GEOMET Report Number EH-788

August 3, 1979

SOCIO-ECONOMIC ANALYSIS OF WATER RESOURCES: A BIBLIOGRAPHY

Final Report

for

U.S. Environmental Protection Agency
Chesapeake Bay Program

under

GEOMET Contract 6156-9(e)

by

Michael B. Harrington, Ph.D.
Harriet R. Stern, M.S.

GEOMET, INCORPORATED • 15 FIRSTFIELD ROAD • GAITHERSBURG, MARYLAND 20760
301/948-0755 • CABLE ADDRESS: GEOMETINC

August 1, 1979

Mr. Thomas DeMoss
Chesapeake Bay Program
U.S. Environmental Protection Agency
2083 West Street
Annapolis, Maryland 21401

Dear Mr. DeMoss:

Enclosed are the results of the literature search on "Socio-economic Analysis with Respect to Large Scale Water Resources Planning and Usage" we have completed for your office. This search was undertaken on July 16, 1979 under GEOMET's Task Order Contract with EPA, 68-01-4144.

This search focuses on the overall topic by taking the following steps. First, two computerized bibliographic searches were conducted for the period 1971 to the present. Included were searches of the National Technical Information Service System, and of Enviroline, a data base containing citations from all the major environmentally oriented journals. Second, an independent hand search was conducted of journals and books outside the environmental field. A variety of published, special topic bibliographies concerned with methods of economic analysis in large scale public programs were consulted during this step.

The results of this three week effort are organized in the following four sections:

- Publicly financed research projects with abstracts of their results
- Photo copies of articles of particular relevance to the socio-economics of water resource use
- A bibliography of journal articles, books, book chapters, and professional presentations of relevance
- Books of special relevance which EPA might consider acquiring for its own library.

We have appreciated this opportunity to assist EPA and hope we can be of further service in the near future. If you have questions concerning this bibliographic search, please do not hesitate to call me at (301) 948-0755.

Sincerely,

Michael B. Harrington

Michael B. Harrington, Ph.D.
Manager, Health and Environmental
Economics Studies

MBH:ltg

Enclosure

TABLE OF CONTENTS

Section 1.0

PUBLICLY FINANCED RESEARCH PROJECTS WITH ABSTRACTS

Section 1.0

PUBLICLY FINANCED RESEARCH PROJECTS WITH ABSTRACTS

Included in this section are the abstracts of research projects funded by public authorities, typically the Federal government. All were obtained through a search of the computerized files maintained by the National Technical Information Service in Springfield, Virginia. These project abstracts are organized in four sections: economic analysis; socio-political analysis; methodology; and environmental case studies. Many of the projects could appear under several headings due to their breadth or for other reasons. Nonetheless, each project appears just once, under the heading which appears to express its major thrust most effectively. Within each section, the projects are alphabetized by title.

1.1 Alphabetical Listing of Economic Analysis Abstracts

1. An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico: Lower Rio Grande Region.

2. Analyzing Reimbursement Mechanisms of Resource Development Project.

3. Alternate Solutions to Water Resource Development--A Case Study.

4. Commercial Navigation on the Upper Mississippi River: An Economic Review of Its Development and Public Policy Issues Affecting Minnesota.

5. Economic Base Study of the Mobile-Alabama-Coosa River Basin.

6. An Economic Analysis of the Proposed Water Resources Project for the Upper French Broad River Basin in Western North Carolina.

7. An Economic Evaluation of Water Quality Management Systems.

8. Effects of Economic Development on Water Resources.

9. The Interrelationship of Economic Development and Environmental Quality in the Upper Colorado River Basin: An Interindustry Analysis.

10. A Methodology for Assessment of Water Resources Development: A Competitive Evaluation Model for Water Resources Development Planning.

11. People and the Sound. An Economic Perspective.

12. Plan for Development of the Land and Water Resources of the Southeast River Basins. Appendix 9. Economics.

13. The Powder River Basin Economic Simulation Model: A Technical Report and Supplement to the Technical Report.

14. Research on Water Resources Evaluation Methodology: A River Basin Economic and Financial Post-Audit.

15. Subsidies, Capital Formation, and Technological Change: Municipal Wastewater Treatment Facilities. Volume 1.

16. The Willamette Basin Comprehensive Study of Water and Related Land Resources. Appendix C. Economic Base.

1.2 Economic Analysis Abstracts

An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico: Lower Rio Grande Region

New Mexico State Univ., University Park. Water Resources Research Inst.
AUTHOR: Lansford, Robert R.; Ben-David, Shaul; Gebhard, Thomas G. Jr; Brutsaert, Willem; Creel, Bobby J.
C2945H4 Fld: 13B, 48B GRAI7414
May 73 122p
Rept No: WRRI-024
Project: OWRR-A-045-NMEX, OWRR-B-016-NMEX
Monitor: OWRR-A-045-NMEX(6)
Includes Rept. nos. OWRR-B-019-NMEX(6) and OWRR-B-026-NMEX(6).

Abstract: An interdisciplinary approach to the solution of the water resource problems of the Lower Rio Grande Region in New Mexico was centered around a socio-economic model, developed to represent the New Mexico economy, with special emphasis placed upon the Rio Grande region. Inputs into the socio-economic model were obtained from separate studies covering the hydrological, agricultural, municipal, and industrial areas. Three sets of alternatives were considered: Growth without a water constraint; growth, with a surface-water constraint; growth, with both surface- and ground-water constraints. (Modified author abstract)

Descriptors: *New Mexico, *Rio Grande River Basin, *Water resources, River basin development, Economic analysis, Forecasting, Economic models, Surface waters, Ground water, Land use, Classifications, Water consumption

Identifiers: NTISOWRR

PB-232 068/7 NTIS Prices: PC A06/MF A01

Analyzing Reimbursement Mechanisms of Resource Development Project

Wyoming Univ., Laramie. Div. of Agricultural Economics.*Office of Water Research and Technology, Washington, D.C.
AUTHOR: Dobbs, Thomas L.; Huff, Charles E.
C5245G3 Fld: 13B, 05C, 05K, 48B, 96B, 92C GRAI7522
1974 25p
Project: OWRT-C-4351(9063)
Monitor: OWRT-C-4351(9063)(2)
Also pub. as Wyoming Agricultural Experiment Station, Laramie. Journal Article-652.

Abstract: Policies proposed by the National Water Commission will create a need for a systematic examination of possible reimbursement mechanisms for project bonded indebtedness and operation and maintenance costs. Increased reliance on the assessment of beneficiaries and the necessity of integrating project evaluation and cost-sharing formulation for water resource development projects are stressed. A framework for analyzing regional resource development projects is developed around an impact matrix and a reimbursement matrix. The impact matrix includes the various development, environmental/recreational, and social effects of a project on various sectors within the region of concern, while the reimbursement matrix accounts for all user charges, taxes, and other repayment mechanisms. The analytical framework is applied to a proposed interbasin water transfer project involving water transfer from Wyoming's Green River to its North Platte River Basin for municpal and industrial (coal development) purposes.

Descriptors: *Water resources, *Economic development, *Social effect, Cost sharing, Bond financing, Indebtedness, Policies, Revenue sharing, Decision making, Water supply, Industries, Municipalities, Green River, North Platte River, Wyoming, Meetings

Identifiers: *Water transfer, *Interbasin transfers, NTISDIOWRT

PB-243 917/2ST NTIS Prices: PC A02/MF A01

Alternate Solutions to Water Resource Development--A Case Study

Texas A and M Univ., College Station. Water Resources Inst.

Technical rept. 1 Sep 72-31 Dec 73
AUTHOR: Basco, David R.; Rahman, K. M. A.
C3215C2 Fld: 13B, 48B* GRAI7418
May 74 187p*
Rept No: TR-55
Contract: DI-14-31-0001-3938
Project: OWRR-B-141-TEX
Monitor: W74-09661

Abstract: An effort is made to develop procedural methodology for the consideration of alternative solutions for water resources development in a short period of time with a view toward reduction of total costs involved in prefeasibility studies. Three techniques were developed to estimate the investment costs of a reservoir project, a levee project, and a basin conservation reservoir project in an economic region. The application of the methodologies were illustrated by a case study. The cost of a reservoir project in the case study area determined by the method developed was in excellent agreement with the Corps of Engineers' estimate using conventional methods. Selected solutions for water resources development problems in the Navasota River watershed were analyzed. The cost of water supply by desalination in the service area of the proposed Millican reservoir was computed. The investment costs of the alternatives were compared. The multipurpose reservoir project for flood control, water supply and recreation was found to be the least costly project.

Descriptors: *Water resources, *Economic development, *Texas, Investments, Multiple purpose reservoirs, Project planning, Cost comparison, Feasibility, Levees, Embankments, Benefit cost analysis, Flood control, Water supply, Cost estimates, Desalting, Navasota River, Bravos River Basin

Identifiers: Millican Reservoir(Texas), Alternative water use, NTISDIOWRR

PB-233 725/1 NTIS Prices: PC A09/MF A01

Commercial Navigation on the Upper Mississippi River: An Economic Review of Its Development and Public Policy Issues Affecting Minnesota

Minnesota Univ., Minneapolis, Water Resources Research Center.*Office of Water Research and Technology, Washington, D.C.
AUTHOR: Christianson, Rodney W.
C4521A3 Fld: 05C, 13B, 13J, 96B, 85B GRAI7511
Oct 74 125p
Rept No: WRRC-Bull-75
Contract: DI-14-31-0001-3601
Project: OWRT-B-054-MINN
Monitor: OWRT-B-054-MINN(6)

Abstract: Inland waterway transport is a significant carrier of domestic cargo, accounting for about 14% of the total traffic. During the past decade cargo carried by the inland waterways increased by 46% (62% when the Great Lakes are excluded). By increasing the absolute amount of freight carried greater than the average (42%), the inland waterway's relative share of total freight traffic has also grown over the past decade. Also, development of the Upper Mississippi River into a major inland waterway has been even more significant for Minnesota and the Midwest than for much of the rest of the nation. A transportation model, based on competitive assumptions and employing a derived demand analysis, is presented. The model predicts that there will be an increase in demand for transportation services, especially barge services. The current issues in commercial navigation which affect Minnesota involve a resolution of the conflict between developmental and environmental values.

Descriptors: *Economic analysis, *Mississippi River, *Waterway transportation, *Minnesota, Economic models, Cargo transportation, Inland waterways, Dredging, Waste disposal, Policies, Benefit cost analysis, Demand(Economics), Commercial transportation

Identifiers: NTISDIOWRT

PB-239 962/4ST NTIS Prices: PC A06/MF A01

Economic Base Study of the Mobile-Alabama-Coosa River Basin

Alabama Univ., University. Bureau of Business Research
D1481C1 Fld: 13B d7604
Jun 67 120p
Contract: PH-86-65-45
Monitor: 18

Abstract: This report presents the results of an Economic Base Study of the Mobile-Alabama-Coosa (MAC) River Drainage Basins. One purpose of the study was to project the economic growth and development of the MAC Basin area to 1965, 1980, and 2015, for development plans of water and related land resources to meet emerging needs. Economic and demographic characteristics, growth rates, and trends are developed through time-series analyses and taken into account in projecting future growth and development patterns for use in planning activities.

Descriptors: *Water resources, *Resources management, *River basin development, Mobile-Alabama-Coosa river basins, Land development, Economic factors, Water pollution

Identifiers: NTISEPAO

PB-260 077/3ST NTIS Prices: PC A06/MF A01

An Economic Analysis of the Proposed Water Resources Project for the Upper French Broad River Basin in Western North Carolina

Georgia Univ., Athens.*Office of Water Research and Technology, Washington, D.C. (153 970)

Doctoral thesis
AUTHOR: Sellers, J.
C4525C2 Fld: 13B, 05C, 48B GRAI7511
1972 313p
Project: OWRT-A-040-GA
Monitor: OWRT-A-040-GA(1)

Abstract: A procedure is developed and tested for evaluating water resources projects based on economic, social, legal, and environmental considerations. The areas of economic theory and public finance that apply to water resources investments supplied the basis for the analysis. Additional information concerning the environmental aspects were integrated with the economic and public finance aspects to develop a systematic process for evaluation. The proposed water resources project for the Upper French Broad River Basin in North Carolina was completely based on the methodologies that have been developed up to the present time.

Descriptors: *Water resources, *River basin development, *Benefit cost analysis, Project planning, Recreation, Flood control, Social welfare, Regional planning, Theses, Water pollution control, Economic impact, Assessments, French Broad River Basin, North Carolina

Identifiers: NTISDIOWRT

PB-240 563/7ST NTIS Prices: PC A14/MF A01

An Economic Evaluation of Water Quality Management Systems

Clemson Univ., S.C. Water Resources Research Inst.*Office of Water Research and Technology, Washington, D.C.

Completion rept.
AUTHOR: Macaulay, Hugh H.; Yandle, T. Bruce Jr
C6201E1 Fld: 13B, 05C, 68D*, 96A* GRAI7609
Oct 75 84p*
Rept No: WRRI-58
Contract: DI-14-31-0001-4041, DI-14-31-0001-5041
Project: OWRT-A-030-SC
Monitor: OWRT-A-030-SC(2)

Abstract: There are three general economic policies for dealing with water pollution, each one with a different following. Politicians and government administrators prefer regulations to restrict the amount of waste discharged by firms. Businessmen prefer government subsidies for cleaning up their effluent. Economists prefer charges on wastes discharged, based on the marginal damage done. All three are discussed. Regulations are described as inefficient, capricious, and destined to create dissatisfaction on the part of all parties affected. Subsidies are even more inefficient, administratively difficult, and have probably reduced the treatment of wastes. Charges may result in significant transaction costs but should be the most efficient in waste treatment and production of final output. But charges should be levied on all users of water quality, not on mills and municipalities only. Water pollution policies in Germany, England, the Netherlands, and France are examined and evaluated.

Descriptors: *Government policies, *Water quality management, *Economic analysis, East Germany, Regulations, Benefit cost analysis, Taxes, Water pollution, Policies, River basin development, Water pollution abatement, Foreign policy, West Germany, Great Britain, Netherlands, France, Grants, Allocations, Europe, Profits, Social welfare, Industries

Identifiers: National government, *Foreign countries, *Water pollution abatement, NTISDICWRT

PB-249 741/0ST NTIS Prices: PC A05/MF A01

Effects of Economic Development on Water Resources

Maryland Univ., College Park. Water Resources Research Center.*Office of Water Research and Technology, Washington, D.C.

Technical rept.
AUTHOR: Cumberland, John H.; Herzog, Henry W. Jr
D3155K1 Fld: 13B, 68D GRAI7720
Apr 77 66p
Rept No: TR-40
Contract: DI-14-31-0001-5020
Project: OWRT-A-028-MD
Monitor: OWRT-A-028-MD(1)

Abstract: An essential first step in evaluating pollution costs and environmental quality is to derive the relationships between the types and levels of economic activity as they effect the generation of residuals. Methods were developed of extending traditional input-output models to account for the generation of residuals, and to trace the flows through treatment processes and environmental media. Specific technical gross residual coefficients were derived for the output of emissions from 92 types of economic activity into the Chesapeake Bay by 15 major river basins.

Descriptors: *Water resources, *Industrial wastes, *Cost analysis, *Water pollution, *Chesapeake Bay, Economic models, Input, Output, Sewage treatment, Benefit cost analysis, Estimates, Flow charting, Water pollution abatement

Identifiers: NTISDIOWRT

PB-269 096/4ST NTIS Prices: PC A04/MF A01

The Interrelationship of Economic Development **and** Environmental Quality in the Upper Colorado River Basin: An Interindustry Analysis

Colorado Univ., Boulder. Dept. of Economics.

Research rept.
AUTHOR: Udis, Bernard; Howe, Charles W.; Kreider, Jan F.
C2102J2 Fld: 13B, 5C, 48B, 96G, 86K GRAI7403
Jul 73 651p
Grant: EDA-OER-351-G-71-8
Monitor: EDA/OER-73-122

Abstract: A set of compatible models relating the economic activities of the sub-basins of the Upper Colorado River, both present and prospective, to air quality and water quantity and quality resulting from those patterns of economic activity is developed. The purpose of such a set of models is to enable the planner to test some of the environmental implications of alternative growth patterns for the region. The report describes in detail the models which have been developed and calibrated for the three upper sub-basins (the Upper Main Stem, the Green, and the San Juan), an area which contains the origins of the most pressing problems of the basin; salinity, shale oil industry future impacts, and the expanded diversions of water of the Rocky Mountain Eastern Slope.

Descriptors: *Upper Colorado River basin, *Economic development, *Water quality, *Water resources, Economic models , Salinity, Air pollution, San Juan River basin, Green River basin, Industries, Hydrology, Regional planning, Water pollution, Water distribution, Atmospheric diffusion, Recreational facilities, Oil shale, Computer programs

Identifiers: *Air quality, EDA

COM-73-11970/3 NTIS Prices: PC E16/MF A01

A Methodology for Assessment of Water Resources Development: A Competitive Evaluation Model for Water Resources Development Planning

Oklahoma Water Resources Research Inst., Stillwater.

Completion rept.
AUTHOR: Reid, George W.; Law, Silas S. Y.
C1984D3 Fld: 13B, 48B* GRAI7401
Jul 73 201p*
Contract: DI-14-31-0001-3836
Project: OWRR-A-036-OKLA
Monitor: OWRR-A-034-OKLA(1)

Abstract: An effective evaluation methodology for assisting in water resources development planning is developed. A new model was contemplated for solving two principal problems associated with the present practices of water resources development planning - the considering of individual development as isolated entity and the using of the benefit and cost ratio as the only analysis in the evaluation process. The model was developed by using game theory concepts. The principal tactics employed in the model are the competitive measuring between benefit categories and the competitive evaluation of the development objectives. The procedures used in the model enables the identifying of the following: the overall system of water resources development as well as the individual or local development, the relationship and priorities of developments in different locations and between various purposes of development. The model is also able to recognize the competitive nature of water resources development and to augment some new measurements. The model as a whole provides a new approach for summarizing a large number of data into a simple and meaningful form in order to formulate systematic recommendations for the decision-maker. (Modified author abstract)

Descriptors: (*River basin development, Mathematical models), (*Water resources, Project planning), Evaluation, Game theory, Benefit cost analysis, Statistical data, Decision making, Regional planning, Systems analysis, Measurement, Heuristic methods, Cost effectiveness, Methodology

Identifiers: OWRR

PB-224 825/0 NTIS Prices: PC A10/MF A01

People and the Sound. An Economic Perspective

New England River Basins Commission, Boston, Mass.*Economic Research Service, Broomall, Pa.*Bureau of Economic Analysis, Washington, D.C.

Final rept.
C5465F4 Fld: 13B, 05C, 91H, 48B, 96A GRAI7525
Aug 75 86p
Rept No: LISS-13
Monitor: 18
Report on Long Island Sound Study. Prepared in cooperation with Economic Research Service, Broomall, Pa., and Bureau of Economic Analysis, Washington, D.C.
Paper copy also available in set of 14 reports as PB-245 233-SET, PC$61.00.

Abstract: The report examines the economic and demographic trends in the Long Island Sound region, with data for use as the basis of all projections made in the Long Island Sound Study. It is part of the final report of the Study, which outlines a strategy for securing the balanced conservation and development of natural resources of the Sound and its shoreline in both New York and Connecticut. The plan for Long Island Sound is an increment of the New England River Basins Commission comprehensive, coordinated joint plan for the water and related land resources of its region, which includes New England and the New York portions of Long Island Sound.

Descriptors: *Regional planning, *Natural resources, *Economic development, *Long Island Sound, Demography, Land use, Water resources, Land development, Industries, Employment, Conservation, Management, New York, Connecticut

Identifiers: NTISNERBC, NTISCOMBEA, NTISAGERS

PB-245 246/4ST NTIS Prices: PC A05/MF A01

Plan for Development of the Land and Water Resources of the Southeast River Basins. Appendix 9. Economics

United States Study Commission Southeast River Basins Atlanta Ga (410288)

Final rept.
D311112 Fld: 13B, 48B, 91H GRAI7720
1963 244p
Monitor: 18
Original contains color plates: All DDC and NTIS reproductions will be in black and white. Appendix 9 to AD-A041 835. See also Appendix 10 and 11, AD-A041 850.

Abstract: This Appendix provides a listing and review of the economic studies and analyses made in preparing a comprehensive, integrated plan of development of the land and water resources of the Southeast River Basins area. Throughout this Report the term economic is used in its broad sense covering many economic, social and institutional conditions and adjustments. Part One sets forth the conceptual framework, objectives, controlling assumptions, criteria, and study guidelines. Part Two summarizes and describes the basic studies carried out to meet the plan objectives. Part Three contains the Economic Framework or general guidelines for planning. Some of these guidelines had their origin in recent national studies, the results of which were adopted by the Commission as general guides for regional planning. Other guidelines were developed by the staff from the basic studies. Part Four presents the principles and procedures used in making economic evaluation studies of programs and projects. Part Five discusses cost sharing and financing as important aspects of the implementation of the resource plan.

Descriptors: *Water resources, *Basins(Geographic), *Economic analysis, North Carolina, South Carolina, Georgia, Florida, Alabama, Planning, Demography, Agriculture, Employment, Commerce, Cost analysis

Identifiers: River Basin development, NTISDODXA

AD-A041 844/2ST NTIS Prices: PC A11/MF A01

The Powder River Basin Economic Simulation Model: A Technical Report and Supplement to the Technical Report

Wyoming Univ., Laramie. Water Resources Research Inst.*Office of Water Research and Technology, Washington, D.C.

Completion rept.
AUTHOR: Carlson, John F.; Phillips, Clynn
E2102H1 Fld: 5C, 13B, 91J GRAI7820

Aug 77 196p
Contract: DI-14-31-0001-5237
Project: OWRT-C-6311(5237)
Monitor: OWRT-C-6311(5237)(1)

Abstract: The development and application of a continuous-growth economic simulation model to a discrete-growth economy are described. The model developed is a further adaptation of the North Platte River Basin Economic Simulation Model (1976) to Wyoming's Powder River Basin, which includes five Wyoming counties. The model is employment-based and simulates economic activity in seven sectors: population, employment, water demand, land use, income, agriculture, and housing. All major economic variables contained in the model are expressed in terms of functions relating dependent and independent variables, thus allowing virtually unlimited experimentation with various functional forms.

Descriptors: *Powder River basin, *Economic models, *River basin development, Economic analysis, Populations, Employment, Water consumption, Land use, Income, Water resources, Manpower, Computerized simulation, Agriculture, Housing studies, Wyoming

Identifiers: NTISDIOWRT

PB-282 562/8ST NTIS Prices: PC A09/MF A01

Research on Water Resources Evaluation Methodology: A River Basin Economic and Financial Post-Audit

Little (Arthur D.), Inc., Cambridge, Mass.*Office of Water Research and Technology, Washington, D.C. (208 850)

Final rept.
AUTHOR: Wilkinson, John M.
C4662I2 Fld: 13B, 05C, 48B, 96A GRAI7513
31 Mar 75 203p
Contract: DI-14-31-0001-4228
Project: OWRT-C-5126(4228)
Monitor: OWRT-C-5126(4228)(1)

Abstract: Benefit-cost analysis has long been relied upon as a tool for planning and justifying river-basin programs. Almost no record is kept of actual benefit accruals to compare with planning expectations. This postaudit of the Pick-Sloan Missouri Basin Program attempted to quantify the 30-year performance of multipurpose programs in dollar terms. Applying current evaluation Principles and Standards of the Water Resources Council on an ex-post basis, the objective was to determine how much physical and dollar realities have differed from original plans, why they have differed, and what are the implications for future planning. Because benefit estimating procedures remain so imperfect, a wide range of values could be quantified; however, it appears that flood control and electric power program performance far exceeded plan, while that for irrigation and navigation programs fell far short of plan. Benefits could be double or half most of those estimated in this post-audit, depending on value assumptions.

Descriptors: *Water resources, *Economic development, *Missouri River, Benefit cost analysis, Financing, Hydrology, Flood control, Irrigation, Recreation, Wildlife, Navigation, Water supply, Hydroelectric power generation, Fishes

Identifiers: NTISDIOWRT

PB-241 061/1ST NTIS Prices: PC A10/MF A01

Subsidies, Capital Formation, and Technological Change: Municipal Wastewater Treatment Facilities. Volume 1

Charles River Associates, Inc., Cambridge, Mass.*National Bureau of Standards, Wasnington, D.C. Experimental Technology Incentives Program. (402 974)

Final rept.
E2673H4 Fld: 5C, 5A, 13B, 96A*, 70F*, 68D* GRAI7825
Jul 77 150p*
Rept No: CRA-302.03
Contract: NBS-6-35744
Monitor: NBS-GCR-ETIP-78-40
See also Volume 2, PB-285 289.
Also available in set of 8 reports PC E19, PB-285 287-SET.

Abstract: The study evaluates the economic impact of federal grants for the improvement of the quality of the nation's waterways. The analysis is confined to the single most important program in this area, namely federal grants to assist in the construction of municipal waste treatment plants as called for in the 1972 Water Quality Amendments. By comparison with this program's annual funding of $5 billion to $6 billion, other programs in this area are virtually insignificant. The program provides municipalities with 75 percent of the costs of constructing wastewater treatment facilities which meet EPA approval and it is often supplemented by additional construction grants from the states. The grant program is part of the broad body of federal legislation which sets forth the nation's water pollution control policy. This legislation provides a system for defining and enforcing efflyent standards pertaining to all point source dischargers. Grants are available only to municipal dischargers except for an implicit, but smaller, subsidy to industries who tie into municipal systems. Of particular concern are the effects of the program both in the production of municipal waste treatment and on the rate of technological change in the industry. Attention is also given to the program's impact on the rate of growth in waste treatment plant construction and on its distributional implications.

Descriptors: *Federal assistance programs, *Economic impact, *Sewage treatment, Grants, Municipalities, Economic analysis, Economic development, Capital, Government policies, Incentives, Construction, Water quality, Legislation, Regulations, Waterways(Watercourses), Water supply, Water resources

Identifiers: *Technological change, *Technological development, Economic growth, *Sewage treatment plants, Innovations, *Water pollution control, NTISCOMNBS

PB-285 288/7ST NTIS Prices: PC A07/MF A01

The Willamette Basin Comprehensive Study of Water and Related Land Resources. Appendix C. Economic Base

Pacific Northwest River Basins Commission Vancouver Wash (410072)
D1984L3 Fld: 13B, 8H, 48B, 68D, 91H GRAI7711
1969 285p
Monitor: 18
Original contains color plates: All DDC reproductions will be in black and white. Appendix C to AD-A036 745. See also Appendix D, AD-A036 749.

Abstract: This is a specialized study designed to serve as a guide to water and related land resources development planning. An expanding economy requires more resources or more intensive resource utilization. As demands for resources increase, the increase in their supply can often be attained only by developing more costly sources or by utilizing resources more intensively. In particular, future demand for water looms large. Assuring that demands for resources will be satisfied in the best manner requires comprehensive development plans. These plans should in turn be based on the character and growth of the basin's economy. The objective of the Economic Base Study is to provide the basis for determining the scale, sequence, and timing of water and related land resources development. These determinations are based on estimates of future economic activity within the basin and the characteristics and size of its population. In estimating the basin's future economic activity, regional, national, and foreign trade in goods and services are recognized. Exports of basin products enhance the economic growth of the basin. The economic parameters projected in this study may be used in determining the need for each of the resource planning objectives. Useful economic parameters include (1) population and its characteristics--age, sex, and per capita income--for estimates of visitor-day use in fish and wildlife, and recreation studies; (2) output of industries using large quantities of water and power, for estimates of municipal and industrial water and power requirements; and (3) changes in urban, industrial, and agricultural development.

Descriptors: *Water resources, *Environmental management, *Economic analysis, *Water pollution abatement, Rivers, Basins(Geographic), Land use, Planning, Population, Urban areas, Rural areas, Agriculture, Industrial production, Recreation, Navigation, Irrigation systems, Flood control, Oregon

Identifiers: *Willamette River Basin, *Economic feasibility, *Water resources development, NTISDODXA

AD-A036 748/2ST NTIS Prices: PC A13/MF A01

1.3 Alphabetical Listing of Socio-Political Analysis Abstracts

1. An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico: Socorro Region.

2. Basin Governance.

3. Comprehensive Basin Study. Red River Below Denison Dam, Arkansas, Louisiana, Oklahoma, and Texas. Volume 3. Appendix V.

4. An Economic Study of Voter Attitudes Toward Different Proposals for the Use of an Undeveloped Island, Sears Island, Maine.

5. Improvement of Planning for Post-Development Water Resource Management: A Study of the Weber Basin Project.

6. Improvements Needed by the Water Resources Council and River Basin Commissions to Achieve the Objectives of the Water Resources Planning Act of 1965.

7. Issues and Opinions on the Social Effects of Water Allocation for Coal Development in the Yellowstone River Drainage.

8. Laws Relating to Industrial and Agricultural Activities.

9. Legal-Political History of Water Resource Development in the Upper Colorado River Basin, Part I. Summary of the Legislative History of the Colorado River Storage Project. Part II. The Politics of Water Resource Development in the Upper Colorado River Basin.

10. Lower Sheyenne River Basin, Water, Land, People.

11. Multiobjective Interagency Study of the Bear River Basin Water and Related Land Resources. (Utah).

12. People and the Sound. Marine Transportation Planning Report.

13. Plan of Study Subproject Report for a Case Study of a Federal Expenditure on a Water and Related Land Resource Project, Boise Project, Idaho and Oregon.

14. Problem Identification and Ranking - An Assessment of a River Basin Planning Process.

15. Proceedings of the Conference on Interdisciplinary Analysis of Water Resource Systems Held at Colorado University, Boulder, Colorado, on June 19-22, 1973.

16. Report of Testing Special Task Force Evaluation Procedures Water Resource Council for Poteau River Watershed, Scott County, Arkansas and LeFlore County, Oklahoma.

17. Rocky Mountain Environmental Research. Quest for a Future. Problems and Research Priorities in the Rocky Mountain Region.

18. Water Supply and Wastewater in Coastal Areas: Proceedings of Southeastern Conference Held on April 2-4, 1975.

19. The Winooski Workshops: An Assessment of Specified Workshop Techniques for Stimulating and Improving Public Involvement in Water Resources.

1.4 Socio-Political Analysis Abstracts

An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico: Socorro Region

New Mexico State Univ., University Park. Water Resources Research Inst.

Partial technical completion rept.
AUTHOR: Lansford, Robert R.; Ben-David, Shaul; Gebhard, Thomas G. Jr; Brutsaert, William; Creel, Bobby J.
C2721G3 Fld: 13B, 48B GRAI7411
Dec 73 107p
Rept No: WRRI-023
Project: OWRR-A-045-NMEX
Monitor: OWRR-A-045-NMEX(4)

Abstract: An interdisciplinary approach to the solution of the water resource problems of the Socorro Region in New Mexico was centered around a socio-economic model, developed to represent the New Mexico economy, with special emphasis placed upon the Rio Grande region. Inputs into the socio-economic model were obtained from separate studies covering the hydrological, agricultural, municipal, and industrial areas. Three sets of alternatives were considered: (1) growth without a water constraint; (2) growth, with a surface-water constraint; (3) growth, with both surface- and ground-water constraints. (Modified author abstract)

Descriptors: *New Mexico, *Water resources, *Economic models, River basin development, Rio Grande River, Surface waters, Ground waters, Utilization

Identifiers: OWRR

PB-230 615/7 NTIS Prices: PC A06/MF A01

Basin Governance

Cornell Univ. Agricultural Experiment Station, Ithaca, N.Y. Dept. of Agricultural Economics.*Utah Center for Water Resources Research, Logan.
AUTHOR: Allee, David J.; Capener, Harold R.; Andrews, Wade H.
C7202B4 Fld: 13B, 8H, 5K, 5C, 48B, 48G, 92C GRAI7621
Dec 75 29p
Rept No: Staff Paper-75-25
Monitor: OWRT-B-136-UTAH(1)
Prepared in cooperation with Utah Center for Water Resources Research, Logan, Contract DI-14-31-0001-5141, Project OWRT-B-136-UTAH.

Abstract: The report is the result of three workshop sessions. The complex organizational problems of regional and river basin management call for a major integrated effort of several social science disciplines. An approach to this research is recommended. Requirements of social science research on this problem are: first, support of an interdisciplinary social science research team through the necessary phases of the broad problem. The mapping and inventorying of river basin management and organization is the first stage of this work. A second requirement is to support the work through an adequate period of time to complete the stages necessary.

Descriptors: *River basin development, *Regional planning, *Socioeconomic status, Research management, Water quality management, Organizations, Social effect, Budgeting, Political objectives, Cost control, Economic analysis

Identifiers: Institutional framework, Intergovernmental relationships, NTISDIOWRT

PB-255 099/4ST NTIS Prices: PC A03/MF A01

Comprehensive Basin Study. Red River Below **Denison Dam, Arkansas,** Louisiana, Oklahoma, and Texas. Volume 3. Appendix V

Red River Basin Coordinating Committee New Orleans La (410089)
D1985A1 Fld: 13B, 8H, 48B, 68D, 48G GRAI7711
Jun 68 260p
Monitor: 18
Appendix to report dated Jun 68, AD-A036 742. See also Volume 4, Apoendices 6 and 7, AD-A036 751. Original contains color plates; All DDC reproductions will be in black and white.

Abstract: The purposes of this document is to: (1) Identify water and related land resource problems; (2) prepare a potential plan for water and related land resource development that could be accomplished under USDA programs; (3) prepare agricultural and forestry data for use of cooperating agencies in planning water and related resource projects under their programs; and (4) compile engineering, economic, and related data that local organizations could use for developing water and related land resources.

Descriptors: *Water resources, *Rivers, *Watersheds, *Land use, *Water supplies, Economic analysis, Management planning and control, Basins(Geographic), Agriculture, Forestry, Soil erosion, Population, Employment

Identifiers: *Red River Basin, Arkansas, Louisiana, Oklahoma, Texas, *Water resources development, *Land development, NTISDODXA

AD-A036 750/8ST NTIS Prices: PC A12/MF A01

An Economic Study of Voter Attitudes Toward Different Proposals for the Use of an Undeveloped Island, Sears Island, Maine

Massachusetts Agricultural Experiment Station, Amherst.
AUTHOR: Seekins, Milton D.; Storey, David A.
E267304 Fld: 13B, 48B, 91H GRAI7825
May 77 80p
Rept No: BULL-651
Monitor: 18
Library of Congress Catalog Card no. 78-622501.

Abstract: The study deals with voters' perceptions of the impacts of various developmental alternatives for a case study tract of coastal wildland at one particular point in time, their resulting attitudes toward the alternatives, and the dollar valuations associated with those attitudes. An attempt is made to evaluate relationships between socio-economic characteristics of individuals and the above measures. Thus, the purpose is to try to explain variations in attitudes and valuations by variations in population characteristics, as an aid to the planning process in other times and other places.

Descriptors: *Land use, *Coastal zone management, *Land development, Attitudes, Socioeconomic status, Sears Island, Water resources, Penobscot Bay, Maine

Identifiers: *Wildlands, Searsport(Maine), Stockton Springs(Maine), Waldo County(Maine), Case studies, Alternatives, NTISSLLC

PB-285 270/5ST NTIS Prices: PC A05/MF A01

Improvement of Planning for Post-Development Water Resource Management: A Study of the Weber Basin Project

Utah State Univ., Logan. Inst. for Social Science Research on Natural Resources.*Office of Water Research and Technology, Washington, D.C.
AUTHOR: Madsen, Gary E.; Andrews, Wade H.
D2515E4 Fld: 13B, 5K, 48B, 92C GRAI7714
Sep 76 98p
Rept No: Research Mono-6
Contract: DI-14-31-0001-5212
Project: OWRT-C-6092(5212)

Monitor: OWRT-C-6092(5212)(1)

Abstract: The objectives of the studies were to: (1) Identify present management problems in the Weber Basin Project of Utah; (2) identify whether the problems are related to the planning process so that relationships between planning and management can be identified; (3) identify recommendations from present management personnel concerning changes in planning which might help alleviate management problems with future projects, as well as recommendations for present solutions to problems; (4) identify theoretical elements which can be applied to future planning. Present management problems were being experienced primarily in two areas, urban pressurized irrigation systems (where the non-treated water is used for residential lawns, gardens and shrubs), and the recreation component of the project. Several recommendations for future water resources planning resulted.

Descriptors: *Water resources, *Social effect, *River basin development, Project planning, Recommendations, Irrigation, Demand(Economics), Water supply, Recreation, Urban areas, Attitudes, Environmental impacts, Utah

Identifiers: *Water management(Administrative), Weber Basin project, Water demand, NTISDIOWRT

PB-266 009/0ST NTIS Prices: PC A05/MF A01

Improvements Needed by the Water Resources Council and River Basin Commissions to Achieve the Objectives of the Water Resources Planning Act of 1965

General Accounting Office, Washington, D.C. Community and Economic Development Div.
E0172F4 Fld: 13B, 8H, 48B*, 48G GRAI7802
31 Oct 77 17p*
Rept No: CED-78-1
Monitor: 18

Abstract: The report reviews selected activities of the Water Resources Council and river basin commissions to assess their progress in implementing the Water Resources Planning Act of 1965. The study concentrates on the Council's responsibilities to review plans submitted by river basin commissions. These responsibilities are (1) to determine both the adequacy of the plans and their ability to contribute to national water needs and (2) to make recommendations to the President, for transmittal to the Congress, about Federal projects and new Federal policies and programs. The study states that the Council and the river basin commissions have made only limited progress in achieving these responsibilities and that they need to further define and implement (1) the planning and coordination goals of the Council and the river basin commissions, (2) the means for accomplishing these goals, and (3) the role of the Council and the river basin commissions in attaining these goals.

Descriptors: *River basin development, *Water resources, Organizations, Government policies, Recommendations, Objectives, Water conservation, Economic development, Land development, National government, State government, Local government, Commerce, Improvement, Research projects

Identifiers: Water needs, Water Resource Planning Act of 1965, NTISGAO

PB-273 552/0ST NTIS Prices: PC A02/MF A01

Issues and Opinions on the Social Effects of Water Allocation for Coal Development in the Yellowstone River Drainage

Montana State Univ., Bozeman. Water Resources Research Center.*Office of Water Research and Technology, Washington, D.C.

Completion rept.
AUTHOR: Faulkner, Lee G.
D1941H4 Fld: 13B, 8H, 48G, 43F, 68 GRAI7710
Jul 76 187p
Rept No: MUJWRRC-78
Project: OWRT-C-6303(5230)
Monitor: OWRT-C-6303(5230)(1)

Abstract: The results of this study define issues of major concern to decision makers, water users, and residents of the Yellowstone River drainage region. These issues revolve around the possible effects of allocation of water from the study area to the coal development industry. Water use issues include potential impacts on water quantity, in-stream flow, water quality, and groundwater, water needs of reclamation, major water development and water rights. Social issues include rapid population growth, lifestyle changes, economic impacts, impacts on the Indian reservations, loss of local control and increases in crime. Policy questions explored in the study include attitudes toward the handling of coal development issues and information by state and local authorities, levels of coal development, and alternate means of shipping coal. Implications for policy are drawn from the results of the residents' survey.

Descriptors: *Water consumption, *Water supply, *Coal mining, *Yellowstone River Basin, Availability, Agriculture, Industrial water, Water quality management, Policies, Social effect, Attitude surveys, Public opinion, Reservoirs, Economic impact, American Indians, Crimes, Population growth, Montana, Wyoming

Identifiers: Environmental protection, NTISDIOWRT

PB-263 484/8ST NTIS Prices: PC A09/MF A01

Laws Relating to Industrial and Agricultural Activities

Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Miss.*Mississippi Univ., University. Law Center.*National Oceanic and Atmospheric Administration, Rockville, Md. Office of Sea Grant.

Preliminary draft.
C444481 Fld: 05D, 05C, 13B, 92D, 96, 48B, 86M GRAI7510
1973 49p
Rept No: MASGP-74-035
Monitor: NOAA-75021811
Prepared by Mississippi Univ., University. Law Center.

Abstract: The volume is one of ten representing a compilation of Mississippi laws which most significantly affect the use and development of the state's marine and coastal zones. Various state, county, and local agencies are charged with implementing a policy of balanced economic development between agriculture and industry. The Mississippi Department of Agriculture has general supervision over all agriculture and agricultural commodities within the state. Management of water resources encompasses a wide area of activities. Extensive legal citations are presented.

Descriptors: *Law(Jurisprudence), *Economic development, *Coasts, *Mississippi, Administrative law, Industries, Land use, Agriculture, Public law, Water resources, Project planning, Government, Land acquisition

Identifiers: Sea Grant program, NTISCOMNOA

COM-75-10326/7ST NTIS Prices: PC A03/MF A01

Legal-Political History of Water Resource Development in the Upper Colorado River Basin. Part I. Summary of the Legislative History of the Colorado River Storage Project. Part II. The Politics of Water Resource Development in the Upper Colorado River Basin

Lake Powell Research Project, Los Angeles, Calif.**California Univ., Los Angeles.*National Science Foundation, Washington, D.C. Research Applied to National Needs.
AUTHOR: Weatherford, Gary D.; Nichols, Phillip; Mann, Dean E.
D1344G3 Fld: 13B, 5D, 48B, 92D GRAI7706
Sep 74 62p
Rept No: Bull-4
Monitor: NSF/RA/E-74-384
Prepared by California Univ., Los Angeles.

Abstract: This study is in two parts. Part I chronicles the dominant events of the legislative history of the Colorado River Storage Project Act of 1956. The major political and legal decisions emanating from the Colorado River Compact of 1922 and resulting in the 1956 Act are identified. Part II approaches these historical events analytically from the perspective of political science. The persistence of distributive politics, in the face of increasing pressure for a more 'regulator' mode of decision-making, is discussed in the context of some of the current problems such as water quality of the river. Also, several unresolved issues of public policy concerning Colorado River management are posed.

Descriptors: *Water resources, *Legislation, *Colorado River Basin, History, Law(Jurisprudence), Political science, Land use, Decision making, Policies, Water rights, Economic development, Lake Powell, Utah

Identifiers: Colorado River Storage Act of 1956, Lake Powell research project, NTISNSFRA

PB-261 674/6ST NTIS Prices: PC A04/MF A01

Lower Sheyenne River Basin, Water, Land, People

North Dakota Water Resources Research Inst. Fargo.*Office of Water Research and Technology, Washington, D.C. North Dakota Agricultural Experiment Station, Fargo.*Sheyenne River Basin Research Team, N. Dak.

Completion rept.
AUTHOR: Barker, William T.; Nelson, William C.
C5871A1 Fld: 13B, 68D, 91H GRAI7605
Sep 74 121p
Rept No: W1-222-005-75
Contract: DI-14-31-0001-4116
Project: OWRT-B-029-NDAK
Monitor: OWRT-B-029-NDAK(1)
Also pub. as North Dakota Agricultural Experiment Station, Fargo, Research rept. no. 55. Prepared in cooperation with Sheyenne River Basin Research Team, N. Dak.

Abstract: Rivers in the Northern Great Plains are carrying increasing pollutant concentrations as the density of human and livestock populations and intensity of land cultivation increase. The major emphasis of this multi-disciplinary project is to quantitatively determine the relationships among land, people, and water quality; and to evaluate the impact of alternative means to increase water quality. Activities during the first year of the project included: (1) Mapping of the land use of the complete basin; (2) mapping the surface geology of the upper portion of the basin; (3) periodic testing of the river water for 22 quality indicators; (4) mapping of population densities; (5) description of socioeconomic characteristics of the basin; and (6) statistical analysis of the relationship among the water quality indicators and basin descriptors. Water quality indicators frequently exceeded established pollution standards. The variation in water quality was related to flow rates, temperature, density of human and livestock populations, and the intensity of land cultivation.

Descriptors: *Land use, *Water pollution, *Sheyenne River Basin, Water quality, Livestock, Agricultural wastes, Geological surveys, Mapping, Concentration(Composition), Population(Statistics), Social welfare, Economic development, Statistical analysis, Standards, Mathematical models, Flow rate, Stream flow, Hydrogeology, North Dakota

Identifiers: Northern Great Plains Region(United States), NTISDIOWRT

PB-248 068/9ST NTIS Prices: PC A06/MF A01

Multiobjective Interagency Study of the Bear River Basin Water and Related Land Resources. (Utah)

Utah Div. of Water Resources, Salt Lake City.

Comprehensive Water Planning Program.
F0071D1   Fld: 13B, 48B, 68D, 91H   GRAI7901
Dec 76   169p
Monitor: 18

Abstract: This study included the formulation and evaluation of plans for use and development of water and related land resources. This report includes an inventory of basic resource data and projected population and associated needs over time, with a National Economic Development Plan, a regional development plan, and an environmental quality plan.

Descriptors: *Land use, *Water resources, *Bear River Basin, Inventories, Populations, Economic development, Regional planning, Climatology, Wildlife, Recreation, Erosion, Geomorphology, Irrigation, Local government, Environmental impacts, Demography, Mineral deposits, Constraints, Social effect, Benefit cost analysis, Evaluation

Identifiers: NTISSLLC

PB-286 282/9ST   NTIS Prices: PC A08/MF A01

People and the Sound. Marine Transportation Planning Report

New England River Basins Commission, Boston, Mass.*Maritime Administration, Washington, D.C.*Department of Transportation, Washington, D.C.*Corps of Engineers, Waltham, Mass. New England Div.

Final rept.
C5465E3 Fld: 13J, 05C, 85B, 91H, 96A, 86L GRAI7525
Aug 75 89p
Rept No: LISS-08
Monitor: 18
Report on Long Island Sound Study. Prepared in cooperation with Maritime Administration, Washington, D.C., and Department of Transportation, Washington. D.C. Prepared by Corps of Engineers, Waltham, Mass. New England Div.

Paper copy also available in set of 14 reports as PB-245 233-SET, PC$61.00.

Abstract: A planning report describes the marine transportation element of the Long Island Sound regional study. It is part of the final report of the study, which outlines a strategy for securing the balanced conservation and development of natural resources of the Sound and its shoreline in both New York and Connecticut. The plan for Long Island Sound is an increment of the New England River Basins Commission comprehensive, coordinated joint plan for the water and related land resources of its region, which includes New England and the New York portions of Long Island Sound.

Descriptors: *Marine transportation, *Regional planning, *Long Island Sound, Ports, Harbors, Conservation, Development, Water resources, New England, New York, Land development, Economic forecasting, Problem solving, Evaluation, Recommendations, Cargo transportation, Commerce

Identifiers: NTISNERBC, NTISDOTG, NTISCOMMA

PB-245 241/5ST NTIS Prices: PC A05/MF A01

Plan of Study Subproject Report for a Case Study of a Federal Expenditure on a Water and Related Land Resource Project, Boise Project, Idaho and Oregon

Idaho Univ., Moscow. Water Resources Research Inst.*Office of Water Research and Technology, Washington, D.C.

Completion rept.
AUTHOR: Haas, Wayne T.; Schermerhorn, Richard

C5872E2 Fld: 13B, 08H, 05C, 48B, 48G, 96 GRAI7605
Jun 74 47p
Project: OWRT-C-4202(9061)
Monitor: OWRT-C-4202(9061)(2)
See also PB-248 150.

Abstract: The purpose of this study is to present an analysis of the role of the federal government in water development in the Boise Project of Idaho and Oregon. As a result of the study and two related support studies, conclusions and recommendations are presented and discussed.

Descriptors: *Water resources, *Land development, *Boise River Basin, National government, Federal budgets, Expenses, Demand(Economics), Management, Decision making, Recommendations, Project planning, Water consumption, Objectives

Identifiers: Boise project, Boise(Idaho), Water utilization, Government supports, NTISDIOWRT

PB-248 149/7ST NTIS Prices: PC A03/MF A01

Problem Identification and Ranking - An Assessment of a River Basin Planning Process

Minnesota Univ., Minneapolis. Water Resources Research Center.**Illinois Univ. at Urbana-Champaign. Dept. of Urban and Regional Planning.*Office of Water Research and Technology, Washington, D.C.
AUTHOR: Blair, L. F.; Harris, A.; Felstehausen, H.; Lamm, W. T.; Austin, T. A.
E1974C4 Fld: 13B, 5A, 91H, 70B GRAI7819
Jan 78 129p
Rept No: REGIONAL RESEARCH SER-2
Contract: DI-14-31-0001-5140
Project: OWRT-B-057-IA
Monitor: OWRT-B-057-IA(2)
Prepared in cooperation with Illinois Univ. at Urbana-Champaign. Dept. of Urban and Regional Planning.

Abstract: The comprehensive, coordinated and joint planning process of the Upper Mississippi River Basin Commission is reviewed, and the process is analyzed according to parameters of efficiency and equity representative of four research disciplines: economics, political science, engineering and planning. Revisions to the existing planning process are recommended, as derived from the multi-disciplinary analysis.

Descriptors: *River basin development, *Mississippi River Basin, *Regional planning, Assessments, Ranking, Evaluation, Benefit cost analysis, Income, Optimization, Citizen participation, Decision making, Systems analysis, Linear programming, Scheduling, Budgeting, Improvement

Identifiers: Tradeoffs, NTISDIOWRT

PB-282 100/7ST NTIS Prices: PC A07/MF A01

Proceedings of the Conference on Interdisciplinary Analysis of Water Resource Systems Held at Colorado University, Boulder, Colorado, on June 19-22, 1973

American Society of Civil Engineers, New York.*Office of Water Research and Technology, Washington, D.C.
AUTHOR: Flack, J. Ernest
C5944H3 Fld: 13B, 08H, 05C, 48B, 68D GRAI7606
1975 410p

Contract: DI-14-31-0001-3757
Project: OWRT-X-126(3757)
Monitor: OWRT-X-126(3757)(1)

Abstract: The Water Resources Systems Committee of the American Society of Civil Engineers' Technical Council on Water Resources Planning and Management saw a critical need for developing an interdisciplinary approach to water resources development. This Conference was intended as an effective means of advancing the systems approach in this area. Formal papers on six interdisciplinary efforts were selected as case studies, around which discussions were built. These six papers include interdisciplinary studies on: (1) large reservoirs in Africa; (2) limnological modeling of the Great Lakes: (3) geothermal development; (4) the North Atlantic Regional Water Resources Study; (5) Corps of Engineers planning experience in the St. Louis-Maline Creek; and (6) University research in the Wisconsin River and the Lower Fraser River (Brit. Columbia) water quality studies. Discussions are given after each paper. Included also is an introductory article on the interdisciplinary aspects of water resources planning and management.

Descriptors: *Water resources, *Water quality management, *Meetings, Systems engineering, Multiple purpose reservoirs, Africa, Limnology, Mathematical models, Great Lakes, Geothermy, Economic development, Maline Creek, Civil engineering, Social welfare, Project planning, Law(Jurisprudence), Interactions, Decision making, Missouri, United States, California, Wisconsin River, Fraser River

Identifiers: North Atlantic Region(United States), Saint Louis(Missouri), British Columbia, NTISDIOWRT

PB-248 596/9ST NTIS Prices: PC A18/MF A01

Report of Testing Special Task Force Evaluation Procedures Water Resource Council for Poteau River Watershed, Scott County, Arkansas and Le Flore County, Oklahoma

Soil Conservation Service, Washington, D.C.*Water Resources Council, Washington, D.C. (388 099)
C7211J1 Fld: 13B, 5C d7621
Dec 69 41p
Monitor: 18
Sponsored in part by Water Resources Council, Washington, D.C.

Abstract: The report describes the objectives of the Soil Conservation Service Test Team in applying methods and procedures for evaluating water and related land development and to give the physical and economic aspects of the Poteau Watershed.

Descriptors: *Water resources, *Land development, *Poteau Watershed, Economic factors, Project planning, Benefit cost analysis, Income, Regional planning, Objectives, Recommendations, Standards, Arkansas, Oklahoma

Identifiers: Scott County(Arkansas), Le Flore County(Oklahoma), NTISUSWRC

PB-255 910/2ST NTIS Prices: PC A03/MF A01

Rocky Mountain Environmental Research. Quest for a Future. Problems and Research Priorities in the Rocky Mountain Region

Eisenhower Consortium for Western Environmental Forestry Research, Fort Collins, Colo.*Forest Service, Washington, D.C.*Environmental Protection Agency, Washington, D.C.*Utah State Univ., Logan. Committee on Future Environments in the Rocky Mountain Region.*National Science Foundation, Washington, D.C. Research Applied to National Needs.

Final rept.
C748581 Fld: 13B, 68, 97 GRAI7623
1975 293p
Grant: NSF-GI-39421
Monitor: 18
Sponsored in part by Forest Service, Washington, D.C. and Environmental Protection Agency, Washington, D.C. Prepared in cooperation with Utah State Univ., Logan. Committee on Future Environments in the Rocky Mountain Region.

Abstract: Rocky Mountain Environmental Research - Quest for a Future was formed with the purpose of identifying environmental problems and research questions in the Rocky Mountain Region. With accurate research to provide facts, wise management decisions can be made which will preserve our heritage and enhance the Region for future generations. The purpose of the research was the following: Identify and evaluate current and potential problems associated with the growing interaction of people and natural environments in the Region, and determine and establish priorities for the research required to provide the necessary basis for environmentally sound resource managements on public and private lands. Task forces were formed to address several subject areas: Biological resources, human needs and responses, institutional arrangements, mineral and energy resources, recreation and tourism, rural residential development, timber and forage uses, and water resources and uses. Task force leaders were asked to select an interdisciplinary and broad-based committee to determine the state-of-knowledge in each field, the gaps in knowledge, and thus the major needs to be researched. Each leader prepared a documented report of the findings. A draft of each task force report was sent for review and the review comments were incorporated where pertinent into the final reports presented here.

Descriptors: *Environmental impacts, Assessments, Forecasting, Management analysis, Mineral deposits, Mines(Excavations), Human ecology, Technology, Utilization, Land development, Recreation, Rural areas, Economic impact, Structual timber, Forage grasses, Mathematical models, Water resources, Sewage treatment, Watersheds, Irrigation, River basins, Flood control, Desalting, Cloud seeding, Population growth

Identifiers: Ecosystems, Energy resources, Environmental impact assessments, *Rocky Mountain Region(United States), NTISEPAO, NTISNSFRA, NTISAGFS

PB-256 446/6ST NTIS Prices: PC A13/MF A01

Water Supply and Wastewater in Coastal Areas: Proceedings of Southeastern Conference Held on April 2-4, 1975

North Carolina Water Resources Research Inst., Raleigh.*National Oceanic and Atmospheric Administration, Rockville, Md. Office of Sea Grant.*Coastal Plains Center for Marine Development Services, Washington, D.C.
AUTHOR: Stewart, James M.
C5874A4 Fld: 13B, 48B*, 68D*, 91H, 86M GRAI7605
1975 194p*
Monitor: NOAA-75120106
Also pub. as North Carolina Univ. Sea Grant reprint no. 83.
Sponsored in part by Coastal Plains Center for Marine Development Services, Washington, D.C.

Abstract: The article details the proceedings of the southeastern conference on Water Supply and Wastewater in Coastal Areas. The Conference was conducted to review the state of the art of proper planning and management of water supply and wastewater disposal in coastal areas. Special attention was paid to defining technological and institutional alternatives, their relation to land use planning and environmental protection, and to identifying those water and wastewater problems of significance in coastal areas. A major problem that was discussed at the conference is associated with increasing population growth and economic development in these areas is the provision of safe and adequate water supplies and management of wastewater discharges in a manner consistent with public health and welfare and environmental protection. Both the presentations and discussion sessions are included in the report.

Descriptors: *Water supply, *Water pollution, *Coasts, *Meetings, *Regional planning, Waste water, Reviews, Water quality management, Sewage disposal, Technology assessment, Land use zoning, Environmental impacts, Population growth, Economic development, Public health, Social welfare, Water resources, Sanitary engineering, Project planning, Ocean environments, Financing

Identifiers: Sea Grant program, *Environmental protection, NTISCOMNOA

PB-248 297/4ST NTIS Prices: PC A09/MF A01

The Winooski Workshops: An Assessment of Specified Workshop Techniques for Stimulating and Improving Public Involvement in Water Resources

Vermont Univ., Burlington. Water Resources Research Center.*Office of Water Research and Technology, Washington, D.C.

Completion rept.
AUTHOR: Wilm, Ann S.; Thomas, Kristi L.
C7602H1 Fld: 13B, 5K, 48B, 68D, 92C, 92B, 43F GRAI7624
1975 99p
Contract: DI-14-31-1-5046
Project: OWRT-A-020-VT
Monitor: OWRT-A-020-VT(1)

Abstract: Public participation is a dynamic communication process within a social system, a source of information and support for social and economic goals. Current interest in citizen participation is sparked by changes in social values and more specifically by a change in the public's perception of government responsibility. Vermont is drawing up its River Basin Water Quality plans for the major rivers of the state. Agencies have called for citizen input. This provided an opportunity to test a commonly used workshop technique for involving citizens against a second format which involved a more social-psychological orientation and small group problem-solving techniques. The purpose of this project was to test the hypothesis that differences in environmental settings reflect, and are reflected in citizen motivation levels to become involved in water resource decision-making.

Descriptors: *Citizen participation, *Water resources, *Social communication, *River basin development, *Water quality, *Winooski River, Decision making, Economic development, Attitude surveys, Social psychology, Questionnaires, Environments, Vermont

Identifiers: NTISDIOWRT

PB-257 545/4ST NTIS Prices: PC A05/MF A01

1.5 Alphabetical Listing of Methodology Abstracts

1. An Analysis of Federal Water Resource Planning and Evaluation Procedures.

2. An Analysis of Water Resource Benefit Determination Methods with Special Reference to the Consumnes River Division Project.

3. Analytical Techniques for Planning Complex Water Resource Systems.

4. A Bargaining Approach for Programming Least-Cost Waste Treatment Along a River.

5. Comprehensive Framework Study Missouri River Basin. Volume 7. Appendix. Plan of Development and Management of Water and Related Land Resources.

6. Development of Regional Supply Functions and a Least-Cost Model for Allocating Water Resources in Utah: A Parametric Linear Programming Approach.

7. Economic Optimization and Simulation Techniques for Management of Regional Water Resource Systems.

8. Estimation of Outdoor Recreational Values.

9. Evaluating Tisza River Basin Development Plans Using Multiattributes Utility Theory.

10. Federal Evaluation of Resource Investments: A Case Study.

11. The Impact of Energy Resource Development on Water Resource Allocations.

12. Improving Institutional Arrangements for Water Development in the State of Washington: Developmental and Environmental Trade-Offs and Constraints.

13. Issues Related to Interfacing Water Resource Planning and Land Use Planning: Development and Application of Quantitative Procedures.

14. Methodology to Evaluate Alternative Coastal Zone Management Policies: Application in the Texas Coastal Zone. Example Application III, Environmental and Economic Impacts of Recreational Community Development, Mustang Island and North Padre Island. Volume II - Appendix.

15. Mixed Integer Programming Models for Water Resources Management.

16. Multiple Objective Redesign of the Big Walnut Project.

17. Multiple Objectives Planning Water Resources. Volume 1. Natural Resources Series Number 5.

18. Ohio River Basin Comprehensive Survey. Volume XII. Appendix K. Development Program Formulation.

19. Optimal Solution to the Timing, Sequencing, and Sizing of Multiple Reservoir Surface Water Supply Facilities When Demand Depends on Price.

20. Optimization Model of Energy Related Economic Development in the Upper Colorado River Basin under Conditions of Water and Energy Resource Scarcity.

21. Plan for Development of the Land and Water Resources of the Southeast River Basins. Appendix 10. Hydrology. Appendix 11. Engineering and Cost.

22. Planning of Regional Water Resource Systems for Urban Needs.

23. Proceedings: The Connecticut River System: A Workshop on Research Needs and Priorities Held at the University of Massachusetts, Amherst on April 24 and 25, 1975.

24. Project Evaluation in Water Resources: Budget Constraints.

25. River Basin Simulation as a Means of Determining Operating Policy for a Water Control System.

26. Significant Interrelationships Between Electric Power Generation and Natural and Developed Resources in the Connecticut River Basin.

27. Systems Simulation of Economic Factors and Their Relation to the Water System of Wyoming's Platte River Basin.

1.6 Methodology Abstracts

An Analysis of Federal Water Resource Planning and Evaluation Procedures

Michigan Univ., Ann Arbor. School of Natural Resources. (409 340)
AUTHOR: Schramm, Gunter; Burt, Robert E. Jr
C7143B1 Fld: 13B GRAI7620
Jun 70 114p
Monitor: 18

Abstract: The purpose of the report was to test a set of new water resources plan and project evaluation procedures published by the Special Task Force for June 1969. The seminar used a designated stretch of the Susquehanna between Pittston and Sayres, Pennsylvania as the focal point of the investigation.

Descriptors: *Water resources, *Project planning, *Susquehanna River, Regional planning, Income, Economic development, Objectives, Environmental impacts, Recommendations, Evaluation, Pennsylvania

Identifiers: NTISUSWRC

PB-255 498/8ST NTIS Prices: PC A06/MF A01

An Analysis of Water Resource Benefit Determination Methods with Special Reference to the Cosumnes River Division Project

California Univ., Davis. Dept. of Agricultural Economics. (405 609)

Interim rept.
AUTHOR: Tratz, Robert F. Jr; Dean, Gerald W.; Carter, Harold O.
C2163C3 Fld: 13B, 5C, 48B GRAI7404
Jun 73 149p
Contract: DI-14-06-200-5075-A
Monitor: 18

Abstract: The general objective of this study is to formulate, construct, and test a theoretical model which will allow measurement of the magnitude of net income and employment impacts of a multipurpose regional water resource development. This model should improve upon the current method of determining municipal and industrial (M&I) water supply benefits (i.e., most likely single purpose alternative). Related objectives are to explore the feasibility of basing municipal and industrial water supply benefits on the value or demand for water rather than, its cost, and to examine the tradeoffs among competing uses of water.

Descriptors: *Benefit cost analysis, *River basin development, *Water resources, Cosumnes River, Multiple purpose reservoirs, California, Economic development, Regional planning, Methodology, Economic models, Employment

Identifiers: BR

PB-226 029/7 NTIS Prices: PC E06/MF A01

Analytical Techniques for Planning Complex Water Resource Systems

Texas Water Development Board, Austin. Systems Engineering Div.

Summary rept.
C2951H2 Fld: 13B, 48B GRAI7414
Apr 74 66p
Rept No: 183
Contract: DI-14-31-0001-3360
Project: OWRR-A-2070(3360)
Monitor: OWRR-C-2070(3360)(3)

Abstract: The report summarizes the research experience of the Texas Water Development Board, the constitutional water planning and development agency for the state of Texas, over the period 1965-1972. Systems analysis techniques were developed to assist in solving some of the long-range water planning problems encountered and identified in the Texas water plan and for refining the Texas water plan as it was originally conceived. The conditions dictating the constraints and opportunities of the Texas water plan are described. The sequential steps in the research program are outlined, and the proposed facilities of the Texas water system are used as an example for research and development of new planning techniques.

Descriptors: *Water resources, *Systems engineering, *Texas, Systems analysis, Ground water, Water supply, River basin development, Mathematical models, Multiple purpose reservoirs, Hydrology, Aquifers, Irrigation, Water quality, Demand(Economics), Water rights, Cost analysis

Identifiers: Water utilization, Water requirements, NTISOWRR

PB-232 158/6 NTIS Prices: PC A04/MF A01

A Bargaining Approach for Programming Least-Cost Waste Treatment Along a River

North Carolina Water Resources Research Inst., Raleigh.***Office** of Water Research and Technology, Washington, D.C.
AUTHOR: Airan, Lalita D.; Seagraves, J. A.; Airan, Damodar S.
C5801B3 Fld: 13B, 05C, 68D*, 96A*, 43F GRAI7604
Jul 75 71p*
Rept No: UNC-WRRI-75-109
Contract: DI-14-31-0001-3952
Project: OWRT-B-054-NC
Monitor: OWRT-B-054-NC(4)

Abstract: A model is developed for minimizing waste treatment costs to achieve a given stream standard. An optimum set of treatment levels is calculated using available information about the cost of waste treatment and the effects of waste in different reaches with an assumed procedure for bargaining among waste dischargers. Each discharger is assumed to be responsible for the quality of water in his reach. The optimum solution suggests an optimum set of discharge permits and charges. However, it does not favor any one administrative system or distribution of costs. The model is run to find optimum or least-cost waste treatment levels for the Neuse River of North Carolina. The optimum solution has much less treatment than is currently being used. The costs of present waste treatment are estimated to be $3.7 million per year while the cost of the optimum set of treatment levels is only $1.09 million.

Descriptors: *Sewage treatment, *Water quality management, *River basin development, *Regional planning, Mathematical models, Optimization, Licenses, Cost comparison, Water quality , Estimates, Neuse River, North Carolina, Cost analysis

Identifiers: NTISDIOWRT

PB-247 108/4ST NTIS Prices: PC A04/MF A01

Comprehensive Framework Study Missouri River Basin. **Volume 7. Appendix.** Plan of Development and Management of **Water and** Related Land Resources

Missouri Basin Inter-Agency Committee (410365)
D3571K4 Fld: 13B, 8H, 48B, 48G GRAI7724
Jun 69 290p
Monitor: 18
Original contains color plates: All DDC and NTIS reproductions will be in black and white. See also Volume 2, AD-A043 936.
Availability: Paper copy available from Supt. of Documents, GPO, Washington, D. C. 20402. HC $5.25.

Abstract: The overall objective was the formulation of a framework plan which would provide a broad guide to the best uses, or combination of uses, of water and related land resources to meet foreseeable short- and long-term needs. Underlying this overall objective, consideration was given to (1) the timely development and management of these resources as essential aids to the economic development and growth of the basin; (2) the preservation of resources, as appropriate, to insure that they will be available for their best use as needed; and (3) the well-being of all the people as the overriding determinant.

Descriptors: *Basins(Geographic), *Water resources, *Planning, *Cost analysis, Natural resources, Land use, Economic analysis, Forecasting, Agriculture, Irrigation systems, Water supplies, Municipalities, Industries, Water quality, Flood control, Dams, Reservoirs, Electric power production, Recreation

Identifiers: *Missouri River Basin, *Regional planning, Water quality management, NTISDODXA

AD-A043 941/4ST NTIS Prices: MF A01

Development of Regional Supply Functions and a Least-Cost Model for Allocating Water Resources in Utah: A Parametric Linear Programming Approach

Utah Water Research Lab Logan*Institute for Water Resources (Army), Fort Belvoir, Va. (405725)

Final rept.
AUTHOR: King, Alton B.; Andersen, Jay C.; Clyde, Calvin G.; Hoggan, Daniel H.
C3882A2 Fld: 13B, 48B GRAI7502
Jun 72 169p
Rept No: PRWG100-2
Contract: DACW31-71-C-0063
Monitor: IWR-74-4-Supp-2

Abstract: The report develops supply functions for agricultural use in ten hydrologic study units in Utah by parametric linear programming. The shadow-price of imported water to each study unit was determined to show the possible economic consequence of interbasin transfer. In general, imported water is of little or no value if water presently being evaporated from Great Salt Lake is available for diversion upstream. A statewide linear programming allocation model was developed to meet projected requirements, subject to various hydrologic constraints and limits on diversions. The primary factor affecting interbasin transfer of Colorado River water is the degree to which evaporation occurs from Great Salt Lake. (Author)

Descriptors: *Water supplies, *Systems analysis, Allocations, Regions, Optimization, Mines(Excavations), Salvage, Linear programming, Restraint, Mathematical models, Hydrology, Evaporation, Rivers, Economics, Lakes, Utah

Identifiers: *Imported water, Great Salt Lake, Colorado River, Intergovernmental relationships, *Water demand, NTISDODA

AD/A-000 822/7SL NTIS Prices: PC A08/MF A01

Economic Optimization and Simulation Techniques for Management of Regional Water Resource Systems

Texas Water Development Board, Austin.

Completion rept.
C2945H2   Fld: 13B, 48B   GRAI7414
Feb 74   60p
Rept No: Rept. no. 179
Contract: DI-14-31-0001-3360
Project: OWRR-C-1070(3360)
Monitor: OWRR-C-2070(3360)(2)

Abstract: The research represents the final phase of a three-phase research project leading towards the development of a computer-oriented planning system for use in planning large, multibasin systems of reservoirs and connecting river reaches and pump-canals. Specifically, the research defines a methodology for finding an optimal size, operation, and staging of construction of a water resource system with highly variable inflows and demands that are increasing over the planning horizon and assessing the impacts of such a system. The computer programs developed during this research are designed to analyze a problem on a monthly basis using historic or stochastic hydrologic input data sequences, a specified demand build-up period, and an economic life as defined by the user.

Descriptors: *Water resources, *River basin development, *Project planning, Texas, Water supply, Models, Irrigation, Economics, Water quality, Systems analysis, Regional planning, Agriculture, Computer programming

Identifiers: NTISOWRR

PB-232 066/1   NTIS Prices: PC A04/MF A01

Estimation of Outdoor Recreational Values

Florida Univ., Gainesville. Dept. of Food and Resource Economics.
AUTHOR: Gibbs, Kenneth C.; McGuire, John F. III
C308312 Fld: 5K, 92C GRAI7416
Jul 73 62p
Rept No: Economics-53
Contract: DI-14-31-0001-3267
Project: OWRR-B-007-FLA
Monitor: OWRR-B-007-FLA(11)

Abstract: A project was initiated at the University of Florida to estimate the value of water in alternative uses and to determine the optimum allocation among the alternative uses. Basically, the study was designed to develop and test two types of water allocation models: linear programming and simulation. In order to allocate water efficiently, values of alternative uses must be estimated. It is the purpose of this report to: (1) present the procedures used to derive estimates of economic value, and (2) derive the economic value of 'water oriented' outdoor recreation in the Kissimmee River Basin.

Descriptors: *Water resources, *Recreation, Recreation facilities, Travel, River basin development, Regional planning, Cost analysis, Mathematical models, Florida, Kissimmee River Basin

Identifiers: NTISOWRR

PB-232 503/3 NTIS Prices: PC E03/MF A01

Evaluating Tisza River Basin Development Plans Using Multiattributes Utility Theory

International Inst. for Applied Systems Analysis, Laxenburg (Austria).

Research rept.
AUTHOR: Keeney, Ralph L.; Wood, Eric F.; David, Laszlo; Csontos, Kornel
E0612L4 Fld: 13B, 8H, 48B, 48G GRAI7807
Mar 76 30p
Rept No: CP-76-3
Monitor: 18

Abstract: Selecting a plan to develop the water resources of a region involves the consideration of economic, environmental, social, and technical objectives. Twelve attributes are defined to indicate the degree to which these objectives are achieved in the Tisza River basin of Hungary. A preliminary multi-attribute utility function is assessed over these attributes. This is combined with existing information describing the possible consequences of five alternative development plans to yield an overall rating of their desirability. The utility function explicitly indicates the preference tradeoffs among attributes. Discussion indicates further uses of the utility function in the planning and evaluation processes.

Descriptors: *Water resources, *Tisza River, *River basin development, *Hungary, Evaluation, Assessments, Objectives, Economic factors, Environmental impacts, Social effect, Project planning, Theorems, Drainage, Mathematical models, Water quality, Water storage, Floods, Recreation, Land use, Values

Identifiers: *Tradeoffs, Energy requirements, NTISIIASA

PB-276 066/8ST NTIS Prices: PC A03/MF A01

Federal Evaluation of Resource Investments: A Case Study

Cornell Univ., Ithaca, N.Y. Water Resources and Marine Sciences Center.*Cornell Univ., Ithaca, N.Y. Dept. of Agricultural Economics.*New York State Coll. of Agriculture, Ithaca.

Technical rept.
AUTHOR: Kalter, Robert J.; Libby, Larry W.; Hinman, Robert C.; Schultz, David A.; Shabman, Leonard A.
C7205J2 Fld: 13B, 5C GRAI7621
Feb 70 100p
Rept No: TR-24
Monitor: 18
Also pub. as Cornell Univ., Ithaca, N.Y. Dept. of Agricultural Economics, A. E. Res-313. Prepared in cooperation with New York State Coll. of Agriculture, Ithaca.

Abstract: The purpose of the report is to further improve and perfect the standards, criteria and procedures to be used for water resource development and management for the proposal for the Stonewall Jackson Reservoir on West Fork River in West Virginia.

Descriptors: *Water resources, *Land development, *Project planning, Investments, Water quality, Environmental impacts, Recreation, Economic impact, Flood control, Regional planning, West virginia, West Fork River

Identifiers: *Stonewall Jackson Reservoir, NTISUSWRC

PB-255 788/2ST NTIS Prices: PC A05/MF A01

The Impact of Energy Resource Development on Water Resource Allocations

Utah Water Research Lab., Logan.*Office of Water Research and Technology, Washington, DC.
AUTHOR: Keith, John E.; Turna, K. S.; Padunchai, Sumel; Narayanan, Rangesan
F0064C4 Fld: 10A, 97 GRAI7901
May 78 109p
Rept No: UWRL-P-78/005
Contract: DI-14-34-0001-6125
Project: OWRT-B-131-UTAH
Monitor: OWRT-B-131-UTAH(1)

Abstract: A linear programming model of the agricultural and energy sectors of Utah was used to examine the economically efficient allocation of water between agriculture and energy. Data were collected for agricultural returns, costs, and water requirements; energy returns, costs, and water requirements; and water supply costs.

Descriptors: *Energy source development, *Water resources, *Resource allocation, Utah, Coal, Crude oil, Natural gas, Coal gasification, Coal liquefaction, Oil shale, Irrigation, Energy transport, Electric power generation, Colorado River Basin, Economic impact, Mathematical models, Linear programming, Allocations, Planning, Scenarios

Identifiers: NTISDIOWRT

PB-286 135/9ST NTIS Prices: PC A06/MF A01

Improving Institutional Arrangements for Water Development in the State of Washington: Developmental and Environmental Trade-Offs and Constraints

Washington Univ., Seattle. Inst. of Governmental Research.*Office of Water Research and Technology, Washington, D.C.

Project completion rept. 1 Jul 72-30 Jun 75
AUTHOR: Pealy, Robert H.
D2971J2 Fld: 13B, 48B, 91H GRAI7718
Jun 76 193p
Contract: DI-14-31-0001-3848
Project: OWRT-A-057-WASH

Monitor: OWRT-A-057-WASH(1)

Abstract: The networks of institutional arrangements in this study consist of federal, state, local, and regional organizations, including the processes they use in planning and developing the functions of irrigation, water supply, electricity generation, navigation, flood control, soil conservation, forest conservation, fish and wildlife conservation and outdoor recreation. The networks are also expected to trade off the values of water development with the values of environmental protection and growth. Each of the networks was originally designed to reach certain objectives: comprehensive, multi-purpose, long-range planning and development of river basins; economic efficiency; engineering or technical efficiency; administrative efficiency; and political consensus. The objective of environmental protection was recently added, and, to a limited degree, growth control. The networks have achieved only a moderate degree of success in achieving the objectives.

Descriptors: *Organizations, *Decision making, *Water resources, *Washington(State), State government, Project planning, Water supply, Navigation, Flood control, Conservation, Objectives, National government, Local government, River basin development, Economic factors, Recreation, Electric power plants, Management, Regional planning

Identifiers: *Institutional framework, *Water management(Administrative), Tradeoffs, NTISDIOWRT

PB-267 919/9ST NTIS Prices: PC A09/MF A01

Issues Related to Interfacing Water Resource Planning and Land Use Planning: Develcpment and Application of Quantitative Procedures

INTASA, Menlo Park, Calif.*Office of Water Research and Technology, Washington, D.C. (406 193)

Final rept.
AUTHOR: Davenport, S.; Jolissaint, C. H.; Betchart, W. B.; Rosing, J.; Skurski, K.
D0424B1 Fld: 13B, 8H, 48B*, 91H* GRAI7703
May 76 227p*
Rept No: IRP-74-01
Contract: DI-14-31-0001-5207
Project: OWRT-C-6057(5207)
Monitor: OWRT-C-6057(5207)(1)

(PC A11/MF A01)

Abstract: The research addresses three of many requirements for interfacing water and land resources planning: (1) Need to coordinate separate resource planning activities and assign regional priorities; (2) need to relate environmental, social and economic benefits and costs of community land use plans to similar decision criteria at the regional water resources planning level; (3) need to quickly convert land use information into water resource requirements and costs. Results include: (1) simplified quantitative procedures based on regional water, land and mass balance relationships and demonstrated in the Platte River, Nebraska Level B regional study; (2) an improved fiscal cost analysis procedure for short term land use decisions based on economic, social and environmental goals, demonstrated in Richmond, Calif.; (3) extension of site development cost models to analyze housing cost associated with community use policies, demonstrated in Napa, California.

Descriptors: *Water resources, *Land use, *Regional planning, *River basin development, Cost analysis, Water flow, Social effect, Water pollution control, Land development, Benefit cost analysis, Community development, Mathematical models, Environmental impacts, Requirements, Platte River, Economic impact, Policies, Nebraska, California

Identifiers: Low flow augmentation, Richmond(California), Napa(California), NTISDIOWRT

PB-259 331/7ST NTIS Prices: PC A11/MF A01

Methodology to Evaluate Alternative Coastal Zone Management Policies: Application in the Texas Coastal Zone. Example Application III, Environmental and Economic Impacts of Recreational Community Development, Mustang Island and North Padre Island. Volume II - Appendix

Texas Univ. at Austin. Center for Research in Water Resources.*Texas Office of the Governor, Austin. Div. of Planning Coordination.*National Science Foundation, Washington, DC. Applied Science and Research Applications. (406 294)
AUTHOR: Kier, Robert S.; Fruh, E. Gus
F058504 Fld: 13B, 48B GRAI7908
1976 674p
Grant: NSF-AEN74-13590-A-01
Monitor: NSF/RA-761639
See also Volume 1, PB-290 132. Sponsored in part by Texas Office of the Governor, Austin. Div. of Planning Coordination.

Abstract: This report on an example application of environmental and economic impacts of recreational community development on Mustang and North Padre Islands is a continuation of a study to establish operational guidelines for Texas Coastal Zone management. Chapters include population projections for scenarios; assessment of recreational population demands on Mustang and North Padre Islands with model examples; geological aspects of barrier island development; selected biological data, water needs and waste generation of these islands; hydronamic and transport modeling in barrier island communities; economic analysis of barrier island development; structural engineering calculations, and environmental and economic impacts of employing the private drive concept. Information is presented on land and water resources, on currents, flooding, shoreline changes, and dune studies. Descriptions of plants, animals and nutrient cycling are given for selected biotopes such as beaches, salt marshes, and grassflats. Mammals and birds indigenous to the islands are described. Economic analysis includes soft-ware development outlines of two program designs, FDISL and SOLVEX.

Descriptors: *Environmental impacts, *Economic impact, *Community development, *Coastal zone management, *Mustang Island, *North Padre Island, Surveys, Populations, Demand(Economics), Mathematical models, Demography, Dunes, Beaches, Water supply, Shores, Vegetation, Constraints, Biological productivity, Wildlife, Benefit cost analysis, Computer programming, Solid waste disposal, Ocean tides, Hydrodynamics, Sewage treatment, Flooding, Nutrients, Texas, Recreation

Identifiers: *Alternative planning, Salt marshes, SOLVEX computer program, FDISL computer program, NTISNSFRA

PB-290 131/2ST NTIS Prices: PC A99/MF A01

Mixed Integer Programming Models for Water Resources Management

Utah Water Research Lab., Logan.*Office of Water Research and Technology, Washington, D.C. (405 725)

Project completion rept. 1 Jul 76-31 Dec 77
AUTHOR: Finney, Brad; Grenney, William J.; Bishop, A. Bruce; Hughes, Trevor C.
E0803I1 Fld: 13B, 68D, 48G, 91H GRAI7809
Dec 77 292p
Rept No: PRWG-198-1
Contract: DI-14-34-0001-7132
Project: OWRT-B-145-UTAH
Monitor: OWRT-B-145-UTAH(1)

Abstract: A regional water quality control model is developed by linking a steady-state water quality simulation model with an optimization model. The water quality simulation model can be applied to complex river systems with both point and nonpoint loads using multiple interdependent pollution parameters described by either linear or nonlinear equations. Twelve water quality parameters can be modeled simultaneously: Four nonconservative constituents (or conservative constituents if the decay rate is set equal to zero); coliform bacteria (MPN); phosphorus; biochemical oxygen demand (BOD); ammonia (NH3); nitrate (NO3); dissolved oxygen (DO); temperature (C); and algae. The water quality model is used to generate constraint equations for the optimization model. The optimization model is formulated as an integer programming problem in which the integer decision variables are wastewater treatment levels or diffuse source management practices to be determined for each load. The model considers the addition or upgrading of wastewater treatment with structural and nonstructural schemes for both point and diffuse pollution sources. A least cost solution is found subject to water quality standards at surveillance points.

Descriptors: *River basin development, *Water quality management, *Water supply, *Sewage treatment, *Regional planning, Upgrading, Mathematical models, Optimization, Coliform bacteria, Phosphorus, Ammonia, Algae, Dissolved gases, Oxygen, Biochemical oxygen demand, Nitrogen, Temperature, Computer programs, Subroutines, Cost analysis, Jordan River, Utah

Identifiers: Path of pollutants, *Model studies, SSAM computer program, NTISDIOWRT

PB-276 699/6ST NTIS Prices: PC A13/MF A01

Multiple Objective Redesign of the Big Walnut Project

Massachusetts Inst. of Tech., Cambridge. Dept. of Civil Engineering.*Water Resources Council, Washington, D.C. (220 010)
AUTHOR: Major, David C.; Bravo, Carlos; Cohon, Jared; Grayman, Walter; Harley, Brendan
C7204L3 Fld: 13B, 5C GRAI7621
1 Apr 70 64p
Monitor: 18
Prepared in cooperation with Water Resources Council, Washington, D.C.

Abstract: The purpose of the report is to discuss the theory of multiple objective planning; provide background information on the Big Walnut project; analyze benefit and cost accounting by the Corps for their proposed project for the Big Walnut Dam in Putnam County, Indiana.

Descriptors: *Water resources, *Land development, *Project planning, Economic impact, Benefit cost analysis, Water quality, Flood control, Recreation, Environmental impacts, Regional planning, Standards, Big Walnut River, Indiana

Identifiers: Big Walnut Dam, Putnam County(Indiana), NTISUSWRC , NTISMITEL

PB-255 685/0ST NTIS Prices: PC A04/MF A01

Multiple Objectives Planning Water Resources. Volume 1. **Natural** Resources Series Number 5

Idaho Research Foundation, Inc., Moscow.*Office of Water Research and Technology, Washington, D.C.
AUTHOR: Michalson, Edgar L.; Englebert, Ernest A.; Andrews, Wade; Stratton, Charles R.
C7491H1 Fld: 13B, 5C, 48B, 68D, 50B, 70E GRAI7623
1974 66p
Project: OWRT-X-142(4259)
Monitor: OWRT-X-142(4259)(1)
Proceedings of the UCOWR Workshop on Multiple Objective Planning and Decision-Making, Held at Las Vegas, Nevada on July 16-18, 1974. See also PB-256 740.

Abstract: The workshop originated as an effort on the part of the Committee for Education and Research in the Social Sciences of the Universities Council on Water Resources. During the 1972 UCOWR annual meeting a task force was established to identify research topics and problems related to multiple objective planning and decision making. The workshop itself was designed to provide a means of exchange between federal agency planners and university researchers. Agency planners -- through position papers -- provided basic input to use in multiple objective planning.

Descriptors: *Water resources, *Project planning, *Meetings, Decision making, Research projects, National government, Universities, Economic development, River basin development, Soil conservation, Fishes, Construction, Land reclamation, Wildlife, Nevada

Identifiers: *Multiple purpose projects, NTISDIOWRT

PB-256 739/4ST NTIS Prices: PC A04/MF A01

Multiple Objectives Planning Water Resources. Volume 2. Natural Resources Series Number 5

Idaho Research Foundation, Inc., Moscow.*Office of Water Research and Technology, Washington, D.C.
AUTHOR: Michalson, Edgar L.; Engelbert, Ernest A.; Andrews, Wade; Stratton, Charles R.
C7491H2 Fld: 13B, 5C, 48B, 68D, 50B, 70E GRAI7623
1975 127
Project: OWRT-X-142(4259)
Monitor: OWRT-X-142(4259)(2)
Proceedings of the UCOWR Conference on Multiple Objective Planning and Decision-Making, Held at Boise, Idaho January 14-16, 1975. See also PB-256 739.

Abstract: The conference discussed was a result of efforts by the Committee for Education Research in the Social Sciences of the Universities Council on Water Resources. During the 1972 UCOWR annual meeting, a task group was established to identify research topics and problems related to multiple objective planning and decision making. At the 1973 UCOWR annual meeting, a resolution was passed calling for a national Workshop-Conference on the topic. The Conference was designed to allow the university people to present their ideas for public discussion by federal agency planners: The present volume contains the Conference papers, together with summaries of the discussion and panels.

Descriptors: *Water resources, *Project planning, *Meetings, Reviews, Decision making, Land use, Policies, River basin development, Public opinion, Social effect, Universities, National government, Environmental impacts, Objectives, Ecology, Cost analysis, Economic impact, Standards, Wildlife, Idaho

Identifiers: *Multiple purpose projects, NTISDIOWRT

PB-256 740/2ST NTIS Prices: PC A07/MF A01

Ohio River Basin Comprehensive Survey. Volume XII. Appendix K. Development Program Formulation

Army Engineer Div Ohio River Cincinnati (410257)
D3011H2 Fld: 13B, 8H, 48B GRAI7719
Jul 68 317p
Monitor: 18
Original contains color plates: All DDC and NTIS reproductions will be in black and white. See also Volume 13, AD-A041 280.

Abstract: This appendix presents background information, planning concepts and procedures, and, as an end product, a generalized plan for the development and management of the water and related land resources of the Ohio River Basin. The plan, comprised of a framework of broad-scaled water resource and related program elements, outlines the water and related land resource development requirements within the basin. It also accounts for general land use and management practices and water based or enhanced activities that may influence, benefit by, or be dependent on water resource development. Program elements of the framework plan were progressively formulated through integration of the various developmental opportunities and alternatives judged to best fulfill the needs of the basin. The plan demonstrates the extent to which the water and related land resources can meet present the future demands for water and water-oriented functions and services, the manner in which these demands can be met, the timing and magnitude of development required, and the cost that would be involved. Elements outlined herein form the basis for the Ohio River Basin development program summarized and discussed in the Main Report.

Descriptors: *Ohio River, *Basins(Geographic), *Resource management, Land use, Planning, Water resources, Economic analysis, Forecasting

Identifiers: NTISDODXA

AD-A041 279/1ST NTIS Prices: PC A14/MF A01

Optimal Solution to the Timing, Sequencing, and Sizing of Multiple Reservoir Surface Water Supply Facilities When Demand Depends on Price

California Univ., Los Angeles.*Office of Water Research and Technology, Washington, DC. (072 250)
AUTHOR: Moore, Nancy Young
F0343J4 Fld: 13B, 48B GRAI7905
Jun 77 146p
Contract: DI-14-31-0001-4208
Project: OWRT-C-5184(4208)
Monitor: OWRT-C-5184(4208)(5)

Abstract: A general multi-period planning model for the optimal timing, sizing, and sequencing of reservoir additions to surface water supply is presented. The objective of the model is the maximization of net economic efficiency benefits subject to hydrologic system constraints. The model is designed to handle system increments which are unique and interdependent. Since firm water, the product of the system, is dependent on existing reservoir sizes, configurations, and hydrologies a rational operating scheme is incorporated into the optimization. A price-sensitive demand curve which changes according to a prescribed growth rate is used. Known reservoir cost relationships which are a function of project capacity determine costs. A forward dynamic programming algorithm is used for solution. The model is tested with an application to the Eel River Project in Northern California. The discount rate, growth rate, and demand elasticity are parameterized and tested over several values.

Descriptors: *Multiple purpose reservoirs, *Water supply, Size determination, Mathematical models, Dynamic programming, Cost analysis, Demand(Economics), Sequencing, Output, Sewage treatment, Water distribution, Theses, Efficiency, Optimization, Prices, Water consumption, Rates(Costs), Computer programs, California

Identifiers: *Water demand, Water levels, Eel River project, Water resources development, NTISDIOWRT

PB-288 155/5ST NTIS Prices: PC A07/MF A01

Optimization Model of Energy Related Economic Development in the Upper Colorado River Basin under Conditions of Water and Energy Resource Scarcity

Los Alamos Scientific Lab., N.Mex.*Energy Research and Development Administration. (3820000)
AUTHOR: Morris, G. E.
D385212 Fld: 10A, 97G GRAI7726
Mar 77 570p
Contract: W-7405-ENG-36
Monitor: 18
Thesis.

Abstract: A mathematical model was designed for computer analysis of the likely impact of energy development in the upper Colorado River Basin in the period 1980 to 1985. The upper Colorado River Basin, with its reserves of coal, oil shale, uranium ore, petroleum, and natural gas is regarded as an important source of increased energy resources. The Basin now contains several major mature oil fields, seven major hydroelectric facilities, and has produced the major portion of uranium mined in the U.S. Energy projects proposed, planned, or under construction in the Colorado, Utah, and Wyoming portions of the Basin in 1977 include 39 new or expanded coal mines, 10 new or expanded thermoelectric power plants, eight oil shale developments, one coal gasification plant, and three tar sand projects, with the possibility of increased uranium mining and milling. The model is an interregional input-output depiction of economic activity coupled with export, water, and energy resource constraints and runs in a linear optimized framework. (ERA citation 02:043458)

Descriptors: *Colorado River Basin, *Energy demand, *Energy source development, A codes, C codes, Coal gasification plants , Coal industry, Computer calculations, Computer codes, Economic development, Economic impact, Forecasting, Industry, M codes, Mathematical models, Oil sands, Oil shale industry, Regional analysis, Thermal power plants, Uranium reserves, USA , Water resources

Identifiers: ERDA/290200, ERDA/290400, ERDA/294000, ERDA/010000, ERDA/020000, *Energy models, NTISERDA

LA-6732-T NTIS Prices: PC A24/MF A01

Plan for Development of the Land and Water Resources of the Southeast River Basins. Appendix 10. Hydrology. Appendix 11. Engineering and Cost

United States Study Commission Southeast River Basins Atlanta Ga (410288)

Final rept.
D3111J4 Fld: 13B, 8H, 48G, 91H GRAI7720
1963 145p
Monitor: 18
Original contains color plates: All DDC and NTIS reproductions will be in black and white. Appendixes 10 and 11 to AD-A041 835. See also Appendixes 12 and 13, AD-A041 851.

Abstract: No abstract available.

Descriptors: *Water resources, *Basins(Geographic), *Hydrology, *Cost analysis, Floods, Climate, Ground water, North Carolina, South Carolina, Georgia, Florida, Alabama, **Dams, Reservoirs**

Identifiers: River Basin development, NTISDODXA

AD-A041 850/9ST NTIS Prices: PC A07/MF A01

Planning of Regional Water Resource Systems for Urban Needs

North Carolina Water Resources Research Inst., Raleigh.**North Carolina Univ., Chapel Hill. Dept. of City and Regional Planning.*Office of Water Research and Technology, Washington, D.C.

Preliminary completion rept.
AUTHOR: Moreau, David H.
E0501G4 Fld: 13B, 8H, 48B, 91H, 48G GRAI7806
30 Mar 72 44p
Project: OWRT-B-021-NC
Monitor: OWRT-B-021-NC(1)
Prepared by North Carolina Univ., Chapel Hill. Dept. of City and Regional Planning.

Abstract: The objective of this study was to examine modifications to existing planning and analytical models that are necessary for the development of limited water and related land resources to serve the needs of several emerging urban areas within a region that spans several river basins in the Piedmont of North Carolina. Three basic tasks were set forth in the proposal for the study: (1) Identify emerging needs for water and related lands within the region; (2) examine a limited set of alternative programs for development and management of a regional system; and (3) examine adaptations of planning and regulatory practices and institutional arrangements to achieve development of a selected regional system. This report covers work completed during the first year of a 2-year project.

Descriptors: *Water supply, *Regional planning, *North Carolina, Management, Demand(Economics), Land use, Mathematical models, River basin development, Project planning , Yadkin River, Deep River, Haw River, Hydrology, Water consumption, Neuse River, Stream flow

Identifiers: *Water demand, NTISDIOWRT

PB-275 058/6ST NTIS Prices: PC A03/MF A01

Proceedings: The Connecticut River System: A Workshop on Research Needs and Priorities Held at the University of Massachusetts, Amherst on April 24 and 25, 1975

Massachusetts Univ., Amherst. Water Resources Research Center.**Massachusetts Univ., Amherst. Inst. for Man and Environment.*Office of Water Research and Technology, Washington, D.C.
AUTHOR: Ertel, Madge O.
D315104 Fld: 13B, 68D, 48B, 91H GRAI7720
Jul 75 149p
Rept No: Pub-52; Completion-FY-75-5
Contract: DI-14-31-0001-5021
Project: OWRT-A-078-MASS
Monitor: OWRT-A-078-MASS(1)

Abstract: A workshop on research needs and priorities on the Connecticut River system was conducted on April 24-25, 1975 at the University of Massachusetts. The goals were to generate multi-disciplinary, inter-institutional interest in a future co-ordinated research program, and define and evaluate the priorities of needed research. Working group activities included: (1) Modeling water quality and quantity; (2) flood-plain ecosystems; (3) aquatic ecosystems; (4) legal and economic issues; and (5) man/environment relations.

Descriptors: *Water resources, *Connecticut River, *Meetings, Research projects, Water quality, Flood plains, Ecology, Recreation, Law(Jurisprudence), Mathematical models, Water supply, Regional planning, Economic development, Massachusetts

Identifiers: Priorities, NTISDIOWRT

PB-268 837/2ST NTIS Prices: PC A07/MF A01

Project Evaluation in Water Resources: Budget Constraints

Massachusetts Inst. of Tech., Cambridge. Ralph M. Parsons Lab. for Water Resources and Hydrodynamics.*Office of Water Research and Technology, Washington, D.C. (406 907)

Technical rept.
AUTHOR: Major, David C.; Cohon, Jared; Frydl, Edward
C5105I1 Fld: 13B, 48B GRAI7520
Sep 74 303
Rept No: 188; R74-52
Contract: DI-14-31-0001-3720
Project: OWRT-C-3370(3720)
Monitor: OWRT-C-3370(3720)(1)

Abstract: A multiobjective mathematical programming model was developed for the Lehigh River, Pennsylvania, in locally and globally optimal versions. Objectives for the Lehigh representing each of the four accounts of the Water Resources Council's proposed 1970 standards are discussed, and the models are formulated for three of these: increasing national income, regional and class income distribution, and environmental quality. The design variables in the model are the reservoirs and power plants considered in the Corps of Engineers' 1961 report on the Delaware river basin, which includes the Lehigh. Runs of the models were made for one, two and three objectives, constrained by total and local budgets of varying size. Results from the globally optimal model are presented. These show the estimated effects on multidimensional net benefit surfaces and on the design variables of the budget constraints. There is a general discussion of the nature and use of budget constraints in multiobjective planning, and suggestions are made for implementing the work at the district (Corps) or region (Bureau of Reclamation) levels.

Descriptors: *Benefit cost analysis, *Water resources, *Project planning, *Water quality management, *Water management, *River basin development, Mathematical models, Computerized simulation, Linear programming, Water supply, Reservoirs, Lehigh River, Budgeting, Cost analysis, Flood control, Stream flow, Recreation, Hydroelectric power generation, Economic analysis, Computer programs, Pennsylvania

Identifiers: *Multipurpose projects, NTISDICWRT

PB-243 567/5ST NTIS Prices: PC A14/MF A01

River Basin Simulation as a Means of Determining Operating Policy for a Water Control System

Florida Univ., Gainesville. Dept. of Food and Resource Economics.

Doctoral thesis
AUTHOR: Kiker, Clyde Frederick
C1813C1 Fld: 13B, 48B, 52I, 60I GRAI7323
1973 123p
Contract: DI-14-31-0001-3267
Project: OWRR-B-007-FLA
Monitor: OWRR-B-007-FLA(7)

Abstract: The problem of dealing with the formulation of water management policy for the area of south Florida within the Central and Southern Florida Flood Control District was undertaken. The objectives were to (a) propose an organizational framework in which hydrologic, economic, and institutional aspects of the region may be used in policy development, (b) develop a simulation model which includes the salient hydrologic, economic, and institutional features of the Upper Kissimmee River Basin to serve as a guide, (c) demonstrate the usefulness of the simulation model in policy evaluations, and (d) determine the appropriateness of the approach for use in policy problems encountered when dealing with a large region. A first-generation simulation model of the hydrologic phenomena and water-oriented activities in the Upper Kissimmee River Basin was developed. Models of the surface water management system, the water use activities, and the institutional constraints were interfaced with rainfall and watershed runoff models.

Descriptors: (*Florida, Water resources), (*Management planning, *Water resources), Computerized simulation, Kissimmee River basin, River basin development, Regional planning, Organization theory, Watersheds, Water supply, Surface waters, Decision making, Theses

Identifiers: OWRR

PB-223 961/4 NTIS Prices: PC E05/MF A01

Significant Interrelationships Between Electric Power Generation and Natural and Developed Resources in the Connecticut River Basin

Federal Power Commission, Washington, D.C. Office of Energy Systems.
D2224K2 Fld: 10A, 13B, 97I, 91A, 48B GRAI7712
Dec 76 280p
Monitor: 18

Abstract: This report assesses the interrelationships between hydroelectric power and natural resources in an entire river basin. It presents a methodology for assessing these interrelationships that has applicability in preparing comprehensive environmental impact statements on entire river basin systems.

Descriptors: *Hydroelectric power generation, *Connecticut River Basin, River basin development, Land use, Social effect, Economic impact, Manpower, Cost estimates, Hydrology, Hydroelectric power plants, Topography, Environmental impacts, Natural resources, Energy demand, Electric power demand, Water resources, Forecasting

Identifiers: *Energy source development, NTISFPC

PB-264 753/5ST NTIS Prices: PC A13/MF A01

Systems Simulation of Economic Factors and Their Relation to the Water System of Wyoming's Platte River Basin

Wyoming Univ., Laramie. Water Resources Research Inst.

Project completion rept.
AUTHOR: Phillips, Clynn
C2392F4 Fld: 13B, 48B GRAI7407
Nov 73 52p
Rept No: Ser-40
Project: OWRR-A-005-WYO
Monitor: OWRR-A-005-WYO(1)

Abstract: That portion of Wyoming within the North Platte River Basin is likely to feel substantial pressure for development in the next decade. The availability and cost of water will be important considerations in future development plans for this area. This study examines the potential for designing an economic model of the Basin, using simulation techniques of analysis, for use in evaluating development impacts that are likely to occur in the near future. A hydrologic model of the Basin is also being developed, using simulation techniques, and it is intended that the two models will eventually be integrated. (Modified author abstract).

Descriptors: *Wyoming, *River basin development, *Economic moaels, Feasibility, Platte River basin, Water supply, Benefit cost analysis

Identifiers: OWRR

PB-227 267/2 NTIS Prices: PC A04/MF A01

1.7 Alphabetical Listing of Environmental Case Studies Abstracts

1. The Cherry Creek-Casselman River Environmental Improvement Plan.

2. Comprehensive Framework Study Missouri River Basin. Volume 2. Appendices. Historical Perspective of the Missouri River Basin. History of the Framework Study. Existing Water and Land Resources Development.

3. Development of Water Resources in Appalachia. Main Report. Part III. Volume B. Project Analyses, Chapters 8 through 10.

4. Evaluation of Estuarine Site Development Lagoons.

5. Genesee River Basin Study. Study of Water and Related Land Resources. Volume 1. Summary Report.

6. Hawaii Coastal Zone Management Program: Technical Supplement 2. Management of Hawaii's Coastal Zone for Water Quality Objectives.

7. Hydro Energy and Irrigation: Rakaia River Concept Study. Summary. Report No. 7.

8. Identification of Water Resources Planning Problems in the Metropolitan Area of Greater San Antonio and its Associated Counties.

9. Kentucky/Licking River Basins. Comprehensive Coordinated Joint Plan. (CCJP).

10. Modified and Updated Comprehensive Water and Sewer Plan for Green River Area Development District.

11. Northern Great Plains Resource Program, Water Work Group Report.

12. Pacific Northwest River Basins Commission Annual Report Fiscal Year 1977.

13. People and the Sound. Outdoor Recreation Planning Report.

14. Regional Ecological Studies.

15. Regional Response Through Port Development: An Economic Case Study on the McClellan-Kerr Arkansas River Project.

16. A River Basin Management Post-Audit and Analysis.

17. Southeastern New England Study of Water and Related Land Resources. Urban Waters Special Study.

18. A Test of Proposed Procedures for Evaluation of Water and Related Land Resources Projects. A Special Study of the Poteau River Watershed Project Prepared by the Staffs of the Southwestern Division and Tulsa District Corps of Engineers.

19. A Test of Procedures Proposed by a Task Force of the Water Resource Council. Special Study of the Mountain Home Division, Southwest Idaho Water Development Division, and Walla Walla District, Corps of Engineers.

20. A Test of Proposed Procedures for Evaluation of Water and Related Land Resources Projects. A Special Study of Stonewall Jackson Lake, West Ford River and Tributaries, West Virginia.

21. A Test of Proposed Procedures for Evaluation of Water and Related Land Resources Projects. A Special Study of the Detroit River, Trenton Channel Project.

22. Testing of Evaluation Procedures on Possible Development of the Lower Hiwassee River.

23. Water Resources of Northeast North Carolina.

24. Water Resources Appraisal for Hydroelectric Licensing Kern River Basin, California.

25. Water Resources Appraisal for Hydroelectric Licensing, Clarion River Basin, Pennsylvania.

26. Water Resources Appraisal for Hydroelectric Licensing. Kings River Basin, California.

27. Water Quality Management Element for the Kentucky River Area Development District. Comprehensive Water and Sewer Plan.

28. Water Resources of the Upper Neuse River Basin, North Carolina.

29. Water Resources Appraisal for Hydroelectric Licensing, Winton Development, Kawishiwi River Minnesota.

30. Water Supply Dilemmas of Geothermal Development in the Imperial Valley of California.

31. The Willamette Basin Comprehensive Study of Water and Related Land Resources. Appendix J. Power.

1.8 Environmental Case Studies Abstracts

The Cherry Creek-Casselman River Environmental Improvement Plan

Maryland Dept. of Natural Resources, Annapolis. Program Planning and Evaluation.*Appalachian Regional Commission, Washington, D.C.

Final rept.
AUTHOR: Hecht, Louis G. Jr
C4981L3 Fld: 13B, 05C, 48B, 68D, 91H GRAI7518
Jan 74 57p
Grant: ARC-72-47/RP-228
Monitor: ARC-72-47-Jan-74

Abstract: The survey was conducted to develop a plan for environmental improvement of the Cherry Creek Basin and the Maryland portion of the Casselman River Basin. It included identification and evaluation of environmental needs associated with coal mining, sewerage, solid waste and industrial operations as well as resource development needs associated with water supply, community development, transportation, and general land use. Environmental restoration was the main priority. Each problem is assessed in terms of its contribution to the overall degradation of the watershed and the current status of corrective action. The plan provides a framework for consideration of funding individual or group environmental improvement in the Cherry Creek-Casselman River watersheds.

Descriptors: *Water pollution, *Regional planning, *Cherry Creek, *Casselman River, Environmental protection, Coal mining, Solid waste disposal, Industries, Water supply, Water resources, Land use, Transportation, Economic development, Watersheds, Maryland

Identifiers: *Mine acid drainage, NTISAPPRC

PB-242 767/2ST NTIS Prices: PC A04/MF A01

Comprehensive Framework Study Missouri River Basin. Volume 2. Appendices. Historical Perspective of the Missouri River Basin. History of the Framework Study. Existing Water and Land Resources Development

Missouri Basin Inter-Agency Committee (410365)
D3571J3 Fld: 13B, 8H, 48B, 48G GRAI7724
Jun 69 178p
Monitor: 18
Original contains color plates: All DDC and NTIS reproductions will be in black and white. See also Volume 3, AD-A043 937.

Abstract: Contents: Historical Perspective of the Missouri River Basin; History of the Framework Study; and Existing Water and Land Resources Development.

Descriptors: *Basins(Geographic), *Water resources, *Resource management, *Cost analysis, Land use, History, Economic analysis, Hydrology, Water supplies, Water distribution, Water conservation, Irrigation systems, Recreation, Dams, Reservoirs, Capacity(Quantity)

Identifiers: *Missouri River Basin, *Regional planning, Land development, NTISDODXA

AD-A043 936/4ST NTIS Prices: PC A09/MF A01

Development of Water Resources in Appalachia. Main Report. Part III. Volume 8. Project Analyses, Chapters 8 thru 10

Corps of Engineers Cincinnati Ohio (410111)
D3014A1 Fld: 13B, 8H, 48B, 48G GRAI7719
Nov 69 422p
Monitor: 18
Original contains color plates: All DDC and NTIS reproductions will be in black and white. See also Part 3, Volume 9, AD-A041 395.

Abstract: This volume is one of six that comprise Part III, 'Project Analyses', to the Main Report for Development of Water Resources in Appalachia. The volume contains three of the 20 chapters that make up Part III. Chapters 8 and 9 were prepared by the U.S. Army Engineer District, Mobile. Chapter 8, Dalton Reservoir Project, presents a plan for a multiple purpose reservoir development on the Conasauga River, about six miles southeast of Dalton, Georgia. Chapter 9, Coosa River Navigation Project, presents a current reevaluation of the economic justification for the authorized Coosa River Navigation Project from Montgomery, Alabama, to Rome, Georgia. Chapter 10, Stannard Reservoir Project, prepared by the U.S. Army Engineer District, Buffalo, presents a plan for a multiple purpose reservoir development on the Genesee River, about four miles south of Wellsville, New York.

Descriptors: *Water resources, *Reservoirs, Dams, Cost analysis, Cost benefits, Hydrology, Planning, Water supplies, Flood control, Recreation, Navigation, Locks(Waterways), Georgia, Alabama, New York, Pennsylvania, Rivers

Identifiers: *Appalachian Mountain Region(United States), NTISDODXA

AD-A041 394/8ST NTIS Prices: PC A18/MF A01

Evaluation of Estuarine Site Development Lagoons

Rutgers - The State Univ., New Brunswick, N.J. Water Resources Research Inst.*Office of Water Research and Technology, Washington, D.C.

Final rept.
AUTHOR: Walton, Grant F.; Nieswand, George H.; Toth, Stephen J.; Stillman, Calvin W.; Westman, James R.
D1335L2 Fld: 13B, 5K, 68D, 91H, 92C GRAI7706
1 Jul 76 187p
Contract: DI-14-31-0001-3614
Project: OWRT-B-040-NJ
Monitor: OWRT-B-040-NJ(5)

Abstract: A large number of estuarine site development lagoon systems have been constructed along the New Jersey shore with little, if any, knowledge regarding the true nature of the system being created and its impact on the existing natural estuarine system. A comprehensive study and evaluation of these lagoon systems was undertaken including consideration of the physical, chemical, biological and socioeconomic conditions. In terms of the socioeconomic conditions, the residents are generally quite satisfied with their lagoon homes in spite of their perception of major pollution and over-development problems.

Descriptors: *Estuaries, *Land development, *Lagoons(Landforms), *Water pollution, *New Jersey, Bays(Topographic features), Water flow, Marshes, Site surveys, Planning, Economic impact, Environmental impacts, Shores, Tidewater, Evaluation, Social effect

Identifiers: *Wetlands, *Salt marshes, NTISDIOWRT

PB-261 367/7ST NTIS Prices: PC A09/MF A01

Genesee River Basin Study. Study of Water and Related Land Resources. Volume I. Summary Report

Corps of Engineers Buffalo N Y Buffalo District (410090)

Final rept.
D310314 Fld: 13B, 48B, 68D, 91H GRAI7720
Jun 69 219p
Monitor: 18
See also Additions to Summary Report, AD-A041 701 and Volume 2, AD-A041 703.

Abstract: The Genesee River Basin covers 2,479 square miles, mostly in western New York, with a small portion, 96 square miles in northwestern Pennsylvania. The river rises in the Allegheny highlands in Potter County, Pennsylvania, at an elevation of about 2,500 feet, flows approximately 157 river miles in a generally northward direction to its mouth at Rochester Harbor on Lake Ontario, at an elevation of about 247 feet. The topography of the southern portion, the Upper Basin, upstream of Mount Morris Dam, is steep and rugged, while the northern portion, the Lower Basin, is gently rolling. The two major divisions of the basin also closely parallel the two land resource areas which comprise the basin: the Allegheny Plateau and the Ontario Lake Plains Service Area, a region of about 750 square miles north and west of the Basin lying between Rochester and Lockport, New York. The principal needs are for flood protection, water quality control, recreation, fish and wildlife enhancement, irrigation, and agricultural land and water management. The most practicable means to provide for these and other needs of the basin is through a comprehensive plan of structural and non-structural measures.

Descriptors: *Basins(Geographic), *Water resources, New York, Pennsylvania, Flood control, Water quality, Recreation, Wildlife, Irrigation systems, Land use, Topography, Planning, Economic analysis, Lakes, Reports, Rivers

Identifiers: *Genesee River, Economic development, Lake Ontario, NTISDODXA

AD-A041 702/2ST NTIS Prices: PC A10/MF A01

Hawaii Coastal Zone Management Program: Technical Supplement 2. Management of Hawaii's Coastal Zone for Water Quality Objectives

Hawaii Univ., Honolulu. Water Resources Research Center.*National Oceanic and Atmospheric Administration, Rockville, Md. Office of Coastal Zone Management.*Hawaii State Dept. of Planning and Economic Development, Honolulu.
AUTHOR: McGauhey, P. H.; Lau, L. Stephen
C7135H3 Fld: 13B, 48B, 68D, 86R GRAI7620
Aug 75 54p
Monitor: NOAA-76032405
Prepared for Hawaii State Dept. of Planning and Economic Development, Honolulu. See also PB-255 336 and PB-255 338.

Abstract: The paper presents an overview of wastewater management as related to the quality of Hawaii's coastal waters. It examines concepts for establishing an inland boundary of the coastal zone, and reflects some of the results of studies made during the course of the 'Quality of Coastal Waters' project supported principally by the University of Hawaii Sea Grant Program during the years 1971 to 1975.

Descriptors: *Coastal zone management, *Water quality, *Hawaii , Water pollution, Waste water, Sewage treatment, Ocean environments, Sewage disposal, Boundaries, Runoff, Ground water, Land use

Identifiers: NTISCOMNOA, NTISUH

PB-255 337/8ST NTIS Prices: PC A04/MF A01

Hydro Energy and Irrigation: Rakaia River Concept Study. Summary. Report No. 7

New Zealand Energy Research and Development Committee, Auckland. (4670300)
D1833A1 Fld: 13B, 2C, 10B, 50B, 97I, 98 GRAI7709
Mar 76 21p
Monitor: 18
Microfiche copies only. U.S. Sales Only.

Abstract: This report presents three schemes for storage and control of the Rakaia River so that better use can be made of the water for irrigation, power development, and recreation. One scheme is recommended for further study. Stage development of the scheme is presented for partial or full operation. Environmental effects are considered and at this level of study it appears that there are no insurmountable problems. In fact this development should enhance recreational uses and fishing. Preliminary cost studies indicate that feasibility studies would be worthwhile to determine cost benefits in more detail and environmental impact. (ERA citation 02:010126)

Descriptors: *Hydroelectric power plants, *Irrigation, *Water reservoirs, New Zealand, Agriculture, Cost benefit analysis, Environmental effects, Feasibility studies, Power generation, Rivers, Storage, Surface waters, Water resources

Identifiers: ERDA/290300, ERDA/296001, ERDA/130600, Recreational facilities, Fishing, Cost estimates, Rakaia River , NTISERDAE

NP-21133 NTIS Prices: MF A01

Identification of Water Resources Planning Problems in the Metropolitan Area of Greater San Antonio and its Associated Counties

Texas A and M Univ., College Station. Water Resources Inst.

Technical rept. 1 Jul 70-30 Apr 73
AUTHOR: Garner, Joseph K.; Shih, C. S.
C1424K1 Fld: 13B, 60I GRAI7318
Jun 73 160p
Rept No: TR-49
Contract: DI-14-31-0001-3244, DI-14-31-0001-3544
Project: OWRR-A-017-TEX
Monitor: OWRR-A-017-TEX(2)
Also sponsored by Contract DI-14-31-0001-3844.

Abstract: The region incompassed by the San Antonio River Basin is described. Included is a brief summary of the regional economy, demography, and geographical characteristics. Additionally, quantitative information including the inventory and planning control for both surface and groundwater resource management of the San Antonio area is presented. Emphasis has been placed upon the identification of the probabilistic nature of regional water quality management. The methods and techniques developed for handling massive data and the reliability analysis for regional water quality control are also presented.

Descriptors: (*Water resources, Texas), (*Water quality, *Texas), Regional planning, Economic development, Demography, Sites, Inventories, Urban areas, Rural areas, Management, Reliability, San Antonio River Basin, Reviews

Identifiers: *San Antonio(Texas), OWRR

PB-222 182/8 NTIS Prices: PC A08/MF A01

Kentucky/Licking River Basins. Comprehensive Coordinated Joint Plan. (CCJP)

Ohio River Basin Commission, Cincinnati.
E2591C2 Fld: 13B, 68D, 48B, 91H GRAI7824
Apr 77 139p
Rept No: 510
Monitor: 18

Abstract: The plan summary contains a summary of the Commission's adopted plan for development as it now exists including conclusions and recommendations. Priorities contains the Commission's recommendations for the collection and analysis of basic data and for investigation, planning and construction of projects. The direction for the future contains the State, Federal and adopted Commission policies, goals and planning objectives and economic and demographic projections used by Commission members. Baseline record contains a list of all identified alternative projects and programs, whatever their stage of development. (Color illustrations reproduced in black and white)

Descriptors: *Regional planning, *Water resources, *Kentucky River Basin, *Licking River Basin, Surveys, Construction, Project planning, State government, National government, Local government, Economic development, Demography, Conflicts, Water pollution, Water supply, Maps, Ohio River, Kentucky River, Licking River, Indiana, Ohio

Identifiers: Priorities, Water management(Administrative), NTISSLRS

PB-284 293/8ST NTIS Prices: PC A07/MF A01

Modified and Updated Comprehensive Water and Sewer Plan for Green River Area Development District

Kentucky Office for Local Government, Frankfort.
C1584E3 Fld: 13B GRAI7320
20 Jun 73 353p
Rept No: CK-OLG-73-34
Project: HUD-CPA-KY-1000
Monitor: 18
Prepared in cooperation with Weston (Roy F.), Inc.. Wilmette, Ill.

Abstract: The regional plan includes a study of the socio-economic factors, land use, and water resources. Water service areas and sewer service areas have been delineated, new treatment facilities or expansion of existing facilities were proposed. Water quality management considerations have been presented and the short-range and long-range priorities have been delineated. Construction and operating costs have been estimated presented for the proposed systems.

Descriptors: (*Regional planning, *Kentucky), (*Water supply, Regional planning), (*Sewers, Regional planning), Land use, Water resources, Water quality, Construction, Facilities, Economic analysis

Identifiers: UPCD

PB-223 058/9 NTIS Prices: PC E10/MF A01

Northern Great Plains Resource Program, Water Work Group Report

Northern Great Plains Resource Program, Denver, Colo.*Department of Agriculture, Washington, D.C.*Department of the Interior, Washington, D.C.*Environmental Protection Agency, Washington, D.C.
C5051H3 Fld: 13B, 08I, 48B, 48A GRAI7519
Dec 74 333p
Rept No: NGPRP/CD-74/200
Monitor: 18
Prepared in cooperation with Department of Agriculture, Washington, D.C., Department of the Interior, Washington, D.C., and Environmental Protection Agency, Washington, D.C.
See also PB-243 149 and PB-243 151.

Abstract: The report analyzes surface water resources of the Upper Missouri River Main Stream and Yellowstone Basin with a brief analysis of the ground water resources in Montana and Wyoming. Constraints to water resource development are analyzed along with historical resource development, water availability above present uses, cost of delivery in Wyoming, Montana, and North Dakota. A separate report is included on in-stream needs. It projects amounts of water that should be left in streams to maintain present riparian and aquatic habitats. It assumes that there is a need for maintaining fluctuating annual flows rather than traditional minimum level flows. A separate report is included on the wild and scenic river recreational values of Upper Missouri and Yellowstone Basin streams that may be affected by coal development.

Descriptors: *Water resources, *Surface waters, *Ground water, *Missouri River, *Yellowstone Basin, Water supply, Economic development, Cost analysis, Stream flow, Coal mining, Recreation, Water rights, Environmental impacts, Water flow, North Dakota, Montana, Wyoming, Northern Plains Region(United States)

Identifiers: *Wild rivers, *Scenic rivers, NTISEPAG, NTISAGOS, NTISDIOS

PB-243 150/0ST NTIS Prices: PC A15/MF A01

Pacific Northwest River Basins Commission Annual Report Fiscal Year 1977

Pacific Northwest River Basins Commission, Vancouver, Wash.*Water Resources Council, Washington, D.C.
E2662L1 Fld: 13B, 48B, 68D GRAI7825
Sep 77 24p
Monitor: 18
Sponsored in part by Water Resources Council, Washington, D.C. _See also report dated 1976, PB-280 947._

Abstract: This report reflects the work accomplished by the Pacific Northwest River Basins Commission for fiscal year 1977, also brief highlights of the decade of the Commission's existence. (Color illustrations reproduced in black and white)

Descriptors: *Research projects, *Water resources, Water supply, Organizations, Land use, Estuaries, Salt water, Water quality, Economic development, Idaho, Montana, Oregon, Washington(State), Wyoming

Identifiers: NTISUSWRC

PB-284 940/4ST NTIS Prices: PC A02/MF A01

People and the Sound. Outdoor Recreation Planning Report

New England River Basins Commission, Boston, Mass.*Bureau of Outdoor Recreation, Philadelphia, Pa. Northeast Regional Office.

Final rept.
C5465D4 Fld: 13B, 05K, 91H, 48B GRAI7525
Aug 75 127p
Rept No: LISS-05
Monitor: 18
Report on Long Island Sound Study. Prepared by Bureau of Outdoor Recreation, Philadelphia, Pa. Northeast Regional Office.
Paper copy also available in set of 14 reports as PB-245 233-SET, PC$61.00.

Abstract: The planning report describes the outdoor recreation element of the Long Island Sound Regional Study. It is part of the final report of the Study, which outlines a strategy for securing the balanced conservation and development of natural resources of the Sound,and its shoreline in both New York and Connecticut. The plan for Long Island Sound is an increment of the New England River Basins Commission comprehensive, coordinated joint plan for the water and related land resources of its region, which includes New England and the New York portions of Long Island Sound.

Descriptors: *Regional planning, *Natural resources, *Recreation, *Long Island Sound, Conservation, Recreational facilities, Water resources, Land use, Shores, Beaches, Swimming, Economic development, Marinas, Connecticut, New York

Identifiers: Open space plan, NTISNERBC, NTISDIBOR

PB-245 238/1ST NTIS Prices: PC A07/MF A01

Regional Ecological Studies

Oak Ridge National Lab., Tenn.*Energy Research and Development Administration. (4832000)
AUTHOR: McCarthy, M. M.; Reichle, D. E.; Betson, R. P.
D1085E4 Fld: 13B, 5K, 91H, 97G GRAI7704
Jul 76 81p
Contract: W-7405-eng-26
Monitor: 18

Abstract: In August of 1974, the newly formed Regional Environmental Assessment group in the Environmental Sciences Division was asked to join the Regional Environmental Systems Analysis (RESA) Program in a two-month regional case study of the Harriman quadrangle in eastern Tennessee. The objectives of this effort were to initiate an integrated analysis of the environmental and socioeconomic impacts of energy resource development in the Tennessee Valley. This report is the result of that two-month study, which illustrates the conceptualization of the problem approach and the methodologies previously developed by the Regional Environmental Assessment group which were applied to energy residual source terms, land-use and hydrologic resources of the case study area. This study was discontinued in September 1974, without completion of the ultimate environmental assessment and socioeconomic integration. (ERA citation 02:001571)

Descriptors: *Energy sources, *Tennessee, *Environmental effects, Energy demand, Environment, Hydrology, Land use, Regional analysis, Socio-economic factors, Tennessee River, Water resources

Identifiers: ERDA/530100, Economic impact, *Energy source development, NTISERDA

ORNL/RUS-24 NTIS Prices: PC A05/MF A01

Regional Response Through Port Development: An Economic Case **Study on** the McClellan-Kerr Arkansas River Project

Arkansas Univ Fayetteville Bureau of Business and Economic Research*Institute for Water Resources (Army), Fort Belvoir, Va.*Army Engineer Div. Southwestern, Dallas, Tex. (408923)
AUTHOR: Belzung, L. D.; Sonstegaard, M. H.; Stark, Paul; Hoyt, Richard
C3754D1 Fld: 13B, 5C, 13J, 91B, 85B, 96B GRAI7426
Aug 74 157p
Contract: DACW63-72-C-0145
Monitor: IWR-CR-74-5
See also AD-786 698.

Abstract: The report documents the port development response of the Arkansas-Oklahoma region to the development of the McClellan-Kerr Arkansas-Verdigris Waterway. Since the initiative for port development comes from state and local levels, the strategy and plans which evolve present significant clues about potential impacts from the region's perspective. The report surveys seven major port areas and thirteen individual ports. Data is presented on physical attributes of the ports, public and private investment and financing, and management arrangements. (Author)

Descriptors: *Harbors, *Economics, *Waterways, *Arkansas, *Oklahoma, Surveys, Growth(General), Industries, Water traffic , Marine transportation, Rivers, Regions, Planning, Management , Finance

Identifiers: Economic growth, Economic development, Industrial parks, Arkansas River, NTISDODA

AD-787 326/8SL NTIS Prices: PC A08/MF A01

A River Basin Management Post-Audit and Analysis

Little (Authur D.) Inc., Cambridge, Mass. (208 850)

Final rept.
AUTHOR: Wilkinson, John M.
C1644K1 Fld: 13B, 5D, 48B*, 52I GRAI7321
Aug 73 276p*
Contract: DI-14-31-0001-3719
Project: OWRR-C-3353(3719)
Monitor: OWRR-C-3353(3719)(1)

Abstract: The water management history of the Pick-Sloan Missouri River Basin Program was analyzed with particular emphasis on federal, State, local and non-governmental institutional arrangements and an evaluation of performance of these institutions over a 28-year period, 1944-1972. The statutory bases for these institutions was documented. Performance criteria included effectiveness in regional policy, planning, programming and operational management and their responsiveness to social change. The regional economy was compared in 1940 and 1970, in the light of expectations of the original plan and actual realization of intended results, with emphasis on the role of water. The analysis prompted recommendations for new institutional re-orientations for the future that would better serve the needs of multi-State regionalism.

Descriptors: (*River basin development, *Government policies), (*Missouri River basin, River basin development), History, Regional planning, Economic analysis, Water resources, Public administration, Management analysis, Water law, National government, State government

Identifiers: OWRR

PB-222 941/7 NTIS Prices: PC A13/MF A01

Southeastern New England Study of Water and Related Land Resources. Urban Waters Special Study

New England River Basins Commission, Boston, Mass.*Economics Research Associates, McLean, Va.*Skidmore, Owings and Merrill, Washington, D.C.*Cortell (Jason M.) and Associates, Wellesley Hills, Mass.

Final rept.
C705414 Fld: 13B, 91A, 91J, 48B, 50B GRAI7619
Jan 75 181p
Rept No: NERBC-65
Monitor: 18
Prepared by Skidmore, Owings and Merrill, Washington, D.C.

Abstract: The report incorporates the findings of the Urban Waters Study project for the Southeastern New England Study Region (SENE). The study is aimed at the particular issues and problems facing the cities and towns with waterfronts on rivers or coastal waters. The report analyzes the physical, economic, ecological, and legal and institutional issues related to urban waterfronts in the region. Specific planning and design guidelines are recommended, as well as institutional and legal mechanisms for implementing waterfront controls, and guiding improvements.

Descriptors: *Water resources, *Land use, *Urban areas, Rivers , Coasts, Harbors, Coastal zone management, Policies, Decision making, Economic development, Industries, Recreation, Beaches, Marine terminals, Law(Jurisprudence), Conservation, Ecology, Massachusetts, Rhode Island

Identifiers: *Waterfronts, New England, NTISNERBC

PB-254 818/8ST -NTIS Prices: PC A09/MF A01

A Test of Proposed Procedures for Evaluation of Water and Related Land Resources Projects. A Special Study of the Poteau River Watershed Project Prepared by the Staffs of the Southwestern Division and Tulsa District Corps of Engineers

Army Engineer District, Tulsa, Okla.*Water Resources Council, Washington, D.C.
C7205A2 Fld: 13B GRAI7621
Mar 70 132p
Monitor: 18
Prepared in cooperation with Water Resources Council, Washington, D.C.

Abstract: The report is the product of studies made by a Corps of Engineers Test Team, which was instituted to test proposed Water Resources Council evaluation procedures as outlined in 'Procedures for Evaluation of Water and Related Land Resource Projects'. An existing Department of Agriculture plan of improvement on the Poteau River Watershed in Arkansas and Oklahoma was analyzed using these guidelines.

Descriptors: *Water resources, *Land development, *Project planning, *Poteau River Watershed, Benefit cost analysis, Objectives, Economic impact, Social effect, Environmental impacts, Regional planning, Arkansas, Oklahoma

Identifiers: NTISUSWRC, NTISDODA

PB-255 689/2ST NTIS Prices: PC A07/MF A01

A Test of Procedures Proposed by a Task Force of the Water Resource Council. Special Study of the Mountain Home Division, Southwest Idaho Water Development Division, and Walla Walla District, Corps of Engineers

Corps of Engineers, Portland, Oreg. North Pacific Div.*Water Resources Council, Washington, D.C.*Army Engineers District, Walla Walla, Wash.
C7204L2 Fld: 13B, 5C GRAI7621
Mar 70 112p
Monitor: 18
Prepared in cooperation with Army Engineer District, Walla Walla, Wash., and Water Resources Council, Washington, D.C.

Abstract: The proposed procedures in the report calls for an evaluation of water resource projects in terms of all relevant national objectives, both in measuring project effects, beneficial and adverse, and in formulating a plan that is responsive to all objectives for the proposal of the Mountain Home Project, Guffey Dam, in Southwest Idaho. Color illustrations reproduced in black and white.

Descriptors: *Water resources, *Land development, *Project planning, Economic impact, Income, Recreation, Flood control, Water quality, Fishes, Dams, Standards, Regional planning, Environmental impacts, Idaho, Snake River

Identifiers: *Guffy Dam, NTISUSWRC, NTISDODA

PB-255 683/5ST NTIS Prices: PC A06/MF A01

A Test of Proposed Procedures for Evaluation of Water and **Related** Land Resources Projects. A Special Study of Stonewall Jackson Lake, West Fork River and Tributaries, West Virginia

Ohio River Div. Labs., Cincinnati.*Army Engineer District, Pittsburgh, Pa.*Water Resources Council, Washington, D.C.
C7142J2 Fld: 13B GRAI7620
Mar 70 124p
Monitor: 18
Prepared in cooperation with Army Engineer District, Pittsburgh, Pa. Sponsored by Water Resources Council, Washington, D.C.

Abstract: The purpose of the report is to determine the advisability of modifying a previously authorized reservoir located between Weston and Clarksburg, W. Va. It includes the guidelines and measurement of the effects of the project for Stonewall Jackson Lake.

Descriptors: *Water resources, *Land use, *Stonewall Jackson Lake, Project planning, Standards, Objectives, Benefit cost analysis, Recreation, Economic development, West Virginia

Identifiers: NTISUSWRC, NTISDODA

PB-255 477/2ST NTIS Prices: PC A06/MF A01

A Test of Proposed Procedures for Evaluation of **Water** and **Related** Land Resources Projects. A Special Study of the Detroit River, Trenton Channel Project

Army Engineer Div. North Central, Chicago, Ill.*Army Engineer District, Detroit, Mich. (407 074)
C7203G4 Fld: 13B GRAI7621
Mar 70 52p
Monitor: 18
Prepared in cooperation with Army Engineer District, Detroit, Mich.

Abstract: The objective of this report is to test the workability, as applied to a commercial navigation project, of the evaluation procedures proposed for the Detroit River - Trenton Channel, Michigan, project which was authorized in the 1968 River and Harbor Act. First, the benefits and costs of the project as authorized, adjusted to a current interest rate of 4-7/8 percent, were identified and evaluated. Second, alternative plans, to meet varying mixes of the national objectives as set forth in the task force report, were evaluated. This report identifies benefits which would be gained by interests other than navigation, but which were not presented in the survey report as project benefits.

Descriptors: *Water resources, *Land development, *Project planning, *Michigan, Evaluation, Navigation, Benefit cost analysis, Detroit River, Regional planning, Commercial transportation, Comparison, Economic analysis, Objectives, Feasibility

Identifiers: Alternatives, NTISUSWRC, NTISDODA

PB-255 536/5ST NTIS Prices: PC A04/MF A01

Testing of Evaluation Procedures on Possible Development of the Lower Hiwassee River

Tennessee Valley Authority, Knoxville.*Water Resources Council, Washington, D.C.
C7204L1 Fld: 13B GRAI7621
Mar 70 154p
Monitor: 18
Prepared in cooperation with Water Resources Council, Washington, D.C.

Abstract: The report deals with trial application of the revised procedures by the Special Task Force Report of the Water Resources Council. Methodology and approach are emphasized rather than the specific numerical values given for items such as benefits and costs. Portions of this document are not fully legible.

Descriptors: *Water resources, *Land use, *Hiwassee River, Research projects, Evaluation, Water quality, Cost estimates, Regional planning, Flood control, Recreation, Income, Wildlife , Benefit cost analysis, Tables(Data), Tennessee

Identifiers: NTISUSWRC

PB-255 682/7ST NTIS Prices: PC A08/MF A01

Water Resources of Northeast North Carolina

Geological Survey Raleigh Nc Water Resources Div (410804)

Final rept.
AUTHOR: Wilder, H. B.; Robison, T. M.; Lindskov, K. L.
E2424G2 Fld: 13B, 8H, 48B, 48G, 91H GRAI7823
May 78 125p
Rept No: USGS/WRD/WRI-78/070; USGS/WRI-77-81
Monitor: 18

Abstract: Associated with economic development of northeast North Carolina are several water-related problems. The solution to these problems depends in part on adequate knowledge of the hydrology of this 8,930 square mile coastal area. Although it is hydrologically the least studied area of North Carolina, enough is known to present this reconnaissance-level picture of its water resources. Average annual precipitation on the area is about 50 inches. Of this amount, about 34 inches returns to the atmosphere via evapotranspiration, about 15 inches leaves the area as runoff, and about one inch leaves through ground-water outflow. No large streams originate within the area, but major streams entering from the north and west bring in three times as much streamflow as originates within the study area. The flat, low-lying terrane does not offer opportunities for extensive development of surface-water supplies through the use of reservoirs. Much of the surface water is contaminated by saltwater from the ocean. Ground water occurs in three major aquifers, all of which contain both freshwater and saltwater. (Author)

Descriptors: *Water resources, *Surveys, *Coastal regions, *Hydrology, North Carolina, Resource management, Reservoirs, Surface waters, Salt water, Contamination, Aquifers, Fresh water, Flooding, Ocean tides, Ecology, Rivers

Identifiers: Landscaping, Evapotranspiration, Chowan River, Roanoke River, Tar River, Neuse River, Outer banks, *Economic development, *Northeast Region(North Carolina), Precipitation-(Meteorology), Stream flow, Runoff, Ground water, Salt water intrustion, NTISDODXA

AD-A057 484/8ST NTIS Prices: PC A06/MF A01

Water Resources Appraisal for Hydroelectric Licensing Kern River Basin, California

Federal Power Commission, Washington, D.C. Bureau of Power.
D2224J3   Fld: 8H, 10A, 48G, 97I   GRAI7712
1977   94p
Monitor: 18

Abstract: The report presents information on existing and possible future development of water and related land resources in the Kern River Basin. The basin is part of the Central Valley in south-central California.

Descriptors: *Water resources, *Kern River Basin, Natural resources, Water supply, Geology, Climate, Hydrology, Water quality, Land use, Economic development, Hydroelectric power generation, California, Surveys, Reviewing, Licenses

Identifiers: NTISFPC

PB-264 750/1ST   NTIS Prices: PC A05/MF A01

Water Resources Appraisal for Hydroelectric Licensing. Clarion River Basin, Pennsylvania

Federal Power Commission, Washington, D.C. Bureau of Power.

Appraisal rept.
C3013A4 Fld: 13B, 48B GRAI7415
May 74 72p
Monitor: 18

Abstract: The report appraises the water resources of the Clarion River Basin in Pennsylvania, and specifically the FPC-licensed Piney hydroelectric development.

Descriptors: *Clarion River basin, *Water resources, Hydroelectric power generation, Water pollution, Mine waters, Recreation, Reservoirs, Economic conditions, River basin development

Identifiers: NTISFPC

PB-232 186/7 NTIS Prices: PC A04/MF A01

Water Resources Appraisal for Hydroelectric Licensing. Kings River Basin, California

Federal Power Commission, Washington, D.C. Bureau of Power.
C3503D4 Fld: 13B, 48B GRAI7422
Aug 74 82p
Monitor: 18

Abstract: The report on the Kings River Basin, California, has been prepared by the staff of the Federal Power Commission as a part of a program of Water Resources Appraisals for Hydroelectric Licensing. It is intended primarily to provide information which the Commission and its staff may use or build upon, as appropriate, when considering matters related to hydroelectric licensing, relicensing, or recommendation for Federal takeover. Licensing considerations are currently underway for several projects in the Kings River Basin. The report has been prepared to correlate and, when possible, to supplement available information and thus enable the staff and the Commission to act expeditiously on matters pertaining to the development of the hydroelectric power potential of the Kings River Basin within the limitations of other desirable water uses.

Descriptors: *Water resources, *Kings River Basin, *Hydroelectric power generation, Licenses, Electric power plants, Project planning, Economic development, Agriculture, Recreation, Water supply, Appraisals, Industries, Flood control, Irrigation, Pumped storage, Environmental impacts

Identifiers: Specific areas, NTISFPC

PB-235 224/3 NTIS Prices: PC A05/MF A01

Water Quality Management Element for the Kentucky River Area Development District. Comprehensive Water and Sewer Plan

Kentucky Office for Local Government, Frankfort.
C1645F1 Fld: 13B, 68D GRAI7321
Jun 73 91p
Rept No: CK-OLG-73-37
Project: HUD-CPA-KY-1000
Monitor: 18
Prepared by Mayes, Sudderth and Etheredge, Inc., Lexington, Ky.

Abstract: There are three principal sources of pollution to the waters of the Kentucky River: coal mining activities, untreated domestic waste, and municipal plant effluent. The report is addressed to the steps necessary to reduce or eliminate pollution from these sources. In each of these cases, the lack of definitive data as to the nature and origin of the pollution is evident. In order to plan and execute an effective pollution abatement program in the Kentucky River Area Development District, the collection of the basic data is necessary. Alternative methods of municipal sewage treatment are covered in this Report. These alternatives include the use of tertiary lagoons, where physically possible, and advanced tertiary treatment facilities. The need for additional sewage collection and treatment facilities is set forth.

Descriptors: (*Water pollution, *Regional planning), (*Stream pollution, Regional planning), Water resources, Population growth, Coal mines, Industrial wastes, Sewage treatment, Lagoons(Ponds), Economic analysis, Local government

Identifiers: Kentucky, Water quality data, Tertiary sewage treatment, *Water pollution abatement, UPCD

PB-223 046/4 NTIS Prices: PC E04/MF A01

Water Resources of the Upper Neuse River Basin, North Carolina

Geological Survey, Raleigh, N.C.*Durham City, N.C.

Water-resources investigations rept. (Final)
AUTHOR: Putnam, Arthur L.; Lindskov, Kenneth L.
C3931G2   Fld: 13B, 8H, 48B, 48G   GRAI7502
May 73   78p
Rept No: USGS/WRI-12-73; USGS/WRD-74-037
Monitor: 18
Prepared in cooperation with Durham City, N.C.

Abstract: To aid planners and developers, the report summarizes data on duration of flow, low-flow frequency, storage requirements, and flood frequency. Data for the 43-year period 1925-68 show that the average annual streamflow for the upper Neuse River basin is about 320 million gallons per day. Comparison of this flow with the total withdrawal of both surface and ground water of 20 million gallons per day, indicates the relatively minor utilization of the water resources of the basin. If proper pollution controls are observed and practiced so that the water in the various streams may be used a number of times, the potential for water-resources development and use is more than 10 times the quantity of water presently used.

Descriptors: *Streamflow, *Neuse River, *Water supply, *North Carolina, Water storage, Floods, Water levels, Surface waters, Ground water, Correlation techniques, Water consumption, Water pollution, Water resources, Regional planning, Economic development

Identifiers: Low flow, Flood frequency, Water utilization, *Water quality data, NTISDIUSGS

PB-237 304/1SL   NTIS Prices: PC A05/MF A01

Water Resources Appraisal for Hydroelectric *Licensing*, **Winton Development**, Kawishiwi River Minnesota

Federal Power Commission, Washington, D.C. Bureau of Power.

Evaluation rept.
C4241H3   Fld: 13B, 97G   GRAI7507
1974   47p .
Rept No: FPC-PWR-469
Monitor: 18

Abstract: The water resources appraisal report evaluates the Winton hydroelectric power project located on the Kawishiwi River in Minnesota. Its purpose is to assist the Commission in deciding whether to relicense hydroelectric projects or recommend Federal takeover. It in no way commits or prejudges later Commission action.

Descriptors: *Minnesota, *Electric power plants, *Kawishiwi **River**, Licenses, Evaluation, Land development, Economic **analysis**, Hydroelectric power generation, Water **resources**

Identifiers: *Winton project, Local studies, NTISFPC

PB-238 963/3ST   NTIS **Prices:** PC A03/MF A01

Water Supply Dilemmas of Geothermal Development in the Imperial Valley of California

California Univ., Livermore. Lawrence Livermore Lab.*Energy Research and Development Administration. (9500007)
AUTHOR: Layton, D. W.
D2835E4 Fld: 8I, 97P, 97I GRAI7716
15 Sep 76 21p
Rept No: CONF-760990-1
Contract: W-7405-ENG-48
Monitor: 18
12. American water resources conference, Chicago, Illinois, United States of America (USA), 19 Sep 1976.

Abstract: There are four known geothermal resource areas in the Imperial Valley that have a combined potential of over 4,000 megawatts of electrical energy for 25 years. The water resources available to support geothermal energy development are imported Colorado River water, agricultural waste waters, Salton Sea water, and ground water. In addition, geothermal power plants can produce their own cooling water in the form of steam condensate. Nevertheless, the relatively high water requirements of geothermal facilities along with a series of real and potential constraints may cause water supply dilemmas involving both the acquisition and use of cooling water. Important constraints are institutional policies, water supply costs, technical problems, and impacts upon the Salton Sea. These constraints and related dilemmas are examined in light of relevant information on the valley's water resources, geothermal resources and energy technologies, cooling water requirements, and water supply options. (ERA citation 02:026132)

Descriptors: *Geothermal power plants, *Imperial Valley, California, Colorado River, Cooling systems, Economics, Geothermal fields, Ground water, Salton Sea, Water requirements, Water resources

Identifiers: ERDA/150200, ERDA/150800, NTISERDA

UCRL-78019 NTIS Prices: PC A02/MF A01

The Willamette Basin Comprehensive Study of Water and Related **Land Resources.** Appendix J. Power

Pacific Northwest River Basins Commission Vancouver Wash (410072)
D1985D1 Fld: 13B, 8H, 48B, 48G GRAI7711
1969 105p
Monitor: 18
Original contains color plates: All DDC reproductions will be in black and white. Appendix J to AD-A036 745. See also Appendix K, AD-A036 763.

Abstract: The purpose of this Appendix is to show the present power needs and existing generating capacity in the Willamette Basin, to determine future power needs, to identify potential projects in the basin which could be developed for power generation, and to evaluate potential projects as to their utility for power development. The power potentials within the basin are presented from a single-purpose viewpoint to determine the maximum extent to which the water resource could be developed for power generation. Power requirements, load characteristics, interconnections, and power-source potentials are projected to the years 1980, 2000, and 2020. These projections are the basis for planning long-range, comprehensive water resource development. The 1980 estimates provide the basis for development of a plan to meet early power needs of the basin. The longer-term appraisals are more conjectural and tentative.

Descriptors: *Water resources, *Environmental management, Oregon, Reservoirs, Rivers, Lakes, Basins(Geographic), Land use, Planning, Requirements, Hydrology, Economic analysis, Nuclear power plants

Identifiers: *Willamette River Basin, Electric power demand, Water resources development, NTISDODXA

AD-A036 762/3ST NTIS Prices: PC A06/MF A01

Section 2.0

RELEVANT PHOTOCOPIED ARTICLES

Section 2.0

RELEVANT PHOTOCOPIED ARTICLES

Included in this section are photocopies of articles which may be of particular relevance to EPA officials concerned with socio-economic analysis of Chesapeake Bay water resources. No claim is made that these articles exhaust the supply of relevant literature. Instead, they are intended to convey a flavor for the range and quality of analysis available in current literature.

The articles are categorized as in the first section: economic analysis; socio-political analysis; methodology; and environmental case studies. Each article appears once under the heading selected as most appropriate.

2.1 Alphabetical Listing of Economic Analysis Articles

1. An Approach to Evaluating Environmental, Social, and Economic Factors in Water Resources Planning.
2. Approaches to Multiobjective Planning in Water Resource Projects.
3. Economic Forecasting for Virginia's Water Resource Programs.
4. Economic Valuation of Shoreline.
5. Economics. (L.D. James, Georgia Institute of Technology).
6. Economics. (L.D. James, Utah State University).
7. Economics. (J.C. Hite, Clemson University and L.D. James, Utah Water Resources Laboratory).
8. Economics and the Environment.
9. The Efficiency and Equity of Cost Allocation Methods for Multipurpose Water Projects.
10. Metarationality in Benefit-Cost Analyses.
11. Socio-Economic Considerations in Water Resources Planning.
12. Water Resource Investment and Economic Development: Balanced Versus Unbalanced Investment Strategies.

2.2 Economic Analysis Articles

WATER RESOURCES BULLETIN
VOL. 8, NO. 4 AMERICAN WATER RESOURCES ASSOCIATION AUGUST 1972

AN APPROACH TO EVALUATING ENVIRONMENTAL, SOCIAL, AND ECONOMIC FACTORS IN WATER RESOURCES PLANNING[1]

A. Bruce Bishop[2]

ABSTRACT. Decisions among water resources planning alternatives must consider, along with engineering and economics, a variety of environmental and social effects which are viewed and weighted differently by different interest groups. This paper briefly discusses present methods of project evaluation and then describes an approach adapted from highway planning literature for evaluating both monetary and non-monetary variables and presenting them to decision makers at all levels. Social and environmental consequences are analyzed and presented using a graphical description called a "factor profile," which measures in appropriate units all relevant non-monetary effects of each alternative. Then, using the factor profile and engineering-economic analysis, a series of paired comparisons are made to obtain a preference ranking among alternatives. Since preference decisions are extremely complex, a step by step procedure to simplify the decision-making process is described. A case example considering four proposed flood control alternatives with the relevant environmental and social impacts is given to illustrate the use of the factor profile and the decision making procedure.
(KEY TERMS. planning; decision making, project evaluation; environmental impacts; social aspects; economic analysis)

INTRODUCTION

Water resources development has a wide range of impacts on the various users, on the surrounding communities, and on the region and nation as a whole. Moreover, these consequences intersect a broad range of economic, social, environmental, and community values which are viewed and weighted differently by different interest groups. Hence, choices and tradeoffs must be made to achieve the highest satisfaction of public wants. Unfortunately, there is no effective market mechanism to allocate resources for public wants as there is for the private sector of the economy. Consequently, other means must be found to induce various segments of the public to reveal their preferences for public goods. At the national level this is accomplished by Congress through the political process. However, at the level of comprehensive planning for river basins or specific projects, this must be achieved by planners interacting with the public through the planning process. In this setting, water resources planning becomes a process of refining and choosing among alternative approaches for satisfying public wants, evaluating them on the basis of their social, environmental, and community feasibility as well as for engineering and economics.

[1]Paper No. 72067 of the *Water Resources Bulletin* Discussions are open until January 1, 1973.
[2]Assistant Professor of Civil Engineering, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.

WATER RESOURCES, NEEDS, AND PLANNING ALTERNATIVES

The problem of the water resources planner is illustrated by the diagram of Figure 1. We have at our disposal a set of limited resources with which to satisfy our needs. As the diagram shows, the aggregate of all our needs will usually exceed the capability of our resources. Generally, within the limits of our resources, there will be sets of alternatives which are feasible from the standpoint of technological and economic considerations, but may not satisfy social, environmental, and political values, and vice versa. To use the language of set theory, the job of the water resources planner is to find that subset of alternatives which is the intersection (the darkest area of Figure 1) of all the feasible (economically, socially, etc.) sets of alternatives. These are alternatives which could be implemented.

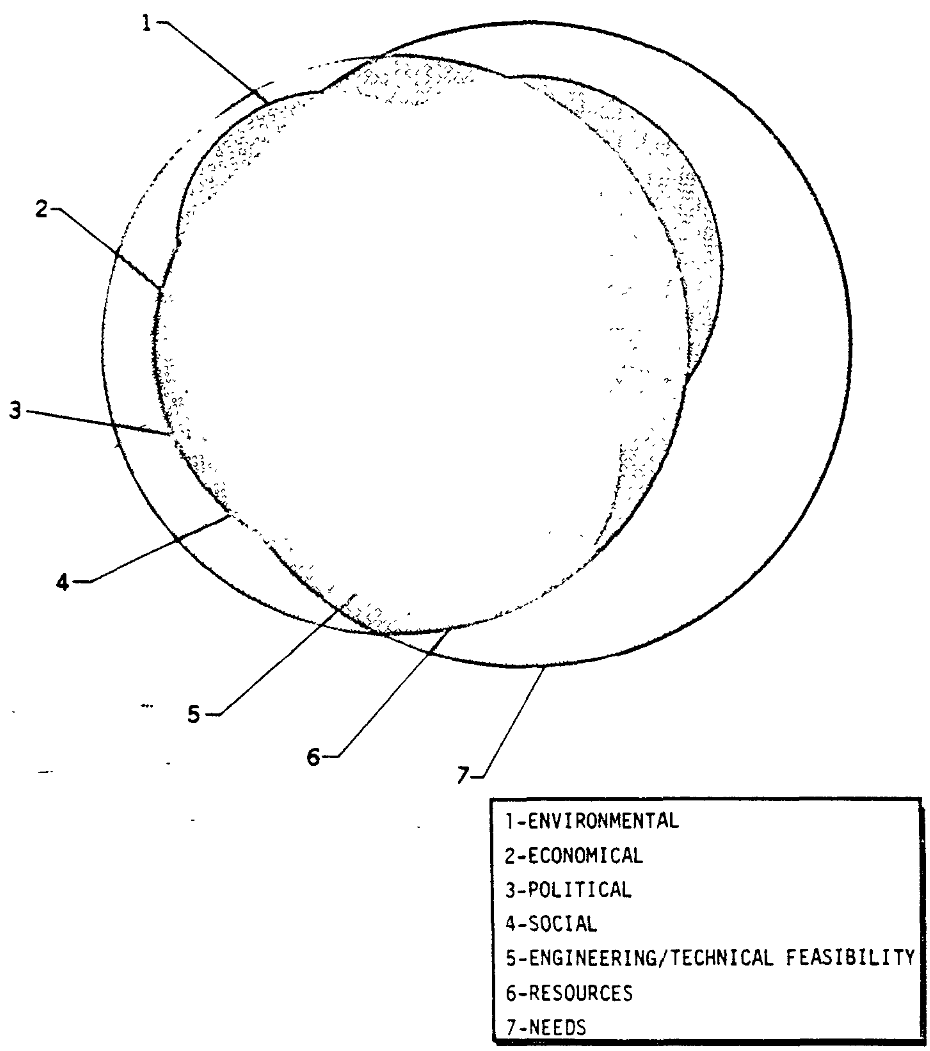


Fig. 1. Limits of feasibility in water resources planning.

The usual approach in water resources planning is to develop a set of technologically feasible alternatives and then to complete the planning effort by determining economic feasibility. The limits of social, environmental, and political feasibility, while not entirely ignored, are largely left to others to be determined after the plan is complete. More often than not these missing ingredients are the ultimate cause of planning failures. For example, some of the broad issues and questions which must be considered in refining the limits for our sets of feasible alternatives are:

Technological/environmental. The technological impact of a completed public work, constructed and in place, represents a definite change in the environment which is difficult to reverse. It is often literally set down in concrete. Since it represents a permanent change, it is important to consider whether or not this kind of physical change should be made at all, and if it is made, should it be made now and in this particular way.

Economic. The costs and benefits of public works are generally distributed among many different interest groups. Construction of a dam or flood control works brings about changes in land use, dislocation of people and property, and alterations in living patterns, all of which serve to redistribute economic resources. In evaluating the impact of public works, one can no longer just assess the benefits "to whomsoever they accrue," but in addition, it must be determined who receives the benefits and who incurs the costs.

Social. Public works tend to have the nature of self-fulfilling social prophecies. If projects are built they will become part of the fabric of an area, and the products from construction of a new dam will cause changes in the social structure, environment, population, and living patterns of the region, which are responsible, at least in part, for creating the needs and demands that the project purposes intend to satisfy. Since projects generate a certain amount of social self-fulfillment, it is important to ask: What would realistically be expected to happen if the project were not built? In asking this question we must recognize that "doing nothing" is a viable alternative, and that it is a dynamic and not a status quo condition.

Political. There is rarely a single decision maker in public works planning, and decisions are made difficult because of the number of interactions among potential decision makers. The planners' success depends on his recognition of which interest groups can and should influence the plans, how and by whom the final decision is made, how to translate technical data into public policy issues and test them politically, and how to make public participation in planning a meaningful activity.

With the broadening public interest in water resources, planners must recognize that environmental, social, and political feasibility are as essential a part of the planning process as engineering and economics. Hence, the planner should refine the limits of social and political feasibility along with engineering and economics throughout the entire planning process. Referring to Figure 1, it appears that much of the earlier technical stages of planning may be of only marginal concern in relation to the end product that can be implemented. Indeed, large amounts of time and resources may be spent in developing plans that are outside the limits of feasibility in one area or another.

In some cases we may find in fact that there are feasibility sets which do not intersect at all. It is important to point out, however, that the areas of social and political feasibility do not necessarily have fixed predetermined limits. They depend to a significant extent upon clear understanding of the possibilities and the range of choices. The key to realistic appraisal of environmental, social, and political feasibility is to maintain constant communication with a broad spectrum of those who will finally determine these limits. If the planner begins to bracket these ranges of feasibility early in the study, then more of the planning efforts can be confined to the subset of plans which is more likely to be acceptable. Thus, adequate interchange of information can serve both as a means to establish the feasibility limits and as a guide to avoid marginal effort.

EVALUATING WATER RESOURCES PLANS

In the evaluation of water resources plans, the practice has been to aggregate the information relevant to the decision which could be quantified in economic terms into a benefit-cost ratio. However, such consequences as environmental, social aesthetic, and community impacts have not been included in the benefit-cost ratio since neither suitable techniques nor adequate data have been available for appraising and quantifying them. Furthermore, in many cases it may be inappropriate to quantify them in money terms. It follows that a discussion and evaluation of alternatives based solely on the benefit-cost ratio will often submerge or exclude information that is pertinent to the decision. It tends to obscure rather than pinpoint the differences among alternatives and leaves no way to identify and contrast these differences in decision making.

Recently a special task force of the Water Resources Council has sought to expand the basis for comparing alternative plans by outlining four "accounts" for evaluation of water and related land resource projects. These include (1) national income, (2) regional development, (3) environmental enhancement, and (4) social well-being. Test teams from several universities and Federal water planning agencies attempted to apply this system of evaluation to a number of current projects. While in most cases national income and regional development benefits and costs were given adequate treatment, the environmental and social well-being effects were generally given only cursory and elementary attention. In reviewing the experience of the test teams there are two particular areas of need in approaching project evaluation [Water Resources Council, 1970]:

(1) Procedures for communicating project impacts to the public to elicit their input in formulating project objectives and evaluating project product outputs.

(2) Procedures for making tradeoffs among various objectives of the four accounts.

These findings underscore the need for methods to describe, analyze, and present to decision makers the principal social, environmental, and community variables in water resources plans. Furthermore, our approaches to plan evaluation should allow each community and interest group to examine the proposed plans and determine the consequences and tradeoffs as seen from their particular viewpoint so that they can be considered in the decision making process. To accomplish these aims, a basis must be established for evaluating and communicating both monetary and non-monetary consequences. To do this two important rules, which have often been ignored in evaluation schemes, must be kept in mind [Grant and Ireson, 1964]:

(1) The decisions must be based on the differences among alternatives.

(2) That money consequences must be separated from the consequences that are not reducible to money terms; then these irreducibles must be weighed against the money consequences as part of the decision making process.

To apply these rules in an engineering, economic, environmental, and social analysis of the effects of water resources development, four important aspects of the problem should be considered. These are:

(a) *Identification of factors relevant to the decision.* Planning experience has shown that it is often difficult for groups to identify or express their objectives at the inception of a study. However, a strong program of citizen participation and the use of survey research techniques can provide needed input for defining an initial set of planning objectives. Then as alternative plans are developed, sets of objectives are seen in terms of their physical and functional form. This can then serve as a basis for evaluating and reformulating objectives, and can also suggest factors (dimensions) to measure and quantify the impact of alternative plans on the planning objectives.

(b) *Quantification.* Comparisons of the differences among alternatives depend on defining the factors which measure the relative merits of the plans. The factors relevant to the decision should be separated into those direct consequences that can be stated in economic money terms at both the regional and national level and those environmental and social effects which fall upon the communities which are not an appropriate part of the economic costs and benefits. Where possible, and there exists a rationale for doing so, these non-monetary factors should be measured and evaluated in some other appropriate unit. Then, monetary and other factors can be weighted against each other to determine the tradeoffs among alternatives.

(c) *Viewpoint.* Different alternatives affect the various levels of government, communities, and groups in different ways. Much of today's controversy in water planning and management results from the failure of one group to appreciate another's values and concerns. The factors which are most important will, of course, vary with each individual project. Various approaches to public participation should be used at the conceptual stage of plan formulation and again during plan evaluation to allow each group to express its principal concerns. By identifying the factors of greatest concern to each community group, the costs and benefits and the points of agreement and disagreement can be clarified. Consideration of varying viewpoints should eliminate confusion and many of the pointless arguments which now afflict planning studies.

(d) *Time period.* The time period over which the consequences of various plans are spread should also be considered. Otherwise short-run effects might be given more weight in the decision as compared to the long-run effects, or vice versa.

In developing dimensions for the description of alternatives, it should be emphasized that both the viewpoint and the time period or horizon will markedly affect the analysis in selecting and quantifying the relevant factors in decision making. These need to be specified before variables are quantified, and indeed a complete evaluation may require that a number of analyses be performed using different viewpoints and planning horizons.

A Method for Presenting and Evaluating Water Planning Alternatives

Following from the two decision rules stated earlier, a two-part procedure is necessary to objectively present and evaluate alternatives: (1) an economy study which includes all items that can be reduced to money terms, and (2) an analysis of all items which cannot be stated in terms of money but which must be weighed in the decision. Recent efforts have been made to develop new methods and techniques which apply these principles in evaluating planning alternatives.

A procedure for decision making among freeway route location alternatives has been proposed by Bishop [1969] and Oglesby, Bishop, and Willeke [1970]. This approach, called a "factor profile," is a method for analyzing, presenting, and comparing the indirect, environmental, social and community effects with the economic effects of alternative highway plans. It appears that the use of such tools can be a valuable step toward a more rational discussion of and decisions among alternatives based on economic, social, and environmental factors in water resources planning as well as transportation planning. The following section of this paper applies the concept of the "factor profile," to water resources plan evaluation, describes the procedure for using it, and presents an example problem. The discussion and example closely parallel that for the highway location alternatives in order to emphasize the similarities between evaluation of transportation and water resources projects.

Factor Profiles: A Decision Making Tool

The "factor profile" is a graphical representation based on the factors which describe by some appropriate unit of measure the effects of each proposed alternative. Figure 2 is a highly simplified and consolidated version of such a profile for four flood control alternatives, numbered 1, 2, 3, and 4. On this figure, each profile scale is on a percentage base, ranging from a negative to a positive 100 percent. One hundred either negative or positive is the maximum absolute value of the measure that is adopted for each factor. Reduction to the percentage base simplifies scaling and plotting the profiles. The maximum positive or negative value of the measure, the units, and the time span are indicated on the right-hand side of the profile for reference. For each alternative, the positive or negative value for any factor is calculated as a percent of the maximum absolute value over all alternatives and is plotted on the appropriate abscissa. A broken line connecting the plotted points for each alternative gives its factor profile. For the profiles, factors and measures should be selected which will adequately describe all important elements of community and environmental impact. Care should be used in defining factor measures to assure that they are not measuring the same consequences. Otherwise in effect there would be "double counting" and disproportionate weight would be given to those factors. This may result in incorrect preference decisions.

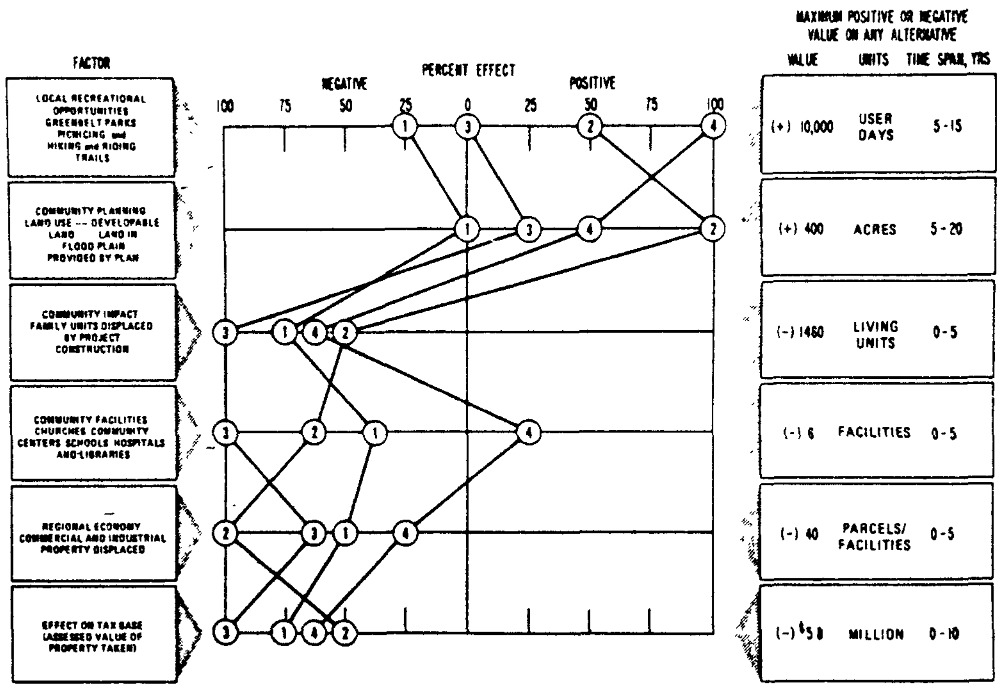


Fig. 2. Factor profiles for flood control alternatives.

In order to reduce the complexity of the diagram and, in turn, of the decision making process, the full set of factors should be reduced whenever it is possible to do so. Two guidelines are suggested for accomplishing this: (1) eliminating all those factors that are not relevant or important to the particular decision, and (2) eliminating all factors where the values are substantially the same for all alternatives. These tests must be acceptable to all parties involved in the study.

It is expected that the profiles will be prepared for each alternative from the viewpoint of each community interest group and will incorporate the factors that are important to that particular group's viewpoint. A composite profile would also be prepared showing the total community effect for each factor. Separate profiles for each alternative could be made on transparent overlays to facilitate the method of comparison proposed in the following paragraphs. In passing it should be noted that research is also under way to provide such displays on a cathode-ray tube activated by a computer. This would permit almost instant recall of any comparisons that seemed appropriate.

Method for Plan Evaluation

Because of the complexity that "real life" factor profiles would often have, a systematic procedure for evaluating and comparing the relative merits of the several alternatives is essential. The method proposed here is that a series of paired comparisons be made using engineering economic analysis and factor profiles as the decision making tools.

First, alternatives 1 and 2 are compared; then the better of these is compared with 3, and so on. In comparing two alternatives the incremental cost or benefit from the economic analysis is weighed against the differences in community and environmental impact between the alternatives as shown by the factor profiles. The decision maker representing each group would appraise the economic and community factors and determine his preference between the two alternatives. After all the paired comparisons among the various alternatives have been completed, there would result preference rankings for each viewpoint in the community. These would be used for comparisons among competing viewpoints in reaching a final decision.

From the point of view of the science of decision theory, the paired comparison approach falls down when more than two parties are involved in the decision. However, this theoretical objection does not mean the paired comparison approach will not work in the real world. This difficulty is widely discussed in the literature [Luce and Raiffa, 1957].

A highly simplified example to illustrate the paired comparison approach is given by the question. "Is it preferable to save $50,000 per year in flood damages accruing to local residents by adopting a bypass flood routing or to dislocate a commercial enterprise situated in the bypass which employs ten people and paying $20,000 per year in property taxes? It is estimated that a substitute enterprise will develop in five years." It is admitted that this example is far simpler than those of the real world where the factor profile would include several elements. Even so, such comparisons make clear the actual points at issue and may greatly reduce the number of irrational arguments that accompany most controversial decisions.

The flow chart of Figure 3 depicts the procedure to be followed in making the paired comparisons just described. Such a procedure should greatly help community groups and decision makers in selecting a preferred alternative.

Step 1: Perform Engineering Economic Analysis. Rank the alternatives in order of preference as determined by the economic analysis. This may be done on the basis of maximum net benefits over cost or total and incremental benefit cost ratios or rates of return. Tabulate the net benefits over costs for each alternative.

Step 2. Prepare Factor Profiles. Factor profiles are prepared from the viewpoint of each interest group showing the plan or project's impact on each relevant factor for that group. A factor profile is also prepared which shows the total or aggregate effect of each alternative over all communities and groups.

Step 3: Economic and Factor Profile Analysis. Compare alternatives on the basis of the economic analysis and the factor profiles. Eliminate any alternative which is dominated by another from the standpoint of both the economic analysis and the factor profile. One alternative strictly dominates another if all percentage values of the factor profile of that

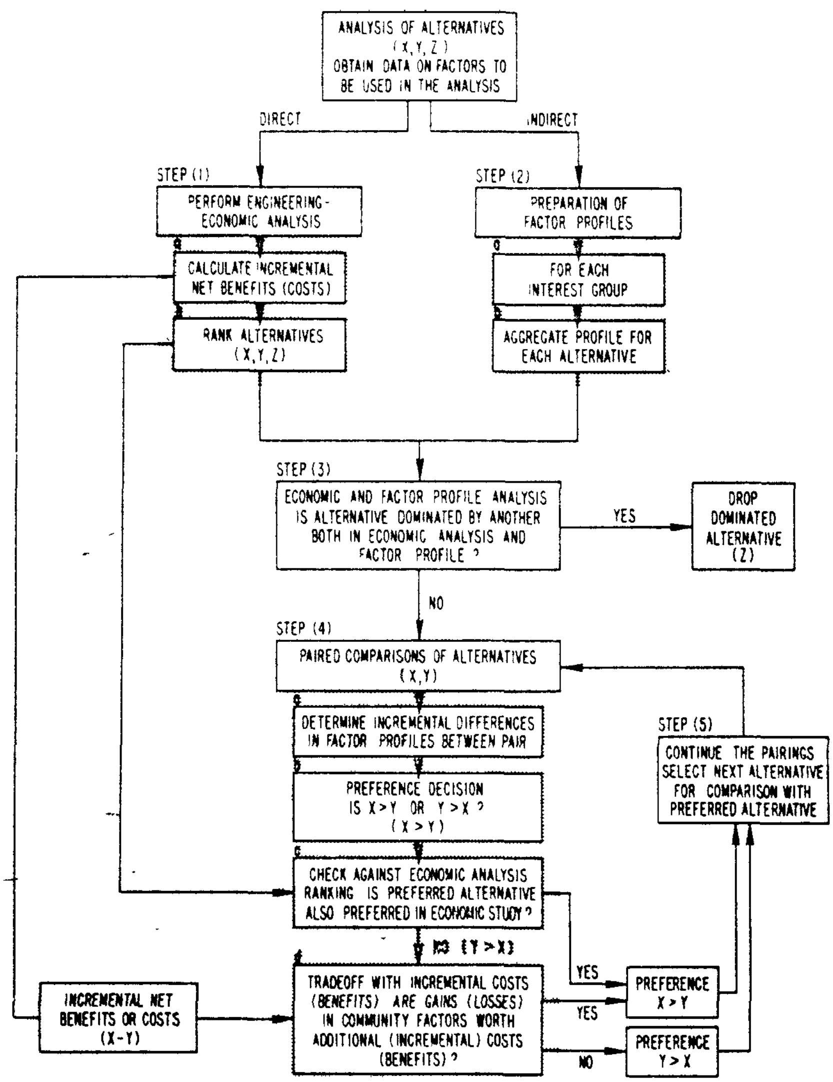


Fig. 3. Flow chart for analysis of alternatives.

alternative are greater than that of the other. This implies that there are no crossovers in the lines of the factor profiles for the two.

Step 4: Paired Comparisons of Alternatives. Paired comparisons are made for each viewpoint on the basis of the incremental differences in community effects from the factor profiles, and comparing these with the incremental differences in costs from the economic analysis. Any two alternatives can be paired, but a reasonable beginning would be to pair one of the alternatives having a good factor profile with the preferred alternative from the economic analysis.

(a) Determine the differences between the alternatives for the community and environmental factors, and compare the increments of values gained with the increments of values lost.

(b) State a preference between the two alternatives based on the importance to the decision makers of the tradeoffs among the factors.

(c) Check the preference statement against the ranking from the economic analysis. This resolves the question, "Is the alternative preferred in (b) also superior from the standpoint of the economic analysis?" If the answer is "yes" then the preferred alternatives is paired with the next alternative selected for analysis. If "no," then the analysis proceeds to (d).

(d) Test the differences in community and environmental factors against the excess of costs over benefits. The decision maker is asking the question. "Are the gains in these factors worth the additional incremental costs of this alternative?" If the answer is "yes" the alternative of higher cost is preferred because of its higher community and environmental benefits. Otherwise, the alternative preferred from the economic analysis is selected and paired against the next alternative for analysis.

Step 5: Continue Paired Comparison Procedure. The procedure (a) through (d) is continued until all feasible alternatives have been included in comparisons. The paired comparisons among the feasible alternatives produce a preferred alternative, and also a preference ranking among all alternatives for each viewpoint if this is desired.

The only constraint imposed on the decision makers in the paired comparisons is that preferences among alternatives must be transitive, i.e., if A is preferred to B, and B is preferred to C, then A is preferred to C. This insures that preferences and decisions are consistent with previous ones, and that the final ranking of alternatives reflects the decision makers' true preferences.

In sum, the purpose of the factor profiles and the procedure for analysis is to help the decision maker apply the two basic principles of decision making: (1) to separate economic effects measurable in dollar values from other consequences, and (2) to compare the differences in alternatives in making decisions. The factor profiles and the method of analysis offer both a visual aid and a systematic procedure for implementing these principles. The construction of the factor profiles does not imply that the area under the curves can be integrated, or the percentage values of factors can be added in order to make a decision.

An Example Application

Consider four proposed flood control alternatives with the relevant community and environmental impact factors and corresponding factor profiles depicted in Figure 2. An analysis of the economic costs and benefits of the alternatives is given in Table 1. The economic analysis indicates that alternative 2 is preferred, since it shows a benefit-cost ratio greater than 1 on the total investment and on all increments of investment. Alternative 1 ranks next, then 4 and 3 have equal desirability from an economic standpoint.

TABLE 1. Economic Analysis of Flood Control Alternatives

Item	Alternative $ (in thousands) 1	2	3	4
Annual Cost	650	750	850	700
Annual Average Savings in Flood Damages	1,000	1,200	1,150	1,000
Net Benefits	350	450	300	300
Benefit-Cost Ratio	1.54	1.60	1.35	1.43

Incremental Analysis	Incremental Cost	Incremental Benefit	B/C Ratio	Increm. Net Bnft. (cost)
4 over 1	50	0	0	(50)
2 over 1	100	200	+2.0	100
3 over 1	200	150	+0.75	(50)
2 over 4	50	200	+4.0	150
3 over 4	150	150	+1.0	0
3 over 2	100	(50)	-0.5	(150)

It must be recognized that the rankings given by this analysis can be changed substantially by changing the interest rate, with lower rates tending to favor higher capital investments. This example is based on an interest rate that reflects the minimum attractive rate of return for a particular planning agency.

In examining the factor profiles, we find that the profile of alternate 4 dominates both 1 and 3. Since 4 is equally attractive as 3 in the economic analysis, alternative 3 can be dropped on the basis of the dominance tests. For the first paired comparison, alternative 2, preferred from the economic analysis, is paired with 4, a dominant alternative from the factor profiles. In comparing the differences between these two alternatives, we find that alternative 2 provides 200 acres of developable land and saves 290 housing units and $.58 million in assessed valuation. On the other hand, alternative 4 increases the average recreational opportunities in the community by 500 user days and saves 25 parcels of industrial property and 2 community facilities. Let it then be assumed that the decision makers agree that alternative 4 is the more attractive of the two, based on the factor analysis tradeoffs.

However, in the economic analysis alternative 2 is preferred to 4 by $150,000 per year, so that additional comparison to the net benefits foregone must also be made. Here it should be noted that alternative 2 costs the agency that will build the project $50,000 more per year; on the other hand, flood damage costs are $200,000 per year less. It could be that the various groups would therefore weigh the economic consequences quite differently. Assuming that, even with the cost differences, alternative 4 is selected over 2, a similar comparison would be made between 4 and 1.

SUMMARY

To summarize, the advantages of the factor analysis method of evaluation are as follows:

(1) It separates the direct money consequences from the social and environmental consequences so that they do not become confused in the analysis;

(2) In complex decision making where it is important to have more rather than less information on which to base the decisions, it provides a visual means by which to display the different factors relevant to making choices;

(3) It provides a means for comparing the incremental differences in environmental and social factors among alternatives, and contrasting them with the differences in economic costs or benefits;

(4) The analysis also provides for separation of viewpoints as well as an analysis of the overall impact. It shows the incidence of community effects upon community groups, brings out the points of agreement or disagreement among those groups, and serves as a mechanism in resolving those conflicts;

(5) Finally, factor identification and factor profiles can be a useful tool during the planning process (a) in defining the factors which are important to the community and community groups, (b) in establishing goals and objectives, (c) as a basis for discussion during the development of alternatives, and (d) as a means of evaluating and making decisions among alternatives.

REFERENCES

Bishop, A. B. 1969. Socio-economic and community factors in planning urban freeways. EEP Report No. 33, Stanford Program on Engineering Economic Planning, Stanford University, Stanford, California.

Grant, E. L. and W. G. Ireson. 1964. Principles of engineering economy. Ronald Press, N.Y. 4th ed. pp. 21-23, 436, 445-448, 456.

Oglesby, C. H., A. B. Bishop, and G. E. Willeke. 1970. A method for decisions among freeway location alternatives based on user and community consequences Highway Research Board Record No. 305. Washington, D.C. pp. 1-15.

Luce, R. D. and H. Raiffa. 1957. Games and decisions. John Wiley and Sons.

Water Resources Council, Special Task Force. 1970. A summary analysis of nineteen tests of proposed evaluation procedures on selected water and land resource projects. Washington, D.C.

WATER RESOURCES BULLETIN
VOL. 11, NO. 5 AMERICAN WATER RESOURCES ASSOCIATION OCTOBER 1975

APPROACHES TO MULTIOBJECTIVE PLANNING IN WATER RESOURCE PROJECTS[1]

Bernard W. Taylor, III, K. Roscoe Davis and Ronald M. North

INTRODUCTION

Recently there has been increasing criticism of economic evaluations performed by water resource agencies. Critics argue that benefit-cost analyses performed by the Corps of Engineers, Tennessee Valley Authority, etc., do not reflect a true valuation of environmental and social objectives. Some critics further charge that water resource agencies do not consider multiple objectives at all and are self-seeking in their economic evaluations. This latter charge, however, may be somewhat erroneous. It is the authors' opinion that water resource agencies have attempted to include environmental and social objectives in the evaluation process but have, in general, not performed the task very successfully. The problem that exists is the method of evaluation employed in attempting to include multiple objectives. Benefit-cost analysis as currently implemented is too limited to accomodate the complexities presented by a multiple objective approach to water resource development.

Because of limitations of benefit-cost analysis, researchers in the management and social sciences have sought alternative approaches to water resource evaluation. It is the purpose of this article to review several alternatives and discuss advantages and limitations of each. These alternatives can be categorized into two areas: mathematical programming and value determination methods. In the mathematical programming area, two techniques will be reviewed, goal programming and the surrogate worth trade off method. In the value determination area, Environmental Evaluation Systems (EES) and personal value determination will be reviewed. While these methodologies are not all inclusive, they do represent an informative cross section of the direction of research in multiple objective decision making.

THE BENEFIT-COST FRAMEWORK

Before reviewing the multiobjective planning techniques, a brief summary of the

[1] Paper No. 75075 of the *Water Resources Bulletin.* Discussions are open until June 1, 1976.
Respectively, Asst. Prof. of Management, School of Bus. Adm., Virginia Polytech. Inst. and State ... Asst. Prof. of Quantitative Methods, College of Bus. Adm., Univ. of Georgia, and Assoc. Institute of Natural Resources, University of Georgia.

evolution of benefit-cost analysis will be presented to provide a better understan... the need for an alternative evaluation approach.

The origins of benefit-cost analysis and its use in governmental processes date... the River and Harbor Act of 1902 (Hammond, 1966). This government le... required the U.S. Army Corps of Engineers to evaluate tangible benefits and cost... would result from navigation projects. The evaluation process resulted in the... computation of benefit-cost ratios for water resource projects.

The Flood Control Act of 1936 formalized the concepts of water re... development and explicitly stated that "... benefits be in excess of costs ..." for a... resource project (Eckstein, 1958). This criterion can be operationalized via... alternative benefit-cost algorithms: the net present value, internal rate of return, a... benefit-cost ratio. The latter technique, the benefit-cost ratio, has become the... popular and most frequently employed.

Through practice and legislation, benefit-cost analysis was extended to water res... projects other than flood control. Popularity of the technique increased to the point... it was applied also in other public areas such as highway development and sani... (Margolis, 1959). The increased demand for public goods that private investment... not supply, in conjuction with the general expansion of the concepts of we... economics, supported evolution of the analysis. Thus, benefit-cost analysis evolved o... period of years so that it became ingrained in the water resources developm... decision-making process.

Within the benefit-cost framework, the economic efficiency of a water resou... project became the sole criterion for evaluating and selecting projects. The nature... analyzed benefits and costs were such that an economic value could be assigned with li... difficulty and with a certain degree of justification. However, the increased pub... awareness of environmental and social factors resulted in the development of a "multio... objective planning framework" In 1970 the Water Resources Council suggested that ... principles and standards specified in previous government documentation incl... environmental and social enhancement and regional economic development (U.S. Government, 1970). The objectives of water resource development were:

1) To enhance national economic development by increasing the value of the natio... output of goods and services and improving national economic efficiency;

2) To enhance the quality of the environment by the management, conservation... preservation, creation, restoration or improvement of the quality of certai... natural and cultural resources and ecological systems in the area under study a... elsewhere in the nation;

3) To enhance social well-being by the equitable distribution of real income, employment, and population with special concern for the incidence of the consequences of a plan on affected persons or groups, by providing educational, cultural, and recreational opportunities;

4) To enhance regional development through increases in the values of a region's income, increases in employment, and improvements in its economic base, environemtn, social well-being, and other specified components of the rregional development objectives.

In 1973, when new principles and standards were finally approved, water resource development was limited to the first two objectives: national economic development and enhancement of the environment (U.S. Government, 1973)

The economic evaluation of benefits and costs resulting from the multiple objective approach has proven quite difficult. It is not so simple a task to place a dollar value on recreation and water quality as is, to a degree, the task of placing a value on navigation and flood control benefits. In addition, there are considerations which environmentalists (supported by the National Environmental Policy Act of 1969) claim cannot be valued at all

Thus, controversies which have resulted between government water resource agencies and environmentalists are not totally a result of an agency's lack of consideration of environmental objectives. The problem, as has been noted, is one of a new multiple objective approach being forced into a limited, outdated and generally incompatible economic framework.

ALTERNATIVE APPROACHES TO WATER RESOURCE EVALUATION

The following overview of some of the more viable alternatives for evaluating water resource projects is divided into two areas: mathematical programming techniques and methodologies which attempt to quantify environmental value outside an economic framework. Goal programming and the surrogate worth trade off method are included in the mathematical programming area. The environmental valuation approaches include Environmental Evaluation Systems (EES) and personal value determination.

...al Programming

There is a scarcity of solution approaches which can accommodate multiple objectives. ...is exists primarily because most mathematical solution methodologies employ a single ...ective function. Goal programming (Charnes and Cooper, 1961; Mao, 1969; Lee, ...), an extension of linear and integer programming, however, is capable of considering ...tiple goals in the objective function. A goal programming framework, thus, allows the ...ideration of both economic and environmental objectives.

The goal programming problem is formulated as follows:

...imize $Z = \sum_{i=1}^{k} (w_i y_i^+ + v_i y_i^-)$

...ect to

$$\ldots - y_i^+ + y_i^- = g_i \quad (i = 1, 2, \ldots, k)$$

...

... = an objective function,

... = a deviational variable measuring the amount of over-attainment of the goal,

... = a deviational variable measuring the amount of under-attainment of the goal,

... = the goal attainment desired for objective function i,

... = the relative weight or penalty cost for over-attainment, and

v_i = the relative weight or penalty cost for under-attainment.

The objective function is interpreted as the minimization of the deviat... desired goals. By weighting the over-attainment and under-attainment ... penalty cost, it is possible to economically quantify the magnitude of ... Policy decisions are necessary to define the desired goal levels, g_i, and the ... weights w_i and v_i. Original objective functions are transformed into constrai... by allowing for under- and over-attainment and setting the equation equal ... goal level. The resulting problem is in the form of an objective function with ... that can be solved via the traditional simplex algorithm. However, the goal pr... model does not confine the solution to the achievement of the goals. The ... satisfactory rather than optimum; i.e., the solution best satisfies the policy le... goal attainment.

Neely (1973) applied this technique to a problem where the best group resources projects were to be chosen from a pool of projects. The best projects w... that had the highest goal levels. The basis of the Neely model was defined as

$$f_1(x) = \sum_{j=1}^{n} NPV_j X_j$$

where,

NPV_j = the net present value of project j, and

X_j = the water resource project (an integer value).

Transformed into a goal constraint, the objective function becomes:

$$\sum_{j=1}^{n} NPV_j X_j - y_1^+ + y_1^- = P$$

where,

P = total dollar value to be attained by the selected projects.

This formulation represents only one of several objective functions employed. Other objective functions were developed in a similar manner to form the complete goal programming structure. In the above formulation the x_j values indicate which project out of a pool of projects would be selected. Thus, the objective function becomes a constraint. The problem becomes one of selecting those projects which best satisfy the constraint, P (net present value), and all remaining goals.

The establishment of policy level (goal attainment) and/or penalty weights can be a significant disadvantage of the goal programming approach. The problem of properly valuing environmental objectives thus also exists in this approach. Environmental objectives still must be quantified; in this case, it is in terms of policy levels. If the Corps of Engineers or TVA established the levels each would be subject to criticism. However, one possible solution is the participation of other groups or individuals in the policy decisions.

Obviously, the goal programming framework provides the advantage of providing a means for considering multiple objectives. But, a criterion for any approach will be its operationality, i.e., ease of implementation. One reason for the popularity of benefit-cost analysis is its flexibility and lack of complexity. Any alternative to benefit-cost analysis will have to be understandable to the parties involved in the decision-making process. While goal programming is relatively complex, the degree of complexity is not prohibitive The technique does offer an approach which warrants further consideration and review.

The Surrogate Worth Trade Off Method

The surrogate worth trade off method (Haimes and Hall, 1974, Haimes *et al.*, 1975) is a mathematical programming methodology similar to goal programming. As in the goal programming model, this method provides a means for considering a vector of noncommensurable objective functions:

$$(f_1(x), f_2(x), \ldots, f_r(x))$$

In numerous decision situations the individual decision maker will evaluate noncommensurable objectives and determine a best solution. In many decisions the individual selects between economic and non-economic entities without any common denominator except subjective preference. The decision maker must compare one or more objectives and determine which is of the greatest value. This type of decision-making process is based on the concepts of Pareto optimality and non-inferior solutions (Ferguson, 1972)

The condition of Pareto optimality exists when an increase in the value of one good in the commodity space can be achieved only at the expense of a decrease in some other good. A point in the commodity space is said to be Pareto efficient when any movement that would augment the value of one good reduces the value of another. This type of decision-making process is transferred to a mathematical programming framework in the surrogate worth trade off method.

Given a set of objective functions, the decision maker assesses the relative value of the trade off of marginal increases and decreases between any two objectives. The optimization procedure requires the determination of when an additional quantity of one objective is worth more or less than that which may be lost from another objective. To determine this trade off between objectives, trade off functions are developed,

$$T_{ij} = \frac{\partial f_i(x)}{\partial f_j(x)}$$

where,

T_{ij} = trade off function between objective functions i and j.

However, when comparing two objective functions, they may be in noncommensurable units. For example, $f_i(x)$ may be measured in dollars and $f_j(x)$ in acres of land. As such, the trade off function would be measured in \$/acres. In order to transfer these noncommensurable units into commensurate units, surrogate worth functions are used. The surrogate worth function is a function of the trade offs which estimate desirability of one objective over another (i.e., is the marginal change in one objective worth more or less than one unit change in the other objective function).

Haimes (1974) defines a scale from -10 to +10, -10 indicating that marginal $f_i(x)$ are worth much less than one marginal unit of $f_j(x)$, +10 indicating the opp... "0" signifying an even trade.

Once trade off functions are developed, the set of feasible solutions is narrow... considering only non-inferior solutions. If improvement of one objective function is possible even at the degradation of another, it is an inferior solution. However, if the... an improvement in the value of one objective function for a corresponding degradation... the other, it is a non-inferior solution. An optimum solution is defined to be ... non-inferior feasible solution that belongs to the "indifference band," a subset ... non-inferior solutions where the improvement of one objective is equivalent to ... degradation of another. The optimum is found at the point where all trade off... selected to make all surrogate functions equal to "0".

The mathematical framework for this approach is not offered here as it is too lengthy and complex. This presentation only reviews the theoretical basis for the meth... However, Reid and Vemuri (1971) present an example in their work which sh... facilitate a more in-depth understanding of the fundamentals of the technique.

The major advantage of the surrogate worth trade off approach is the same as that ... goal programming – the ability to consider multiple objectives. However, in using the surrogate worth trade off method, the decision maker is able to interact with the decision model by assigning subjective preferences to the trade off functions. This enables the decision maker to compare the desirability between two objectives in the decision process.

However, just as the assignment of goal levels is a limitation in goal programming, so is the assignment of surrogates in this method. In fact, the establishhment of surrogates is based almost entirely on subjective preferences. This could prove quite difficult for a public sector agency such as the TVA or Corps of Engineers. The determination of surrogates for trade offs seems to be a more difficult procedure than specifying policy levels for an objective as required in goal programming. The complexity of this technique could also prohibit its eventual use.

Other Mathematical Programming Approaches

Goal programming and the surrogate worth trade off method are examples of mathematical programming alternatives to benefit-cost analysis. Other multiple objective programming possibilities include iterative programming (Dyer, 1972; Dyer, 1973); the step method (STEM) (Benayoun, *et al.*, 1970; Benayoun, *et al.*, 1971), and decision programming (Hatfield, 1973; Silverman and Hatfield, 1973) Ritzman (1974) offers an excellent (brief) overview of all these techniques.

Environmental Evaluation System

Another direction that research has taken is to consider environmental objectives separate from economic objectives. This is achieved by quantifying the value of environmental parameters. Two techniques demonstrate alternative methods for assigning such environmental values.

The Environmental Evaluation System (EES) is a methodology for conducting environmental impact analysis of a water resource project (Dee, *et al.*, 1974). Similar to some of the math programming models, this approach transforms all parameters into commensurate units. However, unlike other techniques, this approach considers only environmental impact. Developers of this technique feel that since environmental impacts cannot be considered adequately within an economic framework, they should be considered separately.

The EES is based on a hierarchical arrangement of quality indicators; an arrangement that classifies the major areas of environmental concern into four major categories: ecology, environmental pollution, esthetics, and human interest. These four categories are further subdivided into 18 components and finally 78 parameters. Each of the 78 environmental parameters represents an aspect of environmental significance worthy of separate consideration. Each parameter is a physical entity which can be quantified based on historical data (Dee, *et al.*, 1974, categorically lists these 78 parameters).

The parameter estimates are related to environmental quality via a value function. The value function relates various levels of parameter estimates to the appropriate level of environmental quality (where environmental quality is measured on a scale from 0, bad quality, to 1, good quality). Figure 1 offers an example of this relationship. (Note that dissolved oxygen is one of 14 parameters in the water pollution component of the environmental pollution category.)

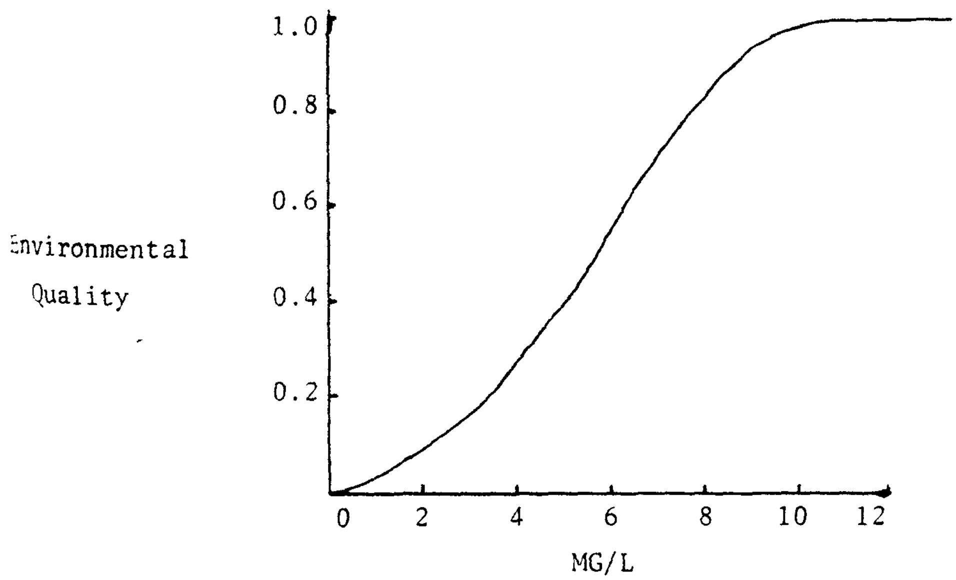


Figure 1. Dissolved Oxygen

In order to determine the relative importance of parameters, each parameter is assigned a weighted point value. These values indicate the degree to which the water resource project may disturb or enhance the "dynamic stability of man's relationship to the environment". These relative weights are based on the quantification of the subjective judgments of the research team performing the analysis.

Once the above conditions are met (i.e., value functions are defined and parameters weighted as to relative importance), results are combined to compute commensurate units. These units, referred to as environmental impact units, are computed as follows:

$$EIU = \sum_{i=1}^{n} (V_i)_w P_i - \sum_{i=1}^{n} (V_i)_{w/o} P_i$$

where,

EIU = environmental impact units,

$(V_i)_w$ = value in environmental quality of parameter i with a project

$(V_i)_{w/o}$ = value in environmental quality of parameter i without a project

P_i = relative weight of parameter i, and

n = total number of parameters.

This equation measures the difference in future environmental quality ... without the project. The commensurate impact units indicate either a positive ... environmental impact for the proposed water resource project. These units ... the magnitude of the positive or negative effects of the project.

Since this approach considers only environmental objectives, it would be ... employ the approach in conjunction with one which considers economic objectives ... may be a more viable solution than considering all objectives within one ... model. The EES offers a means for quantifying Environmental Impact State... requirement of the National Environmental Policy Act of 1969), however ... decision-making process some determination must be made to weigh environ... impact against economic impact. This could pose a serious problem.

Within the EES model itself, the assignment of weights (via subjective judgm... signify the relative importance of environmental parameters, may also be a sig... limitation. One research team's subjective judgements may differ substantially ... another's judgments or from an agency's. It would be necessary to establish a u... measure of parameter weights in order to avoid conflicting situations.

Personal Value Evaluation

This approach, as the title indicates, employs personal value information ar... environmental objectives used in the water resource projects (Groves and Kahalas, 19... It involves sampling the local population, where a project is to be developed, in order ... determine individual preferences. Based on these value judgments, priorities ... established for water resource development objectives.

The personal value evaluation is accomplished via an interviewing process with ... prepared questionnaire. During the interviewing session the subject is asked to place ... scalar value on various environmental parameters.

This evaluation process is limited. Like the EES, this method would have to be used in conjunction with an economic approach. However, unlike the EES, this technique demonstrates the extreme in subjective judgment estimation. The subjective preferences are those of the geographically affected public, which has little scientific or economic expertise on which to base or make judgments. Hopefully, we have not reached a point where the public is considered more qualified to make technical judgments than experts But, the public is qualified to make their desires known in water resource development. Therefore, on a limited basis, this technique provides useful information.

One additional limitation of this approach concerns the cost and effort required in conducting interviews. Many water resource projects are of such magnitude that they can affect states and regions as well as localities. As such, the size of the affected population could make any type of sampling procedure very expensive

CONCLUDING DISCUSSION

The four project evaluation approaches which have been described offer an indication of methods being developed to cope with multiple objectives. Basically, techniques are emerging along two lines. The first, mathematical programming, considers all objectives within a mathematical decision-making model and generates the best or most satisfactory solution. The second, value determination, quantifies only environmental objectives used as inputs to a decision-making process.

The authors are of the opinion that no one methodology offers a complete solution to the evaluation problem. It is probable that a complete solution will not emerge unless a combination of the approaches is employed However, of the four described, goal programming surfaces as the most workable It considers all objectives within a single model framework, with a minimal degree of complexity. Also, the emphasis on subjective judgment (a factor existing to a varying degree in all the techniques) is minimal in goal programming.

It should be recognized that this review is only a limited examination of each of the techniques. However, in each case an effort was made to cite sufficient references. A more in-depth look at particular techniques can be found in the respective references.

LITERATURE CITED

Benayoun, R., J. Tergny and D. Kevneman, 1970. Mathematical Programming with Multi-Objective Functions: A Solution by Progressive Orientation Procedure. Metra, Vol. 9, No. 2, pp. 270-299.

Benayoun, R., J. Montgolfier, J. Tergny and O. Laritchev, 1971. Linear Programming with Multiple Objective Functions: Step Methods. Mathematical Programming, Vol. 1, 1971, pp. 366-375.

Charnes, A. and W.W. Cooper, 1961. Management Models and Industrial Applications of Linear Programming. Vol. I.

Dee, N., J. Baker, N. Drobny, K. Duke, I. Whitman and D. Fahringer. An Environmental Evaluation System for Water Resources Planning. Water Resources Research, Vol. 9, No. 3, pp. 523-555.

Dyer, J.S., 1972. Interactive Goal Programming Management Science, Vol. 19, No. 1, pp. 62-70.

Eckstein, O., 1958. Water Resources Development. Harvard University Press, Cambridge, Massachusetts.

Ferguson, C.E., 1972. Microeconomic Theory. Richard D. Irwin, Inc., Homewood, Illinois.

Groves, D. and H. Kahalas. An Empirical Analysis of Personal Value Information. Contemporary Perspectives in the Decision Sciences (Proc. of 1975 Southeastern AIDS, T.F. Anthony and A.B. Carroll, eds.), pp. 112-113.

Haimes, Y.Y. and W.A. Hall, 1974. Multiobjectives in Water Resources Systems Analysis: The Surrogate Worth Trade Off Method. Water Resources Research, pp. 615-623.

Haimes, Y.Y., W.A. Hall and H.T. Freedman, 1975. Multiobjective Optimization in Water Resource Systems. Elsevier Scientific Publ. Co., The Netherlands.

Hammond, R.J., 1966. Convention and Limitation in Benefit-Cost Analysis. Natural Resources Journal, Vol. 6, pp. 195-222.

Hatfield, G.B., 1973. The Theory and Application of Linear Decision Programming. 8th Intntl. Symposium on Mathematical Programming, Stanford Univ.

Lee, S.M., 1972. Goal Programming for Decision Analysis. Aurbach Publ., Inc., Philadelphia.

Mao, J.C.T., 1969. Quantitative Analysis of Financial Decisions. Macmillan Co., New York.

Margolis, J.A., 1959. The Economic Evaluation of Federal Water Resource Development. American Economic Review, Vol. 49, pp. 96-111.

Neely, W.P., 1974. A Mathematical Programming Approach to Public Water Project Portfolio Selection. Unpbld. Ph.D. Dissertation, Univ. of Georgia.

Reid, R.W. and V.Vermuri, 1971. On the Non-Inferior Index Approach to Large-Scale Multi-Criteria Systems. The Journal of the Franklin Institute, pp. 241-254.

Silverman, J. and G.B. Hatfield, 1973. A Theoretical Approach to Multi-Objective Pr...
20th Intntl. Mtg., Tel Aviv, Israel.

U.S. Government, Water Resources Council, 1970. Report ot the Water Resources Council ... Task Force – Summary of 19 Tests of Proposed Evaluation Procedures on Selected ... Land Resource Projects. Gov't. Printing Office, Washington.

U.S. Government, Water Resources Council, 1973. Federal Register: Water and Related Resources, Establishment of Principles and Standards for Planning. Vol. 38, No 174 ... Gov't. Printing Office, Washington.

WATER RESOURCES BULLETIN
VOL. 9 NO. 5 AMERICAN WATER RESOURCES ASSOCIATION OCTOBER 1973

ECONOMIC FORECASTING FOR VIRGINIA'S WATER RESOURCE PROGRAMS[1]

Charles P. Becker, Allender M. Griffin, Jr., and Carol S. Lown[2]

ABSTRACT. Water resource and water quality management planning depend, to a large degree, on forecasts of industrial activity and population projections. A flexible economic data base is especially important where planning follows varying formats of geographical and industrial detail. Records of employment and payroll are collected in the administration of Unemployment Insurance (U.I.) programs and are available from State Employment Agencies. These statistics have been collected over a long period of record (thirty-five years). Many years of record are available on punched-cards or magnetic tape and may be arrayed and manipulated by computer. This basic approach has been followed in Virginia. Historical U.I. payroll and employment records for the period 1956 through 1970 were procured on magnetic tape. This data was arrayed by major hydrologic area and by regional planning district. Projections of manufacturing activity were then generated by fitting several exponential equations to annual payroll data in two-digit Standard Industrial Classifications. These exponentials were then extrapolated to provide a range of industrial projections. Other parameters of manufacturing activity were then correlated to the payroll data to generate projections of indexes such as employment, value-added, and gross manufacturing output. U.I. payroll data is now being correlated to parameters in non-manufacturing categories. Projections for industries such as trade and services will link extrapolated payroll data with benchmark correlations of payroll and sales receipts.
(KEY TERMS: water resource planning; unemployment insurance (U.I.) statistics; value-added; exponential forecasting; population projections)

Economic data has played an important role in water resource planning and water quality management planning.[3] Parameters such as population, employment and value-added[4] in manufacturing have been correlated to water-use and waste generated

[1] Paper No. 73066 of the *Water Resources Bulletin*. Discussions are open until April 1, 1974.

[2] Economists, Virginia State Water Control Board, Richmond, Virginia, 23230.

[3] Between 1966 and 1972, the Virginia Division of Water Resources of the Department of Conservation and Economic Development was responsible for comprehensive water resource planning for the State of Virginia. On July 1, 1972, the Division of Water Resources was merged with the Virginia State Water Control Board. Since 1946, the Board has been responsible for water quality management in Virginia. The combined agency is now operating as the Virginia State Water Control Board.

[4] "Value-added of an industry consists of labor compensation, proprietors' income, profits, interest, depreciation, and indirect business taxes." (U. S. Department of Labor, B.L.S., 1970).

Water resource planning engineers and sanitary engineers are able to make pred estimates of future water-use and waste levels by making correlations with var population and industrial projections. Water demand, expressed in millions of gallons day (MGD) has been related to value-added in selected manufacturing categor Water-use coefficients are also available for other heavy water-using industries such mining. Domestic water demand can be predicted by applying per capita water-use fa to population forecasts. Parameters of water quality such as biological oxygen dem (BOD) and chemical oxygen demand (COD) have been correlated to economic indexe major water-using industries. Relationships between per capita population and dome waste generated have also been expressed quantitatively in terms of BOD and COD.

In order to produce valid economic forecasts for varying size planning units, the wa resource economist must have a flexible and comprehensive data base. Traditional da sources, such as the Bureau of the Census – U. S. Department of Commerce, publ data[5] which provides a valuable overview to the water resource planner.

Often, however, more detailed, unpublished data is necessary where planning un follow a hydrologic format. Data by reporting establishment must be sorted ar manipulated to produce a valid benchmark or forecast base for hydrologic planning are of river basins. Of course, this same data may be sorted by county or city and furth aggregated into economic planning regions.

The State Employment Security Agencies[6] have collected and stored an impressi record of payroll and employment data for administering Unemployment Insuran programs. This data has been collected in all of the states, in the territories of Puerto Ri and the Virgin Islands. Unemployment Insurance (U.I.) laws vary somewhat from state state in such areas as program detail and reporting coverage. Some states have, f example, full coverage in unemployment-insured industries. Other states have require U.I. reports from firms with four or more employees. Supplementary employment dat may be obtained from the Federal Bureau of Old Age and Survivors Insurance (B.O.A.S.I.) of the Social Security Administration to bring coverage up to a universe o "100 percent" in these "partial coverage" states.

The State of Virginia provides a good illustration where U.I. coverage was partial fo years (required of firms with four or more employees) in unemployment insure industries. An amendment (effective January 1, 1972) to the Virginia U.I. law extende coverage to firms with one or more employees in unemployment insured industries Certain types of employers are still excluded from U.I. coverage. Federal and loca government, railroads, churches and state government (except non-teaching staffs o hospitals and institutions of higher learning) remain exempt from U.I. coverage.

All states, Puerto Rico and the Virgin Islands submit U.I employment and payroll data to the Manpower Administration under the report designation Employment Security (E.S.) 202. The E.S. 202 report is forwarded in the form of a computer print-out. This record (E.S. 202) is assembled using individual establishment reports, i.e., the Employers Quarterly Contribution Report (see facsimile – figure 1). The Contribution Reports are audited for completeness and accuracy, and then key-punched. Each Contribution Report contains the following identification:

[5] In addition to an every-five year Census of Manufacturers, the U. S. Department of Commerce, Bureau of the Census also conducts Annual Surveys of Manufacturing during interim years.

[6] The State Employment Security Agencies are affiliated with the Manpower Administration (formerly the Bureau of Employment Security) of the U. S. Department of Labor

1. A four-digit Standard Industrial Classification (S.I.C.) Code
2. A three-digit area code designating the county or city in which the reporting establishment is physically located
3. A six-digit serial or identification number unique to each establishment

As was mentioned, U.I. Contribution Reports are filed quarterly and contain (in Virginia) the following data.

1. Monthly employment
2. Gross Quarterly Payroll
3. Gross Quarterly Payroll subject to Unemployment Insurance
4. Quarterly contribution, i.e., U.I. tax
5. Quarter and year liability (to U.I.) started
6. Report date (quarter and year)

INSTRUCTIONS ARE ON BACK OF EMPLOYERS COPY OF CONTRIBUTION REPORT

VIRGINIA EMPLOYMENT COMMISSION

EMPLOYERS QUARTERLY CONTRIBUTION REPORT

FOR QUARTER ENDING______________

IMPORTANT NOTE: Enter the number of employees who worked during or received pay for any part of the pay period which includes the 12th of each month of the quarter

1st MO ________

2nd MO ________

3rd MO ________

MAIL THIS REPORT AND MAKE CHECK PAYABLE TO **VIRGINIA EMPLOYMENT COMMISSION** BOX 1358 Richmond Va 23211

ALSO Number of workers on attached payroll by actual count

TAX RATE →

IMPORTANT

Have you sold, merged, or dissolved business?

___ YES, In Whole

___ YES, In Part

___ Date of change

If you have changed your name and or address indicate the new name and address below

PAYROLL DATA

1 TOTAL WAGES for quarter including remuneration other than cash, and including payments over $4 200 per year per individual over $3 000 prior to January 1 1972. $______

2 LESS WAGES paid during quarter to each employee in excess of $4 200 since January 1st ($3 000 prior to January 1 1972) $______

3 WAGES subject to contribution, Line 1 minus Line 2 $______

CALCULATION OF CONTRIBUTION

4. CONTRIBUTION - Multiply total of Line 3 by tax rate shown above $______

5 CREDIT MEMOS NO'S ( ) DEDUCT $______
(Always attach white copy of Credit Memos)

6 INTEREST (computed on contribution -- Line 4 -- at rate of 1% per month from due date to date of payment $______

7 TOTAL AMOUNT DUE for which remittance is enclosed $______

(DO NOT WRITE IN THIS SPACE IF THERE HAS BEEN NO CHANGE)

CERTIFICATION

I, (or we) certify that the information contained in this report required in accordance with the Virginia Unemployment Compensation Act, is true and correct and that no part of the contribution reported was, or is to be, deducted from worker's wages.

DATE______________ Signature______________

Title______________

BATCH NUMBER

ORIGINAL - RETURN TO COMMISSION

VEC FC 20 (R 10 1 71) (300M 10-1 71)

Figure 1. Contribution Report.

MANUFACTURING DATA

Of these items above, employment (item #1) and gross quarterly payroll (item #2) of particular importance to the water resource planner. Payroll is of special relevance since when cumulated by quarter to an annual figure it is a major component value-added. This index, value-added, has been and is currently used extensively as economic indicator (past, present and future) of water-use and waste generated. The payroll in manufacturing is also an important component of gross manufacturing output or value-of-product.

As a prerequisite for access to the E.S. 202 – U.I. data, it is necessary that requesting agency be aware of the publication restraints and data non-disclosure requirements. In Virginia the publication criteria are as follows.

1. The industry group must include at least three independent reporting firms (i.e., companies – not establishments).
2. The industry's employment must be sufficiently dispersed so that the combined employment of the two largest firms does not exceed 80 per cent of the group total.
3. Individual firm data may not be published or disclosed verbally under any circumstances.
4. E.S. 202 data may not be used for law enforcement purposes, except in the administration of the U.I. law under which the data is required.

In most states, other detailed economic data germane to water resource planning is available in both published and unpublished form. In many instances, the unpublished data by firm or reporting establishment is an extremely flexible planning tool. The data usually has been collected by reporting unit and contains identification which is similar to and compatible with the U.I. reports discussed above. In Virginia, an Annual Survey of Manufacturers is conducted by the State Department of Labor and Industry. This survey is based on a selected sample and represents about 75 per cent of all manufacturing activity in the State. Firms which participate in the survey are assigned the following identification data:

1. A four-digit Standard Industrial Classification code
2. A three-digit county or city code
3. A five-digit serial or identification number

The Annual Survey of Manufacturers is conducted by a mailed questionnaire referred to as the S-1 form. Questionnaire data items include:

1. Total employment
2. Production worker employment
3. Salaries and wages (total payroll)
4. Wages paid to production workers
5. Net selling value-of-product
6. Cost of materials
7. Contract work

8. Physical volume-of-product
9. Capital expenditures
10. Anticipated capital expenditures
11. Cost and quantity (KWH) of electric power consumed

Value-added is not surveyed directly as a questionnaire item. It can be easily computed, however, as follows

Value-added = (Net selling value of products)
- (Cost of materials) - (Contract work)

The same publication and disclosure restrictions as outlined regarding the E.S 202 - U.I. data apply to the Annual Survey of Manufacturing records, (i.e. S-1 data).

In Virginia, extensive water resource and water quality management plans are being developed for the nine major river basins (see River Basin Map -- figure 2). These studies were begun by the Virginia Division of Water Resources in 1966 and are being completed by the Virginia State Water Control Board (see footnote 1). This planning is being approached in a six volume format.[7] Within Volume II – Economic Base Study, considerable emphasis is placed on the analysis of manufacturing data. This priority reflects the significance of high water-use and related high waste potential of many manufacturing categories.

Much water resource planning is conducted on a hydrologic format. In order to express benchmark manufacturing data on a hydrologic basis, a major rearrangement of E.S 202 - U.I. data and S-1 data (Annual Survey of Manufacturing) was necessary. This

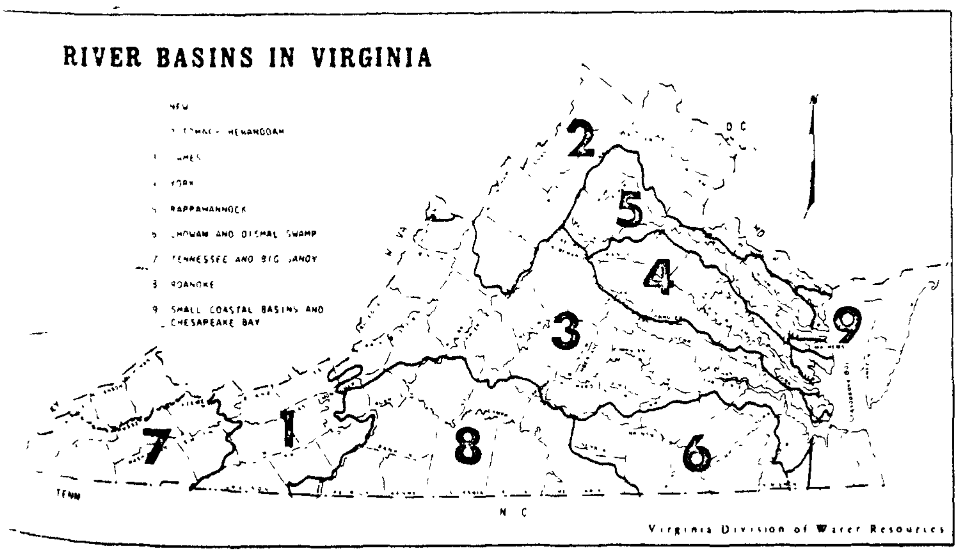


Figure 2. Major River Basins in Virginia.

[7] Volume I - Introduction; Volume II – Economic Base Study; Volume III – Hydrologic Analysis; Volume IV Water Resource Problems and Requirements; Volume V – Engineering Development Alternatives; Volume VI – Implementation of Development Alternatives.

realignment of the data went beyond the normal county and city format. The count city codes were useful, however, as a broad hydrologic sort routine. As a preliminary the punched cards for both the E.S. 202 file and the S-1 file were interpreted and by county and city. Obviously, many counties and cities are completely within the hydrologic areas. In those counties or cities which are situated in two or more hydr areas, however, detailed address determinations of individual firms had to be made necessary, therefore, to have address data for each reporting form or establishment was a specific as possible regarding physical location. Usually the firm's mailing ad coincided closely with the firm's physical location. Based on this address hydrologic address determination could be made. This task was especially easy whe firm had an address indicating a physical location well within a particular river basin more difficult hydrologic address determinations were those where a firm was near a ridge line. In these instances, a good deal of map detail was necessary "ridge-line" address (hydrologic) determinations could be accomplished by field by correspondence with knowledgeable people within the "ridge-line" locality itself latter, less expensive alternative was chosen.

A number of forecasting methodologies[5] (or combinations thereof) are comp with the data base discussed above. The behavior of price-adjusted, annual payroll was quite encouraging when subjected to several exponential growth curves experience, coupled with the availability and continuity of U.I. payroll data, indic that growth curve fitting and extrapolation would be fairly valid as a general fore technique. Asymptotic growth curves describe an industry passing through the foll stages:

1. Period of initial industrial development and limited production – a ph characterized by slow growth
2. Stage of accelerated industrial development, increasing production and expansion
3. Period of relative stability where the growth rate levels off with the main emp on operating efficiency and cost minimization

Curves fitted using the Gompertz equation adhered closely to most historical pa data in the study areas (River Basins and Planning Districts). A Gompertz curve ha shape of a nonsymmetrical "S" when graphed on arithmetic paper. Its nonsymmet nature results from a difference in behavior on opposite sides of the points of infle The Gompertz equation generates a curve in which the growth increments of logarithms are declining by a constant percentage. The general equation of the Gomp curve is.

$$Y_c = Ka^{(b^x)}$$

where:

Y_c = Trend value
x = Time interval

[5]Other forecasting techniques have utilized standard growth rate tables such as those based compound interest rate formula. Industrial projections have also been inferred from predictio population trends.

K = Asymptote or limit which the trend value approaches as x approaches infinity
a = The distance from the asymptote to the Y-intercept
b = The base of the exponential equal to the constant ratio between successive first differences of the log Y

Two other growth trends which are useful as forecasting equations are the Modified Exponential and the Pearl-Reed (logistic). These equations may be categorized with the Gompertz trend in the broad family of exponential curves. The general equations for the Pearl-Reed and the Modified Exponential may be written as follows:

Pearl-Reed

$$Y_c = \frac{K}{1 + 10^{a + bx}}$$

Modified Exponential

$$Y_c = K + ab^{x}$$

The Pearl-Reed curve traces a pattern in which the first differences of the reciprocals of the Y_c values are declining by a constant percentage. The Modified Exponential curve describes a trend where the amount of growth declines by a constant percentage.

Figure 3 provides an illustration of a typical exponential growth curve. As is evident, the trend line (TT') increases, but at a decreasing rate on the right of the point of inflection. The horizontal line (KK') marks the upper limit of growth or the horizontal asymptote.

Asymptotic growth curves approaching horizontal limits were fitted to the price adjusted U.I. payroll data. Whenever a valid "data fit" was established, an equation was derived. An extension of the curve marked a trend of possible growth. Several growth curves fitted to various intervals of data in the same historical series were used to create a range of projections. Value-added, gross manufacturing output and employment were related to payroll data for the forecast reference points.

Prior to growth curve fitting, it is well to look critically at several aspects of the data of the study area:

An appraisal should be made to determine if historical growth experience by the industry under study is actually a valid trend.

Is the available data record of sufficient length to present a representative trend in the area and industry under study?

Is the historical record of sufficient magnitude to represent a data base wide enough to portend future industrial development?

Our experience indicates that price adjusting U.I. Payroll data is an absolute necessity to growth curve fitting. Price adjusting, of course, eliminates the fluctuations of inflation or deflation, leaving "real" changes. Unfortunately, there is no "ideal" price index for price adjusting payroll or labor costs.

The Wholesale Price Index[9] (published by the Bureau of Labor Statistics (B.L.S.), U.

[9] Wholesale Price Index ". . . is an index of the prices at the primary market levels where the first important commercial transaction for each commodity occurs." (Tuttle, 1957). "Wholesale', as used in the title of the index, refers to sales in large quantities, not to prices received by wholesalers, jobbers or distributors." (U. S. Department of Labor, B.L.S. Handbook, 1971).

S. Department of Labor) has proven quite satisfactory when applied to manuf... payroll data. Most applications have been on the two-digit S.I.C. level using the ... converted to 1970.

The Bureau of Water Resources of the Virginia State Water Control Board ... available 15 years (1956-1970) of U.I. employment and payroll data. An IBM computer is currently being used for the exponential curve fitting routines. Previou... Olivetti Programma 101 (a programmable calculator) and an IBM 1130 computer ... used. The IBM 360 has, of course, greatly expedited curve fitting and extrap... routines.

Utilizing the "360" program, fifteen years of historical payroll data were fit... three exponential curves – Gompertz, Modified Exponential and Logistic (Pearl-R... The data was analyzed in 6, 9, 12 and 15-year intervals. For fifteen consecutive ye... data, this method resulted in twenty-two possible curve fits for each two-digit S.I.C. ... there were several different forms which the exponential curves could take, constr... were built into the program to eliminate the curves which did not fit a pattern of ... growth. The desired shape of the growth curve was that which sloped upward to the ... approaching some horizontal limit, while increasing at a decreasing rate (see figure 3).

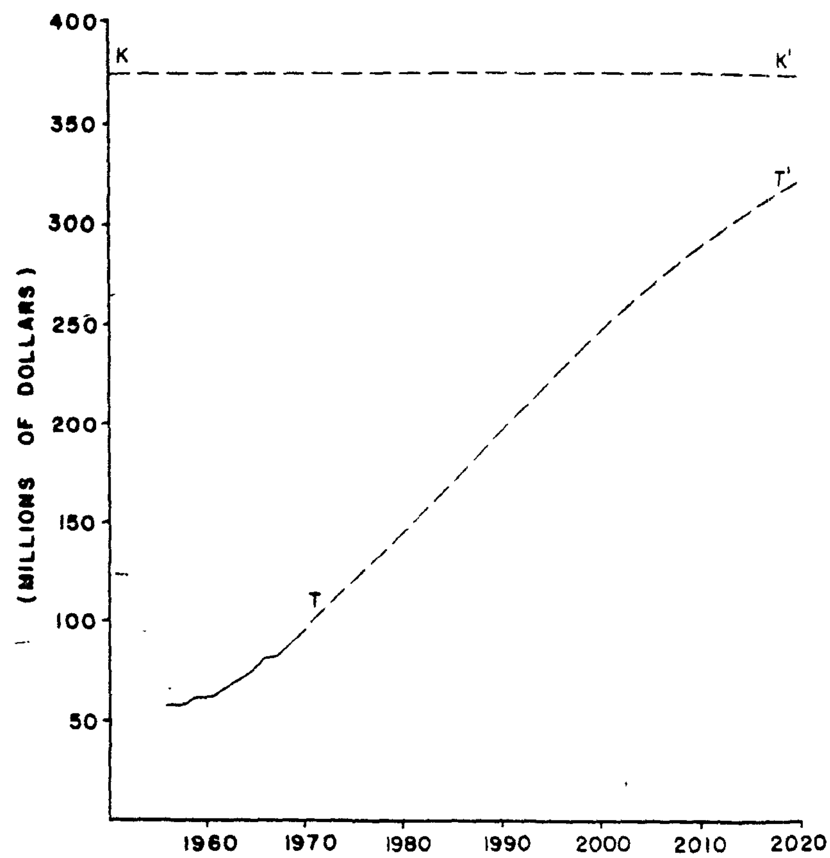


Figure 3. U.I. Payroll estimates and projections in transportation, communications and public utilities for the Southeastern Virginia Planning District (data expressed in constant 1970 dollars).

Fifteen years of annual payroll data (1956-1970) were read in for each industry The first six-year period (1956-1961) was analyzed, and the exponential equation was developed. If the equation did not violate the built-in constraints, then the program extrapolated the historical data from the initial year of the fit period (in this case 1956) to the year 2020. If the equation violated the constraints, a message was printed out indicating that there was no fit for that series. The second group of consecutive years of payroll data (1957-1962) was then analyzed This continued through the twenty-two possible combinations until the final serial (1956-1970) had been analyzed.

The extrapolated universe payroll values, payroll-per-employee, S-1 value-added, S-1 gross manufacturing output and S-1 payroll were used in a Programming Language 1 (PL1) program which generated a table of projections for value-added, gross manufacturing output, payroll and employment The tables were structured for photographic reproduction directly from the printout, thus eliminating virtually all typing and proofing. The value-added projections were developed by computing the ratio of S-1 payroll and S-1 value-added for the benchmark year. This ratio was applied to the extrapolated payroll figures to develop the universe value-added projections The gross manufacturing output projections were developed in much the same way The ratio of S-1 payroll to S-1 gross manufacturing output was computed for the benchmark year, and this was applied to the extrapolated payroll values to give gross manufacturing output projections. The extrapolated payroll values were divided by the extrapolated payroll-per-employee figure to develop employment projections for each S.I.C group.

Because of the large volume of output from the exponentials, another method of analysis has been devised which expedites the evaluation of the extrapolations. A curve plotting routine has been added to the exponential programs so that each curve that extrapolates is also graphed. This enables the analyst to pick the best fit from the plots without having to analyze reams of computer print-outs. A FORTRAN IV[10] program has been written to utilize the plotter capability of the IBM 360. This plotter routine will graph the price-adjusted historical payroll data and all possible extrapolations. By employing transparent plotting paper and a uniform scaling factor, an overlay effect is created for the graphic extrapolations within each S.I.C. The three exponentials – Gompertz, Pearl-Reed and Modified Exponential – are thereby grouped and the trend selection process is greatly facilitated. A clustering effect is a "reasonable" indication of a medium range projection.

A COBOL[11] routine is used at this point to expand the extrapolated U.I. payroll to a universe. This universe payroll figure will include U.I. payroll, B.O.A.S.I. payroll and non-covered payroll. Universe employment data can then be estimated by dividing the universe payroll projections by extrapolations of payroll-per-employee. Value-added and gross manufacturing output (value-of-product) can be projected through correlation of benchmark payroll to value-added and payroll to gross manufacturing output (G.M.O.).

POPULATION STATISTICS

In Virginia, the Division of State Planning and Community Affairs (D.S.P.C.A.) has

[10]FORTRAN IV is a computer language which is used most frequently in scientific and engineering applications. The term FORTRAN relates to the primary use of the language: FORmula TRANslating.

[11]COBOL is a computer language which is used extensively in business and commerical data processing. The term COBOL is derived from the expression COmmon Business Oriented Language.

been designated as the agency responsible for the State's population projections. This Division (D.S.P.C.A.) has recently published population forecasts for all counties and cities in Virginia. These projections are on an every ten year basis to the year 2020.

The planning guidelines of the Virginia Division of Water Resources required a range of population forecasts. The range of projections (high, medium and low) reflect varying demographic assumptions. The low projections assume a very subdued rate of industrial development and continued out-migration of the resident population. The medium forecast is based on a rather vigorous industrial development program. An extremely accelerated rate of economic growth is implicit in the high projection. High and low projections were generated by fitting the compound interest rate formula above and below the D.S.P.C.A. forecast (medium). This trend fitting was accomplished using a FORTRAN IV program on an IBM 1130 computer. County and city population projections developed by the Virginia Division of State Planning and Community Affairs were used by the Division of Water Resources as the medium range on which the high and low projections were based.

The following high and low control totals (in thousands) were assumed for the entire state:

	1970	1980	1990	2000	2010	2020
High		5,632	6 919	8,500	10,140	12,100
(Medium)	4,648	5,415	6,284	7,222	8,217	9,340
Low		5,198	5,629	6,100	6,600	7,100

The average annual rate of change was computed for each ten-year period using the compound interest rate formula:

$$\text{Average annual rate of change} = R = \sqrt[n]{\frac{X_t}{X_I}} - 1$$

e.g.

X_t = 5,629,000 - 1990 State low
X_I = 5,198,000 - 1980 State low
n = 10 (years)
R = 0.00799

A set of ten constants were then computed, five high (H_i) and five low (L_i). These can be defined for each ten-year period as the differences between R for the high protection (RH_i) and R for the medium (RM_i), and the difference between RM_i and for the low (RL_i):

$$H_i = RH_i - RM_i \qquad i = 1,5$$
$$L_i = RM_i - RL_i \qquad i = 1,5$$

These constants were then applied to each county and city in developing the high and low projections.

RC_i was computed for each county and city for each ten-year period, using D.S.P.C.A.'s medium projections:

$$RC_i = \sqrt[n]{\frac{X_t}{X_1}} - 1$$

For a given county or city, then, the high projections were computed as follows:

$$Hi\ (1980) = (1970\ Popl'n)\ (1.0 + H_1 + RC_1)^{10}$$
$$Hi\ (1990) = Hi\ (1980)\ (1.0 + H_2 + RC_2)^{10},\ etc.$$

and the low:

$$Lo\ (1980) = (1970\ Popl'n)\ (1.0 - L_1 + RC_1)^{10}$$
$$Lo\ (1990) = Lo\ (1980)\ (1.0 - L_2 + RC_2)^{10},\ etc.$$

BITUMINOUS COAL MINING

An analysis of Virginia's bituminous coal mining industry was made in Volume II – *Economic Base Study* of the Tennessee and Big Sandy River Basins. Three basic economic indicators – production, employment and productivity – were presented. Production in the coal industry is measured in mine tonnage and has experienced an increasing trend in Virginia since the late 19th century. Record keeping has been quite good in this industry and a comprehensive set of historical data[12] is available from the Virginia Department of Labor and Industry. Based on the availability and continuity of this data, growth curve fitting and extrapolation was selected as a reasonable forecasting technique.

Asymptotic growth curves describe a mineral industry passing through the following stages:

1. Period of initial exploration, market development and limited production, a phase characterized by slow growth
2. Stage of sharply increasing production and rapid expansion
3. Period of relative stability where the growth rate levels off with the main emphasis on operating efficiency and cost minimization

The three exponential curves (Gompertz, Pearl-Reed and Modified Exponential) discussed on the above pages were used in this analysis.

The medium range projection represented the rates of growth believed to be the most probable. High and low projections were also developed. These three forecasts provided a range of data wherein certain water resources planning alternatives could be tested.

Basically the same approach (asymptotic growth curves) was used to project the future low employment trend in the coal industry. Because of the historically declining employment series, a low range curve with a negative trend and a lower limit was fitted and extrapolated.

[12] Annual Reports, Virginia Department of Labor and Industry, 1951-68.

CURRENT PROJECTS

Recent emphasis in Virginia has been on Metropolitan/Regional Plans to the State's Water Quality Management Plan. The Metropolitan/Regional Plans are being developed for Virginia's twenty-two planning districts. Since the planning districts are aggregations of entire counties and cities, the data base, described above, was arrayed and manipulated using the three-digit county or city codes. The basic economic parameters developed in the river basin plans, discussed above, were also generated for the Metropolitan/Regional Plans.

Data is currently being developed for a special water quality management study for the lower James River Basin. The project (The Lower James River Basin Comprehensive Management Study), often referred to as the "3c" Study, was authorized under Section 3(c) of the 1965 Federal Water Pollution Control Act. The purpose of the 3(c) Study is to develop a viable water quality management plan for one of the most intensively developed sections of Virginia's largest river basin.

The data being assembled for the "3c" Study will include standard parameters for all industries and will follow a county and city format Economic data for the "3c" Study is being generated in terms of a 1970 benchmark and ten-year projections to the year 2020 Those indexes requiring price adjustments have been expressed in constant 1970 dollars

The forecasting methodology for the "3c" Study data will generally parallel the techniques discussed regarding the manufacturing data. Again, extrapolations of "growth curves" fitted to price adjusted payroll data will be correlated to other parameters such as employment and sales. The major exception will be in a shift from the B.L.S. Wholesale Price Index to the B.L.S. Consumer Price Index for price adjusting historical payroll data. The "3c" Study will place considerable emphasis on "real" income of the Study area in relation to the proposed expenditures for water quality management. Payroll data (for all industries) price adjusted with the Consumer Price Index should produce a fairly realistic indication of how local income can meet expenditure recommendations Certain non-payroll data, however, such as manufacturing value-added, gross manufacturing output and wholesale trade receipts will be adjusted with the Wholesale Price Index

CONCLUSIONS

Economic data adds an important dimension to water resource and water quality management planning. Payroll and employment statistics collected to administer State Unemployment Insurance programs have a multitude of applications in economic analysis and forecasting. U.I. data is a continuous, carefully maintained and relatively extensive set of historical records. It has been accumulated under national guidelines of the U. S. Department of Labor, Manpower Administration and is quite uniform in format. U.I. records have, for years, been structured for data processing applications. Further manipulation of this data such as price adjusting and trend fitting are thus facilitated. Most of the standard economic parameters of water resource and water quality management planning such as value-added and gross manufacturing output have been correlated to U.I. payroll and employment benchmarks. The Annual Survey of Manufacturing (Virginia Department of Labor and Industry) provides value-added and gross manufacturing output data. County and city detail and a data processing format is an important feature of the Annual Survey (S-1). Both the U.I. and S-1 data have been further formated by hydrologic area in Virginia. On balance, the U.I. and S-1 data have become valuable tools for water resource and water quality management planning in Virginia.

LITERATURE CITED

Tuttle, Alva M. 1957. Elementary Business and Economic Statistics. New York, N. Y. McGraw-Hill Book Company, Inc.

U. S. Department of Labor, Bureau of Labor Statistics, 1971. Handbook of Labor Statistics, Bulletin 1705. Washington, D. C.

U. S. Department of Labor, Bureau of Labor Statistics, 1970. Patterns of U. S. Economic Growth. Bulletin 1672. Washington, D C.

Virginia Department of Labor and Industry. 1951-68. Annual Reports. Richmond, Virginia.

ECONOMIC VALUATION OF SHORELINE

Gardner M. Brown, Jr. and Henry O. Pollakowski*

I. Introduction

SHORELINE development is a growing public policy issue in many urban areas. While there is some published research on a related topic, the importance of ambient water quality, economists have not yet turned their attention to the economic significance of the existence and width of the undeveloped apron offering public use and access to bodies of water in urban areas. There are several important issues to be considered here. May we expect the urban land market to provide a solution which is Pareto efficient? Have public agencies through zoning and other building restrictions acted in a socially optimal way? What contribution can studies of the determinants of property values make to our understanding of these issues? We begin an exploration of these issues and present some empirical results that enhance our knowledge of the economics of water-related open space.

More generally, this paper extends recent economic work that has produced quantitative measures of value for phenomena hitherto restricted to qualitative expression. The process of transforming qualitative into quantitative knowledge, so essential to an empirical science as to be one of its distinguishing features, is well illustrated by the work of Cobb and Douglas on production (1928), Griliches (1961) on the qualitative characteristics of automobiles, and Fogel and Engerman's (1974) controversial piece on slavery.[1] With respect to housing, implicit prices of each attribute contained in the bundle of housing services have been estimated by hedonic price regressions in the spirit of the work by Lancaster (1971) and others.[2]

In the following sections we first examine the choice of housing attributes, including water-related open space and proximity to bodies of water, faced by a household in a metropolitan area. Next, the process of implicit price formation is examined, and, employing data on individual dwelling units in a metropolitan area with numerous bodies of water, these implicit prices are estimated. We then turn to the question of what can and cannot be inferred from these results about the demand for open space and the welfare gains or losses resulting from possible changes in the amount of water-related open space.

II. Implicit Price Estimation

A given housing unit is best characterized as consisting of a bundle of attributes which describe the structure itself, the land upon which it is built, and the relevant locational characteristics. We thus view proximity to water and water-related open space (i.e. the land contiguous to water to which the public has access and which we define as setback) as

Received for publication December 1, 1975. Revision accepted for publication September 27, 1976.

*Richard Parks, Richard Hartman, Levis Kochin, Ronald Trosper, Cindy Watts, and an anonymous referee provided helpful criticism of earlier versions of this paper. Ron Johnson, our research assistant, deserves credit for many valuable suggestions, including the germ of the idea in the final section. The work upon which this paper is based was supported in part by funds provided by the United States Department of the Interior, Office of Water Resources Research as authorized under the Water Resources Research Act of 1964 through the State of Washington Water Research Center. Henry Pollakowski also acknowledges partial support by National Institutes of Health research grant number 1 R01 HD07410-02 from the National Institute of Child Health and Human Development, Center for Population Research.

[1] Research that derives the implicit value of natural environmental attributes or activities that use natural environment intensively includes the work by Hammack and Brown on waterfowl (1974), Castle, Singh and Brown (1964) and Mathews and Brown (1970) on sports salmon fishing, and Davis (1964) and Krutilla and Fisher (1975) on wilderness. The Krutilla and Fisher reference both refers to and summarizes interesting related research by Cicchetti and V. K. Smith.

[2] Contributions employing micro data and specifying the bundle of housing services in an interesting manner include Kain and Quigley (1970), King (1973), Pollakowski (1973, 1977), and Grether and Mieszkowski (1974). The natural environmental attribute so studied has been ambient air quality. See Freeman (1974), Polinsky and Shavell (1975, 1976) and Small (1975) for discussion of the theoretical issues involved in interpreting the results of the air quality studies and for further references.

two locational attributes of the housing bundle. At any given time, there exists a given distribution over space of the supplies of these attributes. We make this assumption since the housing stock is altered only slowly over time, and because some attributes, such as certain neighborhood amenities, are supplied perfectly inelastically.

On the demand side, assuming a given spatial distribution of employment and a given distribution of preferences and income over households, we may envision a distribution over space of demands for these attributes. The housing market is thus viewed as consisting of implicit markets for each of the attributes of housing, broadly defined, and it is assumed that at any given point in time a vector of implicit short-run equilibrium prices exists.

For the sample areas, estimates of the marginal implicit prices of each of the dwelling unit attributes were obtained by regressing dwelling unit selling price on the set of variables representing the attributes that constitute the relevant housing package. The choice of functional form to be employed was based upon a number of considerations. There are, of course, a large variety of possible nonlinearities and interactions among housing attributes one may wish to consider. Limited experimentation, however, with functional forms other than linear ones did not substantively alter our basic results. We thus chose to present results of the linear form, while altering any right-hand variables whenever there was an a priori reason to believe that an important nonlinearity existed.[3]

The sample areas or neighborhoods are located in Seattle; this city is ideal for our purpose since it contains numerous and varied bodies of water, some of which are surrounded by open space and some of which are not. Numerous potential sample areas located close to bodies of water were considered for use. The most important objective was to achieve a relatively high degree of homogeneity within and across areas. Neighborhoods chosen were similar in topography, non-water-related neighborhood characteristics, and accessibility. Areas that contained or were adjacent to large commercial zones were eliminated from consideration, and only those areas adjacent to bodies of water used extensively for recreation purposes were employed. The number of feasible choices of areas with setback was severely limited by lack of variation in the width of the setback area in numerous areas. Finally, a number of otherwise acceptable areas were eliminated due to physical obstructions such as railroad tracks that inhibited ready access to the water's edge or setback area.

This selection procedure yielded three areas —one exhibiting significant variation in setback width and two with no setback. Each of these areas is an almost exclusively single-family residential area, and since each area is within the Seattle city limits nominal property tax rates do not vary. One of the areas without setback is located on Lake Washington, a very large inland body of water. The remaining two areas encircle two smaller lakes, Green Lake (with setback) and Haller Lake (without setback). The boundaries of the sample areas were based, in part, on previous work by others which indicates that the contribution of a water resource to property values generally is not significant beyond 4,000 feet from the water's edge.[4] In one area (Green Lake), 4,000 feet was used. In the other areas, 2,200 feet was selected because our criteria for homogeneity would have been violated had a greater distance been included. For example, in one area a change in topography at a distance of 3,000 feet was accompanied by a sharp change in racial composition of the dwellers.

The data employed consist of market sales data for dwelling units in these areas sold during the period 1969–1974. The data were obtained from listings of sales data gathered from real estate sources.[5] For each observation, this data source includes selling price and a rather rich description of the structural attributes. The selling price data were deflated to constant 1967 dollars by use of a price index

[3] See Grether and Mieszkowski (1974) for further discussion of choice of functional form and for a comparison of results of linear and semilogarithmic forms.

[4] See, for example, Dornbusch and Barrager (1972).

[5] Sales data, including selling price and corresponding structural characteristics, were obtained from the monthly publications of the SREA Market Data Center Inc., April 1969 to June 1974.

for Seattle single family dwellings.[6] The open space variable employed was constructed by measuring the width of setback area abutting the water and closest to the dwelling unit in question. Setback appears in log form in the regression because we had a strong reason to believe that the relationship between setback and selling price was a nonlinear one. That is, we believed that as setback width was increased, marginal contribution to housing value would decrease. We thus assume that the marginal implicit price of setback varies with the quantity of this attribute purchased. The distance to waterfront was measured as the shortest linear distance from the dwelling unit to the nearby waterfront. It, too, appears in the regression in log form because we believe the relationship between distance to waterfront and housing value is essentially nonlinear.

The regression results are presented in tables 1 and 2. It should be noted that not all of the structural information on the individual dwelling units is employed.[7] A number of these structural variables, such as a set of dummy variables representing different heating fuels used, made essentially no explanatory contribution in earlier regressions and are thus deleted in the results presented here. Since tests on preliminary regression runs indicated the presence of heteroscedasticity, all observations are weighted by 1/living area.

Table 1 presents results for our setback area (Green Lake), one of the more interesting areas and the one with the largest sample size. The lake itself has a circumference of about three miles and is completely surrounded by green area with public access. The green area surrounding the lake is very popular for public use, including a cycling/jogging track and swimming, fishing, and boating facilities. As mentioned above, the width of the setback varies a good deal as one moves around the lake, making this an especially appropriate area to study. In table 2 we present results for a pooled sample consisting of the two areas without setback. In both cases nearly all of the coefficient estimates are of the hypothesized signs and the explanatory power of the right-hand variables is quite high.

The results bearing on the value of distance to waterfront and size of open space are quite interesting. Applying the appropriate one-tailed t-tests, in each case we can reject at the 0.01 level the null hypothesis that the coefficient estimate of the distance to waterfront variable is zero. In the setback case (table 1), we can reject at the 0.051 level the null hypothesis that the setback coefficient estimate is zero. Having corroborated our presumption that these variables would be statistically important, the implications of the actual magnitudes of these two coefficient estimates are now examined.

Consider first the effects of setback itself. Recall that we are assuming that the relationship between setback size and dwelling unit value is nonlinear: that the benefits of a green area along the waterfront to which the public has access are captured in land values in the proximity of the body of water: and that the existence and width of setback in the

TABLE 1 —RESULTS FOR GREEN LAKE AREA
Left-hand Variable: Selling Price (deflated to 1967 dollars)
All observations weighted by 1, living area
$N = 90$

Variable	Coefficient	Standard Error
Constant term	15700	3400
Living area (sq. ft.)	3 38	1 17
Age of house	−73 3	15 4
Average room size	−5 51	7 25
Number of fireplaces	1120	415
Number of car garage	674	455
Number of rooms 1st story	−311	265
Number of bathrooms	2830	607
$D = 1$ if basement	1260	464
$D = 1$ if dishwasher	2010	784
$D = 1$ if good or excellent quality	289	486
$D = 1$ if range and oven	255	748
$D = 1$ if hot water heating	1040	1140
$D = 1$ if wall or floor furnace heating	−2200	801
$D = 1$ if electric heating	−1660	903
Lot size (sq ft.)	−0 247	0.195
$D = 1$ if view	573	693
Log of distance to waterfront	−1770	762
Log of individual setback size	1230	744
SSR = 197	S E. = 1 66	$R^2 =$ 84

Sources of Data Selling price and structural characteristics SREA Market Data Center Inc (April 1969 to June 1974) Distance to waterfront and setback size measured on local maps

[6] A local price index for single family residential sales within the Seattle metropolitan area was used as a deflator The source was Seattle Real Estate Research Committee (Fall 1974)

[7] Although available, we did not employ the following structural characteristics: number of rooms above the first floor; the number of bedrooms, the existence of a den, family room, or recreation room; special improvements, type of garage; and type of heating fuel used

TABLE 2.—RESULTS FOR AREAS WITHOUT SETBACK
Left-hand Variable: Selling Price (deflated to 1967 dollars)
All observations weighted by 1/living area
$N = 89$

Variable	Coefficient	Standard Error
Constant term	16500	3580
Living area (sq ft)	4.17	1 84
Age of house	−74.6	40.0
Average room size	−13 8	11 6
Number of fireplaces	417	608
Number of car garage	1510	617
Number of rooms 1st story	−44 4	399
Number of bathrooms	5120	1190
$D = 1$ if basement	300	831
$D = 1$ if dishwasher	308	888
$D = 1$ if good or excellent quality	289	649
$D = 1$ if range and oven	298	839
$D = 1$ if hot water heating	5790	3380
$D = 1$ if wall or floor furnace heating	−540	998
$D = 1$ if electric heating	−2250	1110
Lot size (sq. ft)	0.235	0 104
$D = 1$ if view	1340	1110
$D = 1$ if in Haller Lake area	−1730	706
Log of distance to waterfront	−2790	548
SSR = 380	S.E. = 2.33	$R^2 = 78$

sample affects all dwelling units which are proximate to the body of water equally. The effect of variation in setback in the Green Lake area is quite substantial. A dwelling unit located in an area close to a 200 foot wide setback will sell for about $850 more than a comparable one located near a 100 foot wide setback area. This same dwelling unit, if located near a 300 foot wide setback area, would sell for about $1,350 more than if it were located near a 100 foot setback area.

The estimates of premiums paid for proximity to shoreline are very plausible ones for the Seattle area, and, as we would expect, this premium declines with distance to waterfront much more rapidly in the case of no setback than in the setback case. Applying the appropriate *F*-test, we can reject at the 0.05 level the null hypothesis that the respective coefficient estimates of the distance to waterfront variable are equal. In the case of no setback, we observe that three-fourths of the location value of proximity to water has been lost at a distance of 300 feet from the waterfront.

III. Optimal Open Space

The next question to be examined is whether the amount of open space around the water bodies studied is optimal. A necessary first step is to decide in what manner our estimated hedonic price equation can be used to answer this question.

First, consider the measurement of benefits of open space. Given that willingness to pay is the appropriate measure of the value of open space, we wish to obtain an estimate of the area under the demand function for open space. The estimated hedonic price function itself is most appropriately viewed as an opportunity locus facing households in the housing market.[8] Taking the derivative of this function with respect to setback gives a marginal implicit price function. This function, which will be downward-sloping and convex from below in the case of setback, is most appropriately viewed as the locus of the marginal willingness to pay functions of households.

Assume that the characteristics embedded in housing are not obtainable by the purchase of other products, and that utility functions are weakly separable between housing service characteristics and other characteristics. If we then assume that migration among metropolitan areas is possible, that households have equal incomes, and that households have identical utility functions, it follows that all households will have identical marginal willingness to pay functions.[9] In this case, the estimated marginal implicit price function may be appropriately viewed as the marginal willingness to pay function, and an estimate of the value of open space may be obtained from the function we have estimated. Given the nature of the assumptions necessary to make this calculation, there is good reason to regard the results obtained as indicating only rough orders of magnitude.[10,11]

[8] See Freeman (1974) and Rosen (1974) for a more detailed discussion of these matters.

[9] Polinsky and Shavell (1976), assuming identical Cobb-Douglas utility functions and equal incomes, identify the demand function for air quality in a general equilibrium model.

[10] If we wished to consider only very small changes in open space, it would not be necessary to assume identical preferences. While separability between open space and all other characteristics must be assumed in this case, it may not be unduly restrictive given the degree of change envisioned. See Small (1975) on this matter. We must further assume a zero income elasticity demand for setback in order to make the estimated demand curve correspond to a compensated demand curve. The latter

The determination of optimal open space is straightforward. If those who benefit from the water-related open space are also the owners or renters of property, then the added value for all property affected by slightly changing the amount of open space should just offset the cost of buying the property or the added space. Since a land value gradient can be computed from the estimated hedonic price equation, we have enough information to perform a rough calculation.[12]

On the assumption that the boundary of a water body is well described by a circle with radius r, and that all properties have the same area $\bar{A}$, the number of properties within a band of land of width Q from the water's edge is given by

$$N(Q) = (\Pi/\bar{A})(2rQ + Q^2).$$

The marginal number of properties at Q is

$$N'(Q) = (2\Pi/\bar{A})(r + Q).$$

Optimal open space is found by maximizing with respect to open space, Q_s,

$$W = \int_{Q_s}^{\bar{Q}} N'(Q)V(Q,Q_s)dQ - \int_0^{Q_s} N'(Q)V(Q,Q_s)dQ, \quad (1)$$

where $V(Q,Q_s)$ is the value of a property whose distance to the water is Q, and where Q_s is the width of the strip of open space around the water. $\bar{Q}$ is the distance from the shoreline beyond which it is assumed that properties no longer benefit from this open space.

The first expression on the right-hand side of (1) represents the benefits of setback or open space, embodying the assumption that all property located between the edge of the open space and $\bar{Q}$ benefits from open space. The second expression on the right-hand side of (1) represents the opportunity cost of open space: the foregone private value of each property which could have been located between the water's edge and the terminus of the open space. Anticipating the next stage, we denote the inverse demand function for open space by $h(Q_s)$ and note that it is simply $\partial V(Q,Q_s)/\partial Q$.

Figure 1 illustrates the nature of the problem. In the absence of any setback or public access, the value of all property at the lake shore rim equals N_0V_0. The value of property declines with distance until a distance of $\bar{Q}$ is reached. When setback equals Q_s, the value of all property at that distance from water is higher than it would have been in the absence of setback. The optimal setback occurs when the loss of private property value near the shore, $Q_0N_0V_0AQ_s$, is compensated by the gain to remaining properties, $ABCE$, from additional setback.

The necessary condition for a maximum is

$$\int_{Q_s}^{\bar{Q}} N'(Q)h(Q_s)dQ - \int_0^{Q_s} N'(Q)h(Q_s)dQ - 2N'(Q_s)V(Q_s,Q_s) = 0.$$

Revising, after noting that $h(Q_s)$ is independent of Q, yields

$$h(Q_s)\left[\int_{Q_s}^{\bar{Q}} N'(Q)dQ - \int_{Q_0}^{Q_s} N'(Q)dQ\right] = 2N'(Q_s)V(Q_s,Q_s)$$

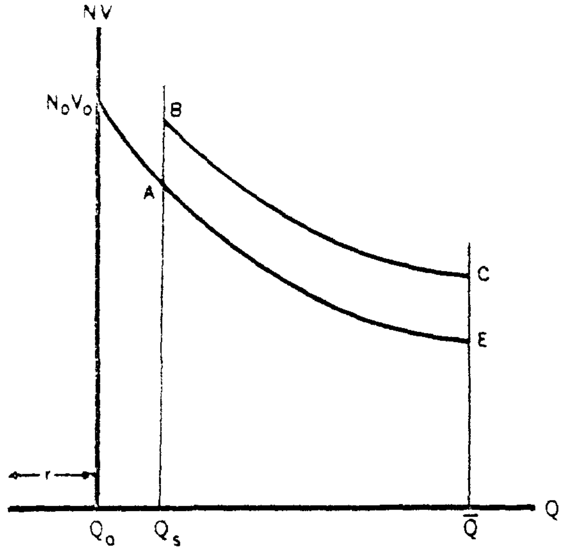
A comparison between actual and optimal open space is made by drawing on the results for Green Lake, and by assuming that the area under the marginal implicit price function accurately reflects willingness to pay. Optimal open space is about 100 feet compared to the actual average distance of about 300 feet. At 100 feet the *net* benefit of open space is about \$13 million, falling about one half million dollars when the amount of setback is 200 feet, on average. Computed net benefits fall by somewhat more than \$1 million (about 10%) when the radius of open space is increased to present levels. Of course, many people in the greater Seattle area benefit from the use of the open space around Green Lake but do not live within the 4,000 feet perimeter specified in the

provides a conceptually preferable basis for estimating willingness to pay.

[11] When assumptions stated in the text cannot be made, Freeman (1974) proposes a pragmatic solution for estimating the value of environmental change. Simply compute the marginal benefit for each individual using the hedonic price equation, find the mean value and assume the demand curve is linear. This "demand" curve will cut through the marginal hedonic price equation revealing that people on the lower end of the ad hoc "demand" curve are willing to pay less than actually has been observed. We point out this limitation without prejudging the practicality of the suggestion.

[12] There may be added cost of restoring the purchased land to "open space" quality if it was formerly developed, but this is an analytically inessential point.

FIGURE —OPEN SPACE, DISTANCE TO WATERFRONT AND PROPERTY VALUE



sample. We have thus provided a lower bound to the measurement of total and marginal benefits of open space, and this must be borne in mind in interpreting the above calculations. We cannot conclude confidently that optimal open space is lower than actual. Note also that the net benefit function is fairly flat. Underestimated marginal benefits amounting to less than a capitalized value of $100 per house would shift the optimal width of open space to 200 feet.[13]

IV. Open Space: A Public Decision

It is appropriate to consider open space as a public good as long as partial rivalry in consumption (congestion) is not an important consideration. While an existing owner of property can capture through exchange a portion of the value of open space, should it appreciate—this was the motivating assumption of our empirical investigation—owners of property cannot individually determine the optimum open space. Some form of collective action is called for. Alternatively, the right to determine the open space could be granted, with or without compensation, to an omniscient entrepreneur, admonishing him to behave in a manner compatible with a competitive solution. But there is a more unconventional aspect to the problem studied which makes the regulated private solution a cumbersome one.

Our empirical results indicate that the value of a property falls with distance from the water.[14] Therefore, the marginal cost of property exchanged in a competitive market is falling as we move away from the water. Since the average cost is greater than marginal cost, an entrepreneur seeking an optimal amount of open space cannot cover his costs if he follows the competitive prescription of setting price equal to marginal cost of open space to all beneficiaries. Either the entrepreneur must be permitted to deviate from marginal cost pricing or he must receive a subsidy. The other major solution is for the public sector to take direct responsibility for providing optimal open space. Falling cost plus inability to exclude are two traditional economic reasons why the determination of open space around water bodies is likely to remain very much a public issue and will be resolved by the public sector.

Of course, with falling marginal costs of acquiring open space, a final calculation must be made to insure that the total benefits of open space are greater than the total costs. This condition holds for our representative area.

REFERENCES

Castle, E. N., A. Singh, and W. Brown. *An Economic Evaluation of the Oregon Salmon and Steelhead Sport Fishery*. Technical Bulletin No. 78 (Corvallis, Oregon State University Agricultural Experiment Station, 1964).

Cobb, C. W., and P. H. Douglas. "A Theory of Production." *American Economic Review* 18 (Mar 1928), 139–165.

Davis, R. K., "The Value of Big Game Hunting in a Private Forest." Transactions of the Twenty-Ninth North American Wildlife and Natural Resources Conference (Washington, D.C.: Wildlife Management Institute, 1964), 393–403.

Dornbusch, D. M., and S. M. Barrager. *Benefit of Water Pollution Control on Property Values* (Washington, D.C., U.S. Environmental Protection Agency, 1972).

Fogel, R. W., and S. L. Engerman. *Time on the Cross, The Economics of American Negro Slavery* (Boston: Little Brown, 1974).

[13] The number of homes benefiting is about 6,300. The discussion is in terms of 100 foot increments to conform with customary lot dimensions.

[14] This result also makes analytical sense in the setback case if the open space yields an unambiguous flow of favorable services. But it might not. Open space can attract groups of people who are noisy, thus creating a disamenity.

Freeman, A. M., "On Estimating Air Pollution Control Benefits from Land Value Studies," *Journal of Environmental Economics and Management* 1 (May 1974), 74–83.

Grether, D. M., and P. Mieszkowski, "Determinants of Real Estate Values," *Journal of Urban Economics* 1 (Apr. 1974), 127–146.

Griliches, Z., "Hedonic Price Indexes of Automobiles: An Econometric Analysis of Quality Change," The Price Statistics of the Federal Government, General Series No. 73 (New York: National Bureau of Economic Research, 1961).

Hammack, J. M., and G. M. Brown, *Waterfowl and Wetlands: Toward Bio-economic Analysis* (Baltimore: Johns Hopkins Press, 1974).

Kain, J. K., and J. M. Quigley, "Measuring the Value of Housing Quality," *Journal of the American Statistical Association* 65 (June 1970), 532–548.

King, A. T., *Property Taxes, Amenities, and Residential Land Values* (Cambridge: Ballinger Publishing Co., 1973).

Krutilla, J. V., and A. C. Fisher, *The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources* (Baltimore: Johns Hopkins Press, 1975).

Lancaster, K. J., *Consumer Demand: A New Approach* (New York: Columbia University Press, 1971).

Mathews, S. B., and G. M. Brown, *Economic Evaluation of the 1967 Sport Salmon Fisheries of Washington*, Technical Report No. 2 (Olympia: Washington Department of Fisheries, 1970).

Polinsky, A. M., and S. Shavell, "The Air Pollution and Property Value Debate," this REVIEW 57 (Feb. 1975), 105–110.

———, "Amenities and Property Values in a Model of an Urban Area," *Journal of Public Economics* 5 (Jan.-Feb. 1976), 119–129.

Pollakowski, H. O., "The Effects of Local Public Services on Residential Location Decisions: An Empirical Study for the San Francisco Bay Area," unpublished Ph.D. dissertation, University of California, Berkeley, 1973.

———, "Local Public Services, Rental Values and Residential Choice," University of Washington, 1977, mimeo.

Rosen, S., "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy* 82 (Jan./Feb. 1974), 34–55.

Seattle Real Estate Research Committee, *Real Estate Research Report for the City of Seattle and Metropolitan Area* (Seattle, Fall 1974).

Small, K. A., "Air Pollution and Property Values: Further Comment," this REVIEW 57 (Feb. 1975), 111–113.

SREA Market Data Center Inc., *Single Family Residential Sales* (Seattle, April 1969 to June 1974).

Economics

L. D. JAMES, School of Civil Engineering, Georgia Institute of Technology, Atlanta, Ga.

A major event involving the economics of water pollution control during 1975 was the release of the draft report of the National Commission on Water Quality (NCWQ).[1] In a summary of the report, Ward[2] noted the projections of downward trends in industrial water use and pollution control costs and generally small price impacts resulting from national water quality standards. Dallaire[3] described how federal grants for construction of municipal water quality control measures are bogged down in the red tape of project evaluation; he discussed findings of NCWQ and EPA that place the cost of meeting 1983 municipal water treatment goals as high as $342 bil: $28 bil for waste treatment, $79 bil for sewers, and $235 bil for stormwater treatment and control. The U. S. Bureau of Labor Statistics[4] estimated that 67 pollution control jobs will be generated for each million dollars of federal expenditure and evaluated the feasibility of transfering manpower to these jobs from other areas of science and engineering.

Chase Econometrics[5] predicted that the expenditures as estimated by EPA needed to meet the deadlines of the Clean Air and the Federal Water Pollution Control Acts would increase prices by annual amounts reaching a maximum of 1.9 percent in 1976, thereby slowing economic growth, reducing the GNP by 2.0 percent, and increasing unemployment by 0.4 percent in 1979. By 1982, the standards would be met and GNP and unemployment would be back to unaffected levels; however, prices would be two percent higher. An EPA study[6] estimated the annual direct cost to industry associated with the Toxic Substances (trol Act to be between $79 and $14 with two-thirds attributable to prem screening and regulatory actions and third attributable to industrial testin reporting. Dallaire[7] reported that the te nology needed to achieve the 1983 eff limits will be available in most cases that the more important issue is whe the benefits justify the staggering c The feeling within industry is that scheduled rise in standards should be layed because of the uncertain econ and the energy situation. Haynes Kleeman[8] modeled the interaction tween the economy and the environ in the Coastal Bend region of Texas predicted little inflationary impact re ing from reducing waste discharges as quired by national standards. Johns suggested that PL 92-500 should be vised in order to reduce the cost of ach ing environmental quality and related cial goals by using the results of compl Section 208 and other studies to vary w quality standards according to reg conditions, to vary the means employed water quality control according to reg costs, to deal uniformly with pollution f all sources, and to alter the rules gover federal financing to encourage adoptio least-cost alternatives.

As part of the continuing interest of e omists in environmental issues, Tyb edited a series of readings on the social economic implications of environmenta sues that discussed, among other to market biases causing pollution and nomic alternatives for industrial w treatment. Krutilla[11] summarized the f ings of the National Environments P gram at Resources for the Future on m odologies for the economic evaluation natural resources.

On the more practical side of envir mental economics, Burchell *et al.*[12] pu lished a standardized approach to the pr aration of environmental impact statem to comply with the requirements of the N tional Environmental Policy Act (NEPA for projects including sewerage and w treatment systems . An Institute of Ecol udy[13] found that environmental impact statements would better serve the goals of NEPA if they were shortened and written emphasize the salient aspects of project purposes, benefits, environmental effects, planned mitigation efforts, and major controversies. Dickson *et al.*[14] reviewed and observed the use of environmental impact statements and reported that the statements are often inadequate for use in making decisions. Frequently, the studies are limited in scope or inadequately defined, the efforts are poorly organized and coordinated, and the methodology adopted is unsuited to the problem at hand. In companion reports, Hill and Ortolano[15] and Randolph and Ortolano[16] examined the influence of NEPA on federal water planning and found it to be reasonably effective in generating information on direct impacts, but less effective on indirect impacts; the process overly emphasizes particular alternatives and makes comparisons difficult to make, but has generally improved interagency coordination.

Ortolano[17] rejected economic efficiency as a sufficient criterion for water resources planning and discussed how multiple objective planning did not overcome his objections. He advocated a planning process using public participation in the integration of four planning activities: identifying concerns, formulating alternatives, analyzing impact, and ranking plans. In contrast, Nash[18] advocated revisions in cost-benefit analysis procedures in order to promote informed public debate by providing information about effects estimated by clearly stated methods. From information obtained from four water resources planning studies in diverse sections of the country, Priscoli[19] found that planners and citizen advisory groups often fail to achieve a common understanding of their roles; this may alienate citizens if their once-high expectations are not met. Water quality was found to be the only area in which the citizens and planners consistently shared perceptions and agreed on plans. Richerson and Johnston[20] discussed water quality control objectives from the holistic, recreation, scenic, health, and economic viewpoints and argued that the difficulties encountered in comprehensive water quality planning are caused by divergent and incommensurable values and by incomplete information. Gore *et al.*[21] interviewed 623 residents of the Fall Creek and Canadarago Lake watersheds in New York to explore their interest in water pollution. They found widespread concern and willingness to act or to pay for pollution control programs, but little real understanding of what can be done. It was concluded that any demonstrably effective program would receive widespread support.

Krause[22] presented the primary national water quality planning objectives as minimize natural resource waste; protect public health and ecosystems; provide an implementable control system; and permit rapid decision-making and implementation. In addition, the progress of current planning efforts toward achieving these goals in the context of the effects of irrigation in Kansas on water quality was discussed. Loucks[23] evaluated multi-objective techniques from the viewpoint of political feasibility and proposed use of a technique that would be able to simulate the bargaining process and predict the outcome of the decision-making. A Technical Committee of the Water Resources Research Centers of the 13 Western States[24] expanded nine comprehensive social goals into 128 measurable social indicators and inverted an input-output model matrix for projecting future values of these indicators in a comparison of alternatives for dealing with water supply and salinity problems in the Rio Grande Basin in New Mexico. Haimes *et al.*[25] reviewed methodologies for employing multiple objectives in problem solving and advocated the surrogate-worth tradeoff method (in which the effects of alternatives on expressed goals are presented for comparison) as one in which noncommensurable objectives can be handled quantitatively through interaction between the decision-maker and a mathematical model. Haimes and Hall[26] detailed a particular model that handles multiple objectives expressed in noncommensurable units by quantifying tradeoffs among primary objectives such as concentration reductions for specific pollutants and secondary objectives such as reduction of algal growth or achieving a water quality suitable for swimming. Cohon and Marks [27] adopted operational criteria for mathematical techniques for multi-objective analysis of water resources projects. They determined that a generating technique weighting the objectives best captures the essence of problems with up to three objectives; a technique that restricts the size of the feasible region such as the surrogate-worth tradeoff method is computationally more efficient with four or more objectives. Taylor *et al.*[28] advocated goal programming (linear programming to minimize weighted departures from preselected goals) as preferable to the surrogate-worth tradeoff method and the separate consideration of environmental and economic effects method. Mercer and Morgan [29] applied the Weibull probability distribution as a method for evaluating uncertainty in four benefit-cost studies.

Bovet [30] provided planners with a critique of the literature on the economic aspects of water quality management through reviews of the influence of water contaminants on various water uses, purification costs, recycling costs, and techniques for economic optimization of treatment systems. Truett *et al.*[31] developed planning indices of overall water quality, of the need for abatement action, and of the need for water quality management planning. Cumberland and Stram [32] developed a materials balance accounting structure to model the waste emission process and advocated follow-up research to develop emission damage functions. Lawrence [33] used Los Angeles data and information from previously reported studies to develop curves for estimating the economic impact of supplying water of varying TDS content to urban water users in various categories.

Angotti [34] analyzed the effectiveness of regional wastewater treatment systems, using the Hackensack drainage basin in New Jersey as an example, and found that regional systems preserve higher water quality in headwater streams (because wastes are taken downstream for treatment) but are less effective than local systems in heavily polluted downstream rivers. Barth and Gutierrez [35] described the Comprehensive Water Quality Management Planning program for Pennsylvania; it covers all types of point and nonpoint pollution sources of surface and groundwater and encompasses alternative environmental features, financial and institutional design, and public participation. Whipple [36] described why water quality planning for the Delaware estuary has been grossly unsatisfactory and advocated regional planning to meet specific environmental goals in order to be more effective and to save billions of dollars. Jensen [37] described fragmented programs, diffuse national leadership, and poor state/federal communications as detrimental to water quality management and advocated closer coordination of water quality control groups with both water quantity management and with non-water environmental programs. With a mathematical model for assessing the water supply alternative for Salt Lake County, Utah, Bishop *et al.*[38] produced a scheme that specified optimal schedules for expansion of wastewater treatment plants as part of the total water resources management for the area.

Marsden *et al.*[39] outlined the use of discriminant analysis in screening waste treatment plant cost data to identify plants that are either exceptionally costly or exceptionally cost effective and for analyzing the economic advantage of large-scale regional waste treatment plants. Hollman *et al.*[40] analyzed factors contributing to the cost of managing municipal water systems and to identified cost variables that particularly improve management cost effectiveness.

Hanke *et al.*[41] analyzed the alternatives and the Water Resources Council recommendations for dealing with inflation in economic analysis and then recommended the use of real prices adjusted as necessary for gross changes in relative values and of a real opportunity cost discount rate of approximately ten percent. Whipple [42] reviewed alternative approaches to determining a discount rate for planning government projects and concluded that there is no basis for using the relatively high returns obtained by investment in private industry, that discount rates based on federal borrowing may be too high during periods of rapid inflation, and that a discount rate of five percent is reasonable. Miller and Erickson's[43] examination of the effect of high interest rate and such water quality parameters as TS, SS, COD, and Cl^- on the design of the least cost urban drainage system with primary and secondary treatment plants showed that the optimum design is not sensitive to the water quality parameters but that open ditch collectors were preferred at high and pipe collectors at low discount rates. Optimum holding pond size was little affected by any of the parameters.

Swan[44] generated continued discussion by stating that, in terms of the Coase Theorem, a Pareto optimum can be reached by bargaining between polluters and those they affect if the property rights of both are well defined. Buchanan and Tullock[45] presented a theory of external control that explains the preference of administrators for direct pollution control, when most economic analyses show penalty taxes are more effective. Ferrar *et al.*[46] collected data on New York City's use of financial incentives to promote environmentally desirable fuels. The data showed how the legal "principle of fairness," requiring uniform treatment of all polluters, effectively prohibited the establishment of an optimal effluent charge. Slater[47] discussed how marginal losses may decrease rather than increase with increased pollution, how in this situation optimal pollution control may be impossible to achieve by means of taxes or other economic incentives, and how regulatory measures may therefore become essential.

Tulkens and Schoumaker[48] created a pure exchange economy with two private commodities and one collective externality and devised a rule for adjusting an effluent charge to achieve an optimum. Bundgaard-Nielsen and Hwang[49] used linear programming to show how some levels of effluent charges can increase production costs and consumer prices without improving environmental quality. In addressing the alternatives for centrally regulating individual behavior in terms of group interests, McManus[50] described how the use of price incentives involves costs in measuring what rights are bought and in enforcing bargains that may cost more than regulatory programs.

Hyden *et al.*[51] simulated the mis-allocation of waste discharge levels that results when conditions change after an effluent standard or charge is established as a basin-wide economic optimum. Kraus and Mohring[52] modeled the use of taxes for pollution control and concluded that sequentially adjusted taxes on both polluters and victims of pollution are required to achieve optimal waste management. Forsund[53] modeled pollution control in a dynamic setting where environmental harm depends on previous as well as current waste discharges; he compared the information requirements and advantages of effluent charge and direct regulation systems in this situation.

Podolick[54] described the sewer-use charge systems being used in response to PL 92-500 guidelines. The systems include a base charge proportional to the contribution that normal domestic wastewater would make to treatment plant loading plus an industrial surcharge based on quarterly adjusted estimates of the additional cost required to treat more potent industrial wastes. Marshall and Ruegg[55] found in evaluating current federal cost sharing practices that more efficient pollution abatement would result if the same cost sharing percentages applied to all abatement techniques and cost categories. Two National Bureau of Standards economists[56] concluded that the EPA construction grant program encourages capital intensive treatment technologies at the expense of technologies involving high labor costs and favors industrialized communities over residential communities.

Smith[57] developed a simple model for showing how effluent charges levied on industrial residuals to reduce production externalities will induce a production technology that improves efficiency evaluation by reducing the nonconvexity of the production relationship. Wenders[58] derived relationships that show that the incentive to improve pollution control is greater if pollution taxes are used than if emission standards or subsidies are used; emission standards are unlikely to be effective instruments for inducing improved pollution control unless the pollution control board promises not to raise its standards after an improved technology is adopted.

McKean and Ericson[59] viewed water quality planning in the context of two equilibrium points: the traditional equilibrium where marginal benefits equal marginal cost; and an equilibrium between the tendency of high water quality in recreation areas to attract population and for that population to create pollution that reduces water quality. Projects should consider the second effect as well as the first; if high water quality is to be achieved, taxation or zoning policies for population control may be required. Nicolson and Mace[60] approached quantification of the relationship between water quality and recreation use by interviewing 240 visitors to Minnesota state parks in conjunction with a program of water quality sampling and laboratory analysis and recommended that water quality control agencies include esthetic degradation to shorelines as an indicator of water quality for recreation purposes. Rabe and Hudson[61] employed multiple regression on Maryland data to examine the effect of sewer service on urban development patterns and concluded that, even though their relationship is not well defined, there is a significant relationship between legal service areas and land development rates. Downing[62] stated three propositions for applying marginal cost pricing of water and sewer services and discussed how such pricing could be better used to guide urban development patterns based on the examples of Knoxville, Tenn., Lexington, Ky., and Greensboro, N. C. Dornbusch and Falcke[63] developed a method for forecasting the effects of water quality enhancement on residential property values in terms of distance from the water's edge, a quantitative Perceived Water Quality Index developed specially for this purpose, public access, and other factors. Weinberger[64] used the dual solution to a linear programming model to show how environmental standards can be implemented efficiently by using a system of pollution licenses, performance standards, and zoning restrictions.

Kneese[65] analyzed the salinity problem in the Colorado River in Mexico as a classic upstream-downstream conflict that is producing an uneconomical approach to reducing salinity in the Mexicali Valley. Markusen[66] developed an economic model involving pollution from one country harming people in another country and used it to derive an optimal pollution tax structure under these conditions and to analyze the dependence and interaction between the two countries. It was concluded that cooperative imposition of national taxes will not achieve Pareto efficiency without a transfer payment. Martin[67] compiled figures showing how improved water management on the farm can control Colorado River salinity at a cost much less than that of the proposed desalting plant. Young *et al.*[68] examined the legal and institutional setting of the present water pollution control program in western Colorado and estimated the economic value of water for waste dilution and the economic impact of programs to control saline irrigation return flows. Sekiguchi[69] analyzed the relationship between pollution levels and economic activity in various regions of Japan; he compared impacts of pollution controls or price rises in the iron and steel, petroleum, and electric power industries in Japan and the U. S. and recommended that international environmental regulation be based on environmental rather than on pollution discharge standards.

Ciccone *et al.*[70] developed a model for determining the least cost combination of raw water sources and renovated wastewaters for a municipality using a dual potable-nonpotable water distribution system. Carlson and Young[71] used statistical cost and demand functions and data collected from 125 southern cities to analyze the

·nomic factors affecting adoption of land ··itment of municipal wastewater; they ·und that federal subsidies were the most ·portant single factor working against .al adoption of land treatment. Also de- ·ed were elasticities indicating rates at ·hich adoption increases with the price of ··gation water, the strictness of allowable ··eam effluent levels, smaller waste vol- ·nes, and dried climate. Markland *et al.*[72] veloped a large-scale mixed integer pro- .·amming model that was useful in per- rming benefit-cost analyses for comparing ·tential land disposal wastewater treat- ·nt sites. Christensen[73] examined the ›nomic and institutional issues involved land acquisition for and the management · land treatment systems in the context of ·e goals pursued by farm managers.

Singleton *et al.*[74] employed a linear eco- ·mic model of a representative chlor-alkali ·ant to quantify the effects of water qual- ·· standards restricting waste discharge of ·. hardness, and heat on the cost of chlo- ··ne and caustic production; they found ·st increases ranging up to 12.1 percent ··r zero discharge of TS from a mercury ell plant. Stone *et al.*[75] employed a simi- ·ır model to ethylene production for plas- ·ic and synthetic fiber and found that zero lischarge could be achieved at an increase ·f 7.0 percent in production cost and at marginal treatment costs/kg of $0.88 for ·s and $1.80 for oil. Unger and Woolver- ·on[76] used discounted cash flow analysis to examine the economic impact of proposed effluent guidelines on the grain milling in- dustry; they predicted that it would be minimal because most of these plants al- ready discharge in municipal systems that provide adequate treatment. Wissman *et al.*[77] assessed the economic impact of pro- posed effluent guidelines on the apple, cit- rus, and potato processing industries and predicted that products such as canned citrus juice and apple sauce will be se- verely affected.

Seitz *et al.*[78] found that stream sedimen- tation could be substantially reduced by shifting to more intensive cropping patterns in agricultural areas and examined regula- tory programs, educational efforts, and eco- nomic incentives to farmers to practice erosion control. Heady and Nicol[79] em- ployed their model of the agricultural econ- omy in the U. S. to examine the effects of soil loss controls on sediment reduction as well as on transport of N and P into streams; they also quantified the nation- wide and regional soil loss reductions that could be achieved with various soil loss standards per acre, the resulting changes in tillage practices by region, and produc- tion shifts among regions, and found that a standard that would reduce soil loss by a factor of 3.5 would increase commodity prices by amounts ranging from none for milk to 15 percent for soybeans. Barker and Nelson[80] evaluated the effects of agri- cultural land use patterns and small towns on water quality in the Sheyenne Basin in North Dakota and the perceptions and at- titudes of the populace toward the prob- lem. Everett and Miller[81] used linear programming and input-output models to evaluate the effects soil erosion control has on the economic rate of timber harvesting and found that minimizing soil loss is not necessarily the best policy for the economy.

Rickert *et al.*[82] presented a framework for collecting data on the relationship between economic activity in the Willamette River basin and river water quality. Nielsen *et al.*[83] presented the iterative approach used in Denmark for minimizing the cost of a water quality sampling program.

REFERENCES

1. "Review Draft: Proposed Report." National Commission on Water Quality, Washington, D. C. (1975).
2. Ward, P. S., "NCWQ Released Staff Findings." *Jour. Water Poll. Control Fed.*, 47, 2350 (1975).
3. Dallaire, G., "U. S. Water Clean-up Program Speeds Up—But Still Much Red Tape." *Civil Eng.*, 145, 8, 71 (1975).
4. "Impact of Federal Pollution Control and Abatement Expenditures on Manpower Requirements." U. S. Bureau of Labor Statistics, U. S. Govt. Printing Office, Washington, D. C. (1975).
5. Chase Econometric Asso., "The Macroeconomic Impacts of Federal Pollution Control Programs." *Environ. News* (EPA) (Jan. 1975).

6. "Draft Economic Impact Assessment for the Proposed Toxic Substance Control Act." U. S. EPA, Office of Toxic Substances, NTIS, PB 242 826, Springfield, Va. (1975).
7. Dallaire. C., "Will Industry Meet Water Quality Requirements?" *Civil Eng.*, 145, 12, 68 (1975).
8. Haynes, K. E., and Kleeman, W. T., "Environmental Quality and Inflation: A Regional Perspective on the Cost-Push Impact of the 1972 Pure Water Legislation." *Environ. & Planning* A (G. B.), 7, 567 (1975).
9. Johnson, R., "President's Page." *Water Resources Bull.*, 11, 5, iii (1975).
10. "Environmental Quality and Society." Tybout, R. A. [Ed.], Ohio St. Univ. Press, Columbus (1975).
11. Krutilla, J. V., "The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources." Johns Hopkins Univ. Press, Baltimore, Md. (1975).
12. Burchell, R. W., *et al.*, "The Environmental Impact Handbook." Ctr. for Urb. Policy Res., Rutgers Univ., New Brunswick, N. J. (1975).
13. "The Environmental Impact Assessment Project: A Critical Appraisal." Institute of Ecology, Washington, D. C. (1975).
14. Dickson, K. L., *et al.*, "Problems in Performing Environmental Assessments." *Jour. Hydraul. Div., Proc. Amer. Soc. Civil Engr.*, **101**, 965 (1975).
15. Hill, W. H., and Ortolano, L., "NEPA's Influence on Federal Water Planning: Part 1, Effect of the 'Review and Comment Process' on the Corps of Engineers and Soil Conservation Service." Progr. in Engr.-Econ. Planning, Stanford Univ., Stanford, Calif. (1975).
16. Randolph, J., and Ortolano, L., "NEPA's Influence on Federal Water Planning: Part 2, Case Studies of Corps of Engineers' Planning in California." Progr. in Engr.-Econ. Planning, Stanford Univ., Stanford, Calif. (1975).
17. Ortolano, L., "Water Resources Decision Making on the Basis of the Public Interest." U. S. Army Engr. Inst. for Water Resources, 75-1, Fort Belvoir, Va. (1975).
18. Nash, C., "An Evaluation of Cost-Benefit Analysis Criteria." *Scottish Jour. Pol. Econ.*, **22**, 121 (1975).
19. Priscoli, J. D., "Citizen Advisory Groups and Conflict Resolution in Regional Water Resources Planning." *Water Resources Bull.*, 11, 1233 (1975).
20. Richerson, P., and Johnston, R., "Environmental Values and Water Quality Planning." *Jour. Hydraul. Div., Proc. Amer. Soc. Civil Engr.*, **101**, 259 (1975).
21. Core, P. H., *et al.*, "A Sociological Approach to the Problem of Water Pollution." *Growth and Change*, 6, 17 (1975).
22. Krause, K. S., "Objectives of Wat... Planning." *Jour. Hydraul. Div., Pr... Soc. Civil Engr.*, 101, 471 (1975
23. Loucks, D. P., "Conflict and Choi... for Multiple Objectives." Econo... Models and Development Plannin... zer *et al.* [Eds.], Oxford Univ. Pre... York, 1975.
24. "Water Resources Planning, Social Go... Indicators. Methodological D... and Empirical Test." The Techn... mittee of the Water Resources R... Centers of the Thirteen Western S... Utah Water Res. Lab., Utah State... Logan (1974)
25. Haimes, Y. Y., *et al.*, "Multiobjective O... zation in Water Resources Systems." ... sevier Scientific Pub. Co., Amst... (1975).
26. Haimes, Y. Y. and Hall, W. A., "Analy... Multiple Objectives in Water Qua... *Jour. Hydraul. Div., Proc. Amer. So... Engr.*, 101, 387 (1975).
27. Cohon, J. L., and Marks, D. H., "A R... and Evaluation of Multiobjective Pr... ming Techniques." *Water Resource...* 11, 208 (1975).
28. Taylor, B. W., III, *et al.*, "Approaches to M... tiobjective Planning in Water Resource... ects." *Water Resources Bull.*, 11 (1975).
29. Mercer, L. J., and Morgan, W. D., "Eval... of a Probability Approach to Unc... in Benefit-Cost Analysis." Water R... Ctr., Univ. of California, Davis (1975
30. Bovet, E. D., "Evaluation of Quality P... eters in Water Resource Planning ... of-the-Art Survey of the Economics of W... ter Quality)." U. S. Army Engr. In... Water Resources, Fort Belvoir, Va...
31. Truett, J. B., *et al.*, "Development of W... Quality Management Indices." *Wa... sources Bull.*, 11, 436 (1975).
32. Cumberland, J. H., and Stram, B N ... of Economic Development Upon W... sources (An Interindustry Appro... Modeling Economic-Environmental ... tems)" Bur. of Bus. and Econ. Res... M... land Univ., College Park (1974).
33. Lawrence, C. H., "Estimating Indirect ... of Urban Water Use." *Jour. Environ ... Div., Proc. Amer. Soc. Civil Engr.*, 101 (1975).
34. Angotti, T. R., "Planning for Regional W... Water Systems." *Growth and Chan...* 36 (1975).
35. Bartal, K. A., and Gutierrez, L. V., Jr. "C... prehensive Water Quality Manag... Planning." *Jour. Hydraul. Div., Proc... Soc. Civil Engr.*, **101**, 371 (1975).
36. Whipple, W., Jr., "Water Quality Plan... for the Delaware Estuary." *Water R... sources Bull.*, 11, 300 (1975).

Jensen, E. T., "Problems in Integrating Water Programs." *Jour. Hydraul. Div., Proc. Amer. Soc. Civil Engr.*, **101**, 467 (1975).

Bishop, A. B., "Economic Assessment of an Activity Analysis Model for Water Supply Planning." *Water Resources Res.*, **11**, 783 (1975).

Marsden, J. R., *et al.*, "The Large-Scale Regional Plant Hypothesis: Discriminant Analysis." *Water Resources Res.*, **11**, 1013 (1975).

Hollman, K. W., *et al.*, "Methods to Facilitate Managerial Effectiveness in Municipal Water Systems." Water Resources Res. Inst., Mississippi State Univ., Starkville (1975).

Hanke, S. H., *et al.*, "Project Evaluation During Inflation." *Water Resources Res.*, **11**, 511 (1975).

2. Whipple, W., Jr., "Principles of Determining a Social Discount Rate." *Water Resources Bull.*, **11**, 811 (1975).

Miller, W. L., and Erickson, S. P., "The Impact of High Interest Rates on Optimum Multiple Objective Design of Surface Runoff Urban Drainage Systems." *Water Resources Bull.*, **11**, 49 (1975).

44. Swan, P. L., "The Coarse Theorem and 'Sequential' Pareto Optimality." *The Econ. Record* (Austl.), **51**, 268 (1975).

45. Buchanan, J. M., and Tullock, G., "Polluters' Profits and Political Response: Direct Controls Versus Taxes." *The Amer. Econ. Review*, **55**, 139 (1975).

46. Ferrar, T. A., *et al.*, "Effluent Charges and Political Realities—A Qualification." *Jour. Environ. Systems*, **5**, 97 (1975).

47. Slater, M., "The Quality of Life and the Shape of Marginal Loss Curves." *The Economic Jour.* (G. B.), **85**, 864 (1975).

48. Tulkens, H., and Schoumaker, F., "Stability Analysis of an Effluent Charge and the 'Polluters Pay' Principle." *Jour. of Public Economics* (Neth.), **4**, 245 (1975).

49. Bundgaard-Nielson, M., and Hwang, C. L., "On Taxation and Firms Choice of Waste Water Treatment Technology." *Water Resources Bull.*, **11**, 805 (1975).

50. McManus, J. C., "The Costs of Alternative Economic Organizations." *Can. Jour. Econ.*, **8**, 334 (1975).

51. Hyden, J. W., *et al.*, "Simulation of Water Quality Management Policies." *Jour. Environ. Engr. Div., Proc. Amer. Soc. Civil Engr.*, **101**, 623 (1975).

52. Kraus, M., and Mohring, H., "The Role of Pollutee Taxes in Externality Problems." *Economica* (G. B.), **42**, 171 (1975).

53. Forsung, F. R., "The Polluter Pays Principle and Transitional Period Measures in a Dynamic Setting." *The Swed. Jour. of Econ.*, **77**, 56 (1975).

54. Podolick, P. A., "An Equitable Sewer Use Charge System." *Pub. Works*, **106**, 91 (1975).

55. Marshall, H. E., and Ruegg, R. T., "Analysis of Cost Sharing Programs for Pollution Abatement of Municipal Wastewater." Nat. Bur. of Stds., U. S. Govt. Printing Office, Washington, D. C. (1974).

56. "Cost Sharing to Help Clean Our Waterways." U. S. National Bureau of Standards, *Dimensions NBS*, **58**, 267 (1974).

57. Smith, V. K., "Detrimental Externalities, Nonconvexities and Technical Change." *Jour. of Public Economics* (Neth.), **4**, 289 (1975).

58. Wenders, J. T., "Methods of Pollution Control and the Rate of Change in Pollution Abatement Technology." *Water Resources Res.*, **11**, 393 (1975).

59. McKean, J. R., and Ericson, R. K., "Quality of Life and Environmental Social Overhead Impact." *Water Resources Res.*, **11**, 789 (1975).

60. Nicolson, J. A., and Mace, A. C., Jr., "Water Quality Perception by Users: Can It be Supplement Objective Water Quality Measures?" *Water Resources Bull.*, **11**, 1197 (1975).

61. Rabe, F. T., and Hudson, J. F., "Highway and Sewer Impacts on Urban Development." *Jour. Urban Plan. & Dev. Div., Proc. Amer. Soc. Civil Engr.*, **101**, 217 (1975).

62. Downing, D. A., "Sewer and Water Pricing and Investment Policies to Implement Urban Growth Policy." *Water Resources Bull.*, **11**, 345 (1975).

63. Dornbusch, D. M., and Falcke, C. O., "A Generic Methodology to Forecast Benefits from Urban Water Resource Improvement Projects." David M. Dornbusch and Co., San Francisco, Calif. (1974).

64. Werczberger, E., "Urban Land-Use Planning and Environmental Pollution." *Environ. & Planning A* (G. B.), **7**, 301 (1975).

65. Kneese, A. V., "A Theoretical Analysis of Minute 242." *Nat. Resources Jour.*, **15**, 135 (1975).

66. Markusen, J. R., "Cooperative Control of International Pollution and Common Property Resources." *Quar. Jour. of Economics*, **89**, 618 (1975).

67. Martin, W. E., "Economic Magnitudes and Economic Alternatives in Lower Basin Use of Colorado River Water." *Nat. Resources Jour.*, **15**, 229 (1975).

68. Young, R. A., *et al.*, "Economic and Institutional Analysis of Colorado Water Quality Management." Environ Resources Ctr., Colorado St. Univ., Fort Collins (1975). Colorado State Univ., Fort Collins (1975).

69. Sekiguchi, S., "Environmental Regulations and Japan's Industry and International Trade." *Jap. Econ. Studies*, **3**, 4, 83 (1975).

70. Ciccone, V. J., *et al.*, "A Present Value-Unit Cost Methodology for Evaluating Munici-

pal Wastewater Reclamation and Direct Reuse." *Water Resources Bull.*, 11, 21 (1975).

71. Carlson, G. A., and Young, C. E., "Factors Affecting Adoption of Land Treatment of Municipal Waste Water." *Water Resources Res.*, 11, 616 (1975).

72. Markland, R. E., *et al.*, "A Benefit-Cost Analysis of Alternative Land Disposal Waste Water Methods in an Urban Environment." School of Bus. Adm., Univ. of Missouri, St. Louis (1974).

73. Christensen, L. A., "A Framework for Evaluating Institutional and Socio-Economic Issues of Land Treatment of Waste Water." *Jour. Environ. Quality*, 4, 143 (1975).

74. Singleton, F. D., Jr., *et al.*, "An Integrated Power Process Model of Water Use and Waste Water Treatment in Chlor-Alkali Production." *Water Resources Res.*, 11, 515 (1975).

75. Stone, J. C., *et al.*, "An Integrated Power Process Model for Ethylene Production." *Water Resources Res.*, 11, 810 (1975).

76. Unger, S. G., and Woolverton, M. W., "Economic Analysis of Effluent Guidelines: Grain Processing Segment of the Grain Mills Industry." Development Planning and Research Asso., Inc., Manhattan, Kan. (1975).

77. Wissman, D. J., *et al.*, "Economic Analysis of Effluent Guidelines: Apple, Citrus and Potato Processing Segments of the Canned and Preserved Fruits and Vegetable Industry." Development Planning and Research Asso., Inc., Manhattan, Kan. (1975).

78. Seitz, W. D., *et al.*, "Evaluation of Agricultural Policy Alternatives to Control Sedimentation." Illinois Water Resources Ctr., Univ. of Ill., Urbana-Champaign (1975).

79. Heady, E. O., and Nicol, K. J., "Models of Land and Water Allocation to Improve Environment and Water Quality Through Soil Loss Controls." *Water Resources Res.*, 11, 795 (1975).

80. Barker, W. T., and Nelson, W. C., "Lower Sheyenne River Basin: Water, Land, People." Water Resources Res. Inst., North Dakota St. Univ., Fargo, 1974.

81. Everett, H. W., II, and Miller, W. L., "Sectoral and Regional Economic Impact of Controlling Nonpoint Pollution in Forested Areas." Water Resources Res. Ctr., Purdue Univ., W. Lafayette (1975).

82. Rickert, D. A., *et al.*, "Methods and Data Requirements for River-Quality Assessment." *Water Resources Bull.*, 11, 1013 (1975).

83. Nielsen, K. S., *et al.*, "A Note on Cost-Effectiveness in Data Acquisition in Water Quality Management." *Water Resources Res.*, 11, 357 (1975).

Economics

L. D. James
Utah State University, Logan

The final report of the National Commission on Water Quality [1] recommended a number of "mid-course adjustments" so that the administration of the Water Pollution Control Act of 1972 (PL 92-500) would restore the integrity of the nation's waters. The recommendations, formulated from a long series of studies, included postponing certain requirements, increasing administrative decentralization and flexibility, and redefining goals to emphasize the conservation and reuse of limited resources rather than waste discharge elimination. The Environmental Sciences sector of the National Commission on Water Quality [2] sponsored 41 river basin studies, covering the entire nation, to characterize present environmental conditions and project biological, ecological, and environmental benefits from effluent loading reductions and water quality changes. In a summary volume, Allen *et al.*[3] outlined the study methodology, projected impacts from abatement of point source loadings, and summarized the findings. A second volume presented such special topics as an evaluation of water quality models, the state-of-the-art of projecting ecological change, and a review of existing water quality data systems.

A study by the Human Resources Planning Institute [4] found that the primary and secondary economic impacts of the 1972 Act will generate more jobs for middle-income white males and reduce job opportunities for females, older workers, and others in low-income categories. An analysis by the Public Research Institute [5] of the effects of the Water Pollution Control Act of 1972 on seven industries (iron and steel, aluminum, copper, textiles, pulp and paper, and leather tanning and red meat) with high pollution abatement costs predicted consequent increased import penetrations of these industries of 1.5 to 6 percent. The total effect on domestic industry was expected to be small because the volume of trade was small compared to domestic production. An analysis of the Act's effects on the dairy industry by Development Planning and Research Associates [6] indicated that the 1983 requirements will reduce the net income of large plants by 30 percent and smaller plants by 50 percent. Approximately 1 plant in 18 will be forced to close, and prices will increase by 1.4 percent. An analysis [7] on the effects on the fruit and vegetable processing industry found that the greatest price increases (up to about 0.5 percent) will be required by smaller plants in the corn, tomato, and sauerkraut sectors and that the greatest number of plant closures because of difficulty in paying required pretreatment costs will occur among Florida citrus plants and potato dehydrating plants in the Pacific Northwest. The same firm [8] also compared costs for 17 technologies for pollution control from beef, turkey, dairy, and hog feedlots and estimated that the greatest expenditure will be required for hog lots and that the greatest price impact (about 1 percent) will be on turkey and dairy lots. An estimated 37 000 to 77 000 lots will be forced to close by 1977.

Lusky [9] used a model developed for allocating resources among original production, production of recycled goods, and waste disposal to show how in cases, like water, where refuse markets are not forthcoming that governmental intervention is necessary for pollution control. Macauley and Yandle [10] noted a consistent record of failure for managing water quality by regulation and government expenditure and recommended trying a system wherein stream responsibility (like land ownership) is sold to the highest bidder and the proceeds are used to finance public programs. Marshall and Ruegg's analysis [11] of the current practice of equal division of user fees collected from industrial waste discharges between the municipality and the federal government concluded that the policy was causing significant efficiency distortions that could be eliminated by returning all collected fees to the U. S. Treasury.

McMillan [12] argued that separate environmental authorities for water, air, and land pollution control can more effectively protect the public interest than can a single overall agency because the multijurisdictional arrangement reduces the adverse effects of the vote trading that occurs within a single governing body. Tomasini [13] presented a concept of fairness (illustrated by numerical example) for use in allocating pollution loadings among waste dischargers. Levi and Beattie [14] described a case in which a Texas court had awarded damages equalling the loss caused to a rancher by upstream pollution and cited this liability for inadvertent downstream pollution damages as a departure from past court rulings and a positive step toward economic equity.

Williams and Rucks [15] outlined the financial dilemma placed on municipalities required to provide waste treatment facilities costing an average of $1 500 per person and advocated that the situation in each city be studied individually to estimate pollution control costs and identify funding sources and financial impacts. Boyd *et al.*[16] reviewed the nutrient loading of the Missouri River near Kansas City in the context of available treatment methods and found that complete nutrient removal at wastewater treatment facilities would be a waste of money.

Among the new books published, Quarles [17] made a strong case for a greater pollution control effort, and Caldwell [18] described the role citizens can take to enhance the environment. Hammer [19] assessed the social implications of abatement alternatives while Dimento [20] analyzed the problems in achieving the behavioral changes required for a higher quality environment. Andrews [21] examined the effectiveness of the National Environmental Policy Act in achieving these changes. Finally, Kneese [22] outlined the role of economics in choosing among environmental management alternatives and in providing incentives to achieve desired goals.

Stephens [23] used a general neoclassical model of growth and pollution to show how technical progress can provide exponential growth of per capita income within the context of improving environmental quality. To do so, the marginal productivities of new technology to limit waste discharge and to augment environmental absorptive capacity should be equalized. Lipnowski [24] employed input-output analysis to gauge the potential for economic growth in the presence of a requirement for complete environmental preservation and to estimate the rate of profit an industry operating without any environmental restrictions would have to have for profitable operation to continue if environmental controls were imposed. Uri's analysis [25] of the effects of environmental quality standards on the power generating industry showed an incentive toward larger investment in new generating capacity in part caused by premature retirement of existing capacity.

Eidem [26] described the role of the Swedish Water and Air Pollution Research Laboratory (IVL) in water pollution control in Sweden. Swedish industry will have to invest annually an amount equal to about 2 percent of the value of goods manufactured for pollution control, but twice that investment would be required to meet all of society's demands. Whipple [27] proposed that the U. S. change a current water pollution control policy that requires treatment at all cost and uniform quality standards in order to pursue basic environmental quality objectives more effectively. Three needed revisions would be to refocus on achievable goals, to coordinate river water quality management with flow regulation, and to make real use of planning results. Whipple and Hufschmidt [28] reported workshop recommendations for priority emphasis in water quality control research on evaluating the costs of environmental and social impacts, on defining additional control alternatives so as to broaden the base of those considered, and on improving the efficiency of water quality control institutions.

Friesema and Culhane's analysis [29] of the effects of the National Environmental Policy Act of 1969 on water resources planning noted an increasing emphasis on public participation, staff hiring of individuals from a broader range of professional backgrounds, and greater effort to ameliorate adverse environmental impacts. Wengert [30] used an analysis of the growing pressures for public participation in resource management to begin an effort to develop a theory of the public participation process that is harmonious with both democratic ideals and pragmatic experience. Tideman and Tullock [31] described a process of offering each individual a chance to change the outcome that would occur without his vote by paying a special charge set equal to the net effect on others of his vote as a mechanism for motivating individuals to reveal their true preferences for public goods.

Lienesch and Emison [32] reviewed the areawide water quality planning program underway under Section 208, PL 92-500, and despite encountered problems in resolving conflicts among interest groups, achieving effective institutional arrangements, and identifying cost effective approaches concluded that the highlighting of issues for public discussion resulting within the planning process is itself an important step toward improved water quality management. Grantham and Bailey [33] described how water quality plans were being formulated to meet federal and state legal requirements in the California Water Quality Control Planning Basins.

Bundgaard-Nielsen and Hwang's review [34] of the literature on regional water quality management classified available planning models according to whether their orientation was toward centralized planning, diffuse decision making, or multiple objectives. McNamara [35] developed and illustrated through numerical example a geometric nonlinear programming model for simultaneous consideration of waste treatment processes, bypass piping, flow regulation, and artificial aeration in determining the least-cost water quality management program for the upper Hudson River. Bovet [36] synthesized several earlier reports in developing planning guidelines for water quality management through optimization balancing the cost of enhancement against benefit. The economic efficiency of water reuse and acid mine drainage control were also discussed.

Rohrlich [37] contributed an extended description of how economic and social factors can be integrated in environmental management. Gum *et al.*[38] illustrated the Techcom system for weighting social preferences for esthetics, economics, and recreation from answers to a mail questionnaire in Arizona and New Mexico. Use of the Metfessel general allocation test provided usable information for comprehensive evaluation of natural resource management policies. Phillips and DeFilippi [39] developed a method for comparing environmental impacts of alternative wastewater management systems that tabulates environmental impacts with respect to identified objectives and collapses the resulting matrix into a numerical impact measure.

Hipel *et al.*[40] presented metagame theory as a nonquantitative or descriptive approach for considering information that cannot readily be expressed in quantitative form together with quantitative data to evaluate conflict situations, such as international pollution disputes, in which decision-making does not conform to the classical assumption of rational behavior. Hipel *et al.*[41] also illustrated metagame analysis as a means for identifying possible political solutions for controlling water pollution from a steel mill. Ragade *et al.*[42] demonstrated how stable compromise possibilities between diverse interest groups can be defined by having each group assign values to benefits and costs from their viewpoint and by applying meta rationality concepts to the resulting pseudo-boolean functions.

Van Praag and Linthorst [43] used returned questionnaires from responsible municipal officials in 550 of 842 Dutch communities to derive municipal welfare functions for each one. Public works expenditures per capita were quantified as decreasing with community size, reaching a point where diseconomies of scale begin to predominate, and then increasing for still larger communities at an elasticity with respect to inhabitants of 1.4. Trigg *et al.*[44] used Winnipeg attitude survey data to confirm the hypothesis that individuals who believe that their rewards depend on their own abilities were better informed on pollution problems than are other people.

Brill *et al.*[45] illustrated for the Delaware Estuary how application of the equity criteria that equals should be treated equally and that non-equals should be treated differently results in a much lower pollution control cost than does a program of uniform treatment standards for each pollutant and concluded that even application of equity criteria with imperfect information can lead to policy-improving insights. Brumm and Dick[46] reviewed current Federal Water Pollution Control policy and concluded that regulatory programs, bargaining strategies, and effluent changes alike require an almost impossibly expensive research program to obtain the information needed for optimal design and that a system of setting standards and raising the charges as necessary to achieve them is overall much more cost-efficient. Herzog[47] assessed the relative efficiency and equity for the Patuxent River (Maryland) of charges set to achieve a water quality standard at minimum cost when both plant treatment costs and residual transfer costs are known, when only the transfer costs are known, and when neither are known (an equal per unit charge to all discharges). He found significant efficiency gain from information availability but no impressive real resource cost savings. Dick[48] synthesized from the literature critical to the Coase theorem that bilateral bargaining in a voluntary, frictionless setting produces optimality only by accident. Because of the facts that the placement of liability affects resource allocation and that liability assigned by voluntary bargaining cannot be expected to produce optimal solutions to externality problems, such nonvoluntary approaches as zoning, standards, prohibitions, or taxes are required to achieve optimality. Mathur[49] showed how a spatially variable pollution tax charged to a firm that may respond either by reducing its waste disposal or moving to another location subject to less tax will not necessarily encourage the dispersal of industries having alternative abatement technologies from highly polluted areas.

Bundgaard-Nielsen's analysis[50] of how the influences of available technology and economic incentives interact in a firm's wastewater treatment investment decisions concluded that subsidy will induce new investment when the subsidy offered exceeds the cost less the accruing savings divided by the interest rate. DeWees and Sims[51] explained why subsidies paid to reduce emissions are not symmetrical to effluent charges as instruments for controlling pollution because of technical problems in establishing a base emission at which the subsidy begins, effects caused by firm entry and exit from the industry, and market distortions caused by unavoidable subsidy discontinuities. Any financial relief required to help firms control emission should be in the form of lump sum payments based on past production. Smith[52] developed a simple model to demonstrate that efficient resource allocation in the presence of product market distortions and pollution externalities requires both an output subsidy and effluent charges. More generally, the number of policy instruments should at least equal the number of imperfections to be corrected.

Orr[53] described how, despite the literature on the difficulties in achieving economic efficiency through user charges, experience has shown (largely because of robustness in spite of incomplete information) charges to be effective, their effectiveness to increase with time, and their impact to have not been excessively disruptive. Emphasis was placed on the importance of reckoning effectiveness in terms of innovative incentives as well as the more traditional allocation efficiency. Holtermann[54] showed that when externalities cannot be directly taxed, Pareto optimality can still be achieved by taxing outputs whose production produced the externality, or by taxing producers of inputs whose use in the production process generates the externality. Compensation paid to the victims of the externality does not affect Pareto optimality unless the victims can influence the compensation rates. Through a survey of 177 South Carolina municipalities, Mulkey and Stepp[55] found that the prevailing practices of flat rate or water bill percentage sewer charges are unlikely to satisfy the EPA criterion of charging proportional to treatment cost and recommended further study to formulate a charging vehicle that can satisfy this equity criterion without requiring costly instrumentation.

Ehler *et al.*[56] identified through a residuals management model the points in the residuals generation and discharge process at which physical action, laws or regulations, and better institutional arrangements can be effectively used to reduce adverse environmental effects. From the simulated consequences of water quality management through effluent charges, effluent standards, and effluent treatment subsidies, Campbell[57] demonstrated that the resulting income distributional effects depend on both the policy instrument and the level of the jurisdiction administering it, and therefore advocated individual design of an appropriate policy instrument for each local situation. Keith *et al.*[58] were not able to establish a causal relationship between water quality controls and income distribution by fitting a beta distribution function to SMSA data and testing the significance of changes. Edwards and Langham [59] used a model with a nonlinear objective function and linear environmental constraints on externalities not quantifiable in monetary terms to estimate that a 50 percent reduction in usage of chlorinated hydrocarbons would reduce welfare, estimated as consumers surplus plus producers surplus, by about 1 percent and that elimination of their usage would reduce welfare by about 3 percent.

Asch and Seneca's examination [60] of the conflict between the adverse welfare impact of monopoly and the environmental benefit of internalizing externalities within a monopoly for the case of the automobile industry showed how undesirable consequences will result without coordination between environmental and antitrust policies, with the optimal balance depending on the monopolist's extra profit margin and marginal cost the externality inflicts on others. Cowing [61] employed a two-input, two-output process model to demonstrate how effluent charges or a polluting monopoly already constrained by rate-of-return regulation may have either a favorable or an adverse social impact. He argued that the policy for dealing with each such monopoly should be specifically designed from detailed knowledge of its production process and the effects of its externalities on others.

Peskin [62] examined four alternatives for adjusting estimates of the GNP for pollution effects and found an adjustment equal to the net value of environmental assets to be best for environmental management purposes, the subtraction of residual damage to provide the best welfare measure, the addition of the net value of environmental asset services to provide the best index of total production, and no adjustment at all to provide the best index of human productive services. Sandler and Smith [63] applied a "reference group" concept to show how Pareto efficiency, maximization of each individual's utility summed over individuals and time, in the allocation of environmental resources over time or among generations requires that each person's incremental benefits from a public good be treated equally, regardless of the time they receive the benefits, rather than be discounted at a constant rate for all individuals and time periods. White [64] observed that economists have a long established taxonomy for analyzing market failure but have never analyzed nonmarket failure systematically. The three principal nonmarket failures in the context of water pollution control were a failure to properly recognize the limitations of governmental structure in assigning functional responsibility, a failure to act in ways that equitably distribute the benefits, and a failure to obtain and use the proper information.

Dworsky *et al.*[65] reported the recommendations of a workshop that examined the interaction between water quality and land use planning for the purpose of proposing policy changes to enhance conflict resolution and management efficiency. Specific recommendations were made in the areas of program evaluation, investment strategies, and institutional arrangements. Bammi *et al.*[66] described application of a model siting urban land development to minimize aggregate adverse environmental impact (including water pollution) to suburban Chicago. Black, Crow, and Eidsness, Inc.[67] found that a suitable technology for abating urban storm water pollution is yet to be developed and that nationwide abatement to a level equivalent to secondary treatment would cost approximately 160 billion dollars.

Walter [68] edited a volume of 15 papers on applications of economics to international issues in environmental management. Individual papers reached such conclusions that large countries applying pollution control measures unilaterally can expect an improvement in the balance of trade that will help pay for the system and that special regulation of multinational corporations is unnecessary unless the adverse environmental consequences physically cross international borders. Pethig [69] applied a two-sector general equilibrium model to international trade among nations with potentially varying environmental policy to derive five theorems relating to the effects of trade on the environment in each country. Differences in national environmental policies were found to not generally imply differences in national environmental qualities.

Dornbusch *et al.*[70] concluded that the effect of water pollution abatement on property values depends on lay perceptions of consequences for wildlife support, recreational opportunity, and esthetics. An analysis of 17 sites showed greater effects on lakes than on streams and on larger bodies of water than on smaller. Klee [71] presented an additive utility model for setting priorities based on environmental threat for dealing with waste discharges and requiring selection of criteria, measurement of parameters, assignment of ratings, and determination and combination of values.

Teniere-Buchot [72] outlined the role that the public has taken in development of the French water quality control and related water management programs. Seifert and Lyons[73] described four approaches under legislative consideration for using economic incentives to reduce wastewater discharges in West Germany. The approaches are to establish separate river basin wastewater management associations with individual charging rules, accumulate collected charges in financial reserves to pay for treatment facilities, allow claims against the reserves when treatment facilities are completed, and uniform charging according to effluent harmfulness based on the average cost of full biological treatment. Johnson and Brown[74] described the use of effluent charges and abatement subsidies in water quality management systems in France, Netherlands, West Germany, Hungary, Sweden, and England and concluded that since no pollution abatement program in the world is free of subsidies, the management choice may be between a second best program with subsidies and an ineffective program without them. Laburn[75] reviewed the water quality control and related water resources management efforts of the Rand Water Board, Republic of South Africa, over the last 70 years and discussed such measures as separate disposal of mine effluent, agricultural, industrial, and potable use of wastewater effluent, dual water supply systems, and piping high quality upstream water to downstream areas.

After describing water pollution problems found in large cities in tropical Africa, Onokerhoraye[76] emphasized that developing countries should not automatically adopt the standards of the more advanced nations (a policy destined to widespread failure) but should rather establish an administrative structure that can solve priority problems with available financial resources and expertise. Gruver[77] employed a neoclassical growth model in an analysis of the optimal division of investment between pollution control capital and production capital for less developed countries that showed an optimal sequence of first emphasizing expansion of production capital (despite the increased pollution) and subsequently emphasizing expanding pollution control capital. In other words, specialization is to be preferred over balanced growth.

Singleton's evaluation[78] of water pollution in the Soviet Union found that the USSR has taken an exploitative development path similar to what one would expect in any developing nation regardless of its institutions. This situation is a result of planning and administrative failures with a primary problem being a lack of incentives to follow leadership preferences within the Soviet command system. Stretton[79] compared the effectiveness of capitalistic and socialistic systems in environmental management.

Adar and Griffin's analysis[80] of situations in which uncertainty in the marginal control cost and in the marginal pollution damage affects the optimal choice from among pollution charges, pollution standards, and the auctioning of pollution rights determined that uncertainty in the damage function has no effect but that cost uncertainty favors charges when the damage function is price elastic and favors standards when the damage function is price inelastic. Rose's analysis[81] of using federal cost sharing to induce communities to adopt socially optimal pollution abatement identified such difficulties as differences among communities in optimal practice, the cost-sharing practice being based on total rather than marginal costs, and the inherent inflexibility of federal funding. Harford[82] used a calculus of variations framework to delineate an optimal time path for expanding a waste treatment program and found that a policy of gradually strengthening standards over time can be justified when the additional cost of adjusting more quickly to higher standards exceeds the consequences of pollution during the intermittent period. Rose[83] explained why a capital adjustment model was superior to an acceleration investment equation for representing the cost of pollution control equipment in input-output modeling.

Briller[84] illustrated discounted cash flow analysis through application to surface mechanical aerators in a municipal sewage treatment plant as a method for minimizing the cost of selected treatment equipment. The sensitivity of the results to 12 independent variables was tested and compared. Paulson[85] described how flexibility to control construction costs decreases as a project progresses from design to completion and how costs can be reduced by drawing contractual arrangements to assure that current construction and operation practices are considered in design. Wolpert[86] documented experiences relating to the siting of obnoxious public facilities in urban areas in an effort to promote more widespread use of equity criteria in the decision making.

Leone[87] reviewed the impact of environmental control on industry. Wiley[88] recited petroleum industry experiences of over one-quarter of the capital investment now being required for pollution control and recommended such policy changes for improving equity as promoting correction at the waste source and reducing excess capacity in facility design. Amberg [89] reported that pollution control requirements were absorbing 30 percent of the capital expenditures in the pulp and paper industry and thereby draining capital that would otherwise be available for technological development. The major need was for change from a regulatory approach that in many cases actually adversely impacts the overall environment by blind adherence to uniform standards to a system of site-specific controls to remedy identified environmental problems. Black *et al.*[90] found that federal water pollution control requirements will require the typical carpet mill to invest up to a million dollars and increase the cost of carpet production by about 5 cents by 1983, but that the resulting price increases are probably too small to reduce sales. Shlottmann and Spore [91] showed with a linear programming model of the coal industry that reclamation regulations would reduce Applachian coal surface mining by 7 percent and increase underground mining by 4 percent but emphasized that the environmental affects of underground mining must be more carefully analyzed before concluding that this is a wise policy.

Lee and Guntermann [92] estimated downstream sediment damages for a wide variety of farm practices within an Illinois watershed as the sum of the costs of induced drainage ditch dredging, reduced reservoir economic life, loss of benefits because of an early end to reservoir economic life, a sediment component of flood damage, and a loss of recreation benefits. Guntermann *et al.*[93] found off-site sediment damages to be far greater than on-site productivity losses, advocated a tax-subsidy incentive approach to reducing sediment production and noted a lack in technical knowledge about sediment movement as a major obstacle to establishing an effective program. Miller and Gill [94] used linear programming to show how statewide soil loss standards in Indiana caused a greater percentage and per acre decline in farm income on small farms or in rolling topography than on large farms or in flat topography. Consideration of tax incentives as possibly more equitable was recommended.

Pfeiffer and Whittlesey [95] analyzed the cost effectiveness of taxing water use, reducing water rights, and improving farm water management as alternatives for controlling the quality of irrigation return flows and concluded that policies relying on higher input costs allocate resources more efficiently while policies relying on input quotas impose less cost on agriculture. Kleinman [96] applied a linear programming model to estimate farm profit in the area served by the Imperial Irrigation District as a function of irrigation water salinity content. Erlenkotter and Scherer [97] outlined alternative mathematical formulations for optimal scheduling of salinity control projects on the Colorado River.

Sims and Baumann [98] used questions administered to 22 state health officials and 98 consulting engineers to define professional bias toward using renovated wastewater and concluded that recognition of bias was as important as use of expertise in the formulation of public policy on environmental issues. From telephone interviews of 1 000 Southern California households on attitudes toward 13 potential wastewater reuses ranging from drinking to toilet reuse, Stone [99] found that the public favored nonbody contact reuses, favored body contact reuses less strongly, and was divided in attitude toward consumptive uses with the primary negative factor being psychological aversion. Industrial plant managers and public water officials were less willing than the public to accept reuse. Gates *et al.*[100] studied the reasons why people are unwilling to swim or water ski on the Neches River (Texas) and related these to measured water quality parameters. Young [101] developed a computerized model that compares the costs of solid-set irrigation, center-pivot irrigation, border-strip irrigation, ridge-and-furrow irrigation, overland flow, and infiltration basins as land application of wastewater technologies. The center pivot system was found least expensive, and results for different kinds of facilities of different sizes were tabulated.

REFERENCES

1. "Report to the Congress." National Commission on Water Quality, Washington, D. C. (1976).
2. "Water Pollution Control Act of 1972, Environmental Impact Assessment." National Commission on Water Quality, Washington, D. C. (1975/6).
3. Allen, H. L., *et al.*, "Public Law 92-500—Water Quality Analysis and Environmental Impact Assessment." 2 volumes, National Commission on Water Quality, 75/100-1,2, Washington, D. C. (1976).
4. Human Resources Planning Inst., "Water Pollution Control Act of 1972, Demographic and Quantitative Analysis." National Commission on Water Quality, 75/44, Washington, D. C. (1975).

5. Public Research Inst., "Water Pollution Control Act of 1972, Economic Impacts, Foreign Trade." National Commission on Water Quality, 75/34, Washington, D. C. (1976).
6. Dev. Planning and Res. Asso., "Water Pollution Control Act of 1972, Economic Impacts, Dairy Products." National Commission on Water Quality, 75/46, Washington, D. C. (1975).
7. Dev. Planning and Res. Asso., "Water Pollution Control Act of 1972, Economic Impacts, Fruits and Vegetables." National Commission on Water Quality, 75/45, Washington, D. C. (1975).
8. Dev. Planning and Res. Asso., "Water Pollution Control Act of 1972, Technologies and Economic Impacts, The Feedlot Industry." National Commission on Water Quality, 75/47, Washington, D. C. (1975).
9. Lusky, R., "A Model of Recycling and Pollution Control." *Can. Journ. Econ.*, 9, 91 (1976).
10. Macaulay, H. H., and Yandle, T. B., "An Economic Evaluation of Water Quality Management Systems." Water Resources Res. Inst., Clemson Univ., Clemson, S. C. (1975).
11. Marshall, H. E., and Ruegg, R. T., "Efficiency Problems from User Fees in Municipal Wastewater Treatment." *Water Resources Bull.*, 12, 903 (1976).
12. McMillan, M., "Criteria for Jurisdictional Design." *Jour. Environ. Econ. and Management*, 3, 46 (1976).
13. Tomasini, L. M., "A Note on the Fair Division of Pollution Rights." *Jour. of Public Economics*, 6, 313 (1976).
14. Levi, D. R., and Beattie, B. R., "Economics as an Input in Environmental Law." *Land Econ.*, 52, 235 (1976).
15. Williams, F. P., and Rucks, A. C., "Water Pollution Control: Crossroads of a Municipal Financial Dilemma." *Public Works*, 107, 6, 86 (1976).
16. Boyd, D. R., *et al.*, "Removal vs. Benefits: It Can Be Too Costly." *Water & Wastes Engr.*, 13, 2, 42 (1976).
17. Quarles, J., Jr., "Cleaning Up America." Houghton Mifflin Co., Boston (1976).
18. Caldwell, L. K., *et al.*, "Citizens and the Environment: Case Studies in Popular Action." Ind. Univ. Press, Bloomington (1976).
19. Hammer, E. R., "Environmental Policy: A Sociological Assessment of Abatement Alternatives." Gordon Press Pubs., New York (1976).
20. Dimento, J. F., "Managing Environmental Change: A Legal and Behavioral Perspective." Praeger Pubs., New York (1976).
21. Andrews, R. N., "Environmental Policy and Administrative Change: Implementation of the National Environmental Policy Act." Lexington Bks., Lexington, Mass. (1976).
22. Kneese, A. V., "Economics and the Environment." Penguin Books, Inc., New York (1976).
23. Stephens, J. K., "A Relatively Optimistic Analysis of Growth and Pollution in a Neoclassical Framework." *Jour. Environ. Econ. and Management*, 3, 85 (1976).
24. Lipnowski, I. F., "An Input-Output Analysis of Environmental Preservation." *Jour. Environ. Econ. and Management*, 3, 205 (1976).
25. Uri, N. D., "The Effects of Environmental Quality Standards on Pricing Electrical Energy." *Environ. and Planning A*, 8, 573 (1976).
26. Eidem, I., "Reasons for Having the IVL Institute for Water and Air Pollution Control Research." *Svensk Papperstidning* (Swed.), 79, 5, 143 (1976).
27. Whipple, W., Jr., "Strategy of Water Pollution Control." *Water Resources Bull.*, 12, 1019 (1976).
28. Whipple, W., Jr., and Hufschmidt, M. M., "Reorientation of Urban-Related Water Resources Research." *Water Resources Res.*, 12, 762 (1976).
29. Friesema, H. P., and Culhane, P. J., "Social Impacts, Politics, and the Environmental Impact Statement Process." *Nat. Resources Jour.*, 16, 339 (1976).
30. Wengert, N., "Citizen Participation: Practice in Search of a Theory." *Nat. Resources Jour.*, 16, 25 (1976).
31. Tideman, T. N., and Tullock, G., "A New and Superior Process for Making Social Choices." *Jour. Pol. Econ.*, 84, 1145 (1976).
32. Lienesch, W. C., and Emison, G. A., "Planning for Implementation under Section 208." *Jour. Water Resources Planning and Man. Div., Proc. Amer. Soc. Civil Engr.*, 102, 283 (1976).
33. Grantham, G. R., and Bailey, T. E., "Water Quality Planning Strategy." *Jour. Water Resources Planning and Man. Div., Proc. Amer. Soc. Civil Engr.*, 102, 11 (1976).
34. Bundgaard-Nielsen, M., and Hwang, C. L., "A Review on Decision Models in Economics of Regional Water Quality Management." *Water Resources Bull.*, 12, 461 (1976).
35. McNamara, J. R., "An Optimization Model for Regional Water Quality Management." *Water Resources Res.*, 12, 125 (1976).
36. Bovet, E. D., "Economic Concepts and Techniques Pertaining to Water Supply, Water Allocation, and Water Quality." U. S. Army Engr. Inst. for Water Resources, Fort Belvoir, Va. (1975).
37. Rohrlich, G. F., "Environmental Management: Economics and Social Dimensions."

Ballinger Pub. Co., Philadelphia, Penn. (1976).

38. Gum, R. L., *et al.*, "Quantifying Societal Goals: Development of a Weighting Methodology." *Water Resources Res.*, 12, 617 (1976).

39. Phillips, K. J., and DeFilippi, J. A., "A Matrix Approach for Determining Wastewater Management Impacts." *Jour. Water Poll. Control Fed.*, 48, 1759 (1976).

40. Hipel, K. W., *et al.*, "Metagame Theory and Its Applications to Water Resources." *Water Resources Res.*, 12, 331 (1976).

41. Hipel, K. W., *et al.*, "Political Resolution of Environmental Conflicts." *Water Resources Bull.*, 12, 813 (1976).

42. Ragade, R. K., *et al.*, "Metarationality in Benefit-Cost Analyses." *Water Resources Res.*, 12, 1069 (1976).

43. Van Praag, B. M. S., and Linthorst, J., "Municipal Welfare Functions." *Reg. Science & Urban Econ.* (Neth.), 6, 51 (1976).

44. Trigg, L. J., *et al.*, "Anti-Pollution Behavior." *Environ. and Behavior*, 8, 307 (1976).

45. Brill, E. D., Jr., *et al.*, "Equity Measures for Exploring Water Quality Management Alternatives." *Water Resources Res.*, 12, 845 (1976).

46. Brumm, H. J., and Dick, D. T., "Federal Environmental Policy and R&D on Water Pollution Abatement." *Amer. Econ. Rev.*, 66, 2, 448 (1976).

47. Herzog, H. W., Jr., "Economic Efficiency and Equity in Water Quality Control Effluent Taxes and Information Requirements." *Jour. Environ. Econ. and Management*, 2, 170 (1976).

48. Dick, D. T., "The Voluntary Approach to Externality Problems: A Survey of the Critics." *Jour. Environ. Econ. and Management*, 2, 185 (1976).

49. Mathur, V. K., "Spatial Economic Theory of Pollution Control." *Jour. Environ. Econ. and Management*, 3, 16 (1976).

50. Bundgaard-Nielsen, M., "A Note on the Use of Economic Incentives in Water Pollution Abatement." *Water Resources Bull.*, 12, 755 (1976).

51. DeWees, D. N., and Sims, W. A., "The Symmetry of Effluent Charges and Subsidies for Pollution Control." *Can. Jour. Econ.*, 9, 323 (1976).

52. Smith, V. K., "A Note on Effluent Charges and Market Structure." *Jour. Environ. Econ. and Management*, 2, 309 (1976).

53. Orr, L., "Incentive for Innovation as the Basis for Effluent Charge Strategy." *Amer. Econ. Rev.*, 66, 2, 441 (1976).

54. Holtermann, S., "Alternative Tax Systems to Correct for Externalities, and the Efficiency of Paying Compensation." *Economica*, 43, 1 (1976).

55. Mulkey, D., and Stepp, J., "A Review of Sewer Charge Experience in South Carolina." Water Resources Res. Inst., Clemson Univ., Clemson, S. C. (1975).

56. Ehler, C. N., *et al.*, "Development of Residuals Management Strategies." Environ. Protection Agency, 600/1-76-01/B, Washington, D. C. (1976).

57. Campbell, H. F., "On the Income Distributional Effects of Environmental Management Policies." *Water Resources Res.*, 12, 1077 (1976).

58. Keith, J. E., *et al.*, "An Empirical Analysis of Predictors of Income Distribution Effects of Water Quality Controls." PRRAE-015, Utah Water Res. Lab., Utah State Univ., Logan, Utah (1976).

59. Edwards, W. F., and Langham, M. R., "Public Welfare in Relation to Alternative Pesticide Policies." *Jour. Environ. Econ. and Management*, 2, 295 (1976).

60. Asch, P., and Seneca, J. J., "Monopoly and External Costs: An Application of Second-Best Theory to the Automobile Industry." *Jour. Environ. Econ. and Management*, 3, 69 (1976).

61. Cowing, T. G., "The Environmental Implications of Monopoly Regulation: A Process Analysis Approach." *Jour. Environ. Econ. and Management*, 2, 207 (1976).

62. Peskin, H. M., "A National Accounting Framework for Environmental Assets." *Jour. Environ. Econ. and Management*, 2, 255 (1976).

63. Sandler, T., and Smith, V. K., "Intertemporal and Intergenerational Pareto Efficiency." *Jour. Environ. Econ. and Management*, 2, 151 (1976).

64. White, R. D., "The Anatomy of Nonmarket Failure: An Examination of Environmental Policies." *Amer. Econ. Rev.*, 66, 2, 454 (1976).

65. Dworsky, L. B., *et al.*, "Workshop Report: Integrating Water Quality and Water and Land Resources Planning." Univ. Council on Water Resources and the Engr. Foundation, Cornell Univ., Ithaca, New York (1976).

66. Bammi, D., *et al.*, "Urban Planning to Minimize Environmental Impact." *Environ. and Planning* A, 8, 245 (1976).

67. Black, Crow, and Eidsness, Inc., "Water Pollution Abatement Technology: Capabilities and Costs, Urban Runoff." National Commission on Water Quality, 75/14, Washington, D. C. (1975).

68. Walter, I., Ed., "Studies in International Environmental Economics." John Wiley & Sons, New York (1976).

69. Pethig, R., "Pollution, Welfare, and Environmental Policy in the Theory of Comparative Advantage." *Jour. Environ. Econ. and Management*, 2, 160 (1976).

70. Dornbusch, D. M., *et al.*, "Benefits from Water Pollution Abatement, Property Values." Dornbusch and Co., San Francisco (1975).
71. Klee, A. J., "Models for Evaluation of Hazardous Wastes." *Jour. Environ. Div., Proc. Amer. Soc. Civil Engr.*, **102**, 111 (1976).
72. Teniere-Buchot, P. F., "The Role of the Public in Water Management Decisions in France." *Nat. Resources Jour.*, 16, 159 (1976).
73. Seifert, K., and Lyons, T. C., "Water Quality Law in Federal Republic of Germany." *Jour. Water Resources Planning and Man. Div., Proc. Amer. Soc. Civil Engr.*, **102**, 23 (1976).
74. Johnson, R. W., and Brown, G. M., Jr., "Cleaning Up Europe's Waters: Economics, Management, Policies." Praeger Publ., New York (1976).
75. Laburn, R. J., "Some Aspects of Water Management in the P.W.V. Metropolitan Region." *Water Resources Bull.*, **12**, 65 (1976).
76. Onokerhoraye, A. G., "Urban Environmental Problems and Planning Strategies in Tropical Africa: The Example of Nigeria." *The Annals of Reg. Science*, **10**, 2, 24 (1976).
77. Gruver, G. W., "Optimal Investment in Pollution Control Capital in a Neoclassical Growth Context." *Jour. Environ. Econ. and Management*, 3, 165 (1976).
78. Singleton, F., Ed., "Environmental Misuse in the Soviet Union." Praeger Pubs., New York (1976).
79. Stretton, H., "Capitalism, Socialism, and the Environment." Cambridge Univ. Press, Gr. Britain (1976).
80. Adar, Z., and Griffin, J. M., "Uncertainty and the Choice of Pollution Control Instruments." *Jour. Environ. Econ. and Management*, 3, 178 (1976).
81. Rose, M., "A Note on Cost Sharing of Municipal Wastewater Pollution Abatement Projects." *Land Econ.*, **52**, 554 (1976).
82. Harford, J. D., "Adjustment Costs and Optimal Waste Treatment." *Jour. Environ. Econ. and Management*, 3, 215 (1976).
83. Rose, A., "A Note on the Investment Equations in Some Recent Environmental-Management Models." *Environ. and Planning A*, 8, 477 (1976).
84. Briller, R., "Discounted Cash Flow Analysis to Select Equipment." *Jour. Environ. Div., Proc. Amer. Soc. Civil Engr.*, **102**, 595 (1976).
85. Paulson, B. C., Jr., "Designing to Reduce Construction Costs." *Jour. Construction Div., Proc. Amer. Soc. Civil Engr.*, **102**, 587 (1976).
86. Wolpert, J., "Regressive Siting of Public Facilities." *Nat. Resources Jour.*, **16**, 103 (1976).
87. Leone, R. A., "Environmental Controls: The Impact on Industries." Lexington Bks., Lexington, Mass. (1976).
88. Wiley, M. A., "Water Pollution Control, Mid-course Correction." *Chemtech*, **6**, 2, 134 (1976).
89. Amberg, H. R., "Environmental and Social Factors in the Paper Industry." *Tappi*, **59**, 4, 68 (1976).
90. Black, B., *et al.*, "Cost of Water Pollution in the Carpet Industry." *Amer. Dyestuff Reporter*, **65**, 6, 16 (1976).
91. Schlottmann, A., and Spore, R. L., "Economic Impacts of Surface Mine Reclamation." *Land Econ.*, **52**, 265 (1976).
92. Lee, M. T., and Guntermann, K. L., "A Procedure for Estimating Off-Site Sediment Drainage Costs and an Empirical Test." *Water Resources Bull.*, **12**, 561 (1976).
93. Guntermann, K. L., *et al.*, "The Economics of Off-Site Erosion." *The Annals of Reg. Science*, **10**, 3, 117 (1976).
94. Miller, W. L., and Gill, J. H., "Equity Considerations in Controlling Nonpoint Pollution from Agricultural Sources." *Water Resources Bull.*, **12**, 253 (1976).
95. Pfeiffer, G. H., and Whittlesey, N. K., "Economic Costs of Controlling Water Quality through Management of Irrigation Return Flows." Washington Water Research Ctr., Washington State Univ., Pullman (1976).
96. Kleinman, A. P., "Evaluation of Economic Impacts of Salinity on Agricultural Water Users in the Lower Colorado River Basin." In "Colorado River Basin Modeling Studies." C. G. Clyde, *et al.* [Eds.], Utah State Univ., Logan, Utah (1976).
97. Erlenkotter, D., and Scherer, C. R., "Investment Planning for Colorado River Salinity Control." In "Colorado River Basin Modeling Studies." C. G. Clyde, *et al.* [Eds.], Utah State Univ., Logan, Utah (1976).
98. Sims, J. H., and Baumann, D. D., "Professional Bias and Water Reuse." *Econ. Geography*, **52**, 1 (1976).
99. Stone, R., "Water Reclamation: Technology and Public Acceptance." *Jour. Environ. Div., Proc. Amer. Soc. Civil Engr.*, **102**, 581 (1976).
100. Gates, D. G., *et al.*, "Effects of Water Quality on the Recreational Use of Water in South East Texas." Water Resources Inst., Univ. of Texas, Austin, Texas (1976).
101. Young, C. E., "The Cost of Land Application of Wastewater: A Simulation Analysis." Econ. Research Serv., Tech. Bull. No. 1555, Washington, D. C. (1976).

Economics

J. C. Hite, Clemson University, S. C.

L. D. James
Utah Water Resources Laboratory, Logan

During 1978 there were no new trends in the literature related to water quality economics. For more than a decade, the mainstream of this literature has focused on potential use of effluent charges or other similar pseudomarket devices as an alternative to standards and regulations. Of the 39 articles, reports, monographs, and texts reviewed herein, 10 concentrated almost exclusively on the use of such market devices, while several others subsumed their existence. Such work has been especially attractive to theoretical economists, probably because it has been relatively easy to refine the theory to explicitly allow for various types of effluent charges, and to do so without becoming involved in time-consuming, often frustrating, data-collection chores. Engineers and public agency administrators are often critical of this work, however, contending that theoreticians fail to account for a myriad of real-world, practical problems. Nevertheless, while much of this work is not directly applicable to specific management and policy problems, a lrage amount of the literature dealing with use of effluent charges has helped to clarify issues and has opened new vistas for policy.

There were a number of articles in 1978 that advanced understanding of how effluent charges might be used effectively. Miedema [1] used a partial-equilibrium, competitive-firm model to test the effects of various types of charges on materials balance accounts. Magat [2] compared unit effluent charges and effluent standards to determine potential effects of each in inducing technological change and was unable to identify any qualitative differences in the R&D expenditures of firms under the two different schemes. He concluded, however, that per unit effluent charges would have to be continually increased to halt a growth in effluents if one assumes advancing technology. Moffit *et al.*[3] developed a methodology for calculating efficient effluent taxes or charges and demonstrated its practicality by applying it to dairy pollution problems in California's Santa Ana River Basin. Many of the critics of effluent charges have focused their criticisms on the practical problems of the charges. The work by Moffit and his colleagues is especially significant, therefore, because it showed that a simple, efficient effluent charge scheme could be developed from the same data base needed to compute uniform, least-cost emissions standards. Harford [4] also replied to the critics of effluent charges in a paper examining the behavior of profit-maximizing firm where both pollution standards and effluent taxes or charges are not perfectly enforceable. He demonstrated that increasing the level of penalties for violating standards would reduce pollution but that stricter enforcement would not necessarily achieve that end. Increasing effluent taxes or charges will reduce pollution, but will also cause firms to use more resources in evasion of the effluent tax. Since the marginal cost of effluent treatment rises with higher and higher levels of pollutant removal the potential rewards of evasion also rise, and thus, the marginal cost of enforcement rises as the control standards become more stringent. The marginal social damages of additional pollution must be sufficient to justify not only the marginal costs of physical removal but also the marginal cost of enforcement. Cartee and Williams [5] also examined enforcement problems, focusing specifically on pollution control in coastal areas.

Some new twists on the use of effluent charges were introduced in the literature in 1978. Oates and Strassmann [6] examined possible application of effluent charges to public sector activities and showed, in certain plausible cases, that such charges can induce significant reduction in pollution. Unger [7] interjected spatial considerations into the analysis, taking specific account of the direction of flow of a stream and the juxtaposition of upstream and downstream users of water. His analysis provided a basis for determining optimal site-specific discharges and the pricing scheme necessary to achieve that optimum. Huszar and Sabey [8] examined how quality levels in the return flow from irrigation might be improved by a pricing scheme. Trock *et al.*[9]

also examined the physical, economic, legal and social measures that might be used to deal with salinity problems resulting from the return flow from irrigation and recommended, among other measures, water trading among users. All of these studies have considerable potential in the insights they provide those charged with refining water pollution control policy.

Yet while policy makers are beginning to warm to the idea of effluent charges and other market mechanisms as tools that have practical use, the debate over policy continues. Portney [10] edited a volume in which five distinguished economists reviewed the social and institutional factors causing the U. S. to favor direct regulations over market mechanisms that use reward and penalty incentives and disincentives. The concensus was that the regulatory approach has (and is) straining the nation's ability to pursue its economic and environmental goals and that a shift toward greater use of charges and so forth, is needed. Ricketts and Webb,[11] however, argued that, in most practical circumstances, very complicated tax (or charge) structures would be needed to achieve environmental goals at least cost. Day,[12] explored a new approach to policy, emphasizing flexibility rather than efficiency. Arguing that economists and other social scientists are incapable of accurately predicting future conditions he stated that they should guide policy makers so as to make them better able to deal with "surprises." The precise implications of his argument relative to the debate over effluent charges is a matter likely to attract considerable attention in the future. Indeed, an article by Storey and Walker [13] explored traditional versus "adaptive" models for setting standards and emphasized the role of uncertainty in making policy decisions.

As in most years, a large part of the literature of water quality economics in 1978 dealt with development or application of planning models. Baker [14] developed a model for planning and locating on-site waste disposal systems, while Brinkley and Hanemann [15] contributed to the literature of recreational resource planning. Muller's [16] econometric study of the Canadian pulp and paper industry indicated that the costs of pollution control were unlikely to adversely affect that industry's economic performance. In what was possibly one of the more interesting papers of the year, Brookshire [17] bridged the gap between regional planning and the theoretical discussions of effluent charges or subsidies for pollution control. He noted that proposed uses of charges, taxes, and subsidies are all premised on existing institutional structures such as schools and roads, and do not address alteration of those structures. Brookshire argued that alterations in the institutional structure of a region through exogenous investments are also valid ways to achieve readjustments needed to achieve water quality and other environmental goals. Peele *et al.*[18] also gave attention to institutional factors and their effect on the distribution of benefits and costs in particular communities. In taking into account possible uses of migration data to draw inferences about the values of environmental amenities, Brookshire briefly explored a topic developed in more depth by Sigmon.[19] Sigmon used the well-known Tiebout Model to develop a econometric procedure for estimating tradeoffs between environmental amenities and income concluding that while serious technical problems must be overcome in the econometric procedures, such an approach has promise for estimating the monetary value of environmental improvements.

The literature showed continued progress in modeling economic-ecologic interfaces. O'Hayre and Mace [20] made use of modified input-output analysis to examine the spatial distribution of pollutants from nonpoint as well as point sources and applied their model to an evaluation of the economic-ecologic effects of various forest management alternatives. Stacey and Flinn [21] also used input-output techniques to estimate environmental impacts of new products developed by specific industries. Honey and Hogg [22] explored use of a cultural-ecological model in social impact assessment with specific application to the temporal and spatial effects of lake restoration programs. Griffith [23] recommended use of a Lorenz curve to show the spatial inequalities arising from project implementation and made a start toward fusing social welfare analysis and economic analysis in assessment methodology. Widstrand [24] edited a study from the Scandinavian Institute of African Studies that also emphasized the need for better understanding of institutional obstacles to improved water quality planning, particularly in Third World countries. Finally, Willeke [25] studied the equity of financial arrangements used in paying for municipal water quality control programs and concluded that some institutional practices, such as rate structures which subsidize new residents, were significant causes of inequity.

In 1978 there was growing public concern about the costs of environmental protection measures and their effect on inflation. Segal and Drieling[26] surveyed expenditures on pollution abatement and control in the U. S. in the period from 1972 to 1976 and found that expenditures on water pollution control and abatement increased at an annual rate of about 15% in the 4-year period. The engineering firm of Dames and Moore prepared three studies for EPA: a study of construction costs of 536 treatment plants,[27] a study of costs of 455 conveyance facilities,[28] and a study of operations and maintenance costs of 348 treatment plants and 155 sewer collection systems.[29] A similar study from Great Britain[30] examined costs of constructions for water supply and wastewater disposal facilities and used the results to develop a model for cost estimation in national and regional planning. Clark and English[31] focused on the costs of using renovated waste water to supplement water supplies and found that the least expensive method would increase the total cost of waters by about 25%. Vaughan[32] concentrated on estimating costs of pollution control at the plant level, using process analysis and a detailed linear programming model, while Brill and Nakamura[33] demonstrated the use of a branch and bound procedure to generate alternative planning schemes in wastewater treatment plant design. A study of the economics of chloroform removal from drinking water by Cumberland and Choi[34] questioned the cost effectiveness of making major changes in treatment of drinking water supplies. Young's study of the cost of land application of wastewater,[35] however, found center-pivot irrigation of municipal waste to be quite cost-effective for small communities.

In closing, a note should be made of several general studies of significance. A monograph by Ayres[36] examined the use of large-scale, materials-balance models in environmental planning. Nijkamp[37] published a major new text in environmental economics that will be useful to advanced students. Goodall *et al.*[38] analyzed the fiscal practices of California water districts and Dale[39] surveyed the impact of Proposition 13 on operations of wastewater treatment facilities in California.

REFERENCES

1. Miedema, A. K., "Short-Run Output and Factor Demand Effects of a Residuals Charge." *Land Econ.*, **54**, 228 (1978).
2. Magat, W. A., "Pollution Control and Technological Advance: A Dynamic Model of the Firm." *Jour. Environ. Econ. and Mgt.*, **5**, 1 (1978).
3. Moffit, L. J., *et al.*, "A 'Putty-Clay' Approach to Aggregation of Production/Pollution Possibilities: An Application in Dairy Waste Control." *Amer. Jour. Agr. Econ.*, **60**, 452 (1978).
4. Harford, J. D, "Firm Behavior Under Imperfectly Enforceable Pollution Standards and Taxes." *Jour. Environ. Econ. and Mgt*, **5**, 26 (1978).
5. Cartee, C. P., and Williams, D. C., Jr., "A Study of Coastal Pollution and Agency Interface." *Water Resources Bull.*, **14**, 1167 (1978).
6. Oates, W. E., and Strassmann, D. L., "The Use of Effluent Fees to Regulate Public Sector Sources of Pollution." *Jour. Environ. Econ. and Mgt*, **5**, 283 (1978).
7. Unger, K., "Locational Pricing of an Environmental Input." *Jour. Environ. Econ. and Mgt.*, **5**, 207 (1978).
8. Huszar, P. C., and Sabey, M. B., "Improving Irrigation Return Flow Quality with a Water Rental Market." *Water Resources Bull.*, **14**, 978 (1978).
9. Trock, W. L., *et al.*, "Socio-Economic and Institutional Factors in Irrigation Return Flow Quality Control." EPA-600/2-78-174-1/4, Robert S. Kerr Environmental Research Laboratory, Ada, Okla. (1978).
10. "Current Issues in U. S. Environmental Policy." Portney, P. R. [Ed.], The Johns Hopkins Univ. Press, Baltimore, Md. (1978).
11. Ricketts, M., and Webb, M. G., "Pricing and Standards in the Control of Pollution." *Scand. Jour. Econ.*, **80**, 53 (1978).
12. Day, Richard H., "Adaptive Economics and Natural Resources Policy." *Amer. Jour. Agri. Econ*, **60**, 276 (1978).
13. Storey, D. J., and Walker, M., "Water Pollution Control Theory—An Economic Taxonomy." *Jour. Environ. Mgt.*, **7**, 205 (1978).
14. Baker, F G., "A Model for Planning and Location of On-Site Waste Disposal Systems." *Water Resources Bull.*, **14**, 144 (1978).
15. Brinkley, C. S., and Hanemann, W. M., "The Recreation Benefits of Water Quality Improvement: Analysis of Day Trips in an Urban Setting" EPS-600/5-78-010, Washington, D. C. (1978).
16. Muller, R. A., "Econometric Analysis of Environmental Policy: Estimation of a Model of the Canadian Pulp and Paper Industry." *Can. Jour. Econ.*, **11**, 263 (1978).
17. Brookshire, D. S., "A Macroeconomic Analysis of Regional Environmental Modeling and Planning." *Jour. Environ. Econ. and Mgt.*, **5**, 268 (1978).
18. Peele, E., *et al.*, "Social Impact Analyses." *Social Impact Assessment*, **28**, 3 (1979).

19. Sigmon, B., "Preferences for Location-Dependent Goods as Revealed by Migration." Paper presented at Southern Regional Science Assoc. meetings, Richmond, Va (April 1978).

20. O'Hayre, A. P., and Mace, A. C., "Hydro-nomic Analysis: A Method of Regional Analysis of Economic and Water Resources Relationships." *Jour. Environ. Mgt*, 7, 125 (1978).

21. Stacy, G. S., and Flinn, J. E., "Development of an Economics-Based Methodology for Projection Future Pollution Problems." EPA-600/5-78-011, Washington, D. C. (1978)

22. Honey, W. D., and Hogg, T. C., "A Research Strategy for Social Assessment of Lake Restoration Programs." EPA-600/5-78-004 Environmental Research Laboratory, Corvallis, Oreg (1978).

23. Griffith, C., "A Welfare Approach to Social Impact Assessment." *Social Impact Assessment*, 34, 9 (1978).

24. "The Social and Ecological Effects of Water Development in Developing Countries." Widstrand, C. G. [Ed.], Pergamon Press, Oxford, U. K. (1978).

25. Willeke, G. E., "Assessing the Social Effects of Water Quality Management Programs." Environmental Resources Center, Rept 03-78, Georgia Inst. of Technology, Atlanta (1978).

26. Segal, F. W., and Drieling, F. J., "Pollution Abatement and Control Expenditures, 1972–76." *Surv. of Current Bus.*, 58, 12 (February 1978).

27. "Construction Costs for Municipal Wastewater Treatment Plants: 1973–1977." Dames & Moore, EPA-430/9-77-013, Washington, D. C. (1978).

28. "Construction Costs for Municipal Wastewater Conveyance Systems: 1973–1977." Dames & Moore, EPA-430/9-77-014, Washington, D. C. (1978).

29. "Analysis of Operations and Maintenance Costs for Municipal Wastewater Treatment Systems." EPS-430/9-77-015, Dames & Moore, Washington, D. C. (1978).

30. "Cost Information for Water Supply and Sewage Disposal." Water Research Centre, Medmanham Laboratory, Tech. Report TR 61, Marlow, Bucks, U. K. (1977).

31. Clark, R. A., and English, J. N., "Cost Studies for Renovated Wastewater." *Jour. Water Poll. Control Fed.*, **50**, 688 (1978).

32. Vaughan, W. J., "Process Analysis for Environmental Quality Management Modeling: General Considerations and a Practical Example." *Jour. Environ. Mgt.*, 7, 101 (1978).

33. Brill, E. D., Jr., and Nakamura, M., "A Branch and Bound Method for Use in Planning Regional Wastewater Treatment Facilities," *Water Resources Res.*, 14, 109 (1978).

34. Cumberland, J. H., and Choi, K., "Economic Analysis of Chloroform Removal from Drinking Water." Water Resources Research Center, Tech Rept. 49, Univ. of Maryland, College Park (1978).

35. Young, C. E., "Land Application of Wastewater A Cost Analysis." U. S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Services, Tech Bull. 1594, Washington, D. C. (1978).

36. Ayres, Robert V. T., "Resources, Environment and Economics." John Wiley and Sons, New York (1978)

37. Nijkamp, Peter, "Theory and Application of Environmental Economics." North-Holland Publishing Co., Amsterdam, New York (1977)

38. Goodall, M. R., *et al.*, "California Water: A New Political Economy." Allanheld, Osmun/Universe Books, Montclair, N. J. (1978)

39. Dale, J. T., "Proposition 13: Most Treatment Agencies Unaffected." *Jour. Water Pollution Control Fed.*, **50**, 2239 (1978).

Economics and the Environment

Allen V. Kneese

Table of Contents

Penguin Books

Chapter 7

Economic Studies of Water-Quality Management in Particular Basins

Chapter 6 has laid the methodological groundwork for a consideration of some actual case studies in this chapter. The first of them is regarded by many as the 'classic' economic water-quality management study. It was conducted in the 1960s by a Federal Government Agency in the United States and focused on the Delaware estuary region. The basic model it developed has found many other applications in both aqueous and atmospheric environments. The other case studies with different geographical setting, somewhat different methodologies, and addressing different aspects of water-quality problems are also reviewed. While all of them made significant contributions, a common deficiency of all of these studies is that they do not incorporate the possibility of land-use controls in an integral manner. In view of this an ongoing study which attempts to remedy this deficiency is reviewed at the end of the chapter.

The Delaware Study

The Delaware river basin, though small by the standards of the great American river basins and draining an area of only 12,765 square miles, holds a population of over six million. Portions of the basin, especially the Lehigh sub-basin and the Delaware estuary area, are among the most highly industrialized and densely populated regions in the world, and it is in these areas that the main water-quality problems are encountered.[1] The Delaware estuary, an eighty-six-mile reach of the Delaware river from Trenton, New Jersey, to Liston Point, Delaware (see Map 1), is most important in terms of the quantity of water impacted, the area involved, the extent of industrial activity, and the number of people affected.

Despite early industrial and municipal development in the basin, water-quality problems were neglected until the last few decades. The Interstate Commission on the Delaware River Basin (INCODEL) was formed in 1936, and under its auspices the states in the basin signed a reciprocal agreement on water-quality control. This provided the legal basis for construction of treatment plants by municipalities after the Second World War. The standards of treatment achieved were not particularly high (on the average not much more than removal of the grosser solids), and the residual waste load from the plants, together with industrial discharges, continued to place very heavy oxygen demands on the estuary. Especially during the warm summer months, DO fell, and still falls, to low levels or becomes exhausted in a few portions of the reach of the estuary from Philadelphia to the Pennsylvania–Delaware state line.

There are many water-quality characteristics which affect the value of the various services of a watercourse. As we saw in Chapter 2, and at the end of the previous chapter, one of the most central is DO, which is affected by meteorological and hydrological variables and by the discharge of organic wastes. DO is also something of a surrogate measure for other quality characteristics. The performance of waste water treatment plants is usually measured in terms of their ability to remove BOD from waste waters. Thus my discussion of the analysis of the Delaware estuary is focused primarily (but not exclusively) on oxygen conditions.

In 1957–8, at the request of the Corps of Engineers (the federal agency responsible for developing 'comprehensive' plans in the river basins of the eastern United States), the U.S. Public Health Service (which at that time was the responsible federal agency in regard to water pollution – now it is the Federal Water Quality Administration) made a preliminary study of water quality in the Delaware estuary. The data it produced regarding the quality of the estuary led state and interstate agencies, concerned with water quality, to request a comprehensive study of the estuary under the provisions of the Federal Water Pollution Control Act. The study was begun in 1961, and in the summer of 1966 a report was issued by the Federal Water Pollution Control Administration – *Delaware Estuary Comprehensive Study: Preliminary Report and Findings*.[2] The study made an effort to measure external costs as well as costs of control associated with various policy alternatives. One of its main contributions was to link the model of waste degradation and reaeration (Streeter–Phelps) for multiple points of discharge, which I described briefly at the end of the last chapter, to an economic optimization model.

The Model

Assume that a watercourse consists of n homogenous segments (thirty segments were used in the Delaware estuary study) and c_i represents the improvement in water quality required to meet a DO target in segment i. The target vector c of m elements can be obtained by changes of inputs to the watercourse from combinations of the n segments. Define another vector $x = (x_j, x_i, \ldots, x_n)$ in which the values of x refer to the volume of waste discharges in each of the segments. In a feasible solution, these values represent the waste discharges at the various points which meet the target vector c. This vector generates DO changes through the mechanism of the constant coefficients of the linear transfer function system already described at the end of the last chapter: a_{ij} = DO improvement in segment i per unit reduction of x_j, $i = 1, \ldots, m; j = 1, \ldots, n$; and, of course $x_j > 0$.

If we let A be the (m by n) matrix of transfer coefficients, then Ax is the vector of DO changes corresponding to x.

Now, recalling that c is the vector of target improvements, we have two restrictions on x, namely, $Ax \geq c$ and $x \geq 0$.

The reader will have noticed that mathematically these are sets of linear constraints exactly analogous to those in the industrial production problem I used as an example in the previous chapter. All we need is an objective function to complete the problem. Let d be a row vector where d_j = unit cost of $x_j, j = 1, \ldots, n$. Notice that this assumes linear cost functions.[3] We can now write the problem as a standard linear program,

$$\text{minimum value of } dx$$
$$\text{such that } Ax \geq c$$
$$\text{and } \quad x \geq 0$$

Of course, the transfer coefficients a_{ij}, as already explained, relate to a steady state of specified conditions of stream flow and temperature. Thus the model turns out to be totally deterministic, and the variability of conditions is handled in this analysis by assuming extreme conditions usually associated with substantial declines in water quality. This is a weakness in programming-type models, and an alternative mode of analysis which can handle some stochastic elements (but with unfortunately its own set of weaknesses) is discussed in connection with the Potomac case in the next section.

A linear programming model of the general type just described was constructed for the Delaware estuary. In addition to DO, it included other, nondegradable, types of material. Computation of the a_{ij}'s is, as noted in the previous chapter, easier for these. Once done, the model provided an extremely flexible tool for the analysis of alternative policies.

Analysis of Objectives

A major part of the strategy of the Delaware study was to use the model to analyze the total and incremental costs of achieving five 'objective sets', each representing a different package and spatial distribution of water-quality characteristics, with the level of quality increasing from set 5 (representing 1964 water quality) to set 1. In some runs, overall costs were minimized by the programming model. In others, additional constraints were added to represent more usual administrative approaches to the problem. The water-quality characteristics and associated levels and the areas to which they apply are shown for objective set 2 in Table 12.

Table 12. Water-Quality Goals for Objective Set 2*

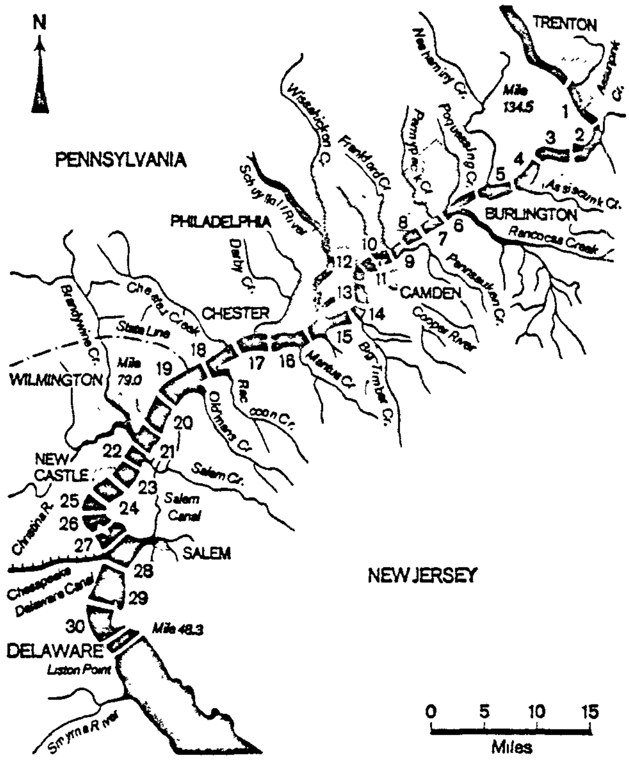
WATER QUALITY PARAMETER*†	SECTION*																													
											PHILADELPHIA																			
	Trenton			Bristol		Torresdale				Camden								Chester		Wilmington					New Castle					Liston Point
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Dissolved oxygen†	5 5						5 5	4 0											4 0	5 0							5.0	6 5		
DO 4/1 - 6/15 and 9/16 - 12/31	6 5																													6.5
Chlorides§															50	250														
Coliforms (#/100 ml)	5 000††						5 000††	5 000**																						5 000**
Coliforms 5/30 9/15	4 000††			4 000	5 000††			5 000**																		5 000**	4 000††			
Turbidity (Tu)	N L.+30																													N.L.+30
Turbidity 5/30 9/15	N.L.			N L.	N.L +30																					N L.+30	N L.			N.L.
pH†† (pH units)	6.6-8.5																													6.5-8.5
pH†† 5/30 - 9/15	7-85				6 5-8 5																					6.5 8.5	7-8.5			
Alkalinity ††	20 50						20-50	20-120																						20-120
Hardness‡‡	95						95	150								150														
Temperature††(°F)	Present levels																													Present levels
Phenols‡‡	0 001						0 001	0.005								0 005	0 01													0 01
Syndets‡‡	0 5						0 5	1 0																						1.0
Oil and grease floating debris	Negligible																													Negligible
Toxic substances	Negligible																													Negligible
SECTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

* *mg/l unless specified* †† *Not less stringent than present levels* † *Summer average* § *Maximum 15-day mean* ‡ *Maximum level* ** *Monthly geometric mean* †† *Desirable range* ‡‡ *Monthly mean* ‡ *Average during period stated* N.L. = *Natural levels*

SOURCE: Allen V. Kneese and Blaire T. Bower, *Managing Water Quality: Economics Technology, Institutions.* Baltimore, Johns Hopkins Press, 1968.

The thirty sections referred to in the table are shown on Map 1. An effort was then made to measure benefits associated with the improvement in water quality indicated by the successive objective sets. Before turning to the benefit estimation, it will be useful to describe the objective sets a bit further.

Map. 1. Map of the Delaware Estuary Showing Analysis Sections



SOURCE: Federal Water Pollution Control Administration, *Delaware Estuary Comprehensive Study*, 1966.

Table 13 shows several water-quality parameters with the associated levels for the five objective sets. The general nature of the objective sets is as follows:

Objective Set 1. This is the highest set. It makes provision for large increases in water-contact recreation in the estuary. It also makes special provision for 6.6 p.p.m. levels of dissolved oxygen to provide safe passage for anadromous fish during the spring and fall migration periods. Thus this objective set should produce conditions in which water quality is basically no obstacle to the migration of shad and other anadromous (migratory) fishes.

Objective Set 2. Under this set the area available for water-contact recreation is constricted somewhat. Some reduction in sport and commercial fishing would also be expected because of the somewhat lower dissolved oxygen objective. This set, like objective set 1, makes special provision for high dissolved oxygen during periods of anadromous fish passage.

Objective Set 3. This set is similar to set 2. Although there is no specific provision for raising dissolved oxygen during periods of anadromous fish migrations, there is comparatively little difference in the survival probability under objective sets 2 and 3. Under the waste-loading conditions envisioned for objective set 3, the estimated survival 24 out of 25 years would be at least 80 percent – compared with 90 percent for set 2.

Objective Set 4. This provides for a slight increase over 1964 levels in water-contact recreation and fishing in the lower sections of the portion of the estuary studied. Generally, water quality is improved slightly over 1964 conditions and the probability of anaerobic conditions occurring is greatly reduced.

Objective Set 5. This would maintain 1964 conditions in the estuary. It would provide for no more than a prevention of further water-quality deterioration.

The costs of achieving objective sets 1 through 4 by various combinations of waste discharge reduction at particular outfalls for the waste-load conditions expected to prevail in

Table 14. Summary of Total Costs (millions, 1968 dollars) of Achieving Objective Sets 1–4 (costs include cost of maintaining present (1964) conditions and reflect waste-load conditions projected for 1975–80)
Flow at Trenton = 3,000 cubic feet per second

	Uniform treatment			Zoned treatment			Cost minimization		
Objective set	Capital costs	O & M costs*	Total costs	Capital costs	O & M costs*	Total costs	Capital costs	O & M costs*	Total costs
1	180	280 (19·0)	460†	180	280 (19·0)	460†	180	280 (19·0)	460†
2	135	180 (12·0)	315†	105	145 (10·0)	250†	115	100 (7·0)	215†
3	75	80 (5·5)	155‡	50	70 (4·5)	120‡	50	35 (2·5)	85‡
4	55	57 (5·0)	130	40	40 (2·5)	80	40	25 (1·5)	65

* Operation and maintenance costs, discounted at 3 percent twenty-year time horizon; figures in parentheses are equivalent annual operation and maintenance costs in millions of dollars/year. † High-rate secondary to tertiary (92–98 percent removal) for all waste sources for all programs. Includes in-stream aeration cost of $20 million. ‡ Includes $1–$2 million for either sludge removal or aeration to meet goals in river sections #3 and #4.

SOURCE: Allen V. Kneese and Blaire T. Bower, *Managing Water Quality: Economics, Technology, Institutions*, Baltimore, Johns Hopkins Press, 1968.

Table 15. Costs and Benefits of Water-Quality Improvement in the Delaware Estuary Area* (million dollars)

Objective set	Estimated total cost	Estimated recreation benefits	Estimated incremental cost		Estimated incremental benefits	
			minimum†	maximum‡	minimum†	maximum‡
1	460	160–350				
			245	145	20	30
2	215–315	140–320				
			130	160	10	10
3	85–155	130–310				
			20	25	10	30
4	65–130	120–280				

* All costs and benefits are present values calculated with 3 percent discount rate and twenty-year time horizon.
† Difference between adjacent minima. ‡ Difference between adjacent maxima.

SOURCE: Allen V. Kneese and Blaire T. Bower, *Managing Water Quality: Economics, Technology, Institutions*, Baltimore, Johns Hopkins Press, 1968.

produce the specified quality levels at about half the social cost of the uniform treatment method. Especially at the higher quality level, the cost saving is of a highly significant magnitude. The present value of the cost stream saved is in the order of $150,000,000. The result occurs because, as we saw in Chapter 5, the incentive effect of the charge is to concentrate discharge reduction where costs are lowest.

Table 16. Cost of Treatment under Alternative Programs

DO objective (p.p.m.)	Program			
	LC	UT	SECh	ZECh
	(million dollars per year)			
2	1·6	5·0	2·4	2·4
3–4	7·0	20·0	12 0	8·6

The least-cost system is capable of reducing costs somewhat further than either the uniform or the zoned charge since it programs waste discharges at each point specifically in relation to the cost of improving quality in the critical reach, but this comes at the cost of detailed information on treatment costs at each point and a distribution of costs such that some waste dischargers experience heavy costs and others virtually none. The least-cost system is closely approached by ZECh at the higher quality level. In effect, this zone charge procedure 'credits' waste dischargers at locations remote from the critical point with degradation of their wastes in the intervening reach of a stream before they arrive at the critical reach. This is a necessary condition for full efficiency when effluent charges are used to achieve a standard at a critical reach in a stream. The reason that the ZECh does not achieve quite the same efficiency as the least-cost program is that the 'credit' is not specific to the individual waste discharger but is awarded in blocks – three in this case.

Another way of putting this is that equalizing marginal waste-water-reduction cost at all outfalls is strictly speaking a necessary condition for cost minimization only when a homogenous 'lump' of assimilative capacity is being allocated – or more formally, when all the coefficients in the transfer matrix corresponding to a binding constraint are identical. When they are not, thorough-going cost minimization requires that prices be 'tailored' for each outfall. This explains why the solution based on a single charge only approaches but does not reach the programmed cost minimization solution. How closely it will approach is an empirical question relating to the magnitude of the a_{ij}'s.

Having the tool of transfer coefficients in hand we can now treat this matter more rigorously than was done in Chapter 5. Assume two industrial dischargers with the following cost functions for reducing waste discharge:

(1) $$c_1 = f(x_1)$$

(2) $$c_2 = f(x_2)$$

where x_1 = waste discharged from plant #1,
x_2 = waste discharged from plant #2,
c_1 and c_2 are costs of reducing waste discharge.

Assuming reach #6 is the 'critical' reach and recalling the meaning of the elements in the transfer matrix,

$R_6 = a_{61}x_1 + a_{62}x_2$ (i.e., 'binding' constraint),

where

(3) R_6 = the 'standard'.

Form the Lagrangian,

(4) $$L = c_1 + c_2 + \lambda(R_6 - a_{61}x_1 - a_{62}x_2).$$

At optimum,

(5) $$\frac{\partial L}{\partial x_1} = \frac{dc_1}{dx_1} + \lambda(-a_{61}) = 0$$

(6) $$\frac{\partial L}{\partial x_2} = \frac{dc_2}{ax_2} + \lambda(-a_{62}) = 0.$$

If we include the constraint $R_6 = a_{61}x_1 + a_{62}x_2$, we have 3 equations and 3 unknowns (x_1, x_2, and λ).
Solving for λ, we get:

(7) $$\lambda = \frac{1}{a_{61}}\frac{dc_1}{dx_1}$$

and

(8) $$\lambda = \frac{1}{a_{62}}\frac{dc_2}{dx_2}.$$

Note that:

$$\frac{1}{a_{61}}\frac{dc_1}{dx_1} = \frac{1}{a_{62}}\frac{dc_2}{dx_2}$$

or

$$\frac{dc_1}{dx_1} = \frac{a_{61}}{a_{62}}\frac{dc_2}{dx_2}.$$

Note also that $\lambda \neq 0$ unless either $\frac{dc_1}{dx_1}$ or $\frac{dc_2}{dx_2} = 0$. Because both equations (5) and (6) are equal to zero, they may be set equal to each other:

$$\frac{dc_1}{dx_1} = \frac{dc_2}{dx_2} + \lambda(a_{61} - a_{62}).$$

Thus at the cost-minimizing solution marginal costs are generally not equal.[6] But the Delaware estuary study showed that for an important real case equalizing them gets pretty close to the cost-minimizing solution.

Further Comments on the Effluent Charge Approach

At an average effluent charge of ten cents per pound of BOD, which the staff estimated would be needed for the Delaware zoned effluent charge program,[7] the funds collected by the administrative agency would amount to about $7 million per year. Nevertheless, for the 3–4 p.p.m. DO objective, the total cost to industry and municipalities as a whole – effluent charge plus cost of treatment – is about the same as the cost of treatment only under the uniform treatment program. About half of this outlay does not represent an actual resources cost but rather a rental-type payment for the use of assimilative capacity.

It should be noted that an important efficiency advantage of the effluent charges programs as contrasted with the least-cost program is their relatively smaller demand for information and analytical refinement. A study of the type already performed for the Delaware estuary could serve as the basis for an effluent charge scheme. An order-of-magnitude estimate of the required charge reveals itself. Actually, since the costs do not take account of the possibility of process change in industry, which is often cheaper than 'end of pipe' treatment, the ten cents per pound of BOD charge was probably too high and could be adjusted downward at a later point (one would need to take inflation into account). Also, the charge provides a continuing incentive for the discharger to reduce his waste load by placing him under the persistent pressure of monetary penalties. He is induced to develop new technology and as it develops to implement it. As new technology develops, the effluent charge could be gradually reduced while the stream standard is maintained, or the standard could be allowed to rise if this is deemed desirable. The process of induced technological change has particularly striking results in this field since the waste assimilative services of watercourses have heretofore been completely unpriced.

The direct control measures implicit in the least-cost program, on the other hand (as well as the effluent standard of the uniform treatment program), provide only a more limited incentive to improved technology. Moreover, the minimum cost program would require not only detailed information on current cost levels at each individual outfall, but also information on changes in cost with changing technology, in regard to industrial processes, product mix, treatment cost, etc., and would be extremely inequitable in its cost distribution.

The Delaware estuary survey was a pioneering study of water-quality management and is of continuing importance. Some of the tools it developed are in use by the Delaware River Basin Commission, and it is still frequently referred to in discussions of policy in the United States – a point I will develop a little later in the chapter. It was the first study to embody at least a rudimentary ecological model into an economic optimization framework, and it provided an illuminating analysis of several policy options including effluent charges.

The study did have some major deficiencies, however. Among them are that only a very limited range of technological alternatives for managing water quality was examined and that the stochastic aspects of water quality were not analyzed. These matters were considered, however, in the Potomac study to which I turn next. Before doing so however, I must introduce one additional piece of methodological equipment – stochastic or probabilistic generators of hydrological records.

Stochastic Hydrology

As everyone knows, the flow of rivers (one of the major determinants of their capacity to assimilate waste materials) is not constant with time. It varies seasonally in somewhat regular patterns but with a large random component. Traditionally, in designing flow regulating structures (reservoirs) an empirical device called a 'mass curve' is used to determine the yield that can be sustained from the reservoir during drought periods. Underlying this technique is the assumption that future flows (measured on a daily or monthly basis) will be an exact replication of flows observed historically (usually there are thirty years or so of good records in the more advanced countries).

An alternative, that is more defensible on statistical grounds, is to assume that the historical record is a sample from a much larger population and that what will remain invariant in the future are only certain of the moments (mean, standard deviation, skewness) of the distribution of observed flows. Based on the latter assumption, stochastic hydrology generators have been devised which can simulate long hydrologic sequences incorporating extreme values and patterns of events not in the historic record while maintaining selected moments of the frequency distribution of that record. There are difficult problems associated with such generators, but many of them have been overcome. The problems involve such things as serial correlation in the record of flows and maintaining cross and serial correlations for separate gauging stations in the same system. I will not attempt to treat these since my intent is just to acquaint the reader with the general recursive relationships used.

In these 'Markovian' models the basic recursive relation used can be represented by the following equation[8]:

$$x_{i+1} = \mu + \beta(x_i - \mu) + t_{i+1}\sigma(1 - \rho^2)^{\frac{1}{2}}$$

In this model, x_{i+1}, the flow in the $(i + 1)$st interval, is a linear function of x_i, the flow in the ith interval; of a standardized random deviate t_{i+1}; and of the population parameters μ (the population mean), σ (the population standard deviation), β (the regression coefficient of flows in the $(i + 1)$st interval on values in the ith interval), and ρ (the correlation coefficient between flows in successive time periods). The standardized random deviate t_{i+1} has zero mean and unit variance.

It can be shown that if the distribution of flows is normal and the regression functions of x_i on x_{i-1} is linear and homoscedastic (of constant variance), the conditional expectation of x_i, given x_{i-1}, is given by

$$E(x_i \mid x_{i-1}) = \mu + \beta(x_{i-1} - \mu)$$

and the expected variance of x_i, given x_{i-1}, is

$$\mathrm{Var}(x_i \mid x_{i-1}) = \sigma^2(1 - \rho^2).$$

Thus, we can see in the recursive equation that the first two

In 1963, the U.S. Army Corps of Engineers submitted the *Potomac River Basin Report*. This report was the first one in which a federal water resource agency submitted a 'comprehensive' plan in which water-quality management was the major consideration. The plan took a quality objective stated in physical terms (parts per million of dissolved oxygen) as given, and recommended a program of waste treatment and low-flow regulation to meet this objective in the future. While it was a pioneering effort, the benefit evaluation techinique, based on the 'alternative cost procedure', was grossly deficient, and the range of alternatives considered for water-quality improvement was still very narrow, even though wider than that included in the Delaware study. Basically, the Corps of Engineers limited its planning to consideration of those quality improvement facilities which could clearly be implemented through existing governmental institutions. As we shall see, this restricted the range of choice greatly and led to the recommendation of a set of facilities which was far from the least costly which could have been devised to achieve the stated water-quality objective.

A later Resources for the Future study,[10] which forms the basis for my further discussion, used the Corps of Engineers data plus considerable additional information to define further the range of alternatives for water-quality management in the Potomac estuary in the neighborhood of Washington, D.C., the locus of most of the water-quality problems.

The Basin and Its Problems

The watershed of the Potomac, an area of about 14,000 square miles, lies in portions of four states and the District of Columbia. About three quarters of the population in the basin is found in the Washington metropolitan area. This area, which extends beyond the District of Columbia into Maryland and Virginia, already has a population of nearly 3 million persons and is one of the most rapidly growing metropolitan areas in the nation. The Washington area lies near the head of terms on the right-hand side are the expected value of x_{t+1}, given x_t has occurred (February's flow, January having occurred), and the last term is the random component consisting of a randomly selected normal, deviate which, when multiplied by the expected variance of x_{t+1}, given x_t, brings the result back into the proper dimension comparable with the first two terms of the right side. It can also be shown that to treat non-normal distributions it is sufficient to alter the distribution of the random additive component and thus maintain higher moments of observed data.[9]

It is readily seen that a recursive model of this type could be used to generate indefinitely long sequences of hydrological record to be used as inputs to a simulation model. As long a generated sequence of flows as is wished (say, several thousand years) can then be used in analyzing the probabilistic performance of a reservoir, or other water quantity and quality management system elements. Stochastic hydrology is used in connection with the Potomac case study to which I now turn.

The Potomac Study

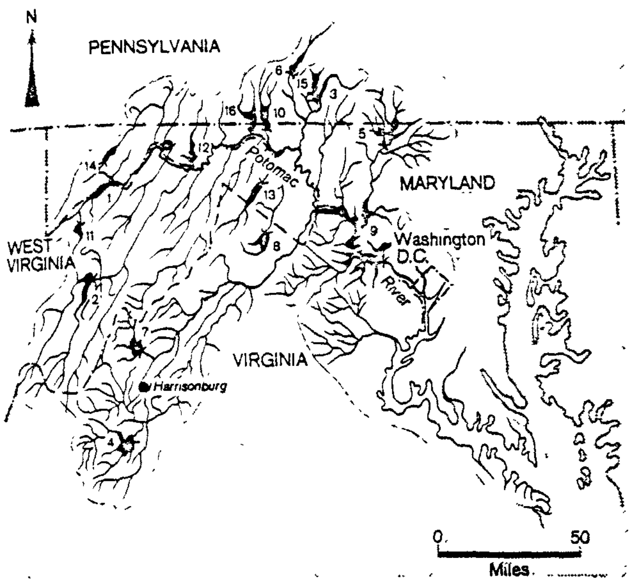
A 1961 amendment to the Federal Water Pollution Control Act of 1948, which, with minor exceptions, was the first step by the United States Federal Government into what had been an exclusive area of state sovereignty, is the starting point for discussion of the Potomac case. The feature of the 1961 Act which is most relevant to present purposes is that it provided for the inclusion of subsidized storage in federal multipurpose reservoirs to augment low flows for the purpose of improving water quality. This opened the door to the possibility of including in federally subsidized water-quality improvement programs technological options other than treatment. Naturally this possibility drew the attention of federal agencies engaged in the planning and construction of public works related to water resources. In the eastern United States the U.S. Army Corps of Engineers is the lead agency in this respect.

the Potomac estuary which is heavily used for recreation. Water supply for the area is taken from the Potomac river above the estuary. The estuary periodically experiences a low level of dissolved oxygen – a condition which could get much worse as waste loads from the metropolitan area and upstream sources mount. The Corps of Engineers as part of its planning effort projected water demands and waste loads to the year 2010. One of the central objectives of the plan was to control the effects of waste loads expected to prevail then. Among the planning assumptions was that the maximum feasible control of waste loads would result from conventional secondary sewage treatment (about 90 percent BOD removal).

The plan made public in 1963 recommended the construction by the year 2010 of sixteen major reservoirs in the Potomac basin and more than 400 headwater structures (see Map 2). These were meant to meet projected water supply, water-quality, and flood control objectives. Of the sixteen major reservoirs, ten were planned to meet projected upstream objectives for the low-flow regulation for water supply and quality control. At the same time, this group of reservoirs would provide a higher sustained flow at Washington sufficient to meet the projected municipal water diversions there. The remaining group of six reservoirs (providing 60 percent of the proposed yield – 2340 c.f.s. (cubic feet per second) out of 3931 c.f.s.) was designed to augment flows into the estuary sufficiently to maintain 4 p.p.m. of dissolved oxygen (twenty-four-hour monthly mean for the minimum month). The projected storage was based on counteracting residual 2010 waste loads and an assumed replication of the historical record of flows into the estuary (i.e., the mass curve approach was used to determine required storage to sustain flows calculated to be needed to offset residual waste loads to the extent of maintaining 4 p.p.m. DO). From a statistical point of view, the mass curve approach has great deficiencies which were discussed in connection with our earlier consideration of stochastic hydrology. I will return to this point a little later.

A benefit-cost analysis was presented which indicated that the benefits from flow regulation would outweigh its costs. But this analysis did not do what benefit-cost analysis is intended to accomplish – assist in deciding whether a pro-

Map 2. Major Reservoirs in Recommended Plan for Potomac Basin



SOURCE: *PRB Report*, Vol. I, p. 30, reproduced in Robert K. Davis, *The Range of Choice in Water Management* (Baltimore, Johns Hopkins Press, 1968).

posed investment is socially worthwhile. The preset physical quality objective of 4 p.p.m. of DO was taken as given in the planning. It was assumed that treatment of the sewage from the Washington metropolitan area could not succeed in removing more than 90 percent of the waste load. This is insufficient to meet the objective. The only alternative seriously investigated was low-flow regulation to improve the waste assimilative capacity of the estuary. Benefits from low-flow regulation were taken to be the cost of a single-purpose reservoir designed to meet low-flow requirements at each point of projected need without regard to the complementary effects of meeting upstream needs. Moreover, costs of the alternative reservoirs were calculated at a higher rate of interest – presumably because it was assumed they would be implemented by state or local governments which have to pay higher rates of interest than the federal agencies use in their own calculations.

This string of planning assumptions was bound to produce positive net benefits for flow regulation. But this result was obtained without even addressing the real question – whether the 4 p.p.m. objective was justified by the willingness of beneficiaries to pay at least as much as it costs to maintain it. Clearly, the benefit-cost analysis as it was performed is not helpful in deciding whether the plan is justified.

Furthermore, for various reasons having to do with limitations on the authority of water resources agencies and their perception of problems and appropriate solutions, the planners made no concerted or systematic effort to search for and evaluate alternative ways (in addition to flow regulation) of achieving the specified water-quality objective. The measures recommended for quality control were limited to basic conventional treatment and low-flow augmentation – measures which could clearly be implemented by the federal and local government agencies which are the traditional purveyors of water services in the United States. To have implemented a program embodying the less conventional measures which the later Resources for the Future study demonstrated would have entered into a cost-minimizing solution and would have required institutional change. The possibility of such change was not contemplated in the planning process. Failure to consider institutional reform as a possible objective of the planning process is a failing frequently encountered around the world and I shall have more to say about it subsequently.

Searching for Additional Alternatives

The follow-up Resources for the Future study showed that if the plan had included certain collective measures – which no existing agency had a clear authority or incentive to finance, construct, and operate – it would have entered into a least-cost system for meeting the oxygen objective. Had such a system served as the alternative for benefit analysis, net benefits for flow regulation, at least for the larger-scale reservoir systems, would have been grossly negative. But, in general, the alternative cost-benefit estimation procedures are inappropriate in cases like this.

In going through the later analysis, the Corps assumption that wastes in the Washington metropolitan area would receive 90 percent treatment was (somewhat arbitrarily) used as a baseline. The costs of other alternatives were then weighed off against the incremental cost of flow regulation for counteracting the residual oxygen deficit.

Costs were obtained for different levels of low-flow regulation by scaling down by various amounts the Corps's proposed low-flow regulation system. The scaled-down systems were roughly optimized by using a computer simulation program which permitted the historical trace of hydrology to be regulated by the various systems.

The line between simulation models and the optimizing type of programming models, such as that used in the Delaware study, is often not very clean cut. In general, however, simulations are used to play out the implications of certain assumptions, (reservoir sizes, operating rules, etc.) either solely in terms of the behavior of the natural system upon which they have an impact or on certain economic variables – such as costs. Normally they do not contain an explicit optimizing procedure but simply enumerate a large number of alternative results. This is a problem because the number of possible alternative results can easily become unmanageably large. This was not so in the case of the Potomac study, however, because the range of variables was carefully limited and only large increments were permitted. The advantage of simulation is that it can more easily handle non-linearities and probabilistic aspects of problems than can mathematical programming.

In the first set of Resources for the Future analyses, historical hydrology was used to maintain close comparability with the Corps results. In computing costs for the successively smaller reservoir systems, account was taken of the difference in flood damage reduction and recreation services realized by any scaled-down system in comparison to the full proposed Corps of Engineers system.

Costs of several alternative ways of equivalently offsetting the waste load were also developed. These included processes for further treatment of the waste load (microstraining, step aeration, chemical polymers, powdered carbon, and granular carbon); costs for effluent distribution via pipeline along the estuary to make better use of its natural assimilative capacity; and re-oxygenation of the estuary which, like low-flow regulation, improves assimilative capacity.

Computer simulation of the effects of these processes in view of variations of river flow (using the historical hydrologic trace) into the estuary show that they need to be operated on the average only three and a half months per year in order to meet the DO objective. Because the alternative systems are high in operating cost and low in capital cost relative to low-flow regulation, they can be comparatively efficient if operated only as needed but would not be competitive if operated continuously, thereby overshooting quality goals most of the time. Accordingly, they could only enter efficiently into the quality management system if institutional means existed for carefully articulated design and operation in conjunction with other elements of the system.

Establishing combinations which would meet the standard required that if one process was reduced another had to be equivalently increased. It was possible to use computer simulation to exhaust all possible combinations of the feasible and sufficient processes given the relatively large increments defined for them. The computer program gave a complete listing and cost ranking of all systems – some 300 in all.

A sampling of alternative feasible and sufficient systems is shown in Table 17.

This analysis shows that many combinations of processes could achieve the objective at less cost than the proposed

Table 17. System Costs by General Class of Process Combinations. Three and a Half Months' Operation (present worth, fifty-year period, 4 percent discount in $ million)

Alternative systems	
1. Reoxygenation	20
2. Chemical polymers and reoxygenation	22
3. Step aeration and reoxygenation	25
4. Microstrainers and reoxygenation	28
5. Diversion and reoxygenation	33
6. Diversion, waste treatment and reoxygenation	45
7. Low-flow augmentation and reoxygenation	60
8. Low-flow augmentation, reoxygenation and waste treatment	60
9. Low-flow regulation	140

SOURCE: Adapted from various tables in Robert K. Davis, *The Range of Choice in Water Management*, Baltimore, Johns Hopkins Press, 1968.

system based upon conventional treatment and flow regulation. It is notable that all of them except the flow regulation alternative would require the construction and closely articulated operation of facilities which have not traditionally been in the purview of either the federal or local government (particularly reoxygenation and regional effluent distribution works). Another salient point is that while low-flow regulation is vastly more costly than reoxygenation or some of the other alternatives, from the point of view of the people in the basin it costs much less, because of subsidies. Low-flow regulation for water-quality improvement is a fully nonreimbursable purpose of federal water development in the United States, used to check that the yield of the proposed reservoirs system would be sufficient to meet the objective. As has already been noted, this analysis makes the statistically untenable assumption that future stream flow will be a replication of the past.

To help illuminate the probability aspect of the water-quality standards conventionally used in planning, a stochastic hydrology was generated for long periods of time and applied to the reservoir simulation program.

Table 18 presents some figures for the different probabilities of violating 2 and 4 p.p.m. DO levels when different

Table 18. Percentage of Time Monthly Mean DO is less than 2 p.p.m. for Five-hundred-Year Trials at Different DO Target and System Capacities

Storage capacity	DO target p.p.m.	Percentage of time < 2 p.p.m.	Percentage of time < target
82,000 acre-ft	2	0·25	0·25
140,000	2	0·03	0·03
600,000	4	0·35	3·30
770,000	4	0·22	1·03
970,000	4	0	0·33

SOURCE: Robert K. Davis, *The Range of Choice in Water Management*, Baltimore, Johns Hopkins Press, 1968.

systems of reservoirs are operated to achieve DO targets. In this presentation it is assumed that low-flow regulation is the only means used to counteract the residual deficit after about 90 percent treatment. This is done to spell out clearly the implication for reservoir storage, even though in an optimized or least-cost system the incremental costs of achieving lower probabilities of violation would be less. It is interesting to note two main points emerging from this analysis.

(1) Reducing the probability of violating the 4 p.p.m. objective from 3·3 percent to 0·33 percent costs about 370,000 acre-feet in storage and around 50 million in dollars.

while no subsidy at all is available for measures like reoxygenation and waste diversion. Thus, the fact that federal water development policy is such that certain measures for development confer large subsidies on a region while others do not can also contribute to choices among alternatives which are distorted from a broader economic point of view.

Both of these factors were undoubtedly implicit considerations in the plan recommended by the Corps. It is thus possible to examine the existing institutional and policy restraints by means of economic systems analysis which is not limited by these restraints, and thus provide information on the desirability of institutional change. Such examination of institutional constraints clearly should be part of the planning process. In the case of the Potomac it appears that much could be gained by institutional arrangements permitting the design and operation of quality management systems embodying a wide range of alternatives.

Stochastic Aspects

So far, in my discussion of cases, I dealt with deterministic models. These, quite imperfectly, recognize the variability of river flow by specifying some level below which flow is unlikely to drop. The Delaware estuary study took this approach and so did the Corps study of the Potomac, as well as much of the Resources for the Future follow-on study. But the availability of the Potomac reservoir simulation model made it possible to study some aspects of the probability question in a more explicit way. It is one of the major disadvantages of optimization models such as that used on the Delaware estuary (which as already mentioned otherwise have great advantages) that it is very difficult to incorporate stochastic aspects into them.

The Corps of Engineers based its design on the specification that DO concentrations in the estuary would not fall below 4 p.p.m. based on the twenty-four-hour monthly mean for the minimum month. A standard kind of mass curve analysis was