); (3) maximum day sprinkling demand, so important to system design are less elastic than average day sprinkling demands ($N_{p(east)} \simeq -1.2$, $N_{p(west)} \simeq -0.4$). The elasticity of total demand is estimated at -0.4 and represents the weighted average of domestic and sprinkling elasticities. The only shortcoming of this article is its age; the data used are over 10 years old.

Hudson, W. D. "Reduction of Unaccounted-for Water." Journal of the American Water Works Association 56 (No. 1, 1964):143-148.

The article discusses the causes of unaccounted-for water and describes the range of the amount of unaccounted-for water that may arise due to problems pertaining to master meters, domestic meters, industrial and commercial meters, unauthorized uses, underground leakage, leaks from hydrants, and unavoidable leaks. The author recommends the checking, servicing, and replacement of inaccurate meters, minimizing use of unauthorized water usage, leak detection campaigns, and recording water use by hydrants and public trucks. A complete audit of the distribution system should be made if the percentage of unaccounted-for water remains high after most obvious checks have been made.

This technically oriented article discusses the range and causes of unaccounted-for water. Ten to fifteen percent unaccounted-for water is about average for a well-operated system with consumption of approximately 100-125 gpcd. As far as conservation, the article is useful only in the causal factors of unaccounted-for water and what can be done to change this.

Hudson, W. D. "Leak Detection in Water Mains." Water and Sewage Works 85 (1975):R104-R106.

This article presents a good review of the methods to detect leaks in water utility transmission and distribution systems. Two methods of determining whether there is a need for large-scale leak detection are: the minimum use ratio and the unaccounted-for water ratio. It is stated that a ratio greater than 35 percent of the minimum night use rate to the average use rate indicates further investigation is necessary. Industrial and commercial night use must be taken into account. For fully metered utilities if the unaccounted water is greater than 15 percent of the water produced then intensified leak detection is usually justified. Seven factors affecting the unaccounted-for water use are given. These include accuracy of master meters measuring total water produced, under-registration of industrial and domestic meters, unauthorized use, use from hydrants, unavoidable leakage and underground leakage. For both methods of determining the need for leak detection consideration must be made for the number of miles of the distributive system and the cost of producing water. The article also provides a good description of three major methods of locating leaks: hydraulic measurements along mains, visual inspection, and audible inspection with mechanical or electrical amplifiers.

Hudson, W. D. "Increasing Water System Efficiency Through Control of Unaccounted-for Water." Journal of the American Water Works Association 70 (July 1978):362-365.

The article discusses the use of the metered ratio as a measure of system efficiency and proposes steps to reduce unaccounted-for water. It is stated that a city with large industrial consumption with a metered ratio of 90%, there can still be much unavoidable leakage and water. Conversely, a system in a city with little industrial use and a ratio of 85 to 90% may be very efficient.

The steps proposed to reduce leakage include: (1) check registration of meters, both master and retail; (2) meter all lines to avoid unauthorized use; (3) record hydrant and other municipal uses; (4) examine lines with leakage greater than 4-12 m^3/day/mile; and (5) make periodic check of valves, hydrants, and services for underground leaks.

Hudson, W. D. "Increasing Water System Efficiency." In Municipal Water Systems, pp. 211-218. Edited by D. Holtz and S. Sebastian. Bloomington: Indiana University Press, 1978.

The purpose of this study is a discussion of various means of reducing the quantity of water use which is unaccounted for. It discusses frequent tests of system-level master meters, rotation of home meters every 10 years, and the regular maintenance of repairable equipment.

Ibsen, C. A. and J. A. Ballweg. Public Perception of Water Resource Problems. Blacksburg, VA: Water Resources Research Center, Virginia Polytechnic Institute. 1969.

The geographical location of this rural residential was southwest Virginia. The purpose of the study was to determine the extent to which the public feels that water use is a problem, what action the public thinks is appropriate to combat the problem, and what the correlates of these attitudes are:

A random sample of 592 was selected from an area phone book. Of these, 453 cooperated with a 66-question fixed interview over the phone. The interview took 20 minutes. Only 3% said that water was one of the five most serious problems in the world. But 34% said they had, at one time or another, considered water as a problem. The younger, better educated respondents were more likely to see water as a problem. Only 3% of the sample thought that water problems couldn't be solved.

The authors conclude that public support of water policies is more likely if the public is involved in the planning stages. Television is the most effective medium for informing the public, and stress should be placed on the benefit to the "common man".

The strength of the study is that it is an empirical study of a somewhat rural population. However, the content of the interview schedule is unspecified and the reported results are sparse compared to the length of the interview. The conclusions drawn are somewhat simplistic and the recommendations manipulative.

James, L. D. "The Challenge to the Social Sciences." In Man and Water, pp. 1-33. Edited by L. D. James. Lexington, KY: University of Kentucky Press, 1974.

This chapter acts as a general introduction to the rest of the book which consists of a series of articles outlining the place of various social sciences in water resource planning. The book is an attempt to begin to solve what is termed the "bottleneck" theory of societal development. By this term the author refers to the process whereby a society advances by means of certain approaches while neglecting others. But a time comes when the emphasis must shift to other approaches to insure further progress. Thus, in water resource planning, we have come as far as possible without emphasizing social factors. Therefore, the linkages between social and physical sciences must be better understood. In addition to the discovery of these linkages, better means of communication from social theorists to front line administrators must be devised. The article seems designed more to "set the scene" for the rest of the book than to provide usable information itself.

Jezler, Harold. "When the Reservoir Almost Went Dry." Journal of the American Water Works Association 67 (June 1975):331-335.

This article describes the activities of the COMASP (water authority for Sao Paulo, Brazil) during a drought. Among these activities was a two-stage water use reduction program. The first stage consisted of public appeals with some rotating cutoffs to some zones. No mention was made of fears of infiltration as a result of these cutoffs. After 30 days, these recommendations were made mandatory with specific uses prohibited (no outside use of water) and with specific limitations for total water use by residences. Instructions were given on how to

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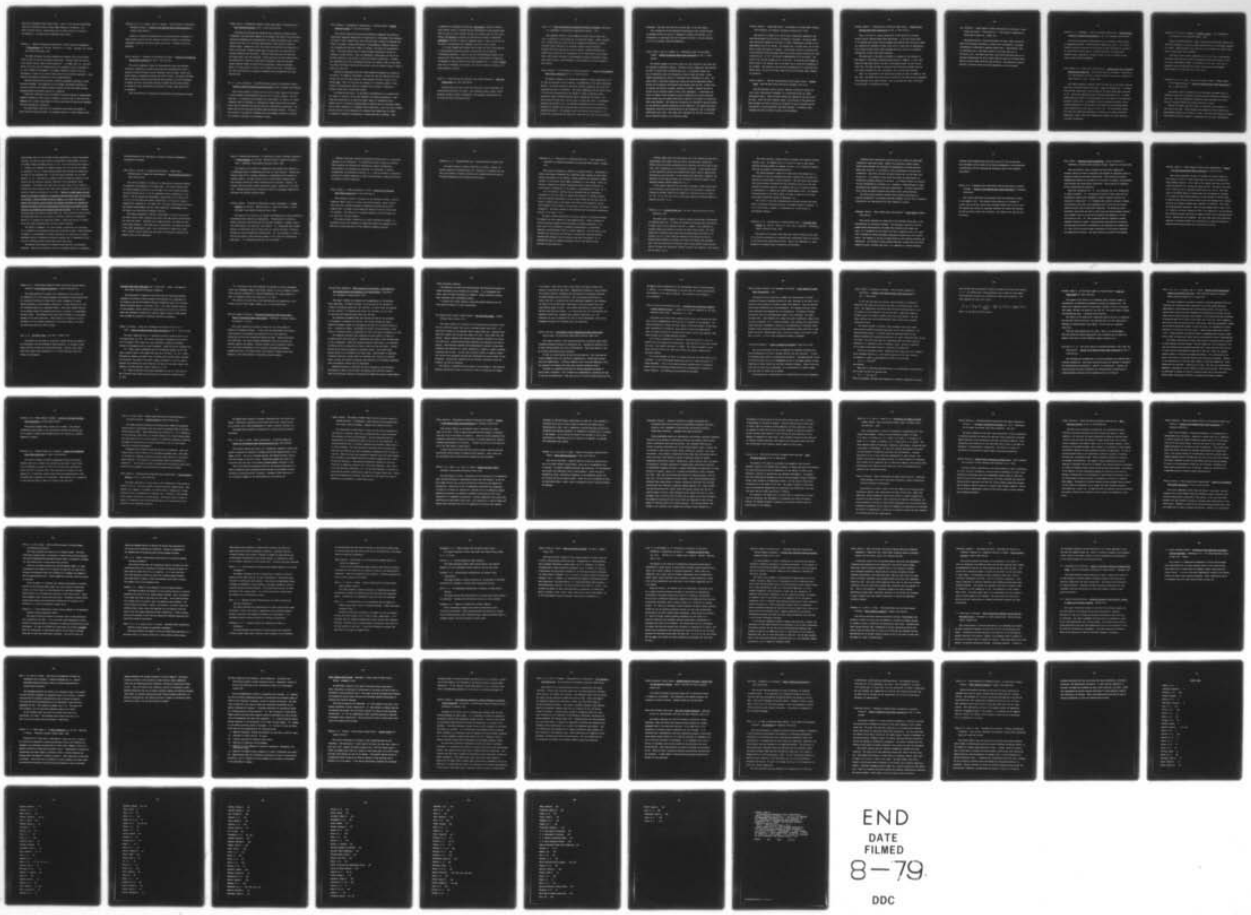

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keep water consumption within legal limits. Only in a few (but well-publicized) cases was a three-day cutoff of water supply imposed on residences. As a result of these efforts, average water use was reduced from 57 to 42 gpd (a 26% reduction). No major serious complaints were noticed.

Johnson, S. "Recent Sociological Contributions to Water Resources Management." In Man and Water, pp. 164-199. Edited by L. D. James. Lexington, KY: University Press of Kentucky, 1974.

The author discusses how water problems and solutions can be better understood in light of certain sociological principles. Societal values are the key to why people pollute. Some of these values are: (1) common land, air, and water belong to all but are the responsibility of no individual (this is referred to as the "tragedy of the commons"); (2) modern industrial societies view the environment in terms of its utility rather than for its intrinsic qualities. Class societies use physical resources to aid in upward mobility.

Societal values are also crucial to devising acceptable solutions to water resources problems. The simplistic use of economic cost-benefit analysis as the major criterion of program evaluation ignores the fact that major resource programs change far-reaching aspects of a community.

Despite the assistance which sociological principles provide in understanding community response to water resource programs, it must be kept in mind that each community has a unique constellation of factors which must be taken into consideration when programs are considered.

The author makes "good case" for considering sociological principles in water resource planning; however, the argument remains at a rather general level.

Jopling, W. F., D. G. Deaner, and H. J. Ongerth. "Fitness Needs for Wastewater - Reclamation Plants." Journal of the American Water Works Association 63 (October 1971):626-629.

Results of intensive investigation by the California State Department of Public Health show the need for improved reliability features at wastewater-reclamation operations for public health protection. Proposed criteria are presented.

Keller, Charles W. "Analysis of Unaccounted for Water." Journal of the American Water Works Association 68 (No. 3, 1976):159-162.

The article summarizes causes for unaccounted-for water and performs statistical comparisons of water utility data for unaccounted-for water in reference to major variables such as ownership, type of supply, svstem size, annual revenue, geographical location and value of water. The author concludes that distribution losses of less than 10% are excellent, 10 to 20% reasonable. If greater than 20%, calculations should be checked and then meters should be checked for under registration and detection of major leaks should also be attempted.

This recent article is technically oriented and not conservation oriented.

Klimek, John C. "Forecasting Industrial Water Requirements in Manufacturing." Water Resources Bulletin 8 (No. 3, June 1973):561-570.

Procedures are developed for estimating and forecasting industrial water withdrawals, with particular emphasis on the Oswego river basin of New York State. Industrial withdrawals are characterized on an intake-per-employee basis, using regional four digit SIC code data where possible (data from 1963 Census of Manufacturing). Industries in the river basin were surveyed for information on water use practices, expected future water use practices, and predictions of economic conditions for the future. Existing reuse practices, and potential for future reuse, were also reviewed. Future water use for each industry group was predicted as a function of base period employment, expected employment change, expected change in productivity per employee, intake per employee, percent of intake subject to reuse, and a weighted reuse rate. The base year was 1964, and forecasts of industrial withdrawals were prepared for the years 1990 and 2020.

Ko, S. C. and L. Duckstein. "Cost-Effectiveness Analysis of Wastewater Reuses." Journal of Sanitary Engineering Division ASCE 98 (SA6) (December 1972):869-881.

This article presents a study of cost as well as other aspects of four plans to reuse secondary treated effluent from the city of Tucson, Arizona. The four plans are: (1) exchange with irrigators for ground water; (2) same as (1) except irrigation land is purchased; (3) exchange with copper mining firms for ground water; and (4) discharge into Rillito Creek for "purification and storage." The report does not show why plan #4 differs from the present solution. Of note in this article is the authors' confidence that the secondary effluent is suitable for irrigation, although little evidence is given.

Kury, Channing. "Prolegomena to Conservation: A Fisheye Review." Natural Resources Journal 17 (July 1977):493-509.

This article reviews and analyzes philosophical assumptions and logics of historically important definitions of "conservation": Aldo Leopold, "The Conservation Ethic" (1933); Walter Firey, "Man, Mind and Land: A Theory of Resources Use" (1960); Ian McHarg, "Design with Nature"; Ciriacy-Wantrup, "Resource Conservation: Economics and Policies" (1968); G. Pinchot, "The Fight for Conservation" (1967). The author argues that one cannot discuss conservation outside of a normative or value context. Thus, his definition: "Conservation is the act of rational behavior in the context of social and natural limitations." He makes the subsequent point that "conservation actions" are conflict laden in that there are always conflicting values and thus prices to pay for whatever course is taken -- nothing is cost free.

Although he understands well that "some normative benchmarks are needed for a relative, if Sisyphean, rationality," he does not take the necessary next step and say that not only must there be a value context, but that it must be of a certain kind. Thus, not only does the concept of conservation require a value context, it requires that there be a certain set of values; it requires an absolute rather than a relativistic stance.

To illustrate this point: If the saving (non-depletion) of a resource were not "good," it wouldn't (or at least shouldn't) be called conservation -- some other word would have to be used (one doesn't speak of "conserving" slag). Indeed, there is a positive evaluation made on anything that is conserved; indeed, that is what a resource is -- something valued positively. Thus, one can go further and say that even if the depletion of a resource were somehow seen as "good," it couldn't be classed as conservation or words would have no meaning. Thus,

if depletion is forbidden by definition, even though it might be rational given certain values, it follows that for conservation to have meaning there must not only be a value context, but one of a certain kind, one that would protect and conserve a resource, one that would not permit its depletion regardless of the cost in terms of competing values. (Thus, one can see how the ethic of conservation will sometimes lose out to other values.)

It is this argument that permits Kury to point out that Ciriacy-Wantrup is forced beyond relativistic value to the position of not allowing "irriversible depletion." Thus, in the end, Ciriacy-Wantrup reneges on his position that "the evaluation of the utility of conservation (or depletion) is dependent on what the goals of the decision-maker are..." Instead, certain goals must be forbidden; for instance, the relief of famine by fishing if it would eliminate a species.

Lahav, R. "Israel Strives for Efficient Use of Water Resources." Water and Sewage Works 124 (June 1977):64-65.

Recycled water will not be used for drinking but will be available for unrestricted agriculture in Israel. Drip irrigation used on sugar, cotton, potatoes, tomatoes, grapes, strawberries, and eggplants reduced water use by 40 percent while increasing yields.

Lance, J. C. Water Conservation to Minimize the Effect of Drought. Washington: U.S. Department of Agriculture, Agricultural Service. 1977.

This pamphlet provides a brief summary of several topics along with a list of references for the reader who is interested further. Topics included are: tillage practices, water losses by seepage and evaporation, drought resistant crops, efficiency of irrigation systems, water harvesting, matching fertilizer application to soil moisture, limited irrigation when optimum water quantities are unavailable, use of saline water, use of wastewater, agricultural practices, snow management, mulches and minimum tillage, wind erosion control, range management, and irrigation at critical stages of plant growth.

Larkin, Donald G. "The Economics of Water Conservation." Journal of the American Water Works Association 70 (No. 9, 1978):470-474.

The author's purpose is to examine the economics of water conservation for the East Bay Municipal Utility District, as exemplified in the recent California drought. An overall cutback of 38 percent had been reached by the end of 1977, surpassing the goal of 35 percent. The article summarizes how the overall costs of the utility increased during the drought in terms of operation costs, engineering costs, customer services, public information and finance. The author points how most water utility costs are fixed and, thus, if consumption decreases prices must go up. The decreased consumption will be relatively permanent as consumers have installed water saving devices and learned water conservation habits. The economic costs to the utility were offset by a 33 percent rate increase and $6.8 million in grant and loan funds from the federal

government. The rates will need to be raised again in the near future.

This informative article delineates categorically costs incurred during the drought and how the utility is managing to address this problem. As to conservation, it speculates that the 38 percent decrease in use may stabalize to a 15 to 20 percent reduction permanently.

Larson, Bernt O. and H. E. Hudson, Jr. "Residential Water Use and Family Income." Journal of American Water Works Association 43 (No. 7, 1951): 603-611.

The authors attempt to correlate water use with variable(s) less gross than the variable of population density. Thirteen Illinois communities were selected in which to collect data on metered water use. A correlation between the use of residential water and estimated net family income was found. Cities sampled represented the variety of conditions found throughout the state. The study found no correlation between per capita use and the population served. Neither was an apparent relationship found between rates and use. Factors such as quantity and quality of supply, existence of sewers, pressure and age of system and use of meters seemed to have little importance. A correlation was found (no numbers cited) between per capita residential use and net effective buying income with use ranging from about 10 gpcd for low incomes to 52 gpcd for high income families. The income use correlation was improved by making allowance for the status of sanitary facilities in each community. The authors gave basic descriptive statistics of plotting points to see correlation, but no correlation coefficients were cited. The study, while important for its time is too gross and not explicit enough to be of much use today.

Laverty, Gordon L. "Leaks Make Lakes." Proceedings of an Urban Water Conservation Conference, Los Angeles, California, January 16-17, 1976.

The article is a report of an active water conservation campaign by the East Bay Municipal Utility District in Oakland, California. By using a small sonar device the company has detected in 2 years, experienced a savings of 4 or approximately 50% of the system. The program uses 2 two-man crews, who go from meter to meter and hydrant to hydrant. The program "involves a long walk over the distribution system and yellow penciling of every service and main on a grid coordinate map." (p. 98) The figure is approximately 2% of the output. The costs of the two-year program so far is $155,000. The program also attempts to locate leaks on the consumer side of the meter and to relay this information to the consumer. The program to date has been uneconomical as it costs more than amount saved. The use of the small sonar device for detecting leaks, however, is innovative.

Laverty, Gordon L. "East Bay Conserves Water with Surveys, Sonar." Willing Water. American Water Works Association (December 1977):12-13.

East Bay Municipal Utility District (Oakland, California) reports the use of sonic leak detection equipment in a system-wide survey for water distribution leaks. Leaks are being located and repaired at the rate of 450 per year. After the first eighteen months, fifty percent of the system has been surveyed, and leaks totalling an estimated 4.0 million gallons per day (two percent of total production) have been repaired. In addition, many customers have been notified of leaks on their premises.

Learned, Albert P. "Determination of Municipal Water Rates." Journal of the American Water Works Association 49 (No. 2, 1957):165-173.

This is the text of a paper presented at a 1956 meeting of the North Central Section, American Water Works Association. It has two central aims: 1) to identify and clarify certain problems confronted by water utilities; namely the occasions for increases in water rates and 2) to show that the appropriate rate schedule should convert these problems and their costs into a equitable distribution of water rates among customers.

The early part of the paper is devoted to a summary of the findings of Abel Wolman in "Providing a Reasonable Water Service", JAWWA 47, 1, Jan. 1955. There are some eight factors, and each is discussed briefly but with clarity. After this, the paper proceeds to discuss recent particular problems faced by the cities of Kansas City, Mo., Cincinnati, Ohio, and Billings, Montana.

Next, is a discussion of the statistical analysis of water in JAWWA 47, 1091 Nov. 1955. The paper then closes with an outline of five basic pricing implementations available to the water utility. Only in the last few lines of the paper is the subject of conservation treated.

Lee, Clifford T. "Legal Aspects of Water Conservation in California - Background and Issues." Staff Paper No. 3. The Governor's Commission to Review Water Rights Law. August 1977.

This paper presents a detailed discussion of water rights law and the legal tools presently available to enforce water conservation. The paper concentrates on individually supplied surface water. Unfortunately, this use represents only a very small portion of the total water use in California (11%). The paper notes that little action has been taken to investigate unreasonable use and to pursue judicial action by the State Water Resources Control Board which has such authority. The authority of public agencies to restrict water use during emergencies is also discussed.

Leonard, L. J. "Management: A Key to Irrigation Efficiency." ASCE Proceeding Journal of Irrigation and Drainage 94 (No. lR3, September 1968):285-293.

This article discusses reducing water use in irrigation through changes in management practices. Several specific examples are given. It is stated (without citation of source) that 42 percent of water delivered to the farm is not beneficially used by plants. Although some water is needed beyond immediate plant requirements, irrigation water use can be reduced in many areas by more efficient management.

Leone, Robert A., J. Royce Ginn, and An-Loh Lin. Changing Water Use in Selected Manufacturing Industries. The National Bureau of Economics. Submitted to U.S. Army Engineer Institute for Water Resources, Contract No. DACW31-72-C-0044, Report No. 74-10. October 1974.

This report presents a detailed review of water use in the paper, chemical, petroleum, and primary metals industries. Among the findings are: (1) Between 1954 and 1968, gross water used increased by 70% while intake water increased by 17%. Gross water applied per unit of product decreased by 7%. (2) These changes were due in part to increased water cost as a result of stricter water pollution control laws. An estimation of price elasticities using a micro-economic perspective in the context of the theory of the firm gives demand (cost) elasticities in the range of -0.5 to -1.0. (3) The findings suggest that water for industrial processing is unlikely to be a major locational determinant; rather, water for transportation seems to be a more important locational determinant.

Leopold, L. B. and W. B. Langbein. A Primer on Water. U.S. Department of the Interior, U.S. Geological Survey. 1960.

Among the authors' findings: "Water engineers have found that families are much more economical in the use of water when their use is individually measured by a meter. Familes paying a flat rate use, on the average, two times as much water as those whose use is metered."

"The final class of water consumption in a city is loss or unaccounted-for-waste; leaks from water mains and unmeasured leaks from faucets, as well as errors of measurement appear to contribute to this loss. This item is amazingly large and generally even careful construction and management cannot reduce it to less than 20% of total use."

Linaweaver, F. P. Jr., John C. Geyer, and Jerome B. Wolff. "Summary Report on the Research Project." Journal of American Water Works Association 59 (No. 3, 1967):767-782.

The authors' seek to determine water use patterns and demand rates in residential areas and to determine the major factors influencing residential water use. Forty-one homogeneous residential areas throughout the United States of varying climates were studied from 1963 to 1965.

Because of seasonal and hourly water use patterns, plant capacity is idle much of the time. "Rates would be more equitable if they reflected the peak demands imposed on the system." (p. 269) Flat rate users exceed all others. "Meters barely influence domestic or household use, but have a considerable

effect on sprinkling." (p. 271) Domestic use is basically non-consumptive; sprinkling is consumptive. Among the major influencing factors are: (1) number of homes; (2) economic level (r - .76 value of home) of consumer; (3) climate; and (4) metered or flat-rate service. In the west, maximum daily use does not greatly exceed average use. "The water system is designed to meet the expected maximum daily use, is operating reasonably close to capacity throughout much of the sprinkling season." (p. 275-277) "A water system in the east, if designed to meet the expected maximum daily use, will seldom operate at capacity." (p. 277)

In summary, it has been found that residential water demands for any duration depend on the number of consumers, their normal domestic or household use, the average irrigable area of their lawns, the rate of evapotranspiration and the quantity of precipitation. The maximum daily water demand, important in the design of water system components, can be estimated by calculating a value for potential evapotranspiration. In flat rate areas, peak demands are more than double because of high sprinkling demands. Domestic use is about the same in metered and flat-rate areas. Domestic use appears to be significantly lower in metered areas utilizing individual septic tanks for sewage disposal." (p. 281) The authors use regression equations and correlation coefficients.

Lupsha, Peter A., Schlegel, D. P. and Anderson, R. U. Rain Dance Doesn't Work Here Anymore, or Water Use and Citizen Attitudes Towards Water Use. Albuquerque: University of New Mexico, Division of Government Research. 1975.

The authors' purpose was to discover what typical consumers thought about water and water policies and how they consumed this resource. They studied Albuquerque, New Mexico, an area of rapid growth and low precipitation (8.4'/yr.) One-half of 1 percent (345 questionnaires) of the residential population was sampled. The sampling was stratified into five levels based on value of home. Samples were then clustered into neighborhoods. Eighty-three interviews were falsified and threw off a quadrant analysis of the NE, SE, SW, NW. Over sampling was done on residential homes with desert landscaping as only 1 1/2% of Albuquerque homes have such landscaping.

In August, 1974, the per capita use was 228 gpd (probably 114-152 gpd without commercial, industrial, users).

The authors' found that water use increases as income increases. Water use also increases as the value of the home increases. Use per capita declines with increasing household size; perhaps a "threshold for use has been passed for washing machines, dishwashers, etc." As the education level increases so does water use. Newer residents use less water than long time residents. Persons raised in cities of over 50,000 population demand less water than do those raised in other places. People from wet and dry climates tend to use less water, thus they reject the "hypothesis about the influence of prior experience and socialization as water use." (p. 16) Different consumption was found in each ethnic background. Eighty-five percent of the respondents said that they were water conscious. "One sees that per capita use at every income level is

significantly lower if one has what we have classified as a water conservation attitude. We also note that this has a particularly strong effect on use at the higher income and demand levels." (p. 21) "If one believes water supply is a problem, one's demands are somewhat lighter than if one feels the supply is unlimited." (p. 21) "These findings suggest that attitude can indeed have an effect on use and means that if one can change attitudes, one can alter demand." (p. 21) "Attitudes are probably filtered through the reality of self interest and the objective economic conditions of the household's micro-environment. The finding that small users are more likely to be in favor of differential rate structures than large users reinforces this self interest and objective condition conclusion." (p. 21-22) "Overall, it would appear that the impact of attitudes on demand is a relatively weak and minor aspect of any water use equation. While attitudes do have an impact, it is small and tends to reflect self interest, which probably has stronger surrogates in economic and appliance variables and micro-environmental factors which are probably better tested by the landscape and sprinkling practice variables." (p. 23) Different landscape types had different obvious water use. Most residents preferred cheap and unregulated water but are willing to consider a variety of conservation methods if it appeared the supply was limited. Seventy-one percent of respondents felt green landscaping was nicer than desert landscape.

The authors' recommend: (1) a move towards a progressive rate structure; (2) a recognition that excessive water-using appliances do make a large difference in demand; (3) encouragement of desert landscaping; (4) limitation or special assessment taxing of underground sprinkling systems; and (5) examination by the city of its billing system, because many errors were found.

The authors have produced an interesting study and use of sociological variables. Their use of statistics, while not extremely powerful, are adequate.

The study points out the importance of economic variables overshadowing psychological variables.

Lynne, Gary D., William G. Luppold and Clyde Kiker. "Water Price Responsiveness of Commercial Establishments." Water Resources Bulletin 14 (June 1978):719-729.

This article presents the results of a cross-section regression analysis of commercial establishments in the Miami SMSA. The results indicate that at the mean marginal water price of the sample ($1.25 per thousand gallons), the price elasticities are -1.33 for department stores (significant to 0.01 level), -0.89 for grocery and supermarkets (significant to 0.01 level), and -0.14 or -0.30 for motels and hotels (significant to 0.05 and 0.01 levels, respectively), depending on the model used. The price coefficients for eating and drinking establishments and for "other commercial" establishments were not found to be significantly different from zero.

This analysis apparently involved a large amount of trials to arrive at the final function forms (primarily log-linear with some log-log linear-linear and linear-log forms). Although this is common practice, the number of such trials seems excessive. This leaves one to wonder about the elasticity values of the other (unpublished) trials. Such a procedure of looking for a good "fit" (high R^2) ex-post usually has the result of artificially inflating the absolute value of the coefficient.

Maass, A. "Benefit-Cost Analysis: Its Relevance to Public Investment Decisions." In Water Research, pp. 311-328. Edited by Allen V. Kneese and Stephen C. Smith. Baltimore: Johns Hopkins University Press, 1966.

The purpose of the study is to demonstrate that benefit-cost analysis is an inadvisable means of determining the worth of a water project. Benefit-cost analysis looks only at economic efficiency, as determined by the increase in national product. But many projects have as their purpose something other than economic efficiency--income redistribution for instance. Moreover, the economic efficiency model weights each dollar equally, regardless of who benefits. Standard policies must be devised to arrive at acceptable trade-offs of desireable but mutually exclusive goals.

Marshall, Hubert. "Politics and Efficiency in Water Development." In Water Research, pp. 291-310. Edited by Allen V. Kneese and Stephen C. Smith. Baltimore: Johns Hopkins University Press, 1966.

The purpose of the study was an attempt to determine why so many economically inadviseable water projects are implemented. ("Inadviseable" is defined as grossly inaccurate pre-construction cost benefits estimates.) Marshall identifies three factors, two political, one economic: (1) Congressmen feel stronger loyalty to constituents than to either party or national interests; therefore, policies are often irresponsibly decentralized. (2) The President is loathe to use his veto power on water projects because it will erode his congressional power base. (3) Construction agencies wish to flourish.

Marshall cites three reasons why engineering professionals in construction companies can be "unethical": (1) professionals share a sense of a cultural ideal regarding the furthering of professional interest (professional socialization); (2) decisions are corporate, not individual, so ethical considerations are diffused and blunted; (3) a lack of consensus on appropriate criteria for economic evaluation of water projects permits, indeed, facilitates the masking of ethical questions.

McLeon, Robert J. "Water Conservation - Good," Journal of the American Water Works Association 68 (June 1976):PRR 17.

This editorial contains a discussion of the Washington Suburban Sanitary Commission (WSSC) views on its water conservation program. Water conservation, which here includes information campaigns and modifications of the plumbing code, is judged to have beneficial impacts on both the utility and its customers. The effects of a successful program on utility revenues are not viewed as a long-run problem.

The author provides a definition of a water conservation program: "a cooperative effort with customers to promote and foster the necessary use of water and to discourage waste of this important community resource."

McPherson, M. B. "Household Water Use." NTIS #PB-250-879, January 1976.

This paper presents a general discussion on economic, quality and quantity aspects of household water use. Variations in household use over short time intervals (minutes and hours) are analyzed using data from individual households and multi-family dwelling units.

McPherson, M. B. "Conservation in Household Water Use." Paper presented at Conference on Planning Alternatives for Municipal Water Systems. October 1976.

This article is basically a rehash of a previous article. "The amount of public water supply withdrawals is a relatively small fraction of total metropolitan withdrawals, on the average. Second, domestic use represents a modest fraction of total public water supply withdrawals, on the average. Third, any savings in domestic use through conservation efforts could be difficult to prove because of ambiguities in the amount of 'unaccounted-for' water." (p. 4)

"It is the writer's opinion that the possibilities for conservation nationwide, in the near term, are greater for reduction in leakage and waste than for household conservation, if for no other reason than the fact that the former is almost solely in the hands of the water works themselves, and the latter depends on the viability of incentives, social and/or economic, for public cooperation. Obviously, pursuit of one objective does not preclude simultaneous pursuit of the other." (p. 4)

The author claims conservation is not just reduction in quantity withdrawn and handled, but also reduction in peak demand periods. "While a decision to conserve existing supplies could conceivably be reached voluntarily, it is more likely to be a response to exogenous considerations, in particular, physical or jurisdictional limits to further expansion. Thus the issue of conservation has arisen much more obviously in water-short areas and wherever jurisdictional disputes over the resource have been encountered." (p. 4) "Residential water use probably represents close to one third of total municipal system production."

"Because almost half of in-house water use is for flushing toilets and an approximately equal amount used for bathing, personal uses, laundry and dishes, there are obvious possibilities for recycling the portion that is free from fecal contamination for the flushing of toilets. A first demonstration of this possibility showed that household water usage could be reduced about one-fourth by such recycling. On the average this might mean a community use reduction of less than one-tenth, but the potential would be highest in predominatly domestic-demand communities." (p. 7)

A 1971 study by Resources for the Future concluded, "Aside from the question of recycling, water-saving devices could save one-third of in-home use, although an economic incentive for adoption of such devices did not exist." (p. 7-8) "It is still not clear to what extent metering constrains demand in response to price." (p. 8)

McPherson, M. B. Household Water Use. New York: American Society of Civil Engineers, 1976.

The author gives a summary of quality, quantity and economic consideration of household water use. He states that people are concerned about the quality of water, and he cites references and current studies. As to quantity, he discusses waste flow reduction research and water reuse sources. The study states that "household water usage could be reduced about one fourth by recycling." (p. 5) "A 1971 study by Resources for the Future for the U.S. National Water Committee concluded on the basis of evidence then available that, aside from questions of recycling, water saving devices could save one-third of in-home use, although an economic incentive for adoption of such devices did not exist." (p. 6)

The author provides a general review of research with regard to economic considerations. He comments that "it is still not clear to what extent metering constrains demand in response to price." (p. 9) because of limited data and the problem of unaccounted-for-water.

The author describes a study of 12 houses which were metered for a 3 month period in 1972 and recorded every minute (Albany, NY); the study was basically an investigation of water pressure. "Not much short time interval data from individual households has been collected, little of it has been subjected to pattern analysis, and probably none of it is readily available to researchers in a complete and readily understandable form." The appendix has detailed data of one minute usage for about 2 weeks of 9 low income, large family households outside of Washington, D.C.

The article is very much technologically oriented, and goes into great detail to describe statistical analysis of pressure changes in plumbing. It is of little value in respect to conservation but is good source of bibliographic material.

McPherson, M. B. "Conservation in Household Water Use." In Municipal Water Systems, pp. 183-199. Edited by D. Holtz and S. Sebastian. Bloomington: Indiana University Press, 1978.

The purpose of the study, which dealt with urban residential water uses, is to show the contribution of household water conservation practices relative to the larger water conservation picture. Some of the impediments to implementation of household water conservation are discussed.

Household water conservation practices can have a small but significant influence on total water usage. Despite this potential, several factors operate which decrease the likelihood of implementation of these practices. Among those cited are: (1) Attitudes of water professionals have been anti-conservation. They have felt that the public should have all the water they can pay for. (2) A dearth of water usage data makes the effectiveness of conservation programs difficult to evaluate. (3) Economic benefits of conservation are interpreted too literally (i.e., sometimes a slight decrease in usage can postpone the necessity of new plant construction). (4) Water input/output often crosses municipal boundaries which makes policy change difficult.

The author places potential benefits from household conservation in realistic perspective. He provides plausible arguments for the lack of household conservation, but justification for these arguments is sparse.

Middlemas, Robin E. "Water Demand Meters Show Results." Public Works (December 1961):81-114.

This article describes the experience of the Milwaukee Water Works in demand metering of 5 wholesale customers. The maintenance experience with the demand meters manufactured by the Badger Meter Manufacturing Company was good. It is estimated that the meters will have a mechanical life of 10 years with "a minimum of tune-up maintenance adjustment necessary only on an annual basis." The response to the use of demand meters by the wholesale customers was substantial. One suburban village provided additional storage facilities which reduced its peak to average hour ratio to 2 compared to a similar wholesale

customer without demand meters which had a value of 4 for the same day. Also described are the results of the $10/ton assessment on "non-conserving" airconditioners and the alternate day sprinkling rules of the Milwaukee Water Works.

Miller, W. H. "Mandatory Water Conservation and Tap Allocations in Denver, Colorado." Journal of the American Water Works Association 70 (February 1978):60-63.

This article discusses the program for water use reduction in Denver in the summer of 1977. "By limiting outside watering to a maximum of 3 hours every third day, Denver water customers reduced use by 21 per cent." This measure was enforced by department employees who issued 5500 warnings and 238 ten dollar tickets for violations. The number of new taps was also restricted.

Milne, Murray. Residential Water Conservation. Davis: University of California, California Water Resources Center. Report No. 35, March 1976.

This non-technical report evaluates over four dozen commercially available devices for water conservation and presents an exhaustive search of aerospace technology and patent applications. These devices and various implementation methods are evaluated in the context of economic, institutional, socio-cultural and technological constraints. Four scenarios of homeowner-builder conservation are presented.

Among the conclusions are: (1) The technology for water conservation is readily available. (2) "Increasing the prices of water alone will not significantly reduce water consumption; however, changing from one rate structure to another may." (3) Plumbing codes should be revised to require cost-effective lower water using appliances and to allow the use of more advanced systems (such as grey water recycling). The Federal and State governments should take the lead in water reuse and should purchase conservation equipment, even if it may not be presently cost-effective, to help drive down the cost. (4) Rate structures should be changed to include commodity charges for sewers. Declining block rates should be eliminated and mastermetering should be prohibited in new apartments and condominiums. (5) Water utilities should promote conservation by educational campaigns and demonstration projects. The study contains an annotated bibliography.

Mitchell, Robert D. "Water Supply of Saint John's Newfoundland." Journal of the New England Water Works Association 71 (1957):173-187.

This article describes, in part, an attempt by the Water Authority that serves St. John's to reduce water waste that results from defective house plumbing fixtures. In St. John's, the average water use (up to 1951) ranged from 180-292 U.S. gallons per capita per day. The author notes that this is high even for an unmetered system such as St. John's. This high usage is attributed mainly to fixture waste and the tendency of consumers to run water at night through fixtures to avoid freezing of service pipes. A house-to-house survey of fixture waste by the City Engineers and a leakage survey by the Pitometer Company were undertaken in 1950-1951. This effort was rated partially successful. Water use was reduced from 9.0 mgd in 1950 to 7.5 mgd for the first 9 months of 1951; a 17% reduction to 140 gal/cap/day. This decrease occurred even while the number of water users increased substantially. Metering was not attempted. This case study shows that significant reduction in household leakage can be achieved in an unmetered system by a combined house-to-house survey and a leak detection survey.

Moran, Edward, "Waterless Toilets -- Modern Home Systems Turn Waste into Compost." Popular Science 212 (January 1978):74-76.

This article presents a consumer report on the use of composting toilets. The article describes the operation of composting toilets and gives prices (which range from $700 to $1500 plus installation). It is noted that "All this is not as easy as pulling a flush lever: a composting toilet does require some additional attention. . .Recent developments indicate that despite such nuisances, composters are here to stay and can co-exist with public health standards."

Morgan, Douglas W. "Residential Water Demand: The Case from Micro Data." Water Resources Research 9 (No. 4, 1973):1065-1067.

The author criticizes segments of Howe and Linaweaver's article (1967) and wants to test the argument that repressed variable dp (persons/dwelling) can be shown to be incorrect by use of microdata. He argues that Howe and Linaweaver deleated from the equation of best fit for metered and public sewer demand, the variable dp. Thus Morgan claims that according to Howe and Linaweaver "the bulk of residential water demand becomes a function of house value and price and is invarient with respect to the number of people residing in the dwelling unit (1065)."

Howe and Linaweaver use average area estimates of demand (with 21 observations) and therefore reduce the variance in dp. The author conducts a first stage opinion survey in Santa Barbara county. It was a random sample of 92 single family residents, with metered water and public sewer. Information was

was collected on dp, yearly water use, and value of property. The water price was uniform. Estimates were made of the linear function of variables and log linear for November-December, January-February, and of all 4 months combined.

In the results, the value and number of persons (dp) coefficients were positive and significant for all equations. There were very low r^2's, e.g., .19-.38, which indicate considerable variation. Income elasticities basically are the same as Howe and Linaweaver's for time periods of 'probable' in-house demand. The January-February set had highest people elasticity and lowest income elasticity, as well as the lowest r^2's.

The results "indicate an economies of scale with respect to household size holding other variables constant." (p. 1066) In an equation with a .57 people elasticity, a 10% increase in household size will produce a 5.7% increase in water use." Transforming the equations to a per capita form, "it is easily seen that as household size dp increases, water use per person declines approaching the asymptotic value of 17.8 hundred cubic feet per year." (p. 1066-1067) As the months become drier, value coefficients increase and dp decrease, but still are significant.

He concludes that the number of persons/dwelling is important and that "area projections based on Howe and Linaweaver's residential domestic demand model could lead to biased per capita use figure unless the people per dwelling unit is similar to their sample mean." (p. 1067)

However, he claims the wetter months of January and February are more closely related to in house demand because in November-December the rainfall is only 4.82 inches. This is an assumption which is not proven. In sum, the number of persons/dwelling was found to be statistically significant variable; as household size increases, however, per capita use decreases.

Morgan, W. D. "A Time Series Demand for Water Using Micro Data and Binary Variables." Water Resources Bulletin 10 (August 1974):697-702.

This study presents the results of an examination of the effects of the imposition of a $3.00 lump sum payment each bimonthly billing period plus an increase of $0.04 per 100 cubic feet of water consumed on 50 single family residences in Santa Barbara, California. A price elasticity of -0.49 was calculated based on an econometric model. This result suffers from the use of average rather than marginal price which is contrary to established economic theory. Using marginal price would have resulted in a much higher estimate of the price elasticity. These results are clouded by a lack of information on the consumer perceptions of this price change in the short run period from which the data was taken.

Moss, F. E. The Water Crisis. New York: Praeger, 1967.

The purpose of this study is to provide a primer for the lay person on the hydrologic cycle and problems of water pollution. It provides a good general picture of water use in the United States. However, since eleven years have elapsed since publication, it is likely that many facts and figures are inaccurate.

Municipal Waste Water Reuse News, No. 9 (June 1978). Denver: The American Water Works Association Research Foundation.

This publication is apparently associated with the Technology Transfer programs of the Office of Water Research and Technology (U.S. Department of the Interior) and the Environmental Research Information Center (U.S. Environmental Protection Agency in Cincinnati, Ohio). This issue includes articles on land treatment, health effects, the Clean Water Act of 1977 (P.L. 95-217), sugar cane wastewater irrigation and digital computer control of AWT systems. Also included are programs of conferences and policy statements.

Murray, C. Richard. "Water Use, Consumption and Outlook in the U.S. in 1970." Journal of American Water Works Association 65 (No. 5, 1973):302-308.

The author summarizes the U. S. Geological Service's study of water use in the United States for 1970. The article describes by geographic region and by use, the present (1970) water use, water withdrawal, supplies and demands, sources and consumption data of water withdrawal. Among the points considered are:

(1) "Public supply withdrawals used for residential purposes in the West cause a greater draft on the supply than they do in the East." (p. 303) "Water delivered for domestic and public uses (including water system losses) accounted for 74 percent (130 gpcd) of the public supply withdrawals in the nine western regions, but accounted for only 65 percent (100 gpcd) of the public supply withdrawals in the more populous eastern regions." (p. 303)

(2) "About 86 percent of the water consumption in the U.S. took place in the 17 western states where only 40 percent of the country's runoff occurs." (p. 304)

(3) "At present, most water problems are problems of resource management rather than inadequate supply; the outlook, however, is that as demands increase, better planning accompanied by increased expenditures for larger supplies of water of acceptable quality will take place." (p. 308)

This article is a good source, both descriptively and graphically of the current status of water supply, demand, etc., in the United States.

National Academy of Sciences. Potential Technological Advances and Their Impact on Anticipated Water Requirements. Washington: National Academy of Sciences, June 1971.

This report analyzes the impacts on water use of a large number of potential technological changes. In each case the technological and institutional barriers are discussed and predictions of the time needed for feasibility and for fully operational systems are made. Research priorities are established. The report analyzes developments that will increase and decrease supplies and demands. Economic aspects are not analyzed in detail. It is noted that developments such as recycling and advanced wastewater treatment may have a far greater impact than systems to augment fresh water supplies or than other methods of conserving existing supplies.

National Water Commission. Water Policies for the Future: Final Report to the President and to the Congress of the United States. Washington: U.S. Government Printing Office, 1973.

This report contains the findings and recommendations of the National Water Commission. Included in Chapter 7 are the areas of (1) "pricing as a means of motivating better use" (pp. 247-259); (2) water rights and reparian law (pp. 260-294); (3) reducing water losses (pp. 291-304); and (4) reuse of municipal and industrial waste water (pp. 305-315).

The commission recommends that water pricing be based on the principle of incremental or marginal cost pricing. This should include the States imposing withdrawal charges on self-supplies but may not be possible because of prior contracts or rights. The problem of failure to price properly is most severe in irrigation which is responsible for 83% of all water consumption (p. 256).

The commission advocates free bargaining of water rights as a means of allocating water more efficiently. Establishing the right to sell salvaged water is also recommended. Within the existing system of water rights it is desirable for Western States to quantify the "duty of water" by crop and region. Similar quantification should be applied to conveyance losses. Uses beyond these amounts should not be included in the water right. Other methods of improving irrigation efficiency include choice of reservoir site, lining of irrigation canals, trickle and sprinkle irrigation, and eradication of streambank vegetation (here environmental effects must be considered).

Improved efficiency in municipal use can be obtained by leak detection, installation of meters, price policy, encouraging water efficient fixtures (38% and 50% possible savings for household and commercial-business establishments

cited) and public relations.

The potential for reuse of treated municipal and industrial wastewater is judged encouraging (cost estimates are included). It is recommended that direct reuse for human consumption be deferred. Sewage effluent-irrigation water exchanges holds considerable promise.

In general this report contains a very good general discussion of the above-mentioned aspects of water conservation.

The National Water Council (Great Britain). The 1975-1976 Drought. London: National Water Council, 1977.

This report details the activities of the British water utilities to deal with the 1975-1976 drought (the worst in recorded history since 1727). Of particular interest are the measures used to reduce water use. Generally these began with appeals which became more urgent over time. Public media were very helpful. Appeals combined with hosepipe bans typically achieved 20 to 25 percent reductions. Savings from pressure reductions were generally less than 10 percent. Leak-reduction programs saved approximately 5 percent in some areas. Industries were generally not closed, apparently in response to public sentiment concerning loss of jobs. In some cases rotating cut-offs or complete residential cut-off with standpipes provided were subsituted with total savings to over 40 percent. Because most residences are not metered, rationing or fines for excessive use were not possible.

The Council is satisfied with the amount of prior planning. More detailed planning, specifically rules as a function of rain or storage are not judged

to be useful. There are too many social factors that must be taken into account to use hard and fast rules. Implementation planning is very necessary for rotating cut-offs, standpipes and leak detection and pressure reduction. No health problems were encountered. Very few persons placed bricks in toilet tank (9%) or installed dual flush mechanisms compared to the responses for pleas to cut in bath water, reuse water, flush the lavatory less, and stop watering garden (76-90%). Here advance distribution of water saving devices would have been helpful. It is noted that the use of prohibitions and mandatory restrictions (hosepipe bans, pressure reductions, etc.) are effective not only in themselves but also in the re-enforcement of the crisis atmosphere necessary for voluntary water use reductions.

Nelson, John Olaf. North Marin's Little Compendium of Water Saving Ideas. Marin County, CA: North Marin County Water District, March 1977.

This report contains a very detailed description of possible water saving techniques primarily directed at residential use. Included are extensive lists of water saving products and lists of distributors. Three case studies in the use of water saving devices are presented.

Of note is a short section on water pricing policies. Flat rates and declining commodity rates are rejected as inappropriate. Uniform and seasonal rates are judged better. Inclining commodity rates "have been employed in very few instances and normally only when water shortage conditions exist."

Included is an appendix describing the drought management programs of Marin County, California. Also included are recommendations concerning the case of grey and reclaimed water. Grey water for use in toilet flushing should go into

the bowl to avoid contamination of the distribution system if system pressure is lowered. It is recommended not to use grey water for either growing fruits and vegetables or for spray irrigation. Do-it-yourself reuse plumbing is not recommended.

Office of Science and Technology Policy. Scientific and Technological Aspects of Water Resources Policy. A Report for the Policy Committee for the Water Resources Policy Study. Washington, D.C., 1978.

This paper cites twelve water resource policy issues and discusses the findings, policy recommendations and directions for research in each category. The issues discussed are: climate and water supply, floods and droughts, ground water, water conservation in irrigation, water quality, erosion and sedimentation, water for energy, methods for increased water supply, future water demands, urban water programs and a systems approach for water.

As for water conservation in irrigation, eighty-two percent of total consumptive use is accounted for by agriculture. Less than half of this water reaches the crops. Much greater efficiency is needed. The authors recommend a policy change that will reflect the high value of water for energy, industrial and municipal purposes.

As to future demands for water, the authors note that the water demand is not inflexible. In the future demand modification will be a viable alternative to supply management. This in turn requires greater sophistication of projection models which will encorporate demand controls as alternatives to investment in greater supplies. Cost-sharing policies should be encouraged.

Office of Water Research, U.S. Department of Interior. Social Aspects of Urban Water Conservation. 1972.

The purpose of this study was to examine the effectiveness of various conservation measures implemented during the water shortages of the 1960s, and to ascertain the attitudes of the public toward these measures. Data was obtained from on-site visitations with city governments. The response from most cities whose cooperation was requested was not enthusiastic. The danger of drawing conclusions from this unrepresentative sample is not discussed. The report concludes that: home consumers will comply with water conservation requests when the need is apparent; it is uncertain whether a rate increase will significantly change home water consumption; opinions on the advisability of voluntary versus mandatory water conservation actions during emergencies varied from city to city; people are poorly informed about water, as little is known of its source, treatment, or price. A list of home conservation methods is appended.

"Can We Use Greywater." Organic Gardening and Farming 24 (May 1977):32-38.

This article discusses the use of greywater for household irrigation and gives recommendations for both "drought reaction" and "the long haul." "55-60% (of household waste water) is classified as greywater." Seventeen percent of this is from the kitchen and is not recommended for use in the garden because of harsh chemicals and grease (which can clog drip irrigation systems). Borax is the only other item to avoid that is mentioned. It is cautioned not to spray irrigate with grey water as leaves will be burned.

Also presented is a "home version of a trickle/filter" for use on greywater.

Orlob, Gerald T. and Marvin R. Lindorf. "Cost of Water Treatment in California." Journal of the American Water Works Association 50 (No. 1, 1958):45-59.

At the time this paper was written, rapid increases in California's population had caused an acute water shortage in the southern part of the state. The comprehensive California Water Plan was delivering water to the Los Angeles area for upwards of $45 per acre-foot. Means were sought to estimate costs of the major treatment works then being planned. The best known available tool was the Hardy-Whitman Index of Water Works Property Construction Costs.

The authors attempt to develop a water treatment plant (COST index) which would be readily synthesized from data on unit costs published in the Engineering News Record. A detailed study was undertaken based on this material breakdown and construction practices of a newly constructed water filtration plant. The unit chosen was the 6 mgd Oakley Water filtration plant designed by R. E. Runsakier & Assoc. of Berkely, Calif., and put in operation by the Oakley County Water District, California in January 1957.

This was a statistical study. Regressing total capital cost of a complete water treatment facility C_c, on the design capacity of the plant in mgd to be reached in n years, Q_n and equations of best fit of the form:

(1) $C_c = 257\ Q_n^{0.67}$

was obtained.

Where cost of operations and maintenance C_c was regressed on average daily plan in mgd, the best fit equation was,

(2) $C. = 68.4\ Q_a^{-.41}$

These two dependent variables were regressed on different independent variables.

Hence further work was required to obtain an equation for total cost, putting $R = Q$. on a growth ratio, and calculating a Q_E in terms of R and several other production variables as an"equivalent" daily water production. The final equation for total cost C_T was:

$$(3) \quad C_T = 704\, Q_n^{-.33} \left[\frac{F}{Q_{E/Qn}} \right] + \frac{68.4}{n}\, Q_n^{-.41} \int_0^n \left[R + \left(\frac{1-R}{n} \right) t \right]^{-.41} dt.$$

where F is the capital recovery factor.

Pagorski, Albin D. "Is the Public Ready for Recycled Water?" Water and Sewage Works 121 (June 1974):108.

The purpose of the article is to determine public response (degree of acceptability) to hypothetical wastewater recycling for domestic use. The author did an empirical survey in Lake Forest, Illinois in 1971 of 114 people (59% female, 41% male, 59% under 30, 41% over 30). The author seems to assume that hypothetical behavior predicts actual behavior.

The results of the study paint a generally positive picture of acceptance; 81% said they would be willing to use recycled water if it met same quality standards as existing public water supply. As cost went up, acceptance levels fell.

There are some problems with the study. There is no acknowledgment that the results are purely hypothetical, and no distinctions are made with regard to the types of usage (drinking, bathing, washing, etc.).

Phillips, W. J. II. "The Direct Reuse of Reclaimed Wastewater: Pros, Cons, and Alternatives." Journal of the American Water Works Association 66 (No. 4, 1974):231-237.

The advantages and disadvantages of recycled wastewater are examined from a technical perspective. Past water recycling projects are examined to determine the effectiveness of purification. Results are encouraging. However, the author cautions that more virological and bacteriological research must be conducted before recycling can be considered safe in the long run.

Pope, R. M., Jr., J. M. Stepp and J. S. Lythe. Effects of Price Change Upon Domestic Use of Water Over Time. Water Resources Research Institute, Clemson University Report No. 56, March 1975.

The report presents an excellent literature review and estimates the price elasticity for residential water through the use of time series data from approximately 1,000 households from 4 South Carolina cities. For each city monthly meter readings for each household were obtained for the period one year before and two years following a price change. Price elasticities were calculated by comparing water use in year one with water use in year two and by comparing water use in year one with water use in year three. When these percentage changes are divided by percentage changes in price the result is 8 estimates of a price elasticity (2 for each of the four cities). These values ranged from +0.094 to -0.512. Other estimates are presented based on disaggregations by month, income class, number of persons per family and by "lawn irrigation" versus "nonirrigation".

The authors contend that the water users return to old habits after a period of time following the price change. The main support for this contention is the fact that elasticities calculated from water use in year three are lower for all 4 cities than the values based on water use in year two. There are, however, several reasons to distrust this supporting evidence. The time period of two years is too short to distinguish between short and long run behavior. Weather is not accounted for in this very small sample of years and communities. Sewer charges are not mentioned. Average price is used. The last, but possibly most important, consideration is that nominal not real price was used. This alone may be sufficient to explain the return to previous water use as real price will decline under inflationary conditions if nominal price remains constant.

Powell, F. "PS Tests Bathroom Water-Savers." Popular Science 211 (August 1977): 120-122+.

This article involves a "consumer reports" type examination of water saving devices. Among its findings were: (1) Five different flow control shower heads ($8-20) (flow 2.5-3 gpm) were found to give good performance (subjectively good showers). Washers ($1) (3-5 gpm) also worked well. (2) Flow reducing faucets were recommended only when replacing faucets for other reasons since most users are volumetric. (3) Toilets with dams in the closet ("Moby Dike", "Little John") (less than $5) (2.5-3.5 gal/flush) performed better than those without dams and used much less water ("cornflake-flushability test"). (4) The dual action flush system tested ("EcoFlush") (no price given) (1.5-2.5 gal for liquid waste) was judged more difficult to install than the dams. (5) Brick-or-bottle-in-the-tanks were judged to significantly reduce effectiveness of flush, were not recommended, and were judged less satisfactory than dams.

The author reported a 30% water use reduction with 3 toilet dams and 2 shower heads in his own home with no reduction in quality of shower or flushing. The author also reported on a 2-qt. compress-air-water toilet ("Metrophor", $600) and a 0.5 gpm compress-air-water shower head ("Minuse", $260).

Primeaux, Walter and Hollman, Kenneth. "Factors Affecting Residential Water Consumption: The Managerial Viewpoint." Water and Sewage Works 1974: R138-R144.

The purpose of this study is to ascertain the effects of price and other socioeconomic variables (13 in all) on water demand in residential households. Data for the study was obtained from personal interviews and from municipal officials. Four hundred and two single family households were randomly chosen from, and distributed evenly among each of 14 Mississippi cities with population between 5,500 - 21,000.

Among the 13 variables studied, 3 are "social" (education, age of head of household, and race). Of these three, only education was found to be related to water quantity consumption; age and race have no influence. Among the other variables studied, variation in consumption was related to number of persons in the residence, presence or absence of a swimming pool, price, and lawn area. In sum, "...consumers are relatively unresponsive to price differences within the price range displayed by the cities in the study group. Price can be used effectively as a revenue raising device but probably ineffectively as a rationing device...the number of residents per household is the primary determinant of per household water consumption..."

Quraishi, G. M. "Water Demand in Sweden." Journal of the American Water Works Association 54 (July 1962):776-780.

This article presents data on water use in Sweden. The positive correlations which appear in U.S. data between average use and peak use do not appear in Swedish data perhaps because lawn watering is a smaller component of demand.

Quraishi, G. M. "Domestic Water Use in Sweden." Journal of the American Water Works Association 55 (April 1963):451-455.

This article presents detailed disaggregated statistics on purely domestic water use in Sweden, both current and projected. Toilet flushing is estimated to account for 30% of use in 1963 and is projected to account for 20% in the year 2000. These statistics are based on a tank capacity of 3.3 gal/flush; however flush tanks being manufactured in 1963 in Sweden have a capacity of 2.4 gal/flush. Total domestic use is projected to rise from 43.5 gpcd in 1960 to 71.5 gpcd in the year 2000.

Rees, J. A. and R. Rees. "Water Demand Forecasts and Planning Margins in South-East England." Regional Studies 6 (March 1972):37-48.

This paper presents estimates for projected water demand for South-East England that are considerably lower than previous estimates made by the Water Resources Board (WRB). These differences are attributed to: (1) a difference in the functional forms used; (2) the WRB estimates use of local figures which have some implicit level of safety margin; (3) different assumptions concerning the impact of higher prices for private abstraction; and (4) local double counting of projected developments.

Procedures for calculating "planning margins" are presented. These procedures suffer from the nature of the regression procedure used. Time (year) is included as a dependent variable even though time cannot be in any sense a causal variable. This feature of the projections makes the procedures inappropriate. The article also fails to explain why the basically linear extrapolation can be expected to be more than the methods used by the WRB.

Reid, George W. "Multistructured Municipal Water Demand Model." Water Resources Bulletin 7 (No. 6, 1971):1238-1245.

This paper represents an initial step in the introduction of the theory of logical causality into the problems of constructing water demand models. Each system, be it supplier or consumer, is viewed as both a subsystem of a larger structure and as an agglomeration of smaller ones. Attention is then focused on the various interactions of those systems. Particular notice is taken of resource conservation and the multifaceted input of the introduction of resources into the simplified structure.

The demand model consists of economic, population and "life style" sub-models. Population is forecast for the entire nation (the logical universal structure) and is then disaggregated to states, countries, regions, etc.

The demand model presented is applicable to a wide variety of planning situations.

Rice, I. M. and L. G. Shaw. "Water Conservation - A Practical Approach." Journal of the American Water Works Association 1970 (1978):480-482.

This article reports the results of a conservation campaign in Dallas that placed a surcharge on residential customers during peak demand periods in the summer of 1977. The ratio of maximum day/avg. day demand declined 8 percent from the average of the last 5 years. Maximum day pumpage was found to be 12 percent less than that of the highest maximum pumpage recording in 1974.

The article details encouraging results of the Dallas pricing policy to reduce residential water consumption during periods of peak demand, showing the merits of pricing policies in general. Although of short duration, it is an excellent example of the effectiveness of a pricing policy.

Ridge, Richard. "The Impact of Public Water Utility Pricing on Industrial Demand and Reuse." Philadelphia: Water Resources System Engineering Lab, General Electric Company. November 1972 (NTIS PB 214-393).

The relationship of water price to water use and reuse is examined for five specific industries: paper mills, paperboard mills, poultry dressing, malt brewing, and fluid milk processing. Data was obtained by mailing questionnaires to representative firms in each of the five industries. Of 380 questionnaires sent, 90 useable responses were received, ranging from 11 to 34 per industry. The rate structure of the water utility serving each firm was also obtained, and used to determine the marginal price of water to the firm. Water use rates were regressed on marginal price and other explanatory variables, giving demand functions for publicly supplied water in each of the five industries. Statistically significant estimates of the price elasticity of demand are given for two of the five industries: malt liquor, -0.3; and fluid milk processing, -0.6. Of the firms surveyed, 35 percent reported having recently limited water intake due to higher intake cost. Typical water reuse measures are reviewed, and found to be well within the range of feasibility as adjustments to higher water prices.

Robie, Ronald B. "California's Program for Dealing with Drought." Journal of the Ameircan Water Works Association 70 (February 1978):64-68.

This article reports on the measures taken in California to reduce water use in 1977. "With an urgent and perceived need cutbacks in municipal water use of up to 50 percent is possible. . .Based on current experience this (mandatory conservation including rationing) is usually required for cutbacks exceeding approximately 20-25 percent. . .Farmers can get by on less water but not to the same degree as urban users."

In many cases short-term ground water mining greatly lessened potential agricultural losses because of reduced surface supplies. Other events and new contingency plans arising from the drought are also described.

Russell, C. S., Arey, D. G., and R. W. Kates. Drought and Water Supply. Baltimore: Johns Hopkins University Press, 1970.

The book presents in part, a description of the activities of 39 communities which suffered shortages in Massachusetts during the 1966 drought. By far the most common activity was to place restrictions on water use and appeals for conservation. Thirty-four of the 39 communities restricted lawn sprinkling; of these 34, 10 banned all outside use. Thirteen of the 39 communities placed mandatory restrictions on industries (primarily recirculation) and 9 other "requested" or recommended recirculation. Nineteen communities also placed some restrictions on some public sector uses. Also reported is a study by Hudson and Roberts which indicated that 64 of 75 communities in Illinois that suffered

shortages in 1953-1955 placed restrictions on water use. Other methods of curtailing water use for short periods of time were not widely used in Massachusetts in 1966. Only 3 communities increased metering activities or increased leak reduction programs. No communities increased price in response to the drought. It is noted by the study if the shortage is 10% or less, restrictions on industrial use are not likely to be imposed. No problems with enforcement were evident.

Schaake, J. C., Jr. and D. C. Major. "Model for Estimating Regional Water Needs." Water Resources Research 8 (June 1972):755-759.

This article describes a computer model for projecting regional water use in the North Atlantic United States. Water use is disaggregated into 3 sections: (1) publicly supplied municipal and industrial; (2) self-supplied agricultural and industrial; and (3) rural domestic. Sector one use is estimated by using a time-series regression on the population served, the use of water and the per-capita income. Sector two use is estimated by using an input-output model. Sector three is estimated by using a fixed per-capita use approach.

Schmisseur, Wilson E. "Economic and Water Use Impacts Associated with Alternative Water Pricing Policies of Established Irrigation Districts." Corvallis, Ore.: Department of Agricultural and Resource Economics, Oregon State University. September 1976 (NTIS PB 259-559).

Linear programming models are constructed of two diverse, operating irrigation districts for the purpose of identifying technical and economic effects attributed to alternative water pricing policies. The irrigation districts are located in separate watersheds east of the Cascade mountain range in Oregon, and are planted in crops such as barley, wheat, alfalfa hay, potatoes, corn, mint, and pasture. Crop response to applied water was taken from the previous work of Salter and Goode ("Crop Response to Water at Different Stages of Growth," Commonwealth Agricultural Bureau, Farnham Royal, Bucks, England, 1967) and Conklin and Schmisseur ("Economic Evaluation of Proposed Water Conservation Practices on Established Irrigation Districts: A General Methodology and Application to Three Districts in Oregon," report to U. S. Bureau of Reclamation, Denver, Colorado, May 1976). Other data was obtained from records of cropping patterns, farm income, etc., for the irrigation districts chosen. The linear programming models maximized farm income subject to various constraints associated with irrigable acreage,canal flow capacities, reservoir storage capacity, etc. Three alternative pricing policies were tested: fixed cost pricing (annual flat fee for a fixed allotment of water), base allotment pricing (annual flat fee for a base allotment, plus a per unit price for water use in excess of the base allotment), and responsive pricing (per unit prices which are increased at times of peak demand to constrain water use to system capacity). The results indicate that changes in the effective price charged for irrigation water (whether as a

consequence of pricing policy or for any other reason) bring about a variety of adjustments on the part of farmers. Available substitutions include types of crops, types of irrigation systems employed, and water application rates. As compared to fixed cost pricing, both base allotment pricing and responsive pricing achieved some reduction in both average and peak diversions, at the expense of reductions in farm income. Base allotment pricing was more effective in reducing average diversions, and responsive pricing reduced peak diversions more effectively, while causing a smaller impact on farm income.

Schufle, J. A. "How Can We Live With a Permanent Water Shortage." Water Resources Bulletin 4 (No. 4, 1968):46-49.

The purpose of the paper is to question the assumption that the arid Southwest should use its limited water resources to expand agriculture and industry. The author decries plans for the importation of vast amounts of water to the Southwest in pursuit of agricultural and industrial development. He suggests that such growth may be untenable in such an arid environment and may, therefore, trigger chain reactions of undesirable results - not the least of which would be destruction of the beauty of the area. The author's opinion is that water used for recreational purposes may be economically more beneficial to the area than water used for either agriculture or industry.

The strength of the paper lies in the fact that it crystallizes and questions the assumption that development is synonymous with social well-being. However, the somewhat simplistic treatment of the subject detracts from the effectiveness of the argument.

Sewell, W. R. D. and B. T. Bower et al. Forecasting the Demand for Water. Ottawa, Canada: Policy and Planning Branch, Dept. of Energy, Mines and Resources. 1968.

This volume presents a series of discussions on methodologies for forecasting water demands. Authors of the discussions include C. W. Howe, R. W. Judy, G. M. Brown, Jr., R. E. Capel, D. W. Ross, P. H. Pearse, W. M. Baker, A. C. R. Albany, in addition to B. T. Bower and W. R. D. Sewell. The water demands treated are municipal, industrial, agricultural, recreational and "in-stream" or flow-demands. In each case a general discussion of the water use and problems of forecasting that water use are presented. A general description of one or more potential methodologies is then outlined. The general conclusions of most papers are that (1) current methods of forecasting water demand are too simplistic and (2) while more complex or more sophisticated methodologies will improve accuracy there will still be considerable error especially for long-term forecasts.

Sharpe, William E. "Water Conservation with Water Saving Devices." Paper presented November 1976 at the "New Jersey Conference on Water Conservation," Rutgers University, New Brunswick.

This article is a basic, "state of the art" summary of the existing water conservation devices, their applications and their success rate. Waste flow reductions, energy consumption reduction and effects on sewage treatment and collection are also discussed. After outlining the available technologies, the author proceeds to outline the steps towards implementation of an effective water conservation program by using a variety of examples both hypothetical and existing. The article is comprehensive, concise and an excellent overview of water conservation alternatives and their applications.

Sharpe, William E. "Residential Water Conservation With Water Conservation Devices." In The Water Conservation Challenge, pp. 32-37. Bloomington, MN: The Upper Mississippi River Basin Commission. May 1978.

The author summarizes three basic topics pertaining to water conservation. In addressing methods for meeting the municipal water conservation challenge, Sharpe discusses pricing and metering and water conservation devices. Water conservation case histories are then described such as those of the WSSC and Gettysburg & Springettsbury, Pennsylvania. The article is closed by a discussion of the potential consumer impacts from water conservation.

Sharpe, William E. Domestic Water Conservation Research Plan. Report prepared for the Office of Water Research and Technology, July 7, 1978.

The major factors contributing to the recent emphasis on water conservation are first outlined, followed by a state-of-the-act assessment of current water conservation technology along with recommended research needs for each area. After outlining a four year research plan, the author concludes that potential savings would be impressive but that the "vitally needed conservation program may be doomed to failure" because of a general lack of basic research. This is one of the most comprehensive surveys of the current status of water conservation technology available.

Sharpe, William E. "Municipal Water Conservation Alternatives." Water Resources Bulletin 14 (No. 5, 1978):1080-1087.

Municipal water conservation alternatives are categorized as public education, pricing and metering, and water conservation devices. Sharpe comments on the rationale for water conservation programs by municipal water utilities, and notes that the desires to reduce sewage flows, or to reduce energy consumption, have played a major role in the programs examined. Public education is considered helpful, and is stated to be necessary to insure speedy and effective adoption of water conserving fixtures and appliances. The use of pricing policies alone is not considered an effective strategy in achieving national water conservation goals. Water conservation devices are stated to be extremely cost-effective. The impact of water conservation on utility revenues is discussed, and the use of marginal cost pricing policies is advocated as a means of avoiding revenue erosion caused by water conservation. Constraints on the adoption of water conservation methods are stated to be the lack of suitable, unbiased data on the performance of water-conserving fixtures, and on the effectiveness of various devices or combinations of devices in reducing water demand. Availability of devices through customer plumbing fixture outlets is also noted as a constraint, as is concern over rate increases resulting from reductions in water use. No empirical data is presented, and the conclusions are based on review of the literature and the author's own experience in the field.

Sharpe, William E. "Water and Energy Conservation With Bathing Shower Flow Controls." Journal of the American Water Works Association 70 (February 1978):93-97.

This article documents a controlled experiment in two dormitories at Pennsylvania State University. Reduction in shower water use in comparison to control periods and control dormitories ranged from 37.5 to 62 percent, with the low flow shower heads. Very low flow rates (2.0-2.5 gpm) were judged satisfactory on the basis of lack of complaints. Other studies have shown that shower time does not increase significantly with lowered flow rates. Flow control devices at the University proved very economic with a complete payback period of 28 days when the costs of hot water are included. The overall reduction in water use from shower head flow controls depends, of course, on the percentage of water use for showering. Estimates from other studies ranged from 7.2 to 30 percent. Caution on retro-fitting is recommended because of possible unique characteristics.

Sharpe, William E. "Why Consider Water Conservation?" Journal of the American Water Works Association 70 (No. 9, 1978):475-479.

The article summarizes recent state and federal legislation, national plumbing codes, local plumbing codes and ordinances, agency regulations and appliance manufacturers promotions as they pertain to the fact that water managers will most probably be forced to consider water conservation in their future plans. Emphasis is placed on the interrelationship between water usage and sewage both in terms of quantity and pricing. Benefits of a conservation

campaign may prolong hydraulic life of sewage plants, as well as water storage and treatment facilities. Conservation will also aid in the deferrment of capital expenditures. Inflation creates a more serious problem in the pricing of water than price charges due to conservation measures. Customers utilizing conservation measures will save money in the long-run however.

This excellent article is a good summary of legislation and its impact on water conservation. The article points out the benefits of conservation, tempered by current economic trends.

Sharpe, W. E., and P. W. Fletcher, editors. Proceedings - Conference on Water Conservation and Sewage Flow Reduction with Water-Saving Devices. Institute for Research on Land and Water Resources. Pennsylvania State University, July 1975. Information Report No. 74.

This report contained the following 20 papers:

Grear, M.J., "Residential Water Conservation: The Suburban Maryland Experience, 1970-1975."

This paper describes the experience of the Washington Suburban Sanitary Commission's water conservation program and outlines research needs. It is noted that little is currently known of the effects of public education programs and utility-sponsored distribution of water-saving devices. It is estimated that a reduction in water use of 6 to 13 mgd was obtained by the utility at a cost of $500,000 for its conservation program.

Sharpe, W. E. "Residential and Commercial Water Conservation and Wasteflow Reduction with Water-Saving Devices."

This paper presents a brief literature review along with recommendations for research. It is noted that the impact of water-saving devices is not well known. "Conflicting results have been reported even in the small amount of existing data."

Coelen, S. P. "Water Price-Quantity Relationships and Their Effect on Water Conservation."

This article notes that although meters can be expected to reduce water use the cost of metering may outweigh the benefits gained. The benefits of metering will depend on the pricing policy of the utility and upon the rate of growth of the community.

Chan, M. L. and S. Heare. "The Cost-Effectiveness of Pricing Schemes and Water-Saving Devices."

This paper presents the results of two computer models. The first (PAM-Policy Analysis Model) is designed to evaluate water pricing policies. The second (EEAM-Engineering Economy Analysis Model) is designed to estimate the cost-effectiveness of eight water-saving devices.

There are two major problems with the PAM computer model: (1) sewer contributions are assumed to be a constant 120 gpcd and (2) under the increasing and decreasing block rate schedules all consumers are assumed to face the same marginal price. These assumptions seriously cloud the results of the model.

Using the EEAM it is estimated that immediate replacement of existing devices by flow-limiting shower heads, dual cycle toilets, shallow-trap toilets, or toilet inserts is cost-effective for individual households. Faucet aerators are cost-effective only from a total water utility - household standpoint under current pricing policies. Thermostatic mixing valves, vacuum flush toilets and recycling for flushing are not currently cost-effective (i.e. have a net positive economic cost).

Bishop, W. J. "Field Experiences in Water Saving Programs of the Washington Suburban Sanitary Commission (WSSC)."

This paper outlines the results of specific tests of water-saving devices conducted by the WSSC. It is noted that large differences can exist between the predicted physical performance of water-saving devices and actual performance. For some of the WSSC test areas water use actually <u>increased</u> after the installation of water-saving devices by the utility (although these may not have been significant increases). The size of water use

reductions depended heavily on whether the devices were maintained by the utility or by landlords and households. Specific recommendations for implementing and evaluating water-saving programs are made.

Cole, C. A. "Impact of Home Water Saving Devices on Collection Systems and Waste Treatment."

This article finds that the transporting capacity of sewers and house connections would not be substantially changed by reducing the amount of water used per flush from 5.25 to 2.0 gallons. It is also noted that this lower quantity of water per flush will increase sewage treatment plant efficiency of removal of BOD and suspended solids and/or increase the economic life of the treatment plant.

Bennett, E. R. "Impact of Flow Reduction on On-Lot Sewage Systems."

This paper estimates the benefits of flow reducing devices on operation parameters and costs of on-lot sewage disposal systems. Water use patterns in six homes were used as the basis for this study. Gross sewage disposal cost savings from a 40 percent water use reduction were estimated. The values obtained were $25/yr., $80/yr., and $170/yr., for spetic tanks with leaching fields, septic tanks with imported fill and leaching field and septic tanks with evapo-transpiration beds, respectively. Aerobic systems would not be expected to cost less but operational problems associated with surge flows would be less severe.

Baker, L. K., H. E. Bailey, and R. A. Sierka. "Household Water Conservation Effects on Water Energy and Wastewater Management."

This paper analyzes the impacts of very low water-using appliances (0.5 gal/flush toilet, 0.5 gal/min shower and a front loading clothes washer).

These devices were estimated to reduce water 65 percent and lower non-space heating and cooling requirement 30 percent. Conversion from conventional hardware and secondary treatment of sewage to these devices and an AWT system (ultrafiltration and reverse osmosis) is estimated to result in a 33 percent reduction in total system costs. No field tests were conducted.

Muller, J. G. "The Potential for Energy Saving Through Reduction in Hot Water Consumption."

This paper concludes that the oil equivalent of roughly 0.5 million barrels per day (BPD) would be cut from an estimated 1.1 million BPD used currently in residential water heating. This could be accomplished through a program of replacement of water heaters, cold water laundering, flow restriction devices and other measures. Flow restriction accounts for about one fifth of the energy saving. It is noted that little is known about the current use of residential hot water.

Moses. H. L. "Research on Water Saving Devices at Virginia Polytechnic and State University."

This paper discusses flow characteristics of water saving shower heads and faucets. Noise, flow control, compatibility with available plumbing fixtures, cavitation and instability problems are investigated. It is concluded currently available devices are "entirely satisfactory".

McLaughlin, E. R. "A Recycle System for Conservation of Water in Residences."

This paper presents the results of a pilot project which installed a recycle system ("gray water" used for toilet flushing) in one residence.

The system worked well and saved 23 percent of the water previously used. At current water and sewer rates (total cost of $0.86/1000 gal.) the system cannot be justified economically.

Smith, Khervin. "The Testing of a Clivus-Multrum (Sewage) System in a Limited Use Campground."

A test of the Clivus-Multrum Sewage System at Hawk Mountain Sanctuary indicated that the system did not function as stated in the manufacturer's literature. Odors and condensation were problems. Potential problems with other no-water systems are discussed.

Hoxie, D. C. and W. C. Toppan. "Maine's Experiences with Reduced-Water Waste Disposal Systems."

This paper presents a general discussion of household waste waters and potential systems for separating toilet waste from other household wastes. Problems with low permeability rates for soils are discussed.

Konen, T. P. "An Investigation of the Performance and the Effects of Reduced Volume Water Closets on Sanitary Drainage. Sewers and Sewage Treatment Plants."

Engineering tests were conducted on two syphon jet and one washdown toilets with flush volumes of 16, 11 and 6 liters, respectively. It is concluded that the washdown performed more poorly and may have acceptance problems. Drainage is not a problem except in horizontal lines which are not good practice in any case. A very brief discussion concludes that there will be no effect on sewage plants.

Montgomery, C. E. "Water Savings with the Save-It Water Saver."

This paper describes a toilet tank insert that reduces flush volume to 2 - 2 1/2 gal.

Sittler, E. L. "Future Research in Water Savings."

This paper describes several water saving devices, with special emphasis on a new thermostatic mixing system at the hot water tank.

Schaefer, R. K. "Socioeconomic Considerations for Domestic Water Conservation."

This paper presents a general discussion on the problems of providing incentives for consumers to install water conservation devices.

Wertz, R. J. "A Plumbingware Manufacturer's Viewpoint on Water Saving Devices."

The design history and characteristics of various water saving devices are presented. Problems with retrofitting toilets are also discussed.

DeArment, W. E. "Impact of Conservation on Water Industry."

Water conservation programs that could be instituted by water utilities are discussed. These include metering leak detection, elimination of declining block rates, sprinkling bans, reducing back-wash water in treatment plants, and cross connection control plans.

Shuval, Hiller I., editor. Water Renovation and Reuse. New York: Academic Press, 1977.

This book contains 15 papers on the technical aspects of water reuse and on water reuse practices around the world. Included are (1) "Advanced Wastewater Treatment Technology in Water Reuse," by F. M. Middleton; (2) "Health Considerations in Water Renovation and Reuse," by H. I. Shuval; (3) "The Use of Wastewater for Agricultural Irrigation," by Josef Noy and Akiva Feineussen; (4) "Water Reuse in Industry," by L. K. Cecil; (5) "Reuse of Water for Municipal Purposes," by G. J. Stander; (6) "Pressure-Driven Membrane Processes and Wastewater Renovation," by George Belfrot; (7) "Alternative Water Reuse Systems: A Cost-Effectiveness Approach," by Lucien Duckstein and Chester C. Kiscel. Also included are papers on water reuse practices in California, the Federal Republic of Germany, India, Israel, Japan, South Africa, The United Kingdom, and at the Environmental Protection Agency's pilot plant in Washington, D.C.

Sims, J. H. and Baumann, D. D. "Psychological Acceptance of Renovated Wastewater: Professional and Public." In Planning for Water Reuse, pp. 75-90. Edited by D. D. Baumann and D. Dworkin. Chicago: Maaroufa Press, 1978.

The purpose of the study was to demonstrate unconscious psychological determinism in career choice, in professional attitudes toward renovated wastewater, and in public response to renovated wastewater. Three studies are summarized, two of which used the Thematic Apperception Test on professional groups (public health officials, water engineers, business executives, career civil service executives); the third used in the Sentence Completion Test on a lay sample.

Among the results: (1) Careers (that is, professions) and persons carry out a mutual selection process at entrance to and during the professional socialization (training) process which results in producing a professional who not only is defined by particular professional knowledge and skills but also by particular attitudes, ways of seeing, biases, etc. of which he is largely unaware. (2) Hence the attitudes of water engineers and public health officials towards the use of renovated wastewater reflect not only their professional considerations but their "professional" prejudices. These biases are detailed. (3) Public attitudes towards renovated wastewater use are found to be related to education and knowledge; possible psychological determinants investigated were found to be unrelated. The authors warn that the instruments are suspect and that the research with the public is hypothetical in nature. The authors argue persuasively that psychological factors of which we are not aware influence our attitudes toward water and water use. It is one of the rare studies that has data, even though the authors themselves acknowledge that their data are weak.

Snodgrass, Robert W. and Duane Hill. "Achieving Urban Water Conservation: Testing Community Acceptance." Colorado Water Resources Research Institute. Completion Report No. 81, 1977.

The study attempts to create a methodology for identifying the political feasibility (community acceptance) of conservation measures. In the process, it ascertains how politically feasible certain conservation and other environmental policies are within two specific urbanizing rural communities, Lafayette and Louisville, Colorado.

The study in every respect is methodologically sophisticated, both in its attempt to produce a model, and in its manipulation of the illustrative data. Using census and questionnaire data, the authors produce a factor analysis resulting in "data constellations" made up of three major components: (1) socio-economic information, such as education, income, age, sex, occupation; (2) community identification information, such as, length of residency, "attachment" to community, level of participation in the community; and (3) attitudinal information, such as, attitudes toward population growth rate of state, industrial growth, pollution, etc. These constellations define "zones" of acceptance; various conservation measures fit logically into one or another zone, and are congruent with the socio-economic facts, community identification and general environmental attitudes that make up a given cognitive-emotional zone (and thus, a given stratum or grouping of persons).

In the specific communities studied, Lafayette and Louisville, Colorado, the application of their model resulted in the following: of the 13 water conservation alternatives offered, the two that would be most politically feasible, most probably accepted by the communities, were (1) restrictions on city growth and population size, and (2) legal restrictions on water use. The two most unacceptable or least politically feasible alternatives were (1) a more equitable resource distribution, and (2) demand for leadership change.

Stone, Lloyd R. "Water and Energy Conservation Through Efficient Irrigation Management." Manhatten, Kan.: Kansas Water Resources Research Institute, Kansas State University, August 1977 (NTIS PB 273-810).

A three-year study of the relationship between crop yield and supplemental irrigation water application was conducted for corn and for grain sorghum. Crops were raised on specially prepared plots at two locations in Kansas. Five irrigation treatments, ranging from no in-season irrigation to three in-season applications, were replicated three times for each of the two crops. With no in-season irrigation, grain sorghum yields were better than comparable yields for corn. Both crops showed improved yields after at least one in-season irrigation, the corn yield being greatest when irrigation water was applied at the time of silk emergence. Increasing irrigation to three in-season applications brought about significant increases in corn yields, but increases in grain sorghum yields were judged insufficient to justify the additional irrigation expense.

Thompson, R. G. and H. P. Young. "Forecasting Water Use for Policy Making: A Review." Water Resources Research 9 (August 1973):792-799.

This article criticizes previous projections of water "requirements" and discusses a method of using linear programming to estimate the demand response to changes in price by industrial and agricultural water users. Estimates from other sources indicate that: withdrawals by electric generating stations for cooling would be lowered 98% if a price of $0.5¢/10^3$ gal were imposed; and that agricultural use in the West would be lowered by 65% if the price of water were increased to a level of $30/acre-foot.

Turnovsky, Stephen J. "The Demand for Water: Some Empirical Evidence on Consumers' Responses to a Commodity Uncertain in Supply" Water Resources Research 5 (April 1969):350-351.

This article presents the results of an estimation of the effect of price on residential and industrial water use from data obtained from a sample of Massachusetts towns for two cross-sectional periods (1962 and 1965). The article has a theoretical model to account for the effect of the uncertainty of water supply. The estimates for price elasticity range from -0.049 to -0.406 for "residential" and from -0.473 to -0.839 for "industrial." This study is important in that both industrial and residential elasticities were estimated together. The results are consistent with those of Renshaw (1955) of residential (-0.45) commercial (-1.04) and industrial (-0.80) (source: Hanke, 1972). The study suffers most in its specification of the stochastic nature of water supply to the customer. The actual water use restriction policies and their implications on consumer and producer behavior are never investigated.

U. S. Army Corps of Engineers. Water Conservation Measures for the New York Metropolitan Area. Northeast U.S. Water Supply Study. Special Studies Branch, January 1976.

This volume presents a detailed description of an implementation program for water conservation measures for New York City and the metropolitan area (NYMA). Included are universal metering, leak detection in the distribution system, industrial recirculation, changes in the plumbing codes to require installation of shallow traps or siphone jet toilets, 3 gpm shower heads and 2.5 gpm faucets, an education program and drought contingency measures. A review of

the literature indicates a price elasticity of -0.15 seems applicable to the New York City domestic water use. Table 1-1 contains a summary of the estimates yields, costs to the public treasury, critical assumptions and uncertainties of the various elements of the conservation plan.

U. S. Department of the Interior. Report on the Water Conservation Opportunities Study. Bureau of Reclamation and Bureau of Indian Affairs. September 1978.

This study focusing on agricultural use of water, contains the results of a study designed to identify federal irrigation projects that would have an attractive opportunity for water conservation. The analysis was performed on 61 existing projects. Estimates are made of potential reductions and total investment costs and the projects are then rank ordered in terms of their potential benefits.

U. S. General Accounting Office. California Drought of 1976 and 1977 - Extent of Damage and Government Response. October 1977.

This report reviews the effects of the 1976-1977 California drought and the laws passed by the Congress and the State Legislature in response. Activities of some local irrigation districts and municipal water utilities are discussed. The report recommends the State plan be re-examined in light of the large expenditures ($4.3 billion federal, $3.4 billion state) and the strong possibility that even these expenditures will not be sufficient to stop the need for overdrafting of groundwater. The report questions the advisability of the projected one million acre-feet increase in irrigation.

U. S. Water Resources Council. The Nation's Water Resources, The Second National Assessment. Washington, D.C.: U.S. Water Resources Council. October 1978. (Draft)

This volume is a comprehensive assessment of current and projected water requirements for the major economic sectors of the United States. Each topical area is broken down into demands, supply, projections and current trends. It is one of the most comprehensive studies of the nations current and future water resources available. Water conservation per se, is discussed along with other current trends in water use.

Upper Mississippi River Basin Commission. The Water Conservation Challenge, Symposium Proceedings. Bloomington, Minnesota: May 10, 1978.

This is an outstanding collection of brief papers presented at the Symposium on the Water Conservation Challenge on May 10, 1978 in Bloomington. The scope of the Symposium ranged from local to national in character with papers reflecting the various levels of focus. The report is broken into three segments. The first investigates the federal, state and local viewpoints toward water conservation as it examines the conservation potential for the U.S. in general, the Upper Mississippi River Basin and selected local areas across the country. The second segment investigates measures for water conservation such as the need for a good water use data base, residential water conservation and devices, municipal water conservation and a discussion on the extent of government control of non-point source pollution. The final section addresses applications and implications of water conservation for industry, steam electric generation management, farm water management, institutional, residential and commercial water management.

In sum the scope of the Symposium was comprehensive and the papers collected are concise and contain valuable and current information regarding water conservation.

WAPORA, Inc. "Water Use and Conservation at Federal Facilities in the Washington, D.C. Metropolitan Area." A report to the U. S. Environmental Protection Agency, Region III, Philadelphia, PA, April 1978.

This report describes water use practices at Federal government installations in the Washington, D.C. metropolitan area. Federal activities account for 15 percent of all water use in the District of Columbia, 13.7 percent in the county of Arlington (Virginia), and smaller percentages in other jurisdictions. Significant difficulties were experienced in obtaining reliable water use data for Federal installations, due to the record-keeping practices of the water purveyors, and the fact that 40 percent of Federal office space in the region consists of leased (often partly leased) premises. Where suitable data were not available, a regression model was used to estimate water use as a function of employees and floor space. It was found that water conservation receives little attention in the management of Federal buildings. Building managers are described as viewing water as a free commodity. This attitude is reinforced in the District of Columbia by the practices of reading meters infrequently and irregularly, and not providing building managers with copies of water bills. Devices and practices with potential for reducing water use at Federal facilities are reviewed, including the use of pricing practices. Various recommendations are listed for increasing the awareness of building managers with respect to the cost of water and the possibilities for reducing its use. It is concluded that the existing data base is insufficient to support estimates of the likely effectiveness of water conservation programs.

Ware, J. E., and R. M. North. "The Price and Consumption of Water for Residential Use in Georgia." Research Monograph No. 40. Atlanta: Publishing Services Division, School of Business Administration, Georgia State University.

This monograph presents the results of a regression study of the effect of price and other variables on residential water use in Georgia. Although very good data on household characteristics were collected by personal interviews and mailed questionnaires for 634 households, these data were aggregated by town. This reduced the sample size to 15. The reason for this procedure was "to facilitate comparison among the 14 areas."

Of the variables used, only price and income were found to be significant (.05 level). The estimated price elasticities were -0.67 and -0.61 for the linear and log-log models, respectively.

Warford, J. J. "Water Supply." In Public Enterprise, pp. 212-236. Edited by R. Turvey. Middlesex, England: Penguin Books, 1968.

Projections of future water "requirements", where water use is taken to be a function of population, housing and appliance stocks, and industrial development, are contrasted to projections of future water "demand", which is an explicit function of, among other variables, price. "Requirements" forecasts are satisfactory only where supply is perfectly elastic (constant marginal and average costs) and demand is perfectly inelastic. Both conditions are described as unlikely. Since water use is responsive to price, properly set prices serve the function of efficiently rationing existing supplies as well as providing

needed information for optimal investment in future supplies. Particular attention is drawn to the situation in Great Britain, where residential water uses are characteristically unmetered, effectively setting price equal to zero. The use of meters (and, therefore, prices) is contrasted to other methods of balancing the cost of supply increments against the benefits obtained. Other water use reduction methods discussed include pressure reductions, industrial recirculation, and rotating cut-offs of supply to residential areas. Metering is shown to be the more efficient strategy.

The Water Resources Policy Studies - Policy Committee. "Scientific and Technological Aspects of Water Resources Policy." Washington: Office of Science and Technology Policy, The Executive Office of the President. January 1978.

Policy recommendations related to conservation are included: (1) Benefits and cost of various conservation methods in agriculture are evaluated (these include on farm irrigation techniques, lining of laterals and ditches. The high value of water for other uses can make such conservation profitable for all parties including the irrigator. "Creating incentives for conservation should be a national policy of first priority." (2) "New irrigation in areas having meager surface and ground water supplies should be developed only after alternative and consequences have been fully appraised." (3) Planning agencies should develop expertise in the determinants of all types of water demand. (4) Changes in cost-sharing policies should be evaluated. (5) "Savings in urban and industrial water can be accomplished by the following method:

I. Improved conveyance, storage and treatment of storm water runoff for reuse.

II. Treatment of sewage effluent for reuse.

III. In-plant recycling of industrial waste waters.

IV. Reduction of industrial cooling demands.

V. Reduction in water demands for decorative vegetation, landscaping, and recreational areas.

VI. Reduction of domestic water consumption to attain "nonwasteful use levels."

(6) "Opportunities exist for substantial conservation of water in agricultural irrigation." and (7) "Efforts to control demand are an attractive alternative to new investments in supply."

Water Resource Policy Study. Washington: Policy Group for Water Policy Review. December 6, 1977.

Of particular interest is the "Water Conservation Task Group Report." Water conservation is defined as "saving water at one place and time to make it available for more beneficial uses." The report outlines the quantities withdrawn and consumed by various users and gives the estimated potential percentage reductions that could be obtained.

Three policy questions are addressed: (1) What should be the role of the Federal Government in water conservation? (2) What changes in Federal policies and programs can promote rate structures (prices) for water use that encourage conservation? (3) How can comprehensive water resources planning be improved to implement water conservation? Various options for each of these policy questions are presented and discussed.

Watkins, A. M. "Sanivac - Revolutionary Vacuum Toilet." Popular Science 197 (August 1970):97+.

This article describes the "Sanivac" toilet system developed by Joel Lelyendhal. The system uses 3.5 cubic feet of air and a bit more than a quart of water per flush. Because the system requires only 2 inch PVC plastic pipe to convey the sewage rather than the normal 3-4 inch sewer pipe, the article claims this more than offsets the cost of the system. "The present Sanivac system can economically handle virtually any kind of housing or other building with a minimum of 30 to 40 people. A new version specifically designed for individual

one-family homes is under development and should be out in 18 months," according to Dick Gregory, Vice President of the Sanivac Division, National Homes Corporation. In the "Sanivac" system human wastes go into a collecting tank which is automatically emptied in a catch basin or periodically pumped out.

Watkins, George A. A Sociological Perspective of Water Consumers in Southern Florida Households. Gainsville: Florida Water Resources Research Center, University of Florida, 1972.

According to the author, due to increased water demands there are many existing programs for water usage. It is important to assess the feelings of a population before water management changes are made. This will help bridge the gap between administrative solutions and hesitations on the part of the consumers. The author provides a general review of the literature in the field. His purpose is two-fold: (1) to verify what relationships there are between water consumption in residential areas as compared with socio-economic variables, e.g., verify Linaweaver, Spauling and others; and (2) to develop a scale to measure attitudes towards water conservation as developed by Watkins (1968).

The study area consisted of Homestead, Florida and areas of northwest Palm Beach. In correlating the scores on a Water Concern Scale with socioeconomic factors, only education and income level of family head were significant. Conclusions--the more urban lifestyle of Palm Beach had more appliances, income and higher consumption. Palm Beach people didn't know their water suppliers, majority of all people hadn't thought about cutting water consumption, and if so would do it in sprinkling then leaks, if a shortage would relegate responsibility to water plant, most never expect a shortage, majority against reclaimed water.

Weeks, C. R., and T. A. McMahon. "Urban Water Use in Australia." Civil Engineering Transactions, The Institution of Engineers, Australia (1974):58-66.

Urban water use in eleven Australian cities is examined for the period 1950-1969. Factors which influence annual use, including population, metering, water quality, and climate, are reviewed. Both aggregate annual use and average per capita use are modelled as simple functions of time. While these models may adequately explain past variations in water use, they found likely to produce misleading forecasts. The authors, therefore, develop a more detailed model which expresses seasonal water use as a function of time and various climatic variables. A further study is made of residential water use, using data collected for 119 residences in the Melbourne (Australia) area during the period September 1969 through August 1970. Household water use, when expressed on a per capita basis, is shown to be negatively correlated with population per household, while garden water use is shown to be dependent upon weather. Unit use coefficients are developed for 29 industry categories, based primarily on data collected in the Melbourne area. These coefficients are compared to other estimates, including data from the United States. Unit use coefficients are also presented for primary and secondary schools located near Melbourne.

Western Governors' Policy Office. Managing Resource Scarcity: Lessons from the Mid-Seventies Drought. Denver: Institute for Policy Research. August 1978.

This report describes the actions during 1977 of the Western States in response to the drought. The coordination with federal agencies and programs is treated in detail. Research needs are also discussed.

White House Drought Study Group. March 1977 Drought Appraisal. Reprinted by the U.S. Army Engineers Institute for Water Resources, March 1977.

This report describes the 1976-1977 drought in California, Oregon, Washington, Idaho and Nevada and presents possible measures for drought management both in the short-and long-term. It is noted that in 1977, production on irrigated lands is expected to be 75% of normal. It is estimated that a comprehensive long-term conservation program in agriculture could achieve annual savings of 6 to 8 million acre-feet of consumption and 40 to 50 million acre-feet of withdrawals. It is estimated that a 20% reduction in residential use can be achieved by the installation of water saving devices. Short-term measures can reduce the average use per person by 50%. Tables of water conservation measures (agricultural and municipal) are presented. A large number of tables matrices and maps describing the drought are also presented.

Wolf, Ray. "Greywater in the Garden." Organic Gardening and Farming 24 (July 1977):83-86.

This article discusses methods for reuse of greywater as household irrigation water. It is noted that it is generally illegal to do so but that this has been overlooked by authorities during the drought in the Far West. Such use of greywater can be done safely. "Because of salts in greywater, do not use it on acid-loving plants. Avoid using greywater on plants that are eaten raw like lettuce and carrots." The article is primarily on do-it-yourself plumbing.

Wong, S. T. "A Model on Municipal Water Demand: A Case Study of Northeastern Illinois." Land Economics 81 (February 1972):34-44.

This article presents a literature review of various econometric estimations of price elasticity and presents the results of 2 time-series regresssions (1951-1961) on the Chicago area and 4 cross-section regressions (from 15-40 observations) on "residential" per capita water use (industrial, commercial, and institutional uses were excluded in an unspecified manner). The estimates of price elasticity of municipal water use obtained from the literature review (excluding Tunowsky [1964] and Wong [see below]) range from -0.12 (Seidel & Baumann 1957) to -1.099 (Bain et al., 1966). The two time-series estimates of short-run price elasticity in the Wong study are -0.02 (not significantly different from zero at .05 level) for Chicago itself and -0.28 (significant .05 level) for outside communities.

The cross-sectional data was separated into communities of 25,000-over,

10,000-24,999, 5,000-9,999 and 4,999-less persons. The estimates of price elasticity are -0.53 (significant .05 level), -0.82 (significant .01 level), -0.46 (significant .01 level) and -0.25 (not significant .05 level), respectively. The last estimate (for communities of 4,999 and less) suffered seriously from the small size of the date net (15 observations) as did the two time-series estimates (11 observations).

Yarborough, Keith A. "Analysis of Seasonal Water Consumption in Danville, Illinois." Journal of American Water Works Association 48 (No. 5, 1956): 479-484.

The author's purpose is to study seasonal consumption in Danville to provide some quantitative information concerning recent water demands of such a medium sized city. The years 1950-1955 were chosen due to an extended water shortage during that period (as reported by Water Works operations). Data was taken from the Company's house meter records for the summer quarter (January 15-September 15) and winter quarter (December 15-March 15) because these periods were believed to reflect the maximum in differential consumption. The study is divided into five different zones based on property valuation; only overall lot area was considered.

The results indicate that per residence consumption increased with land valuation. The author notes that population density will affect the total water use. This seems quite obvious; it might matter in planning, however, which type of area it is to be e.g., high or low income. The upper middle class areas tended to use the most water as opposed to the richest, due to greater population density. Increased consumption during summer was a result primarily of lawn sprinkling. There is a general correlation between the combined climatological conditions and relative demand. There seems to be little effect during the winter.

Young, R. A. "Price Elasticity of Demand for Water: A Case Study of Tucson, Arizona." Water Resources Research 9 (August 1973):1068-1072.

This article presents estimates of the short-run price elasticity of aggregate water use for Tucson, Arizona from the series date for a single utility. The estimates are -0.60 for the period 1946-1964 and -0.41* for the period 1965-1971 (*not significantly different from zero at the .05 level). Both estimates suffer from the use of very small data bases (19 and 7 data points). More importantly, the use of two separate periods was apparently based on an ex-post analysis of the results. A re-analysis of the complete data set (Carver, Ph.D Thesis, 1978) indicates a short-run price elasticity of -0.2 (significant 0.10 level).

Young, R. A., and S. L. Gray. "Economic Value of Water: Concepts and Empirical Estimates." Fort Collins: Department of Economics, Colorado State University. March 1972 (NTIS PB 210-356).

The authors observe that the practice of allocating water among competing uses by means of administered prices and various non-market procedures results in the absence of reliable market measures of value. Instead, values for various uses of water must be inputed from limited market transactions, from theoretical demand functions, from measurements of residual value, or from information regarding alternative costs. A framework for establishing values for water, suitable for use in public or private sector development and allocation decisions, is presented. Specific attention is given to valuation problems arising within the agricultural, industrial, and municipal use sectors, as well as to valuation

problems associated with the use of water for waste assimilation, recreation, navigation, and hydroelectric generation. In each case the literature is surveyed, and empirical estimates of value, where available, are given. These are supplemented by several original derivations of value measures, based on data obtained by the authors. Where value measures are available by region, regional differences in value are characterized as minor.

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