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A Water Policy for the American People



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WATER AND LAND OF THE UNITED STATES

- Scale: 0 100 200 300 400 Miles
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|--|-----------|--|------------------|--|----------|
| | plateaus | | cuestas | | sand |
| | hills | | folded mountains | | sinks |
| | mountains | | basin ranges | | moraines |
| | mesas | | volcano and lava | | drumlins |

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Erwin Raisz, 1950



A Water Policy for the American People

THE REPORT OF THE
PRESIDENT'S WATER RESOURCES
POLICY COMMISSION

1950



IN THREE VOLUMES

Volume 1: General Report

Volume 2: Ten Rivers in America's Future

Volume 3: Water Resources Law

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON D. C., DECEMBER 1950

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THE PRESIDENT'S
WATER RESOURCES POLICY COMMISSION
718 EIGHTEENTH STREET NW.
WASHINGTON 25, D. C.

COMMISSIONERS
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December 11, 1950

The President
The White House

Dear Mr. President:

In compliance with your instructions covered in Executive Order No. 10095 and your letter dated January 3, 1950, we take pleasure in submitting herewith the report of The President's Water Resources Policy Commission, entitled "A Water Policy for the American People." The report proper is contained in Volume 1. Volume 2 contains the details of the several river basin studies and Volume 3 is devoted to the applicable law. Volumes 2 and 3 will be submitted later, as will our response to your request that the Commission give consideration to desirable legislation or changes in existing legislation.

In bringing our work to a conclusion we wish to refer enthusiastically to the cooperation we have received from the Executive Departments, States and the general public. Their assistance has been a very large part of whatever of value the report may possess.

Thanking you for having given us, individually and collectively, this opportunity for public service, we are

Yours very sincerely,

Paul S. Burgess
Paul S. Burgess

Lewis Webster Jones
Lewis Webster Jones

Samuel B. Morris
Samuel B. Morris

Leland Olds
Leland Olds

Roland R. Renne
Roland R. Renne

Gilbert F. White
Gilbert F. White

Morris L. Cooke
Morris L. Cooke, Chairman

*Every human enterprise is the mixture of a little bit of
humanity, a little bit of soil, and a little bit of water.*

JEAN BRUNHES

Errata

Page 189. Last three lines on page are out of order. Sentence should read: The oxygen demand for decomposing or "stabilizing" packinghouse waste is 10 times higher than sewage, while tannery waste solids require $2\frac{1}{2}$ times more.

Pages 242, 243, and 244 are misnumbered and out of order. Page 244 should be 242; 242 should be 243; and 243 should be 244.

Contents

	<i>Page</i>
A NATIONAL WATER RESOURCES POLICY, Including Summary of Recommendations	1

We Must Conserve and Develop . . . The Source of Policy . . . Natural Subdivisions . . . New Problems . . . Healthy Regionalism . . . Evolution of Water Resources Policy . . . From Project to Program . . . Need for Reappraisal . . . Broad Considerations for Federal Policy . . . Democratic Planning . . . The Economic Responsibility of the Federal Government . . . A Framework of Principle . . . Outline of Policy . . . Critical Decisions

Chapter 1

REGIONAL DEVELOPMENT	19
--------------------------------	----

A Cooperative Task . . . Activities of the Federal Government . . . Efforts by Private Corporations . . . Need for Federal Participation . . . The Columbia . . . The Rio Grande . . . The Connecticut and New England . . . The Tennessee

Chapter 2

NATIONAL OBJECTIVES	37
-------------------------------	----

Resources for an Expanding Economy . . . Regional Development and National Strength . . . Deterioration a Threat . . . Existing Legislation Inadequate . . . Statement of Objectives

Chapter 3

UNITY IN PLANNING	43
-----------------------------	----

Local Responsibility . . . Signs of Progress . . . Toward Effective Planning . . . Regional Planning . . . Basins and Groups of Basins . . . The Main Elements . . . General Principles . . . Administrative Aspect . . . State and Nation . . . Coordination at the State Level . . . State and Local Planning . . . Recommendations

Chapter 4

EVALUATION	<i>Page</i> 55
----------------------	-------------------

Interagency Subcommittee Report . . . Effect of Project on Economy . . . Public or Intangible Values . . . Realizable Benefits . . . Regional and National Objectives . . . Elements of Basin Program and Project Evaluation . . . The Technical Aspect . . . The Financial Aspect . . . The Economic Aspect . . . The Public Aspect . . . Functions Are Inseparable . . . Information for Evaluation . . . A Citizen's View . . . Recommendations

Chapter 5

REIMBURSEMENT	67
-------------------------	----

Public and Private Interests Intermingle . . . Objectives of Reimbursement Policy . . . Current Practices . . . Reimbursable and Nonreimbursable Outlays . . . Vendible Products and Services . . . The Subsidy Issue . . . Comprehensive Accounting . . . Reimbursement by Private Beneficiaries . . . Local and State Participation . . . The Federal Government . . . Need for Consistent Policy . . . Recommendations—General . . . Recommendations—Specific Functions . . . Reimbursement Procedure

Chapter 6

A RESOURCES INVESTMENT PROGRAM	87
--	----

Public Investment and Economic Stability . . . Background of Proposed Procedures . . . Coordination at Basin Level . . . Formulation of a Program . . . Justification for Program and Budget . . . Rate of Investment . . . The Cost of Resources Improvement . . . Need for a Resources Investment Program . . . Recommendations

Chapter 7

THE NEED FOR BASIC INFORMATION	97
--	----

River Basin Unit for Information . . . Agencies Which Collect Data . . . Integration of Data With Development Plans . . . Hydrology and Sedimentation . . . Land Management, Runoff, and Erosion . . . Land Classification . . . Social and Economic Information . . . Possible Things to Come . . . Recommendations

Chapter 8

SURFACE AND GROUND WATER . . . 109

The River Basin . . . Storage: The First Principle . . . Storage Begins With the Watershed . . . Joint Management of Land and Water . . . Ground Water Storage . . . The Behavior of Ground Water . . . Importance of Local Factors . . . Regional Possibilities . . . Need for Integrated Program . . . Unseen Reservoirs as Stabilizers . . . We Need More Facts . . . Recommendations

Chapter 9

WATERSHED MANAGEMENT 123

Seriousness of Problem . . . The Community Watershed . . . The Land Reservoir . . . How the Watershed Works . . . Watershed Management Results . . . Raindrops Bombard the Soil . . . Infiltration . . . Evapo-Transpiration . . . Water Storage in the Soil . . . Ground Water Recharge . . . Flood Runoff . . . Management and Total Runoff . . . Erosion . . . Why Wait? . . . Public Lands and Water . . . Mining Operations . . . The Soil Conservation Service . . . The Extension Service . . . The Production and Marketing Administration . . . The Forest Service . . . The Bureau of Land Management . . . Need for Coordination . . . Recommendations

Chapter 10

FLOOD MANAGEMENT 141

The Value of Floods . . . Evolution of Flood Management . . . Magnitude of Flood Control Program . . . Power as a Measure of Conservation Storage . . . Old and New Projects . . . Flood Plain Zoning . . . Flood Forecasting . . . Recommendations

Chapter 11

LAND RECLAMATION 149

Policy Questions . . . Early Development of Reclamation Policy . . . Reclamation Act . . . Extent of Irrigated Agriculture . . . Irrigation Builds the West . . . Extent of Drainage Enterprises . . . Outlook for the Future . . . Present Land Use . . . Productivity Changes . . . Population Trends . . .

Page

The American Diet . . . Future Cropland Requirements . . . Meeting Increased Requirements . . . Increased Yield Required . . . Production Potentials . . . Basis for Decisions on Projects Adding New Farm Land . . . Choice Between Projects . . . Planning and Financing Reclamation Development . . . Acreage Limitation . . . Cost to Federal Government . . . Recommendations

Chapter 12

DOMESTIC AND INDUSTRIAL WATER SUPPLY 175

How Waterworks Grew . . . The Low Cost of Urban Water . . . Increasing Requirements . . . Is Seawater Usable? . . . Purification and Contamination . . . The Need for Nation-wide Reports . . . Metropolitan Water Districts . . . Federal-State-Local Relations . . . Recommendations

Chapter 13

POLLUTION CONTROL 185

Some Case Histories . . . Progress in Control . . . A Serious Waste . . . Effect of Urban and Industrial Growth . . . Industrial Wastes . . . Sedimentation . . . Pollution Abatement and Multiple Use . . . Cost of Pollution . . . Obstacles to Progress . . . Federal Authority Under the 1948 Statute . . . A Task Committee in Search of Byproducts . . . From Sewage to Fertilizer . . . Need for Action . . . Recommendations

Chapter 14

INLAND AND INTRACOASTAL WATERWAYS 197

Importance of Water Transportation . . . Development of Our Waterways . . . Our present Waterways System . . . Adequacy and Economy of our Waterways . . . Savings in Transportation Costs . . . Increasing Benefits . . . Federal Barge Lines . . . Destructive Competition . . . Criticism of Waterways . . . Importance in National Emergencies . . . Passenger Traffic and Recreational Uses . . . User Charges on Waterways . . . Transportation Policy Considerations . . . Necessity for Over-All Program . . . Recommendations

<i>Chapter 15</i>	
	<i>Page</i>
HYDROELECTRIC POWER	219
Policy Questions . . . Our Power Supply . . . Early Development of Federal Power Policy . . . Federal Water Power Act (1920) . . . Hydroelectric Power in River Basin Programs . . . Principles for Marketing Federal Power . . . General Outlines of Federal Power Policy . . . Import of Federal Policy . . . Practical Accomplishments . . . Reductions Reflect Competition . . . Low Rates and Hydroelectric Power . . . Companies in Low Rate Areas Do Well Financially . . . Future Development of Hydroelectric Power . . . Joint Public-Private Effort . . . The Long-Range View . . . Cooperative Utility Responsibility . . . Unified Responsibility for Rates . . . Recommendations	

<i>Chapter 16</i>	
RECREATION	247
Recreation—A Social Goal . . . Vanishing Opportunities . . . What Has Been Done . . . A Look Into the Future . . . A Positive Program . . . Need for a National Policy . . . Recreation in Water Resources Programs . . . Clean Rivers Are Important . . . Shore Lines . . . Use of Ponds . . . Conflicts in Use . . . Recommendations	

<i>Chapter 17</i>	
FISH AND WILDLIFE	259
Federal Responsibilities . . . Wildlife and Water Rights . . . Aquatic Life and Pollution . . . Impoundments and Wildlife . . . Wildlife, Drainage, and Flood Control . . . Land Management and Wildlife . . . Recommendations	

<i>Chapter 18</i>	
CONSERVATION EDUCATION	267
Training for Citizenship . . . Growth of the Conservation Idea . . . The Substance of Conservation Education . . . Three New Concepts . . . Areas of Action . . . Developments in Conservation Education . . . A Good Beginning . . . Teaching Afield . . . Further Teaching . . . A Local Example	

<i>Chapter 19</i>	
LEGAL ASPECTS	277
Constitutional Considerations . . . Navigation . . . Flood Control . . . Irrigation . . . Power and Multiple-Purpose Projects . . . Other Public Purposes	

. . . Related Land Uses . . . Comprehensive Development . . . Comparative Summary . . . The Future . . . Recommendations	<i>Page</i>
--	-------------

Appendix 1

PROCEDURE FOLLOWED BY THE COMMISSION	305
The Commission's Assignment . . . The Commission's Activities . . . Cooperation with Executive Departments and Federal Agencies . . . Getting Ideas from the People . . . Staff . . . Exhibits	

Appendix 2

ACKNOWLEDGMENTS	315
State and Local Governmental Units . . . Associations and Other Organizations . . . Colleges and Universities . . . Federal Agency Personnel . . . Consultants . . . Professional Staff . . . Technical, Administrative, and Clerical Staff	

Appendix 3

REPORT OF THE COMMITTEE ON STANDARDS FOR BASIC DATA	323
Summary . . . Recommendations . . . Introduction . . . Facts, the Basis for Resource Development . . . Relation Between Project Development and Basic Data Collection . . . Basic Physical Data on Water Resources . . . Basic Socio-Economic Data . . . Basic Data Pertaining to Land Classification for Agriculture . . . Basic Data on the Relation of Land Management to Runoff and Erosion	

Appendix 4

EVALUATION OF CONSTRUCTED PROJECTS	385
Constructed Projects . . . Summary of Experience . . . The General Lessons Learned . . . The Specific Lessons Learned	

Appendix 5

DATA PREPARED BY COMMITTEE ON DOMESTIC WATER NAVIGATION PROJECTS AND NATIONAL TRANSPORTATION POLICY	419
Brief Analysis of the Federal Inland Waterway Program . . . Examples of Industries and Communities Benefited by the Provision of Waterways . . . Waterways as Free Public Highways	

ILLUSTRATIONS

<i>Photographs</i> (grouped according to chapters)	<i>Facing page</i>
Chapter 7. The Need for Basic Information	106
Chapters 8-10. Surface and Ground Water, Watershed Management, Flood Management	134
Chapter 11. Land Reclamation	150
Chapters 12-13. Domestic and Industrial Water Supply, Pollution Control	190
Chapter 14. Inland and Intracoastal Waterways	214
Chapter 15. Hydroelectric Power	230
Chapters 16-17. Recreation, Fish and Wildlife	246
Chapter 18. Conservation Education	278

<i>Figures</i>	<i>Facing Page</i>
1. Columbia River Basin—Water Resources and Land Use	23
2. Columbia River Basin—Land and Water Projects	25
3. Rio Grande Basin—Water Resources and Land Use	27
4. Connecticut River Basin—Water Resources and Land Use	30
5. The Tennessee River System	34
6. Comprehensive Development of the Tennessee Valley	45
7. The Hydrologic Cycle	98-99
8. Ground Water Areas in the United States	115
9. Cropland Use	155
10. Population, and Cropland per Capita	155
11. Water Use, Rainfall, Runoff	177
12. Population Change	180
13. Average Annual Precipitation	181
14. Principal Inland Waterways in the United States	206-207
15. Federal Hydro Power Projects	222-223
16. Cost of Electricity to REA Cooperatives	230

<i>Figures</i>	<i>Page</i>
17. Rural Electrification	232
18. Monthly Residential Electric Bills	233
19. Initial Development of Potential Power in New England and New York	234
20. Electric Rate Experience in the Southeast	236-237
21. Electric Rate Experience in the Pacific Northwest	236-237
22. Public and Private Hydro Power Production	239
23. Potential Water Power	241
24. Adequacy of Facilities for Gathering Precipitation Data	337
25. Adequacy of Facilities for Gathering Evaporation Data	338
26. Adequacy of Snow Course Coverage in the West	339
27. Adequacy of Surface Water Stream Gaging Facilities	342
28. Adequacy of Ground Water Data	344
29. Adequacy of Chemical Water Quality Information	346
30. Adequacy of Sediment Load Data	348
31. Adequacy of Reservoir Sedimentation Survey Data	350
32. Status of Topographic Mapping in the United States	356
33. Status of Geologic Mapping in the United States	358
34. Areas Covered by the Soil Survey	359
35. Extent of Soil Conservation Surveys	372
36. Outline of the Land Capability Classification	373
37. Example of a Land Capability Map	374
38. Areas Covered by Land Classification and Irrigation	377
39. Areas of Soil Erosion in the United States	378
40. Average Annual Precipitation of the United States	380
41. Isohyetal Map—Total Storm	381
42. Average Annual Runoff in Inches Depth in the United States	382

TABLES

	<i>Page</i>
CHAPTER 3.—Unity in Planning	
Elements of a water resources plan	47
CHAPTER 6.—A Resources Investment Program	
Federal resources budget, capital	91
Federal resources operation and maintenance program	91
Federal expenditures for water resources development	92
Estimates of future water resources expenditures	93
CHAPTER 9.—Watershed Management	
Amount and rate of infiltration	128
Runoff, percolation and evapo-transpiration under different types of cover	128
Land holdings of Federal agencies	132
Condition of the Public Lands	137

	<i>Page</i>
CHAPTER 11.—Land Reclamation	
Cropland and irrigated acreage in 17 Western States, 1944	152
Total individual income tax revenues from seven Federal reclamation projects	152
Land in occupied farms in drainage enterprises, 1939	153
Total cropland in relation to population, 1910-50	154
Source of calories in the United States diet, 1909-50	156
Difference between adequate diets at moderate and liberal costs	157
Cropland acreage used for various purposes, 1910-50	158
Projected acreage requirements for 1960 and 1975	159
Land suitable for agricultural use which appears feasible for reclamation by flood protection, drainage, and clearing	162
Agricultural production potentials	165

	<i>Page</i>
CHAPTER 12.—<i>Domestic and Industrial Water Supply</i>	
Number and population of cities obtaining water from surface and ground water	176
Estimated industrial water use by major water-using industries, 1947.	178
CHAPTER 14.—<i>Inland and Intracoastal Waterways</i>	
Federal expenditures for river and harbor improvement	199
Commercially active river and harbor projects	199
Mileage-cost scale developed for movements in the lower Mississippi Valley area of commodities moving in carloads or equivalent	204
Annual Federal costs, traffic in ton-miles, and average Federal costs per ton-mile, all rivers, canals, and connecting channels reporting ton-miles, by waterway systems, 1946	215
CHAPTER 15.—<i>Hydroelectric Power</i>	
Charges by private power companies to rural cooperatives in Southeast and Northeast States	229
Charges by private power companies to rural cooperatives in Southwest and West North Central States	229
Cost of wholesale electric power to rural electric cooperatives	231
Developed and undeveloped hydroelectric power in certain rivers of the Northeast and Southeast	233
Rates of return on average net electric plants (areas adjoining TVA).	235
Rates of return on average net electric plants (Pacific Northwest States)	236

	<i>Page</i>
Potential hydroelectric power in the United States	241
APPENDIX 3.—<i>Report of the Committee on Standards for Basic Data</i>	
Basic socio-economic data requirements by types, functions, and stages of development	333
Summary of major deficiencies in basic economic data needed for river basin planning	366
APPENDIX 5.—<i>Data Prepared by Committee on Domestic Water Navigation Projects and National Transportation Policy</i>	
Comparison of traffic and Federal cost for selected waterways	421
Summary and analysis of 15 major inland waterway projects for 20-year period, fiscal year 1929 through fiscal year 1948	425
Cargo	434
Domestic freight traffic in the United States by kinds of transportation	441
Summary of interstate petroleum barge movements	441
Analysis of water-borne traffic on the Ohio River for 1948 and computation of savings	442
Analysis of water-borne traffic on the Illinois waterway for 1948 and computation of savings on existing competitive rate basis	443
Statement of selected commodity movements transported on the Upper Mississippi River and connecting waterways during 1948, showing transportation costs and rates by water and railroad	444

A P P E N D I X

1

**Procedure
Followed by the
Commission**

Procedure Followed by Commission

In completing its report the Commission outlines in this appendix its assignment by Executive order of the President on January 3, 1950, and the means it has followed by communication and conference to obtain the best thinking on the subject of water resources.

To this end the Commission has consulted with laymen, scientists, professional and business men, legislators, and administrators, and held a number of field conferences.

In establishing the Commission, President Truman in a letter to Chairman Morris L. Cooke, dated January 3, 1950, said in part:

Within the past several years the need for careful review and reappraisal of our national water resources policies and related land use problems has become increasingly apparent. On several occasions, during the recent session of Congress, I called attention to the need for developing a consistent and comprehensive policy with regard to our whole water resources program. In many cases, piecemeal or partial approaches to a problem as broad as water resources development tend to confuse, rather than clarify many of the basic, underlying issues. It is essential in my judgment that a comprehensive study and review be made of all existing water resources legislation and policies and that recommendations be made in the full knowledge of national needs and objectives.

Therefore, I am creating by Executive order a temporary Water Resources Policy Commission of seven members to study and to make recommendations to me on the policies which should be followed by the Federal Government in fulfilling its proper responsibilities for the development, conservation, and use of the Nation's water resources.

The Commission's Assignment

Executive Order No. 10095 (see exhibit A), establishing the Commission, directs that it—

... shall give consideration in particular to (a) the extent and character of Federal Government participation in major water resources programs, (b) an appraisal of the priority of water resources programs from the standpoint of economic and social need, (c) criteria and standards for evaluating the feasibility of water resources projects, and (d) desirable legislation or changes in existing legislation relating to the development, utilization, and conservation of water resources.

By the terms of the Executive order, the Commission was to confine its studies and recommendations to policies which should be followed in the water resources field. The proper allocation of functions among agencies, or who is to do what, and related problems of organization, while admittedly closely related to the development of

consistent policies in the field of water resources, had been studied by the Commission on Organization of the Executive Branch of the Government (Hoover Commission) and are now under active consideration in the executive branch and in Congress. The President therefore requested this Commission to confine its recommendations to questions of policy under the four main headings indicated above, together with related legislation. But aside from matters of organization, the Commission's assignment is as broad as water resources and necessarily includes consideration of related land uses. Consequently, the Commission had to come to grips with many major land economic problems.

The Commission's Activities

The Commission worked out a broad program of activities to fulfill its assignment. Obviously, the short time available for preparation of its report precluded any possibility of conducting extensive new research or studies. Even were adequate time available, it is doubtful that this would have been as productive of desired results as were the techniques and procedures which the Commission followed. After all, numerous Federal, State, and private agencies have studied many water resources problems intensely in recent years. But no one agency has brought the various studies, problems, and recommendations together to develop an over-all picture covering the diverse phases of water resources policy involved in an adequate national program.

At its first meeting the Commission decided to open the doors of its discussions to every available angle of public and private opinion. While each of the members of the Commission had professional training and experience bearing on one or more phases of water resources use, it was clear that no seven men could possess all the definite physical and economic information, and the social implications, or marshal the legal capacity required for meeting the President's request.

Consequently, the Commission sought to tap technical, economic, and social knowledge by establishing relations with a great variety of sources. These included the faculties of many colleges and universities, departments of the State and Federal Governments, and their bureaus and specialized agencies. Authorities in physical science, including agronomists, chemists, entomologists, ecologists, geologists, and hydrologists were brought into the councils of the Commission. Outstanding individuals in the social sciences, including economists, political scientists, and sociologists, were consulted. The Commission also con-

sulted engineers in many fields, including chemical, civil, electrical, hydraulic, mechanical, mining, and sanitary State, county, and local public officials and numerous national, State, and local associations devoted to irrigation, forestry, soils, flood control, conservation, and waterway developments were contacted, as well as business associations such as State and local chambers of commerce.

Private and public power associations and trade associations in various industries were asked to give the Commission the benefit of their knowledge. The Commission had the active interest of farm groups—the Farm Bureau Federation, the National Grange, and the Farmers Union; and of labor unions—the national bodies of the Congress of Industrial Organizations and the American Federation of Labor, and numerous affiliated locals. The Commission was fortunate in having consultations and conferences with Members of Congress who have had long and enlightening experience in water resources legislation.

The Commission wrote the governors of each of the States explaining its assignment and invited them or any of their State agencies to make suggestions and recommendations (see exhibit B) in the field of water resources policy. A letter was also sent to the attorney general of each State, asking that he furnish the Commission with a report on the water laws of his State and of the judicial decisions interpreting such laws.

More specifically, the Commission prepared a general outline of the field to be covered and sent it to agencies throughout the country interested in water resources. This went to some 800 public and private agencies, including water users associations, municipal water departments, public utility associations, State agencies such as water conservation boards and State engineers offices, interstate compact commissions, farm, business, and labor organizations, development associations, and many others.

The Commission prepared a set of 18 major questions on various phases of water resources policy and sent it to the presidents of 80 universities and colleges (see exhibit C, "Questions Relating to Water Resources Policies"), including every land grant college or university in the Nation, and others both public and private where some of the departments or staff had shown special interest in water problems, or had given consideration to the subject in their teaching or research programs. The presidents were requested to refer the questions to members of their faculties interested in and qualified to consider them and to let the Commission have the benefit of their individual and group thinking. Some of these questions were also included in a letter sent to the directors of each of the State agricultural experiment stations requesting their views and ideas. The Commission also sent the same set of questions to the Engineers Joint Council (Joint Committee of the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Institute of Electrical Engineers, American Institute of Chemical Engineers, and American Society of Mechanical Engineers).

More than 600 returns, many of them running into hundreds of pages, were secured by the Commission, with numerous helpful suggestions, ideas, and recommendations. The Commission asked a group of 15 leading economists and sociologists to consult with it for several days concerning the over-all program of work and the

major phases of water resources policy which should be analyzed.

Cooperation With Executive Departments and Federal Agencies

The Commission requested personnel from certain Federal departments or agencies to assist it in its work. A liaison staff member in each of these departments assisted in working out assignments with the Commission. Personnel were assigned to the Commission's work by the Department of Agriculture: Office of the Secretary, Soil Conservation Service, United States Forest Service, Bureau of Agricultural Economics, Bureau of Plant Industry, Production and Marketing Division, and Rural Electrification Administration; Department of the Army: United States Corps of Engineers; Department of the Navy: Bureau of Yards and Docks; Department of Commerce: Office of the Assistant Secretary, Bureau of Foreign and Domestic Commerce, Bureau of Public Roads, Transportation Division, Weather Bureau, and the Coast and Geodetic Survey; Department of the Interior: Office of the Secretary, Bureau of Reclamation, Bureau of Land Management, Oil and Gas Division, Bonneville Power Administration, Fish and Wildlife Service, and Geological Survey; Federal Security Agency; United States Public Health Service and Office of Education; Treasury Department: United States Coast Guard; Executive Office of the President; Bureau of the Budget and the Council of Economic Advisers; Department of Justice; Federal Power Commission; Interstate Commerce Commission; and Tennessee Valley Authority.

The Commission requested these agencies to give it a statement of interpretation of their responsibilities under existing statutes for water resources development programs in the Nation. This request is shown in exhibit D, "Federal Agency Responsibility for Water Resources Development." The Commission also requested these agencies to furnish it with reports covering their plans and programs in 12 of the major river basins of the country.

Getting Ideas From the People

In addition to the opinion of the expert, the Commission sought the opinion of the nonspecialist and the people generally. The Commission held public conferences in eight cities located in widely separated areas—Sioux City, Iowa; Spokane, Wash.; Berkeley, Calif.; Denver, Colo.; Fayetteville, Ark.; Columbus, Ohio; Springfield, Mass.; and Atlanta, Ga.

More than 2,000 people attended the regional conferences and some 500 individuals expressed themselves on various phases of water resources development programs and policies. Everyone who wanted to talk had an opportunity to do so, and all were invited to present written statements of their views. These conferences gave the people the opportunity to talk with the Commission members and gave the Commission members an opportunity to find out what the people in different sections of the country thought about water resources development problems and policies. Out of these conferences came numerous suggestions, ideas, and recommendations which helped the Commission get a comprehensive picture of the Nation's water resources problems.

Staff

In addition to the staff loaned it by Federal departments and agencies, the Commission recruited a small staff of its own from college and university staffs, State and local governments, and private life. The Commission divided its work into 12 major divisions and assigned committees, consisting of members of its own staff as chairmen and those loaned to it by Federal agencies, to prepare extensive reports on each of these major phases of water resources policy. These committees covered the following fields: (1) Evaluation of selected typical water resources projects already constructed to furnish a guide to future project selection policy; (2) objectives of water resources projects, coordination of planning, and project selection; (3) determination of the minimum essential background information necessary for sound planning of river basin projects and programs; (4) formulation of acceptable principles and procedures for determining benefits and costs of water resources projects; (5) project reimbursement; (6) water resources policies involving land use economics, particularly agricultural lands; (7) Federal power policy; (8) recreation and water resources; (9) inland water navigation projects and national transportation policy; (10) domestic and industrial water supply; (11) major river basin program analysis; and (12) water resources law.

The chairman of each of these committees, together with the full-time Commissioner in Charge of Studies, constituted a general committee to analyze over-all water resources policies. Other members of the Commission were assigned special phases of water resources policy and worked with the specific committees dealing with these phases. In the late summer the Commission analyzed the committee reports and recommendations and prepared the general report (Vol. I). The Commission through this procedure came to grips with each of the significant problems of national water resources policy, and after thoroughgoing consideration reached general unanimity in the major recommendations and conclusions presented in this report.

EXHIBIT A

Executive Order 10095

ESTABLISHMENT OF THE PRESIDENT'S WATER RESOURCES POLICY COMMISSION

By virtue of the authority vested in me as President of the United States, it is ordered as follows:

1. There is hereby established in the Executive Office of the President a Commission which shall be known as the President's Water Resources Policy Commission, and which shall be composed of a Chairman and six other members to be designated by the President.

2. The President's Water Resources Policy Commission shall study, and make recommendations to the President with respect to, Federal responsibility for and participation in the development, utilization, and conservation of water resources, including related land uses and other public purposes to the extent that they are directly concerned with water resources. The Commission shall give consideration in particular to (a) the extent and character of Federal Government participation in major

water-resources programs, (b) an appraisal of the priority of water-resources programs from the standpoint of economic and social need, (c) criteria and standards for evaluating the feasibility of water-resources projects, and (d) desirable legislation or changes in existing legislation relating to the development, utilization, and conservation of water resources.

3. All executive departments and agencies of the Federal Government are authorized and directed to cooperate with the Commission in its work and to furnish the Commission such information and assistance as it may require in the performance of its duties.

4. Each member of the Commission shall receive such compensation as the President may specify, and while away from his home or regular place of business, and engaged in the official business of the Commission, shall receive actual traveling expenses and per diem allowances in lieu of subsistence in accordance with the rates established by the Standardized Government Travel Regulations, as amended.

5. During the fiscal year 1950, the compensation of the members of the Commission (including traveling expenses and per diem allowances) and the expenditures of the Commission shall be paid out of an allotment made by the President from the appropriation appearing under the heading "Emergency Fund for the President" in the Independent Offices Appropriation Act, 1950 (Public Law 266, approved August 24, 1949); and during the fiscal year 1951 such compensation and expenditures shall be similarly paid from any corresponding or like appropriation made available for the fiscal year 1951. Such payments shall be made without regard to the provisions of section 3681 of the Revised Statutes (31 U. S. C. 672), section 9 of the act of March 4, 1909, 35 Stat. 1027 (31 U. S. C. 673), and section 213 of the Independent Offices Appropriation Act, 1945 (58 Stat. 387), and without regard to such other provisions of law as the President may hereafter specify.

6. The Commission shall submit its final report to the President not later than December 1, 1950.

HARRY S. TRUMAN.

THE WHITE HOUSE,
January 3, 1950.

EXHIBIT B

THE PRESIDENT'S
WATER RESOURCES POLICY COMMISSION,
Washington, D. C., March 6, 1950.

MY DEAR GOVERNOR -----

This Commission has been set up by President Truman to make a report to him on water resources policy on or before December 1, 1950. For your information I am enclosing a copy of the White House release announcing the appointment of the Commission and outlining its task. You will note that we are relieved of any consideration of organizational matters and asked to give attention to:

- (a) the extent and character of Federal Government participation in major water-resources programs,
- (b) an appraisal of the priority of water-resources programs from the standpoint of economic and social need,
- (c) criteria and standards for evaluating the feasibility of water-resources projects, and
- (d) desirable legislation or changes in existing legislation relating to the development, utilization, and conservation of water resources.

The Commission has asked that you be advised as to our assignment. Further we invite any suggestions you may care to make as to the conduct and range of our

inquiries. We are particularly anxious to know of special water problems affecting your State which should be included in our inquiries.

It is entirely possible that through the good offices of Mr. Frank Bane, and otherwise, we may be in process of hearing from specialized agencies of your State government. But the Commission is desirous that you as head of the State should know something of our plans and of our great desire to have our work made of benefit to the people of your State.

With assurances of my high regard, I am

Yours very sincerely,

MORRIS L. COOKE, *Chairman.*

Enclosure.

EXHIBIT C

THE PRESIDENT'S WATER RESOURCES POLICY COMMISSION

QUESTIONS RELATING TO WATER RESOURCES POLICIES

(1) *Multiple-purpose projects—economic justification.*—To determine the economic justification of a project such as a multiple-purpose dam and reservoir, the following general principles have been suggested: (a) total benefits, to whomever they may accrue, should be greater than total costs; (b) the benefit-cost ratio of any single purpose for which development is undertaken should be greater than the ratio for any alternative means of achieving the same purpose; (c) existing projects should be enlarged in respect to any and all purposes to the extent that incremental benefits exceed incremental costs.

Are these general principles adequate for the determination of the economic justification of a project? If not, what changes would you suggest?

(2) *Reimbursable and nonreimbursable costs.*—With regard to water development projects in this country, expenditures for certain purposes (e. g., power) have come to be thought of as reimbursable by the beneficiaries or users, expenditures for certain purposes partially reimbursable (e. g., irrigation), and expenditures for certain other purposes nonreimbursable or to be paid for out of the Federal Treasury (e. g., flood control and navigation). Recently, proposals have been made to add to the number of nonreimbursable purposes to which allocations of costs may be made by including such purposes as national defense, general welfare, recreation, improvement in public transportation, sediment control, and public health. Obviously, the more of the cost that can be written off to nonreimbursable elements, the less has to be repaid by particular beneficiaries.

What economic and social principles should govern in this matter? Would you favor permitting allocations to additional nonreimbursable purposes in considering costs to be borne by beneficiaries or users of water development projects? If so, which nonreimbursable items would you recommend be added, and why? How would you determine the value to be placed upon each?

(3) *Use of surpluses to pay subsidies.*—At present all Federal irrigation projects are subsidized to the extent that interest on project investment is not included in the annual costs which must be balanced by estimates of benefits. Furthermore, in accordance with ability-to-pay determinations, most users of water for irrigation pay less than the amount allocated to that purpose on an interest-free basis, the balance of the allocated irrigation costs being defrayed, so far as possible, from surplus revenues yielded by power sales over and above the costs allocated to power at the multiple-purpose dam and reservoir projects. Complicating this matter is the opinion of the

Solicitor of the Department of the Interior permitting the interest component on the power investment, which is collected through power revenues, to be applied toward the repayment of the irrigation costs.

Should direct interpurpose transfers or subsidies of this kind be continued? Or should surpluses collected from any group of users be either eliminated by reduction in rates or covered into the Federal Treasury with necessary subsidies paid from the Federal Treasury? What steps should be taken to identify clearly the nature and amount of such transfers? Should the interest component be treated differently from other elements of cost? If so, why and in what way?

(4) *National versus regional interests.*—The preceding question, along with many others, leads into the issue of national versus regional interests in river basin projects and programs. Without sacrificing growth, it is desirable to promote greater balance and stability nationally. It is also desirable to promote balance and stability in the major regions of the country. Conflicts between national and regional economic judgments arise with regard to water development projects and programs as with other government activities. As an example, in terms of national economic considerations and the national pattern of location of economic activities, it may be preferable to obtain additional agricultural output from new land reclaimed by drainage or from more intensive cultivation of those areas already mature and highly productive in agriculture, rather than by irrigation of arid land in the less developed areas. Likewise, it may be preferable from a national economic viewpoint to locate additional industrial operations in the already congested but highly productive areas in the East and Midwest. From a regional point of view, however, having in mind the desirability of encouraging industrial and high-value agricultural growth in certain parts of the country whose economies suffer from the lack of such development, it may be most important to locate such activities in these less developed parts of the country, such as the West and South. Economic stability in such regions and the increase in economic welfare may depend largely upon additional activities of this kind. In addition to economic reasons for increasing regional stability and growth there may be compelling social, military security, and other reasons.

What considerations should be uppermost in reconciling or compromising national with regional concerns, particularly as they relate to water development projects and programs? How may these interests, which frequently seem to conflict, be reconciled? In what ways may the desirability of decentralization for social, national security, and other noneconomic reasons be taken into account? What principles should control the balancing of regional and national interests?

(5) *Irrigation versus industrial demand for water.*—In many river basins competition for limited supplies of water is developing between major potential uses. More specifically, in areas in which irrigation has been recognized as having a primary claim on available water, after domestic water supply, newer industries in the metallurgical and chemical fields, and especially proposals to supplement our waning petroleum reserves with large synthetic liquid fuel production, are presenting demands for water which could only be met at the expense of expansion of irrigation.

What principles might be invoked to resolve or compromise this conflict? What determining conditions do you expect to be different in the future as compared to the past? What social or economic standards might be set up as guides for periodic and systematic reappraisals of the relative values of such competing claimants on a given supply of water? From this long range point of

view should agricultural use of water, assuming that the land in question is adapted to irrigation, take precedence? What are the assumptions underlying your answers?

(6) *Rate of interest and payoff period.*—The economic justification of most water projects, involving large capital expenditures, hinges in large measure upon the rate of interest to be charged and the number of years allowed for paying off the investment. At present, interest and pay-out practices vary among the various Federal water development agencies. These questions are important from the point of view of repayment, as well as basic economic justification.

Should definite standards be established covering the interest rate and the pay-out period? If so, what should these principles or standards be? Should they be applied retroactively?

(7) *Upstream versus downstream interests.*—Considerable conflict has arisen in many river basins between the upstream and the downstream interests. In the West, those in the upper portions of river basins have been more interested in land reclamation and irrigation; upstream flood control; and upstream forest, range, and agricultural land conservation. Those in the lower portions of the basins have been more concerned with river navigation and flood control by means of dams, reservoirs, levees, diversion channels, and the like. These seemingly conflicting interests have to be reconciled in both engineering plans and budgets. The problem is partly one of making comparisons of the economic value of water used, controlled, or handled in one way as compared to other ways.

These differences in treatment appear to persist in spite of the fact that the natural unity of the whole basin is a widely recognized principle.

Can economic analysis be utilized to reduce the conflict between upstream and downstream interests and to point toward integrated and balanced total basin programs before wasteful projects, whatever they are, become crystallized? If so, please explain how.

(8) *Hydroelectric power policy.*—Certain policies have evolved with respect to the marketing of hydroelectric power from Federal river basin projects. These policies generally include the sale of power at the lowest possible rates consistent with the recovery of operating and fixed charges, including amortization of costs allocated to power over a fixed period with interest; construction and operation of basic transmission facilities by the Federal Government where necessary to assure resale of the power on a basis contributing to more widespread use of electricity for regional development and higher standards of living; and preference to public bodies and cooperatives, as distributing agencies to implement this objective. In connection with certain projects, however, these policies are modified, either by change in allocation, use of interest, or otherwise, to provide excess power revenues for other basin purposes.

Should these policies be reexamined? What changes in them would you suggest? Where power revenues are in excess of those necessary to return properly allocated costs, should the rates be reduced in order to stimulate increased consumption of electricity? Should consideration be given to establishing especially low rates for hydroelectric power to encourage its use as an alternative to power generated from nonreimbursable resources such as oil and natural gas? To what extent should sale of power from Federal projects at low rates provide a competitive influence on rates charged by the private power industry? Where necessary to implement its power policy should the agency responsible for marketing the power be authorized to construct steam-generating stations?

(9) *Can benefits be assessed and paid for equitably?*—Federal Government policy and practice with regard to reimbursability on the part of similar groups of benefi-

ciaries are not now consistent. Irrigation farmers receiving water from Federal projects are required to repay the costs allocated to irrigation to the extent of their ability. Farmers on flood plains receiving protection from Federal flood control projects or those benefiting by drainage projects, as a general rule, are not required to pay anything for such protection. In each case, the value of the farm land and the annual income of the farmers over a period of years are increased because of the Federal project.

Partly this question involves the issue of identifying local and individual responsibilities for Federal expenditures from which they benefit and the ways and means of levying the necessary charges. One way of making it possible for local beneficiaries to defray a suitable portion of the costs is by means of local water user or conservancy districts authorized by State law to appraise certain benefits and levy charges.

How may these inconsistencies be eliminated? Can you list other means of assessing local benefits received so that specific charges could be levied against them? Please indicate which means you believe to be most desirable.

(10) *How should benefits be estimated?*—Federal practices in estimating benefits from water development projects vary considerably from agency to agency. For instance, in justifying irrigation projects, various indirect benefits are taken into account including the estimated increase in income resulting from increased general business associated with the new irrigation crop production. In the case of justification of many power projects, or the power portion of multiple-purpose programs, the estimate of benefits is much more narrow. In most instances, the increase in industrial production which may be attributable to the increased power supply is not considered.

Is it desirable to continue such diversified methods of estimating benefits? If it is not desirable, what suggestions would you have for altering the estimating methods so that benefits from water used for irrigation may be compared with the benefits from water used for power? Particularly how may the indirect or the secondary and subsequent beneficial effects be taken into account?

(11) *Food surpluses and new land.*—There has been a good deal of criticism to the effect that it is unsound to spend large sums to irrigate and bring into production new land or to increase the production from old land by this method when we already are forced to pay hundreds of millions of dollars to farmers in the form of price supports, particularly when some of the new land will probably be used for crops such as potatoes which already have to be dumped or destroyed as surplus.

How may long-range requirement goals, which will necessitate increased production of most agricultural crops, be reconciled with such short-range phenomena as the potato surplus? What bearing does this have upon water policies and agriculture?

(12) *Consideration of long-range need for agricultural production.*—For the long range there undoubtedly will be a need for additional agricultural production. This need may be met in a number of ways, including land reclamation by irrigation, drainage, or clearing; increased use of fertilizers and farm machinery; improvements in seed and various agricultural practices; increased imports; and other ways. Several of these methods directly involve water use or control; the others are competing alternatives. At present we have no systematic way of determining the economic desirability of increasing agricultural production by one as compared to another method.

What suggestions can you make for improving our practice in this regard, so as to make possible economic comparisons of benefits and costs of increasing agricultural production by different means? What general considera-

tions or principles should be utilized in attempting to make such comparisons? How will each affect national water policy? Please cite any illustrations of present measurement practices which you know to be working well.

(13) *Inland waterways and freight rates.*—Many feel that the chief purpose served by much of our river navigation improvement work is to provide a yardstick for, or bring about reductions in, railway freight rates. Development of water-borne trade as a result of such improvements is envisaged as an objective only to the extent necessary to accomplish that end. In certain instances lower rail rates have become effective as a result of such improvements, while in others proposed reductions have not been viewed with favor by the Interstate Commerce Commission. As an example of this approach many feel that the channel improvements, embodied in the so-called Pick-Sloan program for the Missouri River, have as their main purpose, not so much to develop river traffic, as to exert a downward pressure upon railway freight rates.

In addition to this yardstick question, which Federal navigation undertakings share with Federally developed power, there is another and probably more basic question. It is to determine the proper economic place of inland waterway transportation in the total transportation system of the nation. More specifically, it is to formulate principles to guide public expenditures and actions in this field.

Is it sound national policy to utilize inland waterway projects to secure lower rail rates? Do you believe that it can be effective? Can regions where opportunity for inland waterway transportation is available depend upon regulation of rail rates to accomplish the same objective? What specific changes in principles or their application affecting appraisal of waterway projects would you propose? Would it be possible to integrate a program for improving the nation's waterways into a sound coordinated transportation program designed to serve the public interest on a long-range basis? Along what lines would you suggest that this integration be worked out?

(14) *Inland waterways and tolls.*—Another question relating to navigation concerns the charging of tolls. The traditional policy is to provide free use of improved inland waterways with channel improvements paid for out of the Federal Treasury. It is now suggested that the cost of major navigation improvements on the St. Lawrence International Waterway be recovered by levying tolls against freight. Tolls are charged on shipments through the Panama Canal.

What are your views on this question of tolls? What economic or other considerations should govern in any policy decisions with regard to tolls? Is a mixed policy of tolls on certain waterways whose traffic will bear a toll and no tolls on other waterways desirable? If so, how would you formulate the necessary principles?

(15) *Adjustment of water resources policy to diminishing justification ratios.*—The tendency has been to construct those water resources projects for flood control, irrigation and navigation which have the highest ratios of benefits to costs under existing standards. The projects remaining for future construction, therefore, are likely to offer lower justification ratios. The time has already arrived when few new projects could be justified on the basis of the more limited benefits considered during earlier stages of development of the country's water resources.

The question is: should our water resources programs be allowed to taper off short of economically and socially desirable goals because of failure to meet older benefit and cost standards; or should we seek new lines of justification warranting continuation of otherwise desirable programs which will result in fuller utilization of water?

Does the present situation indicate that current prac-

tice fails to take long range, social factors sufficiently into account? We should like your comments on this issue.

(16) *Reservoir projects—conservation storage versus agricultural land.*—The portion of river basin programs which can be carried out only by the construction of dam and reservoir projects necessarily involves the flooding of lands. This, in turn, involves provision of conservation storage to control and improve stream flows for many purposes as well as provision of the necessary heads for development of hydroelectric power. Improvement of stream flow may be an important factor in pollution abatement, water supply, recreation and improvement in conditions for fish and wildlife. Availability of hydroelectric power offers the possibility of regional economic development. But, in many localities, there is strong opposition to construction of such reservoir projects because they involve the permanent elimination of agricultural lands and the consequent destruction of specific community values.

The question is whether it is possible to arrive at a reasonable comparative economic and social evaluation of the gains as against the losses from any specific project of this kind in order to determine whether it should be authorized. Can you suggest any guiding economic or social principles to follow?

(17) *Water resources projects and the business cycle.*—As with other public construction programs, expenditures on water resource projects have a definite bearing on economic stability in the business cycle sense. During the 1930's numerous such projects were undertaken largely in an effort to provide employment, increase incomes and purchasing power, and restore prosperous economic conditions. Economists and others recognize the importance of timing, sequence, magnitude, location, employment characteristics, and rate of acceleration of the various types of water resource projects and activities in determining their effect on the business situation. The need for advance planning is also recognized. At the same time there is much to the argument that public works expenditures contribute most to economic stability by being carried on steadily on a basis of genuine long-range needs without regard to business cycle considerations. For investments in water resources projects this argument may have special force since expenditures for these are not readily accelerated and decelerated.

Should the undertaking of such projects be integrated with monetary, fiscal, and other antidepression governmental measures? If so, what factors do you consider most important in determining the extent to which and the manner in which water resources should be scheduled for anticyclical purposes? How would you formulate policy statements to cover this issue? Should economic stabilization benefits be taken into account in determining the feasibility or desirability of a project? If so, in what ways? Should the weight given economic stabilization benefits be increased during periods of widespread unemployment?

(18) *The issue of the 160-acre limitation.*—In keeping with our traditional policies favoring individual farmer-owned farms and opposing farm-land speculation, Reclamation Law limits the size of Federally aided irrigation farms to 160 acres per individual. It is claimed that in certain areas of the country efficient farm management and operation, taking advantage of modern technical and other improvements, would require more than 160 acres per individual farm. It is claimed further that in certain semiarid areas in which economic farm units include some acres under irrigation, plus a much larger number in range, units of more than 160 acres are necessary for profitable agriculture. The fact that farmer beneficiaries from projects constructed or operated by other agencies than

the Bureau of Reclamation are not bound by the 160-acre limitation creates another serious problem.

Should the 160-acre limitation be modified? If so, in specific terms how should it be made flexible? What standards should govern any exceptions to the present limitation? Would you favor uniformity in this matter among the relevant Federal agencies? Why or why not?
MARCH 17, 1950.

EXHIBIT D

THE PRESIDENT'S WATER RESOURCES
POLICY COMMISSION,
718 EIGHTEENTH STREET NW.,
Washington 25, D. C., March 20, 1950.

AGENCY REPORTS—LEGAL

Please prepare separately each of the following eight reports, in the form specified at the conclusion of the listing, and submit each report as soon as completed in tentative form:

I

(Name of Agency)

Water-Resources Responsibility and Participation

A brief, narrative statement of each of your agency's responsibilities for, and participation in:

- (a) Development of water resources.
- (b) Utilization of water resources.
- (c) Conservation of water resources.
- (d) Land uses related to development, utilization, and conservation of water resources.
- (e) Other public purposes to the extent that they are directly concerned with water resources.

II

(Name of Agency)

Analysis of Water Resources Authority

A sectional analysis of each statute and executive or administrative order imposing a responsibility upon your agency or authorizing its participation in any of the categories specified in I above, omitting those sections unrelated to your agency's responsibility or participation. At the end of each statutory section analyzed, state within parentheses the date of the act of Congress, and also the citation to the United States Statutes or Revised Statutes and the United States Code; include like references for amendments. In the case of executive or administrative orders, state within parentheses complete identifying data and attach copies if feasible. In the left margin and opposite the first line of each section analyzed, indicate by letter or letters within parentheses the category or categories (a), (b), (c), (d), or (e), set forth under I above, in which such section belongs.

III

(Name of Agency)

Legislative History of Water Resources Authority

A detailed legislative history of each statute or portion thereof, including all amendments, which imposes a responsibility upon your agency or authorizes its participa-

tion in any of the categories specified in I above. Include supporting references to hearings, committee reports, debates, and other relevant matter. Spell out clearly the ascertainable considerations leading to enactment of the legislation discussed, detailing the reasons for congressional adoption of the policy established by such legislation.

IV

(Name of Agency)

Water Resources Conflicts and Duplications

A full specification, with appropriate citations, of each conflict and duplication between the responsibility and participation of your agency, in the categories specified in I above, and those of any other Federal or State agency. Place emphasis upon any such conflict or duplication which even tends to impair or preclude consistency in federal water resources policy, for example, a conflict in responsibilities creating or accentuating differences in criteria and standards for evaluating feasibility of projects.

V

(Name of Agency)

Water Resources Authority and State Law

A thorough discussion of all state statutes and judicial decisions which have either aided or impeded fulfillment by your agency of its water resources responsibility and participation in any of the categories specified in I above. Include a discussion of action taken or attempted by your agency, independently or in cooperation with others, to avoid or overcome impediments resulting from state law, whether statutory or resulting from judicial decision.

VI

(Name of Agency)

Judicial Views on Water Resources Authority

An analysis of all judicial decisions having significance in determining or interpreting the scope of statutory or other provisions which impose responsibility upon, or authorize participation by your agency in any of the categories specified in I above.

VII

(Name of Agency)

Water Resources Policy

A comprehensive but concise statement of the Federal water resources policy sought to be achieved through fulfillment of your agency's responsibilities or participation in any of the categories specified in I above.

VIII

(Name of Agency)

Miscellaneous

Outline special legal problems encountered by your agency in connection with its responsibility or participation in any of the categories specified in I above and which you deem appropriate for inclusion in the studies

to be made by the Commission. Also, the Commission will welcome your suggestions respecting any of the legal aspects of its efforts directed toward development of a consistent and comprehensive Federal water-resources policy. In this connection, it will be observed that organizational problems are not within the purview of the Commission's assignment.

SPECIFICATIONS FOR PREPARATION OF REPORTS

The Commission will appreciate receiving 25 copies of each of the foregoing reports as soon as each is completed in tentative form, and prepared in accordance with the following specifications:

- (a) Number and title of each report to conform to the number and underscored headings in the above listing.
- (b) Mimeographed on 8 x 10½ white paper.

(c) To be typed double spaced excepting quoted material, which is to be single spaced.

(d) Margins: top and bottom, 1 inch; right, 1¼ inches; left, 1½ inches.

(e) Each report to be numbered separately beginning with page 1, and page numbers to be typed in the center of the bottom margin.

(f) Each report to be stapled separately in the extreme upper left corner.

(g) At the end of each report, set forth the name of each person preparing the report and of each person reviewing it, together with the telephone code and extension for each.

(h) Inquiries addressed to the Commission concerning these reports should be marked for attention of Bernard A. Foster, Jr. (Executive 3300, Government Code, 189, Extension 737 or 791).

A P P E N D I X

2

Acknowledgments

Acknowledgments

The Commission gratefully acknowledges the assistance rendered by many public and private agencies, groups, and individuals. It is impossible to list all of them here, but the following have contributed data, suggestions, or recommendations on various phases of water resources policy. The Commission is especially grateful to its staff for its fine cooperation and effective work in the preparation of the report. The Commission is, of course, solely responsible for the interpretations, conclusions, and recommendations presented.

State and Local Governmental Units

Alabama: Executive Office, Attorney General, and State Planning Board. Arizona: Executive Office, Corporation Commission, Fish and Game Commission, Interstate Stream Commission, Power Authority, State Land Department, and Office of the Mayor of Phoenix. Arkansas: Resources and Development Commission, Office of the Attorney General, and State Board of Health. California: Executive Office, Office of the Attorney General, Colorado River Board of California, Department of Health, Department of Public Works, Fish and Game Commission, Office of the Mayor of San Diego, San Diego Water Department, Office of the Mayor of San Francisco, Regional Water Pollution Board, State Soils Conservation Commission, Imperial County Health Department, Office of the Mayor of Los Angeles, Los Angeles Department of Health. Colorado: Department of Law, Game and Fish Department, Water Conservation Board.

Connecticut: Executive Office, Department of Health, State Water Commission. Delaware: State Board of Health. Florida: Attorney General, Game and Fresh Water Fish Department, State Board of Conservation, State Board of Health. Georgia: Executive Office, Attorney General, Forestry Commission, Public Service Commission, Office of the Mayor of Atlanta. Idaho: Executive Office, Attorney General, Department of Fish and Game, Department of Public Health, Department of Reclamation. Illinois: Executive Office, State Water Resources and Flood Control Board, in cooperation with other State agencies concerned with water resources problems, Mayor of the city of Decatur. Indiana: Attorney General, Flood Control and Water Resources Board. Iowa: Department of Health, Natural Resources Council for the State Conservation Commission, Office of the Mayor of Sioux City. Kansas: Executive Department, Attorney General, State Board of Health, Topeka Board of Commissioners.

Kentucky: Department of Conservation, Department of Health, Agricultural and Industrial Development Board, Agricultural Problems Board. Louisiana: Attorney General, Department of Health, Department of Conservation. Maine: Executive Office. Maryland: Board of Natural Resources, Water Pollution Control Commission, Department of Geology, Mines and Water Resources, State Planning Commission. Massachusetts: Executive Office, Attorney General, Department of Public Works, Department of Conservation, Department of Public Health, State Planning Board, Merrimack River Valley Sewerage Board, Holyoke Municipal Plant.

Michigan: Water Resources Commission, State Department of Agriculture. Minnesota: Executive Office, Department of Conservation, Division of Game and Fish, Port Authority of St. Paul. Mississippi: State Highway Department. Missouri: Executive Office, Office of the Attorney General, Missouri Division of Resources and Development, Office of City Manager of Kansas City, Chief Sanitary Engineer of the Environmental Sanitation Service.

Montana: Executive Office, Attorney General, Fish and Game Commission, State Water Conservation Board. Nebraska: Executive Office, Department of Justice. Nevada: Executive Office, Department of Attorney General, Office of State Engineer. New Hampshire: Forestry and Recreation Commission, Water Pollution Commission, Water Resources Board, Fish and Game Department. New Jersey: Department of Conservation and Economic Development, Department of Health, Department of Law and Public Safety. New Mexico: State Game Commission, State Engineer, Resources Development Board, Economic Development Commission.

New York: Conservation Department, Department of Commerce, State Board of Health. North Carolina: Executive Office, Department of Justice, Department of Conservation and Development, State Board of Health, Wildlife Resources Commission. North Dakota: Executive Office, State Department of Health, State Game and Fish Department, State Water Conservation Commission.

Ohio: Water Resources Board. Oklahoma: Planning and Resources Board, State Department of Health. Oregon: Chief Executive's Natural Resources Advisory Committee, Department of Justice, State Game Association, Fish Commission, Eugene Water and Electric Board. Pennsylvania: Executive Office, State Planning Board. Rhode Island: Port and Industrial Development Commission, Department of Health, Department of Public Works. South Carolina: Department of Health, Public Service Authority. South Dakota: Executive Office, Office of the Attorney General, Department of Game,

Fish and Parks, State Geological Survey, Office of State Engineer.

Tennessee: Executive Office, Department of Conservation, State Planning Commission, Memphis Light, Gas and Water Division, Office of the Mayor of Nashville. Texas: Executive Office, Department of Health, Water Conservation Commission, Water Code Committee, Board of Water Engineers, Office of the Mayor of Amarillo, Office of the Mayor of Houston. Utah: Attorney General, Fish and Game Commission, Office of State Engineer. Vermont: Executive Office, Attorney General, State Water Conservation Board, Water Resources Commission. Virginia: Department of Conservation and Development, Attorney General, Division of Planning and Economic Development, State Board of Health, State Water Control Board. Washington: Department of Conservation and Development, Department of Health, Department of Fisheries, Department of Game, Pollution Control Commission, Tacoma Department of Public Utilities, City of Seattle Department of Lighting.

West Virginia: Office of Attorney General, State Planning Board. Wisconsin: Executive Office, Consolidated Report of State Agencies, State Planning Board, Office of the Mayor of Milwaukee, Milwaukee Department of Public Works. Wyoming: Executive Office, Attorney General, State Engineer, State Planning and Water Conservation Board, Department of Public Health, Upper Colorado River Commission. Alaska: Department of Health Development Board. Hawaii: Executive Office, State Board of Health. Puerto Rico: Planning, Urbanizing and Zoning Board.

Associations and Other Organizations

Alabama State Chamber of Commerce, American Chemical Society, American Fisheries Society, American Merchant Marine Institute, American National Livestock Association, American Planning and Civic Association, American Paper and Pulp Association, American Public Health Association, American Public Power Association, American Railways and Water Committee Association, American Society of Civil Engineers, American Society of Heating and Ventilating Engineers, American Watershed Council, American Waterways Operators, American Water Works Association.

Arizona Game Protective Association, Arkansas Basin Development Association, Arkansas River Basin Association, Associated Drilling Contractors Association, Associated Missouri Basin Conservationists, Association of Washington Irrigation Districts, Association of Western State Engineers, Atlanta (Ga.) Chamber of Commerce, Atlanta (Ga.) Freight Bureau, Atlantic States Marine Fisheries Commission, Audubon Society, Banta-Carbona (Calif.) Irrigation District, Bellingham (Wash.) Chamber of Commerce, Bonner County (Idaho) Sportsmen Association, Brandywine Valley (Pa.) Association.

Brotherhood of Locomotive Firemen and Enginemen, Butte (Mont.) Chamber of Commerce, California Farm Bureau Federation, California Farm Research Legislative Commission, California Irrigation District Association, California Municipal Utilities Association, California State Chamber of Commerce, Central Colorado River Authority, Central Rural Electric Cooperative, Chamber

of Commerce of the United States, Cheyenne (Wyo.) Chamber of Commerce, Cleveland (Ohio) Chamber of Commerce.

Colorado Farm Bureau, Colorado Forestry and Horticulture Association, Colorado State Association of County Commissioners, Colorado State Association of REA Cooperatives, Colorado State Chamber of Commerce, Colorado Water Resources Committee, Columbia River Fishermen's Protective Union, Columbia River Salmon and Tuna Packers Association, Congress of Industrial Organizations, Connecticut State Chamber of Commerce, Connecticut State Farm Bureau Federation, Connecticut Water Works Association, Conservation Foundation, Cumberland Valley TVA Association, Dairyland (Wis.) Power Cooperative, Denver (Colo.) Chamber of Commerce, Eastbay (Calif.) Municipal Utility District, Ecologists Union, Edison Electric Institute, Electric Coordinating Council of New England, Electric Power Companies of the Rocky Mountain area.

Water Policy Panel Engineers Joint Council, Federation of Western Outdoor Clubs, Flood Protection and Planning Committee of Kansas City, Florida Sewage Works Association, Georgia State Chamber of Commerce, Greater Kansas City (Kans.) Flood Planning Committee, Helena (Mont.) Chamber of Commerce, Houston (Tex.) Chamber of Commerce, Idaho Development Association, Idaho State Reclamation Association, Imperial County (Calif.) Irrigation District, Interstate Commission on the Delaware River, International Association of Game, Fish and Conservation Commissioners, International Brotherhood of Electrical Workers, Iowa Rural Electric Cooperative Association, Iowa Sewage Works Association, Iowa State Valleys Association, Izaak Walton League of America, Irrigation Districts Association of California.

Kalispell (Mont.) Chamber of Commerce, Kansas Electric Cooperative Association, Kansas Reclamation Association, Kansas River Valley Water and Land Conservancy Association, Kaweah Delta (Calif.) Conservation District, Kings River (Calif.) Water Association, Lawrence (Kans.) Chamber of Commerce, League of Ohio Sportsmen, Lehigh Valley (Pa.) Flood Control Council, Lewiston (Idaho) Chamber of Commerce, Libby (Mont.) Chamber of Commerce, Little Sioux (Iowa) Works Commission, Los Angeles County (Calif.) Flood Control District, Maine Water Utilities Association, Manufacturing Chemists Association, Minnesota State Prison Industries, Minnesota Farm Bureau Federation, Mississippi Valley Association, Mississippi Valley Flood Control Association.

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A P P E N D I X

3

Report of the
Committee on Standards
for Basic Data

Committee on Standards for Basic Data

WALTER C. LOWDERMILK, *Committee Chairman, President's Water Resources Policy Commission*

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SEPTEMBER 1950

To The President's Water Resources Policy Commission:

The Committee on Standards for Basic Data established in April 1950, submits herewith a report, pursuant to the following instructions from the Commission:

This Committee will determine the minimum essential background information necessary for the sound planning of river basin projects and programs. It will further determine the principles which should govern the basic information gathering programs of the Federal Government to assure as rapidly as possible the required data on a continuing basis and its analysis. The objective will be to establish standards which will assure that projects and programs will go forward on the basis of adequate data.

In its consideration of the many aspects of basic data collection and their relation to the development of our water and land resources, the Committee was fortunate in having the assistance and advice of a group of qualified individuals as alternates, chairmen, and members of subcommittees representative of various fields of activity in basic data collection and in the use of such data in resources development. The contributions and counsel of this group have aided materially in the preparation of this report. The Committee is grateful for this cooperation and espe-

cially for the professional counsel of Messrs. Robert H. Randall and Arthur H. Sweet.

The report expresses the consensus of the Committee with respect to broad fundamental needs for and character of basic data in water and related land resources development, although it does not necessarily represent views of individuals or agencies on particular points in all cases. assistance of Miss Dora E. Potter.

In submitting this report the chairman wishes especially to express by this means his great appreciation for the generous and effective assistance of all members of the Committee, of all members of the seven subcommittees and their chairmen, and of the editorial panel. Most of the detailed work was done by subcommittees whose statements were processed by the Main Committee during its twenty-five sessions over a period of nearly five months. The editorial panel deserves the thanks of all members of the Committee for its diligence in fitting numerous amendments voted by the Committee into the text and in the final editing of the entire report, with the able assistance of Miss Dora E. Potter.

WALTER C. LOWDERMILK
Committee Chairman

I. Summary

The pressure of increasing demands upon water resources and the prospect of serious shortages and other water problems have led to the present review of all phases of water resource development. Development of water resources covers a wide field involving expenditures of considerable funds. These activities include projects for flood control, irrigation, hydro power development, navigation, shore protection, beach erosion control, national defense, watershed treatment, soil erosion control, drainage, domestic and industrial water supply, ground water recharge, conservation storage, pollution abatement, recreation, wildlife refuges, the control of disease, and improvement of public health. Related activities include construction of highway and railroad bridges and airfields.

Success in conservation, use, and development of our national water resources is largely dependent upon an adequate knowledge and understanding of the physical (including biological and chemical) and socio-economic facts involved. These basic facts are essential to sound engineering and proper economic development of these most valuable resources. The principal physical facts are in the fields of hydrology, sedimentation, topography, geology, soils, cadastral surveys, vegetation, and fish and wildlife. The principal socio-economic facts relate to such items as transportation, markets, power, production, and damages from floods and droughts and the like.

The Committee on Standards for Basic Data has investigated each type of basic data for its importance to resource development, its status, and its degree of adequacy for optimum resource development, as well as for possible improvements in techniques to accelerate the collection of such data and to increase their usefulness. The committee recognized that needs for data are not the same for all projects and vary for different areas. Hence, no attempt has been made to establish priorities in importance or need for each type of data.

Adequacy of coverage of basic data cannot be defined once and for all time to come. In considering adequacy,

it was recognized that uses for data will vary as needs expand or change, and that the amount of data which can be collected will change as the science of resource surveying develops. The percentage of adequacy of coverage as given in this report for the various items is based, therefore, upon the present concepts of future needs and existing techniques for the collection of essential data.

Basic data already available have permitted the development of many successful water resource projects. But many of the best dam sites have been used, and some of the most profitable irrigation projects have been established. Consequently, further development will require more detailed and precise information concerning physical and socio-economic facts which formulate the basis for project and river basin development. It must be said that there are great deficiencies in the basic data required for present and further developments. For example, in the case of topography, only 25 percent of the area of the United States is covered by maps considered acceptable by modern standards. With respect to geology, only 10 percent of the area has been mapped.

It is paramount that deficiencies in factual knowledge be overcome as quickly as possible. Planning and programing for the collection of essential basic data should be accomplished through further Federal and State interagency cooperation in the interest of efficiency and economy.

The status of basic data has been reviewed in light of the urgency for optimum development of water and related land resources. The committee has endeavored to determine the minimum requirements for basic data so vitally needed for continued development of these resources. The committee's recommendations are designed to assure that such development proceed in an efficient and orderly manner and in the best interest of the present and future welfare of the American people.

II. Recommendations

General

1. In view of the recognized deficiencies in basic data required for water and land resource development, it is imperative that immediate steps be taken to provide this information on the basis of annually prepared programs.

2. Continuity in collection of basic data must be maintained for those items which fluctuate widely, so that greater dependence can be placed upon analysis and use of such data. Furthermore, this continuity should prevail regardless of changes in location and magnitude of current construction works. An adequate national program for collection of data should be supported without interruption.

3. The procedure for developing our national water and associated land resources should, insofar as possible, work from the whole to the part, thereby procuring an over-all basis of information about our national territory in sufficient detail to identify areas within the total which may require intensive study and planning.

4. Since there is indisputable need for proceeding with the development of our resources, in spite of large deficiencies in basic data which cannot be met for a period of years, annual programs of resource surveying should be designed to provide the maximum amount of information in time to meet the current needs of the development agencies. The present procedure of the Bureau of the Budget, in collaborating with the basic data-collection agencies and the resource development agencies in the preparation of such programs, should be continued.

5. The adequacy of relevant factual information should be a principal criterion in approving or rejecting proposals for programs or projects involving water and related resource development, and a statement showing in detail the basic facts available should be an integral part of any proposal for such development.

6. There is a definite need for further processing of the large amount of data which have been collected by Federal, State, and private interests, to put them in more suitable form for use of resource development agencies, both public and private.

7. Programs of research directed toward improving our knowledge of the physical, chemical, biological, and socio-economic phenomena affecting resource development, should be continued and enlarged. Similarly, it is essential that research be continued to improve techniques and instrumentation, and to expedite analyses of data.

8. Applied research should be directed toward the application of findings of basic research to solutions of the many problems involved in resource development.

9. *Hydrology*.—It is recommended that during the next 10 years:

(a) An additional 5,600 precipitation gages and 500 evaporation and other type meteorological stations be established to supplement the 10,000 precipitation and 1,000 meteorological stations now in operation in the United States.

(b) The Nation's climatological data be processed, utilizing available modern machine methods and that climatic maps be prepared.

(c) Installation of 550 snow courses in the West in addition to the 1,100 now in existence, and installation of 200 in the remainder of the country where there are now approximately 500.

(d) Installation of 5,800 new surface water stations for gaging streams, reservoirs, and lakes, in addition to the 6,300 now in existence; daily temperature readings be taken at approximately 3,000 of the stream-gaging stations, 100 of which should be temperature recorders.

(e) Reconnaissance, or general coverage surveys, be carried out in all areas of the United States for which no ground water surveys now exist; that intensive surveys be made in those river basins where acute need exists in connection with projects; and that, for purposes of gaging ground water supplies and estimating safe yields of aquifers, sufficient observation wells, to supplement the 359 now in operation, be installed.

(f) The existing soil moisture stations be increased to several thousand.

(g) Twelve hundred stations for daily sampling of chemical quality of water with daily temperature readings be established in addition to the 220 now in existence.

(h) Sanitary water quality sampling stations be established where necessary for water-pollution control in connection with water resource development projects and at other suitable locations to meet the needs of the general public.

(i) A series of stations to measure meteorological elements, surface water, and ground water be established in the Territories and island possessions to overcome present deficiencies.

(j) The programs for collection of basic data and hydrologic research should be designed so as to make the most of information obtained with funds available, guided by sound engineering, hydrologic, and statistical principles.

10. *Sedimentation*.—It is recommended that the following be accomplished during the next 10 years:

(a) Thirteen hundred stations for the daily sampling of sediment loads in streams be established in addition to the 300 now in existence.

(b) The program of surveys of deposited sediment be increased to encompass 1,400 reservoirs instead of the 417 now fitted with ranges for detailed surveys, and, further, the surveys should be repeated at regular intervals.

(c) An enlarged program of channel stability surveys be carried out, particularly as a part of the design and operation of projects.

(d) A series of stations to obtain sediment data be established in the Territories and island possessions to overcome the gross deficiencies now existing.

11. *Topography*.—It is recommended that:

(a) Topographic mapping of the continental United States, at scales of approximately 1:62,500 or 1:24,000, be

completed during the next 20 years. To date only 25 percent of such mapping is completed.

(b) Topographic mapping of critical areas in Alaska (approximately one-third of the total area) be completed at the scale of 1 inch equals 1 mile or larger, within the next 20 years.

(c) Provision be made for periodic revision of topographic maps, to show up-to-date information.

12. *Geology*.—It is recommended that the United States, its Territories and island possessions be covered by standard general purpose geological maps, which show surficial as well as structural geology, within the next 30 years. Only 10 percent of such mapping is now completed.

13. *Soils*.—It is recommended that:

(a) Nation-wide soil classification and mapping be completed during the next 20 years.

(b) There be further cooperation among the soils data-collecting agencies and the users of soils data, to develop standard specifications and nomenclature for soil classification and mapping to meet both agricultural and engineering requirements.

14. *Cadastral Surveys*.—It is recommended that:

(a) The cadastral survey of the public domain in continental United States and necessary resurveys be completed in the next 10 years. This requires survey of 116,000,000 acres and resurvey of 50,000,000 acres.

(b) An orderly program of cadastral survey necessary for the settlement and development of Alaska be completed in the next 10 years. At present less than 1 percent of the total area of Alaska has been surveyed.

15. *Vegetation*.—It is recommended that the forest and range surveys be completed in 15 years with periodic rechecks every 10 years thereafter.

16. *Fish and wildlife*.—It is recommended that collection of data pertaining to fish and wildlife, including fresh- and salt-water fish, shellfish, and crustaceans, be accelerated. Further, information is needed on population density and trends for the various fish and wildlife species.

17. *Socio-economic*.—It is recommended that:

(a) Basic socio-economic data concerning population, means of livelihood, transportation, markets, power, industrial production, and flood damages, not regularly collected by other agencies and intercensal interpolations, be provided for project planning; and that collection of data be continued for the appraising operations of water development projects and river basin programs.

(b) State and local units be encouraged to make population estimates for intercensal years, and that Federal agencies develop a method for adjusting State and local data.

(c) Necessary data on agriculture be obtained through the incorporation of additional appropriate questions in the census of agriculture.

(d) Necessary data on manufacturing be collected by the incorporation of appropriate questions in the census of manufactures.

(e) Tourism and recreational aspects of water development be investigated concurrently with the survey investigation stage of project development.

(f) The Federal Power Commission conduct an annual canvass of manufacturing and mining establishments, and markets, to maintain data on power and energy for the years for which census data would not be available.

(g) Collection of data be continued on the amounts and effects of flood damages and more emphasis be placed upon these data by appropriate agencies.

(h) Collection of data on domestic and industrial water supply be accelerated.

(i) Collection of information on water pollution be accelerated and placed on a continuing basis.

18. *Land classification for agriculture*.—It is recommended that:

(a) Collection and field integration of soils and other basic data used in land classification required for land use and soil conservation, irrigation, drainage, clearing, and control of soil erosion, be accelerated.

(b) Needs for basic or specialized data be anticipated and all available and applicable information be assembled and studied in preparation of legends for field surveys.

19. *Land management effects*.—It is recommended that:

(a) Investigations be continued and enlarged to determine effects of land management on watershed hydrology, giving special attention to critical river basins and further, to bridging the gap between effects on runoff, water supply, and erosion on experimental plots and small watersheds, and such effects in larger river basins.

(b) Provision be made for interagency cooperation in planning new experimental work, standardizing methods of analyzing and publishing data, maintaining an up-to-date inventory of data being collected by various agencies, and facilitating free interchange of information on unpublished data.

III. Introduction

All water that falls on the land as rain and snow is raw material annually recurring and available within varying limits for control, use, and conservation. The average annual depth of this precipitation varies over the 48 States

from less than 1 inch to 146 inches and averages about 30 inches. Of this, about 30 percent returns to the sea in stream flow varying over the country from little or none to 80 inches. Availability varies widely and is

affected by many factors, such as character and frequency of storms, topography, permeability of soils and underlying country rock, condition and use of land surfaces, temperature and evapo-transpiration, and dams and other works of man for storage and control of surface and ground waters. Optimum use of the water resources and related land uses requires an understanding of a host of facts adequate to planning, design, and operation of projects and programs.

The over-all amount of water withdrawn from reservoirs, rivers, lakes, streams, and underground sources and utilized in one way or another in the United States is estimated at 200 billion gallons per day. This daily consumption of water represents a substantial increase over the amount utilized 10 years ago, and, at the present rate of increase, the consumption of water in this country will be doubled in the not too distant future.

There is call for a full realization of the trends in growing needs of the American civilization, and with it, foresight of what those needs will be, and provision for finding the facts that will be required to develop resources accordingly. Sufficient confidence in the future is called for to begin and to enlarge present programs adequate to these needs.

In many parts of the country water in amounts and quality has already become the limiting factor in growth of farming, of industries, and of domestic facilities to support the American standard of living. Greater deficiencies and economies in making use of local waters in highly developed and established sections will be required if these areas continue to expand.

Congress early recognized Federal responsibility in a statute of 1807 providing for examinations and observations of banks and shoal areas along the Atlantic Coast of the United States. Legislation in 1819 and 1820 appropriated small sums to the military service of the United States to make surveys of tributaries of the Mississippi River. From this small beginning, Federal responsibility has broadened in scope so that today many agencies are engaged in the collection of basic data, and in making surveys of the Nation's resources.

From the act of 1819 and succeeding legislation, the Army Engineers were authorized to make surveys of navigable streams, including stream-flow measurements and other investigations necessary for planning and proper consideration of all uses of the streams affecting navigation. In 1888, the Army Engineers were further authorized to establish water gages and make daily observations on the Mississippi River and its tributaries. The act of January 21, 1927, further authorized surveys of the principal rivers of the Nation. These were published as "308 Reports," which contain plans for improvement of navigation in combinations with flood control, power, irrigation and other resources development.

Functioning under the organic act of February 10, 1807, the Coast and Geodetic Survey of the Department of Commerce conducts hydrographic and topographic surveys, including tide and current observations, geodetic control surveys, and investigations to determine variation in latitude and longitude.

The Department of Agriculture was established by the act of May 15, 1862 and was authorized to engage in research, regulation, planning, education, and action programs. Many later acts extended the authority and re-

sponsibilities related to water resources, such as the Weeks Forest Purchase Law of March 1, 1911, for the protection of watersheds of navigable streams, and the Soil Conservation Act of April 27, 1935 (16 U. S. C. 590a) to provide permanently for the control and prevention of soil erosion and thereby to preserve natural resources, control floods, prevent impairment of reservoirs, and maintain the navigability of rivers and harbors and to conduct surveys, investigations, and research.

The Flood Control Act of 1936 among other purposes authorized surveys and operations for runoff and water-flow retardation and soil erosion prevention on watersheds.

The Geological Survey of the Department of the Interior, established by the act of March 3, 1879, was given responsibility for classification of public lands, examination of geological structure, mineral resources, and products of the national domain. In an 1894 statute, Congress made funds available to the Survey for gaging streams and determining water supply of the United States. Included within its duties is the classification of public domain lands for power purposes.

The act of October 1, 1890, established the Weather Bureau with the responsibility to collect hydrologic and meteorological data and to forecast floods and frosts. Previously the Signal Corps and the Smithsonian Institution had collected meteorological data.

The Reclamation Act of 1902 established the service that became the Bureau of Reclamation, and amendatory and supplementary legislation authorized various investigations and surveys in the preparation of reclamation projects in the Western States.

Under the Federal Power Act of June 1920, the Federal Power Commission makes investigations and collects data concerning the utilization of water resources in any region to be developed, their relation to the water power industry, and its relation to other industries in interstate and foreign commerce, and concerning the location, capacity, costs of development, and relation to markets of power sites. The Commission also has extensive power to investigate and to secure information regarding ownership, operation, management, and control of all facilities for generation, transmission, distribution, and sale of electric energy, however produced.

Congress by the act of May 18, 1933, created the Tennessee Valley Authority, which was "charged with the broadest duty of planning for the proper use, conservation, and development of the natural resources of the Tennessee River drainage basin and its adjoining territory for the general, social, and economic welfare of the Nation."

Through the Water Pollution Control Act of 1948, the Public Health Service derives authority to conduct a program of research and to collect and disseminate information relating to water pollution, its prevention and abatement, and to make available the results of specified work conducted by it and cooperating agencies.

The growth of national importance of the water and related land resources and the numbers of people involved in the development of these resources can be suggested by a listing of the types of works involved. They include such as the following:

1. *Flood control.*—Storage reservoirs, levees, floodwalls, flood channel improvements, floodways, spillways, and pumping stations.

2. *Irrigation*.—Storage reservoirs, major canal systems, water-distribution systems, land-leveling and improvement.

3. *Power development*.—Dams, turbines, generators, and transmission lines.

4. *Navigation*.—Harbor improvements, locks and dams, open channel improvements by dredging, jetties, bank revetments, contraction works and canals.

5. *Shore protection and beach erosion control*.

6. *Watershed treatment*.—Establishment and control of vegetal cover, reforestation, terracing, contour farming, check dams, stock farm ponds, and other measures for improving land use.

7. *Drainage*.—Canals, ditches, levees, pumping stations, control structures, and water conservation areas.

8. *Domestic and industrial water supply*.—Reservoirs, aqueducts, wells, ground water recharge, filter plants, pumping stations, and sewage disposal plants.

9. *Pollution abatement*.—Reservoir storage to increase low flow, and plants for treatment and systems for disposal of sewage and industrial waste.

10. *Construction of railroad and highway bridges, culverts, and airfields*.

11. *Fish and wildlife facilities*.—Hatcheries, fish ladders, and refuges.

Certain activities are related to the foregoing types of resource development. Some of these are flood forecasting, flood plain zoning, water supply forecasting, and

measures to control disease and for improvement of public health.

Billions of dollars have already been spent in all portions of the country for the development of our water resources. The pressure of increasing demands upon our water resource and the prospect of serious water problems has indicated need for a thorough review of all phases of plans of development. The basic facts pertinent to planning include a multitude of types, many of which are essential to the optimum development of our most valuable national asset. The success of these programs will rest on the foundation of basic facts. Thus, the standards, adequacy, and accuracy of the basic data are primary considerations and yardsticks for evaluating potential projects.

An intelligent over-all plan for water resource development requires a complete knowledge of the quantity, distribution, quality, and availability of the resources. In addition, to develop water resources to their fullest potential, it is essential to evaluate the relation of the water to the land.

This report evaluates the present status and adequacy of basic data, establishes standards for the collection of data, defines the relation between basic data collection and project development, and recommends improvement in the collection and analysis of basic data to provide a full understanding of the potentialities of our water resources.

IV. Facts, the Basis for Resource Development

Success in the conservation, use, and development of our national water and related land resources is largely dependent upon adequate knowledge and interpretations of relevant facts and conditions. Facts have to be used in an intelligently applied planning procedure. Those who prepare and process plans may be counted on to use the available basic data. Although adequate data may not guarantee adequate plans, the lack of such data tends toward faulty plans, and prevents optimum development at minimum cost. Examples of such faulty plans may be found in the record of water and land use projects and programs in the United States.

A. The Facts Needed

For the success of projects and programs concerned with our water and land resources, two principal classes of facts are needed. These are:

1. Physical (including biological and chemical).
2. Socio-economic.

Those of the first class, facts about our national assets in physical resources and environment, are concerned with data that can be observed, measured and recorded. The principal categories are:

1. Hydrology.
 - (a) Precipitation.
 - (b) Evaporation and other meteorological data.
 - (c) Surface water.
 - (d) Ground water.
 - (e) Soil moisture.
 - (f) Chemical quality of water.
 - (g) Sanitary quality of water.
2. Sedimentation.
3. Topography.
4. Geology.
5. Soils.
6. Cadastral survey.
7. Vegetation.
8. Fish and wildlife.

Information of the second class relates to socio-economic facts. These, also, are in most instances capable of being observed and measured. They include such as the following:

1. Over-all basic economic facts:

- | | |
|-----------------|-----------------|
| (a) Population. | (e) Employment. |
| (b) Income. | (d) Production. |

2. Functional facts relating to:

- | | |
|---------------------------|------------------------|
| (a) Agriculture. | (g) Transportation. |
| (b) Forestry. | (h) Power. |
| (c) Fishing and trapping. | (i) Flood damages. |
| (d) Manufacturing. | (j) Water supply. |
| (e) Mining. | (k) Pollution. |
| (f) Recreation. | (l) Fish and wildlife. |

B. Not Enough Facts

The status of information in each category of our physical resources is a matter of record. Considering the Nation as a whole, it may be said there are serious deficiencies in basic data required for purposes of planning and development. For example, in the case of topographic maps only 25 percent of the area of the United States is covered with maps of acceptable standards. There are even less geologic data in that only 10 percent of the United States is adequately covered with geologic maps. Accepting the obvious situation of a critical deficiency in factual information, there remains the question of how adequacy is to be determined.

C. Determination of Adequacy

The answer to the question of adequacy determination is that those who are to use the information should specify what they need. The consumer's interest is paramount. The agencies in the Federal Government that supply the various kind of data can advise the users as to the available data and can help to determine its adequacy. Close cooperation between the data-collecting agencies and the resource developing agencies is essential. The resource development agencies should advise the basic-data collecting agencies of their priority needs for various resource data. In so doing they are concerned

with: (1) The kind of information needed, and (2) the areas and priorities for making the required information available.

D. Definition of Adequacy

The first step in determining adequacy of information is that of definition. This is the responsibility of resource development agencies and other users of the data, always working with the benefit of advice from the basic-data agencies. The kind of information needed by the developers should in each case be spelled out in sufficient detail to make sure that they get the necessary information.

Adequacy cannot be defined once and for all. Basic data considered essential by the development agencies at any time will depend upon (1) the uses for which the information is sought and the time limit and area involved, and (2) the information the basic-data agencies are able to supply. The first will vary from time to time and from place to place, as needs expand or change. The second will change as the science of resource surveying, interpretation of data, and research unfold. New possibilities are continually being opened up by scientific and technical advances.

The definition of adequacy is, therefore, in each and every instance a current consideration. To meet the developer's needs as conditions change, and to take advantage of opportunities that arise as resource surveying progresses, adequacy is a matter requiring constant and continuing study.

E. Annual Programing

The procedure for meeting deficiencies in information regarding physical resources involves the preparation, annually, of advance programs of resource surveying. Currently the Federal resources development agencies, in collaboration with the Bureau of the Budget and the basic-data agencies, specify the kinds of data they require, expressing these requirements in terms of area, degree of coverage, and of time priorities. From these statements of priority needs, annual programs of collection, analysis, and interpretation of basic data are developed. The Bureau of the Budget assists in the planning and coordination of these annual programs.

V. Relation Between Project Development and Basic Data Collection

A. Correlation Required

Agencies charged with the collection of basic data follow a general pattern in their conduct of survey operations.

The Federal agencies concerned in the conservation, use, and development of our natural resources likewise follow generally consistent procedures, which are largely prescribed by statute.

There is now a general correlation between the procedure followed in stages of project development and in the phases of data collection. In programming the collection of basic data, the time element is of vital importance. Generally, the types of data relating to the physical features of project development such as topography and geology do not change; hence, these data are readily collected in an orderly procedure but collection should be started in sufficient time for their availability for project development. On the other hand, the elements of hydrologic and sedimentation data fluctuate so widely within a year and from year to year that records collected for short intervals are inadequate and often misleading. For that reason it is essential that a national network of stations for the collection of all such data be maintained continuously to sustain an inventory of the Nation's water resources and to facilitate general planning for project development. Basic socio-economic data must be collected, recorded, and interpreted in a similar way.

The basic data-collecting agencies strive to serve in the best and most economical manner the information needs of the development agencies. Continuing operations of both groups require increased and closer cooperation. This should result in ever-increasing correlation between the stages in project development as followed by the development agencies and the phases into which data collection are divided.

With this concept in mind, the general correlation referred to is illustrated as follows:

Stages in project development for—

1. Preliminary investigation.
2. Survey investigation.
3. Definite project investigation.
4. Plans and specifications.
5. Construction.
6. Operation and maintenance.

Phases of data collection in—

1. Preliminary coverage.
2. General coverage.
3. Specific coverage.
4. Intensive coverage (if required).
5. Construction.
6. Operation.

The above stages in project development are those employed generally by the resource development agencies, and the phases of data collection are geared to them. Due to the time element involved, the need for certain types of data must be anticipated considerably in advance of the specific stage of project development for which they are required. This is particularly true in the general coverage type of basic data required for the survey investigation stage of project development, as collection of basic data of this type requires considerable time and effort on the part of the basic data agencies.

B. Stages in Project Development and Phases of Data Collection

In general, the integration of stages of project development and phases of data collection are shown in the fol-

lowing paragraphs. However, land use capabilities and land classification do not lend themselves to such treatment. Under certain conditions, special basic data are needed in order to classify land properly and to determine its potentialities. Land classification must proceed along with planning and project development.

PRELIMINARY INVESTIGATION AND PRELIMINARY COVERAGE

The *preliminary investigation* stage consists of the assemblage of all existing and available resource data that are considered pertinent to the proposal under consideration. This may be a single project, a group of related projects, or a program involving many projects or extending over an entire drainage basin. The information assembled is analyzed and studied to the extent considered essential at this point in the proposal's development, and public hearings are usually held.

The *preliminary coverage* phase of data collection is the assemblage of all available pertinent material. In addition to the immediate use of the data, preliminary coverage provides an inventory of existing facilities and points out the deficiencies and requirements in the event of further development.

SURVEY INVESTIGATION AND GENERAL COVERAGE

If, from the previous stage, the proposal is judged to have sufficient merit, a *survey investigation* is made and a report is prepared. This stage is directly precedent to a justification for authorization. It should, therefore, be based upon sufficient information to establish clearly such justification.

The *general coverage* phase of data collection is likewise of paramount importance because data collected for this stage of project development forms the fact basis for authorization. The data may be considered as being in two categories: (1) physical data (including biological and chemical) and (2) socio-economic data.

Physical data

- | | |
|-------------------|--------------------|
| Hydrology: | |
| Precipitation. | Topography. |
| Evaporation. | Geology. |
| Surface water. | Soils. |
| Ground water. | Cadastral surveys. |
| Quality of water. | Vegetation. |
| Sedimentation. | Fish and wildlife. |

Socio-economic data

- | | |
|-----------------------|--------------------|
| Over-all basic facts: | |
| Population. | Employment. |
| Income. | Production. |
| Functional facts: | |
| Agriculture. | Transportation. |
| Forestry. | Power. |
| Fishing and trapping. | Flood damages. |
| Manufacturing. | Water supply. |
| Mining. | Pollution. |
| Recreation. | Fish and wildlife. |

Hydrology.—This phase of data collection for the variable hydrologic items requires a general and broad observation program having an adequate length of record. At

this planning stage considerable expense is warranted for processing and summarizing all existing data. Such analysis will reveal deficiencies in network density and pattern. This phase is most advantageously served by national observation programs. Depending on the item, continuous or periodic observations are required for relatively long periods of time to gain knowledge of possible extremes of the factors. The principal items of hydrologic data required for the general coverage phase are:

Precipitation.—Full utilization is made of all published summaries and unpublished data are compiled and summarized. Needs for more intensive coverage within the project area beyond that afforded by basic networks should be considered and the necessary stations established at the earliest possible date.

Evaporation and other meteorological elements.—All available data are used in this phase of data collection. Additional stations should be established if the basic network is considered inadequate for the purpose of the project or program. Long-term records are most desirable.

Surface water.—Data from a long-term network of stream gaging stations should be available.

Collection of any additional data found advisable should be undertaken as early as possible because the value of stream-flow records increase with length of period covered.

Ground water.—Comprehensive regional studies of ground water hydrology are required in this phase. Then studies require knowledge of the dimensions, geologic structures, the yields, and other hydrologic properties of aquifers. Such essential data cannot be obtained at once as water level fluctuations determinations of safe yields in rates of recharge of ground water require many years of record to be of optimum value.

Chemical quality of water.—Information about the chemical quality of surface waters is determined by the establishment of stations on streams to collect daily and intermittent samples for laboratory analysis. Records covering several years are desirable especially for those streams that are highly variable in turbidity and chemical quality or where these factors are expected to change. Provision should also be made for systematic sampling of ground waters to determine their quality.

Sanitary quality of water.—For each source of pollution by sewage and industrial wastes, data must be collected on the flow, strength, and character of the pollution, and on the physical, chemical, bacteriological and other biological changes in the stream resulting from pollution.

Sedimentation.—Sediment sampling stations should be established to obtain sediment load characteristics of the streams under consideration. Reconnaissance sedimentation surveys of representative reservoirs in the area, valley cross sections of sample subwatersheds to measure valley fill and damage to bottomland caused by sediment, sample mapping of sediment source areas to determine relative amounts and character of sediments derived from various types of erosion, and similar studies should be made in this phase.

Topography.—Topography for this phase should be recorded on general-purpose maps giving systematic large-area coverage. Maps should show relevant details necessary for a general inventory of the area, normally at scales of about 1 inch equals 1 mile, or 1 inch equals one-half mile. Preferably, maps should be made

available for the entire project area. Deficiencies in topographic mapping are so great, however, that often the project area cannot be entirely covered in time for the maps to be of fullest use. In such cases, close cooperation between the development agency and the data collection agency in inaugurating mapping programs is required for areas; first, where information is most urgently needed, and other areas, in turn, to meet needs of development progressively.

Geology.—General coverage for geologic data, like that of topography, should be general purpose in nature. Geologic maps and subsurface sections are basic facts in determining the soundness of a project or program, and should be in sufficient detail to insure such a determination. Geologic maps and subsurface sections must provide information on workable mineral deposits in the area so that the significance of such deposits may be considered in determining the economic feasibility of proposed projects. Geological studies are also a basic and integral part of investigations for ground water supply. Generally, geologic features are mapped at scales of 1 inch equals 1 mile.

Soils.—Under this phase of data collection, basic soils data are needed to show boundaries and areas of soils having different inherent characteristics and properties. Such data are best presented at scales which fit the needs for showing soils in classes or associations that are reasonably uniform in their principal observable characteristics. Standard topographic maps, where they exist, furnish the best base map for recording information on soils.

In water and related land resource development, data on certain characteristics of soils are required for estimations of rates of infiltration and percolation, for determining storage capacities of soils and underlying material, and for erodibility, under various uses, as well as other properties of soil types and associations.

Vegetation.—Information on density and condition of natural vegetal cover, as well as condition of croplands, is required for planning watershed programs and in carrying out measures and practices of watershed management. Preparation of maps showing the natural cover and its condition is the first step in the assemblage of such data. More detailed information is obtained as required.

Cadastral surveys.—Before development of the water resources can be undertaken in areas of intermingled public and private land, boundaries and limits of ownership must be established. The cadastral survey of the public domain constitutes a basic fact for any resource consideration of the public lands.

Fish and wildlife.—In connection with the general coverage phase of data collection, it is necessary to obtain all pertinent data of fish and wildlife, to collect and compile readily available biological data, and to conduct fairly detailed biological investigations of the project area.

Socio-economic data.—Socio-economic data collected in this phase provides a financial and social basis for project justification and authorization; therefore, it is the most important phase of economic study. The entire field of socio-economic data may be required in the survey stage, but the amount and kinds of data, as well as the emphasis to be placed on the individual items, depend in any one investigation upon the nature of the project and program. See table I. Typical kinds of economic data

are given below for each of the main phases of resource development. Economic items which are common to all studies are population, price levels, and costs. These data are needed for all studies listed below and are not indicated individually for each one.

Navigation.—Water and mineral resources, mining, manufacturing, transportation, agricultural production and markets, and industrial production and markets.

Flood control.—Land, water, and mineral resources, mineral, and other industrial production, and flood damages, in small as well as large streams.

Drainage.—Land and water resources, agriculture, agricultural and industrial production, and damages from improper drainage.

Hydroelectric power.—Land, water, and mineral resources, mining and manufacturing, value of power markets and power in industry and other uses, and mineral and other industrial production.

Irrigation.—Land, water, and mineral resources, agriculture, power, agricultural markets, and agricultural production.

Water supply.—All data on water and mineral resources, mining and manufacturing, power, industrial markets, and mineral and other industrial production.

Pollution abatement.—Water resources, mining, manufacturing, mineral, and other industrial production, costs of recovery of values.

Recreation.—Land and water resources.

Watershed management.

PROJECT INVESTIGATION AND SPECIFIC COVERAGE

After authorization of a project or program, the definite *project investigation* is prepared. This is based upon all of the data assembled for the preceding stages, with additional *specific coverage* for those portions of the total area of concern in which more detailed investigations are advisable. Cadastral surveys are necessary for this stage.

As a phase of surveying procedure, *specific coverage* required in each category of physical resources, is as follows:

Hydrology.—The specific coverage phase for variable hydrologic facts consists primarily of collecting data for detailed project design. These collections of specific basic data, although often of great importance, are of necessity of short duration. It is often desirable or necessary to continue collection of certain items of these data after the immediate needs have been met in order to serve as useful units in the national data network as well as for project operations. Such special data generally are made fully useful only through the availability of the general coverage data and by means of appropriate correlations.

Sedimentation.—Sediment sampling stations referred to under general coverage should be continued. Plans for establishing ranges in reservoir areas, upstream from the reservoir and downstream from the dam, should be made in order to obtain detailed information on rates of reservoir

TABLE I.—Basic socio-economic data requirements by types, functions, and stages of development

P—Planning (preliminary examinations, surveys, and definite project reports).
C—Construction (including plans and specifications).
O—Operation and maintenance.

	Navigation	Flood control	Drainage	Hydro-electric power	Irrigation	Water supply	Pollution abatement	Recreation	Watershed management
Population:									
Number, location, density.....	PO	P	P	P	PO	PO	PO	PO	PCO
Income and expenditures.....	PO			P	P	P		PCO	PCO
Age, sex, race, size of family.....	PO			P	P	P	P	PCO	PCO
Resources:									
Land.....		PCO	PCO	P	P			PCO	PCO
Water.....	PCO	PO	PCO	PCO	PCO	PCO	PO	PO	PO
Mineral.....	P	PCO		P	P	PO			P
Industry:									
Mining.....	PO			PO		PO	PCO		P
Manufacturing.....	PO			PO		PO	PCO		PO
Agriculture.....		PO	PCO		PCO				PCO
Services:									
Transportation.....	PCO								P
Power.....				PCO	PCO	PO			
Utilities.....									
Markets:									
Agricultural.....	PO				PCO				PC
Industrial.....	PO			PO		PO			
Other.....	PO			PO					
Production:									
Agricultural.....		PO	PO		PCO				PCO
Mineral.....	PO	P		PO		P			P
Other industrial.....	PO	P	P	PO		P	P		P
Damages.....		PCO	PCO				PO		PCO
Prices.....	PCO	PCO	PCO	PCO	PCO	PCO	PCO	PCO	PC

sedimentation, and stream aggradation and degradation. Detailed surveys of representative reservoirs should be completed. Detailed erosion surveys should be made to delineate the source areas of sediments and their relative importance to the sediment problem.

Topography.—Larger scale maps are required in this phase in addition to those described under general coverage. Map scales should be adequate to show details required for plans, drawings, and specifications of construction projects. Map scales usually vary from 1:24,000 to 1:12,000. Mapping required at the smaller scale is generally performed by the basic data agency. Larger scale mapping is done or contracted for by the development agency.

Geology.—Geologic examinations in detail are required at all proposed construction sites during this phase. Geologic factors affecting the preparation of engineering plans and specifications should be evaluated and presented in understandable form. Detailed site investigations are usually performed by the geologic staff of the construction agency. General coverage geologic maps greatly aid detailed site investigations in this phase. More detailed study of individual mineral deposits and ground water reservoirs may carry over from the preceding phase. Geologic maps for this phase vary in scale depending upon the scope of the project and the nature of geologic formations.

Soils.—This phase may require more complete and comprehensive data on soils for land treatments and management; they include descriptions and analyses of inherent characteristics of soil profiles, and external features such as degree of erosion and stoniness. Such facts provide a framework for organization, evaluation, and extension of information on use and management of soils within fields, in pastures, and in forests to areas of like soils and land features. Soils data collected in this phase should be sufficient for classification of land in terms of safe use and management, for recommending and applying measures on site for control of runoff and erosion, for guidance in use and management of specific tracts of land, and as general aids in estimating storm runoff, erosion, and sediment production as they may affect water resource developments.

Fish and wildlife.—Information regarding vegetation and land-use practices; fish (including shellfish and crustaceans); wildlife habitats; populations and harvests; fishing and hunting; hatchery opportunities; relation of fish to stream obstructions; and local and national importance of the affected fish and wildlife, is collected from all available sources and censuses and surveys are conducted when needed to overcome deficiencies in data. All aspects of the proposed project are studied in detail and estimates of future effects on the life cycles of fish and wildlife are made.

PLANS AND SPECIFICATIONS AND INTENSIVE COVERAGE

The title of this stage in project development is self-explanatory. It is the prelude to and a necessary basis for actual construction.

For this stage in project development it may be necessary to undertake some still more detailed investigations, a phase in resource surveying which is called *intensive*

coverage. These, in respect to each of the principal resource categories involved, are discussed as follows:

Hydrology.—The intensive coverage phase of data collection for the variable hydrologic factors consists primarily of collecting data for detailed project design. It is often desirable or necessary to continue collection of certain items of these data after the information has supplied the immediate need in order to serve as useful units of general coverage relating to the national network of data or for project operations.

Sedimentation.—In this phase periodic resurveys of ranges in, above, and below proposed reservoir areas to measure long-term rates of sedimentation are made to determine possible disposition of sediment within proposed reservoirs, and aggradation and degradation tendencies in the channels above and below such reservoirs. Detailed surveys of small reservoirs and sub-watershed erosion above proposed reservoirs are undertaken for the purpose of analysis and determination of rates of sedimentation. It would be desirable to establish new sediment measuring stations above and below reservoirs to determine trap efficiencies and to continue in operation certain of the sediment-sampling stations in order to obtain long-term records and to determine changes in volume and character of sediments as a result of watershed and sub-watershed treatment. Size analysis of sediment in channels and reservoirs, density determinations of sediment in reservoirs, and similar studies related to construction and operation should also be made in this phase.

Topography.—Intensive coverage maps cover a broad field of requirements ranging from a detailed investigation of a limited area to large-scale plans for a construction project. These are usually prepared by the construction agencies at scales of 1:12,000 or larger.

Geology.—Geologic data are collected in this phase in much more detail than in the preceding phase. As detailed plans are developed, need frequently occurs for intensive study of particular aspects of geologic formations by the construction agency.

Soils.—For intensive coverage in locating and in planning drainage and irrigation projects, information must be more complete as to soil characteristics and its behavior under irrigation or other treatment, and must show locations and limits of different kinds of soil more exactly to furnish the basis for intensive classification and subsequent land preparation.

Fish and wildlife.—In this phase an intensive investigation of the area is made, in cooperation with the State, to select appropriate sites for development, and determine plantings, fencing, or other developments required, and management needed. The proposed development is evaluated on the basis of the wildlife populations and harvests expected to occur, after a complete biological study. Similarly, plans for fish ladders, fish screens, and other fish-protective devices may also be prepared.

Socio-Economic Data.—Basic socio-economic data are needed in this phase of data collection to confirm justification of the project after possible changes in price levels immediately prior to construction. See table I.

CONSTRUCTION STAGE AND PHASE

The title of this step in project development is self-explanatory.

Meteorological and hydrological data are particularly necessary during the construction phase of projects to efficient utilization of construction facilities and to protect the contractor's equipment, coffer dams, and other temporary works. Further these data lay the groundwork for operation and maintenance of the project.

OPERATION AND MAINTENANCE

After a project is completed, there is a continuing need for the collection of meteorological and hydrologic data essential to the efficient operation of the project. This is particularly true in the case of multiple-purpose projects and in the case of projects which are a part of a system which has unified or integrated operation. The operation of an integrated system of reservoirs involves dispatching water through the system for efficient utilization, and conservation of water and protection of life and property from floods. This is a complex task and requires an adequate amount of data of high accuracy to satisfactorily control and dispatch the water.

By categories, the following data should be obtained for operation of a project or a system of projects.

Precipitation.—There is needed an adequate network of stations covering the watershed of a project so located that they provide in advance essential information from which runoff may be estimated. Such stations must be located so that regular reports, daily or oftener, can be sent from the station to some central point for use in forecasting river flow and water-control operations. In remote areas, where ordinary means of communication are not available, then automatic transmitting radio precipitation gages are needed. A certain number of these radio gages are also desirable to provide insurance in the case of storms which disrupt line communications. In addition to the regular network of reporting stations, other stations are required to refine forecasting of runoff stages for each watershed.

Evaporation and Other Meteorological Data.—Records should be collected for appropriately located stations so that reservoir losses may be estimated.

Surface Water.—There is needed an adequate network of stream gaging stations so located as to provide essential data regarding the current flow of water in all important streams throughout the watershed. The stations must be located with respect to the stream pattern. If communication facilities are available for quick transmission of stream stages, then ordinary recording gages installations are satisfactory. If such facilities for communication are not available, then automatic radio transmitting gages must be used. These radio gages, as in the case of precipitation gages, provide excellent insurance against wire

transmission failing during storm periods. For a system of multiple-purpose reservoirs, greater accuracy of stream flow determination is required for operating purposes through a series of reservoirs. Without a high degree of accuracy, the water-dispatching operations are greatly handicapped due to apparent flow discrepancies. Water temperature data throughout a reservoir are needed in order to determine the flow pattern of water through the reservoir. Water temperature data are also important in other operating situations such as water cooling.

Ground water.—Data on the quantity of water in the ground at any time are very important in operation. Such water is actually in storage and will be discharged over a period of time varying with the watershed. In a multiple-purpose system, it is important to know what this quantity of water is in order to plan for the most efficient use of water over perhaps 1 or 2 months in the future. Ground water and amount of soil moisture in a watershed also give the water-control engineers a basis for estimating runoff from rain storms since storm runoff is influenced greatly by the moisture condition of the watershed at the time of the storm. Soil moisture meters and ground water well installations are necessary to provide data on ground water and soil moisture.

Quality of water.—Additional data may be needed in connection with domestic water supply, industrial difficulty in the use of polluted water (either bacterial or chemical pollution), or reservoir operation for irrigation.

Sedimentation.—Data are needed with regard to reservoir sedimentation in order to determine when the project operation may be affected by deposition in a reservoir. Likewise, the planning of current corrective measures that may improve operating conditions or prolong project life require that accurate sedimentation data be secured on a regularly planned schedule.

Topography.—Maps prepared for purposes of project report and design should be adequate. Maps should be available covering the watershed of the operating projects so that the engineers will have information as to the character of the topography which is an important factor in estimating stream flow.

Geology.—Information previously obtained is usually sufficient.

Fish and wildlife.—Biological investigations are conducted and various types of operational data collected in connection with the management of Federal and State fish and wildlife. Various types of data may be collected in connection with biological investigations in the project area during its operational life.

Socio-economic data.—After a project is built, basic socio-economic data are needed to evaluate costs of operation and maintenance as shown in table 1.

VI. Basic Physical Data on Water Resources

A. Hydrology and Sedimentation

This section of the report was prepared from material supplied by the subcommittees on Hydrology and Sedimentation of the Federal Inter-Agency River Basin Committee. It was recognized that these subcommittees, the membership of which is made up of representatives of basic data agencies as well as resource development agencies, were well qualified to advise on the status and adequacy of hydrologic and sedimentation data. The subcommittees had been engaged for about 5 years in the review of existing sources of hydrologic and sedimentation data and had considered recommendations concerning anticipated future needs for such data and the most effective means for its collection.

In the following sections, statements as to the adequacy of all types of hydrologic and sedimentation data are presented. Included also are statements on research in these fields. In most cases maps are used to show graphically the status of such data and data-collecting facilities. The boundaries of the major drainage basins and sub-basins are delineated on the maps and each sub-basin is identified by a number. Under each of the classes of data certain recommendations are made for expansion of existing facilities. Provision of these facilities is an essential step toward efficient development of the water resources of this country. For reasons of efficiency and economy the additional facilities should be installed and in operation within 10 years.

PRECIPITATION, EVAPORATION, AND OTHER METEOROLOGICAL DATA

The Weather Bureau is the principal agency collecting precipitation, evaporation and other meteorological data. Although many of these data are employed by the Weather Bureau in its own river forecasting operations or in serving the general public, they have many important applications in the planning, design, and operation of works for water control and utilization.

Figure 24 shows the adequacy of facilities for gathering precipitation data. The current percent of adequacy is equal to the number of existing stations divided by the sum of the existing and recommended new stations. Approximately 25 percent of the sub-basins have precipitation-gathering facilities between 0 and 50 percent adequate, while 75 percent have facilities between 50 and 100 percent adequate. In addition to consideration of the adequacy of facilities based solely on the number of stations, it is appropriate to comment briefly on the adequacy with respect to instrumental equipment.

A nonrecording rain gage does not supply adequate information regarding rainfall intensity for durations of less than 24 hours. The present percentage of recording gages in the network (about 30 percent) is too low. A

distribution of about 50 percent recording gages should be adopted as a reasonable target. Recording gages now in general use have a capacity of 12 inches of precipitation, which is insufficient to accommodate the most intense storms in many areas. Wherever amounts in excess of 12 inches in 24 hours can be expected, larger capacity gages should be installed. In many remote areas where daily or weekly attendance is not feasible, large capacity nonrecording storage gages are in use. A sufficient number of recording gages capable of operating from 30 days to 6 months without attendance should be installed to make possible reliable determination of daily rainfall increments in remote areas.

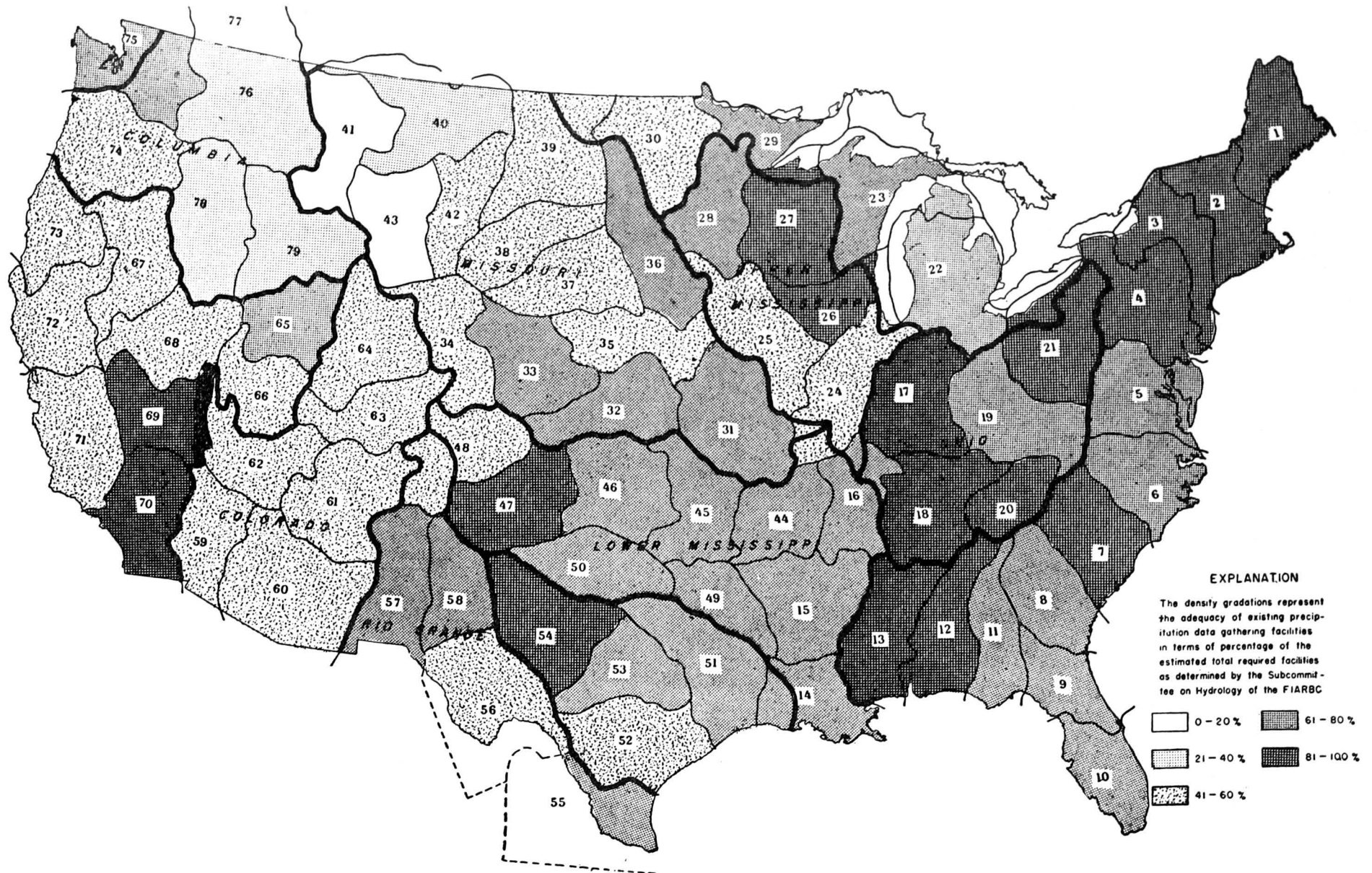
The definition of an adequate network is based upon the considered judgment of field representatives of the various Federal agencies. The recommendations are limited to the needs which can be foreseen within the next 10 years. A change in national policy, or new technical discoveries, may, in the future, require a redefinition of an adequate network.

The adequacy of existing data, and the extent to which these data have been processed and summarized, must be considered on the basis of rather arbitrary standards. It is generally considered that 50 years of observations from a network such as recommended would provide data of minimum adequacy. Also, these data should be processed by the use of punch cards, adjusted where necessary for such changes as station location, exposure, and instrumentation. Finally, certain standard summaries and analyses such as frequency curves and monthly and annual isohyetal maps should be prepared and published.

The average length of precipitation record for the United States from gages now installed is approximately 23 years. These same records when applied to the recommended network would give an average length of record of approximately 16 years, which is generally conceded to be too short for completely reliable planning of the development of our water resources. Data now available on punch cards represent only a small percentage of the total, while few data have been adjusted for changes in location, exposure, and instrumentation. Analyses and publication of rainfall intensity-duration-frequency relationships are badly needed for the entire United States.

Figure 25 shows the adequacy of facilities for gathering evaporation data. The need for evaporation data gathering facilities are the greatest in arid areas having low average annual runoff. In areas represented by sub-basins, as shown in figure 2, having an average annual runoff of 10 inches or less, the minimum number of required evaporation stations is 6. In those sub-basins having an average annual runoff in excess of 10 inches, the minimum requirement is 3.

Deficiencies in other meteorological elements are less easily evaluated. Temperature is reasonably uniform



EXPLANATION

The density gradations represent the adequacy of existing precipitation data gathering facilities in terms of percentage of the estimated total required facilities as determined by the Subcommittee on Hydrology of the FIARBC

- 0-20%
- 21-40%
- 41-60%
- 61-80%
- 81-100%

FIGURE 24.—Adequacy of facilities for gathering precipitation data.

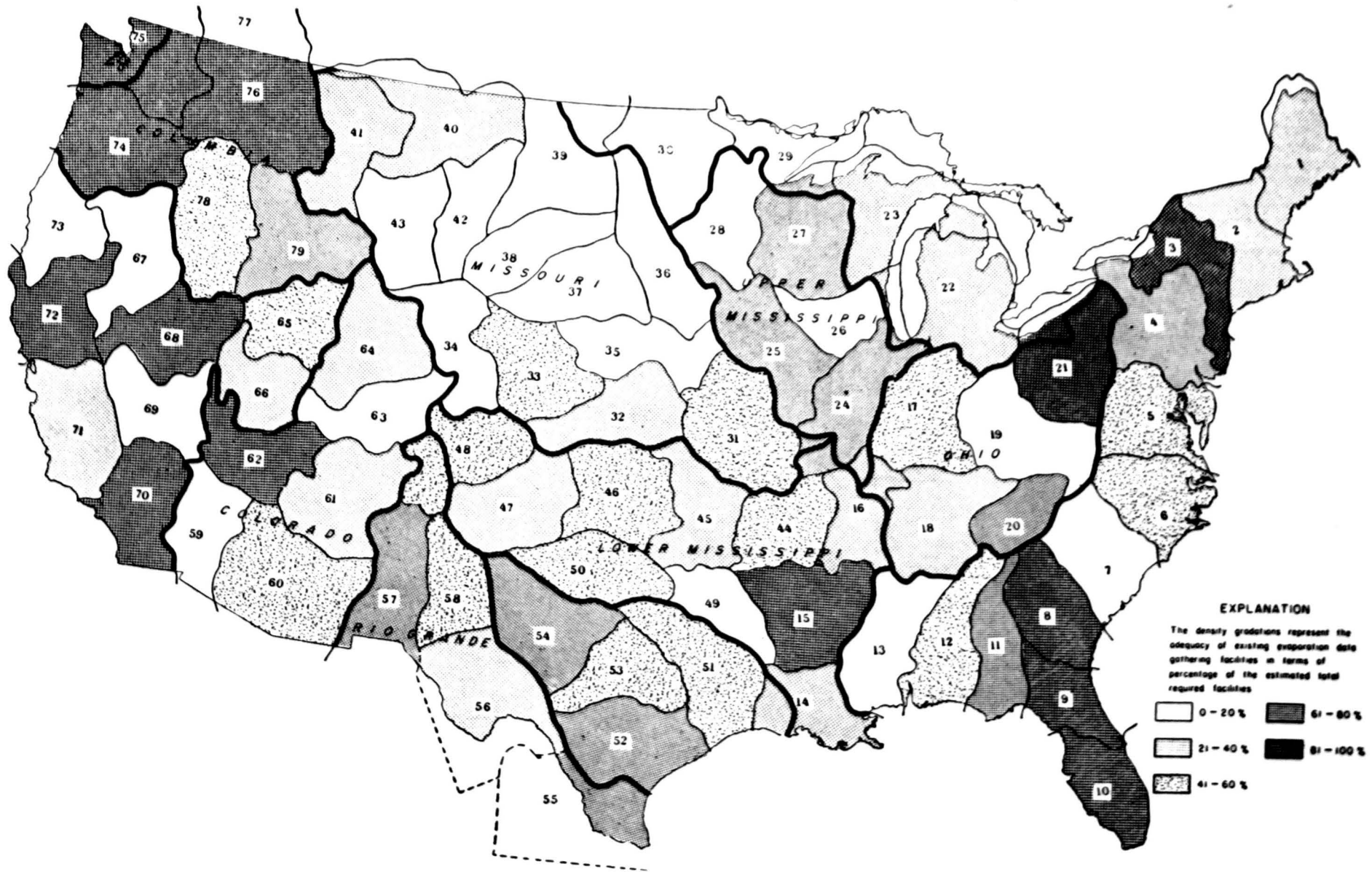


FIGURE 25.—Adequacy of facilities for gathering evaporation data.

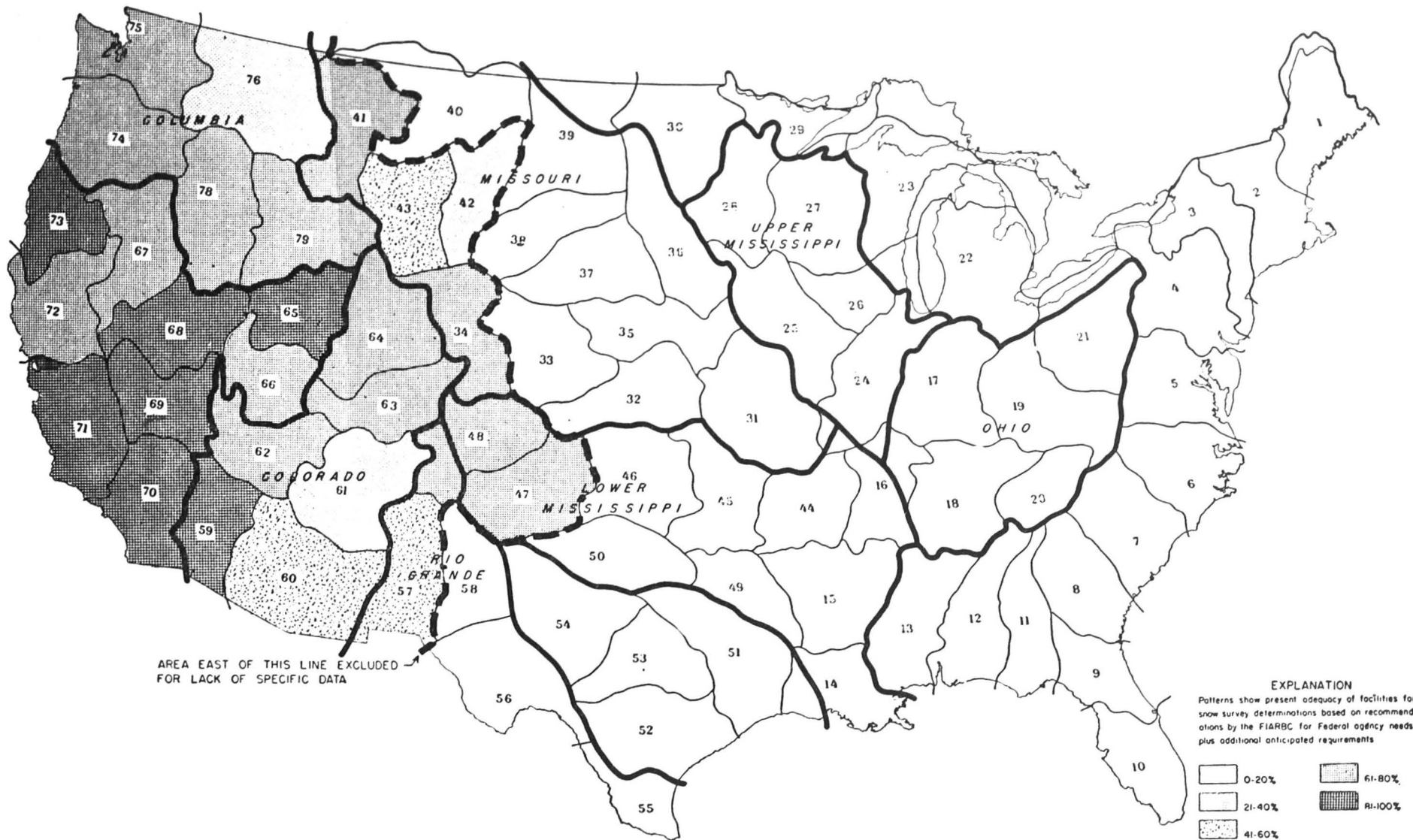


FIGURE 26.—Adequacy of snow course coverage in the west.

over large areas, and is well represented in the data now collected, except for isolated areas. Psychrometric data, likewise, are represented in the observations taken at the regular reporting stations of the Weather Bureau. Solar radiation, water temperature, soil and water temperature, and wind data are not yet adequate to meet the needs of analysts in the field of applied hydrology.

To be of greatest value, these data must be collected from well located installations for a significant period of time. These data must then be processed and published currently. Only then is the facility serving its intended purposes. The longer the record for each installation, the more valuable it becomes.

To meet deficiencies in the United States, there are required about 5,600 precipitation gages and 500 evaporation and other types of meteorological stations. These additional stations should be installed in order of priority in areas of greatest need within the next 10 years. This expansion should be accompanied by a corresponding expansion in facilities for processing and analyzing data collected.

CLIMATIC MAPS

Climatic maps have been used to show graphically the classification of climate in generalized terms or as empirical indexes. Average annual isohyetal and isothermal maps of the country have been considered to be forms of climatic maps, but these have come to be regarded as inadequate for regional planning purposes. This is accounted for in the fact that climatological data are at present not in form to allow their presentation, either in the form of detailed summaries, or the presentation of the summaries in the form of maps.

With the trend toward regional planning has come the necessity to consider more factors than areas of obvious water abundance or deficiency. The optimum utilization of water in areas ranging between these extremes constitutes the greatest opportunity for expansion in the future. These water appraisals must be based on some expression of dependability of precipitation, and considered in the light of the best use of water under soil and other conditions characteristic of these areas.

Climatic maps, in common with other kinds of maps showing physical data, have the principal purposes of (1) presenting a comprehensive view of the regional climatological characteristics for which the map is intended, (2) providing the means of quick and accurate interpolation, and (3) the identification of areas in which specified climatic characteristics can be considered as homogeneous. For example, a regional planner, in considering an agricultural program, may want to identify areas in terms of an average recurrence interval of, say, one year in seven, in which a certain crop or crop-group having the following specifications for water can be successfully established:

* * * precipitation to exceed 14 inches in the months of April, May, and June, to be preceded by a 3-month accumulation of precipitation of not less than 7 inches and followed by 3 months in which the average monthly temperature does not exceed 87° F.

A map showing lines of equal probability of the above-specified characteristics could be prepared quickly for almost any part of the country from existing data by the

modern methods employing punch cards and machine techniques.

Climatological data have been gathered at a progressively increasing number of points in the United States through the past 75 years. A total of over a billion items have now been collected. For the past 2 years the Weather Bureau has placed current observations on punched cards, and used machine methods to expedite publication of climatological summaries. However, until the "back-log" has been put onto punched cards, statistical expression cannot be given to past observations, nor can the machine methods of summarization be applied.

It is recommended that the Nation's climatological data be processed, utilizing available modern machine methods, and that climatic maps be prepared.

SNOW-COVER DATA

Snow surveys are conducted for the purpose of forecasting the seasonal runoff that will be available for the benefit of such uses as irrigation; power generation; domestic, municipal, and industrial water supply; navigation; and flood-control operations. Such surveys are carried out by obtaining representative samples, or cores, along established lines which are called "snow courses."

Many Federal and State agencies and private organizations collect and disseminate snow-cover data. The Soil Conservation Service coordinates the collection and dissemination of snow-survey data in the Western States. Figure 26 indicates the adequacy of snow course coverage in the West.

There are many variables in the preparation of forecasts for seasonal runoff, and therefore, an understanding of such variables increases the value of snow-cover data with the years of record. For planning purposes a long record is essential. Snow-course installations in Western States show a rapid increase in recent years as a result of increased use of water supplies. The following table indicates the rapid increase in installations in recent years, and by implication, the length of record for snow-course surveys.

Year:	Number of western snow courses installed and measured
1900.....	0
1910.....	3
1920.....	22
1930.....	130
1940.....	750
1950.....	1,007

About 550 additional snow courses are needed to provide an adequate network in the West.

The New York Cooperative Snow Survey was formed in 1937 by a group representing 16 Federal, State, municipal, and private interests. In 1940 the work of the New York Cooperative Snow Survey was merged with that of the New England States to form the Eastern Snow Conference. The data collected are coordinated, printed, and distributed periodically during the winter and spring by several field offices of the Geological Survey. The information on snow collected by the members of the Eastern Snow Conference is published annually by the Weather Bureau as "Snow Cover Surveys by Eastern Snow Conference." The 1940 publication indicated 246 stations in New York State and 176 in the New England States.

Snow-cover data in New York and the New England States are not considered complete. Additional stations at higher altitudes would be helpful. More snow-cover data would aid materially in determining the water available for municipal water supply and would permit more efficient watershed management and operations of hydroelectric power plants. Additional snow-cover data are also required to provide information on the recreational aspects of snow. For this purpose data should be collected frequently and distributed promptly.

The installation of 550 snow courses in the West is recommended. This represents an increase of about 55 percent over the present number. Installation of about 100 stations, an expansion of about 25 percent, is recommended for the Northeast. To meet requirements for snow-cover data for the entire United States about 100 additional stations should be placed in the North Central States.

SURFACE WATER DATA

Total stream flow from an area represents in most cases the upper limit of water potentially available for sustained development from both surface and underground sources. Stream flow is the integration of all factors as they affect the movement of water through and over the land. It is the end product of a long chain of events.

By far the largest source of water used in the United States is surface waters. Streams and lakes not only supply roughly three-quarters of the water used for municipal supplies and for irrigation, but also supply the larger part of the water used by industry. Important uses of surface water take place in natural and artificial channels for navigation, production of hydroelectric power, recreation, and dilution of wastes.

Most of the uses of surface water mentioned are achieved by the construction of structures for the regulation and distribution of stream flow. Flood protection requires control works, such as reservoirs, levees, or dikes. Stream-flow data are used in the design of these structures to assure safety and economy. Large expenditures for operation of existing works and the sums contemplated for future river developments makes the collection of reliable basic data on stream flow a precautionary and economic necessity.

Analysis of actual stream-flow records give the only reliable information on floods, total flow, maximum flow, minimum flow, and time duration of flow. For the many ungaged streams, other hydrologic studies backed up by spot discharge measurements and ground-water investigations are necessary. Long-term stream-flow records from a base network of gaging stations are fundamental to such hydrologic studies. The more closely spaced these base stations are and the more representatively located, the more reliable will be hydrologic analyses.

Records of stream flow are regularly collected at about 6,000 gaging stations. The network of stations covers all States in variable amplitude. There are broad areas, chiefly in the West and on small streams in all parts of the country, where the number of gaging stations is inadequate.

The variability of runoff in place and in time emphasizes a need for long-period gaging of most rivers. Water resources of the United States can be adequately evaluated only by assured continuity in gaging. Continuity is vital

because of the possibility that a once-in-a-lifetime flood or drought may occur during a short lapse of time.

It is estimated that temperature observations are being made once daily at approximately 200 locations on surface streams throughout the country. Relatively few automatic water temperature recording instruments are currently in use on surface streams other than those that may be operated in connection with private industrial plants. Information about temperatures of surface waters is essential for many industrial purposes. The location of certain industries is dependent in large part on temperatures favorable of available water supply. Surface water temperatures are also needed for determining suitable water supplies for fish and wildlife and for recreational purposes.

Basic information of our surface water resources is derived primarily from stream gaging stations, and from lake and reservoir stage gages. Most of these are operated by the Geological Survey. Adequacy of coverage of stream gaging facilities is based upon the ratio of the number of existing stations to the total number of stations required. The percentage of adequacy is shown graphically for subbasins on figure 27. This figure shows the adequacy of data-gathering facilities to be less than 60 percent in 54 of the 79 subbasins, and to exceed 80 percent in only 1 of the 79. Although the length of record is an extremely important factor in determining adequacy of surface water data, that element is not reflected in Figure 4. It must be recognized that the determination of adequacy is not absolute but is a matter of judgment, and that it is not fixed but will change as present needs disappear and as additional needs develop.

In addition to collection and computation of basic data, certain special analyses of these data are needed to permit the Federal Government to fulfill its responsibility for a comprehensive Nation-wide program of appraisal of the surface water supply and its utilization. These analyses include, but are not necessarily limited to, flood frequency and time-duration studies, indices of water data, compilation of published water data, and evaluation of stream flow records. Many agencies have made analyses of stream flow data in connection with studies performed by them, but for the most part this information is not generally in a form convenient for public use.

The number of existing surface water stations (stream gaging, stream stage, reservoir, and lake) in the continental United States is approximately 6,300 and the number of proposed additional stations is 5,800. It is recommended that (1) the installation of the proposed 5,800 stations be carried out progressively during the next 10 years in order that data required for planning, design, and operation should be available for these purposes, and (2) correspondingly expanded analysis and special study of past and present records should be undertaken so that the maximum benefits can be derived from all available data. Daily temperature records should be collected at about 3,000 stream-gaging stations. Where once-daily observations are inadequate it is recommended that about 100 water temperature recorders be installed in the United States.

GROUND WATER DATA

Available ground water data are among the most incomplete of all those essential for an understanding of the

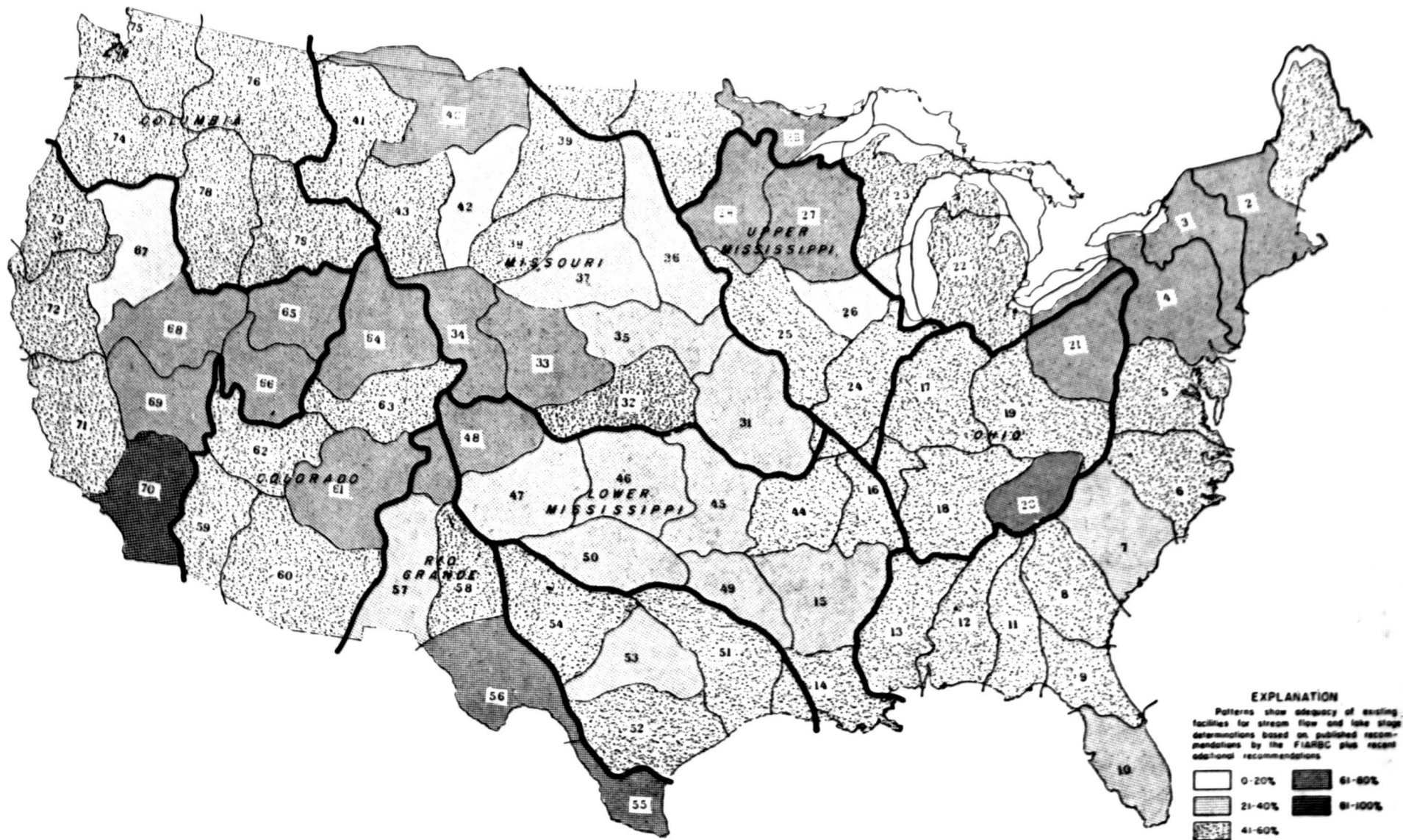


FIGURE 27.—Adequacy of surface water stream gaging facilities.

hydrologic cycle. Although surface water sources at present furnish several times as much water in the country as do the underground reservoirs, yet ground water is the chief source of supply for domestic and stock uses on our Nation's farms, for its small municipalities, and even for some of our larger cities. Many industrial plants and irrigation projects are dependent upon wells, and the dry weather flow of most streams stems from ground water.

An evaluation of a water-bearing formation is ordinarily quite complex. The size, shape, depth, and capacity of the water-bearing formation to store and transmit water must be measured by means of geologic studies, exploratory test wells, geophysical probing, and pumping tests. Water level fluctuations must be measured as a means of determining quantitative changes in storage, either naturally with time or as affected by man's activities; water table maps must be prepared; areas of recharge and discharge determined, and temperature observations recorded. All these data must be analyzed and put in form for use by development agencies and by the general public.

Figure 28 shows percentage of adequacy of ground water data available to the public, based on completion of investigations of specific areas. On the whole, limits of water-bearing formations are not coexistent with river basins, and ground water investigations have seldom been conducted on a scale to cover drainage basins. Instead, ground water studies usually have been made on a county basis, covering county by county those areas where ground water problems have been recognized as being of sufficient importance to require these basic studies. In some instances, as in Pennsylvania, the entire State has been covered by reconnaissance studies; in others, as in Alabama, studies have been made by major geologic units (as the cretaceous rocks, the tertiary rocks); still other States, such as Illinois, have carried on their own studies, usually at places and at times where acute ground water problems have occurred.

Although installation, operation, and maintenance of observation wells are essential elements in the total ground water data picture, it has not been feasible to prepare a separate figure to indicate adequacy of facilities, but a large number will be required. This element has been included in the figure showing adequacy of ground water data coverage.

Ground water data are available to the general public in both published and unpublished form. Of the published information, the chief sources are: (1) Geological Survey water supply reports, professional papers, bulletins, and geologic folios; (2) reports published by agencies cooperating with the Geological Survey, such as State geological surveys, State water boards or commissions, and State departments of conservation and natural resources; (3) State geological or water board papers published independently. Only in the last 20 years—but chiefly in the last 10—have quantitative and intensive ground water studies been made. Thus, the published ground water data of this Nation, taken as a whole, are quite inadequate. Unpublished data are available in numerous Federal and State organizations. Chief sources are the Geological Survey's district offices, and State geological surveys, and Federal agencies making local studies.

It is recommended that, as a general policy: (1) Effort be made to cover with reconnaissance surveys (6 to 20

percent coverage), within the next 10 years, all areas in the United States for which no ground water data now exist; and (2) intensity of coverage be stepped up in all other places in the Nation where need exists, with special attention being given to those river basins or subbasins where Federal irrigation, power, flood control, navigation, atomic energy, and similar projects are planned for construction or are now being constructed. Much of the study involved in this second category will be highly intensive (80 to 100 percent coverage).

SOIL MOISTURE DATA

The need for soil moisture data for the more complete understanding of the hydrologic cycle has long been recognized. A knowledge of soil moisture conditions, whether it be in the form of frost or liquid moisture, will enable the hydrologist to predict more accurately the amount of water which will percolate to ground water or will become surface flow. The moisture present in the soil at the time of flood-producing precipitation influences the quantity which becomes runoff. Soil moisture characteristics are also an important factor in determining the magnitude of water yields.

The quantity of moisture lost from any soil by transpiration is determined by the type and depth of root penetration of its vegetal cover, and hence, under any particular climatic conditions, the vegetal cover and the soil determine the availability or nonavailability of soil moisture at any time.

A knowledge of the effect of vegetal cover on soil moisture will enable the more exact prediction of water yields and flood flows. It will also improve watershed management for runoff control.

Very few soil moisture data are being collected at present for hydrologic purposes. Some data were collected at scattered locations in connection with other soil and related studies, but these do not serve the general purpose of hydrology. These data indicate, however, the importance of soil moisture as an aid in determining runoff and the important fact that soil moisture quantities are intimately related to the rooting habits of vegetation. Very little of the data, and practically none of its interpretations, have been published.

There are a great number of well-recognized soils in the United States and its possessions with physical characteristics which differentiate them from each other, and which affect their hydrologic influences and cultural capabilities. Soil moisture data should be obtained from an appropriate number of stations situated in contrasting soil types in forests, pastures, and croplands.

As the data become available for analysis and hydrologic techniques are improved, an increasing number of stations may be needed to cover more important areas. It is estimated that several thousand stations will be required over a 10-year period. It is recommended, therefore, that this program be initiated and pursued in a systematic manner in order to provide these basic data as early as possible.

CHEMICAL WATER QUALITY DATA

The chemical quality of surface and ground water is directly related to its suitability for a great variety of purposes. The concentration of dissolved mineral matter,

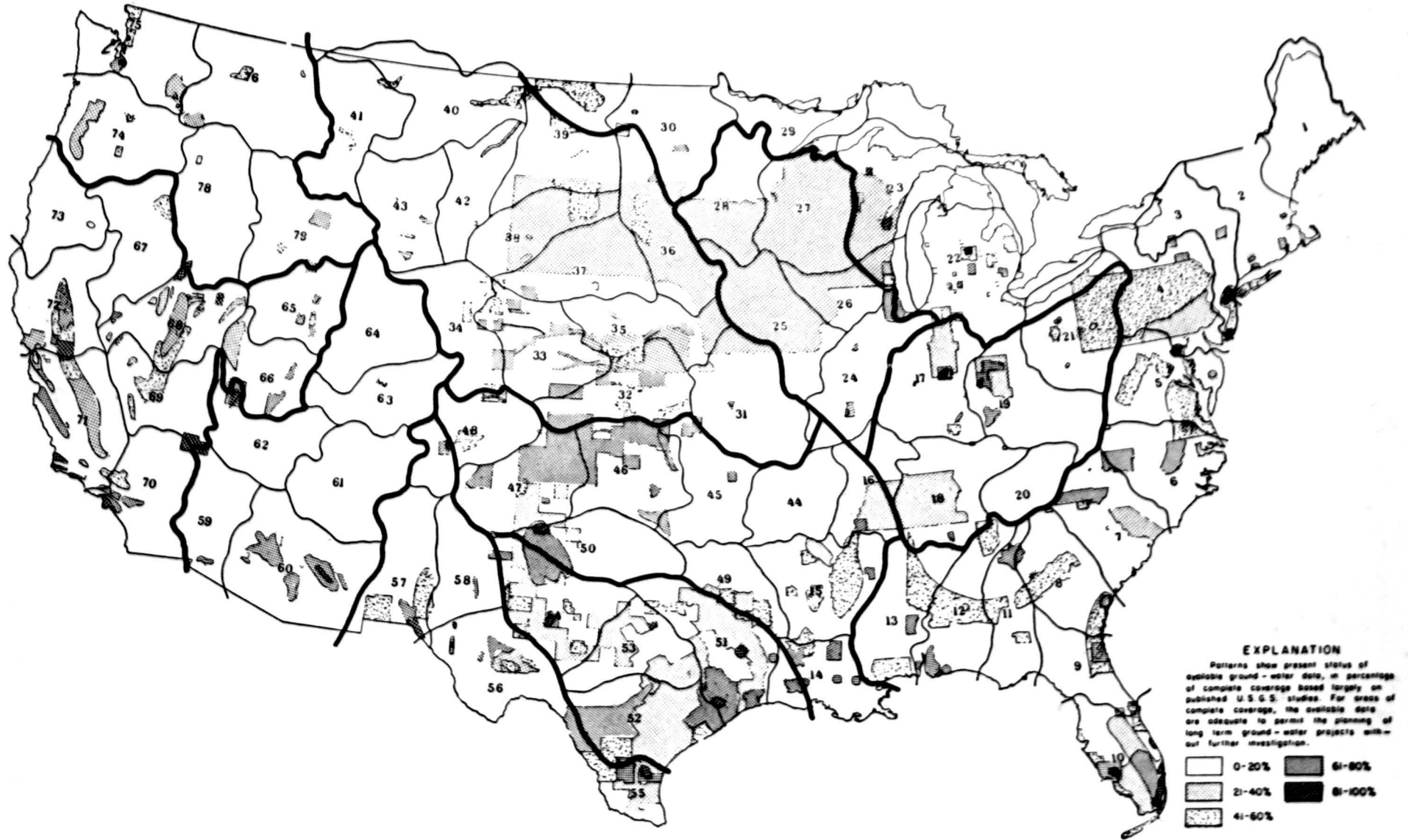


FIGURE 28.—Adequacy of ground water data.

which all natural water contains in varying amounts, determines whether the water is good, poor, or unsatisfactory for industrial, agricultural, municipal, and other uses. Increasing demands for water meeting exacting quality specifications require the expansion of facilities for collecting and evaluating the water resources of the Nation with reference to chemical quality. The Geological Survey is currently collecting most of the data on the chemical quality of natural waters.

Figure 29 shows the adequacy of chemical water quality information for surface and ground waters in terms of percentage of adequate coverage. In order to determine the present coverage, each subbasin was considered in the light of current and past records. An estimate was then made of the amount of chemical quality information required for the development and utilization of water resources in each subbasin. The percentage of adequacy was computed from the ratio of existing records to the estimated total records required.

Chemical water quality studies consist of two distinct phases, (1) determination of basic chemical data on surface water and ground water supplies, in accordance with standard methods of the Geological Survey; (2) the interpretation or evaluation of these basic records with respect to geology and hydrology. The studies include salt water intrusion problems in coastal areas. After determining the present status of information concerning the quality of ground and surface water supplies, appropriate weighting for surface water coverage, ground water coverage, and interpretation of the records were used in arriving at the present adequacy of chemical water quality information in each subbasin.

In the States west of the Mississippi River a survey was made, in 1949, to determine the needs of all Federal agencies for information on the quality of surface waters, primarily in connection with irrigation. The recommendations for water quality stations for irrigation, together with allowance for other major uses of water, such as industrial and municipal, were considered in the preparation of figure 6.

There are currently about 220 daily water-sampling stations in operation for determination of chemical quality. To overcome the deficiencies in these data, it will be necessary to establish approximately 1,200 additional daily sampling stations (or their equivalent) throughout the country. Daily temperature readings should be taken at these stations. These additional stations should be activated in an orderly manner during the next 10 years. Additional laboratory facilities will also be needed to handle the large number of samples that will result from an expanded program.

SANITARY WATER QUALITY DATA

The Federal Water Pollution Control Act of June 30, 1948, gives the Public Health Service a major responsibility for reclaiming and conserving the sanitary quality of our interstate waters. The Public Health Service is directed to prepare or adopt comprehensive programs for abatement and prevention of stream pollution, and to improve the sanitary quality of water needed for various uses including: "Public water supplies, propagation of fish and aquatic life, recreational, agricultural, industrial, and other legitimate uses." Comprehensive programs in

cooperation with other Federal agencies, State water-pollution agencies and interstate agencies, municipalities, and industries are being developed.

The first step in this Nation-wide program involved a study of the effect of every sewage and industrial waste discharge on the receiving stream. For each source of pollution, data must be collected on the flow, strength, and character of the pollution and on the physical, chemical, bacteriological, and other biological changes in the stream resulting from pollution. These data are used, together with stream discharges and velocities, precipitation, wave action, wind action, ice cover, and other factors which influence the self-purification capacity of the stream.

Before stream pollution data may be used, the most desirable downstream water uses must be determined. Such water uses will govern the amount of pollution that may be tolerated. In this connection, it should be stated that there are no generally accepted quantitative bacteriological standards for many important water uses, including irrigation and bathing. Research in these water uses is now being conducted to relate bacteriological concentrations in the water to disease incidence.

The situation is even less satisfactory at present with respect to industrial pollutants. Such wastes may not only make the water unfit for human use, but may also be toxic to fish or to the microscopic organisms that serve as food for fish. Research to determine allowable limits for such pollutants has been undertaken by Federal and State agencies and by various universities. Until maximum tolerable values are known, the fitness of a water for a given use must be based to a large extent on direct observations of pollution and on experience and judgment.

Since 1939 the Public Health Service has maintained an up-to-date inventory of sewage facilities which covers 22,500 communities in the Nation, including 9,000 served by sewer systems. The data comprising the inventory are furnished annually by the sanitary engineering divisions of the State departments of health. A supplementary arrangement was completed in 1949 whereby the States undertook to furnish additional information, including annual data, on: Flow and character of wastes, treatment applied, downstream water uses, effect of pollution on these uses, and corrective measures required.

Determinations of sewage strength are routinely performed by most State health departments or by treatment plant laboratories under their supervision. Data on sewage flow are usually available at larger treatment plants. Flow data at smaller plants may usually be estimated with acceptable accuracy. In respect to sewage data, it is believed that minimum needs in most areas will be satisfied.

With the exception of a few States which have stressed industrial waste investigations, the situation with respect to data on industrial wastes can be much improved. The task of determining the flow and character of the industrial wastes will take years at the present rate of progress. Active cooperation of industry has been enlisted as a practical approach to the problem of securing minimum essential data within a reasonable period of time. Existing resources of the States and the Federal Government are being applied to evaluate many thousands of independent industrial waste discharges.

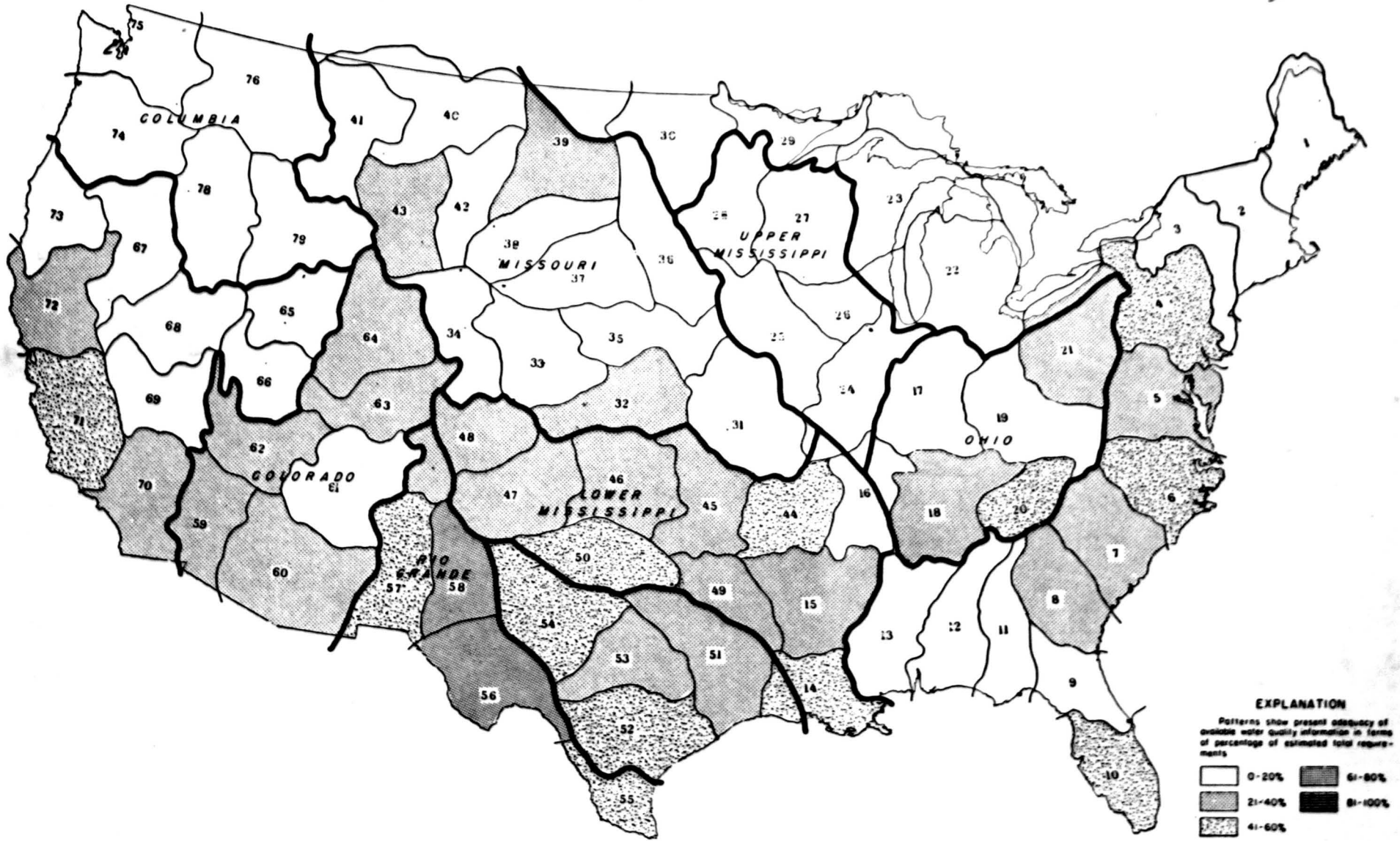


FIGURE 29.—Adequacy of chemical water quality information.

Present knowledge of stream-pollution conditions is highly inadequate. Except in a few States, data on streams polluted by industrial wastes need to be augmented. Experience indicates that multiple sampling stations are usually required for each source of pollution. The participation by industry in programs for obtaining industrial-waste pollution data is one solution for this problem.

Wide gaps in our present knowledge of pollution conditions will be reflected in interim comprehensive programs for controlling pollution in the Nation's streams. The Public Health Service proposes to complete these interim programs by January 1, 1951. These programs will list the sources of pollution, the effects of this pollution on water uses, including Federal, State, municipal, and private uses, and the corrective measures required for each major stream in the Nation. However, these purposes will be served only to the degree that available data permit. Since comprehensive programs will not be static, but, instead, will represent the best knowledge available at any time, additional data will be utilized to develop more precise and complete plans.

In order that the needs of other Federal agencies and of the general public may be served directly, it is recommended that (1) sampling stations be established to provide sanitary water-quality data at locations of Federal development projects and at selected stations which would produce useful and significant data, and (2) that such useful and significant data be published. The selection of sampling stations should be based on the recommendations of the interested Federal agencies.

It is not feasible to show graphically the status of adequacy of the data described.

SEDIMENT LOAD DATA

All streams transport some sediment. The quantity and quality varies tremendously from one part of the country to another, and, in every stream, from season to season. In the Plains States and in the Western and Southwestern States, the amount of sediment transported by streams is causing increasingly serious problems. Examples are the Rio Grande, Missouri, and Colorado Rivers and their tributaries. Streams in other parts of the country also carry large quantities of sediment.

Sediment loads of streams include not only important losses of soil from accelerated erosion of agricultural and range lands, from cutting of stream banks, and from erosion of stream beds, but also adversely affect the construction and operation of dams and other hydraulic structures. In addition, sediment in streams interferes with irrigation, navigation, highway and railroad construction and maintenance, recreation, the utilization of stream waters for industrial and municipal supplies, and is detrimental to fish and wildlife.

In order to evaluate the effects of sediment in streams, to take remedial measures for controlling or retarding various forms of erosion, and to make proper allowance for control and use for sediment in the development of river basins, it is essential that reliable and comprehensive information be available about the quantities and qualities of sediment transported by streams throughout the country. Primary and immediate emphasis should be placed on

those river basins where the rate of sediment production is highest or where the need for information is greatest.

Basic information about the sediment load of streams is being obtained from samples collected at stations located at selected points on streams. In most instances sediment sampling stations are located at or near stream flow gaging stations since concurrent water discharge measurements are necessary to compute the sediment load. Most sediment stations must be operated for a least 10 or more years to provide adequate records. The frequency of sample collection varies from stream to stream but should be sufficient to make possible the calculation of daily, monthly, and annual sediment loads.

Figure 30 shows the present status of available sediment load data for different areas in percentage of adequate coverage. In order to evaluate the adequacy of available information, consideration was given to past records as well as to records being collected currently. The present adequacy is the ratio of existing information to the total requirements.

The map shows the relatively low coverage of sediment load data on a Nation-wide basis and indicates the need for a large amount of additional information. This method of portrayal does not, however, indicate the areas where sediment production is highest nor the priority of need for additional data. There is much greater need for additional sediment records in such river basins as the Missouri, Colorado, Delaware, and Savannah than, for example, in the Penobscot River Basin. On the other hand, the order of importance for activating sediment measuring stations will probably shift from one area to another as time goes on, depending on changes due to development and the variety of problems that are bound to arise. No part of the country can be completely ignored, therefore, in regard to the amount of sediment transported in its streams.

An important phase of the sediment load problem is the analysis and interpretation of data. In the past, insufficient emphasis has been placed on analytical and interpretive studies of available records. Future programs for measurements of sediment loads of streams should provide for more thorough studies of these basic data in order that they may be of greatest value in the solution of specific problems.

At the present time there are about 300 daily sampling stations in operation. To overcome the deficiencies indicated, it will be necessary to establish an additional 1,300 daily sampling stations within the next 10 years.

RESERVOIR SEDIMENTATION SURVEYS

Approximately 10,000 storage reservoirs larger than farm pond size have been constructed in the United States for power, irrigation, flood control, municipal and industrial water supply, navigation, recreation, and other purposes. About 10 percent of these reservoirs have capacities of more than 5,000 acre-feet. All reservoirs are subject to loss of storage capacity resulting from deposition of stream-borne sediment. The rate of storage loss in individual major reservoirs ranges from a negligible fraction of 1 percent to as high as 2 or 3 percent annually. At present the average annual loss of storage in the Nation's reservoirs is approximately 350,000 acre-feet. With the accelerated program of reservoir construction

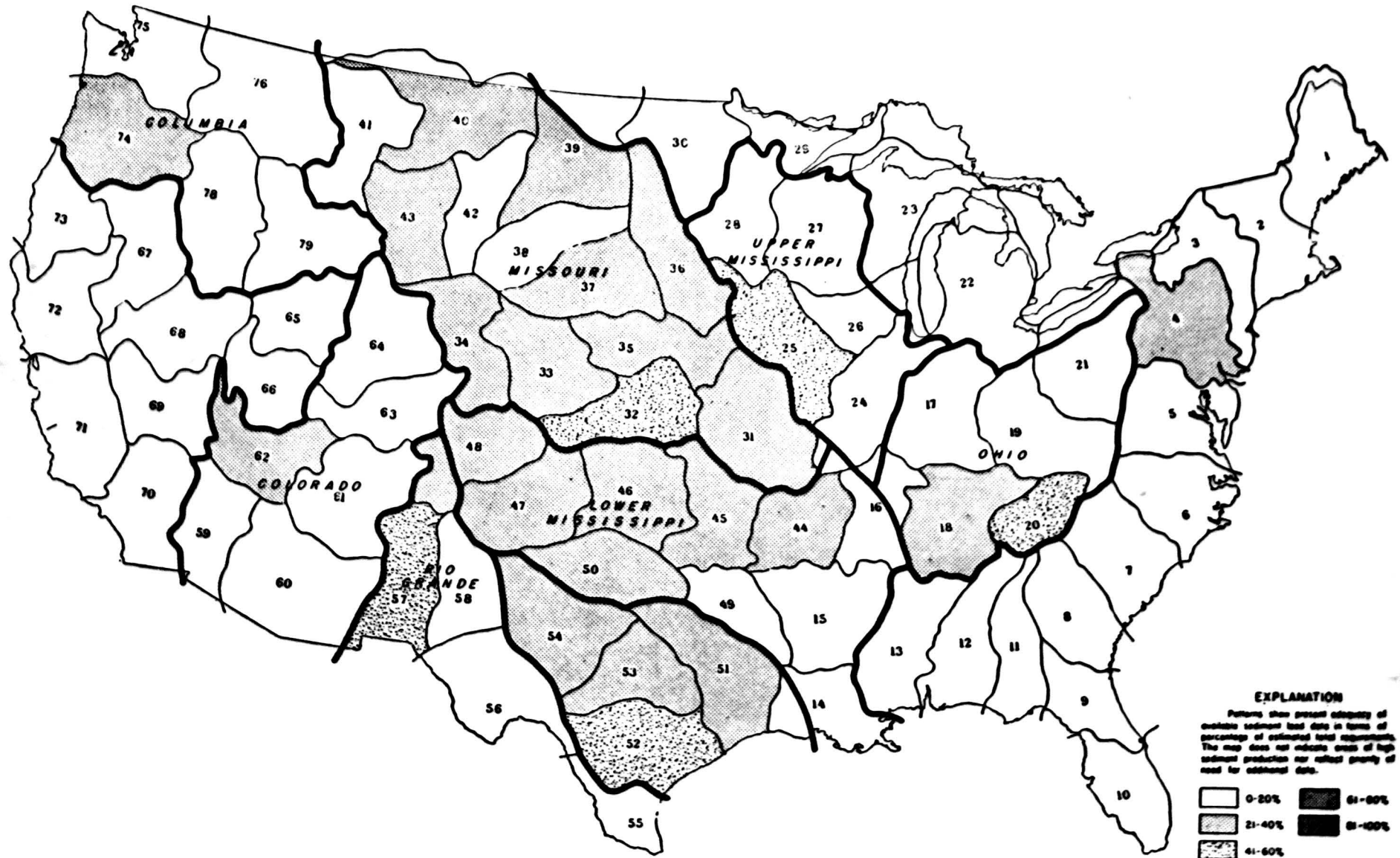


FIGURE 30.—Adequacy of sediment load data.

now under way, especially on streams carrying heavy sediment loads, as in the Missouri River Basin, the average storage loss may be expected to reach 600,000 acre-feet annually within a decade or two.

In recognition of the potentially serious effects of reservoir storage losses, several Federal, State, and local agencies have made sedimentation surveys of approximately 600 reservoirs and have established or authorized range systems for making such surveys on an additional 84 reservoirs. Approximately 417 detailed surveys have been or will be made in such a way that they can be repeated from time to time to maintain a periodic check on storage loss. Sedimentation survey ranges are being established on practically all reservoirs constructed by the Federal Government, and resurveys are made at frequent intervals. The Soil Conservation Service, in cooperation with various State and local agencies, carries on a program of surveys on non-Federally owned reservoirs.

Basic data obtained from reservoir surveys are necessary for several purposes, namely:

1. To permit periodic correction of capacity curves which is required for efficient reservoir operation.
2. To maintain a periodic check on storage loss and determine the timing of storage replacement.
3. To provide data on rates of sediment production from watershed areas as a basis for developing design criteria for new reservoirs, and for determining the need for sediment control measures.

The present reservoir survey programs of all Federal agencies engaged in the construction and operation of reservoirs should be continued and, where necessary, expanded to provide complete coverage by survey ranges and periodic resurveys at appropriate intervals, depending on the rate of storage loss. Federally-owned and operated reservoirs at present constitute less than 3 percent of the total number of reservoirs in the United States, but contain about three-quarters of the estimated total developed storage capacity of 200,000,000 acre-feet. Of the remainder of State, local, and privately owned reservoirs, a representative selection of 10 percent of the total number should be resurveyed with approximately the same frequency. Improved survey techniques promise to expedite this kind of operation and to reduce its cost so that it would appear feasible to carry out such a program. Altogether, approximately 1,400 reservoirs should be included in the program of detailed surveys, or 14 percent of the estimated total number constructed or expected to be constructed during the next 10 years. Of these, surveys have already been made on approximately 400 reservoirs. After the initial surveys are completed on the remainder, resurveys on an average of once every 10 years would require approximately 140 surveys annually.

Figure 31 shows the adequacy of reservoir sedimentation surveys to date. It is based on the above estimates of need with relation to those already made, as well as the number of existing or authorized reservoirs available for survey. Furthermore, it assumes that the general practice is to survey the reservoirs once every 5 to 10 years, except where local sediment conditions may dictate other intervals. This figure does not show, however, the priority of need for additional surveys in different areas. For example, there is need for a much larger number of surveys in some sections of the Missouri River Basin than in Maine or Florida, although the areas show the same

percentage adequacy. Moreover, sedimentation surveys of a large number of farm ponds or small reservoirs may be needed to develop rates of sediment production from different physiographic and soil problem areas.

In addition to the need for more reservoir surveys, a large amount of existing basic data as well as that to be obtained should be analyzed and interpreted to develop more adequate information on such factors as: (1) Sediment distribution with respect to operating levels, (2) specific weight of sediment, (3) trap efficiency of different kinds of reservoirs, and (4) sediment production rates indicated for various conditions of inflow and watershed characteristics, including land use and management.

CHANNEL STABILITY SURVEYS

A design and maintenance problem which is receiving attention in several agencies of the Government is that of anticipating the rate and extent of degradation (cutting and lowering of stream beds) of stream channels downstream of dams and aggradation (filling and raising of stream bed) above the reservoirs. In recent years, several attempts have been made, and are continuing, to evolve methods of analysis; and these have brought out the necessity for, and have stimulated basic laboratory research. In parallel with the analytical approach, it is necessary to make field observations of degradation and aggradation of stream channels in selected areas.

Several agencies currently require that surveys be made above and below authorized or existing dams on rivers where moderate or severe channel changes will occur. The Colorado River, where surveys have continued since construction of Hoover Dam, the Rio Grande, the Arkansas River, and the Missouri River are streams where extensive survey programs are in progress at the most critical locations. Data which have been obtained to date are not sufficient to foretell adequately future channel conditions.

Lack of adequate basic relationships expressing the laws of sediment transportation is felt also in other design and maintenance problems for projects such as some canal and irrigation systems, control of meandering streams and aggrading streams which because of rising ground water tables decrease agricultural production. Surveys of the existing channels provide information which aids in solution of design and maintenance problems. Such surveys generally are made by the agency which operates the project giving rise to the sedimentation problem. Occasionally a survey is a joint undertaking of several agencies coordinated by the Subcommittee on Sedimentation of the Federal Inter-Agency River Basin Committee. These methods of conducting surveys are satisfactory and should be continued.

In addition to the channel surveys made in connection with project design and operation there are a number of critical areas not involved in active projects where channel cross sections should be established and resurveys made from time to time. It is not feasible to estimate the percent adequacy of the existing channel stability investigations, but provision should be made for collection of basic data in areas where project investigations are not providing the minimum essential information on the condition of unstable channels.

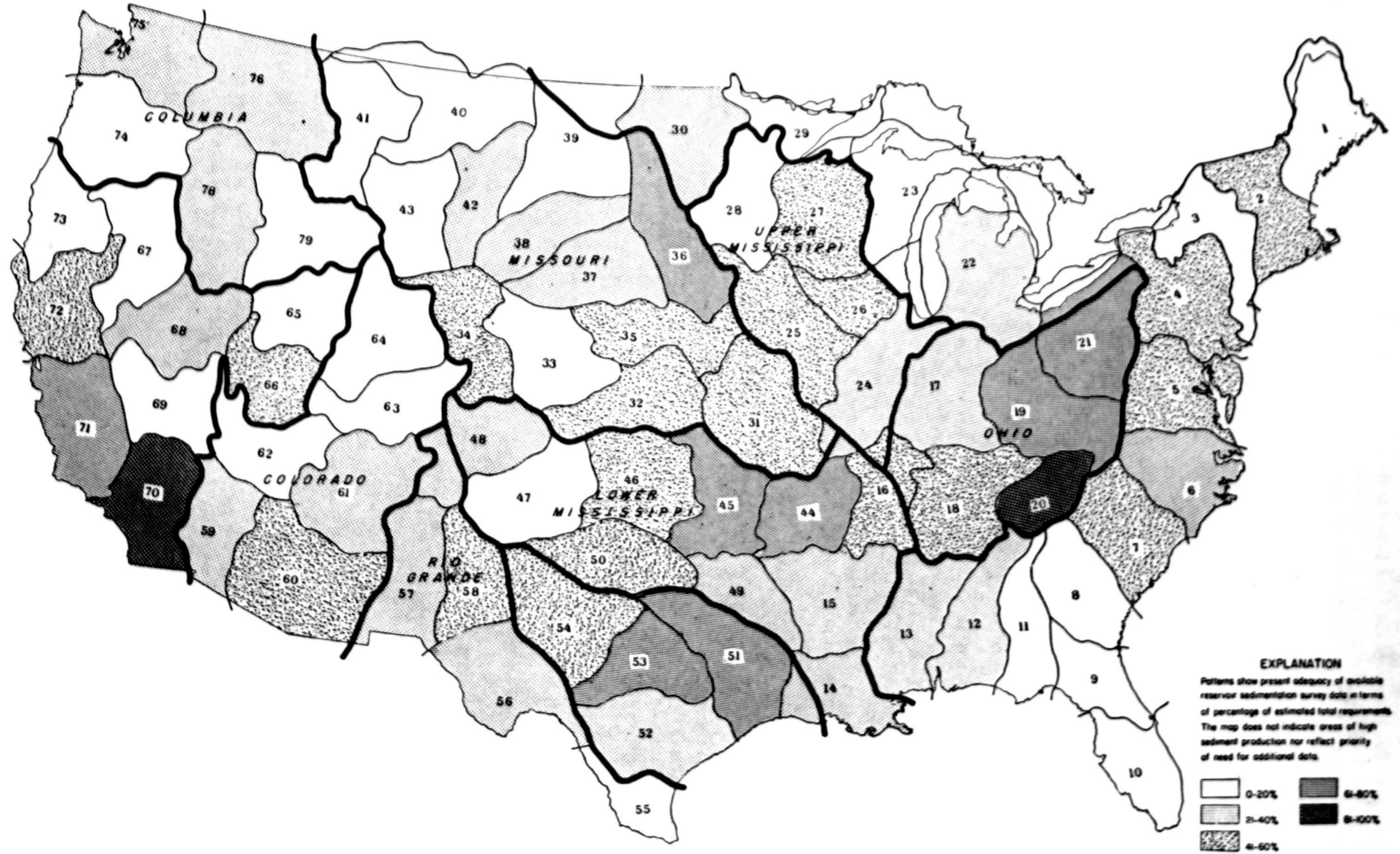


FIGURE 31.—Adequacy of reservoir sedimentation, survey data.

HYDROLOGIC AND SEDIMENTATION RESEARCH

Basic research in hydrology and sedimentation is essential to full interpretation and utilization of data, and to further improve standards for programing, collecting and processing of basic data. There is a definite need for a more intensive program to improve the accuracy of many phases of collection of hydrologic and sedimentation data and, if possible, to reduce the unit cost of this collection.

Basic research in hydrology and sedimentation may be defined as study or investigation directed toward a more nearly complete understanding of the physical, chemical, and biological phenomena involved in the entire hydrologic cycle. Basic research involves intensive study in many sciences and is being undertaken by many agencies, usually with reference to their special problems. Integration of such research, however, is urgently needed.

Projects proposals necessarily must contain factors of probabilities because sampling can never be perfect or complete. The logical way to meet this situation is (1) to reduce the uncertainties through hydrologic research and (2) to evaluate the remaining unknowns through statistical research. Therefore, such reports should present data on the probabilities of deviations from estimated benefit-cost ratios and the means by which economic losses from underdesign and the waste of overdesign may be minimized.

Applied research is the application of the results of basic research in the solution of a specific problem. Major development projects justify the employment of specialists who apply the results of basic research to each project. Minor projects, on the other hand, cannot separately support such personnel. Consequently there is a definite need for applied research in hydrology and sedimentation directed toward supplying concise presentations of significant results of basic research for use by designers. In the aggregate, investments for minor projects may approach the total investment in major projects and therefore the research needs of such projects warrant careful consideration.

A distinction should be made between applied research as defined above and processing of observed data. Research is involved in developing the techniques of processing, but the routine application of such techniques is not research. Processing consists of the reduction of the observed data to appropriate forms of presentation. Processed data should be published promptly.

With these definitions clearly in mind, deficiencies in basic hydrologic and sedimentation research can be discussed. In 1940 the Special Advisory Committee on Hydrologic Data of the National Resources Planning Board pointed out that "Understanding of the basic processes by which water circulates on the earth and in the atmosphere is far from complete."¹ Despite the excellent studies which have been conducted in the interim, this statement is equally true today, partly because we have reached a more mature conception of the complexities of the hydrologic processes and partly because the growth in population and industry require more precise informa-

tion to insure the maximum utilization of available water resources. It is noteworthy that sedimentation, given scant notice in the 1940 report, is now regarded as a major field of research.

A few of the major problems in which basic research is needed to improve our knowledge are as follows:

1. Frequency, intensity, and areal distribution of precipitation and orographic influences on precipitation.
2. Evaporation from free water surfaces.
3. Evapo-transpiration from land surfaces with various types of vegetation and soil depth.
4. Solubility of minerals and rock materials.
5. Effect of vegetal cover and land use on peak rates and distribution of total amounts of runoff, and on sediment loads for large as well as small streams.
6. Long-term fluctuations in annual and seasonal precipitation, runoff, ground-water levels, and sediment movement.
7. Sources and processes of recharge to and discharge from water-bearing formations.
8. Significant physical, chemical, bacteriological, and other biological criteria covering concentration of pollutants in relation to each important water use.
9. Bed and suspended load transportation, including aggradation and degradation.
10. Techniques of estimating sediment production of watersheds from their physical characteristics.
11. Determination of density and rates of compaction and consolidation of sedimentation in bodies of water.
12. Flocculation of sediments.

This list is merely representative of the wide range of problems in basic research in which intensive studies are urgently needed. Although much research is under way, some of the problems significant to water resource development have been scarcely touched.

Positive provision should be made for interchange of information on basic research. The 1940 report on *Deficiencies in Hydrologic Research* recommended the establishment of a "clearinghouse" on hydrologic research, but that recommendation has never been fully implemented. The annual publication of a bulletin giving concise information on the objectives, work in progress, accomplishments, and reports for individual research projects would stimulate hydrologic and sedimentation research and be helpful to all agencies engaged in water resource development.

Reports on basic research should be prepared and published as promptly as usable increments of data become available. Such reports should be systematically circulated to all agencies, both public and private, interested in hydrologic and sedimentation research.

Analysis and study of interrelation in basic hydrologic data should be a continuing effort so that deficiencies in the current collection and processing of data may be more quickly recognized, and accumulations of unprocessed data may be avoided.

One of the most important research needs is the availability of techniques for extrapolating research experience from the environment of small, controlled research areas to large operational areas such as river basins. Until such techniques are available, quantitative application of research results from small areas to the solution of specific problems is exceedingly difficult and results may at times be misleading.

¹ *Deficiencies in Hydrologic Research*. Report of the Special Advisory Committee on Hydrologic Data, National Resources Planning Board (Washington: 1940).

The availability of personnel trained in hydrology and in sedimentation is lagging far behind the demand. More emphasis should be placed on training personnel both to carry on basic research and to apply the results of basic research to specific problems. In general, the curricula of our universities do not provide for adequate hydrologic training.

HYDROLOGIC AND SEDIMENTATION DATA IN TERRITORIES AND ISLAND POSSESSIONS

Alaska.—Urgent need for adequate information on water supplies in the Alaskan region that can be economically and quickly developed for industrial, domestic, agricultural, municipal, and military uses demands that the collection of such data be accelerated.

As of December 31, 1949, there were only 45 stream-gaging stations being operated in Alaska, all of which had been installed within the previous 3 years. Studies by the Geological Survey indicate need for more than 100 additional stations. There also is need for the analysis and special study of all surface-water records. An example of a stream for which data are badly needed is the Yukon River. It is exceeded in drainage area only by the Mississippi and Missouri Rivers in North America, and is estimated to have the fifth largest annual runoff of all rivers in North America. A definite knowledge of the discharge and the flow pattern is imperative, both for the river development itself, and as a basis for international agreement. Yet no records are now being obtained and only spasmodic, fragmentary records have been obtained in the past at any point on the river. At the Ramparts on the Yukon exists the largest potential power development in Alaska. A gaging station would be larger and more costly than any in the United States and would be difficult of access and of operation, but should be installed prior to detailed planning for power development.

Ground-water investigations have just begun in critical areas of Alaska. Complications are introduced by characteristics of occurrence of ground water in Alaska which are quite different from those in the continental United States because of permafrost conditions. As a result, investigations must be accompanied by adequate research. The program for these investigations should be expanded to include detailed examinations of additional critical areas and reconnaissance of the remaining Alaskan region. Explorations so far disclose that Alaska has enormous ground-water supplies of poor quality which makes treatment for most uses costly. Small quantities of good water have been found, but the safe withdrawal rate in these localities should now be investigated.

A small amount of information about the chemical quality of surface and ground waters in Alaska has been collected by Federal and Territorial agencies. Practically all of the scant available data relate to municipal and military supplies in widely scattered areas. Water supplies for military operations in the field are particularly important. Because of the accelerated military activity and the necessity for providing reliable information as a part of our national security, it is recommended that at least 40 to 50 chemical quality stations be established. In addition, provision should be made for special studies of the quality

of surface and ground waters in strategic areas, and for adequate laboratory facilities.

Information on sanitary water quality as affected by sewage pollution is more nearly adequate. Periodic inspections of sources of pollution and analyses of water samples are conducted by the Territory of Alaska Board of Health. However, additional data are required on the wastes in receiving waters. A considerable amount of information is required on the effects of sustained low temperatures on treatment of ground water for domestic and industrial purposes and on sewage treatment processes.

No comprehensive measurements have been made of the sediment loads transported by streams in Alaska. It is known that some rivers such as the Yukon carry large quantities of sediment, especially during the spring and summer seasons of melting ice and snow. Miscellaneous observations show that most streams flowing from glaciers and ice fields carry fine sediment known as glacial flour which is detrimental to turbine blades in power plants. To provide for systematic investigations of sediment in streams of Alaska it is recommended that about 40 sampling stations be established in the Territory.

The collection of basic meteorological data in Alaska is far behind that of any other territory or island possession. There are approximately 130 precipitation and temperature stations serving an area of 586,400 square miles—an average of 1 station for approximately 4,500 square miles. Of the precipitation stations available less than 10 are of the recording type, while 6-hourly precipitation observations are made from about 30 stations. On a comparative basis, the network density is only about 6 percent of that in the United States.

Installation of additional precipitation stations, using existing equipment, will not provide an adequate data source for all parts of Alaska. This is especially true in the Bering Sea, Yukon, and other interior valleys, and Arctic drainage areas where precipitation for most of the year is in the form of snow and often accompanied by high winds. Further development of instrumentation is an essential part of an expanded data-collecting program for Alaska.

In order to make available the minimum precipitation data-gathering facilities it is recommended that 125 stations be installed immediately with additional installations to follow in northern and more remote areas as quickly as suitable instrumentation is available. Because of the existing sparse network and comparatively small amount of available data, it is further recommended that all existing data be immediately processed and analyzed.

Soil moisture and temperature data are needed in Alaska for the fuller interpretation of hydrologic data now being collected and proposed for future collection. These data will be particularly useful in Alaska in the indication of permafrost characteristics. They will be useful in refining the forecasting of stream flow and water yield from snow storage and rainfall and for determining the effect of watershed management practices on runoff and water yields. It is estimated that close to 1,000 soil moisture and temperature stations will be required over a 10-year period.

After viewing the needs for knowledge of Alaskan water resources, it is recommended that the proposed additions to the surface water, ground water, sediment, hydrologic and meteorological, and soil-moisture programs be car-

ried out progressively during the next 10 years. This will assure that most of the minimum necessary data will be available for the sound planning, design, construction, and operation of future hydraulic structures and water-supply development projects.

Hawaii.—The economy of the Territory of Hawaii depends greatly on the availability and location of water supplies for agricultural, domestic, municipal, military, and industrial uses. Certain areas on the leeward side of the islands in the Territory have scarcely any precipitation and, consequently, very little water is available. The permeability of the ground is generally high where the surface is composed of volcanic rocks, but alluvial deposits in valleys are relatively impervious. Alluvium composes the caprock providing artesian head in many wells near the coasts.

A stream-gaging program for Hawaii was started in 1909 in which the Geological Survey is cooperating with the Territorial government. At present, records of discharge are obtained at approximately 120 points on streams and irrigation ditches. The drainage basin of a characteristic stream on these islands is short with steep slopes, extending from the crests of mountains to the sea in narrow, closely-spaced valleys. Flows of the natural surface streams are highly variable with frequent high intensities of runoff. The high permeability and steep gradients of the ground surface make the storage of water in reservoirs uneconomical except on a very small scale. The high value placed on water for irrigation, the importance of observing water rights, and the growing importance of flood control create a great need for a continued and an expanded stream-gaging program. It is recommended that the present coverage of gaging stations be increased 50 percent during the next 10 years.

Of all our island possessions and trust territories, the Hawaiian Islands are best known from the standpoint of ground-water hydrology; however, much still remains to be done there. Ground-water reconnaissance studies ranging from low to high order have covered all the major islands of the Territory of Hawaii, and in a few local areas intensive studies have been made. The geology is complex and recharge to the aquifers is highly variable from place to place and from time to time. It is believed that large additional ground-water supplies can be safely developed in some areas, but other areas apparently are either overdeveloped resulting in salt-water intrusion, or are nearing that stage. The draft on the ground-water reservoir in the Honolulu area already exceeds the annual recharge. Detailed investigations of the fluctuations of the salt water fringe and the levels and volumes of recharge will be increasingly necessary in the next decade in order that existing supplies are protected from salt contamination during dry years.

Only a relatively small amount of information is available about the chemical quality of surface and ground water in the Hawaiian Islands. Available data indicate, however, that the quality is generally good and satisfactory for practically all purposes except in those areas where the fresh water is contaminated with sea water. Salt-water intrusion in ground water is the principal quality problem in certain areas, especially where ground water is used for irrigation. This has been partially overcome by collecting fresh ground water in tunnels and galleries just above the salt water layer on which the

fresh water floats. Additional information is needed concerning the extent and thickness of the fresh water lens during different periods of the year in order to make more effective use of the available fresh ground-water supplies.

Information on sanitary quality as affected by sewage pollution is generally adequate. Periodical inspections of sources of pollution and analysis of water samples are conducted by the Territory of Hawaii Board of Health. Additional data are required on pineapple cannery and on sugar mill wastes in certain areas, and on the distribution and effects of these wastes in the receiving waters.

To guarantee that existing water sources are utilized in the most economical manner, it is imperative that an adequate network of gaging stations and ground water observation wells be established in the near future. Surface and ground water sources are heavily used for irrigation. An expanding population in Honolulu will soon require the diversion of water now used for irrigation to municipal use. Equitable adjustment of this problem will require an expanded program of data collection which must be started immediately if the data are to be available when the various needs for water begin to conflict.

Available basic hydrologic and meteorological data in the Hawaiian Islands are probably more complete than for any other area under the jurisdiction of the United States.

There are approximately 825 precipitation and 60 temperature stations in the 6,420 square miles comprising the islands. Of this total, records from about 300 precipitation and 60 temperature stations are published by the Weather Bureau. The greatest density of precipitation stations, 1 for about $2\frac{1}{2}$ square miles, is found in the Island of Oahu, while the least density, 1 gage for about 20 square miles, is found in the Island of Hawaii. Temperature station distribution varies from a density of four per square mile in the Island of Oahu to 1 per 200 square miles in the Island of Hawaii.

Although a very dense network of precipitation gages is in operation, the number of recording gages is very small. With the exception of Oahu, which has about 20 recorders, all of the other islands have but 1 or 2 each.

Another consideration of the precipitation network in the Islands is an unbalanced distribution of gages. For example, the Island of Hawaii with a total of about 220 gages has about 190 located at elevations below 5,000 feet. The remaining 30 gages are installed at elevations between 5,000 and 9,500 feet, while the maximum elevation of the Island is about 14,000 feet. The area above 5,000 feet elevation represents about one-third of the area of the island.

In view of the unusual density of the nonrecording precipitation network, it is recommended that about 20 recording and 10 storage-type gages be added to the network. Most of these gages would be installed on the islands of Hawaii and Maui at the higher elevations.

There were four evaporation stations in operation on the Islands until two or three years ago, at which time they were closed. It is recommended that these stations be reopened or that an equivalent number be established at different locations if more desirable sites are available.

Soil moisture data are also needed in Hawaii for more precise interpolation of hydrologic data. It is estimated that installations of several hundred stations in the next 10 years will suffice for improving the techniques of

determining the effect of watershed management practices on runoff and water yields and in refining the forecasting of stream flow and water yield from snow storage and rainfall.

Island Possessions and Trust Territories.—Surface water investigations have been very limited, and even non-existent, in some cases. A relatively small amount of data is available in Puerto Rico as a result of work done by its Water Resources Authority and other government agencies. The Virgin Islands have practically no streams, and consequently no surface water data. Except for the slight amount of information that may have been obtained for military purposes during World War II, no information is readily available concerning surface-water supplies on the Trust Territories of Guam, Wake, and American Samoa. In all probability, very little data have been collected due to the occurrence of most of the water in the ground rather than on the surface. In the Panama Canal Zone rather intensive surface-water studies have been made over a period of years, particularly in connection with maintaining the water level of the canal.

Some ground-water studies have been made in these possessions. Reconnaissance studies have been made on Puerto Rico and one of the Virgin Islands group in connection with municipal supplies and irrigation. The entire Island of Guam has been covered by a medium-order reconnaissance survey and several low-order reconnaissances. No detailed or intensive studies have been made and only generalized knowledge of the ground water exists. A low-order reconnaissance study has been made covering the Islands of Tutilla, Annuu, Ofu, Olosega, Tau, and Rose of American Samoa.

A small amount of information about the chemical quality of surface and ground water in Puerto Rico and the Virgin Islands has been obtained in connection with reports on ground-water supplies. Practically no records about the quality of water are available for Guam, Wake, American Samoa, and the Panama Canal Zone.

Additional data should be obtained on the water resources of the island possessions of Puerto Rico and the Virgin Islands in order to determine the availability and evaluate the suitability of all water supplies for industrial and domestic uses. Some information should be obtained with reference to public supply, domestic use, and military needs in the Trust Territories. In all of these areas one concern is salt-water intrusion by overdevelopment of ground-water supplies. Reconnaissance surveys should be made for over-all water resource needs, followed by detailed studies for those areas where problems exist or are likely to arise.

There are at present 92 precipitation, 38 temperature, and 2 evaporation stations on the Island of Puerto Rico. Within an area of 3,435 square miles, this represents a station density comparing favorably with that in continental United States. Only two of the precipitation stations, however, are equipped with recording gages. An addition of about 30 recording rain gages, uniformly distributed, would provide much more adequate information on rainfall intensity and, moreover, would increase the network density, which is considered reasonable in the absence of specific need for greater density.

Within the 133 square miles of the Virgin Islands, there are 19 precipitation stations and 4 temperature stations. This would appear to be adequate coverage

with the exception that one evaporation station should be established.

Soil moisture data should also be collected in the other insular possessions. Several hundred stations will be needed in these possessions for the fuller interpretation of hydrologic data now being collected or which will be collected in the future.

B. Topography

Topographic mapping is the science of measuring and depicting on maps the physical and cultural features of a place or region. In general the maps portray (1) relief, the physical features of the earth's surface; (2) drainage, by which is meant streams, marshes, lakes, oceans; and (3) culture, or man-made features, such as roads, railroads, buildings, boundaries, place names, and other similar items. Such maps are considered the base maps, or master maps, of the land area. Most of the other types of maps needed by Government and industry are compiled from, or are based upon, the topographic maps.

Accurate topographic maps are regarded as a prerequisite for developments and programs involving land and water utilization. They are important in the planning of all navigation, flood control, and reclamation projects, in land classification, and in conservation programs. Topographic maps provide essential base maps for plotting and analyzing geologic, soil, hydrologic, and other types of basic data. For military use, topographic maps are of paramount importance for conception and execution of operational plans, combat training, troop movements, and coordination of land, sea, and air activities.

In the early stages of this country's development most of the mapping done by Federal agencies was for the particular needs of the individual agencies. In the case of the Geological Survey, for example, topographic mapping was originally undertaken primarily to obtain base maps for geologic and mineral investigations. For many years, no real effort was made to develop coordination of Federal mapping activities into a program of systematically providing for national map requirements. In 1940, the Bureau of the Budget, recognizing the importance of basic surveys of our physical resources and of related mapping and charting, began its work in programming such activities and in coordinating the operations of Federal surveying agencies toward the effectuation of planned programs.

The Geological Survey of the Department of the Interior is the principal producer of topographic maps, its activities representing approximately 80 percent of the topographic mapping currently being accomplished in this country. Before it and the other Federal agencies concerned begin actual mapping, however, a basis or framework of controlling positions, of latitude and longitude and of elevation above mean sea level, is established by the Coast and Geodetic Survey of the Department of Commerce.

The Army Map Service of the Corps of Engineers of the Army produces a small volume of domestic maps, although its efforts are mostly devoted to mapping of overseas areas.

Likewise, the Coast and Geodetic Survey, requiring topographic information of coastal areas for the nautical

charts which it produces, also does topographic mapping in such areas if the Geological Survey has not mapped the required areas or is unable to map them in time for the Coast Survey's use.

The Forest Service of the Department of Agriculture is another producer of topographic maps, its operations being confined to the national forests. The Tennessee Valley Authority also has a staff producing such maps in the area under its control, in cooperation with the Geological Survey. By interdepartmental agreements, the Geological Survey is recognized as the principal producer of topographic maps, in the sense that it does the great majority of the work, and that the maps made by other agencies are submitted to it for final editing before publication and general distribution.

PUBLICATION SCALES

The topographic maps published by Federal mapping agencies vary in scale from 1 : 24,000 to 1 : 250,000. In general, maps distributed to the public are now produced at scales of 1 : 24,000, 1 : 31,680, and 1 : 62,500. The choice of scales is based upon the type of terrain and the particular use to be made of the maps. In recent years, there has been an increasing demand for maps at the larger scales and at present mapping at these scales is considerably in excess of that at the smaller scales.

Topographic maps are produced for purely military purposes at scales of 1 : 25,000, 1 : 50,000, 1 : 100,000, and 1 : 250,000. In general, these maps are prepared by photographic reduction or enlargement of the civil editions. In the process, the military grind is added and the border information changed to provide data which the civil editions do not require.

CONTOUR INTERVALS

The contour intervals for topographic maps at scales of 1 : 24,000, 1 : 25,000 and 1 : 31,680 are generally 5, 10, or 20 feet, depending upon the terrain. Maps at scale 1 : 50,000 and 1 : 62,500 use intervals of 10, 20, or 40 feet and sometimes 100 and 200 feet where the terrain is particularly rugged. Maps at scales smaller than 1 : 62,500 usually have larger contour intervals in proportion to their scales.

NATIONAL MAP ACCURACY STANDARDS

Since 1941, nearly all topographic maps, produced by or for Federal mapping agencies, have been prepared on the basis of standard specifications for accuracy. By this procedure, each user of a topographic map is assured that it has been properly made and that he can rely upon the information shown. To bring this fact to the attention of the map user there is imprinted at the bottom of each sheet the statement, "This map complies with National Map Accuracy Standards."

STATUS OF TOPOGRAPHIC MAPPING

The status of topographic mapping is indicated in figure 32. There are available to the public two status maps in greater detail which are published annually by the Geologi-

cal Survey. One map shows the status of mapping at scales of 1 inch equals 1 mile or larger, and gives indications of the relative quality of the maps produced. The other shows coverage by maps of reconnaissance quality at scales smaller than 1 inch equals 1 mile. In general terms, approximately 25 percent of the area of the United States is covered by acceptable topographic maps on scales of 1 : 62,500, 1 : 31,680, and 1 : 24,000. Maps at these scales are available for a very small percentage of Alaska, but an attempt is being made to obtain interim map coverage with maps at scale of 1 : 250,000.

The demand for topographic maps is evidenced in the annual map priority requirements submitted by Federal agencies to the Bureau of the Budget, letters from the public, contacts with State or municipal governments, and the resolutions of technical and civic societies. There are few areas within the United States and its territories and possessions for which there is not a request for topographic maps from some source. The critical program deficiency is revealed in a startling manner in that the present annual mapping program constitutes less than 2 percent of the expressed demand.

RECOMMENDATIONS

It is recommended that topographic mapping of the continental United States, at scales of approximately 1 : 62,500 or 1 : 24,000, be completed during the next 20 years.

It is recommended that topographic mapping of the critical areas in Alaska (approximately one-third of the total area) be mapped at the scale of 1 inch equals 1 mile or larger during the next 20 years.

Provision should be made for periodic revision of topographic maps to insure that they show up-to-date information.

C. Geology

Geologic maps, with related reports and records, portray the make-up of the earth's crust. They show the kind, character and distribution of all the solid rocks, and of the unconsolidated rocks as well, since loose bodies of sand, gravel, and glacial clay are just as much geologic formations as are the hard rocks. They also show the structural relations of one rock body to another, their folds and faults or dislocations, and the distribution and character of mineral deposits.

The Geological Survey is the Federal agency primarily responsible for making and publishing basic geologic maps and reports. In addition, nearly all of the States maintain staffs of geologists and produce some geologic maps, of quadrangles, counties or other areas, either independent of, or in cooperation with, the Geological Survey.

Basic geologic maps are published at various scales, depending upon the particular purpose for which they are prepared. In general, the scale range is between approximately 1 inch equals 1 mile and approximately 1 inch equals one-half mile. These are general purpose geologic maps. Larger scale maps are prepared for specific coverage of small areas, where the geologic information required must be shown in rather minute detail. Standard topographic maps are utilized as a base for field studies and for plotting the geologic information.

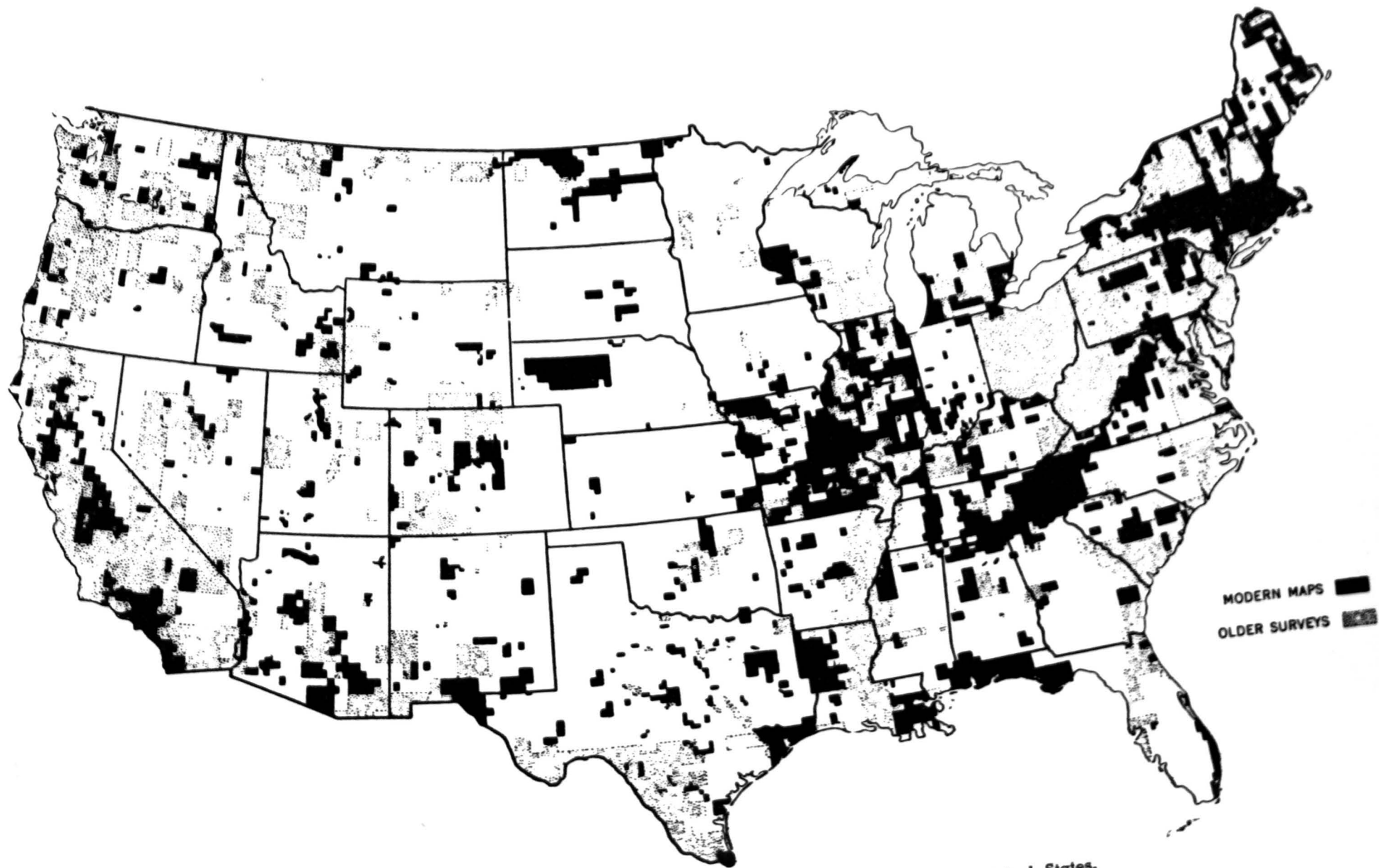


FIGURE 32.—Status of topographic mapping in the United States.

Geologic maps are prime requisites for investigations of mineral resources, underground waters, construction materials, and foundations for engineering structure. Since water control structures of all kinds, such as dams, levees, tunnels, and canals, are built on or under the surface of the earth, the determination, interpretation, and application of geologic facts cannot be safely or economically avoided. The planning, designing, or building of such structures requires knowledge as to the strength, durability, water-tightness, and ease of excavation of the geologic materials that underlie them. Highways, like dams and levees, are built both on, and of, geologic materials. Plans for them must include accurate estimates, not only of the amount of cut and fill required, whether or not they will tend to slide after every rain, and whether or not the material removed from cuts will stand up when used as fill or for subgrade. Agricultural development, whether by irrigation, drainage, or other means, as well as the classification of lands for these purposes, requires knowledge of the permeability of the soils and rocks beneath them, and of the chemical nature of these materials.

STATUS OF GEOLOGIC MAPPING

As shown on figure 33, approximately one-tenth of the United States has been mapped geologically on scales of 1 inch equals 1 mile, or larger. One mile to the inch is considered to be the minimum usable scale for any but the broadest kind of planning purposes. Small scale geologic maps (8 miles to the inch or smaller), useful for broad generalizations but for little else, are available for most States. But of these maps, some were compiled years ago and do not include the results of subsequent detailed geologic mapping, and eight States—Maine, North Carolina, Florida, North and South Dakota, Nebraska, Nevada, and Oregon—do not have even this kind of coverage. Consequently, for any given proposal for water resources development, geologic maps on adequate scales are rarely available. To make matters even worse, large numbers of existing geologic maps have been prepared for some special purpose, such as the discovery and delineation of mineral resources. Hence, they tend to stress selected geologic data, such as the character and structures of the rocks at depth, rather than data on rocks closer to the surface, those on which man must live and build. Too, the minerally rich areas that have been mapped seldom coincide with the areas of greatest interest for water and land resource development.

The foregoing analysis is based on the scale of mapping as the sole criterion of adequacy. As a result many large areas are included with those classed as adequately mapped, even though the maps do not show the surficial geology or other features in sufficient detail. It is, therefore, apparent that though our national store of geologic knowledge is fairly voluminous, including unpublished geologic maps in the files of governmental agencies, of universities, and of private companies, the chances of finding really adequate published data that bear on a given problem are small indeed. The only real cause for optimism is that today no large engineering structures, and fewer small ones, are built without the advice of staff or consulting geologists. These geologists, however, lack adequate geologic data on the surrounding region on

which to base detailed investigation and recommendations at and near the construction site, and consequently must seek out the regional basic data they need, with the resultant loss of time and use of funds that should be spent on details of the job in hand.

Geologic mapping in Alaska is far behind that of continental United States. More than half of the Territory is essentially unknown geologically, and about 45 percent of the area have been covered only by exploratory geologic mapping. An estimated 3.5 percent has been mapped geologically at scales adequate to permit a general analysis of geological features pertaining to mineral exploration or to land and water development and use.

At the present rate of progress, it is estimated that it will take at least 75 years to complete the coverage of United States with general-purpose geologic maps. Our needs for basic geologic data will be met completely only when modern, general-purpose geologic maps, on a scale of 1 inch equals 1 mile, or larger, are available for the entire area of the United States and Alaska. Only then can we hope really to know our land and our mineral resources position. Only with such maps can we be certain that the basic geologic facts needed for soils mapping, hydrologic investigations, and for safe and economical planning, design, and construction of engineering works, are available and will be used.

RECOMMENDATIONS

In view of the recognized deficiencies in our knowledge of the geology of our country, it is recommended that there be a rapid acceleration of general-purpose geologic mapping. It is believed that the goal should be to complete the coverage of the Nation with mapping of this type during the next 30 years. Along with this acceleration in the mapping effort there should be programming of operations based upon the priority needs of the principal users of geologic data. The procedure employed in preparing the annual programs for topographic mapping, whereby the users each year indicate graphically the priorities of their needs for maps, should be applied to geologic mapping.

D. Basic Soils Data

Basic soils data are collected to discover the location and extent of the different kinds of soil. This information is shown graphically on maps which are accompanied by descriptions of the various soils encountered in an area, together with other physical and chemical data essential to their interpretation and use.

Classification of soils is based upon a number of factors, internal and external. Included among these are: Number, arrangement, and thickness of horizons of significant layers in the soil profile; texture, color, structure, and consistence of each horizon, and its chemical and mineralogical composition; reaction (acidity or alkalinity) and permeability of each horizon; effective depth (depth to layer that seriously interferes with root and water penetration); natural soil drainage (including presence of ground water at or near surface); moisture capacity (field capacity and wilting coefficient); organic matter content; salinity (kinds and amounts of soluble salts) of each significant layer; stoniness; depth to and character of

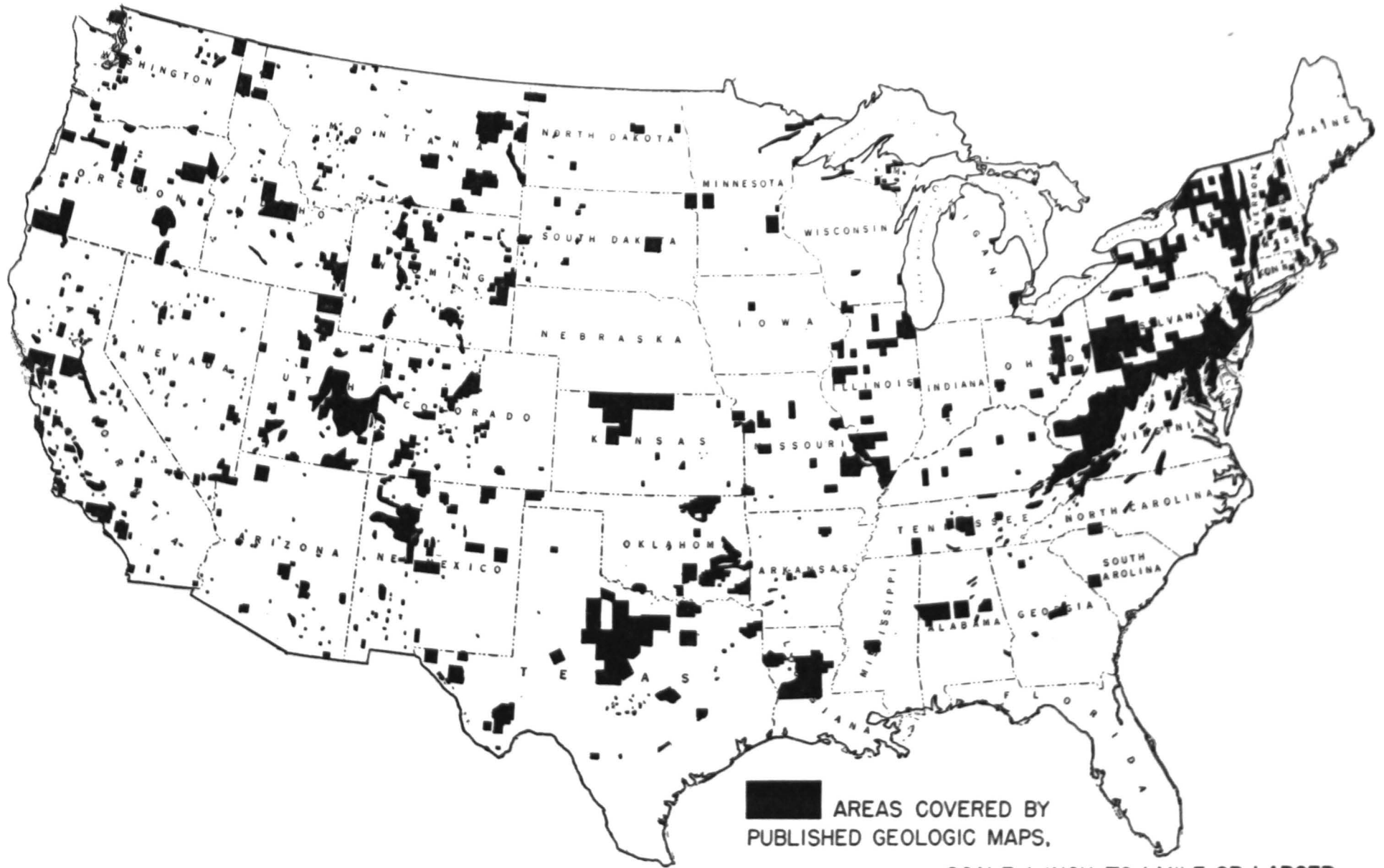


FIGURE 33.—Status of geologic mapping in the United States.

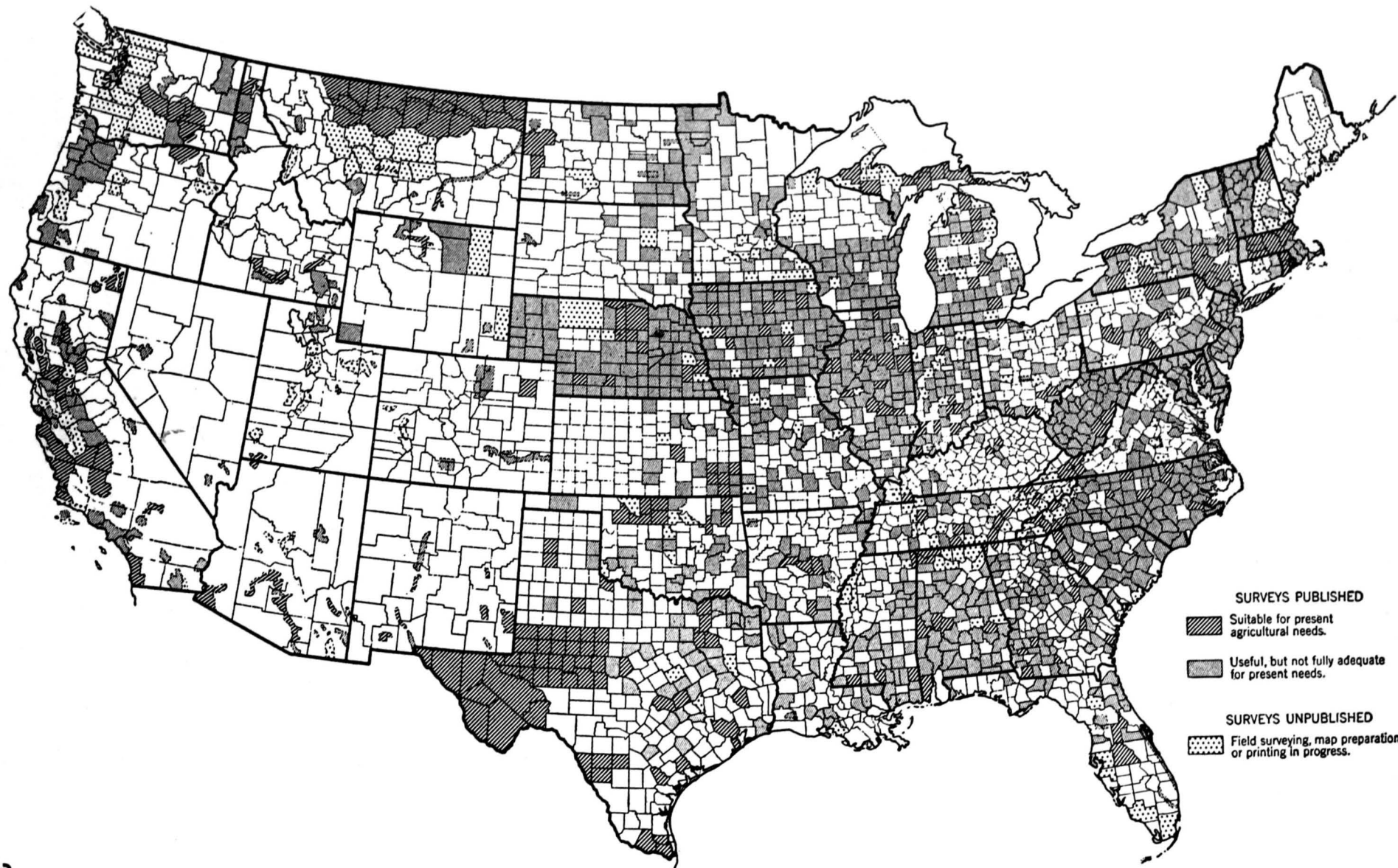


FIGURE 34.—Areas covered by the soil survey.

substratum (C and D horizons); slope gradient and micro-relief; and kind and degree of past erosion.

All the foregoing are not of equal importance in every soil. Furthermore, the importance of any one will depend upon the others with which it is found.

The characteristics or properties in the list are those that must be considered in defining soil types or phases, or comparable classes and units of soils in making soil maps. Some are directly observable and can be used as criteria in field operations; others must be correlated with and inferred from directly observable characteristics. Investigations have shown that certain characteristics tend to be associated in soils and that it is, therefore, possible to define kinds of soils having relatively narrow ranges in the important characteristics or properties. After these relatively uniform kinds of soils have been defined and shown on maps, they serve as a basis for accumulation and analyses of experience and research. Furthermore, the background of information is drawn upon in planning further investigations, in future interpretations of research, and in the planning and development of various programs.

Basic soils data are collected by a number of Federal agencies and by several of the States. The Bureau of Plant Industry, Soils, and Agricultural Engineering collects soils data and publishes such data in the form of soils maps and related descriptive material. The Soil Conservation Service also collects and publishes soils data on land capability maps. Likewise, the Bureau of Reclamation collects such data for use in the classification of irrigable lands.

Soils data are also needed for engineering purposes, such as for roads, levees, dams, and the like. At present, not all of the requisite data useful to engineers are shown on soils maps or are considered in accompanying descriptions. This should be remedied. It can be done by obtaining certain added information on soil characteristics, such as shearing strength, consolidation, compaction, and plasticity. Such information, if obtained concurrently with other phases, would broaden the usefulness of the soils maps and furnish information needed in planning and construction.

Greater coordination between agencies and groups interested in soils is needed. Such coordination should lead to better understanding of soils problems, better integration, and greater usefulness of various soil data.

STATUS OF SOILS DATA

The soil surveys made by the Bureau of Plant Industry, Soils, and Agricultural Engineering, in cooperation with the State agricultural experimental stations, cover approximately 650 million acres, of which approximately one-third consists of early works in need of revisions. In these detailed surveys the mapping units are soil types and phases. Most of such soil maps that have been produced are on a scale of 1:62,500. The areas covered by these surveys are indicated on figure 34.

The soils data collected by the Soil Conservation Service as a part of soil conservation survey cover approximately 322 million acres. Areas covered by such maps are shown on figure 35. Soils data which have been collected for irrigability surveys by the Bureau of Reclamation cover approximately 39 million acres and the areas are indicated on figure 38.

It would be helpful in many areas if soil mapping were done by quadrangles, permitting soils to be superimposed on basic topography and geology.

Although there are great gaps in the knowledge of soils, the greatest deficiency exists in the soil information for forest and range lands. This is particularly true on the public lands. This lack of adequate soils information for the public lands is resulting in heavy losses to public property.

There are other deficiencies with respect to basic soils data. These are both physical and chemical. For example, some 15,000 infiltration tests have been made on perhaps 100 soil types throughout the country. Such information needs to be extended to all the important soils as a basis for runoff and other determinations. Similarly, erodibility is not known for many important soils although land classifications and land management practices should be based on such information. Knowledge of the true depth of root penetration and of the march of soil moisture throughout the root zone is imperfect.

A great storehouse of information in soils has been collected, as a result of the activities of many investigators. Soils have been under study by Federal and State agencies, experiment stations, and laboratories for many years. Despite all this study, there are still great gaps in our knowledge, which can only be closed by continued and further research.

A whole new field of effort has been opened to the soils scientists by recent atomic developments. Isotopes are beginning to permit study of such matters as the passage of water through the soil, the rate at which vegetation takes water into its system, and the rate at which water is transpired. Such studies will improve understanding of the physical, chemical, and biological properties of soil and the water relations between soils and plants.

Information about the soils of this country should be obtained over the Nation as a whole without waiting in each place until the imminence of some program demands it. This information will help in solving many problems, no one of which would justify an independent investigation, and at the same time avoid the necessity of obtaining such facts every time a new problem arises.

There is need for proper balance among the segments of a program of soil investigations. Field mapping provides a part of the information on which soil classification can be based. Physical, chemical, and mineralogical analyses and careful morphological studies also provide a part. Investigations that disclose the behavior of soils under various treatments and uses ultimately make the classification of maximum usefulness.

RECOMMENDATIONS

All interested Federal and State agencies should cooperate in collecting basic information on soils. Agencies should, wherever practical, contribute toward completing basic soil studies.

Nation-wide soil classification and mapping should be accelerated on the basis of an orderly and periodic programming. It should be completed in 20 years.

The proper content and degree of detail needed in soils activities should be subject to periodic review and adjustment to procure the widest possible service consistent with reasonable cost.

There should be cooperation among the soils data collecting agencies and the users of such data to develop standard specifications for soils classification and mapping, and to provide for standard nomenclature.

Efforts should be made to obtain soil data that will be as generally useful as possible. Before initiation of surveys, all anticipated needs in the particular area should be considered and satisfied as far as practicable. This would, in some instances, require the collection of data over and above that necessary for ordinary purposes.

Soils data should meet all foreseeable requirements insofar as practicable. This would necessitate that the requirements of sciences other than agriculture, particularly engineering and hydrology, should be met.

Research on soils should be greatly expanded and intensified.

E. Cadastral Survey of the Public Lands

The cadastral survey of the public lands is executed by the Bureau of Land Management for the purpose of subdividing the areas into units suitable for administration or disposal and to mark on the ground the boundaries of those subdivisions. Original cadastral surveys create the boundaries of these units of the public lands and provide the basis for their legal description. The first surveys were made in Ohio in 1786 and were extended south and westward beginning about 1800. Most of the surveys were made west of the Mississippi River beginning in 1800 and continuing to the present. No area of the public domain can be adequately described until it has been surveyed; none of the public lands can be patented until it has been surveyed.

In the early stages of surveying the public lands, cadastral surveys were executed under contract and during that period the corners were generally monumented by native stone or wooden posts. Since 1910, when the contract system was abolished, the corners of the public land surveys have been monumented with standard metal posts. The unit of survey of the public lands is the township, being an area 36 miles square. The township is subdivided into 36 sections, each 1 mile square. Monuments are established at the four corners of each section as well as the one-fourth corner of the boundaries of the section.

Cadastral surveys by the Bureau of Land Management, unlike scientific surveys of an informative character which may be amended with changing conditions or because the survey was not executed according to present standards, cannot be ignored, repudiated, altered, or corrected, if they mark the boundaries of lands patented by the United States. The plat of the cadastral survey is a graphic representation of the survey made in the field. It shows the courses and lengths of the survey lines between monuments, the description and area of each parcel of land included in the survey and, as far as practicable, a delineation of the important relief, drainage, and culture.

The township plats are generally prepared at the scale of 2 inches equal 1 mile although plats of less than a full township are frequently prepared at the scale of 4 inches equal 1 mile. The direction of all lines of the public land surveys is determined with reference to true north or south at the point of record, based on solar or stellar observations.

AREAS IN CONTINENTAL UNITED STATES

There are approximately 116,000,000 acres of the public domain in continental United States, located in 11 Western States, which have not been surveyed. This is equivalent to about 15 percent of the total areas of those States.

The unsurveyed area in general consists of two types; rough mountainous lands covered with timber and brush, which has been included in national forests, and desert or arid lands, located in Nevada, Utah, Arizona, and California. The value and future need of timber and the potential mineral deposits in the unsurveyed areas constitute one of the primary needs for the completion of cadastral surveys. Original surveys are also needed for the establishment of the boundaries of the areas leased under section 15 of the Taylor Grazing Act and for grazing administration; and also for the identification of lands leased under the Oil and Gas Act.

Title to approximately 55 percent of the area of the 11 western States is still in the Government. When the contract system was abolished, approximately 67 percent of the area of those States had been surveyed. Since 1910 approximately 137,000,000 acres have been surveyed, and corner positions have been monumented with iron posts. During the same period more than 50,000,000 acres were resurveyed and the corner positions marked with iron posts. The Government still has an interest in about half the area surveyed prior to 1910 which is not properly monumented. For example, the United States owns approximately 2,600,000 acres of Oregon and California revested land. Many of the original surveys were made from 75 to 90 years ago. The corners are obliterated and the entire area should be resurveyed. Timber values in the Oregon and California area are extremely high—often running \$250,000 to \$400,000 a section. A difference of 100 feet in the location of a section corner may involve timber valued at \$5,000.

The demand for resurveys in continental United States will depend to a large extent upon the development of the river basins. For example, 10,000 square miles are now being resurveyed in the Missouri River Valley as requested by the Bureau of Reclamation, and it appears that before the project is completed the resurvey of a considerably larger area will be necessary.

Resurveys are needed for grazing administration, determination of the boundaries of the areas leased under section 15 of the Taylor Grazing Act, and determination of the boundaries between Government land and privately owned lands. They are also needed in the national forests and on the public domain in connection with the sale of timber, in the settlement of trespass cases, and for the identification of lands leased under the Oil and Gas Act.

Resurveys and subdivision of sections are necessary for the proper administration of the Small Tract Act passed in 1938. Numerous small tract classifications have been made in Arizona, Nevada, California, New Mexico, and Florida. The surveys are needed in order that the applicants may be able to locate the tracts.

SURVEYS NEEDED IN ALASKA

The area of the Territory of Alaska is 365,481,600 acres. The rectangular system of surveys has been extended over 2,499,784 acres, or less than 1 percent of the

total area. Although the entire area of Alaska never will be brought under the rectangular system of surveys, it will be necessary to keep a substantial force of engineers employed in the Territory to make the surveys necessary for settlement and development. At the present time there is an urgent need and demand for the survey of approximately 140 isolated tracts, such as homesites, homesteads, trade and manufacturing sites; the survey of 8 townsites; the survey of approximately 450 small tracts in southeastern Alaska required for homes for the employees of the pulpwood industry; and surveys along the Glenn and Richardson Highways, and in the Chena, Dunbar, Haines, and Chilkat Lake areas for settlement purposes.

RECOMMENDATIONS

It is recommended that the cadastral survey of the public domain in continental United States, and necessary resurveys required in the administration of Government-owned lands, be completed in the next 10 years. This requires survey of 116,000,000 acres and resurvey of 50,000,000 acres. It is also recommended that an orderly program of cadastral surveys necessary for the settlement and development of Alaska be accomplished in the next 10 years. At present less than 1 percent of the total area of Alaska has been surveyed.

F. Natural Vegetation

Information on our natural vegetal resources is obtained from surveys and field measurements. Such information is required in preparing basic plans for the full development of water and land resources of a basin, in planning specific watershed programs, and in carrying out watershed management on the ground. These data are needed in planning measures for reducing sedimentation in streams, for replenishing ground water, and for reducing surface runoff or for increasing water yields. They are also required in determining the best use of land, in preparing plans for land-clearing projects, for recreational and wildlife programs, and evaluating the effects of national and regional land policies. Such data are needed by all public agencies involved in watershed management controls.

The preparation of maps showing the natural vegetal cover and its condition and the assemblage of information associated with them, are among the first steps necessary in land classification or in developing watershed management programs. Knowledge of the distribution and kind of cover, and of its characteristics as to composition, density and condition is basic to full appreciation of the value of the resource, its relation to the soil and water resource, and its place in the basic economy and development.

Information on the vegetal cover is essential in watershed management planning and operation, for cover class alone often indicates the kinds of land treatment measures to be used. Under some conditions knowledge of the plant associations gives broad indications of a needed program and the degree of effectiveness to be expected from it. Vegetal cover information is also helpful in determining the degree to which various forms of wildlife may be found, where competition between different kinds of game may occur for different types of food, and where

wildlife might survive when transplanted. Such information also helps in translating other biological facts into the whole resource development program.

Data on vegetal cover also give certain broad clues which can be interpreted into such matters as rates of infiltration and permeability of the soil, need for drainage, character of soil for agricultural or other development, and in some places, the chemical nature of the soil itself.

The condition of the cover lends even more strength and emphasis to land treatment programs. It determines to a large extent the degree and often, when associated with topography, the relative amount and character of erosion. It helps determine among others things, infiltration rates, runoff conditions, and provides a substantial base for land use programs. Cover information gives an indication of the location of actual or potential high runoff or silt and sediment-producing areas. Data on cover conditions are essential in developing watershed management programs and on a regional or national scale, and help determine broad programs of land use.

Other facts relative to the vegetal cover are essential in watershed management programs. As applied to the range they help determine the degree or extent of grazing that should be permitted on range lands whether by livestock or by big game. They indicate the extent to which changes in cover have been made by overgrazing or other abuse. They also furnish the basic information on which range policies and range management are developed especially for those range lands under Federal jurisdiction.

As applied to forest lands, such facts help determine the needs for fire control, reforestation, stand improvement, and the like. They also aid in determining the forest management budget, that is, the balance between growth and the amount cut by classes such as pulpwood, saw timber, and mine props, both nationally and regionally. They also help determine areas which because of location, kind, or character, or which because of slope, soil, or geology, should be maintained as watershed protection areas free from use which may start or encourage damaging runoff or erosion.

STATUS

Data on the natural cover conditions are inadequate for detailed management for a large area of the forest and range lands of the country. Cover maps are available for much of the country on a generalized basis. Some of these indicate broad natural types, others show only partial data or some local classification that cannot be fitted into national standards. Maps prepared for one unit often do not agree with those for an adjoining area and rarely are made on the same scales.

The Forest Service, through its Forest Survey, has been working on a national inventory of the forest area for two decades, but the job is far from done. Only two-thirds of the 624 million acres of forest land in the United States have been initially surveyed. This leaves one-third untouched, mostly in the Rocky Mountains and California where water is of high value. Resurveys of one-half the area previously inventoried are needed to bring the results of the initial survey up to date and to desirable present-day standards. This is especially necessary because heavy cutting during the war period and

normal depletion and growth before and since, combined, served to bring about extreme changes in the forest cover and timber volume.

RECOMMENDED STANDARDS

Both initial surveys and resurveys of the forests need speeding up and intensifying in order adequately to serve many public and private purposes. Maps of natural cover types can serve most purposes best when superimposed upon standard topographic maps as a base. Consequently mapping of these types should follow the preparation of acceptable topographic maps. Units of measurement to serve maximum purposes would have an area of 10 acres in important vegetation types and 20 acres in less important and significant types. All such mapping should be to national uniform standards.

Initial surveys to cover some 200 million acres of forest land in the Rocky Mountains, California, Central and Northeastern States are required. In addition, it is desirable that resurveys of about 200 million acres covered more than 10 years ago in the Northwest, Lake States, and South, be made as rapidly as possible. Progress on this job has been slow. Available information is also not sufficiently intensive to satisfy commercial demands. More detailed surveys are needed. Contributions from private and State agencies make possible acceleration of survey techniques to meet some local requirements. At the present rate of progress 6 to 8 years will be required to complete the initial survey. And when this is done, resurveys will be far behind.

The United States should be covered by a forest inventory every 10 years. This means surveying 62 million acres per year. Such surveys could be intensified and adjusted to meet the needs of water resources development.

A Nation-wide range inventory, or more properly, a western range inventory, has not been attempted. Instead various surveys of the range resource have been made, primarily of certain range allotments on public lands rather than for large areas. Perhaps 10 percent of the range area has been mapped and surveyed to determine species, composition and degree of use, but these surveys have not been to the same degree of accuracy or standards. In addition, the separation of range types has not been uniform. Of late, agreement has been reached among many range resource surveyors as to the standards to be sought and the items to be cataloged. The stage is now set for going ahead on a uniform western-wide basis.

RECOMMENDATIONS

A complete coverage of the range area is needed. This should be completed in about 15 years with a periodic recheck every 10 years thereafter. Such surveys should encompass all lands, public and private.

It is recommended that a cover type map be prepared according to nationally uniform standards and specifications, and that this map should be completed within 5 years of the time that topographic quadrangles for the country are finished.

The forest surveys of the United States should be completed within the next 5 years with a new forest inventory on an extensive scale every 10 years thereafter.

G. Fish and Wildlife

Planning for the full development of our water resources requires adequate basic data covering fish and wildlife. They are urgently needed where migratory fish are involved because development can block passage to spawning grounds. They are also needed when planning developments that affect the food and nesting areas of water fowl, especially of migratory birds. They are needed because many water developments may affect the habitat of various game and other forms of wildlife, and in turn the wildlife may affect water developments. They are also needed because quality of water and sedimentation may adversely affect shellfish and crustaceans. These needed data are derived from surveys and from research. Data that are available today are inadequate in many areas to meet the requirements of water resources development, both in scope and in coverage.

STATUS

Stream and lake surveys and the mapping of vegetation to provide information on habitat conditions suitable for fish, birds, and mammals, have been made for about 10 percent of the country. Many of these surveys, however, are out of date because changed industrialism, land uses, and water developments have substantially affected conditions. Surveys of important water and land habitat should be made frequently enough to keep current the collection of important facts.

Knowledge of fish and wildlife populations and ecology is even less adequate. Detailed information on population densities and trends for the various fish (including shellfish and crustaceans) and wildlife species, including such things as growth, recruitment, exploitation, and natural mortality rates, has been obtained only rarely and with great difficulty. A very much widened base for comparison and correlation is essential.

A related field of knowledge much in need of reinforcement concerns fishing and hunting. Generally speaking, only approximate estimates can be made of the numbers of people who fish and hunt, either as a livelihood or as recreation, the amount of time they spend fishing and hunting, and their successes. Even less is known of the important and less tangible factors, such as needs and desires of the public which influence participation in this form of recreation. Sound statistical data are needed.

Accumulations of the above sorts of fundamental information would have significant usefulness. The limited data now at hand have been used in determining conservation activities associated with water developments, such as the programs for hatcheries, new shellfish and crustaceans spawning beds, refuges, and wildlife restoration. Although many of these measures have been reasonably successful, their efficiency could be increased with more extensive basic data. At the present time, the lack of background data has been a limiting factor in several areas in meeting fish and wildlife requirements in planning water use developments.

It should be clearly understood that basic data for fish and wildlife cannot be accumulated once and for all; its acquisition must be a continuing process. Populations of fish and wildlife fluctuate widely even under natural conditions. Under the impact of changed uses of land and water such as agriculture, lumbering, industrial development, pollution and reservoirs, fish and wildlife resources change with great rapidity. Changes in human population density, interest in hunting and fishing, accessibility, and the availability of alternative recreation, also quickly alter the picture of fish and wildlife utilization. Consequently, it will continue to be necessary to bring data up-to-date at frequent intervals.

The need for a background of information has long been recognized, but its assemblage has been inadequate. Although conservation agencies remain under pressure for results, the various biological surveys are time consuming and the techniques and procedures are still not clearly defined.

An extended and coordinated survey program should be undertaken as early as possible. This continuing inventory is a function of and should be undertaken by State conservation departments, with the Fish and Wildlife Service participating.

Associated with basic data needs are those for research results. Although marked progress has been made in the past decade, many problems affecting the water development programs need further study. Answers are needed to such questions as how to maintain or increase the fishing resource in reservoirs subject to a large draw-down, and how to cope with the effects of modified flows on stream fishing below dams. The effect of swamp drainage and flood control works on all forms of wildlife is still far from settled; how to provide alternative habitats for wildlife; the effect of new pollutants—all these and many more features require intensive study.

RECOMMENDATIONS

It is recommended that collection of data pertaining to fish and wildlife, including fresh- and salt-water fish, shellfish, and crustaceans, be greatly accelerated. Further, information is needed on population density and trends for the various types of fish, fowl, and wildlife species.

A strong Federal fish and wildlife research program is needed.

VII. Basic Socio-Economic Data

A. Types and Analyses of Data

To plan and form a program well, it is necessary to know: The needs of the people in the river basins or larger regions of which the river basin may be a part; the future levels of population, employment, income, and production that the planning and programing must be designed to serve; the problems needed to be overcome to make these levels and associated activities possible.

Certain basic economic and social data are required for the analysis of the over-all economic base of the region and of its separate activities. This section attempts to appraise the types of economic and social data and analyses needed for river basin planning and programing and, in particular, attempts to point out the major deficiencies in those data at the present time. Recommendations for the elimination of these deficiencies and establishing standards for the data are offered.

The Bureau of the Census and other Government agencies now collect much of the basic data required for socio-economic analysis of river basin and other regions. The deficiencies in data cited to intercensal years, to special data not regularly collected, and to availability for geographic units sufficiently small for river-basin purposes. Existing deficiencies of various types of economic and social data and analyses are summarized for convenient

review in table II. This table is organized under two main types of economic studies: The over-all socio-economic base study, and the functional studies of the various segments of the watershed or regional economy. Although these two types of studies are here separated for convenience, it should be obvious that the over-all economic base study should draw upon and integrate the findings of the functional studies.

The adequacy and standardization of basic socio-economic data needed in water resource planning require consideration of type of data, purpose for which used, and amount of detail required. In addition, the time element must be considered.

B. Extent of Coverage

Although it would be desirable if all basic socio-economic data bearing directly or indirectly upon water resources development were available for planning, this is neither essential nor justifiable. In most cases, it would not be practicable to collect basic socio-economic data beyond the extent now followed by the Bureau of the Census and other Government agencies. In many water resources projects, it is necessary to obtain certain detailed socio-economic data in connection with the actual investigation which it would be impractical to secure on a national basis.

C. Types of Socio-Economic Studies

There are three types of studies of basic socio-economic data necessary for river basin planning:

1. An over-all economic base study of the river basin and the larger region of which the watershed may be a part, setting forth future population, employment, income, and production levels and needs to which water resources planning should be geared—the major conclusion of such a study to be reviewed from time to time in light of new knowledge and events.

2. Separate functional studies of the various economic activities and individual problems of water resources in the light of present and probable future requirements of the basin.

3. Continuing background information on socio-economic conditions for evaluation and review of individual projects and programs with respect to timing and need.

Some of the more important data under the various functional studies not covered elsewhere in the report are listed in the following paragraphs:

1. Food requirements under given diet standards related to the land available.

2. Food production trends and factors and practices which might affect them.

3. Inventory of present and prospective agricultural areas with respect to present development and programs needed, such as flood control, drainage, clearing, and irrigation, to make new areas available.

4. Data on costs and benefits of improving production on present agricultural areas in comparison to bringing in new areas by various methods.

5. Agricultural prices and costs and their relationship to farm production.

6. Data for alternative sources of supply of agricultural products as between major regions of the country.

Coordinated with the foregoing classes of basic economic data required are the types of data needed in connection with land ownership and water, especially use and ownership of land outside farms, crop rotation and cover crops, methods and costs of land improvement, and farm product prices.

Forestry.—Fundamental economic data needed in connection with forestry are complete inventories. Two-thirds of the 624,000,000 acres of forest land in the United States has been initially inventoried. This leaves one-third untouched mostly in the Rocky Mountains and California. Resurveys of one-half of the area previously inventoried are needed to bring the results of the initial survey up to date. This is especially necessary because heavy cutting during the war period and normal depletion and growth before and since have brought about changes in forest cover and timber volume. After a reasonably up-to-date inventory has been obtained for the entire country, it would be desirable to maintain records and to make resurveys at a sufficient rate to keep the over-all inventory current.

Commercial fishing.—Although annual statistics are collected and published on quantities and values of fish taken, fishery products, and the numbers of fishermen, vessels, and items of equipment, there is not complete coverage of the country or of detailed data regarding costs and incomes. Present data apply principally to the coastal,

Great Lakes, and Mississippi Valley fisheries. The majority of reservoir and inland stream fisheries are not included. Additional coverage, particularly by river basins, is needed and more detailed data should be gathered to enable studies of the effect of river basin projects on the fishing industry.

Commercial trapping.—Present data on the wild fur catch are gathered by States and by species. Data are lacking for specific river basins and it would be desirable to have intensive surveys of commercial trapping and associate activities in each river basin area to be used as a basis for determining the effects associated with river basin projects.

Manufacturing.—Basic economic data for manufacturing are needed in many types of analyses including river basin development. Particularly important are data on source and use of water by types of industries, similar to that gathered by Geological Survey and Public Health Service, and information on its cost. The more general data on water usage by different types of industries should be correlated with indices of plant size—for example, employment or production—and can be collected on a Nation-wide basis or on a sampling basis. Forecasts of industrial water demands should be based on specific surveys made in river basins, as required, and the techniques and methods of sampling developed for this purpose should be employed in other areas.

Mining.—The general categories of economic data required for analysis of mining in connection with river basin planning are essentially the same as those needed for manufacturing. Data on amounts and values of mineral products, including petroleum, are of fundamental use in transportation studies involving navigation, in flood control, and hydro power investigations where the mining properties might be affected by the improvements, and in water supply studies where, as in manufacturing, the need for water is a basic part of the process.

Recreation.—Economic data are lacking in this category. The value of recreational pursuits has never been clearly established and basic data are needed which would permit the standardization and adoption of values which reflect as accurately as possible the benefit to recreation from the development of river-basin projects. At the present time the principal data available are figures on attendance and additional information is needed to convert attendance into per capita or over-all monetary benefits. Recreational surveys are essential also to determine what people require in the way of recreation, how much, and where.

Navigation.—Much economic data is now available on traffic and commerce on the waterways of the United States as collected by the Corps of Engineers, the Tennessee Valley Authority, and the Inland Waterways Commission. The standards and kinds of economic data collected are normally sufficient for most studies of this nature. The costs of transportation by water as distinguished by rates are an important part of the problem, and data for this kind of analysis are obtained generally as needs arise. Although data now available or being collected are generally sufficient for the study of new projects or modifications of projects, collection of similar data for completed projects should continue to permit current analyses of the effects of waterway improvements.

Power.—There have been and are being collected data on power markets in connection with river basin developments. These data are usually assembled in connection with a specific study. The principal elements in these surveys are the factors which affect the markets for power, the present and estimated future power requirements, the present power supply, and the need for additional generating capacity, and the value of power. Additional data would be desirable on smaller areas than are now covered and for intercensal years. A breakdown of data would also be desirable in accordance with the uses; that is, commercial, industrial, farm, residential, nonfarm, etc., and in some cases, breakdowns within these categories.

Flood damages.—Data on damages caused by floods are essential for consideration of flood-control projects and also for developing designs for structures or facilities which may be subject to flood damage. Records of flood damage which are used as a basis for project benefit determinations are scarcely ever as complete as would be desired and increased effort should be made to obtain adequate data. As time goes on, it is believed that the gathering of flood damage data will result in a collection of information which will eventually be adequate for the study of flood-control projects in general. For individual areas, of course, it will probably always be necessary to make more detailed surveys, checking with local sources of information.

Water supply.—Data on domestic and industrial water supply required for analysis of river-basin developments

usually include those needed for the other studies. Since this problem involves use of water by population and by industries, it is necessary to have available most of the information on these factors. As water-supply systems are designed to serve under future conditions, it is necessary to forecast future population, income, and industrial activities as contemplated in the over-all economic base study. Data on changed trends in water consumption are also necessary in forecasting future use.

Pollution abatement.—Basic economic data required in this connection involve estimates of direct and indirect damage from pollution of streams and benefits from its abatement. These data are similar to flood-damage information and must, in general, be obtained from local sources.

Fish and wildlife.—Data similar to that required under commercial fishing and trapping are needed to evaluate the impact of a river-basin development on various kinds of fish and wildlife. An appraisal of the costs and values of protecting these resources from commercial, recreational, and purely aesthetic points of view needs to be made in connection with each river-basin program.

D. Tabular Summary of Major Deficiencies

In table 2, referred to previously, is summarized the major deficiencies, needs, and recommendations with respect to basic economic data in river basin planning.

TABLE 2.—Summary of major deficiencies in basic economic data needed for river basin planning

Item of deficiency	Description of deficiency	Need for the data	Comment and recommendation
A. Over-all economic base study:			
1. Population.....	Age, sex, race, size of family data need to be provided on an annual basis for as small as the county unit. These are provided by the decennial census but estimates for intervening years are necessary.	For analyzing present and future demands of the river basin economy for water and other services that can be provided by river development. Also for evaluating impact of programs.	State and local units should be encouraged to make these estimates for interim census years on the basis of uniform estimating techniques developed on the national level. Federal agencies in cooperation should develop a method for adjusting State and local data now being collected to accord with the United States census data.
2. Labor force and employment.	Uniform annual data for as small as the county unit, and by principal industry groups.	(See above.)	
3. Income.....	Income estimates are now made annually on a national and State basis and the need is for county estimates not only in aggregate terms but by principal sources of income.	(See above.)	Periodic bench-mark income estimates by counties should be prepared by the National Government, and extended and supplemented by State and local agencies. In the absence of official estimates, the latter agencies should be encouraged to prepare county estimates by breaking down the available State estimates, using local-area data and a uniform technique of estimation.
4. Production.....	Discussed below in connection with specific activities.		

TABLE 2.—Summary of major deficiencies in basic economic data needed for river basin planning—Continued

Item of deficiency	Description of deficiency	Need for the data	Comment and recommendation
<p>B. Functional studies: 1. Agriculture: Inventory of land use and ownership.</p>	<p>Important deficiencies are the major uses and ownership classes of rural land outside farms by different types of cover correlated with other characteristics of the land, such as, its productive value.</p>	<p>Information on major uses of land outside farms is needed periodically similar to the census of land in farms. In preliminary examinations and surveys of river basins and in watershed management specific data by counties on the use, cover and ownership of all land are essential for intelligent action.</p>	<p>The necessary data possibly can be obtained in one of two ways: (a) Incorporation of appropriate questions and procedure in the Census of Agriculture which will permit assembly of information by counties on major uses and ownership classes of all rural land, and (b) a survey conducted possibly in cooperation with State and county officials utilizing available airphotos, maps, land and assessment records.</p>
<p>Estimates of conservation needs.</p>	<p>More precise and complete estimates are needed of the extent and character of the total land and water conservation job and the time in which it should be completed in order to maintain the suitable agricultural area in use. Data on the conservation works installed, areas covered, and effectiveness of installations also are needed.</p>	<p>As additional river basin and related land and water programs are developed the problem of maintaining an up-to-date inventory of needs and accomplishments will become increasingly important in the interest of wise investment and economical administration of installation and watershed management programs.</p>	<p>The needed data can be obtained by establishing more uniform procedures for use of interested public agencies for classification and annual reporting on estimates of needs, plans, and areas covered by necessary land treatments and water control measures. This procedure could be made a part of the present system of published annual reports, and would make it possible to obtain total national balance sheet of conservation needs, estimates and installations, excluding duplications.</p>
<p>Costs of land development.</p>	<p>Information is insufficient for the on-the-farm costs of land improvement measures, such as, clearing, drainage, preparing land for irrigation, the cost of irrigation water to users and beneficial effects, reclaiming gullied land, seeding pastures, ranges and other measures and practices used in the land phase of river basin development and watershed management.</p>	<p>For analyzing costs and probable returns in planning needed land measures and in judgment by farmers as to whether they can afford the improvements.</p>	<p>Needed data could be obtained by a few sample surveys to represent the different major situations of the country. Urban and industrial construction costs generally are not applicable to farm costs.</p>
<p>Prices of farm products.</p>	<p>Data on prices of farm products are essential in river basin planning in order to convert production estimates into income estimates.</p>	<p>Cost and income estimates are needed in the economic analysis of proposed projects and component measures. Studies of prices and costs also are necessary to make a determination of the relationship between withdrawals from the land and additions necessary for production and maintenance.</p>	<p>The price data collected by the State agricultural statisticians generally can be supplemented to reflect local conditions in current river basin planning. Periodic studies to estimate the expected future general price level for various commodities also are desirable.</p>
<p>Economic relationships of weather and floods.</p>	<p>Weather and flood data and information on important economic relationships of weather and floods are inadequate in some regions. A larger number of weather recording stations is needed in several agricultural and forest areas with the observations correlated with data for planting and harvest dates, crop and pasture yields and quality, as well as for crop damages and extra costs resulting from weather and floods.</p>	<p>More complete coverage of the country by weather and flood information is needed to guide further agricultural developments and watershed management programs.</p>	<p>The necessary data could be obtained by increasing the present program of weather data collection and analysis and by relating agricultural data on crop and pasture yields, condition and quality to the seasonal weather records.</p>
<p>Economic aspects of land classification.</p>	<p>An inventory of areas and production of land suitable for development, and the new land currently being developed by clearing, drainage, and irrigation is vitally needed to help in projection of agricultural production trends, probable needs, land requirements, and potential lands available.</p>	<p>Investigation of land areas believed to have potentialities should precede actual construction planning so as to aid in selection of good land for development.</p>	<p>The necessary data can be obtained by continuation and expansion of soil survey, and land classification work, in river basins believed to have good potentialities for further land development.</p>

TABLE 2.—Summary of major deficiencies in basic economic data needed for river basin planning—Continued

Item of deficiency	Description of deficiency	Need for the data	Comment and recommendation
<p>B. Functional studies—Con. 2. Forestry.....</p>	<p>Initial surveys to obtain information on the location, area, stocking, volume, kind of trees, condition, growth and drain are needed on some 200,000,000 acres of forest land. In addition, resurveys of areas covered about 10 years ago should be made as rapidly as possible. Data are also needed on stand improvement and reforestation needs, and on cost and returns on various forest projects.</p>	<p>Satisfactory development of water resources requires adequate information on the condition of the forest land, because of its economic importance in terms of income employment and other benefits.</p>	<p>The United States should be covered by a forest inventory every 10 years. This means surveying 62,000,000 acres per year. Such surveys should be intensified and adjusted to meet the needs of water resources development.</p>
<p>2. Commercial fishery and trapping.</p>	<p>In connection with broad river basin planning, there is a major deficiency in the amount of production, employment and income data presently available by States. Such data are needed for the harvesting, processing, and distributing levels of these industries. More information regarding the fresh-water fishing industry is needed by States and by major bodies of water within each State. More information regarding fur trapping is needed by States and by counties within each State.</p>	<p>These data are all required to evaluate properly the role of this activity in the economy of the region, and to make proper program provisions in connection with water resource planning.</p>	<p>Needed data might be collected jointly by the Bureau of the Census, the Fish and Wildlife Service, and the individual States. Much of the information could be obtained by increasing the coverage of the Census of Manufactures and through the collection of more detailed income data by county and by principal occupational sources of income. Additional information regarding fish and fur production could be obtained through more intensive surveys by the Fish and Wildlife Service and the States.</p>
<p>4. Manufacturing and mining.</p>	<p>A major deficiency is the use of water (quantity and quality) by different types of industry and mining correlated with other characteristics of the industry such as employment. Information on present usage and circumstances of use by different sources of water (direct river, municipal water and ground water) also are needed. Deficiencies in production and other data are not cited here inasmuch as needs for these data are more directly related to other than river basin planning needs.</p>	<p>As rivers are more fully developed, the problem of competition among the several uses will become real. Intelligent planning should take into account the use of water for industry. Adequate data on industrial and mining use of water do not exist to forecast such use even if the future level of manufacturing in the area were known. Mineral resource data are needed to provide advance indication of where mining and dependent manufacturing industries are likely to decrease because of exhaustion of reserves and conversely where new mining and manufacturing industries may start because of the development of new deposits.</p>	<p>The necessary data can be secured for manufacturing in 1 of 2 ways: (1) Incorporation of appropriate questions in the Census of Manufactures which will permit correlation with other data, and (2) a sample survey of different types of industries which will permit a fuller set of questions. For mining, the collection of data on water consumption perhaps could be made part of the Bureau of Mines program.</p>
<p>5. Tourism and recreation.</p>	<p>Most data requirements can be satisfied by special surveys in connection with contemplated projects for basin developments.</p>	<p>Special surveys are required to fit recreational potentialities of proposed water resource developments into proper balance with regional and local needs.</p>	<p>Tourism and recreational aspects of water developments should be investigated concurrently with surveys for other purposes which should be coordinated closely with data the Geological Survey will collect.</p>
<p>6. Transportation and navigation.</p>	<p>Readily available basic data on costs (not rates) of transportation by competing means, such as railroads, truck, and alternative waterway routes; costs of operation of airlines and airports; economic costs of operation of bus lines, private passenger cars. Lack of complete coverage of costs and economics of completed waterways in operation. Data on basic origin and final destination of commodities.</p>	<p>For determination of most economical alternative means of transportation in evaluating waterway improvements; determination of flood losses and benefits to transportation in flood control studies; estimating costs of operation on relocated routes in project cost estimates. Sufficient data has generally been available or obtainable by special effort; data are needed for evaluation of transportation savings by new improvements.</p>	<p>Data affecting railroads and commercial trucking costs could be collected by Interstate Commerce Commission in regular reports by the carrier; for airlines and airports, by the C. A. A. More widespread study of economics and costs of transportation on completed waterways.</p>

TABLE 2.—Summary of major deficiencies in basic economic data needed for river basin planning—Continued

Item of deficiency	Description of deficiency	Need for the data	Comment and recommendation
<p>B. Functional studies—Con. 7. Power and energy-----</p>	<p>A major deficiency exists in data on electric energy purchases, generation, sales, and maximum demands for industrial (mining and manufacturing) establishments of the country in each year on an individual plant basis.</p> <p>Improvement is needed in data on sales of electric energy by electric utilities for classified use, namely, for the farm, residential, commercial and industrial classifications. As presently reported to the Federal Power Commission these data are lacking in uniformity and accuracy of definition.</p> <p>A deficiency exists in data on the use of electric appliances in homes and on the amount and types of electrically operated equipment used on farms. A limited amount of information on electric appliance use is collected by a few trade groups and Government agencies, but the data obtained are not uniform or adequate as to coverage, subject matter or geographic unit.</p>	<p>For analyzing industrial power requirements and supply and their relation to river basin hydroelectric developments.</p> <p>These data are needed to analyze utility load growth and to prepare estimates of future loads for use as a measure of the need for additional generating capacity that may be required in connection with planned river basin developments.</p>	<p>It is recommended that the Federal Power Commission conduct an annual canvass of manufacturing and mining establishments to obtain these data in years for which the census data would not be available.</p> <p>It is recommended that data on energy deliveries by electric utilities to ultimate consumers be sought on the basis of classified use rather than on the present loose sales classifications.</p>
<p>8. Trade, services, and construction.</p>	<p>Water requirements for these activities are included in over-all domestic water supply requirements and generally require no special treatment.</p>	<p>Existing data generally adequate for determining place of these activities in present and future regional economy.</p>	<p>Analysis should be made occasionally of these activities to determine significant departures or trends in water use.</p>
<p>9. Government installations.</p>	<p>Water requirements of special installations such as in connection with atomic energy needed in areas of limited water supplies. Impact studies on governmental revenues and costs of the total river program would be helpful.</p>	<p>Need to appraise full effects of river basin programs on governmental costs and revenues—beneficial as well as adverse—on a case study basis. Should be a continuing study to get full effects of programs.</p>	<p>Location of defense and other governmental installations requiring large amounts of water should be coordinated with river basin planning. Case studies of full effects of river basin programs on government should be initiated especially in areas where programs have been in operation for some time.</p>
<p>10. Flood control (flood damages).</p>	<p>Flood damages differ with flood characteristics and usually require special surveys in each flood area for evaluation. Where flood conditions may be considered similar, standardized or sampling techniques may be applied. Further study of effects of floods; determination of standard relations and their limits of applicability desirable. More information would be desirable on the physical effects of floods on structures and their contents, particularly when complete destruction does not take place, but merely requires cleanup and effects more rapid depreciation. Specific data for flood areas are generally lacking, and must generally be secured by special surveys or approximation by prorating larger unit data.</p>	<p>For evaluation of flood damages and benefits, standard data, if determined to be applicable to a given situation, would expedite and lower costs of studies, and evaluation of effects of floods and improvement projects. County-wide or larger units do not give specific enough data for evaluating trends of development in flood areas.</p>	<p>Further study of measurement procedures, basic data, and the applicability of "standard relations" by Corps of Engineers or FIARBC. Effects of floods on more rapid depreciation would be best secured from property owners if they could be encouraged to keep more accurate records; follow-up surveys after completion of improvements. Specific or sample surveys by investigating office will probably continue to be the most economical means of securing the necessary data on a less-than-county-wide basis, unless local governmental agencies can aid in periodic surveys or censuses. Much of this information is already being gathered by the Corps of Engineers, but additional data is needed.</p>
<p>11. Watershed management (discussed under B 1).</p>			

TABLE II.—Summary of major deficiencies in basic economic data needed for river basin planning—Continued

Item of deficiency	Description of deficiency	Need for the data	Comment and recommendation
B. Functional studies—Con.			
12. Domestic and industrial water supply:			
a. Population.....	See item A 1.	See item A 1.	See item A 1.
b. Employment.....	See item A 2.	See item A 2.	See item A 2.
c. Income.....	See item A 3.	See item A 3.	See item A 3.
d. Industrial activity.	By type of industry, i. e., manufacturing, trade, etc., and by specific industry within each type, i. e., rayon manufacturing, coal mining, etc.	To permit: (1) estimate of future of industries; (2) estimate of future water requirements.	Census of manufacturing and of business made as frequently as possible with information on specific industries by counties, major urban centers and river basins.
e. Building and other construction.	Official data by types of buildings and other construction for counties, major urban centers and river basins for intercensus years.	To predict future construction activity and resulting water usage.	Data might be gathered at time of each Census of Manufactures and for Census of Business.
f. Water usage.....	A major deficiency is the use of water (quantity and quality) by different types industry, commercial building and residences. See also item B 4 above.	Adequate data on use of water under varying climatic and industrial situations do not exist to forecast either future use of water or future ability of area to expand its industrial activities or even the population which it can support. See also B 4 above.	Data should be collected both from municipal water systems and from individual manufacturing and processing concerns. To a considerable extent, this is already being done by the Public Health Service for quantity and quality of domestic water supplies, and this agency has facilities for extending their program. Supplementary information might be collected either in connection with existing census procedure or through special studies covering only this purpose. See also B 4 above.
13. Pollution abatement:			
a. General data.....	The same as items 12a to 12f above.	See 12 above.	See 12 above.
b. Specific data on pollution.	Data on sources of pollution, effects of pollution on economic values, costs, and estimated effects of pollution abatement have not been systematically gathered for the country as a whole.	Adequate planning of pollution control in the interests of industrial development is impossible without comparable data for each river basin.	Collection of information should be put on a continuing basis under the Water Pollution Control Division of the Public Health Service. This activity has recently commenced.
14. Fish and wildlife.....	Data similar to those discussed under B 3 above are needed on commercial fishing and trapping and on the commercial aspects of recreational hunting and fishing which require protection from adverse effects of river-basin development.	See B 3 above.	Data could be collected as suggested under B 3 above.

VIII. Basic Data Pertaining to Land Classification for Agriculture

A. General Nature of Land Classification

Land may be classified for many purposes. In a broad sense, land classification may include on the one hand rough subdivisions of the earth's surface into plains, hills, and mountains, and on the other a careful and highly detailed classification, acre by acre, to show suitability for a specialized use. This report is concerned with certain basic data used in land classification required for land use, irrigation, drainage, clearing, and soil erosion control.

Classification groups the characteristics of land, surface and subsurface as they affect amounts and availability of waters that fall as rain and snow; that affect the disposition of this prime supply to soil water, to ground water and to stream flow; that affect its availability for use, control, storage, and conservation; and that set bounds to practical and economic projects and programs in development of interrelated water and land resources of the Nation.

B. Basic Data for Land Classification

Basic data required for land classification in a water resource program will vary with the immediate purpose of that classification and also with stages of development. Data already available in the form of topographic, geologic, soil classification, and vegetal cover maps, and from climatic, hydrologic, and other records are interpreted and evaluated in terms of their application to the needs of a particular type of land classification. Such an analysis should integrate various items of basic data necessary for the land classifications required in planning, design and operation of water resource programs. As statements covering these items of basic data are contained elsewhere in this report, the following discussion will deal principally with the status of available information of the kinds obtained through field surveys of land classification.³

After a thorough study has been made of the information supplied by the pertinent items of basic data referred to above, a field survey is required to integrate soils and other data and to collect supplemental data necessary for the type of land classification desired. As a part of the field survey, information must also be obtained as to use made of the land, whether forest, grassland or cropland. Supplemental facts will be collected, such as type, density and condition of vegetation, degrees of erosion, and effectiveness of measures, if any, of runoff retardation and soil conservation.

In initiating field surveys, it is important that requirements of the various action programs be given consideration in developing the specifications and map legends in order that basic data obtained will prove adequate. This will involve such things as determination of scale of map-

³For a more complete study of the entire subject, see "Land Classification in the United States." National Resources Planning Board, March 1941.

ping and expression of all factors in appropriate class ranges, either qualitative or quantitative and their integration in the field survey.

C. Status of Available Information

The status of the most widely used types of land classification is briefly discussed. They include classifications for land capability of agricultural, range and forest lands, for irrigation, for drainage, for land clearing and for occurrence and hazards of soil erosion.

The coverage of field surveys adequate for classifying land according to its capability and for planning runoff retardation and conservation measures on farms and ranches is shown in figure 35. Coverage amounts to about 322,000,000 acres, mostly of farm and ranch land in soil-conservation districts.

Land classification surveys of existing and proposed irrigation projects have been made to determine the extent and degree of suitability of land for sustained irrigation farming. Figure 38 shows the coverage of these surveys. About 38,800,000 acres have been classified as to irrigability. The classification involves primary consideration of (1) productive capacity, (2) costs of land development, and (3) costs of production associated with each land tract. The land class assigned to a specific parcel of land is a composite evaluation of all the interrelated physical and economic factors which have an influence on the land's value for irrigation.

Attention is called to the fact that limited information is available on irrigability of land in the western part of the country. It is true generally in the United States that the amount of basic data available on the public lands is generally inadequate.

D. Land Use Capability Classification

Land classification for programs of safe land use should recognize inherent land characteristics that affect physical suitability of land for use and stability or for permanence of land while it is in use. A combined interpretation of this kind is made in the land-capability classification, which is used in the program of technical assistance to farmers in soil conservation districts, in water flow retardation by watershed management, and in related activities.

In the land-capability classification, bodies of land are grouped for easy reference in determining safe land uses and in recommending land use and conservation practices. The grouping is made at four levels: (1) Land suited or not suited for cultivation; (2) eight land-capability classes distinguished according to the degree that safe, sustained land use with a given technology is limited by essentially permanent land features; (3) subclasses distinguished according to kind of limitation; and (4) significant

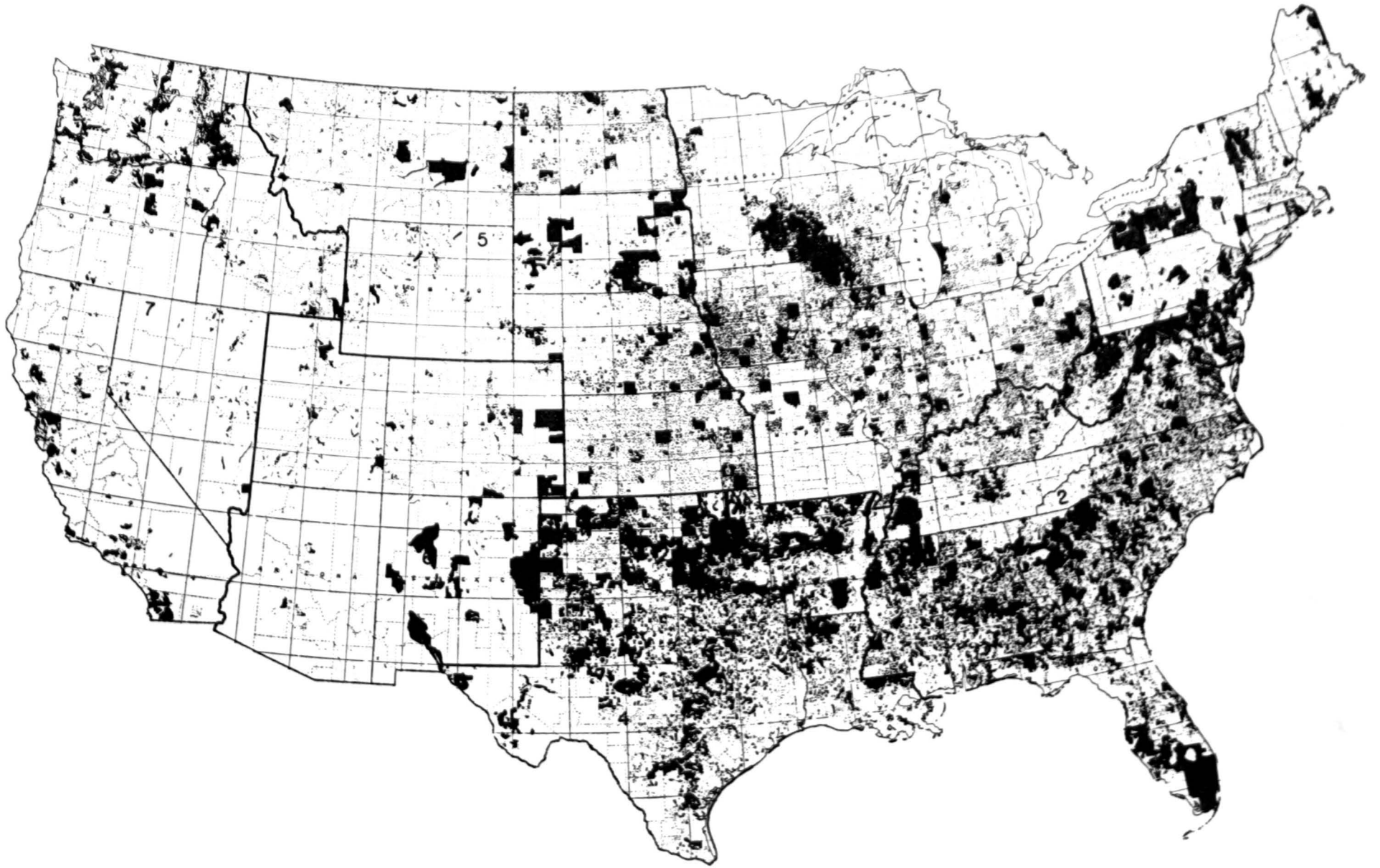


FIGURE 35.—Extent of soil conservation surveys.

OUTLINE OF THE LAND-CAPABILITY CLASSIFICATION





MAJOR LAND-USE SUITABILITY (Broad grouping of limitations)	LAND-CAPABILITY CLASS (Degree of limitations)	LAND-CAPABILITY SUBCLASS (Kind of limitations) (Groupings of land-capability units. Examples of possible subclasses in class III:)	LAND-CAPABILITY UNIT (Distinctive physical characteristics) (Land-management groups based on permanent physical factors. Example:)
Suited for cultivation.	I Few limitations. Wide latitude for each use. Very good land from every standpoint.		
	II Moderate limitations or risks of damage. Good land from all-around standpoint.		
	III Severe limitations or risks of damage. Regular cultivation possible if limitations are observed.	 Limited by hazard of water erosion; moderately sloping land.	} 13-C-2 Moderately sloping, slightly acid soils on limestone. 9-C-2 Moderately sloping, highly acid soils on sandstone or shale.
		 Limited by excess water; needs drainage for cultivation.	
		 Limited by low moisture capacity; sandy land.	
IV Very severe limitations. Suited for occasional cultivation or for some kind of limited cultivation.	 Limited by tight, very slowly permeable subsoils; claypan land.		
Not suited for cultivation; suited for permanent vegetation.	V Not suited for cultivation because of wetness, stones, overflows, etc. Few land limitations affect grazing or forestry use.	Groupings of range, pasture, or forest sites.	Land-management groups based on permanent physical factors, such as range sites or forest sites.
	VI Too steep, stony, arid, wet, etc., for cultivation. Moderate limitations for grazing or forestry.		
	VII Very steep, rough, arid, wet, etc. Severe limitations for grazing or forestry.		
	VIII Extremely rough, arid, swampy, etc. Not suited for cultivation, grazing, or forestry. Suited for wildlife, watersheds, or recreation.		

FIGURE 36.—Outline of the land capability classifications.

Description of Land-Capability Classes on This Farm

Class I. Very good land that is easy to work and can be cultivated safely with ordinary good farming methods. Soils are deep and productive. The land is nearly level and there is little or no erosion.

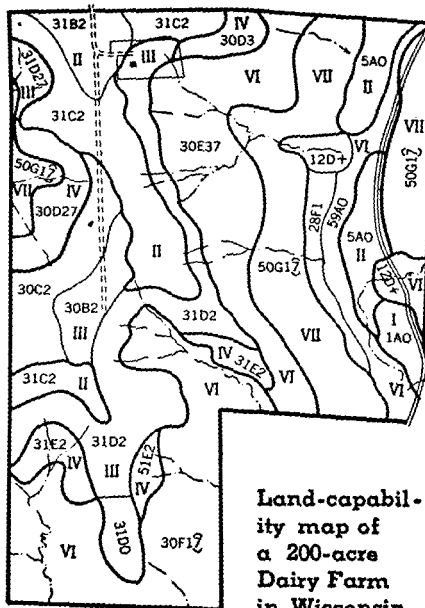
Class II. Good land that can be cultivated safely with easily applied practices. Soils are deep and productive but need liming and fertilizing. Gentle slopes need contouring. Bottom land needs improved drainage.

Class III. Moderately good land; can be cultivated safely with intensive treatments. Soils are good; slopes are from 4 to 14 percent. It has moderate to severe erosion and washes easily. Needs contour strip cropping, a rotation with not more than one clean-tilled crop every 5 years, cover crops, and soil-building practices.

Class IV. Fairly good land that can be cultivated only occasionally. Slopes are 12 to 18 percent and erosion is moderate to severe. It is best suited to pasture or hay, and if cultivated should be contour strip cropped and protected with diversion terraces.

Class VI. Land not suited for cultivation but should make good pasture with careful management and improvement through reseeding and fertilizing. It is also suited for trees. It washes easily and has steep slopes that range from 18 to 26 percent.

Class VII. Land not suited for cultivation but suited for grass or trees with very careful management. It has shallow soils and steep slopes that range from 26 to 60 percent.



This farm does not have any land that falls in land-capability classes V or VIII. Class V land is suited for grazing or forestry with slight or no limitations. It is nearly level and usually there is little or no erosion. It is too wet or stony or is otherwise unsuited for cultivation. It needs only ordinary good management to remain productive for grass and trees. Class VIII land is not suited for cultivation, grazing, or forestry, but is suited for wildlife or recreation or for watershed protection. It is usually very steep, rough, stony, sandy, wet, or severely eroded.

The large Roman numerals and heavy boundary lines on this farm map show the land-capability classes. Three-part symbols show further subdivisions according to kind of soil, steepness of slope, and degree of erosion.

Land-capability maps furnished to farmers are usually on an aerial photograph base. Present land use, as cropland, pasture, or woodland, usually is shown in addition to the information given on this sample map. Standard colors are used to show the land-capability classes: Class I, light green; class II, yellow; class III, red; class IV, blue; class V, dark green; class VI, orange; class VII, brown; and class VIII, purple.

FIGURE 37.—Example of a land capability map.

variations called land-capability units within the subclasses. See figures 36 and 37.

E. Land Classification for Irrigation

Land classification for irrigation projects is accomplished in large part through the application of physical and chemical criteria and the consideration of economic factors. The latter are important because, in establishing the land classification specifications for a given project, it is necessary to evaluate each class of land not only in terms of sustained production under irrigation, but also in terms of its probable use and the income which will be available to meet land development and project costs. Additional data must be obtained, beyond those which are already available. See figure 38.

Whenever land classification for irrigation is contemplated, specifications are developed in terms of "arable" land. This is defined, in light of all information available at the time, as land which in adequate units and when properly provided with essential improvements of leveling, drainage, building, irrigation facilities, and the like, will have sufficient productive capacity for crops, under sustained irrigation agriculture, to meet all production expenses. Included in the latter are a reasonable return on the investment, repayment of reasonable irrigation and improvements costs, and a satisfactory level of living for the farm family. As the project investigations are extended and additional information obtained, the "irrigable" lands become the specific lands which would be served with water under the final project plan.

Three types of land classification for irrigation purposes are recognized, each representing a standard scale of operation, i. e., reconnaissance (1 : 24,000), semidetalled (1 : 12,000), and detailed (1 : 4,800). The detailed classification is applicable to reappraisal of existing projects, development of the final plan for projects approaching construction, and feasibility investigations for project authorization. Depending upon local conditions, the reconnaissance or the semidetalled classification may be used in the preliminary analysis and in delimiting areas for the detailed classification. The semidetalled classification may be used also as the basis for project authorization but it is considered inadequate for development of the final project plan.

Six classes of land, four arable and two nonarable, are recognized as follows:

Class 1.—Lands which are highly suitable for irrigation farming, being capable of producing sustained yields of a wide range of climatically adapted crops at reasonable costs. They are smooth lying with gentle slopes. The soils are deep and of medium to fairly fine texture with mellow open structure allowing easy penetration of roots, air, and water and having free drainage, yet good water holding capacity. Land development such as leveling and providing the farm distribution and drainage system is relatively simple to accomplish and can be attained at reasonable cost.

Class 2.—Lands measurably below class 1 lands in productive capacity, adapted to somewhat narrower range of crops and more costly to prepare for irrigation or to farm. They have one or more deficiencies in soils, topography or drainage, either susceptible of correction, at justifiable

costs, or provide lowered yields or increase production costs.

Class 3.—Lands which are inferior to class 2 lands because of greater deficiencies in soils and have unsuitable topography or drainage. Although approaching marginal utility for general crop production they are still considered suitable for irrigation especially if intermingled with better class lands.

Class 4.—Lands having an excessive deficiency or restricted utility but which special engineering and economic studies show to be suited to irrigation under certain conditions.

Class 5.—Lands temporarily held as nonarable pending completion of economic or engineering studies to determine their suitability or feasibility for irrigation.

Class 6.—Lands not meeting the minimum requirements of the next higher class and small areas of suitable land lying within larger bodies of nonarable land.

F. Land Classification for Drainage

Land classification for drainage partakes of many of the same elements found in both land capability and irrigation. Its purpose is to determine those wet lands which are or may be made suitable for agricultural use through drainage. It takes into account the potential productive capacity, the costs of development, and the costs of production.

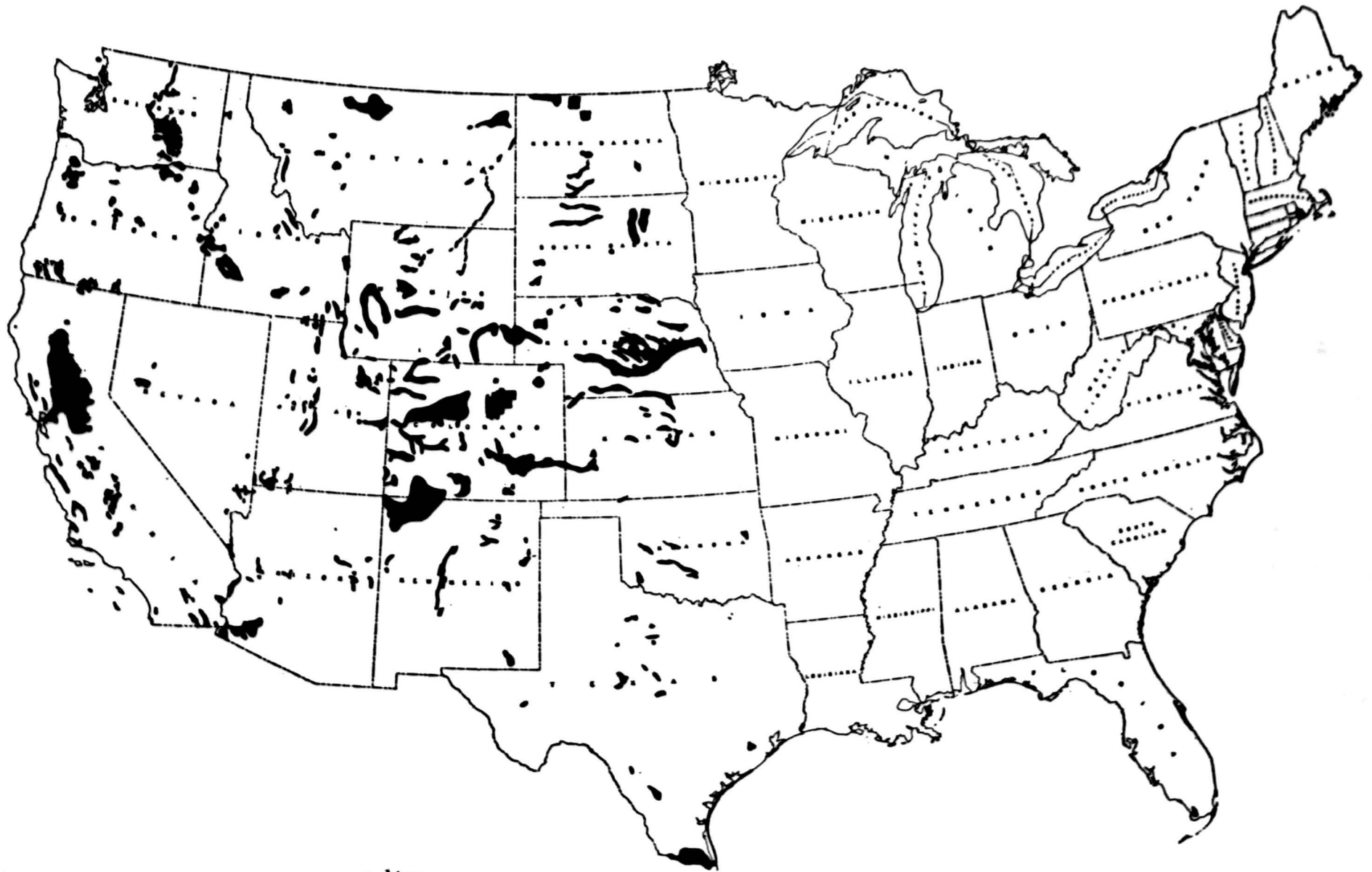
Land classification for drainage is developed through consideration of pertinent basic hydrologic and soils data with reference to the potential crop productive capacity of the area where drained. Thus specifications are developed which provide a measure of determining not only the suitability of land for crop production, but also whether the potentialities of the land are sufficient so that the benefits resulting from drainage will equal or exceed the development costs.

The classification of the land for drainage purposes follows with certain modifications those outlined above for irrigation. At present about 5,000,000 acres have been classified, which is 10 percent of the lands potentially available for drainage.

G. Land Classification for Land Clearing

The clearing of land suitable for agriculture but now covered with trees and other growth requires a type of land classification comparable to those outlined above. There are about 10,000,000 acres of such land in the United States, most of which has not been classified, and approximately 7,000,000 in Alaska which should be classified in the near future. Its primary purpose is to determine those wooded or brush-covered lands which may be suited for agricultural production when cleared of impeding vegetation. Such a classification takes into account the same elements of productive capacity, costs of clearing and associated development, and the cost of production.

Land classification for land clearing purposes is developed by consideration of climatic, hydrologic, topographic, and soils information and in reference to the capability of the land to produce crops when cleared.



■ Areas covered by land classification and irrigation.

FIGURE 38.

Specifications are developed to meet the particular needs for information as to whether the land can meet the costs involved in making the land ready for use. These are comparable in many ways to those indicated as needed in considering land for irrigation.

H. Land Classification of Soil Erosion

A land classification of soil erosion is needed to delineate those lands which have been subjected to erosion as well as those which are now or may be eroded. Such a classification provides the basis for determining critical sediment source areas that are the cause of damaging sedimentation. Such land classification is particularly essential for the public lands for which information is generally lacking.

Classification of soil erosion is generally developed in field mapping of soils and of land capabilities, together with interpretation of aerial photos. The classification takes into account the extent, degree, and character of erosion as they are related to such factors as topography, geology, soil, precipitation, hydrology, climate, and character and use of vegetal cover. Specifications are established for both geologic and accelerated erosion based on the kind and extent of sheet, gully, and wind erosion. They are applied to the surface of the land and to stream channels, and are related to the kind, character, condition, and use of the vegetal cover or land. Maps showing erosion are prepared according to purpose to be served, usually on a scale of 1:24,000 or 1:12,000. For detailed operation programs, a scale of 1:4,800 may be used. See figure 39.

IX. Basic Data on the Relation of Land Management to Runoff and Erosion

Land management, as used herein, refers primarily to the manipulation of vegetal cover by forest culture, grazing management, and agricultural practices. The evaluation of the effect of these practices on peak flows, water yield, ground water recharge, erosion, and sedimentation is a major hydrologic problem.

The relation of land management to floods, water yield, ground water recharge, erosion, and sedimentation of reservoirs has been the subject of much discussion and study for a number of years. While the net result has been to demonstrate that land management does affect the disposition of precipitation and the incidence of erosion and production of sediment, there is still much to be learned on the subject. The need for further data has become particularly apparent in view of the ever increasing demands for water, the depletion of the land

I. Conclusions

Basic data requirements for land classification will vary with the immediate purpose of the classification and the stage of development of the program under consideration. With respect to water resource and related land development, however, there are many basic data needs common to the various applicable land classifications. Many elements of the primary data needed are included in other sections of this document. Essential to most of these classifications are such common basic factors as topography, geology, soils, climate, and vegetation, and various elements considered under hydrology and economics. There are in most classifications various special elements which are required to meet the particular purpose for which classifications are made.

J. Recommendations

It is recommended that:

The collection and analysis of basic soils and other data used in land classification surveys for agricultural purposes be accelerated;

Needs for basic or specialized data be anticipated and all available and applicable information be assembled and studied in preparation of legends for field surveys;

Basic data be collected to classify public and private lands for agricultural purposes according to their capabilities, irrigability, the yield and use of water, the degree and extent of erosion, and the kind and character of improvements and management to be accorded them.

resource by erosion, and the threat of rapid and costly sedimentation to many of our reservoirs.

Evaluation of the effects of land management requires an understanding of movements of water as it relates to the earth, and requires collection of data on a nearly limitless series of combinations of such factors as plant cover (both type and condition), cultural practices, soil, slope, drainage area, and drainage pattern. These factors and their interrelations may vary with different conditions of climate, including character of precipitation, temperature, humidity, radiation and wind, and also from one topographic feature to another.

A. Basic Data Available

The basic data available for evaluating the effects of land management on rates and amounts of runoff and

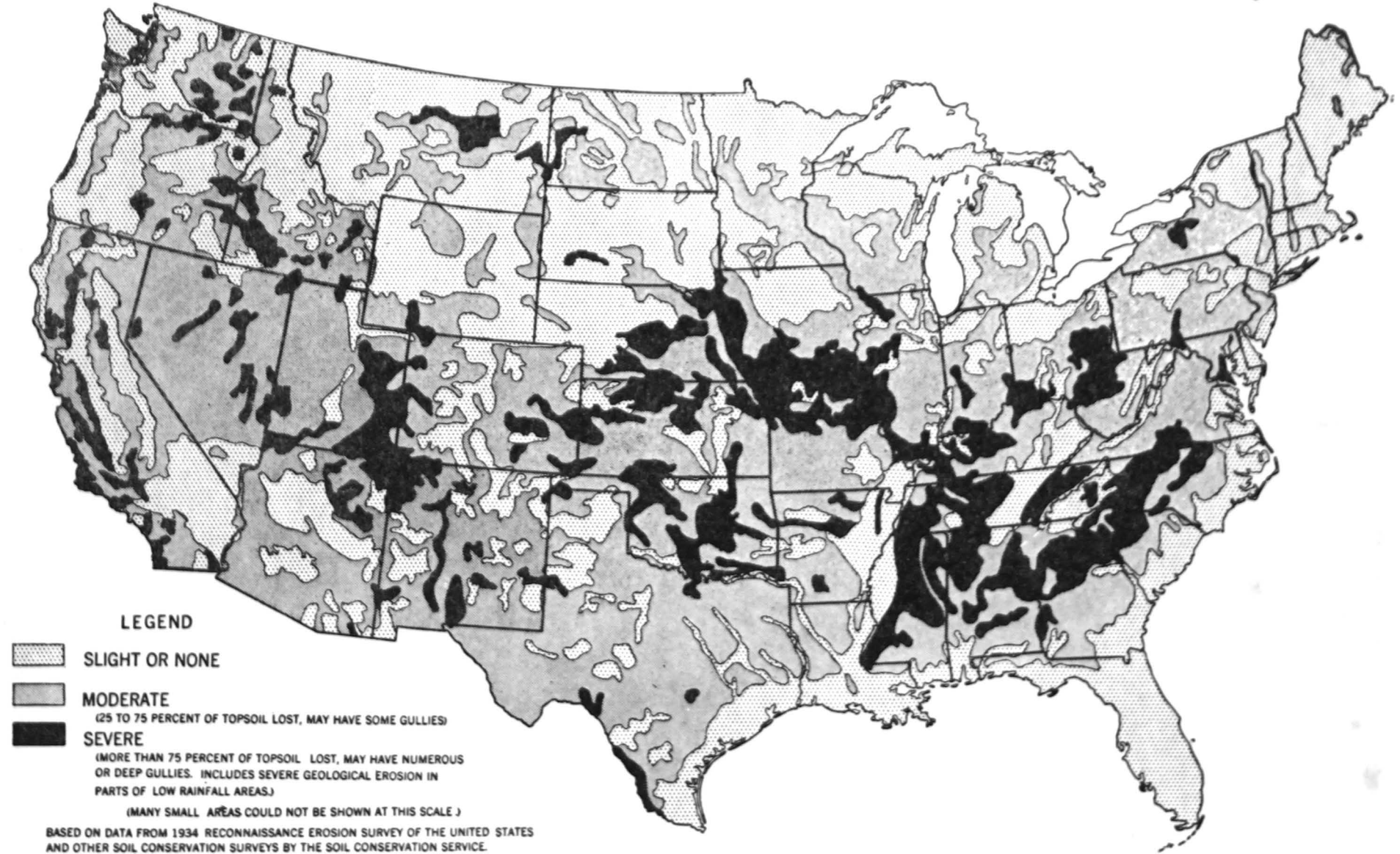


FIGURE 39.—Areas of soil erosion in the United States.

erosion may conveniently be classified according to the size of the area from which the data were obtained.

A large amount of data has been collected on the relative infiltration capacity values of different soils under various vegetal covers from infiltrometers, which are essentially devices for simulating rainfall on isolated plots or applying a constant head of water to samples of soil. The results, despite many tests, apply to only a portion of the many possible combinations of the principal variables involved. Infiltrometer data, nevertheless, do furnish indices of relative infiltration capacities, detention, and erosion characteristics of typical soils under certain fixed conditions and are useful in delimiting areas of soil types with respect to such characteristics.

Lysimeters are essentially tanks of soil for measuring accurately the amounts of water transpired from plants and evaporated from the soil, and waters percolated through soils. Because of the high cost of lysimeters, only a few types of soil and vegetation have been investigated. Weighing lysimeters also provide information on the condensation of moisture within the soil.

The sprinkling devices used in the infiltrometer tests have also been used to investigate the hydraulics of flow of water across the land surface before channelization takes place (overland flow). These investigations have confirmed the theoretical overland flow equation and established detention coefficients for artificial surfaces, such as pavements and turf, for short lengths of flow. A change in type of flow has been indicated for longer lengths, and an investigation is in progress on paved strips which will provide such basic data. There are virtually no data to establish detention coefficients for turbulent flow on grassed areas.

A large number of small plots with uniform soil, slope, and vegetal cover have been operated under natural rainfall conditions. Unfortunately much of the resulting data have not been analyzed and published in such form as to be readily available. Usually, only the surface elements of runoff and sediment resulting from natural rainfall are measured. Plots afford a high degree of control and have been particularly valuable in erosion studies to establish relative soil losses. Plot data do not ordinarily agree quantitatively with runoff from larger watersheds, although relative agreement exists between soil cover combinations and runoff.

Data on effects of land management on rates and total amounts of runoff and erosion are available from numerous watersheds ranging in size from one acre to about 10,000 acres. Such data automatically integrate the effects of the many variables involved and become increasingly valuable with the length of record. Small watersheds, like plots, are not true indications of runoff and erosion rates on larger watersheds, but they may be used in explaining or interpreting the runoff and sediment production of larger areas.

Variability in land management and flow pattern on the larger watersheds makes it difficult to evaluate the separate effects of different types of land management on total runoff and erosion. In cases where there has been a radical change in land management over a large part of the watershed, good records of precipitation, stream flow, and sediment load before and after the change might have

provided data on the apparent effects of the change in land management. See figures 40, 41 and 42.

B. Major Deficiencies

The effect of land management upon runoff and erosion from plots and small watersheds is well-established for a number of combinations of soil, cover, condition, and climate. But little has been done to bridge the gap between these small areas and large watersheds. Special attention should now be given to the development of methods for the accurate estimation of the effects of land management for larger watersheds.

Erosion has received considerable attention from the standpoint of the effect of different types and densities of cover on rates of soil loss, but relatively little attention has been paid to the erosion process itself. Insufficient knowledge is available on the natural laws involved in the detachment and transportation of soil particles, and facts are lacking on the effects of plant cover, litter and biological population in the soil, and on the stabilization of soil particles.

Infiltration rates have been investigated with various types of infiltrometer equipment for a relatively large number of plant-soil complexes, but variations in rates under what appear to be similar conditions have been difficult to explain. Improved methods of determining infiltration rates and better utilization of available data will require greater knowledge of the mechanism of the infiltration process, and thereby extend its application to plant soil complexes not yet investigated.

There is a lack of sufficient information to determine surface storage characteristics of different kinds of soil and land use for various rates of rainfall and runoff.

More data are needed as to the influence of land management on subsurface storage and on the rate at which storage opportunity is affected by evapo-transpiration.

Although considerable data have been accumulated on the rate of transpiration for different individual types of vegetation, much of them are not applicable in water balance computations for combinations of types of cover because they have been obtained largely under laboratory conditions. Data are needed on rates of evapo-transpiration for various field conditions, particularly in relation to available supplies of water, and the interrelation of evaporation and transpiration under different site conditions. The mechanism of evapo-transpiration requires further study.

Further studies are needed to determine (1) the disposition of precipitation after it enters the soil, in order to arrive at the amount which goes to ground water reservoirs, and (2) the influence of watershed management practices in water yields.

C. Recommendations

1. Continued study with greater emphasis should be made of the effects of land management practices upon watershed hydrology, with particular attention to the solution of such problems as bridging the gap between conclusions drawn with regard to small experimental plots and watersheds and their application to larger areas, such as river basins.

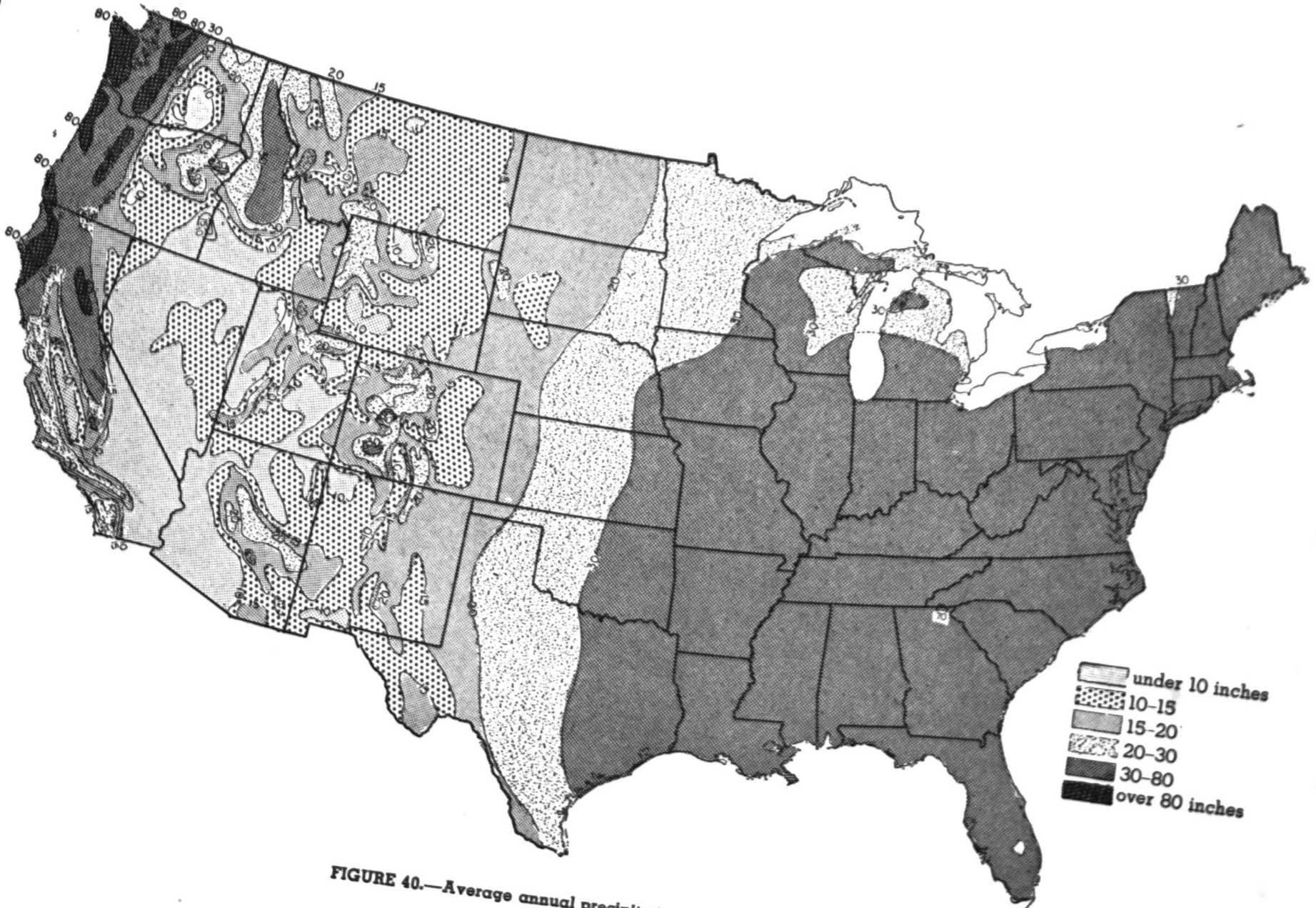


FIGURE 40.—Average annual precipitation in the United States.

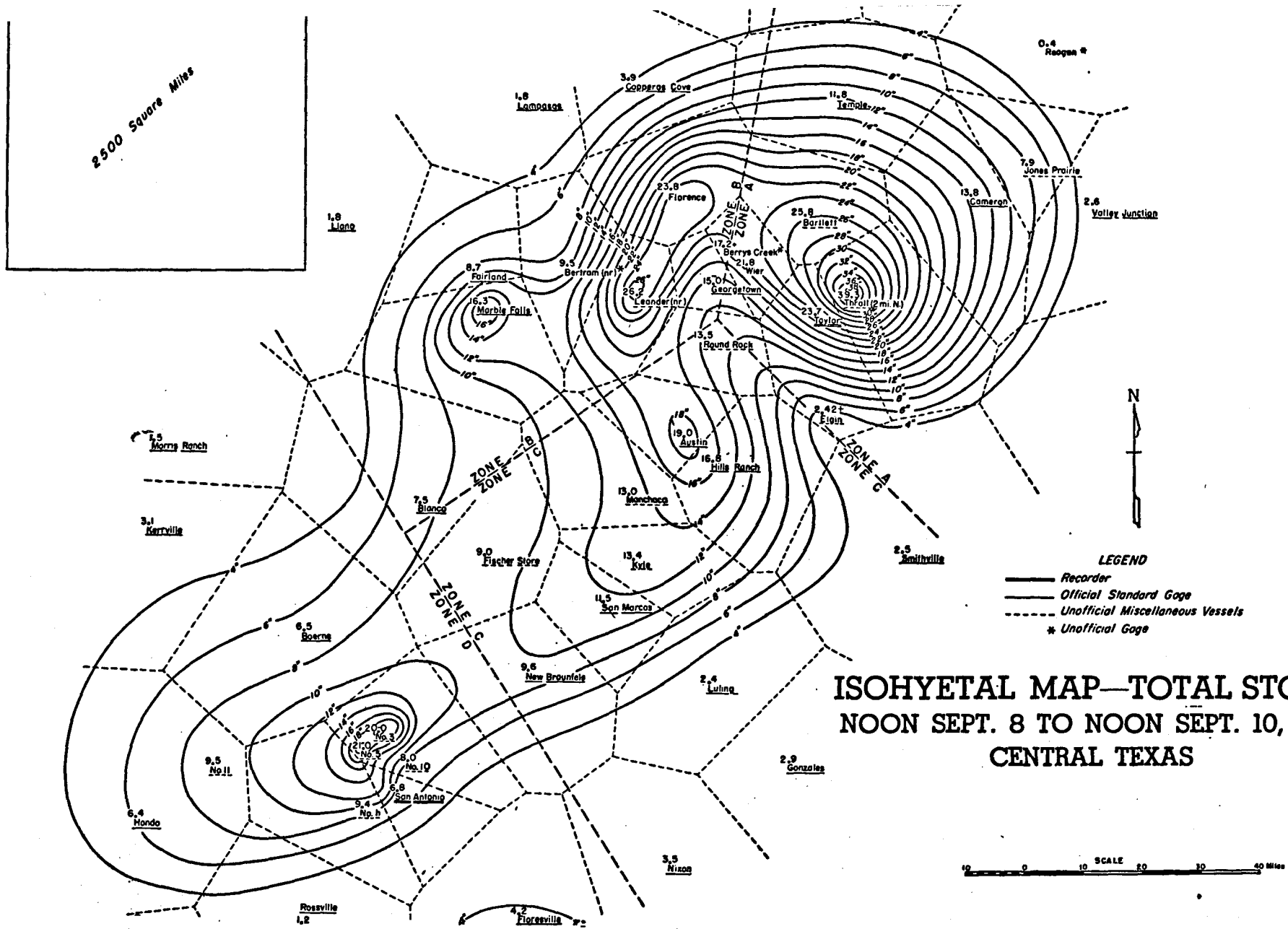


FIGURE 41.

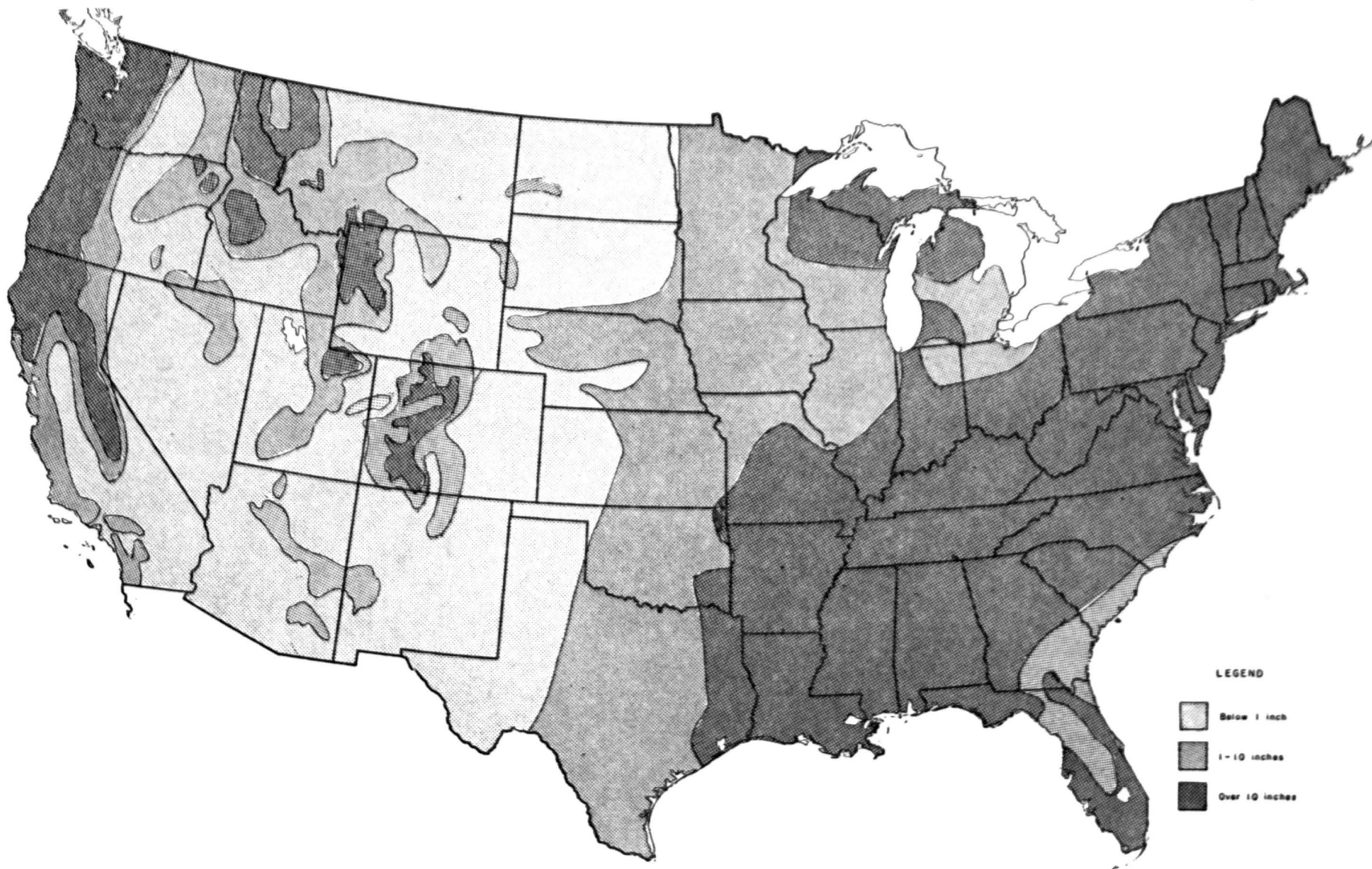


FIGURE 42.—Average annual runoff in inches depth in the United States.

2. Additional systematic field observations and measurements should be undertaken to evaluate the effects of soil conservation and other watershed management programs.

3. Provision should be made for interagency cooperation in: Planning new experimental work; developing methods of analysis; publishing data and results of research; maintaining an up-to-date inventory of data being

collected by various agencies; facilitating free interchange of information on unpublished data.

4. Greater emphasis should be placed upon the analysis, interpretation, publication, and distribution of collected data to insure that they will keep pace with data-collecting activities.

5. Attention should be given to those basins and areas now being considered for project development for which little or no experimental data are available.

A P P E N D I X

4

**Report of the
Committee on Evaluation
of Constructed Projects**

Committee on Evaluation of Constructed Projects

JOHN C. BEEBE, Committee Chairman, President's Water Resources Policy Commission

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SEPTEMBER 1, 1950

To The President's Water Resources Policy Commission:

The Committee on Evaluation of Constructed Projects submits herewith a report, indicating the lessons learned by review of some 55 constructed projects. The subject covered has been broad, including the whole field of project construction over a century of this Nation's progress. This review has touched only the high places, because of time limitation. However, the time has been well spent in bringing into focus some of the weaknesses of the past which are indicative of the problems of the future. Many of the problems suggest policies that are fundamental—requiring national consideration and often legislation. These are presented for your consideration.

In this review all committee members have participated actively and have contributed to the report. The Committee asked me to transmit this as a Committee report and as representing their consensus.

JOHN C. BEEBE
Committee Chairman

Introduction

Water resources development began generations ago, with only local objectives, generally implemented by individual or local capital. As broader conceptions became necessary, programs of greater magnitude followed, under the sponsorship of larger private corporations and by municipal and State legislation. Now the basin, the region, and the national interests are considered—a broad concept, worthy of the interest of the whole Nation. The protection and conservation of the wealth of the Nation are considered for the permanent benefit of all through national programs. Private and public enterprise may prosecute the programs, but often the support of the Nation as a whole is required to assist in or to undertake the program. The regional or national approach is necessary, and the multiple-purpose projects on a basin basis are now the accepted procedure in water-resource development.

Public actions in water-resource development have encountered problems, successes, and shortcomings as have private developments. The difficulties have been greater, because the general scope of the undertakings has been greater. By and large, public action took place after private action had long been used. For example, the most easily developed sites and the most feasible projects in irrigation had already been partially or fully utilized before the Federal Government entered the field of land reclamation by irrigation. Also, some of the types of projects and activities could only be undertaken by the Federal Government, because the scope of the work was beyond the efforts of individuals and local public bodies. In others the return on investment was too low, or uncertain, or too long term to attract private capital. Consequently, the nature of the problems handled by public action in water-resource development has been more complex, of broader scope, and more difficult than those handled by private undertaking. But counterbalancing this handicap are the larger resources, available on a national scale for projects affecting the Nation as a whole.

Development of water resources, in one or another manner, has been encouraged and has long been aided by the public. Private developments could not be undertaken without the framework of law, the protections to property, the incentives to progress, and the rules and regulations

provided by organized government. The expansion of public action, the growth in kinds of services performed, and the spread in both regulation and direct construction and management of facilities, by and large, have all come about through expressions of demands by the people. There has been an increasing demand for water resources because the population and industrial growth have been increasing. With the increasing complexity of our economy and the increasing recognition of the interrelations of the various classes of water resources, there has grown a realization that only through the pooling of effort could the problems be efficiently handled.

The results of these many years of design, construction, and operation can now be examined in order to put to use the experience gained in planning our future course of development. The Committee on Evaluation of Constructed Projects has reviewed in detail some 55 operating projects and has drawn from the knowledge of the committee members information relative to many other projects. Information on these projects, which was furnished the committee by the agencies in charge of these projects, is summarized in section I. The projects reviewed are distributed over the whole United States. They cover many types designed for various purposes, including those constructed (1) by private or local public enterprise, (2) under Federal licenses, and (3) by the Federal Government. The Federal projects include the older developments as well as the more recent integrated multiple-purpose projects.

The inclusion in this report of detailed analyses of numerous projects is impossible because of space limitations. Complete and careful study of even one multiple-purpose project, covering all the important and related phases, requires months of work. However, the main lessons from experience derived from such projects can be demonstrated by general analysis of specific examples. These lessons are discussed and described herein.

The study here is in no sense to be interpreted as a condemnation of past private or public programs. On the whole, the results of those programs have been good, in view of the complexity and scope of the problems involved. The purpose of this examination is rather to assist in program improvement.

I. Constructed Projects

The Legislative Framework

The United States has been generously blessed with natural resources, including its river systems and harbor potentialities. The development of the Nation's water resources for navigation, irrigation, water power, flood control, and other benefits has been a vital factor in our progress. From modest beginnings, steady advances have been made. Both private and public funds have financed these improvements that have contributed to the overall national wealth.

Control by the Federal Government over the navigable waters of the United States is derived from the Constitution which provides that Congress shall have power "To regulate commerce with foreign nations, and among the several states, and with the Indian tribes." The first distinct national legislation for improving navigation was an act of Congress in 1824, which appropriated funds for removing sand bars from the Ohio River and snags from the Mississippi River. Improvement of the natural waterways expanded from 1826 to 1866, and during that period a large proportion of the inland commerce was carried on inland waterways. While some early navigation canals were constructed by private interests and were subject to tolls, most of the waterway navigation improvements have been made by the Federal Government, and have, except for the Panama Canal, been free of tolls. The Federal improvement of inland waterways has followed a definite plan which has been continuously revised and modified in order to keep pace with the economic growth and general development of the country.

Early settlements were located adjacent to the oceans, rivers, and lakes, mainly to be accessible to the water for navigation and water supply. Industrial expansion occurred at certain locations, first because of the availability of a favorable site for a mill to grind agricultural products for flour and feed, and later for direct connected turbines to turn machinery. Those developed later into the modern hydroelectric power plant to supply power to interconnected systems. Congress in 1920 passed the Federal Water Power Act enabling the Federal Power Commission to issue licenses to develop water power, to provide a safeguard for navigation, and to assist in development of the Nation's water resources for water power and navigation and other public purposes.

As agriculture migrated westward into the semiarid regions, it became dependent upon irrigation. The construction of the railroads gave impetus to development of irrigation by giving access to distant markets. Irrigation was first developed by private interests but with the passage of the Reclamation Act in 1902, large and successful irrigation projects have been developed by the Federal Government, with capital investment to be repaid by the water users interest-free. This act, as modified, has been a vital factor in the development of the arid and semiarid West.

Congress recognized that control of floods was necessary in the interest of navigation, and early improvements

along the Mississippi resulted. After the Nation-wide destructive floods of 1936, Congress passed the 1936 Flood Control Act, in which it was "recognized that destructive floods upon the rivers of the United States, upsetting orderly processes and causing loss of life and property, including the erosion of lands, and impairing and obstructing navigation, highways, railroads, and other channels of commerce between the States, constitute a menace to national welfare; that it is the sense of Congress that flood control on navigable waters or their tributaries is a proper activity of the Federal Government in cooperation with States, their political subdivisions, and localities thereof; that investigations and improvements of rivers and other waterways, including watersheds thereof, for flood-control purposes are in the interest of the general welfare; that the Federal Government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected."

In 1933 Congress passed the TVA Act "To improve the navigability and to provide for the flood control of the Tennessee River; to provide for reforestation and the proper use of marginal lands in the Tennessee Valley; to provide for the agricultural and industrial development of said valley; to provide for the national defense by the creation of a corporation for the operation of Government properties at and near Muscle Shoals in the State of Alabama, and for other purposes."

The Soil Conservation Act of 1935 provides for Federal responsibility in soil and moisture conservation activities. The Omnibus Flood Control Act of 1936, as subsequently amended and supplemented, establishes Federal policy with relation to flood control and major drainage and authorizes the Secretary of Agriculture to cooperate with local agencies on matters related to soil and water conservation including drainage. These acts also authorize the Corps of Engineers to provide channel and major drainage improvements.

The interrelated use of the land and water resources has been recognized. Flooding above engineering works and sedimentation in irrigation, navigation, water power, and related works has emphasized the need for retarding run-off in upstream areas and controlling erosion. Consequently, following the passage of the Omnibus Flood Control Act of 1936, upstream watershed management programs have been recognized as necessary and complementary to engineering works.

In 1948 Congress passed the Water Pollution Control Act which provided "that in connection with the exercise of jurisdiction over the waterways of the Nation and in consequence of the benefits resulting to the public health and welfare by the abatement of stream pollution, it is hereby declared to be the policy of Congress to recognize, preserve, and protect, the primary responsibilities and rights of the States in controlling water pollution, to sup-

port and aid technical research to devise and perfect methods of treatment of industrial wastes which are not susceptible to known effective methods of treatment, and to provide Federal technical services to State and interstate agencies and to industries, and financial aid to State and interstate agencies and to municipalities, in the formulation and execution of their stream pollution abatement programs. To this end, the Surgeon General of the Public Health Service (under the supervision and direction of the Federal Security Administrator) and the Federal Works Administrator shall have the responsibilities and authority relating to water pollution control vested in them respectively by the Act."

With the increasing density of population in urban centers, domestic and industrial water supplies along with pollution abatement have become acute problems. Planners of water control projects for flood control, water power, navigation, and irrigation have recognized that water supply and pollution abatement can be successfully combined with the other purposes in many cases. Benefits to domestic and industrial water supplies along with pollution abatement by dilution are often considered in order that the full potentialities of available sites may be realized. They have also found that the rivers and waterways have important values for the fish and wildlife resource and in providing healthful environments for recreation.

The modern multiple-purpose developments of our rivers, along with coordinated development of land and water resources, have evolved out of the pressure of population to take full advantage of our natural resources.

The Experience Framework

Existing projects studied accomplished the purposes for which they were designed. Some were relatively more successful than others. The pioneer developments in the various fields were the laboratories in many cases. They were the proving grounds in which unforeseen problems were encountered. In them, procedures were worked out to eliminate comparable mistakes in successive similar projects. As the economy of the country expanded, many original projects became obsolete. Some were abandoned, others were modified and improved to meet changing conditions.

The existing water resource projects have been preceded by many failures. Some failures grew out of the lack of sufficient data and competent investigation. Some resulted from poor design, poor construction or lack of maintenance. Dams and canals failed due to unforeseen floods. Others have failed for lack of sufficient finances. From the lessons learned in these early failures, mostly privately financed ventures, present procedures have been evolved which provide adequate water control structures and safeguard the public.

One of the first ventures in navigation outside of tidal waters was the construction of the Chesapeake and Ohio Canal. That private venture was started in colonial days under the leadership of George Washington. The company succeeded in constructing 74 locks, combining canals with open river reaches to provide small barge navigation along the Potomac River for a distance of 184 miles between Washington and Cumberland, Md. The barges carried coal downstream from the mines and provided one

of the first gateways to the West. The project was disrupted a number of times by high water and finally failed after the flood of 1884.

The first privately financed locks and dams on the Monongahela River in Pennsylvania were rock-filled timber cribs with hand operated gates. These have been gradually improved and replaced and now federally financed and operated concrete dams and locks, with electrically operated machinery and steel gates, permit the easy manipulation of heavy barges to haul coal and other bulk commodities economically. The Erie Canal, linking the Great Lakes with the Atlantic via the Hudson River, was first started in 1817. After many improvements, it is still in operation as the New York State Barge Canal.

The first irrigation works were privately financed. First only crude brush, rock, and log diversion works were built. Most failed because of drought and floods. Later storage dams were built to hold excess water over from 1 year to the next. Techniques of design and construction improved. Many of the early well conceived projects are still in existence and extremely successful. Modern irrigation works now include the largest dams in the world, some of the longest tunnels and lined canals, and the greatest water power plants.

Modern privately financed water power projects evolved from modest beginnings, through small run-of-river developments, to a series of head developments with stream fluctuations ironed out by upstream storage reservoirs.

The first flood-control projects were agricultural levees, some built with slave labor. Most of these have been destroyed by floods. Modern well designed and expertly constructed levees and flood walls, with adequate interior drainage facilities, now provide protection to many important rural and urban areas. Such local flood-protection works are now jointly financed by the Federal Government and local interests. Other recent flood-control works were provided by upstream dams of the detention and retention type, often coordinated in basin operation with downstream channel improvements, local flood-protection works, and power developments. Some of these were financed by local conservancy districts, but since 1938 the flood-control reservoirs have been financed by the Federal Government. Many of the first flood-control dams were single-purpose projects but recent basin-wide flood-control programs have incorporated multiple-purpose reservoir projects in order to insure development of other potential water resources.

Large cities have developed along the banks of rivers and tidal estuaries, depending entirely upon the waterways to carry away domestic and industrial wastes. Pollution is now gradually being cleaned up by sewage and industrial waste treatment plants. In some cases, it has been found that aggravated pollution conditions can be abated most economically by primary sewage treatment plants augmented by increased low flow of rivers with upstream storage reservoirs to increase the low flow of rivers. An example of this is the Tygart Reservoir on a tributary of the Monongahela River that flows past the highly industrialized Pittsburgh area.

Modern drainage programs have evolved from individual farm programs, through relatively small privately financed reclamation programs, to large comprehensive drainage works, integrated with flood control and irrigation programs.

Modern watershed management programs have unfolded from scattered efforts by individual farmers to prevent topsoil losses, to present land use practices and measures to obtain adequate cover control, reforestation and Federal and State purchase and management of marginal lands. Various agricultural educational programs are an additional factor in planned conservation.

Projects Reviewed

The following descriptions of typical projects were submitted by the agencies and reviewed by the Committee.

CORPS OF ENGINEER PROJECTS

1. *The Tygart Reservoir, in West Virginia.*—Authorized in 1934 for flood control in the Pittsburgh area and water supply for navigation in the Monongahela River, was completed in 1938. Based on the results obtained to date, this project has been an unqualified success. Total evaluated benefits of all types which have been provided to date aggregate about \$22,500,000, or 122 percent of the first cost of the project. The experienced benefit-cost ratio is of the order of 2.23 to 1.0, compared to the original estimate of 1.38 to 1.0. Benefits realized from organic and acid pollution control and improvements of domestic and industrial water supplies were found to be much greater than originally anticipated. Also, land enhancement in protected urban areas and recreation in connection with the reservoir have greatly exceeded those originally contemplated. The project has fulfilled its design purposes, and has realized substantial collateral benefits.

2. *The Norfolk Dam, Arkansas and Missouri.*—On the North Fork of the White River, this dam was authorized in 1938 for flood control; the power features were authorized in 1941. It was completed in 1944. Basic data available at the time the project was designed were adequate and very few, if any, modifications appear to be necessary. The project appears to be used economically, except for minor difficulties in sale of dump energy.

The ratio of the benefits to cost since the project has been in operation is about 1.51 to 1.0, exclusive of intangible and recreational benefits. Although flood-control benefits were not stated in monetary terms in the authorizing documents, such benefits realized to date have greatly exceeded average annual costs that would be allocated for that purpose. Average annual power benefits are about 1.5 times those originally estimated. Physical, economic, and political conditions appear to have been anticipated. Experience gained in this project, one of the first multiple-purpose reservoirs, has materially assisted in formulation of procedures for cost allocation, and in reservoir development for recreational purposes. The project has accomplished its design purposes, and incidental benefits have been realized from fish and wildlife propagation and recreation.

3. *The Bonneville Dam, Oregon and Washington.*—This Columbia River project was authorized in 1933 for navigation and water power. The initial project was completed in 1939 and additional power units were added up to 1943. It originated as a depression project, and detailed investigation and design were sacrificed to the desire to start work quickly. After construction of the spillway dam was begun, a more economical site was found

about a quarter of a mile downstream, and the work was moved to the lower site.

Two main power units were provided initially with substructure for four more and foundations for four additional units. These were the largest of their kind in the world up to that time. With the advent of World War II, the eight additional units were installed. The additional generators had a larger capacity than the initial two, and considerable economy was realized from the experience gained in the meantime.

At the time the initial power units were installed, it was generally believed that they would suffice for a long time. The advent of World War II jumped the power demands and postwar progress has accelerated the need for power. Congress has recently authorized the construction of additional upstream storage reservoirs which will increase the potential power capacity at Bonneville. If the demand had been foreseen, some economy would be realized when additional units are added if structural provisions for even more than ten power units had been incorporated in the initial plans. The immense amount of power generated at Bonneville was a vital factor in meeting the manufacturing needs of World War II.

The original plans contemplated tandem flight locks for the then commonly used small barges; these were changed during construction to a single lift 76- by 500-foot ship lock. Since completion of Bonneville Dam, new upstream locks are being built to 86- by 675-foot dimensions to accommodate the present type of barge tows. Studies are now being made of the economy of enlarging the Bonneville locks.

Through cooperation with State and Federal agencies and to meet unprecedented requirements of preserving the salmon, an important national resource, fish-passing facilities were greatly expanded during construction from those originally contemplated. The project as a whole has an economic ratio in excess of 2 to 1, much higher than originally contemplated. It is accomplishing the purposes for which it was designed—to help in the economic development of the Northwest. Repayment of the investment in the power features is ahead of schedule.

It may be concluded from the experience gained at Bonneville, that ample preliminary investigations and analyses are necessary; that funds should be provided for definite planning prior to initiation of construction; and that large blocks of cheap power capacity when provided will readily be absorbed.

4. *The Tionesta Reservoir, Pennsylvania.*—This project is a single-purpose flood-control project designed as one of a system of reservoirs for the protection of the Pittsburgh area. It was authorized in 1936 and completed in 1941. The project is being used economically. The ratio of benefits to costs of the project since completion is estimated at 4.57 to 1, compared to the original estimate of 1.24 to 1. The project has encouraged further growth of the Pittsburgh industrial area, and collateral recreational benefits have been realized. The project has fully accomplished its design purposes.

5. *The Knightville Dam, Massachusetts.*—This dam and reservoir in the Connecticut River Basin was authorized in 1938 and completed in 1941. It is a single-purpose reservoir for flood control with provision for later adding spillway crest gates to insure the storage capacity

for power production at the site and at downstream existing plants. The project has accomplished its design purpose.

However, greater hydrological knowledge and understanding of multiple-purpose functions since this project was conceived indicates that a larger storage capacity would be desirable for flood control and conservation storage for generation of water power at the site and at existing downstream plants, and for industrial water supply, and other beneficial uses. The benefit to cost ratio of 2.2 to 1 realized from the project is well above the original estimated ratio of 0.8 to 1. Analysis of the project indicates that where there are no physical or economic limitations, overdevelopment of a site is preferable to underdevelopment. Changing conditions are more likely to result in a need for more rather than less storage.

6. *The Cottage Grove Dam, Oregon.*—This dam is located on Coast Fork, Willamette River, and it is one of a series of dams in the Willamette River Basin to control floods and to increase low water flows in the interests of navigation, irrigation, power production, and stream purification. It was authorized in 1938 and completed in 1942. The project is meeting its portion of the system's designed purposes, with incidental benefits from recreation.

Had the postwar increase in population and economic development been foreseen, a small increase in storage capacity would have been warranted. The project is being used economically and it appears that the original estimated benefits have been greatly exceeded, the present average annual benefits being about twice the average annual costs. Unduly conservative spillway requirements, unfavorable geological conditions brought to light as foundation investigations progressed, the addition of facilities not originally planned, and the general rise in construction prices have increased the original cost estimates. This increase in cost has been more than made up, however, by the increase in benefits.

7. *Wilkes-Barre, Pennsylvania.*—This local flood-protection project was authorized in 1936 and substantially completed in 1942. It has provided protection against major floods in 1943, 1946, and 1948, with ample margin of safety. The flood damages already eliminated have been estimated to be about double the cost of the project. The project is thus accomplishing its design purposes, to protect people and city property. Some minor damage still occurs because of inadequacies of the storm sewer system, the rectification of which is a local responsibility.

The experience of this project points to several conclusions. The standards employed for economic analyses were conservative, those for engineering design have been adequate, and relatively minor difficulties encountered were promptly overcome. Local authorities assumed responsibility for sandbagging a stretch of levee left low, at their request, for aesthetic reasons and although they later requested relief from this responsibility and levees were raised at some increase at Federal cost, the interests of flood control and its acceptance by the people are considered to have been furthered by the democratic course pursued. Expected flood reductions to be afforded by upstream reservoirs should not be given great weight in arriving at the design discharge for a local protection project unless such reservoirs are in place, under construction, or early construction is firmly assured.

8. *The Huntington Local Flood Protection project, West Virginia, was authorized in 1937 and completed in 1943.*—It successfully passed a flood 10 feet higher than flood stage in 1943 and the fourth highest flood of record in 1948. Damages eliminated to date have amounted to about one and a half times its cost. Public sentiment indicates that the people of Huntington realize the importance of the protective works in the future development and growth of the city.

The project is part of a comprehensive basin plan for the protection of the Ohio Valley from floods. The local works along with upstream reservoirs contemplated in the basin plan will protect the city from a flood substantially larger than the largest on record. A portion of the reservoir system has been completed. In general, the project has shown no defects in design which affect the safe or economical operation of the project in any manner. Although the original estimated ratio of benefits to costs was 5.0 to 1.0, the actual experienced ratio so far is 3.09 to 1.0. No unanticipated physical or political conditions have affected the expected results of the project. The damages that would be eliminated in a recurrence of the maximum flood on record would be considerably greater than the actual damages experienced in that flood due to the unprecedented development that has occurred in the protected area since the project was completed.

9. *Local flood protection, Glasgow, Mont.*—This project was authorized in 1936 and completed in 1938. It has successfully protected the city against five major floods with ample margins of safety. The project to date has a benefit-to-cost ratio of 5.8 to 1. There have been no unforeseen collateral benefits or consequential damages. No unforeseen conditions have affected the results, except that the project has been somewhat more successful than was originally expected. Although integrated into a comprehensive plan of development, the project was constructed ahead of proposed upstream reservoirs. Since the project to date has eliminated damages amounting to several times its costs, it would not have been prudent to defer its construction or modify its design to allow for the possible effects of a basin-wide development that had very little prospects of early fruition.

10. *The New Haven Harbor, Connecticut.*—This is a tidal bay of Long Island Sound. It was deepened in 1948-49 under an authorization of 1946 to provide a navigable channel for deep-draft vessels engaged in transportation of bulk commodities. The use to which the 35-foot improvement was put during the past year has been gratifying. The change-over from small tankers to those of increased capacity, as developed during the war, has far exceeded that anticipated. With the project completed, the tributary area is assured of a supply of oil and coal transported in the most economical type of vessels. The completed project is better than originally anticipated, as indicated by the benefit-cost ratio during the first year of its use. Its many and varied substantial benefits stress the wisdom of its adoption.

11. *The Huron Harbor, Ohio.*—This is an important transshipping point for the movement of iron ore from upper lake ports to inland steel manufacturing centers and reverse flow of bituminous coal. The project was authorized in 1935, completed in 1940, and provides for a 2,000-foot pier, breakwater, and widening and deepening of the

river. The project is being used for purposes for which constructed.

The estimated ratio of benefits to cost prior to construction was 6.1 to 1 and afterward proved to be 5.5 to 1. No collateral or incidental benefits were estimated or realized. The basis for justifying the improvement of Huron Harbor, typical of similar analyses of Great Lakes ports, seems to be reasonable and the benefits being realized are comparable to those expected. Future investigations of proposed improvements should take full cognizance of the trend toward larger bulk cargo carriers, and that the highest degree of improvement which is economically justified be adopted.

12. *The Warrior and Tombigbee Rivers, Ala.*—The original Federal project for improvement of navigation on the Warrior and Tombigbee Rivers began with minor work adopted by Congress in the act of 1875 and continued until initiation of the existing project in 1887. The present project provides for a navigable channel 9 feet deep and 200 feet wide by canalization, from Mobile 472 miles up the Mobile, Tombigbee, and Warrior Rivers into north central Alabama. In addition to the 15 dams and 16 locks involved, dredging and snagging operations are carried on to maintain 9-foot-channel depths as required. The project has met the area's need for economical transportation of bulk commodities such as coal, cement, and petroleum products. The waterway was generally completed by about 1915 and its growth and extension kept pace with type and equipment in use up to 1929. Modifications completed since that time, now under construction, and contemplated in the future are needed to replace obsolete structures and modernize the waterway to meet the growing tendency toward larger tows.

Although the waterway has not been used to its fullest capacity, favorable benefit-cost ratios have existed, the average for the past 20 years being about 1.9 to 1. The tonnage hauled during the depression and World War II years declined, but present high labor and other costs have revived demand for cheaper water transportation. Importation of ore from South America into the Birmingham industrial area will create additional commerce not anticipated prior to World War II. The waterway has proved its value in the development of a large area of Alabama. Changes in operators' equipment and expected growth in commerce indicate a need for improvement and modernization of this waterway.

13. *Illinois Waterway, Illinois.*—The original Federal project for improvement of navigation on the Illinois Waterway was adopted by Congress in the River and Harbor Act of 1852 and was continued under the acts of 1869, 1870, 1880, and 1907, at a Federal capital cost of about \$2,500,000. The State of Illinois, through a bond issue of \$20,000,000 in 1908, constructed several locks and dams to improve the waterway. These were transferred to the United States in 1927.

The present Federal project authorized initially by the River and Harbor Act of 1927, and modified by subsequent acts provides for a waterway 9 feet deep from the Mississippi River to Lake Michigan at Chicago, and cost to 1948 amounted to about \$26,300,000 more. The project involves improvement of the Illinois and Des Plaines Rivers by means of locks and dams and dredging; and the Chicago Sanitary and Ship Canal on the South

Branch of Chicago River. The total channel length is 336 miles. The project has accomplished its design purpose.

Traffic has increased from 1.7 million tons in 1935 to 12.3 million tons in 1948, far exceeding the original estimates. It is contemplated that when widening and deepening of the Calumet-Sag connecting waterway now under construction is completed, the potential traffic will more than double the present tonnage. If this much traffic had been fully anticipated prior to authorization, duplicate locks might well have been included.

The tangible annual benefits in 1948 were over three times the annual cost, including interest, amortization, maintenance, and operating costs. The project is operated free of tolls. The project permitted vessels constructed on the Great Lakes to be transported to the Gulf for utilization during the war.

DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION

14. *Orland project, California.*—Authorized in 1906, construction of the Orland project was initiated in 1908 and water deliveries started in 1910 for 14,000 acres of irrigable land included in the project. Storage facilities were increased on two subsequent occasions; the first permitted extension of the system to 20,000 irrigable acres, and the second provided supplemental water which a series of unusually dry years during the early 1920's indicated to be desirable.

Although some operational difficulties and added cost have been occasioned by the original design of gates in the first storage dam constructed (East Park), by lack of facilities to sluice debris from behind a diversion structure, by the character of canal lining employed, and by the lack of inadequate access roads for canal maintenance, the project features are adequately serving their design purposes. No major inadequacies in design have been revealed during 40 years of operation.

Operation and maintenance responsibility has been retained by the Government, but drainage was made the responsibility of water users. In the absence of a financially responsible water users organization, the individual water users have not been able to cope with the drainage problem as a whole, and needed remedial measures have been planned.

Estimates of anticipated benefits in relation to costs were not made prior to project construction, but results achieved indicate a highly satisfactory outcome. The value of crops raised on the project to date aggregates \$27,000,000, which is more than 10 times the total construction cost. Project lands have increased in value from \$25 per acre in 1908 to as much as \$750, and the project has given rise to a city service center where nonfarm employment supports approximately 5,000 persons. About 50 percent of the total construction cost (\$2,448,000) has been returned by the direct beneficiaries, the water users, and the remainder is to be returned by 1977 through their continuing payments.

15. *Rio Grande, New Mexico, and Texas.*—Construction of the project was initiated in 1912. The key structure, Elephant Butte Dam, and other major features were completed in the succeeding 4 years. With additions and improvements subsequently made, construction was inter-

mittently in progress until 1940 when the Caballo Dam for flood control and regulation and the Elephant Butte power system were completed.

The need for drainage facilities, not incorporated in original plans, became evident during the first year of operation, and development of a drainage system was immediately initiated. No major change in original plans for structures has proved necessary and the design and construction based upon available data have proven successful. Conceived originally to serve purposes of irrigation and the fulfillment of the 1906 treaty obligation to deliver 60,000 acre-feet of water annually to Mexico, the project modifications have added power and flood-control functions, and the development has also created unanticipated benefits to fish and wildlife and to recreation.

Although benefits were not estimated in advance of construction, it seems extremely doubtful whether benefits of the order of \$22 million being realized annually from irrigation and power alone, as opposed to costs of less than \$2 million, would have been fully anticipated. The project provides water for 159,000 acres of project lands, the current value of crop production from which is currently \$40 million annually, and supplementing the supply on an additional 16,000 to 18,000 acres, contributing measurably to development of the Rio Grande Valley. Of the total capital costs incurred to June 30, 1949, \$14,927,994 has been allocated to irrigation, and of this allocation \$11,486,266 assigned for return by water users. The balance of the irrigation allocation is being returned through power revenues. The two irrigation districts of the project have returned about 60 percent of their obligation and will complete payment in 1967.

16. *Boulder Canyon project, Arizona and Nevada.*—The Boulder Canyon project was authorized in 1928, storage began in 1935, and power was first produced in 1936. Hoover Dam, twice as high as any dam then in existence, revolutionized high masonry dam design and construction in the United States and throughout the world. The carrying out of this bold concept for full control of the lower Colorado is one of the outstanding accomplishments of our time.

Based upon many years of careful study, the project is an eminently successful example of a multiple-purpose development for irrigation, water supply, power, and flood control. Storage behind Hoover Dam and the All-American and Coachella Canals combine to provide water for 191,400 acres of new land and for large established areas in the Imperial Valley. That 400,000-acre irrigated agricultural empire is thereby relieved of the alternating threat of floods and drought.

Water made available for the Metropolitan Water District of Southern California and the city of San Diego, and the great blocks of power from the Hoover plant (ultimate capacity, 1,332,300 kilowatts) transmitted to southern California, are major stabilizing factors in the continued growth of industry and population in that area. Recreational use of Lake Mead has proved to be an attraction of national significance. The project not only is fully adaptable to the comprehensive development of the Colorado River Basin, but is the keystone of new projects in the lower basin.

The only significant modification of the project which would have been made had additional data been available, is the reduction of the capacity of the All-American Canal.

A recent and detailed land-classification study conducted jointly by the Bureau of Reclamation and the University of California has materially reduced the estimate of irrigable acreage, with the result that certain parts of the canal system have an unduly large carrying capacity.

Repayment of the entire Federal cost of Hoover Dam and appurtenant works is payable with interest from power and water revenues, with the exception of a \$25-million allocation to flood control, which is payable without interest after the remaining cost is returned. In contrast to most Federal power developments, but conforming with the Boulder Canyon Project Act, municipal and private power allottees are responsible for the generation and transmission of power to load centers. As of May 31, 1950, the total reimbursement from Hoover Dam to the Treasury was \$60,456,302, of which \$46,689,853 represented interest and \$13,766,449 represented payment on principal. The outstanding amount of the principal on May 31, 1950 (excluding \$25 million allocated to flood control) was \$108,283,492.

Costs of the All-American Canal and associated works (excepting nonreimbursable costs, estimated at \$4,500,000 and allocable to flood control) are to be repaid without interest by water users. Repayment has not yet been initiated because of complications resulting from the Mexican Water Treaty of 1944, requiring delivery of water to Mexico from the All-American Canal, and from the reduction in irrigable new-land acreage. Notwithstanding, \$1,050,000 has been returned to the Treasury from miscellaneous sources as of May 31, 1950.

17. *Salt River project, Arizona.*—Authorized in 1903, the original system for the Salt River project was completed in 1911 and in 1917 was transferred to the Salt River Valley Water Users Association for operation and maintenance. That organization subsequently designed and constructed additional facilities, with Government review and approval of plans. Additional Government construction included the enlargement of spillways on several structures built by the association and the construction of Bartlett Dam. The project provides a water supply for 243,000 acres of land which have become a primary base for economic development in central Arizona and the seat of the State's largest city. It resolves a chaotic situation involving strife for unregulated low flows which were inadequate even for the 85,000 acres irrigated at the time of project authorization.

Costs were slightly higher than what, in retrospect, might be considered the minimum essential cost as a result of certain difficulties. The originally planned spillway capacity of Roosevelt Dam had to be enlarged as relatively short-term runoff records were supplemented, and the design of some minor features involved unnecessary cost. A critical drainage problem was corrected by pumping ground water to supplement surface supplies, utilizing project power. These problems and difficulties, however, have in no way precluded the accomplishment of the project purpose, and if anticipated would not have involved significant modification of project plans, or resulted in a significantly greater measure of benefits over costs. The latter measure, though not estimated quantitatively in advance of development, has been far greater than anticipated.

Taking into account (1) project revenues prior to transfer to the association, (2) an obligation assumed by the

Office of Indian Affairs, and (3) a reduction in water user repayment obligation of \$382,097 found equitable by a Board of Review, the Salt River Water Users Association contracted to repay \$17,482,688 of the \$22,607,408 Federal cost for the project. As of December 1, 1949, there had become due and had been paid \$10,793,047. The balance, principally payable on the later Bartlett Dam contract, will be amortized through annual payment by December 1, 1979. In addition to the vast indirect benefits to the Nation stemming from the development of central Arizona which is attributable to the project, full return of the capital investment to the Treasury thus is in prospect.

18. *Belle Fourche project, South Dakota.*—Authorized in 1904 and providing delivery of irrigation water as early as 1908, the Belle Fourche project has been the source of many lessons applied profitably in subsequent undertakings. From the standpoint of physical development and repayment of investment, the project has fallen short of original expectations. Initially planned to irrigate about 100,000 acres, the project now serves 55,700 irrigable acres. This results both from inexperience in determining the suitability of soils for irrigation, which led to the inclusion of large blocks of land which today would be excluded, and from failure to realize a dependable runoff of the volume indicated by the inadequate records available. The total construction cost of \$5,315,000 was considered reimbursable in full, despite flood control and fish and wildlife benefits which under current procedures would have justified nonreimbursable allocations, the water users were relieved of paying \$1,417,000, or about 27 percent. Although, as on other early projects, repayment of the construction obligation was not achieved in the optimistically low 10-year period provided in the original Reclamation Act, the project water users have returned \$1,187,000 (through 1948) and will complete payment of the \$2,711,000 outstanding obligations under existing contracts.

Several factors have contributed to this repayment record. In addition to a smaller paying acreage than anticipated and the time required to evolve the type of farm economy best suited to the area, inexperience and lack of authority with respect to selection of settlers and to control of land speculation were important in earlier years. Many of those taking up project homesteads were entirely unqualified, and land speculation resulted in farm investments in excess of productive capacities. Although the Belle Fourche Dam and other project works, which are satisfactorily meeting their design purposes, would be designed and constructed somewhat differently in the light of present practices and standards, the application of present standards in all probability would not have reduced the costs.

Despite shortcomings indicated, the project represents a profitable investment in view of the monetary and social benefits achieved. The aggregate value of crops produced on the project in the period 1912-46 was \$32 million, more than six times the total Federal cost, and in 1949 the gross crop value was equivalent to nearly half the Federal investment in the project. In the fluctuating economy of the adjoining plains, subject to the vagaries of seasonal precipitation, the irrigated lands of the project constitute an island of stability where farm level of living exceeds the average for the United States

and for South Dakota, and where continuing services of kinds and qualities not otherwise available persevere for the benefit of adjoining areas.

19. *Yakima project, Washington.*—Shortly after passage of the Reclamation Act of 1902, the Reclamation Service (later Bureau of Reclamation) initiated investigations of possibilities in the Yakima Valley, where somewhat more than 100,000 acres were then under irrigation. Authorized in 1905, development by the Federal Government was planned and has been carried out on a basin-wide basis from the outset. Initial investigations revealed a total potential of approximately 500,000 acres of irrigable land in the basin. This figure is closely approached by the 450,000 acres in the five existing divisions and one authorized division of the project and in other lands served by storage water from the six project reservoirs, which have an aggregate capacity of 1,063,800 acre-feet. Construction of the Kennewick Division at the lower end of the valley where the water supply, as contemplated in early plans, will consist in large part of return flows from lands irrigated in the basin above, will virtually complete the irrigation development in the valley.

Project facilities are adequately serving their designed purposes, although some modifications of original plans were required. Original estimates of water requirements for orchards on the Tieton Division, the first division wholly constructed by the Government, proved to be about 50 percent below actual requirements, necessitating an increase in the capacity of the main canal of the division, and failure of rock in a pressure tunnel under 500 feet of head in a siphon on the Kittitas Division necessitated the installation of a steel lining. Drainage problems resulted in alkali damage to extensive areas, particularly on the Sunnyside Division, but these have been largely corrected by the installation of drainage facilities. Before canals were screened and dams provided with adequate fishways, damage was done to runs of anadromous fish.

The creation by the project of benefits of great magnitude is evident in the stable and prosperous agricultural community of irrigated farms, cities and towns supporting 200,000 people which largely owes its existence to the development. Crop returns equivalent to about 45 times the construction costs of the Tieton Division were received during the 37 years the water users were repaying those costs. In addition to completion of full payment for that division, scheduled payments are being continued by the water users of other constructed divisions. Of total project construction costs to date, aggregating \$44,286,000, water users have been relieved of payment of \$4,000 and have returned a total of \$22,309,000, somewhat more than 50 percent of the total.

20. *Boise project, Idaho.*—The initial work on the Boise project was authorized in 1905 and Boise River water was delivered to some project lands in the following year. Additional storage and distribution facilities added during the ensuing years have resulted in full economic development of the Boise River and the importation to the Boise Valley of some water from the adjacent Payette River Basin. These Federal developments, resulting in the irrigation of 220,000 acres of new land, have been additional to the initial development by local groups of 167,000 acres. Of the latter, 117,000 acres are provided with supplemental water from Boise project storage works.

The project has effectively met the purposes for which it was designed. Arrowrock Dam, the highest concrete dam in the world when completed in 1915, contains many features adopted in dams subsequently built. The concrete utilized did not have good weathering characteristics, necessitating the resurfacing of the downstream face of the dam after 20 years, but has proved to be well suited to the internal mass of the dam. Works to alleviate drainage problems which developed on some of the valley lands have been effectively used to provide a water supply for other project lands.

In addition to meeting fully its irrigation purpose, the project has created other, incidental but substantial benefits to flood control, fish and wildlife and recreation. Project reservoirs are operated to reduce flood damages in the Boise Valley, are used for fishing and other recreational purposes, and an offstream reservoir provides one of the more valuable resting areas for migrating waterfowl in the Pacific Northwest.

A successful development, the project unquestionably has created benefits in excess of expectations. It is the seat of a prosperous farm and urban economy dependent on irrigation agriculture. The average value of crops produced on lands brought under irrigation by the project was \$14,865,000 in the period 1939-48 and the total value of crops from all lands of the valley was estimated to be \$30,000,000 in the last year of that period. The latter figure exceeds the total estimated irrigation construction cost of the project, including features not then in operation. Ada and Canyon Counties, embracing most of the project area in 1939, had 1,737 manufacturing, wholesaling, and retailing establishments, employing 7,000 persons.

Two parts of the development are just being completed; payments have not started on one and are just beginning on the other. The three parts earlier completed have an aggregate irrigation construction cost of approximately \$13,600,000. Of this, water users have returned to date about \$9,000,000. Remaining irrigation construction costs will be returned by future payments.

21. *Shoshone project, Wyoming.*—Originally authorized for examination in 1902 and for construction in 1904, the Shoshone project was designed as an irrigation and power project. In the light of standards and experience prevailing at the time of its construction, the project was well designed and has functioned efficiently as planned in major respects.

Several modifications would now be incorporated in plans for earlier units of the project as a result of continuing Reclamation experience during the past 30 to 40 years. Inexperience with the suitability of lands for irrigation resulted in a land classification and in drainage measures which were inadequate by the standards applied to subsequent divisions, some of which are still being developed. Similarly, the power developments incorporated are not equal to those which would be provided as a result of subsequent experience. The estimated runoff, though based on only 3 years of record, has been very close to that actually experienced and entirely adequate for project purposes.

The full measure of benefits realized was not foreseen. In addition to the planned functions of irrigation and power production, the project has also created unan-

anticipated benefits for flood control, and important municipal, domestic, and industrial water supplies. Moreover, the power benefits have been far in excess of expectations in view of the early low estimates of demand. The 102,929 acres of project land, of which 63,912 were irrigated in 1949, support farmers on 1,240 farms at a level of living represented by an index of 143 in 1945 (Park Country) as contrasted with indexes of 124 and 100, respectively, for the State and Nation; support the growing towns of Powell, Deaver, and Ralson and contribute materially to the support of Cody, Lovell, Byron, Frannie, and Cowley; and have yielded crops between 1909 and 1949 with a value more than two and a half times the total construction costs of the project, including power facilities. Water users on the earlier divisions constructed have been relieved by congressional action of the payment of \$1,554,972. This is about 7 percent of the total irrigation construction costs of the entire project. Water users, chiefly on earlier constructed divisions which represent an irrigation investment of roughly \$10,000,000, have returned \$1,876,000. The balance and the irrigation construction costs of new divisions are to be returned by water users and through power revenues.

22. *Provo River project, Utah.*—Final authorization for the Provo River project, a development for the provision of irrigation and municipal water supplies, was given on June 22, 1936, and construction started in 1938. Deer Creek Dam and Reservoir were completed in 1941, but work on the other project features was delayed or stopped by the war and the shortage of labor and construction materials. At the present time, construction work on the canal system and the Salt Lake Aqueduct is practically completed. Terminal Reservoir and Duquesne Tunnel are scheduled for completion in 1951 and 1953, respectively.

The engineering design and construction of the project features are adequate for the project needs. Because of provision for future municipal needs, the project works have not yet been utilized to their designed capacity, with the exception of the Weber-Provo Diversion Canal.

Marked increases in construction costs have resulted in an increase in the estimated total cost of the project from \$13,150,000 in 1936 to \$31,300,000 as of May 1950. Despite this fact the project remains economically justified. Flood control and recreational benefits along with benefits from industrial use have ensued which were not anticipated or evaluated originally, and full payment of costs is in prospect through requiring a longer period than originally anticipated. Increased construction costs have made necessary the execution of supplemental repayment contracts with the Provo River Water Users' Association and the Metropolitan Water District of Salt Lake City for the Deer Creek Division and Aqueduct Division, respectively. By special legislation, Congress provided that these excess project construction costs can be repaid on an annual basis of fees and charges fixed by the Secretary of the Interior for rental of project water facilities. Both the association and the district have agreed to repay the excess project costs in addition to the amounts called for under the respective repayment contracts. When these excess costs have been paid, the association and the district will commence payment of the regular 40 equal annual installments under the repayment contracts.

FISH AND WILDLIFE SERVICE PROJECTS

23. *The Souris River Chain of National Wildlife Refuges in North Dakota.*—This development, undertaken shortly after establishment of the National Wildlife Restoration Program in July 1934, is an outstandingly successful example of waterfowl restoration. The Souris River enters North Dakota from Canada and meanders 358 miles through that State before again crossing the international line into Canada. Two tracts in the Souris Valley, 237 miles apart, have been acquired—the uppermost comprising 32,011 acres and the lower 58,565 acres. Water stored in a reservoir on the Upper Souris Refuge and released to maintain a minimum flow of about 100 second-feet in the river between the refuges, is spread in both refuges by low dikes across the wide valley and held at ideal depths for nesting marsh conditions.

The development has restored the tremendous output of waterfowl produced by the areas prior to disastrous drainage activities in the early part of the century and the protracted drought of 1929-34. The peak daily concentration of birds on the Lower Refuge has ranged from 500,000 in 1942 to 1,946,500 in 1947. The two refuges together commonly have a concentration of 3 million birds. In addition, the storage reservoir affords flood protection for the city of Minot and other towns on the river; 7,500 acres of hay land are provided with flood irrigation water; and water for sanitary flushing and disposal of municipal waste is provided for communities on the river below the reservoir.

The development has involved a capital expenditure of about \$3,350,000. Inasmuch as the development is primarily in the interests of migratory waterfowl, and its benefits are widely scattered throughout the United States and Canada, its costs are treated on a nonreimbursable basis. Nevertheless, some income is received from various sources. Hay harvested on project lands brought a return of \$4,313 in 1949, grazing permits on project uplands brought \$5,861, and fur harvests have accounted for more than \$8,000 in some years.

BUREAU OF LAND MANAGEMENT PROJECTS

24. *Alzada Water Spreading System, Montana.*—The Alzada water-spreading-system project on range lands of southeastern Montana consists of a series of earth dikes to retard surface runoff and consequent soil erosion, and to increase production for forage by providing supplemental water through spreading of flood flows. A small experimental development on heavy soils, the system covers 980 acres, of which 760 acres receive benefit from water spreading. Where the soil received heavy flooding, the original vegetation of sagebrush and cactus has given way to a thick stand of western wheat grass. The dikes and increased plant cover have effectively controlled sheet and gully erosion. The increase of 350 percent obtained in grazing capacity has a value, based on livestock prices of the past 8 years, adequate to return costs of construction and of maintenance in a 40-year period, with an annual return of 13 percent on the original investment of \$3,300. The improvement has resulted in an increase in appraised value per animal unit of land investment from \$100 to \$190.

INDIAN SERVICE PROJECTS

25. *Fort Hall Indian Irrigation project, Idaho.*—Construction of the Fort Hall Indian Irrigation project started in 1907 to irrigate 47,044 acres of land, of which 30,500 acres are in Indian ownership and the balance of 16,544 acres in non-Indian ownership. The construction cost to date has been \$2,275,000. With additional work to complete the development, the total cost of the project is \$2,525,000.

The project has been successful in spite of the fact that operation of the Indian-owned portion of the project has been hampered by existence of fractionated heirship tracts which will not permit economic operation. In fiscal year 1948, 33,000 acres were irrigated producing crops valued at \$2,540,000, or roughly a value of \$77 per acre, which exceeds the average gross crop return for the last 10 years on the Fort Hall Unit of \$58 per acre. Approximately all of the white-owned lands are under production, and 10,000 acres of Indian-owned lands, most of which are in heirship status, were leased to non-Indians.

Non-Indian owned lands are assessed for their pro rata share of annual operation and maintenance costs, whereas Indian-owned lands under existing legislation are not subject to these assessments unless under lease. Annual costs for operation and maintenance for Indian-owned lands are provided by annual Treasury appropriation.

26. *San Carlos Indian Irrigation project, Arizona.*—The San Carlos project, in Pinal County, Ariz., was constructed to irrigate 50,000 acres on the Gila River Indian Reservation and 50,000 acres of white-owned lands contiguous to the Indian reservation.

Irrigation was practiced by the Indians in the Gila River Valley in prehistoric times. In 1903 five wells were drilled by the Government at Sacaton for the irrigation of Indian lands in the San Tan area. The construction of the modern project was initiated in 1926 by the construction of the Coolidge Dam and power plant to provide 1,250,000 acre-feet of storage in the Gila River. The project, as constructed, consolidates and embraces lands of the former Florence-Casa Grande project.

The construction cost to date is approximately \$13,000,000, of which approximately \$2,100,000 are charged to the power features of the project, which include two generating units in the Coolidge Dam of 7,500 kilowatts each; the Coolidge Diesel generating plant consisting of three units of approximately 4,500 kilowatts total generating capacity, a small Diesel generating plant located at Christmas, Ariz., and a network of transmission and distribution lines. Estimated cost to complete is approximately \$500,000, exclusive of land subjugation on Indian reservation lands and the construction and extension of power transmission and distribution lines.

The project has suffered critical water shortages during the past decade of drought in the general Southwest area. During the calendar year 1948 approximately 130,000 acre-feet, or 65 percent, of the water supply was obtained by pumping from the underground. This resulted in progressive lowering of the water table. At present the average static lift is 82 feet and the water table has receded approximately 38 feet since the drilling of the wells in 1934. During the calendar year 1949 increased precipitation occurred in the watershed above Coolidge Dam which provided an additional 180,000 acre-feet for project use. As a result, crop production on 73,650 acres amounted to

\$10 million as compared to \$4½ million on 51,350 acres for the calendar year 1948. The increased water supply available resulted in a much greater use of project area but did not permit any substantial reduction in pumped water supplies. The underground water supply of the entire valley is rapidly being pumped beyond the safe annual yield and this condition apparently will continue until a maximum economic pumping lift is reached. The Department, at various times, has considered ways and means of limiting project pumping. Due to the fact, however, that 70 percent of the water extracted from the underground in the valley is taken by nonproject landowners, there has been no incentive for the project management to reduce pumping activities. The area, moreover, has not been declared a "critical area" by the State of Arizona. The Department has recently requested the Geological Survey to make an examination and study of underground water supplies in the entire area of the Gila River Basin.

Annual operation and maintenance costs are covered by annual assessments on a per acre basis against all lands of the project, both Indian and white-owned.

NATIONAL PARK SERVICE PROJECTS

27. *Lake Mead National Recreational Area, Arizona and Nevada.*—The unique attractions and widespread interest in recreational opportunities on the lake and shorelands above Hoover Dam led to the establishment of the National Recreational Area there in 1936 under the administration of the National Park Service. The principal developments have centered around the provision of a road system and recreational facilities at Boulder Beach and other sites on Lake Mead. The principal development is at Boulder Beach where harbor, bathhouse, picnicking, and swimming facilities have been provided by the Government and where nearby overnight accommodations are operated by private concessioners.

The provision of adequate facilities has been an ever increasing problem. The facilities at Boulder Beach, the lesser developments at other points, and the 180 miles of road and 23 miles of trail already constructed constitute only a part of the development planned to meet fully the recreational needs. The total number of visitors to the area in 1948 was 1,607,422, of whom about half utilized the recreational facilities. The construction costs to date aggregate somewhat more than \$3.5 million, including an investment by concessioners conservatively estimated to exceed \$300,000. Fees are collected from concessioners by the National Park Service and credited to the Reclamation Fund. Costs to complete the development are estimated at \$9,368,000, of which \$7,250,000 is for roads and \$2,118,000 for other facilities.

FEDERAL POWER COMMISSION

The Federal Power Commission does not construct or operate power projects, but issues licenses to public and private agencies to construct, operate, and maintain power projects affecting streams over which Congress has jurisdiction, affecting Government lands and at Government dams and reservoirs. Licenses are issued only after full notice to all interested States and local groups, a finding by the Commission that the project is adequate to make the best use of the resources, is adapted to a compre-

hensive plan of development of the region's resources and will be safe. Preference is given to States and municipalities. Agencies administering Government land or with other Federal interests are asked for recommendations as to license terms.

Plans for the project are reviewed for adequacy and safety and, during construction, inspections are made as to compliance with plans and as to adequacy of foundation and construction. After construction, frequent inspections are made to assure continued proper maintenance and compliance with license provisions. The license is for a period of not more than 50 years. At the end of the license period the Federal Government has the right to recapture the project in compliance with the terms of the Federal Power Act, or may issue a new license.

PUBLIC POWER PROJECTS.

28. *Santee-Cooper project, South Carolina.*—The Santee-Cooper project on the Santee River in South Carolina was constructed between 1938–42 as a navigation and hydroelectric power development and has fulfilled these purposes. With respect to navigation little use of the navigation lock has been made to date but it is probable that navigation will develop in the future. Due to the scarcity of rock a porous concrete slab was used for the upstream slope protection on the earthen structures. After a few years of operation progressive failure of this slab took place making it necessary to break up a major portion of the existing slab and top it with conventional rock riprap. It might have been possible to definitely forecast such failure if adequate tests had been made originally with respect to effect of wave and chemical action. The project is operated economically as a power project even though the annual cost of clearing the Lake Marion Reservoir of floating logs continues to be high due to the fact that the clearing of this reservoir was never completed. The total cost of this project was about \$64,880,000, of which only \$29,494,000 is the actual cost to be borne by the State of South Carolina. The balance was in the form of a grant by the United States and a contribution for the Works Progress Administration.

29. *Diablo project, Washington.*—The Diablo project in Washington was constructed between 1927–37 as a hydroelectric power development and has fulfilled this purpose. This project is a part of the Skagit River development of the city of Seattle which also includes the Gorge and Ross Dam projects. The project is operated economically and the rates charged by the city of Seattle for electric energy delivered to its various customers are among the lowest in the United States.

30. *Morris Sheppard (Possum Kingdom) project, Texas.*—This project on the Brazos River in Texas was constructed between 1938–41 as a hydroelectric power development and has fulfilled this purpose. This project is part of a proposed master plan involving several projects consisting of dams and power plants principally for the production of hydroelectric power, flood control, and water for domestic, industrial, and irrigation purposes. The project is operated efficiently and the entire output of the plant is sold to the Brazos River Transmission Electric Cooperative, Inc., for an amount purported to be sufficient to pay for plant operation and maintenance, a portion of general and administrative expense, amortization of

plant cost in 50 years, other incidental expenses, and interest. This project cost \$8,677,000, of which \$4,500,000 was a grant from the United States.

31. *Pensacola project, Oklahoma.*—The Pensacola Project on the Grand River in Oklahoma was constructed between 1938–41 to develop hydroelectric power and flood control, and has fulfilled these purposes. Some unanticipated erosion has developed below the spillway and had adequate tests been made on the foundation rock it might have been possible to definitely forecast such erosion and construct suitable spillway aprons originally. The project is operated economically as a power project and in accordance with the direction of the Secretary of the Army in the interest of flood control to the extent that such flood-control storage is available. Under Executive Order dated November 21, 1941, this project was taken over under section 16 of the Federal Power Act and operated by the United States during the recent war emergency. It was returned to the licensee on August 31, 1946, under the Act of July 31, 1946 (60 Stat. 743). The project cost about \$21 million, of which about \$10 million was a grant from Public Works Administration. In addition the Government is in the process of purchasing lands between elevations 750 and 755, the uppermost of the reservoir reserved for flood control. Available records indicate that the project has been operating at a profit.

NON-FEDERAL POWER PROJECTS

32. *Bagnell project, Missouri.*—The Bagnell project on the Osage River in Missouri was constructed between 1929–31 to develop hydroelectric power and has fulfilled this purpose. This project was designed prior to the experience of large floods on the Osage River, and prior to the recent methods used in estimating such floods. Experience with large floods subsequent to operation of the project has made it necessary to protect the power plant from damage due to tailwater. Since the May 1943 flood the licensee relocated some transmission lines to prevent damage from high water and constructed a flood wall about 4 feet high over the deck of the generator room to prevent flooding for a discharge of about 245,000 second-feet past the power plant. The project was originally designed as a power project with no provision for flood control storage. Subsequent to its construction the Commission received many complaints of flood damages to riparian owners downstream from the dam presumably resulting from the operation of the Bagnell Dam. The Commission staff investigated this matter, including a public hearing, and on June 3, 1947, the Commission issued an order prescribing operating regulations for the purpose of assuring that the operation of the project would not aggravate floods. Actually, in the normal operation of the project certain of the flash floods were reduced in severity, thus benefiting downstream riparian owners. The project has been operating efficiently for the production of hydroelectric power.

33. *Bartletts Ferry project, Georgia.*—The Bartletts Ferry project on the Chattahoochee River in Georgia was constructed between 1925–28 to develop hydroelectric power and has fulfilled this purpose. Inspections and tests made in 1949 revealed that the drainage system in the dam was not functioning properly. It was decided to strengthen the dam by the use of a prestressed system of buttresses subsequent to a general grouting operation, thus

improving the safety factor of the structures. In addition, the earth abutment sections are being raised to provide additional freeboard during times of flood. The project has been operated efficiently for the production of hydroelectric power consistent with the safety of the project structures and in conformance with the special conditions of the license relating to navigation and public health. This project fits into a comprehensive plan of development and the licensee is now installing an additional 20,000-kilowatt unit in the power plant.

34. *Saluda project, South Carolina.*—The Saluda project on the Saluda River in South Carolina was constructed between 1927–30 to develop hydroelectric power and has fulfilled this purpose. Alterations to the dam and enlargement of its spillway and spillway discharge channel were completed in recent years in accordance with more recent views regarding the designs of earthen dams and spillways, and including actual soil analysis of the materials in the dam. These remedial measures have enabled the licensee to operate the project for full realization of maximum benefits for the past 4 years.

35. *Chelan project, Washington.*—The Chelan project on Chelan Lake and River, tributary to the Columbia River near Wenatchee, Wash., was constructed between 1926–28 to develop hydroelectric power and it has fulfilled its purpose. The project makes efficient use of the stream flow of the Chelan River except as limited by license requirements to operate Lake Chelan within certain prescribed limits during the summer months for the purpose of recreation. Lake Chelan is used extensively for this purpose.

36. *Claytor project, Virginia.*—The Claytor project on the New River, tributary to the Kanawha River, near Radford, Va., was constructed between 1934–39 to develop hydroelectric power and it has fulfilled its purpose. The license provides that the discharge from the project shall at all times be regulated by such rules and regulations as the Secretary of the Army may prescribe to prevent undue interference with navigation. The license also permits the United States to construct navigation facilities at the project if and when required. The project is operated efficiently for the generation of hydroelectric power.

37. *Rock Island project, Washington.*—The Rock Island project on the Columbia River near Wenatchee, Wash., was constructed between 1930–33 to develop hydroelectric power and it has fulfilled its purpose as limited by its present installation. The project as it now exists does not make best use of the head or regulated flow in the river. However, available records indicate that when the project is completed to its ultimate height and the installation of the power plant is completed, the project will then fit into the comprehensive plan for the Columbia River Basin. This project has been involved in condemnation proceedings with the Public Utility Districts of the State of Washington. Although it may be justified at this time to complete construction of the Rock Island project, the licensee claims it cannot finance the construction. The project generates power and utilizes the flow of the river to the capacity of its turbines.

38. *Power plants at navigation dams, Kanawha River, West Virginia.*—Kanawha Valley Power Co. constructed between 1934 and 1937 and is operating under Federal Power Commission licenses powerhouses at the London,

Marmet and Winfield locks and dams of the Corps of Engineers located on the Kanawha River, tributary to the Ohio River, in West Virginia. The operation of these projects is subject to regulations imposed by the Department of the Army in the interests of navigation. Sufficient engineering data were available for the design of the three power plants. The power plants have been operated efficiently and have accomplished the purposes for which designed. The company pays to the United States annual charges amounting to \$104,000 for the use of the three Government dams.

DEPARTMENT OF AGRICULTURE

39. *Los Angeles River watershed flood-control project, California.*—This project was initiated in 1940 on a partial basis and undertaken on a basin-wide basis following full authorization in 1944. The project is only about 15 percent complete to date because of inadequate funds, and was to reduce erosion and debris flow, and to retard flash floods.

The project is not yet sufficiently under way to provide full measure of accomplishment. The debris basin functions were fulfilled; fire control plans changed to take advantage of new techniques in using helicopters to reach fires instead of roads; plans also altered to construct few barriers instead of numerous check dams to prevent downward cutting of channels and to stabilize side slopes.

Local political difficulties arose due to county organization and divided authority. Inadequate clearing was responsible for contamination of water supply and inadequate data then available prevented carrying out fully all the vegetative aspects of the plan. Work in the valley lands was restricted due to unexpected growth of Los Angeles.

40. *Nantahala National Forest, North Carolina.*—The Weeks Act of 1911 authorized Federal acquisition of forest land at the headwaters of navigable streams to stabilize runoff and to reduce sedimentation. The Nantahala purchase unit was established by the Forest Service with a gross area of 1,349,000 acres. At present 366,500 acres have been purchased at an average cost of \$5.93 per acre. At the time acquisition was begun, the United States Geological Survey reported 40 percent of Balsam Gap unit was deeply gullied and most agricultural lands had been abandoned; floods were more sudden and disastrous; streams were always muddy, and were clogged with debris.

After purchase, fire control measures have been applied to the whole area; several thousand acres reforested and gullies healed; transportation developed; recreational improvements installed. Expenditures for 1914-49 amounted to \$7,119,000, or about \$20 per acre.

A forest property has now been built up with a stand of almost a billion feet of timber worth approximately \$10 million, and growing rapidly. Receipts from the area to date, chiefly of old and defective material, are almost \$1,200,000, or \$3.30 per acre, 55 percent of the purchase price and 16 percent of the total cost. A benefit-cost ratio of 1.5 to 1.0 is possible on basis of worth of the timber alone. The land is worth about twice its purchase price.

Private forest lands within the national forest and those adjacent have greatly benefited from forest fire protection which has cut losses and permitted increased growth, from the transportation and communication sys-

tem, and from increased values in recreational privileges of hunting, fishing, and general recreation. Communities in area have become stabilized with increased revenues from tourists, sales of homecraft work, permanent wood-working plants, and specialty shops.

Streams now run clear, flood flows have decreased, and sedimentation is practically at a standstill.

41. *Everglades drainage project, Florida.*—The original drainage project in south Florida was initiated through State action in 1881. Overspeculation was followed by the collapse in 1925. Hurricanes and the depression of the 30's resulted in further heavy losses. In 1941, the Reconstruction Finance Corporation bought refinanced bonds for \$20 million. Water improvements needed are estimated still in excess of \$20 million. The development of a navigation channel and the undertaking of flood-control works have provided canals, levees, channels, and other needed works which the local people could not finance.

Drainage was instituted without knowledge of the amount of water to be handled, the levels to be maintained, or the effect of drainage on the soil. As a result, no canals were of proper size or shape to meet demands, the drainage effort was unsuccessful, and many farming ventures were lost. The present Federal program in which local interests are to share to a slight extent, will make agriculture possible over a considerable portion of the area. However, soil subsidence with drainage is rendering the present works of decreasing usefulness, and with cultivation it is doubtful if the area can long be kept in agriculture.

42. *Little Tallahatchie River watershed flood-control project, Mississippi.*—Authorized in 1944, the Little Tallahatchie project got started after World War II. It was designed to reduce flood damages above the Sardis Dam and reduce sedimentation. The watershed area of 867,000 acres is in a serious condition as a result of prolonged land abuse, some lands being wholly ruined for any use without reclamation. Annual damages estimated at \$1,200,000. Program cost estimated at \$10.4 million over 20 years, of which \$4.6 million was the Federal cost, including \$1.0 million for land purchase.

Program development by the Department of Agriculture was held up at very start by State legislation which prevented Federal land purchase. Local oil prospects were a factor that influenced local interests against further public ownership of land.

Drainage, an important element, was omitted from the program but authorized in later legislation.

The program is now proceeding on a somewhat different basis than originally intended but meeting program objectives. The State has relaxed part of its ban on public acquisition as evidences of oil have faded and worsening land conditions become more apparent. The program is progressing with full local cooperation and satisfactory local arrangements.

43. *Scofield irrigation project, Utah.*—A private irrigation dam was built in 1924 and partially failed in 1926. It was originally expected to irrigate 52,000 acres, but only 10,000 acres were suited for development. It was proposed to reconstruct the project under the Case-Wheeler Act, which provides for construction of irrigation works by the Bureau of Reclamation and for agricultural development by the Department of Agriculture

with provision of financial assistance in both phases of the work through the use of WPA labor. The cost of rebuilding the dam was calculated at \$640,000, and that of developing the land on a proper basis \$308,000. As a measure of relief, a repayment of \$413,000 was proposed, \$216,000 for the works by the Bureau of Reclamation, and \$197,000 by the Department of Agriculture. An allocation of \$393,000 was proposed for flood control and from other sources \$111,000. A District was created to underwrite local costs on the new basis.

The project was dropped. High costs made farmers reluctant to invest further in the enterprise. The farmers were primarily coal miners and with rising wages and employment, became less interested in the irrigation enterprise. All this coupled with much public indifference led to the cancellation of the project. Work in the better lands is continuing, however, on an advice basis from the Soil Conservation Service.

44. Bartholomew-Boeuf-Tensas Basin drainage, Arkansas.—In the Bartholomew-Boeuf-Tensas Basin intensive drainage reclamations were begun by private interests shortly after 1900 and continued on a large scale until the flood of 1927. More than 1 million acres of the basin were brought into drainage districts, were assessed drainage taxes, and were made the site of drainage constructions, ranging from large stream diversion ditches to simple farm laterals. Almost \$6 million in bonded debt was assumed by local people through their officially created districts; and many other obligations, more difficult to measure, were undertaken by individuals and informal groups. Since 1927 the attention of local people has centered on completing plans in progress at the time of the flood and on salvaging the established organizations from the financial ruin that followed the flood of 1927 and reached a crisis in the depression of the 1930's.

The history of drainage development in the Mississippi Valley, particularly in Bartholomew-Boeuf-Tensas Basin, has too often been written in terms of floods and depressions rather than in terms of the more analytical concepts that embrace and describe the major interests, groups, institutions, and practices which gave form to the drainage movement as it developed and is practiced in this area.

The major causes of past failures to achieve adequate drainage are:

(a) Shortage of basic engineering data.

(b) Inadequacy of district funds for carrying out complete plans.

(c) Lack of common interests among many of the groups sponsoring local projects leading in some cases to the construction of terminal drainage satisfying non-agricultural interests but giving little, if any, benefit to agricultural lands on which heavy drainage taxes ultimately fell.

(d) Intensive localization of organization and management which prevented the integration of work on a basin-wide scale.

(e) Lack of adequate maintenance.

(f) Insufficient attention to sound business policies, particularly in regard to methods of financing and record-keeping, brought about by inadequate revenue or lack of properly trained supervisory personnel.

(g) A legal structure unsuited to situations in which drainage planning requires intercounty and interstate consideration.

TENNESSEE VALLEY AUTHORITY

95. Wilson project, Alabama.—The Wilson Dam multiple-purpose project, serving navigation and power, was started as a World War I project and was placed in operation in 1925. Located on the main Tennessee River in Alabama, about 259 miles above the mouth, this project became the keystone about which the remainder of the Tennessee Valley Authority multiple-purpose system was planned and constructed. The construction of numerous upstream projects, both on the main stream and tributaries, has provided the requisite storage to permit the optimum development of power at Wilson through the installation of additional power units. The project has fully accomplished the purposes for which it was designed and is being operated efficiently and economically as a part of the Tennessee Valley Authority system.

46. Wheeler project, Alabama.—The Wheeler multiple-purpose project is located on the main Tennessee River in Alabama, next upstream from Wilson Dam, about 275 miles above the mouth of the river and only about 16 miles above Wilson. It was constructed by TVA, beginning in 1933, as a part of its system, the lock and one power unit being placed in operation late in 1936. As in the case of the Wilson project it has been feasible here, by reason of the provision of the large amount of upstream storage after this project was initially constructed, to expand hydropower production at the site to the ultimate by the installation of additional units. The purposes of navigation, flood control, and power, for which the project was designed, have been fully realized, and the project has been used economically as a unit in the TVA system.

47. Norris project, Tennessee.—The Norris project was constructed at the same time as the Wheeler project, these being the first two projects built by TVA. It was also the first project built on a tributary stream. The dam, located on the Clinch River in eastern Tennessee about 80 miles above the mouth, forms a large reservoir which, upon completion and closure in 1936, became effective immediately for the purposes for which it was designed. Its large storage capacity was used for flood control in part during the flood in the spring of 1936, while the reservoir was being filled initially, and again to a large degree during the great flood in January and February 1937 when the Mississippi River reached the highest stage of record at Cairo. It has been so used many times since. In addition, the reservoir subsequently furnished water during low flow periods to augment flows for power and navigation. As a part of the TVA multiple-purpose reservoir system this project has economically fulfilled the purposes for which it was designed.

PUBLIC HEALTH SERVICE

48. Sealing abandoned coal mines.—Acid drainage from active and abandoned coal mines is an important water pollution problem particularly in the Ohio River Basin. One method of control which was tried on a large scale is the sealing of abandoned coal mines. The sealing program was started in 1933 under the auspices of various State health departments, Federal relief agencies and the Public Health Service. The work was placed on a regional basis in 1935 under the WPA and the Public Health Service. This activity continued until 1941. As of 1940 the WPA had spent roughly \$7 million in nine States on this

program. In general, this activity was beneficial in reducing the mine acid load on surface streams. However, at the inception of the program the exact fundamentals of the mechanism of mine acid production and methods of preventing its formation were not completely understood. A better understanding might have resulted in somewhat different program emphasis with resultant greater benefits per dollar spent. Of even greater importance was the fact that no provision was made for maintenance work on sealed mines and at present most of the benefits of the \$7 million sealing program have been lost through lack of maintenance.

49. *Effect of flow increases on water pollution.*—Increasing low flow in polluted streams is an important contribution to the solution of water pollution problems. However, this is only a partial solution, as at least primary sedimentation is needed to remove sludge deposits, floating sewage solids, and scum. Additional benefits also accrue from reduction of hardness and reduction in temperatures when the stream is used for cooling water.

Under conditions of partially regulated flow after construction by private interests of Milton Reservoir on the Mahoning River, an Ohio tributary of the Beaver River, the minimum expected flow at Youngstown was 145 cubic feet per second during the summer months and 110 cubic feet per second in the winter. Nuisance conditions existed frequently in the stream in the Youngstown area. It was estimated that it would be necessary to remove approximately 96 percent of the combined municipal and industrial pollution load to prevent this nuisance. Such a high degree of waste treatment is impractical, both technically and economically.

Under flow conditions in the current operating schedule after Corps of Engineers construction of Berlin and Mosquito Creek Reservoirs in the Mahoning Basin, the minimum monthly average flow at Youngstown is 470 cubic feet per second in July and 185 cubic feet per second during winter months. While conditions are not now satisfactory, inasmuch as raw sewage and industrial wastes are being discharged, the stream has improved to such a condition that it is estimated that it can be cleaned up to a satisfactory degree by practical known treatment and other pollution abatement methods.

Greatly improved temperature conditions have been reported by the many industrial users of the river. Hardness has been reduced and acidity due to the discharge of acid pickle liquor has been reduced.

50. *Water supply reservoir drainage areas.*—Complete control of catchment areas has been the ideal of waterworks officials for many years. The principal motivating factors are the desire for minimizing pollution, reducing water color and turbidity, controlling erosion with accompanying maintenance of reservoir storage capacity, and regulating yield from a catchment area. The presence of lakes and ponds in the areas, farming operations, forestation or forest cover, and the spread and type of watershed population will influence these factors.

A far-sighted policy of acquiring drainage areas needed for current and future water-supply development has been practiced by the city of Akron, Ohio, since 1912, when the community purchased the holdings of a private water company then furnishing the supply. As of 1949 the municipal water-supply system was serving a popula-

tion of about 250,000 and had an average output of about 35 million gallons per day.

The city is now drawing its supply from three reservoirs located in the Cuyahoga River Basin. These involve a total catchment area of about 5,000 acres, all of which the city owns. Reservoirs cover 2,200 acres of the 5,000 acres. The drainage area surrounding these reservoirs is devoted mainly to forests, the growing of fruit, wild fowl and game preservation, and fish breeding. As the orchards become too old to be profitable the areas are cleaned and either covered by grass or reforested.

In the early 1920's it became apparent that the city would at some future time require further storage areas for water-supply purposes. The purchase of additional lands in the same watershed was begun. To date about 8,000 acres have been acquired under this program. The areas are now devoted mainly to farming, forests and wood lots, pasture for sheep and cattle, and to the production of maple sugar. These various activities produce an income which is sufficient to offset the cost of maintaining the property.

The Akron Water Bureau has worked closely with the several State agencies interested in the conservation and development of natural resources. This procedure, in addition to making the various projects self-supporting, has had a high public relations value.

Since these various lands were not originally purchased primarily for farming, recreational, or other similar purposes, the items of taxes, interest, and land retirements are not charged to the cost of operating the various projects. Such items are more properly charged to the operation of the water-supply system as a whole.

51. *Mississippi River below Minneapolis and St. Paul.*—The construction of Hastings Dam on the Mississippi River below Minneapolis and St. Paul changed a section of the river from a running stream to a slow-moving, navigable waterway. The discharge of sewage from both cities subjected the river to marked pollution, particularly denoted by the prevailing low dissolved oxygen content. Extensive laboratory data were collected both before and after 1931 when the dam was constructed.

Prior to 1931, the summer laboratory results with flows between 5,000 and 7,000 cubic feet per second over a 4-year period showed a monthly average dissolved oxygen content of 3.4 parts per million. Similar data, with the same range in flows, and collected after 1931 showed an average dissolved oxygen content of 2.1 parts per million. Pollution loads changed very little during the period. From an analysis based on these values together with stream flows, it was found that the magnitude of pollution must be reduced by approximately 25 percent more in order that equivalent stream quality conditions be maintained.

52. *Ohio River between Cincinnati and Louisville.*—The Public Health Service conducted sanitary surveys of the Ohio River between Cincinnati and Louisville during the periods 1914-16 and 1929-31. To facilitate navigation in this 164-mile section, two dams between the two cities were constructed and a third dam at Louisville was heightened 8 feet during the period between these surveys. The resulting change in channel conditions created a series of pools when the dams were in operation, thereby increasing the time of flow and permitting sedimentation to take place. The effect of this change cannot be di-

rectly ascertained by comparison of the analytical results of the two surveys, because of a significant increase in sewage and industrial waste pollution and the much lower river flows during the latter survey. Nonetheless, certain qualitative comparisons were made and are set forth in Public Health Service Bulletin No. 205 (1933). The summary of this report is quoted, in part, as follows:

Canalization, permitting sedimentation and allowing longer times of flow between points in which natural purification agencies may operate, appears to have decreased the bacterial load in the river both above and below the Cincinnati and Louisville metropolitan areas during the summer and fall months when the navigation dams are usually in operation.

While canalization has a tendency to decrease the bacterial load in the stream, improve the bacterial quality of the water entering the metropolitan areas, and shorten the distance downstream that the effects of pollution can be observed, it also has a tendency to move the point of probable nuisance, due to oxygen depletion and anaerobic conditions, from points downstream to within the zone of pollution in the vicinity of the sewer outlets, where sludge banks form as a result of decreased velocities in the pools.

While decreased bacterial loads at the water works filtration plants make the production of an effluent of satisfactory bacterial quality less difficult, the effects of low turbidities in the river and increased numbers of microscopic organisms, with their tendency toward odor and taste production and shortened filter runs, more than offset the good effects of decreased bacterial loadings.

In addition, the concentration of decomposition products in the water from the fermentation of deposits of organic materials within the pools when the dams are in continuous operation, may have public health aspects heretofore not appreciated. Reference is made to the suspected water-borne outbreak of gastroenteritis along the Ohio River at the time of and following the low-water conditions in the fall and winter of 1930-31.

Canalization, at least between Cincinnati and Louisville, has had a tendency to complicate rather than simplify the problems connected with sewage disposal, possible nuisance production, the operation of water-treatment devices, and the preservation of the public health.

53. *Harriman, Tenn., in the Tennessee Valley.*—The Watts Bar Dam of the TVA on the Tennessee River results in backwater up the Emory River which is now an arm of the Watts Bar Reservoir. At Harriman, Tenn., located on the arm of the reservoir, industrial and municipal pollution is discharged at a point normally below the Harriman municipal water intake. However, under certain conditions when cold water from Fort Loudoun Dam is discharged into Watts Bar Reservoir it flows beneath the warmer surface waters and up the bottom of the Clinch and Emory Rivers. Pollution from the Harriman sewage and industrial waste outlets has caused damage to the supply to the municipal water intake. Control measures have consisted of altering the schedule of discharges from Fort Loudoun Dam on the Tennessee River and Norris Dam on the Clinch River in such a way as to minimize the difficulties plus barging of some of the industrial wastes into the center of Watts Bar Reservoir.

54. *Industrial pollution creates need for new source of water supply.*—The necessity for developing new sources of water supplies because of high industrial waste pollution is illustrated by the experiences of the cities of Saginaw and Midland, Mich. Both municipalities were using water from the Saginaw River Basin. Although the quantity of supply was adequate, modern treatment methods were used, and strict laboratory control was maintained; nevertheless it became increasingly difficult to produce a supply free from objectionable tastes and odors, as well as one reasonably low in chlorides and hardness.

Following a detailed study of the water supply requirements by representatives of the two cities in 1945, it was recommended that the local sources be abandoned and that the development of a supply from Lake Huron, about 65 miles away, be undertaken. It was also recommended that the new system have a basic capacity of 43 million gallons per day. This quantity provided for a 100 per cent increase over the requirements at the time of the study.

Construction on the pipeline was begun in early 1947 and the system placed in continuous operation on October 23, 1948. The final cost was about \$10,300,000. The project was financed through the sale of water revenue bonds by the cities of Saginaw and Midland, individually.

The principal physical features of the project include:

- (a) A 66-inch steel pipeline extending 2 miles to an intake crib in Lake Huron.
- (b) A pumping station, with 70-million gallons daily capacity, at the lake shore.
- (c) Forty-eight miles of 48-inch pipe extending from the lake shore to a second pumping station, designated as the junction pumping station and designed for 70-million-gallons-per-day capacity.
- (d) A 5-million-gallon-capacity reservoir at the junction pumping station.
- (e) Two branch lines of 36-inch prestressed reinforced concrete pipe, from the junction pumping station, extending 17 miles to Midland and 15 miles to Saginaw, respectively.

55. *A malaria outbreak near Santee Reservoir, S. C.*—During the summer of 1943, while the incidence of malaria was progressively declining elsewhere throughout the United States, an explosive epidemic of this disease occurred in South Carolina. This significant outbreak of "man-made" malaria was directly attributable to conditions on the 97,000-acre Santee Reservoir.

The South Carolina Public Service Authorities' Santee Reservoir project was started in 1938. The dam was completed in November 1941, and water reached the normal maximum pool elevation in September 1942. Several factors of design, construction, and operation were responsible for the increased malaria transmission potential which resulted in an epidemic the following summer.

II. Summary of Experience

In order to hasten completion of the project, with the advent of World War II, plans for the complete clearing of the site in accordance with the South Carolina State Board of Health regulations, were modified to the extent that 47,000 acres of standing timber were left in the center of the reservoir. (The cleared strip varied from one-half to 1 mile from shore.) An entomological survey conducted after impoundment demonstrated stupendous production of malaria mosquitoes in the region, particularly in uncleared areas.

In addition, the development of wildlife areas were improperly planned. Two wildlife refuges (Potato Creek and Jack's Creek), of a type favorable to the high production of malaria mosquitoes, were located in regions with a relatively high human population. Many susceptible humans were thus exposed to vast numbers of the insect vectors of malaria.

Improper early management permitted small colonies of aquatic plants to gain a foothold in the reservoir. In 1944 there were less than 100 acres of alligator weed in the Santee Reservoir. By 1948 the infestation had increased by thousands of acres. Despite expensive later control (\$13,000 were spent in fiscal year 1947) colonization has so progressed that eradication of the obnoxious plant has now become a tremendous task which is probably beyond the realm of economic feasibility. Lack of early recognition of a potential problem has immeasurably increased the expense involved in achieving control of the plant and of the malaria mosquito breeding associated with it.

The Extent to Which Projects Have Accomplished the Design Purpose

Nearly all projects now operating are accomplishing the purposes for which they were built. Many have been altered since original construction to make them more satisfactory. The agencies have learned much from the construction and operation of these projects and have put this knowledge to use not only on these projects, but on new projects. Some of the original faults or lack of techniques are cited herein to indicate the types of problems that were encountered. Similar types of problems will arise in new programs but in the development of similar projects the agencies have adopted the appropriate improvements.

On a number of irrigation projects, salts, toxic to plant growth under irrigation, have risen to the surface. Many alkali areas within irrigation districts are no longer productive. Such lands can be found in the Belle Fourche project in South Dakota and in many other projects. The charges applying to such lands are held in suspense accounts so that when it will be possible to remove the salts or to raise crops on such lands, they may bear their proportionate part in the project cost. The remainder of these projects is successfully serving the purpose for which they were planned.

The alkali problem is also intimately related to waterlogging of the land from lack of drainage. This problem is now cured by providing adequate drainage and flushing. These measures have materially added to the cost of some projects. Other types of soils, such as "hard-pan," "greasewood," or "gumbo," are highly impervious and unfit for cultivation. These types of land have been excluded from some projects as in the case of the Shoshone, Belle Fourche, and other projects.

Engineeringly, these irrigation projects are sound and supplied water to the land. This was the real design purpose. With respect to the acreage of land brought into production, however, some projects fell short of the goal, because of a definite lack of adequate knowledge or basic data on soils.

On many of the privately constructed irrigation projects, especially the smaller ones, serious trouble has developed so that now a critical condition exists. Much of this is due to lack of adequate financing, poor engineering, and the use of temporary structures. There are many of these small projects that must be rehabilitated or much of the present economy will be lost.

Federal flood control projects, though having been operating for only a few years, have in general been successful. Many locally constructed projects have not had as good a record, although that of the Miami Conservancy District has been an outstanding success. Some have proven inadequate, and have been enlarged to provide greater benefits. The Hogan Dam on the Calaveras River, Calif., built by the city of Stockton, is to be replaced by a larger structure to provide additional protection and at the same time supply irrigation water. The town of Bonners Ferry, Idaho, built levees to protect it from the flood waters of the Kootenai River. These have recently been materially modified and strengthened by the Corps of Engineers.

Watershed management programs have not yet gone beyond their initial or trial stages of construction. Consequently, they have not as yet demonstrated whether or not the full benefits claimed will be realized.

Drainage projects notably have not produced the results originally contemplated because of lack of adequate design, financing, and operation and maintenance. They were primarily of a private or local interest and had for their purpose the draining of a small area without sufficient consideration of the amounts of water to be derived from either the drained land or its surroundings. Consequently, they failed because their ditches were inadequate to carry the amount of water which actually had to be conveyed.

Navigation projects generally have been engineeringly sound. A few have not developed the traffic for which they were designed although the project successfully reduced freight rates in the locality. This was the case in the Illinois-Mississippi canal in northern Illinois. Other navigation projects have been greatly modified, as on the Ohio and Warrior Rivers, where new types of barges and tows have developed. It has been necessary to deepen harbors

and channels of navigation projects because of the increasing draft of boats and barges.

All of the hydroelectric projects investigated were adequately serving the purpose for which they were designed. In some instances it has proven necessary to make modifications of the project structures in order to improve their safety.

The Extent to Which Projects Would Have Been Modified If More Adequate Data Had Been Available

Many modifications have been made in existing projects since the date of their construction due to increased knowledge and more technical data. However, probably no project will ever be built that at some future time cannot be improved upon.

Experience has shown that in the development of any project it is essential to have adequate data on all factors which enter in the design or may affect the operation and maintenance of the project. In practically every project for water resource development it is essential to take into account not only the water but also the land. It is impossible to leave the soil out of consideration in any irrigation or drainage project. Sedimentation affects to a greater or less degree every navigation and reservoir project.

Many older projects would have been designed differently if they were to be constructed today because of the increase in data and knowledge gained since the time of their construction. The outlet works of Grand Coulee Dam are to be modified so as to permit regulation for flood control. Such use was impracticable without the large additional flood control storage reservoirs recently added to the basin plan as a result of developments subsequent to construction of the dam. Grand Coulee also might have had provision built in it for more power units to provide for the use of upstream storage that may be created. Bonneville Dam might have had additional initial provision for the installation of future power units as additional stream flow is created by storage in upstream reservoirs. The navigation locks at Bonneville might have been larger—at least as large as those now being built at McNary—had there been knowledge of the changes in type of transportation required on the Columbia.

As Arrowrock Dam the facing concrete did not withstand the elements and has had to be replaced. Similar conditions exist at several privately constructed projects. Studies of concrete in these dams have developed new knowledge, and have resulted in greatly improved concrete for all types of construction.

The outlet tunnel and gates at Shoshone Dam at the time of installation represented an experiment in operation under a head much higher than those on which experience had been obtained. Experience in the design and operation of these features has made it possible to design comparable features with assurance. Much new data are obtained from life-sized models.

Even projects constructed in recent years would be slightly different had more data been available. At the Knightville Dam in Massachusetts the present hydrologic criteria would call for a somewhat larger spillway ca-

capacity. With present knowledge of flood magnitudes the flood control storage would be at least 6 inches and preferably 7 or 8 inches of runoff from the watershed rather than the 3.6 inches for which the dam was planned, and if multipurposes were considered the Knightville Dam might have been designed for 12-inch runoff. These possible alterations indicate changes due to more complete knowledge, to improved criteria, and to a broader approach.

Even though many of the older projects, both Federal and private have been a success, they have been in many instances based on inadequate basic data. The Shoshone project was based on 3 years of stream flow record, but the structures would not have been materially altered had there been a longer record. There might have been more spillway capacity according to present standards but the spillway has successfully passed all floods for more than 40 years. By contrast, the record of approximately 30 years used in planning the San Carlos reservoir embraced years of runoff so much higher than has been experienced since that the water supply has been insufficient for the irrigation contemplated. Whereas runoff exceeded the mean during 15 of the 30 years prior to construction, it has exceeded the mean during only 3 of the 22 years since construction.

A great many private projects have failed due to lack of knowledge of soils, amount of water available, the floods to be expected, and present engineering techniques which have been developed since their construction. The St. Francis Dam in California failed due to lack of knowledge of the bearing capacity of the foundation rock. The Florida-Everglades drainage venture failed due to a number of reasons such as the lack of adequate data, the volume of water to be handled, a lack of knowledge of characteristics of peat soils, and overspeculation.

Where experience was lacking, such as in the irrigation of alkali or gumbo soils, many irrigation districts have had trouble, such as the Frannie unit of the Shoshone project and the Belle Fourche project. Many large areas in bogs or swamps in the upper Mississippi Basin were drained thus destroying a wildlife habitat before knowledge had developed concerning the best utilization of such land. Eagle Lake in California was drained through a tunnel and an agricultural economy was developed by private enterprise only to find that the tunnel lost a large percentage of the water necessary for irrigation, and the water supply itself was insufficient. Thus an existing economy developed over a period of years was lost.

When the Hastings Dam was built on the Mississippi River below St. Paul, changing the river from a fast moving one to a sluggish stream, the pollution load became serious as the average dissolved oxygen content reduced from 3.4 parts per million to 2.1.

Construction of additional storage facilities to supplement water supplies originally provided has been necessary on many irrigation projects. Many causes are involved. Among them are: Overexpansion of irrigation facilities resulting from many diversions of stream flow; the occurrence of increasingly severe periodic shortages in a generally declining cycle of runoff; and the intensification of agriculture with resulting inability to withstand periodic water shortages without great loss.

Are the Projects in Fact Being Used Economically?

With few exceptions, projects reviewed are being operated at costs within the range anticipated, taking into account the general increase in wages and price level, and in no instance have costs become so large in relation to benefits or returns as to make project operation uneconomical. Relative economy in operation undoubtedly varies from project to project, but peculiarities affecting costs on individual projects obscure the comparative degree of economy.

Experience has repeatedly indicated that where a responsible, directly interested local agency is available, such as an irrigation, drainage, or levee district, or a municipality, to operate local flood protection works, federally constructed works can be more economically operated by such an organization than by the Federal Government. Although such local operation and maintenance are desirable, care must be exercised to make certain that minimum standards are met. There is evidence, in many cases, that some of the apparent economy effected by local operation has been because of continued and unwise deferred maintenance, which has hastened the need for project rehabilitation and has actually increased the total annual cost of the project. When works are turned over to local agencies which do not have adequate technical staffs, arrangements should be made for periodic inspections and reports by agencies and organizations with such staffs. Such arrangements have been made in a number of cases and appear to be working satisfactorily.

The mine sealing program to ameliorate the acid mine waste problem in the Ohio River Basin, operating as a relief measure during the 1930's, promised worth while benefits but failed in general due to inadequate maintenance.

The Extent to Which Original Estimates of Benefits and Costs Have Been Realized

In general costs have been higher than originally anticipated, due to the generally upward trend in construction cost, initiation of urgent construction before detailed explorations and plans were completed (as in the case of Bonneville Dam), and construction during the war period when both material and labor shortages existed. Although formal estimates of benefits were not made in many instances (repayment rather than benefits has been the criteria in evaluating irrigation and some other Federal developments), the data available indicate that in most cases the benefits actually realized have surpassed those anticipated to an even greater degree than the actual costs have exceeded the estimated costs. Increased values of lands protected from flood and increased value of agricultural products, and accelerated development of project areas help account for the large benefits in addition to those evaluated. Conservative estimates of other benefits, notably recreation and pollution abatement, have been greatly exceeded. In a few instances, anticipated benefits from private projects were not realized initially because the projects could not safely be operated as designed due to structural defects. Such defects, however, were later corrected and the projects are now operating as anticipated.

Attainment of the full benefits estimated for some flood-control developments has not yet materialized because the higher floods against which they afford protection have not yet occurred. For example, the annual benefit-cost ratio realized for the local flood-protection project at Huntington, W. Va. (in only 8 years of operation) is 3:1, whereas the ultimate to be achieved is estimated at 5:1. Similarly, although amply justifying themselves individually, some flood-control reservoirs designed as parts of a system (as in the case of the Cottage Grove Dam and Reservoir, which is a part of the system of reservoir planned for flood protection and other purposes in the Willamette Valley) will not realize their anticipated full potential until the system is complete (2+:1 now rather than 4.5:1 at Cottage Grove).

Certain benefits have been received beyond those contemplated, many that were not considered at all at the time the projects were authorized or constructed. Thus the pollution-abatement benefits that have been realized from the Tygart Reservoir are about 40 times that originally contemplated. All such benefits need particular attention as indicating possibilities in future projects. In some there may be the opportunity to enhance these possibilities.

Recreation is becoming an important aspect of many water resources developments. The types of recreation are quite varied. A large body of water attracts many varied types of recreation, such as boating, fishing, swimming, water polo, or scenery enjoyment. Such reservoirs as the Cottage Grove in Oregon, where high recreational use has developed in an area with many natural lakes and streams, and the Tionesta Reservoir in Pennsylvania, where more than 100,000 people visited the recreation area in 1 year, are examples. There were about 1,600,000 visitors recorded at the Lake Mead recreational area at Hoover Dam in 1948.

In some instances the utilization of power storage in reservoirs is limited at certain times during the year in the interest of recreation. An example is the Lake Chelan water power project in the State of Washington.

The bass fishing in Lake Mead provides an outstanding recreational sport in an area where bass fishing was not known previously. Also, the clear water in the Colorado River flowing from Lake Mead provides an excellent habitat for trout, a species that could not exist prior to the construction of the dam on account of the heavy load of sediment carried. Ducks and geese are found in increasing numbers in the Tennessee Valley since the development of the TVA program.

What Effect Have Unanticipated Physical, Economic, or Political Conditions Had on the Results Obtained?

Studies of a considerable number of completed projects reveal that unanticipated conditions have had an effect upon them. In general, these conditions have been more beneficial to the projects than otherwise. In the past quarter century, economic conditions generally have been such as to provide greater benefits than were anticipated when the projects were constructed. The population has greatly increased especially in industrial and urban areas; needs for power, domestic water, navigation, and pro-

tection from floods have generally increased, prices have increased materially making in many instances early investments more profitable.

Some projects even with such increments in their favor, still were unable to fulfill their basic objectives. These for the most part were those which were too inadequately financed, too poorly planned, and overly ambitious. This was particularly true of numerous private irrigation and drainage works.

Unanticipated physical conditions have proved a serious factor in a few cases. One of the most serious causes giving national concern to the whole problem of water resource development is sedimentation. Early investigations had revealed the seriousness of erosion nationally and regionally, but comparatively little attention was given this factor until recently.

Sedimentation will, in time, affect the utility of many engineering works. It has filled many small reservoirs built for a variety of purposes. It has created situations which will necessitate the expenditure of large sums of money to protect the existing economy. Outstanding in this respect is the Middle Rio Grande Basin. Here, within a floodway constructed by local interests, the river bed is rising because of the inability of the stream to move its sediment load. This has resulted in a major flood and drainage problem throughout some hundred miles of river. Below the floodway and above the upper end of Elephant Butte Reservoir, sediment deposits have become overgrown with brush and small trees; the river channel has greatly deteriorated so that a swampy area thickly covered with vegetation has been formed, resulting in a high nonbeneficial consumptive use of water. Now a major operation is necessary to save the Middle Rio Grande. Sedimentation is also serious on the Colorado, Pecos, and other southwestern streams.

Sedimentation is also a major factor in the Los Angeles flood-control project. Here numerous small debris basins at the mouths of steep canyons are catching the products of erosion from a degrading mountain mass. Costs of removal of this debris are increasing from an original 5 cents to more than a dollar per cubic yard as sites in which to pile the debris are more expensive or more distant due to the encroachment of residential construction.

Urban growth has had a marked effect, both beneficially and detrimentally, on many projects. Many flood-control projects, by reducing the volume of floods, have permitted higher use of lands. Much property in Pittsburgh has attained a greater value. Along the rivers where levees are built, use of the flood plain is more desirable. On the other hand, the urban growth around Los Angeles has preempted the debris cones and increased the hazard. The construction of a large number of expensive concrete lined channels, upstream reservoirs, and debris basins were required to permit safe urban development in these later hazardous areas.

Some unanticipated physical conditions have proven beneficial. When the Salt River project in Arizona was inaugurated, groundwater was found at a considerable depth. However, as irrigation progressed, drainage from the project caused the groundwater to rise making it possible for many to irrigate certain areas by pumping instead of from the ditch. Thus a considerable acreage of land outside of the project benefitted indirectly from the project. However, excessive pumping is increasing to the

point where the groundwater has been and is being seriously lowered.

Other instances of failures or of declining values in projects are in pump irrigation. Overpumping as in the San Joaquin Valley has resulted in considerable acreage of land going out of production because pumping has exceeded the replenishment. This process is also under way in the Panhandle portion of Texas, in the Gila and Salt River Valleys in Arizona, and in Las Vegas Valley in Nevada, as well as in many other areas.

War needs necessitated the construction of reservoirs for low water regulation on the Mahoning River for a cooling water supply to speed up steel production. The creation of these reservoirs for that purpose has complicated the problem of providing sufficient flood protection in the basin.

Other types of physical factors affecting the success of projects include inadequate investigations and interpretations of geological conditions of foundations, such as water soluble material, or highly permeable gravels, prior to start of construction. These inadequacies in the design of a few projects in the past have shown the need for acquiring services of competent geologists and engineers to ascertain the suitability of foundations in the planning stage.

Political considerations have adversely affected some projects. For example, the Tallahatchie-Yazoo watershed flood control project in northern Mississippi involved the public acquisition of worn-out and badly eroded farms, and the submarginal and poorly managed forest lands. This resulted in a fear that the whole area would be depopulated. As most of the loss and most of the watershed programs were in a single congressional district, the upland watershed land treatment program was held up by State legislation. This upset the whole plan as originally conceived and brought many new problems to the fore.

Another unforeseen political action was the loss of "Emergency" help to the Wheeler-Case irrigation projects. In these projects relief labor was to be used as a subsidy to help projects get on their feet, physically and financially. The loss of this relief subsidy for some of the projects put them out of commission.

The treaty of 1906 with Mexico which required delivery of 60,000 acre-feet of water annually to Mexico made necessary the construction of the Elephant Butte Dam, the main reservoir of the Rio Grande project. Negotiations with Canada concerning the waters of Milk River materially affected the amount of water available for the Milk River project as originally planned, and for which the works were partly constructed. Conflicts with Mexico had much to do with the development of the All-American Canal.

A recent decision of the West Virginia Supreme Court to the effect that the State could not abrogate its police functions nor commit future legislature to make expenditures, would practically nullify the Ohio River Valley Water Sanitation Compact, and if supported by the United States Supreme Court, will throw doubt on the effectiveness of desirable State compacts.

Both benefits and damages develop from the changing of the Colorado River below Hoover Dam from a muddy stream of irregular discharge to a clear, regulated river. Most of the damages arising from deposits of sediment downstream at the head of Lake Havasu and the reservoir

formed by Imperial Dam are such that they can be controlled with reasonable expenditures since the movement of sediment from the bed of the stream is rapidly decreasing and local contributions to the load of the stream are minor in character. Degradation of the stream channel while generally beneficial in improving drainage conditions, in reducing channel losses and in increasing power head, rendered ineffective the diversion works for the Palo Verde irrigation district until a temporary weir was installed across the river. A permanent solution of this diversion problem is now under study by the Bureau of Reclamation and Bureau of Indian Affairs which may involve the replacement of the weir with a low-head pumping plant.

The silt flowing in the Colorado River before the construction of Hoover Dam had certain beneficial and certain detrimental effects when carried through the canals for the irrigation of lands in the Imperial Valley. The silt filled the ditches and required cleaning. Silt removal cost was in the order of one million dollars a year in the case of Imperial Valley alone. At the same time it carried high fertility to the lands and assured their continued fertility under heavy use. The silts also tended to seal the canals and prevent loss of water. Since the building of Hoover Dam, the removal of aquatic growth from the Imperial Canal requires continuous costly expenditures to enable the canals to carry their full supply. These are all problems the engineering profession is now cognizant of and will be able to design for in future structures where a stream heavily laden with silt is regulated.

Are Any Projects Not Justifying Their Annual Operation and Maintenance Costs?

An examination of a considerable number of water projects reveals that those which are functioning today are more than meeting their annual operation and maintenance costs. Projects which have failed for one reason or another have gone out of existence. Others are operated on a reduced scale (such as the King Hill, Idaho, project), serving only those lands readily irrigable and are able to meet current costs. A few minor exceptions can be found. These are, however, essentially small local projects of no great special or national significance. Examples can be found in the improperly located and developed small drainage works which individual farmers or drainage districts attempt to keep alive. That such works are continued at all is due in considerable part to such factors as high prices for agricultural products or price support programs.

Another example is in certain pump irrigation projects. In some localities ground water has been so exhausted by overpumping from the underground reservoir that water levels have fallen below the economic limit for pumping. When such cases occur, as in some areas in the San Joaquin Valley, the operation and maintenance costs mount until the operator can no longer stay in business.

Federal Repayment Experience

There is no uniform policy for the repayment of projects as between the several construction agencies of the Federal Government. Each agency is working under special congressional directives. Under the 1936 Flood Control

Act and amendments thereto, it is required as a condition precedent to the construction of local flood protection projects, that local agencies provide lands and rights-of-way, hold and save the Government free from damages due to the construction, pay for alterations to sewers, utilities, highway bridges, and contribute a portion of construction cost if drainage or land enhancement is involved. No repayment of the Federal portion of the cost is required under the same act. As amended in 1938, the Federal Government bears the whole portion of the cost of reservoirs allocated to flood control. This is different from the Boulder Canyon Project Act of 1928 which requires that the cost allocated to flood control in the Boulder Canyon project, amounting to \$25 million, is to be repaid—without interest—by the power users after the power costs have been repaid. The land treatment programs of the Department of Agriculture under flood control legislation are also generally nonreimbursable. Local contribution to the programs is provided by the landowners on their own land.

Power is vendible and the power features of projects have indicated a definite return to the Treasury beyond the amounts estimated in the repayment schedules. For example, Bonneville has made repayment from power revenues of nearly \$30 million of which some \$18 million covered interest and operating expenses, and about \$12 million was for amortization including some \$4 million in advance payments.

The project repayment that is most frequently discussed is that covering Federal irrigation projects. One of the reasons for this is that reclamation, unlike most other Federal undertakings, requires that beneficiaries pay back directly a substantial part of the cost. This repayment has been a bothersome problem. There have been losses—more on the part of the settler than on the part of the Federal Government. In the early days the settler was intrigued with the promise of a home and with the assurance of adequate irrigation water at low cost and 10 years in which to pay. This seemed to be a wonderful opportunity, but when the project was built some found that the water would cost more than was originally estimated. This resulted, in many instances, in undue hardships on the part of the homesteader. It was years before many settlers had their places in full production. By that time they found that the water table was rising and their land needed drainage. Although the repayment period was extended, first to 20 years, then to 40, and now on many projects repayment is based on a percentage of the crop, they are still pioneering and are making their farms assets to the Nation. On the whole, the irrigation farmers are now paying their bills to the Government when due. One unit of the Yakima project has already paid out and several others have nearly paid out, although the Federal Reclamation program is only a little over 40 years old.

The total investment in Federal Reclamation projects as of June 30, 1950, aggregates about \$2 billion. Of this total about \$20 million, or 1 percent, has been written off largely because of shortcomings of earlier irrigation developments. In addition, repayment obligations have been temporarily suspended on about 173,000 acres of irrigable land because of low productive capacity commonly due to excessive alkali. These lands represent about 3 percent of the 5,678,500 irrigable acres in Federal Reclamation undertakings. Of the 173,000 acres

on which payment has been temporarily suspended, approximately 54,000 are currently being farmed, to work the alkali out of the soil and make the land useful. The remainder awaits further remedial measures to permit their agricultural use. It is contemplated that all of these lands will be restored to a paying class when their productivity is brought up to satisfactory levels.

Beneficiaries of the same type are treated entirely different depending upon the legislation under which a project was constructed. In most, other than irrigation projects, the beneficiaries are not charged for the cost of preliminary surveys and investigations, but all such costs are a direct charge to those on irrigation projects, and this amount is often an important element of the cost. If an early study reveals an irrigation project infeasible but a subsequent study finds it feasible due to changed conditions, the costs of both studies are charged to the beneficiaries.

Some agencies can charge beneficiaries for collateral benefit, such as land enhancement, but others do not. The planned development of the Point Park and the Gateway Center development of the Point Area in Pittsburgh, made possible by the flood control reservoir developments in the Upper Ohio, is an example, in which the beneficiary did not contribute directly toward the construction cost. Also, in the New Haven Harbor project, waste material from the channel excavation provided a filled area to be used by the State highway department at a saving of at least \$1 million as well as enhancing other property. The communities within and adjoining irrigation projects benefit greatly by such developments but bear no appreciable part of the project costs. Similarly, the beneficiaries of most navigation projects pay nothing directly toward their costs, but contribute indirectly through Federal taxes.

III. The General Lessons Learned

Past experience has resulted in major contributions to the improvement of procedure and policies for water resource development and will continue to do so. That mistakes have been made is inevitable. This has not precluded the success of undertakings of the kind reviewed, which have added so materially to the economy of the Nation. Nor should the inevitable mistakes of the future, as new and untried procedures and policies are applied, preclude the advancement of worthwhile undertakings.

Whether the lessons learned are effectively applied is the important question. This has been done promptly in the case of physical structures, as their adequacy or inadequacy can be quickly determined, and the development agencies have full freedom to apply the experience in the design of subsequent structures. In cases of water-resource development such as those involving economic and social problems, there is no such ready determination of adequacy, agreement on the character of remedial measures needed, or freedom to undertake these measures. The result has been a slower, more cautious application of experience in these latter fields.

The increase in experience and the improvement of procedures and policies have been a gradual evolutionary process. It is not revealed by the isolated reviews of individual projects. These tend to emphasize, on the one hand, examples of deficiencies which promoted efforts toward subsequent improvements or, on the other, successes in which are incorporated the results of past experience, good and bad, without indicating the subsequent or antecedent steps.

The following discussion has been arranged, therefore, to present a summation of principles and policies which

have evolved from past experience. The contributions made to many of the policies by experience on individual projects discussed above will be apparent, but the presentation is not limited to isolated lessons learned only from those examples. Nor is distinction made as to the extent to which individual principles and policies are currently being applied. Some represent present practices of all agencies in the water-resource-development field, whereas others will require additional legislation before their application or uniform adoption is possible. Finally, it should be recognized that they represent a guide for the near future, and that the subsequent and continuing summation of experience may indicate desirable modification.

Basin Development

Alternative and possible future developments on a stream have long been considered in planning individual projects. The need for more comprehensive surveys of all potentialities has been demonstrated, however, as developments in a given basin have progressed. Alternatives have decreased in number, the interrelationship of remaining possibilities has become closer, and the costs of projects left for development have become relatively high. These conditions have made it imperative that individual projects be made part of the most efficient and economical plan for development of the entire stream basin.

1. The following recommendations for the formulation of basin plans are drawn from experience demonstrating the need for such basin plans and experience in their preparation and application:

(a) Plans for the comprehensive development of all phases of water resource development should be prepared for river basins where not now available.

(b) The plan should present a comprehensive outline of physical development possibilities which will meet anticipated regional and local needs.

(c) The plan need be in detail sufficient only (1) to provide working understandings of the interrelationships between projects in the plan and their possible alternates; (2) to isolate superior individual projects; and (3) to establish desirable priorities for earlier development.

(d) The plan should be periodically reviewed and revised as required in the light of changing needs, and the adaptability to them of existing and potential structures and program schedules.

(e) Regional and local needs should determine the character and schedule of basin development so long as not in conflict with national objectives.

(f) Early and continuing participation in development of the plan at the field level by all Federal, State, private, and local agencies concerned should be encouraged to assure the requisite coordination of interests.

Illustrative of the indicated need for consideration of all phases of water resource development is the experience in the Rio Grande Valley where reservoir siltation and stream bed aggradation have increased by overgrazing of range lands in the watershed.

The desirability of adjusting the basin plan so as to meet indicated minimum requirements, to provide for periodic review, and thereby to maintain flexibility is illustrated in the Columbia River Basin. Bonneville Dam and Grand Coulee Dam are structures which, it was indicated by a basin plan, would meet regional and local needs, would constitute nonconflicting elements of a rational basin development, and were superior individual undertakings. Accordingly, they were selected from the possibilities indicated by the plan, investigated in detail and constructed. Subsequent to their completion, the flood of June 1948 in the Columbia River Basin demonstrated the desirability of providing more fully for flood control. The plan was accordingly revised with substantial additions of storage to upstream potential projects. The projects selected from the revised plan were then investigated and designed to meet the new modified needs. The Bonneville Dam, which, practically, can serve only the major purposes of navigation and power under any form of basin development, accordingly fits in with the revised plan. The situation at Grand Coulee is different. Here a large volume of storage was practicable and had been provided for power and irrigation. It is now recommended that the outlet works be modified to permit more effective use of reservoir space for flood control in conjunction with the other purposes. A workable flexibility in the plan thus has been attained. Further, effort and funds have not been pointlessly expended on detailed studies of projects in the initial plan which were not required for earlier development.

Active participation by Federal, State, private and local agencies concerned in developing a basin plan which will meet regional and local needs to the fullest possible extent has been demonstrated. Procedures have been established for achieving this, but experience has indicated that encouragement of more active participation at the field level

should be sought in the interests of most effective coordination.

2. The following recommendations stem from experience in the execution of basin plans:

(a) Coordinated programming and budgetary actions should be obtained for all elements of a basin plan. The objectives of coordinated comprehensive planning obviously cannot be fully met if a corresponding degree of coordination is not achieved in the execution of the plan. A major difficulty in the latter connection, experienced recently in proposed actions on a comprehensive plan for the Columbia River Basin, is the fact that traditional methods of authorization and appropriation preclude single action on a joint program involving projects of two different departments. Congressional arrangements to permit such actions are needed.

(b) Execution of the plan should keep pace with the expanding national economy, both present and future. Individual projects discussed above clearly illustrate that the addition of productive capacities through water resource development has created benefits to a growing population and economy far in excess of expectations, even during a period when opportunities and achievements in such developments by private initiative were far greater than those now in prospect.

(c) There should be a clearer line of demarcation as to authority of the Federal Government, States, private, and local agencies with reference to undertaking elements of a basin plan. Examples include proposals by non-Federal interests for construction of power developments which fit into a comprehensive plan; proposals by non-Federal interests for a contribution from the Federal Government to cover the cost of flood control storage and storage for purposes other than those allocable to power, as in the case of the Pensacola project; proposals for the operation of generation and transmission facilities of Federal power plants by private companies and other public agencies as in the case of the Boulder Dam project; the utilization of existing transmission systems; the extent of construction of new transmission lines to deliver power from Federal power plants; and power market studies.

Project Development

1. *Formulation of project plans.*—All Federal water resource projects (and related land programs) should be formulated on the following principles:

(a) The need for each purpose of a project should be established. This usually involves determination of objectives in quantitative terms such as protection against a "standard project flood" of a certain magnitude, market for the power generated from the project, or provision of a specific amount of storage for irrigation or water supply.

(b) All uses of a project site should be considered in order that the most efficient use may be made of its possibilities toward meeting the established needs or objectives.

(c) The scope of the project should be established at the point where the excess of benefits over costs is at a maximum. Exceptions may be advisable when intangible factors are of sufficient importance.

(d) The type of project and its details should be the most economical available method of accomplishing the specific purpose involved.

Establishment of need for a project.—A project can have value only to the extent that it can be shown that there will be a need or demand for the service to be rendered by the project. Although the need or demand may be obvious in the case of many purposes for which water resource projects are built, the nature of need or demand may give rise to limitations on the type or scope of project. For flood control, a "standard project flood" should be established as the maximum flood against which protection need be provided. The demand to be expected for hydroelectric power depends on future economic developments in the market area, on the price at which power from the project or from other sources will be offered for sale, and on similar factors. Similarly, possible limitations of need or demand should be considered in project formulation for all purposes to be served by the project.

Selection of type of project.—A study of each site for possible river basin development being considered to meet any specific purpose or purposes should also take into account other established justifiable needs or purposes. All physically possible methods of meeting each of the needed purposes which could be served by river basin development should be analyzed and compared to permit formulation of the most effective plan for meeting all needs from the standpoint of engineering, economic, and other pertinent considerations. The numerous combinations of methods and projects which require analysis under this criteria can be reduced to practicable limits by a process of approximate comparisons and proceeding successively through comparative analyses of increasing detail until a reasonable number of combinations remains for detailed analyses.

Establishment of scope or scale of development.—In the final stages of formulation of the plan, the scope (i. e., scale of development) of each project and of the plan as a whole should be established at the point where the excess of benefits over costs is at the maximum. This is the point at which the last increment of scale of development will add benefits equal to the cost of that increment. Further increments would add more cost than benefits. Extension of the project beyond this point is not economically justified. If the development is stopped short of this point, the over-all benefit-cost ratio may be higher but the full potentiality of the project would not be utilized.

Application of the foregoing principles would result in selection of the most effective scale of development if all factors could be completely taken into account in the estimates of benefits and costs. There may be, however, intangibles that cannot be readily evaluated in monetary terms. The significance of these intangibles must be considered to determine if departure is warranted from the results indicated by analysis of monetary values. For example, in flood control there are a number of factors which may prove important enough to warrant extending the scope of a project beyond the point where the excess of tangible benefits over costs is at the maximum. Whenever establishment of that point results in a project of lesser scope than that required to provide protection against the "standard project flood," consideration should be given to such intangibles as the reduction of hazard to life and health and the improvement of general welfare and security of the area involved. These factors and the value of avoiding creation of a false sense of security through providing only partial flood protection may war-

rant extending the scope of the project to a reasonably high degree of protection.

The fullest cooperation should be practiced between Federal agencies and State and local agencies, as well as with private concerns and interests, preferably at the field level.

Economic factors in project design.—At several stages in the analysis and design of a project it will be necessary to make a choice between alternative methods of accomplishing a given purpose. For example, the choice of type of dam, i. e., earth, concrete-gravity, concrete-arch, etc., are the choice of materials for a part of the project such as roofing materials for a powerhouse. For the most part, such questions are resolved on the basis of physical and engineering factors, but where a choice remains after those considerations are satisfied, the relative costs of otherwise equally satisfactory alternatives may govern. Also, it may be necessary to consider which of two or more equally satisfactory alternatives at the same cost will give the greatest benefits. In any event, the selected project and each of its components should be the most economical type or method of accomplishing the desired purpose.

2. Project justification—Justification of individual projects.—Among the principles for project formulation outlined in preceding paragraphs are the following criteria:

(a) A project as well as its components should be the most economical available method of accomplishing the specific purpose being served.

(b) The scale of development of a project should be established at the point where the excess of benefits over costs is at the maximum.

If these criteria are met, the total project benefits will necessarily exceed total project costs, and the project will be economically justified. The amount by which benefits exceed costs can be conveniently indicated by the ratio of benefits to costs. This ratio is also useful for comparing the relative desirability of a number of justified projects as outlined below.

Comparison of several justified projects.—The relative economic desirability of a number of justified projects is directly proportional to their ratios of benefits to costs. If economic considerations alone were involved, it would be proper to undertake projects with the highest benefit-cost ratios first. There are, however, other pertinent factors to be considered. For example, funds available may be so limited that a large project with a high ratio cannot be initiated until it can be foreseen that the total funds required can be obtained on a definite schedule. Meanwhile there may be funds available for smaller projects with lesser benefit-cost ratios.

Regional needs must also be taken into account in determining the order of construction of projects in a basin plan. Also, physical factors such as the interrelation of projects from an operational standpoint may dictate the order of priority of construction. For example, a downstream reservoir may be designed with a capacity for flood control such that prior completion of another reservoir upstream is required before the downstream project can fulfill the purposes for which designed. Similarly, there may be governmental policy considerations of intangible factors of sufficient importance to warrant undertaking

projects in other than the order indicated by their benefit-cost ratios.

Benefits should be evaluated in monetary terms wherever practicable and all intangible benefits should be considered in the formulation of the project.

The various types of benefits should be evaluated on a common basis to facilitate ascertaining the scope of development to realize each function.

The preliminary planning prior to congressional authorization should be carried forward to such an extent and with only sufficient detail to ascertain the scope of the project and to determine a reasonable estimate of cost. The estimate of cost should contain sufficient allowance for contingencies to cover factors which are not fully investigated, and the aspects of which may change when more detailed investigations are made at a later date in the formulation of definite project plans. The scope of the project should be sufficient in its engineering and economic features to accomplish adequately the purposes for which the project is formulated.

3. *Project reimbursement.*—Two general conclusions with respect to the reimbursement of costs may be drawn from the review of constructed projects:

(a) Reimbursement requirements should be established on a uniform basis for all functions and types of water resource development; and

(b) The costs of water resource developments should be distributed as equitably as possible in relation to benefits, having full regard for practical considerations of cost collection.

The lack of uniformity in reimbursement requirements arises from differences in the acts providing for Federal development of different types of projects. No requirement is placed upon the return of any cost incurred for commercial navigation purposes, or for flood protection provided by storage reservoirs, whereas in the case of local flood-protection facilities, beneficiaries pay costs of operation and maintenance and also capital costs for lands, easements, and rights-of-way. Reclamation law requires the return of all construction costs for irrigation facilities, without interest, and of costs for operation and maintenance. The same provisions apply to power developments made under Reclamation law, although it is also required that rates for power from these developments include an interest charge. Federal power investments associated with flood control and navigation are required to be returned with interest, in addition to costs of operation and maintenance.

The lack of uniformity has had several undesirable consequences. It has imposed unequal payment burdens in return for comparable benefits or for benefits of comparable magnitude. It prejudices continuation of developments having high reimbursement requirements in favor of those with low requirements and results in unbalanced water resource development. In a few instances, also, as in the case of the Pine Flat Reservoir in California, it has promoted local efforts to have construction done by one Federal agency rather than another and developed competition between the agencies involved.

Illustration of the first point above is provided by development in the Boise Valley, Idaho. The Anderson Ranch Reservoir, the last feature of the Boise project to be constructed, provides a supplemental supply of water

needed for presently irrigated lands, particularly during years of exceptionally low stream flow. The supplemental supply may be considered essentially as insurance against losses in such years. Payment by the water users for this insurance is required. Many of the same lands are also subject to losses in other years by reason of floods which either would inundate the lands or cause damage to headworks of canals serving them. Insurance against these losses is to be provided by a flood-control reservoir. For this insurance, however, no payment is required.

The increasing difficulties and costs presented by proposed and prospective irrigation projects make it impossible in most cases to meet the requirement of full return of construction costs under present law. Without modification of that law, therefore, the development of irrigation projects is being held up and will continue to be deferred, while developments with no greater or even less benefit in relation to cost go forward by reason of their less stringent reimbursement requirements.

Apportionment of the project payment burden in accordance with benefits cannot be questioned as a desirable goal. Such apportionment should be recognized as an objective and the closest practicable approach to it should be sought. Steps taken in that direction, however, must give full consideration to practical difficulties involved. The application of rigid requirements might well mean that benefits would be withheld from the many because the few could not meet payment obligations established.

The towns, cities and entire nonfarm economies which have grown up in irrigated communities which without irrigation would be unpopulated desert exemplify a type of benefit beyond that to the water user. Similar, though less obvious, benefits accompany increased production made possible by other types of water resource development. Beyond the local area, similar benefits add to the economy of the region and the Nation.

This general incidence of benefits is well understood and accepted. The amount of the benefits accruing to each level or group, however, is not understood and is extremely difficult to measure in a manner which is widely acceptable. Even an acceptable measurement of total benefits to all levels or groups which is applicable to all types of water resource development has yet to be agreed upon. Benefits not readily measured in dollars, but nevertheless real and requiring consideration, further complicate an acceptable determination of benefit distribution.

Beyond difficulties of determining an acceptable distribution of benefits lie greater difficulties in securing payments in proportion to the benefits. Assignment of the costs to be borne by the taxpayers at large in return for widespread national benefits is, of course, the easiest of the several assignments which might be made, because it can be done by the Congress through the recognition of a part of the cost as nonreimbursable.

In return for regional benefits, payments by users of federally generated power have provided a relatively simple means in some instances of securing contributions from people of the region, although new provisions for the pooling of costs of power and other water resource development would be essential in most basins. Payments from direct beneficiaries are comparatively easy to obtain where, as in the case of irrigation, the direct beneficiaries form a compact group and where, through the withholding of water, a means of compulsion is available. In other instances, how-

ever, such as flood protection along an entire river system, the direct beneficiaries are widely scattered and no direct means are available to compel payments. Even more difficult would be the securing of payments from local business communities in proportion to benefits received, particularly those on new land irrigation or drainage projects which do not exist prior to project development. Conservancy districts with taxation powers to do this have been successfully established where the business community was in existence prior to project development and where additional profit to the business community was in prospect by reason of the development and without the necessity of major new capital outlays in the community. Efforts to establish such districts have not been successful in new land developments, where the business community was faced with heavy capital outlays for community facilities.

In view of these practical difficulties, rigid formulae for the return of costs from the several benefited groups have proven unworkable. Although every effort should be made to secure equitable contributions from direct beneficiaries and from indirect beneficiaries of the community and region, much additional study of benefits and their distribution and of means for collecting costs will be required before a close approach to the goal can be attained.

4. *Project construction.*—(a) The construction of a project should not be started before adequate preconstruction studies have been completed. Some projects such as Saluda Dam, even after detailed investigations, failed to achieve their full purposes initially because of insufficient experience with problems encountered. Some, however, have been initiated without the fullest practicable investigation, and others have been started before studies had been undertaken which were recognized to be necessary.

It is with the latter two types of situations with which this statement is concerned. The Los Angeles River Watershed project, where remedial measures were undertaken before investigation had fully disclosed the type of structures required, provides one illustration. The Bonneville Dam provides a second. In this case, construction was initiated as a work relief measure before needed preconstruction surveys could be made. A change in location of the axis of the dam found necessary after the start of construction entailed additional cost which would have been avoided had there been opportunity to make detailed studies in advance.

Like Bonneville Dam, most instances of the latter kind involve projects built to meet particularly urgent needs under circumstances which made costs of relatively minor concern. Nevertheless, it will be apparent that the availability of a shelf of fully investigated projects designed to meet regional and national needs would eliminate difficulties and costs of the kind experienced at Bonneville Dam, and would insure that the needs could be met more fully. To permit the development of such a shelf, specific advance planning or preconstruction funds should be provided after authorization or formal approval of projects.

(b) Once started, construction of a project should proceed to completion at the most economical rate. Exceptions have occurred and may again occur in national emergencies when the increased cost resulting from construction at a rate either faster or slower than that most economical is entirely justifiable. The cost of wartime installation of Shasta Dam generator units at Grand Coulee Dam, and their subsequent removal, and increased costs

attending the virtual cessation of work on Anderson Ranch Dam of the Boise project provide examples. Under normal circumstances, however, appropriations should be so anticipated and made as to permit construction at the most economical rate.

(c) Federal projects should be constructed by those means which will achieve the lowest total project costs. This objective, it has been generally assumed, will be attained by competitive bidding on the part of private contractors. Construction by this means is compelled in some instances by language of appropriation bills restricting work which can be performed by Government forces. Experience has indicated, however, that some types of work on many projects can be done more economically and satisfactorily by Government forces than under contract. Dredging operations on the Colorado River below Hoover Dam are examples. Furthermore, the TVA has demonstrated that many advantages can be achieved by the successive construction of a series of structures by Government forces. A technical and labor force was held intact over an extended period and full advantage secured of training and experience as work progressed from one project to another with the result that greater flexibility and efficiency with resulting lower costs undoubtedly were achieved than could be obtained under contract arrangements. In view of these facts, the matter requires further consideration to the end that Federal agencies shall be free to have the work done in the manner most advantageous to the Government.

(d) Funds should be provided but construction deferred on project features for which need is anticipated, but which cannot be most effectively designed until the project is in operation. Drainage facilities on irrigation projects provide a good example. The ultimate need for drainage facilities on most, if not all, irrigation projects has been demonstrated by experience. The difficulty of determining in advance the level and attitude which the ground water table will assume after irrigation water is applied also has been established by experience. In some instances, drains constructed at the time of project construction did not perform as expected and additional expenditure proved necessary. The more desirable method of dealing with the problem has proved to be: Estimation of probable requirements, the provision of funds to meet those requirements, and a project program to meet actual needs as they develop. A similar approach to stage development of recreational facilities may well prove desirable.

(e) In the authorization of licenses for the construction and operation of non-Federal projects, the Federal Power Commission license insures that the project fits into a comprehensive plan of development. The Commission has required modifications of plans of project structures until they are found to be completely satisfactory.

5. *Project operation and maintenance.*—(a) Facilities and means for efficient operation and maintenance should receive full consideration in project plans and construction. In the interests of minimizing construction costs or in the absence of full appreciation of all operation and maintenance problems, adequate facilities have not always been provided, as in the case of access roads for canal maintenance on the Orland project, California. In resolution of such problems, the justifiable operation and

maintenance facilities should be established as those which will entail the minimum total annual costs.

(b) Technical and financial assistance should be made available to settlers on agricultural lands brought into production by water resource developments. Special problems beyond the experience of settlers commonly arise in connection with the development of new lands and of appropriate types of farm economies for them. Assistance in the solution of these problems and in the early establishment of efficient farm irrigation or drainage systems to promote careful land use, results in attaining project benefits earlier and more completely and in avoiding unnecessary settler hardships. Cooperation of the development agency and local groups through the Agricultural Extension Service has been demonstrated as a successful means of achieving these ends.

The lack of adequate credit for farm development purposes continues to be a handicap to settlers on new land projects. Risks involved have been reduced through experience in the selection and treatment of lands so that further extension of Federal credit in this field appears entirely justifiable. This extension, as in the case of technical assistance, will bring earlier and fuller realization of project benefits and will lessen settler hardships.

The absence of these forms of settler assistance contributed heavily to the slow development and slow return of project costs in some earlier irrigation undertakings, including among those reviewed above, the Shoshone, Wyoming, and Belle Fourche projects.

(c) Wherever practicable and in the public interest, operation and maintenance of federally constructed facilities should be turned over to local or State agencies. Operation and maintenance of such facilities by local or State agencies will be in the public interest under the following circumstances: (1) Where there is, or can be established, a fully responsible local agency capable of performing the work efficiently and well; (2) where that agency directly represents the interests of the people benefited; and (3) where the facilities serve a single purpose.

These criteria have evolved from experience with water resource developments of the past. It has been found that irrigation distribution facilities, as for example on

virtually all of the irrigation projects discussed above, can be operated as efficiently, and normally at lower cost, by local irrigation districts than by the Federal Government, whereas storage reservoirs and major supply works serving purposes other than irrigation, or serving a number of districts, can most effectively be operated by the Federal Government in close collaboration with local agencies.

Similar experience and reasons have led to turning over to local agencies the operation of local flood control facilities, as at Huntington, W. Va., and Wilkes Barre, Pa., and local drainage facilities. Federal operation has proved desirable, on the other hand, for multiple-purpose resource systems, such as that of the TVA and reservoirs such as Tygart, Norfolk, Tionesta, Lake Mead, and others discussed above, and in the case of navigation improvements, such as the Bonneville Dam lock and Huron Harbor.

Although more limited, experience with recreation facilities associated with Federal reservoirs indicates likewise that such facilities used primarily by local residents, if built by the Federal Government can best be operated by local or State agencies which most closely represent the interests of those making predominant use of the facilities. State operation of recreational facilities on Federal reservoirs in the Tennessee Valley and on the Tygart and Tionesta reservoirs in the Ohio Valley are examples. Where recreation interests and use importantly involve several States or the Nation, however, as in the case of the Lake Mead National Recreation area, or where the facilities are logically a part of other Federal recreational facilities, as in national parks, operation and maintenance should be by the Federal Government.

In order to make the most effective utilization of water power and in order to achieve the maximum power benefits from a water resource development it is highly desirable that power plants and transmission line systems be interconnected and operated so as to realize the maximum capacity and energy capabilities when integrated in the load of the market area in which the project is located. The marketing and generation of power from the Government's Shasta, Bonneville, and Grand Coulee projects, are examples of such integration.

IV. The Specific Lessons Learned

Listed below are a few of the important lessons and conclusions resulting from a review of constructed projects:

Over-All Conclusions as to Development

Basin.—In developing the country's water resources, major river basins should be studied and treated as a whole so that to the greatest extent possible optimum re-

sults, consistent with economic aspects, may be realized. Only by basin-wide treatment can assurance be had against the construction of projects which do not fulfill all of the purposes which may be desirable or projects which may be incorrectly located or be otherwise inadequate, in size or type, to meet the needs of the area.

A basin-wide plan, based on adequate basic data and study, will minimize conflicts and will afford the oppor-

tunity to show the relationship between projects and permit the selection of projects to be built in the most desirable sequence. In the preparation and execution of such a plan regional and local needs should be given careful consideration beginning at the field level and should be satisfied insofar as consistent with the national needs. The plan, while taking into account all reasonable future needs, should be based primarily on present and immediately foreseeable requirements.

Planning for basin developments should be predicated on (a) flexible over-all plans which are adaptable to changing conditions, (b) realistic determination of appropriate stages for refining the plan and developing units in it, (c) recognition of the data needed in the different stages and establishing programs for accumulating the data.

Improvements in the basin which are economically justified in their own right, definitely needed, and which will not interfere with other worth-while projects should go forward. When they have an important bearing on or are related to other water resources developments, they should be incorporated in the basin-wide development plan.

Whenever feasible and economically justified, multiple-purpose projects should be constructed when the purposes to be served can be developed at less cost than by separate single-purpose projects and when it is found to be desirable and in the public interest.

Planning and design of projects.—First of all, in planning water-development projects to fit into the basin plan, the need for each project must be established. The mere fact that a project is physically feasible is not sufficient. Once the need has been determined the type of project to be constructed must be selected, and then its scope of magnitude must be fixed. This will be influenced by its position in the basin plan and by economic considerations. It should not be overbuilt or underbuilt.

In the formulation of plans for a project in the basin plan, adequate basic data are essential if success is to be achieved. Some of the data required is of the long-term variety, such, for example, as hydrology. Also, of great importance in project planning is a determination of the method of operating the project. Design must consider fully the operating requirements, otherwise the finished project will be at least less useful.

The probable effect of existing related developments and the need, type, and scope of such developments as do not exist should be considered.

The fullest cooperation should be practiced between Federal agencies and with State and local agencies, as well as with private concerns and interests, beginning at the field level, and extending through all reviewing authorities.

Lastly, and of controlling importance, is the matter of project justification. The estimated benefits to be derived should exceed the cost of the project, else it should not be constructed. Also, there should be a comparison of the project with any known alternatives to ascertain the possibility of their adoption.

Operation of projects.—Those engaged in operating projects should be fully informed concerning the background of the planning and design stages, particularly in the case of a planned integrated operation of projects in a system. There should be a continuous collection of

hydrologic and other data essential to the proper operation of the projects. A specially devised system of forecasting meteorological conditions to which the area is subject should be provided to aid in water control operations.

Local Cooperation

The interest of the State and local groups has an important part to play in the development of a project, and in its success. Unless the people support a program or project, it cannot be of maximum benefit. There should be a demand for the project. In the planning stage all of the local people, and especially the local newspapers, should have detailed information regarding the plans proposed and how they will affect the interests of the individual, both beneficially and adversely. Often projects and programs can be developed only with the support and interest of the people or the States.

Cooperation With States and Local Agencies

In order to develop greater local interest, and to increase the real value of projects as a part of the local economy, it appears desirable to provide for greater State and local participation in the planning of projects. Many States have agencies authorized to plan the development of water resources. Some State agencies have plans at present for the fuller realization of benefits from these resources. These States would welcome the opportunity of cooperating, and the resulting projects or programs would have the more active support of the State and local groups, and thus would be of greater value and produce greater benefits through such support.

It, therefore, appears desirable to foster such cooperation between the Federal agencies and States, through them individually and through State compacts where appropriate.

Beneficiaries and Cost Allocations

All direct beneficiaries of a project should return to the Federal Government an appropriate share of the costs. Thought should also be given to some types of secondary benefits, in order that costs may be shared in some ratio to benefits received. The Miami Conservancy District illustrates a method of assessing charges.

Many definite beneficiaries are not required to reimburse the Federal Government, even though the benefits are real and acknowledged. The chambers of commerce, the utilities such as the railroads and power companies, and the contractors are the primary ones who urge developments, such as irrigation or drainage projects. Persons other than farmers receive direct benefits from the water development, but pay no part except through general taxation. As another example, in the New Haven navigation project, waste material from excavation saved the Highway Department \$1 million in costs of highway location, by use of dirt for fill; but the State made no contribution for this direct saving.

The States as a Vehicle for Collecting Costs

The negotiation of contracts with States, to provide for collections which cannot be made in full from direct beneficiaries, should receive consideration as a prerequisite

federal investment in a water resource development. The contracts should cover the total of the project costs which equitably should be carried by all benefited groups in the State. The distribution of cost and the collection should be the responsibility of the State.

Some States have agencies enabled to respond in part to negotiations. The California State Water Resources Board is empowered to underwrite the local contribution required under the terms of the Federal Flood Control Act. In many States, however, some agency or officer should have to be empowered to represent the State, through proper legislation.

Such a policy would immediately stimulate the greater interest and responsibility of the States in water resource development which experience has indicated to be desirable. That interest would be continuous and active through the initiation of studies through the whole life of the project. Such a policy also would provide a means of obtaining appropriate returns from indirect local and State beneficiaries which it is difficult if not impossible for the Federal Government to secure by direct arrangements with groups involved.

Some projects or services for collection would be made to include irrigation, flood control, navigation, watershed management, recreation, pollution abatement, and fish and wildlife. Present methods of collecting costs for power for municipal water supplies should be retained. In instances where benefits of a development involved more than one State, an equitable distribution of cost among States and agreements with all States affected would be required.

Consider Areas Contiguous to Project

In any study of a land or water resource development program for an area, consideration should be given to all contiguous areas, and the plans and program integrated to provide the best use of the combined area to provide the maximum over-all benefits. In many irrigation areas, the available land may well serve as a supplement to the adjoining range land. Often the value of the range land is greatly increased by even a small amount of irrigated land. The Belle Fourche project in South Dakota is an example of a project that has enhanced the economy of adjoining grazing lands. In the Bartholomew-Tensas Basin, in Arkansas and Louisiana, the discharge from one drainage canal flooded the land below, which was endangered by the discharge from the area above.

Assistance to States and Individuals

Each Federal agency with responsibilities for the development and protection of land and water resources should be specifically empowered to cooperate with States, local agencies, or individuals, to give advice and counsel in the design, construction, and operation of works and programs, in line with such agencies' responsibilities. No Federal funds should be expended either directly or indirectly in assisting in such development or program without the approval of such agency as to the adequacy of the plans and programs and assurance that the proposed methods or practices are consistent with an accepted basin plan. If those responsible for the work had had adequate assistance, many non-Federal irrigation and drainage projects

would be in a much sounder condition, had compliance with such advice been mandatory.

Agency Cooperation

Cooperation among the agencies interested in water development has in general been excellent at the field level. A few cases of lack of cooperation have resulted from inadequate appropriations, or inadequate coordination within an agency.

Each agency should be alert to take necessary steps so that it is in a position to participate both as regards personnel and funds in planning and construction activities within its sphere.

Uniform Authorization Procedure

It appears both necessary and desirable to have uniformity among all Federal agencies in authorization procedures. Each agency operates under different legislation and under different procedures in obtaining authorization, even when comparable functions are involved. Projects involving different functions in a basin plan are considered by separate congressional committees. Thus, separate elements in a basin plan may not receive uniform consideration, and programs may not be authorized as a unit nor projects be constructed with a maximum of integration.

Basin plans are worthy of coordinated consideration. It, therefore, appears desirable that arrangements be made to proceed legislatively in the most effective and practical manner with uniform authorization.

Uniform Policy Throughout Different Agencies

The objectives of each phase of water resource development should be clearly set forth in statements of policy, together with a clear statement of the responsibility of each agency in accomplishing the objectives. At present, agencies in two or more departments have programs which have different and sometimes conflicting procedures. For example, there are various methods of selling power from federally constructed dams. It seems that a single power policy should be applicable to all Federal agencies. Some of the existing differences are listed below:

(a) At the Saint Marys River project, Michigan, the Secretary of the Army sells power and any excess water under such terms and conditions as he may determine.

(b) At Hoover Dam the purchasers pay a rental for water and the head created by the dam. The purchasers own the generators and transmit the electricity through their own facilities. The Secretary of the Interior administers the sales at contract rates negotiated prior to the construction of the dam. The rates are subject to the jurisdiction of the Secretary of the Interior under the provisions of the Boulder Canyon Act.

(c) At the Marmet, London, and Winfield Federal navigation dams on the Kanawha River, W. Va., power plants were constructed and operated by a private utility under Federal Power Commission licenses. The licensee pays annual charges for recompensing the United States for the use of these Government dams and for the occupancy of lands of the United States adjoining the dams. The rates for the sale of power are subject to regulation by the State regulatory commission.

(d) Tennessee Valley Authority generates power at its own hydroelectric and steam-electric power plants and

sells directly to municipalities, industrial concerns and to Federal agencies. TVA transmits power by its own transmission lines to substations of the industries and public bodies. The latter distributes the power to smaller consumers.

(e) In the Columbia River Basin in Oregon, Washington, and Idaho, the Bonneville Power Administration markets the power from Bonneville Dam and Grand Coulee Dam. The Administrator is responsible to the Secretary of the Interior. Preference is given in the sale of power to public bodies and cooperatives, although large amounts are sold directly to industries and power companies. Government transmission lines, built by Bonneville Power Administration, feeds power into the Northwest power pool, which connects most of the main public and private power plants of the Northwest. The Bonneville Act provides for initial but not continuing approval of the power rates by the Federal Power Commission.

(f) The 1944 Flood Control Act provides that all water power generated at multiple-purpose dams, constructed by the Corps of Engineers, shall be marketed by the Department of the Interior at rates initially approved by the Federal Power Commission. Preference is given to public bodies and cooperatives. Most of the power has been sold at the dam and transmitted over agency and private power company transmission lines.

(g) The power from the Fort Peck Dam, constructed by the Corps of Engineers, is sold by the Bureau of Reclamation at rates approved initially by the Federal Power Commission. Transmission lines are built and operated by the Bureau.

(h) Power generated at irrigation dams is marketed by the Bureau of Reclamation. Power is transmitted to market by transmission lines constructed by that agency, and rates are set by the Secretary of the Interior.

(i) The rates charged for retail sales and for interstate sales of power generated at licensed privately owned hydroelectric plants are subject to regulation by State commissions and in the absence of State commissions such rates are subject to complete regulation by the Federal Power Commission.

(j) The interstate wholesale rates charged by privately owned utilities for energy are subject to regulation by the Federal Power Commission.

Uniform Interest Rates

The rate of interest used for determining costs, payment obligations and benefits of Federal water resource developments should be the same for all types of developments and should be established at a uniform rate for all agencies and generally at the prevailing cost of long-term money to the Government. Existing laws and policies regarding interest rate vary, among agencies, uses, and areas. For example, in estimating annual costs on flood control and navigation projects to compare with estimated average annual benefits, an interest rate of 3 percent is used by the Corps of Engineers on the Federal portion of the costs and 3½ percent on the portion contributed by local interests.

The Department of Agriculture uses 2 percent for the Federal costs and 4 percent for local portions of the costs. The Department of the Interior uses 2½ percent. The Tennessee Valley Authority uses 2 percent.

In establishing power rates, the Department of the Interior uses an interest rate of 2½ percent on projects constructed by the Corps of Engineers; but interest at 3 percent is used in establishing rates for power from projects constructed under Reclamation law. A rate of 2 percent has been applied currently by the Secretary of the Interior in the case of costs to be returned for municipal water supplies provided from reclamation reservoirs. Conflicts will be avoided, costs and benefits truly evaluated and payment obligations fairly established by adoption of a uniform rate of interest.

Bases for Economic Studies

A uniform policy for all agencies to use in computing economic costs and benefits should be determined. The period of time used in pay out and other economic studies has an important bearing in determining the estimated annual cost to compare with the estimated average annual benefits. Some agencies have assumed 100 years or the useful life of the project, whichever is shorter, as the economic life, while others use only 50 years. Also, some agencies use current price levels as the measure of expected future levels, while other agencies use other bases as the measure of expected future price levels.

Priority in Land Development

In the development of irrigation and drainage lands, priority should be given, when economically justified, to the further improvement of those units which are now in operation. Many small irrigated areas, such as those in Utah, require repaired structures, additional reservoirs, or new ditches. In an existing local economy, with communities, roads, schools, and other services already provided, limited public funds may give greater additional results than if used elsewhere. Construction of new projects which fit into an existing economy should be given high priority. Throughout the West a great number of such projects are possible and would strengthen the existing economy.

Land and Water Relations

Both land and water are limited resources. Although water has uses apart from the land, the land has few uses in which water is not an important factor. The following thoughts concerning the land and water relationship were suggested by projects considered and appear desirable, provided the benefits exceed the costs in each case:

(a) In authorizing, allocating funds for, in the management of, and in the development of lands, first measures should be those that protect the soil and water values. The Angeles National Forest was created for this purpose only and its administration pointed to that end.

(b) Land management problems cannot be solved readily on a basin-wide basis where varied forms of land ownership, management, and public administration exist without coordination. In the Middle Rio Grande Valley there are some 26 types of public land administration agencies and the problem of obtaining coordinated action in conservation measures is critical. Legislation is needed to harmonize conflicting Federal land management practices.

(c) Public ownership, Federal or State, is indicated as necessary for lands which are unsuited to private ownership. Large areas of arid lands are so unproductive that they are an asset neither to the Nation nor the owner, as presently managed.

(d) In any Federal land purchase program for watershed purposes attention should be directed to the acquisition of areas that are actual and potential sources of erosion and flood runoff, as a means of delaying runoff and decreasing sedimentation.

(e) In any watershed treatment program hydrologic classification of lands should be made a part of soil surveys to determine soil condition and use in relation to the water resource. This would form a basis for selecting problem areas, conducting various restoration activities on such areas, extending Federal aid, and cooperating with non-Federal interests.

(f) Programs and activities directed primarily to increased crop, forage, or timber production or developing area facilities for such use generally, should be based on minimum standards essential to improve and maintain those soil and cover conditions which are favorable to optimum water relations.

Encourage Small Water Developments in Grazing Areas

Programs of agencies administering grazing lands should be provided every encouragement to enable them to construct small water development projects, such as that constructed near Alzada, Mont., to stabilize the grazing industry and prevent soil erosion. The Alzada project, at a total cost of \$3,300, constructed contour dikes and provided for spreading water from an earth dam to irrigate a portion of the area. The forage increased from 120 animal months to 420 annually.

Federal Land Acquisition

Federal and State acquisition of land for all purposes should be made consistent with basin plans for development of land and water resources. Public policies and legislation as to land acquisition should recognize and have as its major objective the protection and use of land and water resources. Many industrial sites and airfields are located on the best irrigated land, taking such lands out of the agricultural economy. During the war many army camps, supply depots, and flying fields were located in the best irrigated areas as around Salt Lake City and Ogden, Utah. Highways often cross through the centers of small irrigated areas leaving fields too small or in poor shape for cultivation. This emphasizes the need for adequate land use studies indicating lands that should be devoted to agriculture, and to other purposes, and areas where other particular uses could be developed.

Underground Water Law

Future irrigation projects involving the use of ground water supply should require of the State, as a condition precedent to any authorization, the enactment of an ample underground water law. In Arizona, pumping from underground storage has seriously affected the operation and success of the San Carlos project of the Indian Service. This project is in need of "rescue" on account of

heavy pumping to lands outside of the district boundaries. The situation is also serious in parts of Central Valley, Calif.

Adverse Local Pressures

Local pressures often have prevented the full realization of the possible economic benefits of a site or project to be developed by the Federal Government. In the case of water pollution, particularly, local pressures interfere with remedial measures. Coal mining interests, for example, have used various means to forestall the installation of power facilities in multiple-purpose dams on the tributaries of the Ohio River. They have also in many cases hindered progress in eliminating acid mine waste from the tributary waters, reaching the Ohio River. This situation is worthy of serious consideration because of its possible effects on the national interest in the full development of the potentialities of the regional water resources, and the protection of health.

Assurance of Maintenance

When projects are developed for use by local interest and turned over to the local interests for operation and maintenance, some positive method should be found to assure the protection of the public investment. Recreation areas within the national forest and around reservoir projects frequently have no permanent provision for maintenance; the Federal agency lacks funds, and the local agencies may lack interest or incentive. Many such projects have lost their value due to lack of repairs, or ability of the cooperating agency to properly maintain them.

Zoning

It appears desirable, where appropriate and feasible, to have zoning ordinances as a prerequisite to development. Without zoning supported by local interest, many benefits from construction are nullified. The increased urban growth upon the debris cones and even in the erosion channels in the Los Angeles area has complicated the removal of debris and the development of remedial measures. In the Rio Grande area sound remedial measures to control the continued siltation will require adequate protection to the drainage area against overgrazing.

Zoning for some type of restricted use may be practicable in some circumstances. The construction or administering agency, during the course of development, can well afford to encourage local protection through police power regulation. The opportunities for coordinated actions by local, State, and Federal agencies through local districts may thus be enhanced by the responsible Federal agency.

Research in New Programs

In new types of endeavors, adequate research and experimental operations under actual field conditions should be the prerequisite of action programs. Research should be adequately financed so that conclusive criteria are established to assure adequate construction or remedial measures. Significant savings are often possible, through research. For example, when the work of sealing aban-

A P P E N D I X

5

**Data Prepared by Committee on Domestic
Water Navigation Projects and National
Transportation Policy**

Committee on Domestic Water Navigation Projects and National Transportation Policy

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The information contained in this appendix has been selected from more comprehensive data prepared by the Commission's Committee on Domestic Water Navigation Projects and National Transportation Policy as exhibits to its report.

No. I summarizes data for 15 principal waterways and analyzes the data to determine their economic justification.

No. II is a selection of a few of many examples of industrial enterprises that find it convenient and profitable to use water transportation. Some of them attribute a large part of their growth and success to this water service.

No. III presents a brief but significant discussion of inland water transportation policy since the early days of the Nation, the conflicts that have arisen with respect to extending water navigation, and the manner in which Congress, from time to time, has modified or strengthened the original policy.

Tables 4 and 5 summarize briefly and indicate sharply shifts in uses of transportation facilities in response to changing economic conditions and the ability of each form of transportation to meet special needs of shippers. Space has not permitted presentation of data covering water-borne traffic on all of the waterways in use. Tables 6, 7, and 8, however, are typical of the larger developments. Here data are presented, by commodities, to permit comparison of charges by rail and water, and indicate savings for these commodities when waterway facilities are used.

I. Brief Analysis of the Federal Inland Waterway Program

1. The Federal river and harbor program, which includes improvements of inland waterways, has been in effect since 1824, when Congress passed the first appropriation act for improvement of rivers and harbors. The total costs of this program to the Federal Government from this beginning until June 30, 1948, as set forth in the annual report of the Corps of Engineers for fiscal year 1948, may be summarized as follows:

Seacoast harbors and channels.....	\$1, 275, 642, 000
Great Lakes harbors and channels.....	363, 479, 000
Inland and intracoastal waterways.....	1, 789, 991, 000
Total	3, 429, 112, 000

The total cost for inland and intracoastal waterways of \$1,789,991,000 includes \$1,184,093,000 for new work (construction), and \$605,898,000 for maintenance and operation. This cost for inland waterways does not include improvements in the lower reaches of rivers, such as the Mississippi below Baton Rouge and the Delaware River to Philadelphia, which are for seagoing traffic and are included as coastal harbors and channels.

2. In this paper an effort has been made to present a concise and factual summary and analysis of the Federal inland waterway program. To this end 15 projects have been selected and analyzed. The results are summarized in table 1. The 20-year period ending June 30, 1948, has been selected for this analysis in order to make use of cost figures given in the latest published report of the Corps of Engineers, and because 1948 is the latest year for which complete waterway traffic records are available. Records of waterborne cargo movements prior to 1929 are fragmentary and unsatisfactory as a basis for computing savings, which precluded analysis of a longer period.

3. The selected waterways constitute the great bulk of the inland waterway program as indicated by the following comparisons:

TABLE 1.—Comparison of traffic and Federal cost of selected waterways

	15 waterways	All other waterways	Total
Total Federal costs:			
In dollars.....	1, 411, 362, 000	378, 629, 000	1, 789, 991, 000
Percent of total.....	79	21	100
Waterway traffic:			
Cargo in thousands of ton-miles 1948.....	29, 195, 000	7, 268, 000	36, 463, 000
Percent of total.....	80	20	100

4. The only major active waterways not analyzed include the Tennessee River which was omitted because of its interrelationship with the Tennessee Valley Authority; and the Atlantic Intracoastal Waterway which was omitted because of its use and value for recreational boating which could not be reflected in a commercial traffic analysis. The other waterways not analyzed are small feeder channels of less than 9-foot depth, or natural river channels kept open for light draft traffic by occasional snagging and clearing operations. While these small improvements constitute the greater length of navigable channels they carry very little commercial cargo and have represented relatively small part of the Federal expenditure for inland waterways.

5. The total Federal costs for the group of 15 waterways have been as follows:

New work (construction):	
Original projects (superseded).....	\$96, 471, 000
Existing projects.....	870, 379, 000
Total	966, 850, 000
Maintenance and operation:	
Prior to fiscal year 1929.....	113, 463, 000
From 1929 to 1948, inclusive.....	331, 049, 000
Total	444, 512, 000
Total Federal cost (except interest)	1, 411, 362, 000

Annual charges.—For purposes of comparison with annual benefits the costs of the 15 waterways have been expressed in terms of total annual charges for each year, including maintenance and operation and interest and amortization. Interest and amortization has been computed using an interest rate of 3 percent and a 50-year economic life, and applying them to costs as they build up during the 20-year period, beginning with costs unamortized at the start of the period. These annual charges are summarized in table 1.

6. *Categories of projects.*—The 15 selected waterways fall generally into 4 categories:

(a) On certain waterways, exemplified by the lower Mississippi, Ohio, Monongahela, and Warrior, traffic has developed prior to the 20-year period under consideration, and has continued at a reasonably high level or has grown steadily. These projects show a substantial economic return to the Nation on all Federal funds expended.

It is considered that they represent what may be expected from soundly conceived and well-operated waterway improvements.

(b) Waterways such as the Illinois and the upper Mississippi are examples of waterways which have been started and placed in operation during the period under consideration. Traffic has developed slowly under certain difficulties, but is now in excess of commerce anticipated when the projects were authorized, and the waterways are producing benefits far in excess of costs.

(c) The Missouri and Columbia River projects represent a still earlier stage in the development of major navigation improvements. Both of these waterways are integral parts of comprehensive plans of water resources development for their respective basins, and works for navigation also serve other water resources purposes. In both cases project dimensions have not yet been obtained and only a small part of anticipated waterborne commerce has had an opportunity to develop. It is believed that traffic and navigation benefits on these waterways will develop as anticipated, as they have done on other similar improvements.

(d) The Ouachita River improvement in its present state is an example of those inland navigation projects which, due to changing economic conditions or other reasons, have failed to develop or maintain anticipated waterborne commerce. Such uneconomic projects represent less than 10 percent of the cost of the total inland waterway program to June 30, 1948; and the Corps of Engineers expends only minimum amounts for caretaking and maintenance for those waterways.

7. *Traffic.*—(a) *Volume.*—Data on waterborne commerce on the 15 major waterways, expressed in short tons and ton-miles, have been compiled from the annual reports of the Corps of Engineers for the 20-year period, 1929–48 inclusive, insofar as records are available in comparable form. During the earlier years of this period it has been necessary to omit traffic figures for certain waterways to avoid duplications inherent in the earlier records, which broke down traffic by short reaches of river. In most cases records cover the entire 20-year period, while for others the records vary from 12 to 15 years. The cargo traffic on the 15 selected waterways, compared with the total inland waterway traffic reported for the period, is as follows:

Cargo traffic in thousands of ton-miles:

Total for period:	
15 waterways.....	244, 200, 000
All other waterways.....	93, 800, 000
Total	338, 000, 000
Current, 1948:	
15 waterways.....	29, 195, 000
All other waterways.....	7, 268, 000
Total	36, 463, 000
Average annual:	
15 waterways.....	12, 210, 000
All other waterways.....	4, 690, 000
Total	16, 900, 000

(b) A significant survey of commodity movements would involve a breakdown by ton-miles; space permits

reference to only a few representative cases. For instance, sand and gravel accounted for 14 percent of the total moved during the period, according to the best estimate that could be made. The ton-mileage, however, of this essential short-haul commodity constituted only about 1 percent of the total ton-mile cargo movement on the 15 waterways during the 20-year period. On the other hand the movement of petroleum products accounted for about 21 percent of the barge-borne tonnage, but constituted 52 percent of the ton-mileage. Similarly, manufactured iron and steel products represented only 3.5 percent of the tonnage, but accounted for over 8.5 percent of the total ton-mileage on these waterways.

8. *Transportation Benefits.*—(a) *Method of Analysis.*—In order to obtain a reasonable estimate of transportation savings which obtained on the 15 waterways during the 20-year period, analysis was made of the principal commodities conveyed and of representative cargo movements, as well as of rail rates and waterway costs applicable to such commodities and movements. Fluctuations in rail and truck rate levels and in barge- and pipe-line service cost levels during the period under analysis were established from the comprehensive files of the Board of Engineers for Rivers and Harbors; and the difference between the water transportation charges and those that would have applied by the cheapest alternative means were developed as unit savings per ton-mile of water route. Full barge line service costs plus reasonable profit were used for comparison in place of common carrier tariff rates because the great preponderance of the barge-borne freight is known to have moved by contract and industry-owned carrier services. The unit savings thus derived were applied to the estimated ton-mileages of the various commodities for each of the selected waterways for each year of the period, and the results are given as annual transportation savings in summary form in table 1. In view of the time requirements, it was not attempted to establish the average length of haul of each of the principal commodity movements by actual computation, but such averages were estimated in accordance with the knowledge and judgment of the Board's experienced staff of water transportation analysts.

The estimates of savings differ from various published analyses of waterway transportation principally in the use of normal competitive rates for comparison, rather than rates already depressed to meet waterway competition, as giving a truer measure of savings to the public. This study involved analysis of more than 800 normal and "water-compelled" rates on representative movements throughout the period. Every effort was made to present a fair and conservative estimate of savings. Rafted freight, for example, was disregarded in computing savings, as deriving no benefit from channel improvements; and water movements believed to originate or terminate at off-river points were penalized for circuitry and by including ample charges for the extra terminal handling and switching required. A detailed study to obtain the exact savings which have resulted from these waterways would require much more time than has been available for this analysis, and would be very difficult because of lack of detailed and comparable records for the early years. It is believed, however, that this analysis, though concededly approximate in nature, gives a fair general picture of the economic value of the waterway program.

(b) *Savings*.—As indicated in table 1, there has been a considerable variation in unit savings per ton-mile between the various waterways, ranging from 4.6 mills per ton-mile for the Illinois waterway which results largely from the movement of coal, to 19.5 mills per ton-mile on the Sacramento River, where petroleum products constitute the largest item in the tonnage movement. Average unit savings are shown in table 1 only to indicate the magnitude of unit savings in a general way. They are composite figures based on many specific cargo movements. The average annual savings shown, however, are a good index of the value of each of the waterways.

9. *Comparison of Benefits and Costs*.—Examination of table 1 will show that for 10 of the 15 waterways the average annual benefits for the 20-year period have definitely exceeded average annual charges. On two of the waterways developing traffic has resulted in average benefit-cost ratios for the period of slightly less than unity; but traffic is increasing and the benefit-cost ratios for the year 1948 are above unity. On two waterways, the Missouri and Columbia, a definite benefit-cost ratio based only on present navigation savings would be meaningless as these waterways are now under construction and traffic has not yet developed, and they are parts of comprehensive plans for water resources development. Only one of the selected waterways shows a definitely unfavorable benefit-cost ratio for the average of the 20-year period and for 1948, the latest year of record. As a matter of general interest it may be noted that total savings for the group of 15 waterways, when compared with total costs for the group including costs of the incomplete waterways, show a benefit cost ratio of 2.5 for the group as a whole for the 20-year period, and a comparison of savings and charges for the group for the year 1948 shows a benefit-cost ratio of 3.8 for that year.

10. *Summary*.—The economic value of the entire inland waterway program from its beginning to date may be shown briefly as follows:

(a) The total Federal economic cost of the entire inland waterway program since its inception in 1824, including all projects now abandoned or superseded, has been:

New work:	
15 major waterways.....	\$966, 850, 000
All other waterways.....	217, 243, 000
Total.....	1, 184, 093, 000
Maintenance and operation:	
15 major waterways.....	444, 512, 000
All other waterways.....	161, 386, 000
Total.....	605, 898, 000
Interest: Assuming a 3 percent rate and applying to costs as they built up over the period since 1824, approximately...	600, 000, 000
Grand total.....	2, 389, 991, 000

(b) During the 20-year period ending June 30, 1948, the annual cargo traffic reported for inland waterways has increased from 7.2 billion to 36.5 billion ton-miles. The cargo movement for the period has totaled 338 billion ton-miles. Transportation savings due to the inland waterways as described previously in this study, have

ranged from 4.6 mills to 19.5 mills per ton-mile and have averaged 6 mills per ton-mile for the 15 waterways which now carry about 80 percent of the traffic. This average unit saving applied to the total cargo movement shows a total saving during the 20-year period of \$2,028,000,000. In other words 81 percent of the entire economic cost of the Federal inland waterway program which cost has accrued since 1824, has been returned by savings produced in the 20-year period 1929-48.

(c) The foregoing summary ignores the substantial transportation savings produced prior to 1929 because of lack of comparable traffic records. If these earlier savings could be identified it is obvious that a still larger part of the present economic cost would be covered.

(d) If Federal expenditures for inland waterways and commerce on the waterways continue substantially at present levels it is estimated that in 4 years after fiscal year 1948 or by the end of fiscal year 1952, the total Federal economic cost of the waterway program since 1824 will have been fully covered by transportation savings produced in 24 years. At that time the individual projects will have many years of useful life in prospect.

11. The federally improved inland waterways comprise an important element in the basic transportation structure of the Nation. They supplement other forms of transportation and are not a substitute for the rails, highways, and pipe lines for freight movement. The waterways, however, do provide a unique means of transportation and are able to handle certain commodities and movements which are not practicable on other transportation media. Federal activity in waterway improvements, as indicated by this study, has been largely concentrated on a relatively few major waterways which carry the bulk of waterborne commerce. The value of these waterways is indicated by the steady growth of water-borne commerce, which has taken place when adequate inland navigation facilities have been provided; and by the substantial savings to shippers and receivers of cargo which have accrued from use of these waterways. In addition to the purely commercial value of the inland waterway system there are noncommercial values which are not revealed by an analysis based on freight movements. For example, it is not practicable to place a monetary value on use of the inland waterways during World War II for military and defense purposes.

Inland Waterways in World War II

Inland waterway transportation during World War II was of the utmost importance to this Nation and contributed vitally to the ultimate victory of the United States and its Allies. Strategic commodities were moved efficiently and safely over the inland waterways, seagoing vessels were floated to the sea from inland shipyards, and new war industries were established in the interior near water transportation. During this period traffic on the inland and intracoastal waterways continued to grow and each year of the full war effort a new record in ton-miles of barge-borne freight was set.

Millions of tons of petroleum products were transported on the inland waterways by tank barges during the war period. This helped to make up for the loss in petroleum shipments caused by the sinking of coastwise tankers and the transfer of vessels to naval service. The water move-

ments of this vital commodity made by the barge lines in conjunction with pipelines, tank cars, and tank trucks, brought about one of the most efficient coordinations of transportation facilities ever seen in this country. The result was that industrial plants on the eastern seaboard as well as in the Middle West were able to continue to operate at full capacity, people in frigid areas were able to keep warm, and combat training planes were kept flying. From December 1941 through August 15, 1945, the incredible total of 1,731,030,485 barrels of petroleum and petroleum products was loaded at inland waterway ports. A 10,000-gallon railroad tank car holds the equivalent of 238 barrels of petroleum products, so this gigantic figure is the equivalent of more than 7 million tank car loads, representing 72,732 trains of 100 cars each. These figures indicate the considerable extent that inland waterway transportation helped to alleviate the situation that had resulted from the wartime overburdening of the railroads. To quote a statement of the Office of Defense Transportation: "If our waterways rendered no service beyond that of transporting petroleum and its products during the war they would have amply justified their improved existence."

In addition to petroleum products, the inland waterways moved a large volume of many other essential war materials—sulfur, coal, iron and steel products, grain, bauxite, scrap iron and steel, chemicals, alcohol, and acids. All of these commodities were required for total war production and without inland waterway transportation for them many industries vital to the war effort could not have operated efficiently.

The inland waterway transportation industry's success in the floating of war vessels from inland shipyards to the sea was a remarkable wartime achievement. It had been found imperative, because coastal yards and docks were operating to fullest capacity, to turn to the interior of the country to meet the shipbuilding requirements of the war effort. More complete utilization of the manpower and production facilities of the Great Lakes area and the Mississippi and Ohio Valleys was made possible by the existence of improved navigable waterways. New as well as available shipyards and drydocks were put in operation on nearly all inland waterways, and many types of oceangoing vessels as well as light-draft craft were built in the interior. More than 4,000 vessels were completed, over 1,500 on the Mississippi River alone, nearly 900 on the Ohio River, and nearly 1,000 on Great Lakes points, moved via the Illinois River to the sea. Of this total there were many types—torpedo tenders, coastal transports, auxiliary repair ships, destroyer escorts, barges, oceangoing cargo ships, Coast Guard cutters, infantry and tank landing craft, subchasers, tugs, submarines, and others including structural ship sections. All of these war vessels were safely and efficiently handled to deep water over the inland waterways system. Many of them, due to their drafts, had to be pontooned or otherwise floated and towed to the sea. No other type of transportation could have accomplished the feat of delivering all these vessels to deep water.

America's rivers and canals made possible through the years a widespread geographical diffusion of manufacturing processes that otherwise would have been forced into congested coastal areas. It is a significant fact that, according to the 1940 census, the 19 largest cities of the United States are all located on navigable waterways. As a result, many of the principal production centers of the war period were situated in the interior of the country and were served by water transportation—Chicago, Detroit, Cleveland, Pittsburgh, St. Louis, and Minneapolis, to name a few. Many industries that supply or use bulk commodities owe their development in a substantial degree to low-cost inland waterway transportation facilities.

Certain waterways contributed more than others to the war effort. In general, the long-haul waterways showed the greatest wartime traffic gains. During the war period, the total annual ton-mileage more than doubled the record peacetime movement on the Mississippi, Ohio, and Illinois Rivers, waterways that connect such large metropolitan centers as New Orleans, St. Louis, Minneapolis, Chicago, Pittsburgh, and others. The Gulf Intracoastal Waterway, southern supporting link of the inland waterway system, was extremely valuable in the transportation of strategic commodities, particularly of crude and refined petroleum, and in 1944 carried five times as much freight as in 1939. Another outstanding contribution was made by the Atlantic Intracoastal Waterway extending from Trenton, N. J., to Miami, Fla., which provided a sheltered route for more than a billion ton-miles of traffic in 1942 and 1943, the peak years of submarine warfare, or twice the amount carried in the years immediately preceding the war.

In the Ohio Valley are to be found the basic materials of this country's industrial economy, notably coal and steel, materials that are also essential to defense and the prosecution of a war. These vital commodities were handled in vast quantities on the Ohio River and the tributary Monongahela River. Petroleum and other products also moved in large quantities on the Ohio River and its tributaries, traffic on the Ohio reaching a total of over 7 billion ton-miles in 1944, an all-time high for that river. Grain barges on the Mississippi and Missouri Rivers and the Illinois waterway were constantly on the move, with wheat and corn and other grains out of the Dakotas, Kansas, Iowa, and the rest of the Midwest farm States. The wartime peak for all traffic on the Illinois waterway was more than a billion ton-miles.

The service rendered by inland waterway transportation during World War II demonstrated conclusively that it is a vital instrument of national defense. Its performance in contributing toward the winning of the war more than justified the confidence of Congress in the Corps of Engineers' waterway improvement program prosecuted for and sponsored by the people, and more than repaid the Federal Government for all of the expenditures of public funds for that program.

TABLE 2.—Summary and analysis of 15 major inland waterway projects for 20-year period, fiscal year 1929 through fiscal year 1948

Name of project	Length, miles	New work costs				Maintenance and operation costs			Total Federal costs
		Original project	Existing project	Total	Unamortized at end of fiscal year 1948	Prior to fiscal year 1929	From fiscal year 1929 through fiscal year 1948	Total	
Lower Mississippi River.....	736	\$0	\$179,936,000	\$179,936,000	\$162,393,000	\$25,204,000	\$64,375,000	\$89,579,000	\$269,515,000
Middle Mississippi River.....	195	1,495,000	46,866,000	48,361,000	37,789,000	15,193,000	20,413,000	35,606,000	83,967,000
Upper Mississippi River.....	663	49,694,000	153,322,000	203,016,000	138,888,000	7,516,000	36,090,000	43,606,000	246,622,000
Ohio River.....	981	17,657,000	126,702,000	144,359,000	102,435,000	25,506,000	84,785,000	110,291,000	254,650,000
Monongahela River.....	128	5,421,000	10,756,000	16,177,000	8,712,000	14,631,000	13,391,000	28,022,000	44,199,000
Allegheny River.....	72	0	18,350,000	18,350,000	13,969,000	2,447,000	4,770,000	7,217,000	25,567,000
Illinois Waterway.....	336	551,000	28,684,000	29,235,000	25,725,000	982,000	12,162,000	13,144,000	42,379,000
Missouri River.....	762	9,847,000	173,483,000	183,330,000	155,270,000	2,822,000	44,573,000	47,395,000	230,725,000
Cumberland River.....	513	826,000	8,832,000	9,658,000	5,865,000	1,969,000	5,959,000	7,928,000	17,586,000
Warrior River System.....	472	657,000	16,493,000	17,150,000	12,229,000	5,648,000	11,217,000	16,865,000	34,015,000
Ouachita River.....	351	674,000	4,575,000	5,249,000	2,786,000	2,156,000	5,561,000	7,717,000	12,966,000
Gulf Intracoastal Waterway.....	1,387	4,627,000	37,627,000	42,254,000	35,483,000	33,367,000	16,275,000	19,642,000	61,896,000
Columbia River.....	183	542,000	41,356,000	41,898,000	37,508,000	360,000	4,107,000	4,467,000	46,365,000
Sacramento River.....	245	185,000	551,000	736,000	516,000	2,121,000	3,238,000	5,359,000	6,095,000
Kanawha River.....	91	4,295,000	22,846,000	27,141,000	20,616,000	3,541,000	41,330,000	7,674,000	34,815,000
Total.....	7,095	96,471,000	870,379,000	966,850,000	760,184,000	113,463,000	331,049,000	444,512,000	1,411,362,000

COMPARISON OF BENEFITS AND COSTS

Name of project	Average annual charges			Charges, fiscal year 1948	Average annual traffic in thousands of ton-miles	Average unit saving per ton-mile in mills	Average annual savings	Savings fiscal year 1948	Benefit-cost ratio	
	Maintenance and operation	Amortization and interest	Total						Period	Fiscal year 1948
Lower Mississippi River.....	\$3,219,000	\$4,167,000	\$7,386,000	\$13,455,000	14,370,792	5.6	\$24,635,000	\$67,979,000	3.3	5.0
Middle Mississippi River.....	1,021,000	955,000	1,976,000	2,560,000	1,536,825	5.4	2,887,000	8,620,000	1.5	3.4
Upper Mississippi River.....	1,805,000	3,433,000	5,238,000	8,295,000	1,871,612	5.2	4,569,000	11,521,000	0.9	1.4
Ohio River.....	4,239,000	4,043,000	8,282,000	10,235,000	3,681,091	4.8	17,488,000	41,827,000	2.1	4.1
Monongahela River.....	670,000	339,000	1,009,000	1,344,000	1,136,891	9.7	10,984,000	19,913,000	10.9	14.5
Allegheny River.....	239,000	471,000	710,000	871,000	41,512	11.2	466,000	946,000	0.7	1.1
Illinois Waterway.....	608,000	702,000	1,310,000	2,128,000	1,882,722	4.6	4,054,000	12,094,000	3.1	5.7
Missouri River.....	2,229,000	4,293,000	6,522,000	11,456,000	1,41,428	5.8	242,000	303,000	(¹)	(²)
Cumberland River.....	298,000	236,000	534,000	899,000	1,86,852	7.9	683,000	1,582,000	1.3	1.8
Warrior River System.....	561,000	388,000	949,000	1,271,000	319,082	5.9	1,894,000	2,471,000	2.0	1.9
Ouachita River.....	278,000	118,000	396,000	315,000	20,670	6.0	123,000	22,000	0.3	0.1
Gulf Intracoastal Waterway.....	814,000	539,000	1,353,000	4,068,000	43,309,255	7.2	23,851,000	55,270,000	17.6	13.5
Columbia River.....	205,000	725,000	930,000	2,005,000	82,206	5.0	412,000	689,000	(³)	(³)
Sacramento River.....	162,000	8,000	170,000	154,000	49,426	19.5	965,000	2,499,000	5.7	16.2
Kanawha River.....	207,000	529,000	736,000	1,026,000	173,547	5.0	876,000	1,981,000	1.2	1.9
Total.....	16,555,000	20,946,000	37,501,000	60,082,000			94,129,000	227,717,000		

¹ 14 years.

² 20 years.

³ Projects now under construction, and present traffic is no indication of economic value of waterway. See project sheets.

⁴ 12 years.

II. Examples of Industries and Communities Benefited by the Provision of Waterways

A. Ohio, Monongahela, Allegheny, Kanawha and Cumberland Rivers

PITTSBURGH, PA.

Pittsburgh, Pa., at the junction of the Monongahela and Allegheny Rivers, is the center of one of the leading steel and industrial regions of the world due largely to its tremendous advantage in navigable waterways transportation and vast reserves of coal in the contiguous area. Located at the point of origin of the long Ohio-Mississippi River transportation system, Pittsburgh enjoys a permanent advantage in transportation routes whereby large quantities of the necessary coal and other raw materials can be moved to the steel plants, and iron and steel and finished products of all kinds can be moved to destinations by low-cost water hauls.

Tonnage movements on the Monongahela River probably represent the densest river traffic in the United States. In the year 1947 there were 27,800,000 tons of coal and coke alone carried on its waters out of a total of all classes of cargo amounting to 31,700,000 tons. Tonnage on the Monongahela River increased from 6,000,000 in 1900 to a peak of 33,900,000 in 1942, of which 29,600,000 was coal and coke.

LITTLE FALLS, MONONGALIA COUNTY, W. VA.

An important expansion in the coal mining industry is taking place in the upper Monongahela River Basin due to further improvement of a navigable waterway to provide cheaper water transportation for coal in quantity. The total reserves of mineable coal within 10 miles of the river in Monongalia and Marion Counties exceeds 3,000,000,000 tons.

The Weirton Steel Co. recently has opened a new mine near Little Falls, 110 miles above the mouth of the river in the Upper Freeport coal bed for the production of metallurgical coal. The mine, cleaning plant, and other structures are situated about 2 miles from the river. The coal is transported by conveyor through a tunnel to a river terminal, thence by barge via the Monongahela and Ohio Rivers to the company's steel plant at Weirton, W. Va., a distance of about 170 river miles. Production is scheduled to be increased rapidly to 1,800,000 tons per year.

NEVILLE ISLAND, PA.

Neville Island, located in the Ohio River about 3 miles below Pittsburgh, is about 5 miles long, and from one-half to 1 mile wide. It is a highly developed industrial strip of land.

Prior to canalization of the river, Neville Island was practically all farm land. The American Steel & Wire

Co. began construction of its plant on the island almost immediately after water transportation was made available by the construction of locks and dams. By the beginning of World War I there were nine industrial organizations on the island, comprising Carnegie-Illinois Steel Co., Concrete Products Co. of America, Independent Bridge Co., Pittsburgh Demoiner Steel, Dravo Steel Corp., Vulcan-Detinning, Graham Nut & Bolt, Witherow Steel Co., and Lee Moore.

After World War I, land was bought up by the industries at prices up to \$7,700 per acre, and additional companies located on the island. These included: Foundation Co., Gulf Oil Co., Frick & Lindsay, Shenango Furnace, Air Reduction Ways Co., National Cylinder Gas, F. Mallinger Co., Marcus-Ruth-Jerome Co., and F. G. Kirkpatrick Construction Co. World War II brought a second period of expansion. The industries turned to production of needed war materials and expanded their plant facilities. Chief among these was the Dravo Corp., which during the war built 150 landing craft alone, costing \$193,000,000. All of the above craft were floated down the Ohio and Mississippi Rivers to the Gulf of Mexico for service in far parts of the world.

The Gulf Oil Co. refinery was built on Neville Island in the Ohio River, Allegheny County, Pa., in 1932. Gasoline is shipped by barge from this plant to Morgantown, W. Va., Brownsville, Pa., Donora, Pa., McKeesport, Pa., all on the Monongahela River and to points on the Ohio River as far as Parkersburg, W. Va., which is 179.5 miles downstream from the plant. This plant refines about 14,000 barrels of pipe line crude oil a day, of which a large portion of the finished product is distributed by barge on the navigable waters of the Monongahela and Ohio Rivers.

JONES LAUGHLIN STEEL CORP.—ALIQUIPPA WORKS

After slack-water navigation was established in the upper Ohio River, construction of the Aliquippa Works of the Jones & Laughlin Steel Corp. was started on the bank of the Ohio River, 26 miles below Pittsburgh. The works is now a modern integrated steel plant stretching about 3½ miles along the river front and employing about 12,000 people.

The Jones & Laughlin Aliquippa Works was one of the pioneers in the shipping of finished steel products to southern ports by river transportation as a means of cutting cost. Finished steel products are delivered by water to Cincinnati, Louisville, Memphis, New Orleans, and points on the Gulf Intercostal Canal. Development and expansion of the Aliquippa Works caused a remarkable increase in the entire company's production of steel, effected principally by its use of the navigable waterways.

DUQUESNE LIGHT CO. RIVER PLANTS

The Duquesne Light Co., which produces electric power for most of Allegheny and Beaver Counties, has made excellent use of the navigable river system in the area. Its five generating plants are located on the Allegheny and Ohio Rivers in order to avail themselves of cheap river transportation of coal and to insure adequate water supply for steam generation and cooling purposes. The sixth plant is under construction on the Monongahela River. About 60 percent of the coal used for fuel is brought to the power plants by barge shipment, amounting, in recent years, to about 1,000,000 tons annually.

WHEELING STEEL CORP., WHEELING, W. VA.

The Wheeling Steel Corp. was incorporated in 1920, about 3 years after the system of locks and wicket dams were completed on the Ohio River connecting Wheeling and Pittsburgh and the Monongahela and Allegheny Rivers slack-water navigation.

In addition to the Wheeling Mills the corporation has six other plants in the Steubenville area and several subsidiaries.

The corporation now has three twin-screw Diesel towboats handling about 2,000,000 tons of coal from their mines on the Allegheny River to their terminal at Follansbee, W. Va., for consumption in three nearby mills. Manufactured goods shipped by water consist of about 50,000 tons of formed steel and tin plate annually handled by the barge lines.

ASHLAND OIL & REFINING CO., CATLETTSBURG, KY.

The Ashland Oil & Refining Co. is an excellent example of the development of an industry through the stimulation of low-cost water transportation afforded by an improved waterway. The refining company moved from Lexington, Ky., to Catlettsburg, Ky., about 25 years ago when it was determined that a saving of 25 cents per barrel in the transportation of crude oil and refined products could be realized at the new location on the Ohio River. Starting out with 25 employees, and an investment of \$250,000, and doing a business of a few thousand dollars per year, the company has developed in the past 25 years so that in its most recent fiscal year the company did a \$100,000,000 business. The company now has 2,500 employees and is refining at Catlettsburg between 35,000 and 40,000 barrels of crude oil daily. The company has constructed a river terminal and operates a fleet of 6 towboats and 64 barges.

A large portion of the refined products move from Catlettsburg to points along the entire length of the Ohio River, from Pittsburgh, Pa., to the Mississippi River. The company has stated that their products can be moved by water from its refinery to any point in this 980-mile reach of the Ohio River at a lower cost than the products could be moved by either truck or rail for a distance of 10 miles from their refinery into Ashland, Ky. Also, crude oil and refined petroleum products are being moved by water from the Gulf coast area to Catlettsburg, a distance of 1,700 miles, for less than a cent per gallon whereas it is not possible to ship gasoline by truck or rail for 75 miles at a cent per gallon.

MARIETTA MANUFACTURING CO.

The Marietta Manufacturing Co., located at Point Pleasant, W. Va., since 1915, is engaged during normal times in the building of river towboats, dredges, packet boats, ferry boats and barges of steel construction, as well as steam engines and auxiliaries for use on river vessels. However, during World War II, the capacity of the shipyard was used primarily for the construction of ships and boats for the armed services and the Defense Plant Corporation. Location on an improved inland waterway made it possible to use labor and basic materials, plentiful in the area, for fabricating and equipping ships for national defense which otherwise would have required space and manpower in the congested seacoast shipyards.

SEMET-SOLVAY DIVISION, ALLIED CHEMICAL & DYE CORP., IRONTON, OHIO, AND ASHLAND, KY.

The Semet-Solvay Division, Allied Chemical & Dye Corp., located on the Ohio River, with plants at Ironton, Ohio, and Ashland, Ky., altered its operations so as to utilize low-cost water transportation afforded by improved waterways. The firm utilizes large tonnages of coal for its manufacture of coke, coal tar, ammonia, and several byproducts. The Ashland plant, which is the largest user of coal, originally obtained its coal by rail from mines in the interior of Kentucky. In 1938, after modernization of the Kanawha River navigation system was completed, the firm began obtaining its coal supply from Harewood, W. Va., where it is loaded directly into barges and towed down the Kanawha and Ohio Rivers for a total distance of 140 miles to unloading docks at the two plants. The firm owns and operates 2 towboats, 1 tug, and 55 barges in meeting its demand for about 70,000 tons of coal per month.

ARMCO STEEL CORP., ASHLAND DIVISION, ASHLAND, KY.

The Ashland Division of the Armco Steel Corp. is using the waterway to reach new markets for existing products. At the present time, the plant is shipping about 3,000 tons of finished steel sheets by waterways to Memphis, Tenn., and Houston, Tex., for redistribution to the southwestern part of the country. The market was developed entirely as a result of low-cost water transportation afforded by the improved inland waterways.

KANAWHA-OHIO CHEMICAL INDUSTRY REGION

The Kanawha River Valley and the Ohio River Valley upstream and downstream from the mouth of the Kanawha River represent one of the major chemical-producing regions of the world. The existing industries are expanding in the Kanawha River Valley and many new centers are being established along the Ohio River. The capital investment in chemical plants in the Kanawha River Valley alone is estimated to be \$400,000,000. The location and growth of the chemical industry in the Ohio-Kanawha region can be attributed to many factors, chief among which are the following: abundance of coal, natural gas, and brines; the availability of labor; the excellent transportation facilities provided both by the railroads and the

improved waterways; and the ample and stable water supply afforded by the pools of the navigation projects.

Many of the bulk raw materials used in the chemical industries of the region are transported by barge.

THE COMMERCIAL BARGE LINES

The operations of the Commercial Barge Lines on the Ohio River and its improved tributaries and on the Mississippi River and Gulf Intracoastal Waterway exemplify the manner in which improved waterways attract new businesses and open new markets for the products of industry.

In August 1949, the Commercial Barge Lines inaugurated a movement of highway tractor trailers by barge, between the ports of Cincinnati, Ohio, and Louisville, Ky., making daily trips each way overnight between these two ports. Trailers are loaded at points within the tributary areas of the ports of origin and are then concentrated at these ports. Here the loaded trailers are transferred to barges, without handling the cargoes, and are transported by water to port of destination. At the latter port the loaded trailers are landed and local tractors convey them throughout the port's tributary area, distributing their cargoes at ultimate delivery points. It is estimated that an average of 15 trailers are transported each way daily. The Commercial Barge Lines is now proposing to extend this service ultimately to provide transport between the ports of Pittsburgh, Pa., New Orleans, La., and Houston, Tex., with pickup and delivery to be made at intermediate points.

In addition to the trailer movement by barge, the Commercial Barge Lines has operated a waterway transport for automobiles and trucks for a number of years. This service was inaugurated in 1935 and at the beginning the number of units hauled averaged approximately 1,000 per month. This movement represented a cargo value of approximately \$1,000,000 per month and it covered relatively short distances. At the present time the lines load approximately 10,000 cars per month at the Evansville, Ind., and Cincinnati, Ohio, river ports. Approximately 3,000 of the 10,000 cars are loaded at Cincinnati, with the remainder being loaded at Evansville. The number of units hauled monthly by the lines represent a cargo value of about \$20,000,000. The service has been extended greatly since its inauguration, as is indicated by the fact that the units loaded at Cincinnati and Evansville are destined for ports at Guntersville, Ala., on the Tennessee River, and Memphis, Tenn., St. Louis, and New Orleans on the Mississippi River, and Port Arthur and Houston, Tex., on the Gulf Intracoastal Waterway. Furthermore, many of the units transported to the port of New Orleans have been consigned to South American ports and are trans-shipped from New Orleans.

CUMBERLAND RIVER INDUSTRIES

The following are typical examples of industries which have benefited because of adequate and low-cost transportation facilities provided by the improved Cumberland River:

The Nashville Bridge Co., a large barge and boatbuilding concern, in peacetime has been able to assume a share in boatbuilding which otherwise would have

gone to shipyards on the Great Lakes, sea coasts, or other inland waterways. The ability of this company to undertake the construction of war vessels during World War II was vitally important to the success of this Nation's war effort, in view of the overload in coastal yards. During that war this plant delivered more than 100 vessels to the military services, most of them for deep-water war use.

The Cumberland Warehouse & Storage Co., of Nashville has leased the city's terminal facilities to provide an iron and steel distribution point in the Cumberland River Basin. In an agreement with the Jones & Laughlin Steel Co. and the Carnegie-Illinois Steel Corp., the warehouse company acts as jobber for the steel firms, handling such packaged products as nails and wire, sheet steel and metal roofing. In 1949 these shipments, totaling 45,000 tons, were valued at \$3,600,000 compared to a 1939 tonnage of 15,000 with a value of \$825,000.

As still another example of industry locating to take advantage of low-haulage costs, 10 oil companies (Gulf, Standard of New Jersey, Pan-Am Petroleum, Lion, Shell, Ingram Products, Ashland Oil & Refining, Arkansas Fuel Oil, Pure Oil, and Southern Oil Service) operate bulk terminals at Nashville, with 1949 shipments aggregating 728,000 tons—virtually the total of bulk shipments used within the area, including most of middle and a large part of eastern Tennessee.

B. Mississippi River Between the Ohio and Missouri Rivers

The following is a short list of illustrative instances in which the Mississippi River, between the Ohio and the Missouri Rivers, has influenced the location of industries, individual businesses, and water-front communities. The navigable 9-foot channel, authorized in 1927, is an essential transportation resource for the Mississippi Valley in the vicinity of St. Louis, Mo., and for the entire Nation. It has stimulated the expansion of existing businesses by providing them with a low-cost alternate means of transportation, and has been the principal reason for the establishment of new industries. During 1948, about 9,500,000 tons of traffic were moved on the middle Mississippi River. The principal commodities are wheat, corn, flour, coffee, other agricultural products, coal, aluminum ore, sand and gravel, crude petroleum, sulfur, lumber, gasoline, fuel oil, kerosene, chemicals, iron and steel, automobiles, cement, paper, sugar, and feed.

Union Electric Light & Power Co., Meramec Plant, located a new power plant on the Mississippi River about 10 miles downstream from St. Louis, Mo., because of the availability of water transportation and supply. This plant, of 500,000 kilowatts ultimate capacity, is to be constructed in four sections, the first of which (110,000 kilowatts) is under construction at an estimated investment of \$26,000,000. One of the principal factors in the selection of the site was the use of west Kentucky coal for steam generation. This coal will be shipped by barges via the inland waterways.

St. Louis Shipbuilding & Steel Co. is located on the river at St. Louis, Mo., and began operations in 1933. During World War II. This company built 4 lighters for the Navy, 6 towboats costing \$1,000,000 each for the Defense Plant Corporation, 39 derrick boats costing

\$100,000 each, and 30 barges for the Army Transportation Corps, and 15 vessels for Russia, costing \$800,000 each. The yard constructs six to seven towboats and 50 to 60 barges per year, with sales totaling between \$5,000,000 and \$6,000,000 annually.

Wood River Oil & Refining Co. is the newest oil company in the St. Louis area. Wood River, Ill., is approximately 10 miles above St. Louis, Mo. Movements of products via the inland waterways plays an important part. The company has steadily grown until today its capacity is 25,000 to 30,000 barrels of crude oil treated per day.

Shell Oil Co.'s Wood River Refinery is the company's largest and most modern and covers an area of more than 2 square miles. It has about 3,500 employees and processes daily over 100,000 barrels of crude oil. Movement of products via the Mississippi River plays a large and important part.

The Street Towing Co. moves 2,150,000 barrels of oil by river annually.

UPPER MISSISSIPPI RIVER

The Northern States Power Co. located plants adjacent to the Mississippi River in Minneapolis, St. Paul, and Red Wing, Minn., and La Crosse, Wis., prior to the inception of barge transportation. They now transport nearly a half million tons of coal annually by barge to their plants. The fuel is unloaded directly at the St. Paul, Red Wing, and La Crosse plants with resultant savings over the cost of transportation by rail. The company has a new plant under construction along the Minnesota River, tributary to the Mississippi River 9-foot project, in which one of the considerations is the potential ability of receiving barged coal for direct unloading at the plant. The provision of a 9-foot channel on the Minnesota River is under study by the Corps of Engineers.

The Shell Oil Co. and Socony-Vacuum Oil Co. employ private river transportation facilities on the Mississippi River at St. Paul.

Cargill, Inc., is one of the large grain corporations in the country. During World War II, because of the location of property adjacent to a waterway, the company erected a shipyard and constructed several naval tankers and river towboats. Acquisition of the property was initially made for the purpose of shipping grain from inland points by water to ports in the lower Mississippi and Tennessee River Valleys. Since the war the company has been shipping grain from a terminal constructed near the shipyard. So apparent have been the advantages of shipping by water that the company has undertaken maintenance of a tributary channel connecting their terminal with the established Mississippi River 9-foot canalization project. Now bulk grain is loaded directly into barges from cars and trucks arriving from inland points without incurring switching charges through the Twin Cities.

The Minnesota Farm Bureau Service Co., having plants in St. Paul and Winona, Minn., has found it economical and feasible to transport phosphate rock by water from Tennessee Valley and lower Mississippi River ports to their terminals and plants along the river.

Bettendorf, Iowa, Tank Farm (bulk oil and gas storage) represents a development which is entirely the result of the improvement of the upper Mississippi River for navi-

gation. The firms represented in this improvement are the Socony Vacuum Oil Co., Inc., Shell Oil Co., Standard Oil Co., Paraland Oil Co., the Texas Co., and the W. H. Barber Co. Construction of this tank farm which was begun in the late 1930's has steadily increased in capacity so that to date it can store more than 1,250,000 barrels of gas, fuel oil, and kerosene. It receives more than one-half million tons of these commodities by water each year.

Dairyland Power Cooperative, La Crosse, Wis., has just completed the construction of a steam, coal-burning, electric-generating plant at Cassville, Wis., on the Mississippi River. Its main reason for building at that site was because of the fact that all their coal can be shipped in by water. This plant will tie in with their Alma and Genoa, Wis., plants and serve portions of Iowa, Illinois, Wisconsin, and Minnesota.

TENNESSEE RIVER

Pennsylvania Salt Co. and Pittsburgh Metallurgical Co. are examples of businesses recently located new plants on the Tennessee River and are using it. Sulfur, coke, and scrap metals currently are received by water at the two plants. Pittsburgh Metallurgical Co. has announced intention also to use water transportation for imported ores. Total announced investment in Tennessee River plants of the two firms is \$3.6 million.

Wolverine Tube Division of Calumet & Hecla Consolidated Copper Co. located on the waterway, not with serious intentions of using it, but because of effect of such location upon rail rates. The firm located in Decatur, Ala; investment is estimated at about \$10 million.

Alabama Flour Mills was established primarily because of availability of the waterway. Parent organization in Nebraska Consolidated Mills Co. A grain elevator and flour mill (said to be the first mill in the State of Alabama) were established in Decatur, Ala. Original plan was to bring in grains from west of the Mississippi by barge at a saving of about \$3.50 per ton. Although substantial quantities of yellow corn and wheat are being brought in by water, the firm has been able to buy much of its grain from north Alabama farmers. Local grain purchases totaled \$1,444,000 in 1949 as contrasted with \$20,000 in 1941. Current payroll is \$490,000, and represents over five times as many employees as in 1942. Elevator capacity is now 800,000 bushels, or twice initial capacity. Milling capacity is 1,200 barrels per day, cornmeal production 600 barrels, and commercial feed capacity is 700 tons.

Badgett Corp. will use the waterway to reach a new market for an existing resource. Badgett is about to build a \$300,000 rail-to-barge coal terminal at Grand Rivers, Ky., just above Kentucky Dam. The terminal will handle coal from west Kentucky fields whose only previous route to market was by rail. (Illinois Central Railroad, incidentally, has assisted the enterprise by establishing a reduced rate from the mines to the terminal.) Impetus for the undertaking was coal requirements of TVA's Johnsonville steam power plant, 75 waterway miles from the terminal.

Texas Co. and Gulf Refining Co. have reshaped their organizations so as to take advantage of water transpor-

tation. Texas Co. has built four terminals and bulk storage plants on the Tennessee; Gulf has built five. Bulk products are brought in by barge to riverside bulk-storage plants located in five port cities. They are stored and distributed inland by truck and rail as needed. Gulf supplements this system with pipeline receipts at Chattanooga. It also receives packaged petroleum products at a special river terminal at Knoxville.

Ingalls Shipbuilding Corp. located in Decatur, Ala., in 1930 on the unimproved river. Work was limited to building only one or two barges at a time, and these frequently could not be launched when built for lack of water depth. Now the yard has a 9-foot navigable connection with the Mississippi waterway system and the Gulf. During World War II, Ingalls and another shipyard, operated during the war only by Decatur Iron & Steel Co., turned out 135 vessels for the military services. Seagoing 3,600-ton cargo vessels, landing craft, barges, towboats, derrick boats, dredge tenders, and others were built.

Guntersville, Ala., is a port of entry to the Southeast for steel, grain, petroleum, and automobiles and is the home port of a Naval Reserve training ship. Not the least important changes are the tourist and sportsmen's attractions Guntersville now offers, including an extensive small-boat harbor.

During World War II, the Chemical Warfare Service of the Department of the Army built an extensive arsenal adjacent to Wheeler Reservoir, in the vicinity of Huntsville, Ala. During construction, large quantities of sand, gravel, and other construction materials were barged to the site. One of the finest terminals on the Tennessee was built at the arsenal to handle coal used after operations were begun. The plant also received by water many of the heavy-gage steel cylinders used for storage and shipment of products.

ST. JOHNS RIVER, JACKSONVILLE TO LAKE HARNEY

On this stream, near Sanford, two oil-burning steam-electric plants were located, one a 10,000-kilowatt plant of the Florida Power & Light Co., the other a 12,500-kilowatt plant of the Florida Power Corp. The location was selected because it affords an ample supply of cooling water, and because it makes possible low-cost water transportation of fuel oil from Jacksonville via the river.

WITLACOCHEE RIVER, FLA.

At Inglis a 25,000-kilowatt oil-burning steam-electric plant, constructed by the Florida Power Corp., is served by barge delivery of fuel oil from Tampa Harbor.

Tombigbee-Warrior Waterway.—Connects the 32-foot-deep harbor at Mobile with the industrial area around Birmingham. Over 2,000,000 tons of raw materials and products were transported on the waterway in 1948.

The Ford Motor Co. Assembly and Distribution Plant on the St. Johns River at Jacksonville, Fla.—Receives automobiles and auto trucks by barge from Norfolk via the Intracoastal Waterway for redistribution throughout its territory.

The Pulp Mill of the Southern Kraft Division of the International Paper Co. on Sampit River at the Head of

the Georgetown Harbor Channel, Georgetown, S. C.—Consumes about 1,500,000 tons of pulpwood annually. In 1948, nearly 500,000 tons of the pulpwood requirement were delivered to the mill by barge via the Intracoastal Waterway.

The Sugar Refinery of the Savannah Sugar Corp. on the Savannah River at Savannah, Ga.—Receives raw sugar from Cuba, Hawaii, the Philippines, and other sources, and ships refined sugar, in part by water on the Intracoastal Waterway.

DU PONT CO.

Forty-one du Pont manufacturing sites are located directly on or close to the inland and intracoastal waterways of the United States. Five of these plants are equipped with docks suitable for ocean-going vessels; the remainder rely on shallow-draft transport for any water-borne commerce they employ. In addition to the above 41 sites, the company also operates 5 on the Great Lakes, and materials shipped to some of these Great Lakes plants are handled on portions of the inland waterways. Six of the seven new plant sites developed since 1945 have been located on or close to inland waterways.

In the transportation of raw materials and chemical intermediates, 2 million tons are currently being handled on inland waterways, and use of the waterways by this company is increasing. The 2 million tons of du Pont freight moved on inland waterways represent approximately 1.0 percent of all such movements in the United States.

Annual freight bills paid for transportation on the inland and intracoastal waterways are approximately 5 percent of du Pont's total annual freight expenditures for rail, highway, water, and air transportation.

The company is an active user of the inland waterways system. The establishment of major manufacturing units on developed waterways will tend to increase use of water transportation wherever and whenever cost and investment differentials exist in favor of water freight hauls. Current studies show that maintenance of existing inland waterways channels and their developed tributaries will result in expanded use of water transportation by this company.

Such expanded use is hampered by certain limitations in the service. The more important of these are discussed in the following paragraphs:

Time of transit is generally longer on waterways than on competitive overland routes. Increased inventories are required, and the added investment of such inventories reduces the benefits of savings inherent in water travel.

Interruptions of service on inland waterways from floods, fog, drought, and ice also contribute to the necessity for large inventories. Service is completely suspended during winter months on some northern routes. Continuous operation of manufacturing plants, therefore, requires building up stockpiles of water-borne raw materials during the periods open to navigation.

Supplementary services are more frequently needed for initial collection and final delivery of water-borne freight than in the overland routes, which are equipped with a network of interconnecting facilities.

Equipment for bulk chemicals at terminals and at plants located on water's edge is inadequate. Barge loads of materials are large quantities, and the facilities for efficient

dock-side handling and storage of chemicals, both liquid and solid, have not been developed to the extent that barges and ships have been designed for special hauls.

These factors, and others affecting the over-all convenience and completeness of service, tend to restrict barge-adapted freight to large volume items.

The compensating advantage of the inland and intra-coastal waterways is the inherently low freight cost of water transportation. The competitive costs and investment factors for each individual commodity movement are considered in the selection of the economic method of transportation.

This company is chiefly interested in the use of waterways to transport raw materials which originate near the waterways and to handle large volumes of chemical intermediates between two manufacturing plants. At the present time the major raw materials received by du Pont plants along inland waterways are coal from West Virginia, fuel oil from Delaware River refineries, benzene from Pittsburgh, and sulfur from Texas. The major movements of intermediates are the distribution of methanol from an operation in Texas and of sulfuric acid from a Delaware River plant.

III. Waterways as Free Public Highways

The development of present Government policy with respect to waterways can be traced back to the first days of the Republic. Both the assumption of river and harbor development by the Federal Government and the treatment of waterways as free public highways found expression as early as the 1780's. Article 4 of the Ordinance of 1787 for the Government of the Northwest Territory stated:

The navigable waterways leading into the Mississippi and St. Lawrence, and the carrying places between the same, shall be common highways, and forever free, as well to the inhabitants of the said territory as to the citizens of the United States, and those of any other States that may be admitted into the confederacy, without any tax, impost, or duty therefor.

River and harbor development was foreshadowed by a congressional act passed in 1789 authorizing the Federal Treasury to assume the costs of the lighthouses, beacons, buoys, and public piers that had been erected by the Colonial Government. It assumed major program stature in the early nineteenth century with Federal subsidies and grants of land to States ~~to~~ aid in canal construction and river improvements, and more important, with the river and harbor acts, beginning with 1824, which provided for direct Federal activity under the direction of the Army Engineers.

Statements of Government objectives in waterway development seldom have found their way into the river and harbor legislation which, since 1824, has become an annual congressional fixture. The no-toll policy was reaffirmed in the Act of July 5, 1884, as amended by Act of March 3, 1909, which said:

No tolls or operating charges whatever shall be levied upon or collected from any vessel, dredge, or other water craft for passing through any lock, canal, canalized river, or other work for the use and benefit of navigation, now belonging to the United States or that may be hereafter constructed.

Rivers and harbor acts have been almost exclusively concerned with authorizing works of improvement of specified rivers and harbors in accordance with reports previously submitted by the Chief of Engineers. The predominant purpose of the legislation, although seldom clearly defined, can, however, be summed up as

the encouragement and development of water transportation as a means of promoting the commerce of the United States.

Aside from river and harbor legislation, promotion of domestic water navigation projects has been encouraged through the establishment of the TVA and through concern with the navigation aspects of multipurpose projects by other Government agencies.

Public Law No. 185, Sixty-eighth Congress, approved June 3, 1924, established the Inland Waterways Corporation for the general objective "of carrying on the operations of the Government-owned inland canal, and coastwise waterways system to the point where the system can be transferred to private operation to the best advantage of the Government, of carrying out the mandates of Congress prescribed in section 201 of the Transportation Act of 1920, as amended, and of carrying out the policy enunciated by Congress in the first paragraph of section 500 of such act." The newly formed corporation was the outgrowth of Government operation of waterway services during World War I to aid in meeting the abnormal wartime demand for transportation. The Transportation Act of 1920 shifted the administration of waterway activity from the Railroad Administration to the Inland and Coastwise Waterways Service under the direction of the Secretary of War until enactment of the Inland Waterways Corporation Act. In 1939, the Inland Waterways Corporation was transferred from the War Department to the Department of Commerce.

In 1937, Congress granted authority to extend barge-line services to include the Savannah River. However, this extension was never made.

In the historic policy statement of the 1940 act, Congress proclaimed the national transportation policy to be "to provide for fair and impartial regulation of all modes of transportation subject to the provisions of this act, so administered as to recognize and preserve the inherent advantages of each; to promote safe, adequate, economical, and efficient service and foster sound economic conditions in transportation and among the several carriers; to encourage the establishment and maintenance of reasonable charges for transportation services, without unjust discriminations, undue preferences or advantages, or unfair or destructive competitive practices, * * * all

to the end of developing, coordinating, and preserving a national transportation system by water, highway, and rail, as well as other means, adequate to meet the needs of the commerce of the United States, of the postal service, and of the national defense."

The significant difference between the two policy statements is the emphasis on further development of water transportation in the act of 1920 and the stress on preservation of the inherent advantage of each mode of transportation in the act of 1940. It might also be added that one of the bitterest conflicts between waterway development under existing procedure and the aims of the 1940 act comes when such development does not generate new traffic but merely diverts traffic from already existing means of transport.

That projects concerning navigation are handled by a military agency, is due to the fact that in the early period of river development the Army was the only Federal agency that had available the necessary trained engineers, and that all efforts at reorganization have been successfully resisted because of the Army's engineering competence, the absence of a central transportation agency, and the engineers' excellent relations with local interests and Congress.

In the transportation field, the two main agencies interested in waterway development are the Interstate Commerce Commission, with its partial regulatory control over water transportation services, and the Department of Commerce which was originally established to "foster, promote, and develop," among other things, "the transportation facilities of the United States."³

Conflicts and Inconsistencies of Governmental Policy and Administration.—Domestic water navigation fits into two major fields of Government activity, that of water-resources development and that concerned with national transportation policy. Added to this difficulty is the fact that Government policy in each of these fields has developed in piecemeal fashion; action often has been marked by legislation designed to meet the need of the moment. As a result, national policies are inconsistent and conflicting, jurisdictions overlap, and gaps occur in the over-all policy structure.

In the transportation field, the conflicts are perhaps most glaring, with promotional and regulatory activities to a great extent moving in opposite directions, and with no one agency responsible for the execution of the transportation policy enunciated in the act of 1940. In regard to water transportation, the Engineers, TVA, and other agencies to a smaller degree, are charged with its promotion through the improvement of the Nation's harbors and inland waterway system, while, on the other hand, the use of the improved waterways is restricted through the regulatory activities of the ICC. And both types of activity are often in conflict with the aim of recognizing and preserving the inherent advantage of each mode of transportation.⁴

³ Interior and Agriculture, mentioned with respect to water-resource development, are also among the agencies concerned with the transportation aspects of waterways, because of their interest in the hauling of mineral products and farm produce, respectively.

⁴ A more specific inconsistency is the practice of charging tolls on the Panama Canal while no user charges are made on the inland waterway system; the important role of the Canal in international trade and its competitive position vis-a-vis the Suez Canal are cited to justify this special treatment.

Furthermore, there are the basic conflicts between optimum water resource developments and the requirements of a national transportation policy. The former calls for maximum river improvement and canal construction and encouragement of water transportation; the latter demands a careful balancing of the advantages of water transportation in comparison with other modes of transport, principally railroads. The question of toll charges highlights the conflict. From the viewpoint of the development agencies such as TVA, the levying of toll charges would prevent the full utilization of improvements made for the purpose of stimulating water transportation—improvements which are an integral part of the over-all water development plan. From the viewpoint of a national transportation policy, the fact that water carriers are not required to pay their own way at present whereas railroads are⁵ required to do so, constitutes a barrier to the goal of traffic allocation among the competing types of carrier service according to inherent economic advantage.⁶

While domestic water navigation projects are in the midst of a tremendous conflict in both policy and administrative jurisdiction, the former is not the result of administrative policy making and the latter is not the result of an unauthorized poaching on the reserves of one executive agency by another; the policy conflict is a policy conflict expressed in the laws of the land; and the conflict over jurisdiction is the inevitable result of apportioning among several agencies what is basically one job.

The policy of not charging tolls is clearly stated in rivers and harbors legislation, more specifically in the act of July 5, 1884, as amended by the act of March 3, 1909. And the policy of preserving the inherent advantage of each mode of transportation is just as firmly expressed in the Transportation Act of 1940. The policy of promoting waterway development is stated in the Transportation Act of 1920 as well as in river and harbor legislation, and the policy of restricting and conditioning water carrier service is authorized by the Interstate Commerce Act, as amended in 1940. Instead of a situation in which policy making by executive agencies creates frictions in a unified legislative program, the reverse situation exists in that the basic incompatibility of present waterway development policy and national transportation policy has been obscured by lack of appropriate executive consideration and action on the latter.

In regard to administrative conflicts, none exists on single-purpose navigation projects. These are and always have been the job of the Army Engineers.

Conflicts on past multiple-purpose projects are not so much due to a difference in method, but, at least in the case of navigation, to a division of responsibilities and overlapping of jurisdictions of various agencies.

Pressure to allocate costs to a nonreimbursable use such as navigation would be eliminated through the establishment of a policy of toll charges.⁷

⁵ In their development stage, the railroads received huge subsidies, but Congress has concluded that these have all been amortized, so that the rails now stand on their own feet.

⁶ In theory, a fair test of economic efficiency between the various domestic carriers would be provided either by subsidizing them all to the same extent (for example, financing all fixed costs) or by having no subsidies at all.

⁷ Flood control would still remain nonreimbursable, of course. Probably, benefits are too widespread to make a policy of recovering costs by user charges practicable or desirable.

The economic desirability of a domestic water navigation project is dependent mainly on three things:

1. The direct transportation savings effected.
2. The indirect effects of the project on other parts of the economy, including the rest of the transportation system.
3. The worth of the project in comparison with alternative uses of the funds involved.

Absence of Common or Unified Promotional and Regulatory Policy.—It is generally agreed that Federal promotional activities encourage entrance into and expansion of water transportation services. It is likewise true that regulatory restrictions tend to limit in some degree such enterprise and thereby inhibit utilization of waterway facilities. This conflict between regulatory and promotional policy further points up the need for a centralized and unified promotional and regulatory policy which will assure the Nation of an efficient and adequate transportation system.

The fundamental objective of Federal regulation of transportation is preservation for the public of adequate low-cost and nondiscriminatory service. Decision with respect to the extension or relaxation of regulatory controls over water carriers should be made on the basis of the net and ultimate effect upon the transportation user. It may be that effective price and service competition would be superior to the limited regulation now under Interstate Commerce Commission jurisdiction. Since the basic water facilities are provided by the Government for all who wish to use them, and water services can be established with moderate amounts of capital, and shippers, if rates became excessive, could always resort to other methods of transportation, there is little reason to suppose that water carriers would not provide services in adequate volume and at minimum cost. However, removal or further relaxation of present regulatory controls over water carriers would seem to accentuate the need for the imposition of user charges.

Nature and Extent of Federal Regulatory Restrictions Upon Inland Waterway Transportation.—Although, over the years, domestic water transportation has been brought under generally increasing regulation, it is still only partially regulated today. A number of types of water transportation are wholly exempt from regulation under the Interstate Commerce Act by reason either of an outright statutory provision or of action by the Commission under a so-called conditional exemption, while the water carriers which are regulated are not subject to certain provisions which apply to other modes of transportation (e. g., control over abandonment of service and issuance of securities; also, the commodities clause, applied to the railroads is absent in the case of water carriers). Because waterways are public highways, they are used by private individuals and corporations for the transportation of their own property, as well as by carriers for hire. The exemption of bulk carriers in part III of the Interstate Commerce Act excludes a large and important part of domestic for-hire water transportation from the jurisdiction of the Commission.

An analysis of the evolution of control for this type of carrier over inland waterways reveals that regulation developed more slowly than regulation for railroad carriers, and that it is not as comprehensive in its coverage

or as complete in its controls as railroad regulation. An obvious reason for this situation is that inland water transportation is not as easily monopolized as railroad transportation and competitive conditions are more likely to prevail. Competition between railroads, therefore, requires a duplication of the railway with its large investment. Competing carriers by water, however, can operate over the same waterway, and no duplication of the investment is necessary. Common carriers over a waterway, moreover, encounter substantial competition from contract carriers and private carriers. As a result, there are fewer opportunities for monopoly charges by water carriers, and complaints of excessive rates are infrequent.

Provisions of the Transportation Act of 1940 for regulation of water carriers are generally similar to those applicable to other carriers except that issuance of securities by water carriers is not regulated and safety standards for such carriers are left to the Coast Guard. There are also extensive exemptions to water-carrier regulation.

The provisions affecting through routes, joint classifications, joint rates, fares, and charges already in effect when the 1940 act was passed, were carried forward in the 1940 act.

Some Effects of Regulatory Restrictions on Development of Water Transportation Services.—Regulatory restrictions on water transportation generally have retarded to some degree the volume of water transportation and the relative further development of additional common carriers. Regulated water carriers on domestic waterways have been controlled less restrictively than intercity motor carriers, but the more liberal treatment of water carriers does not appear to be the result of specific legislative direction. Under certificate and permit provisions, very similar to those applying to motor carriers since 1940, the Commission has been liberal in granting operating authority to domestic water carriers in "grandfather" cases, but in recent years largely has closed the door to the small-business man who would seek to enter the regulated common carrier water transport field. A petition presented to the ICC for such a certificate is invariably followed by lengthy litigation, a series of hearings in different cities, further hearings, compilation of additional evidence and presentation of testimony, all of which costs so much that many small-business men are fearful of making the gamble.

Most water lines do not have the wide and diversified range of traffic enjoyed by the railroads and generally cannot afford the time and expense entailed in uncertain rate litigation before the Interstate Commerce Commission, whereas the railroads severally and jointly have legal and technical staffs quite well prepared to engage indefinitely in a lawsuit over rate matters. The result usually is that barge lines turn away from the prospect of such litigation and prefer to stick to uncontested traffic. Representatives of the barge lines maintain that if proceedings before the Commission were not required or were simpler and conducted against more specific standards, the barge line industry would be more aggressive in expanding its traffic, thereby increasing the tonnage and variety of traffic on the river system. The benefits of cheaper water transportation resulting from the large expenditures of public funds on the improvement of channels would flow in an increasing volume to an expanding segment of the shipping public.

An appraisal of the past effects of regulating certain classes of commodities becomes apparent by analysis of the quantitative relationship of those commodities which fall under regulation by reason of the Transportation Act of 1940. The following tables* classify the principal commodities transported by water on the Mississippi River, the Ohio River, and the Gulf Intracoastal Waterway, in 1939 compared with 1948, the latest year for which complete figures are available.

This tabulation reveals the tremendous growth in the bulk classification of cargo, such as coal, sulfur, ores, and petroleum, and the static position of the regulated group, which includes sugar, grains, food products, textiles, forest products, paper, and iron and steel. These figures show that the importance of regulated traffic on inland waterways is on the decline, and would seem to indicate that the restrictions imposed by regulation are partly to blame for this decline in the relative position of such cargo.

Another effect of regulatory restrictions on development of water transportation has been a tendency to decrease the use of common carrier water transportation by the small shipper, since certificate restrictions do not allow a common carrier to carry all commodities to any and all destinations. As a result, the small shipper, who cannot afford a traffic manager, after discovering that water carriers which serve his premises are unable to

provide the desired service, may turn to some other form of transport, even though water transportation might be more economical.

Many Water Carriers Exempt From Regulatory Control.—Only a small portion of the total transportation by water performed in the United States comes under the jurisdiction of the Interstate Commerce Commission, because there are numerous water carriers, part or all of whose operations are exempt from the provisions of the Interstate Commerce Act. So far as the nature of the exemption permits, the several exemptions found in part III are stated in terms of the transportation involved, rather than in terms of the carriers by whom that transportation is rendered. A given carrier may be regulated as to part of its transportation operations, or it may be engaged in wholly exempt transportation as to one voyage of a given vessel and regulated on the next voyage of the same vessel.

An enumeration of the important segments of water transportation that are exempted from certificate and permit control will indicate why relatively little water transportation comes under the Commission's control.

Sec. 303. (b) *Transportation of commodities in bulk, when the cargo space of the vessel in which such commodities are transported is being used for the carrying of not more than three such commodities at one time.*—In the discussions over a period of years which led to the passage of the Transportation Act of 1940, much attention was given to the question of the need for regulation of the transportation of bulk commodities. Coordinator Eastman and the Interstate Commerce Commission favored a conditional type of exemption, under which the Commission could relieve a given type of transportation from regulation if it found it consistent with the requirements of the national transportation policy to do so. Representatives of the carriers, however, advocated an outright exemption, and their view prevailed. The reasons advanced for the outright exemptions at the time the legislation was passed were basically either the low cost of such transportation and the lack of competition with common carriers (most bulk tonnage is carried, it was said, by contract carriers), or the presence of Canadian competition in the export field.

Sec. 303 (d). *Liquid cargoes in bulk in tank vessels designed for use exclusively in such service and certified under regulations approved by the Secretary of Commerce* pursuant to the provisions of section 4417a of the Revised Statutes. Opponents of the regulation of carriers engaged in tanker transportation of petroleum and petroleum products advanced substantially the same reasons as were urged by representatives of carriers engaged in the transportation of dry bulk cargoes.

The exemptions provided in part III of the act apply only to all-water traffic. They do not apply to through water-rail traffic of a common carrier moving under joint rates or under through rates on the basis of combinations of water and rail rates.

Section 1 (a) of the act applies to all common carriers engaged in transportation partly by railroad and partly by water when both are used under a common control, management, or arrangement for a continuous carriage or shipment. Section 1 (b) similarly applies to common carriers engaged in "the transportation of oil or other

TABLE 3.—Cargo

[In thousands of tons]

	Mississippi River		Ohio River		Gulf Intra-coastal Canal	
	1939	1948	1939	1948	1939	1948
Sugar, syrup, and molasses.....	1,231	1,427				
Grains.....	1,176	1,877				
Food products.....	1,726	2,340			350	
Textiles and allied products.....	718	532				
Forest product and paper.....	1,747	1,286			485	
Coal and coke.....	575	1,208	14,206	21,330		
Petroleum and products.....	15,553	36,541	3,081	10,444	5,370	23,052
Iron, steel and other metals.....	2,084	1,687	1,840	1,382	367	538
Sulfur.....	737	1,486				581
Ores and nonmetallic minerals.....	2,137	6,521	671	962	546	
Chemicals and products.....	622	1,050	325	549		
Sand and gravel.....			5,191	7,624		
Sea animal shells.....						2,081
Limestone and shale.....					548	480
All other commodities.....	1,200	1,193	641	501	462	1,134
Total.....	29,506	57,148	25,955	42,792	8,168	27,866

Percentage of total cargo—regulated vs. bulk

Regulated.....	29.5	8.5	9.5	4.4	22.0	6.0
Bulk.....	70.5	91.5	81.5	95.6	7.0	94.0

Source: U. S. division engineer, Vicksburg, Miss.

* Mimeographed Statement by J. W. Hershey, V. P., Commercial Petroleum & Transport Co., before the subcommittee of the Senate Committee on Interstate and Foreign Commerce, conducting hearings under S. Res. 50, July 25, 1950 (p. 2).

commodity, except water and except natural or artificial gas, by pipeline, or partly by pipeline and partly by railroad or by water." These provisions were superseded in 1940 by section 303 (a).

Private Carriers.—The Interstate Commerce Act contains no provisions for any restrictions on private water carriers.

Some of the other conditional or qualified exemptions are:

Sec. 302 (e). *Conditional exemption of contract carriers furnishing equipment for use by private carriers.*—The term "contract carrier by water" means any person which, under individual contracts or agreements, engages in the transportation (other than transportation referred to in paragraph (d) and the exception therein) by water of passengers or property in interstate or foreign commerce for compensation. The furnishing for compensation (under a charter, lease, or other agreement) of a vessel, to a person other than a carrier subject to this Act, to be used by the person to whom such vessel is furnished in the transportation of its own property, shall be considered to constitute, as to the vessel so furnished, engaging in transportation for compensation by the person furnishing such vessel, within the meaning of the foregoing definition of "contract carrier by water". Whenever the Commission, upon its own motion or upon application of any interested party, determines that the application of the preceding sentence to any person or class of persons is not necessary in order to effectuate the national transportation policy declared in this Act, it shall by order exempt such person or class of persons from the provisions of this Part for such period of time as may be specified in such order. The Commission may by order revoke any such exemption whenever it shall find that the application of such sentence to the exempted person or class of persons is necessary in order to effectuate such national transportation policy. No such exemption shall be denied or revoked except after reasonable opportunity for hearing.

Sec. 303 (e). *Conditional exemption of noncompetitive transportation by contract carriers.*—It is hereby declared to be the policy of Congress to exclude from the provisions of this Part, in addition to the transportation otherwise excluded under this Section, transportation by contract carriers by water which, by reason of the inherent nature of the commodities transported, their requirement of special equipment, or their shipment in bulk, is not actually and substantially competitive with transportation by any common carrier subject to this Part or Part I or Part II. Upon application of a carrier, made in such manner and form, the Commission may by regulations prescribe, the Commission shall, subject to such reasonable conditions and limitations as the Commission may prescribe, by order exempt from the provisions of this Part such of the transportation engaged in by such carrier as it finds necessary to carry out the policy above declared.

Contractor's equipment is not readily susceptible of handling by common carriers by rail, truck, or water, and transportation thereof is not substantially competitive with transportation by such carriers. Movement of all types of contractor's equipment used in construction work on the Mississippi River and its tributaries and at points along such waterways, exempted (Warner and Tamble, 265 I. C. C. 147 (151)).

Sec. 303 (g) (2). *Exemption of small craft.*—Except to the extent that the Commission shall from time to time find, and by order declare, that such application is necessary to carry out the national transportation policy declared in this act, the provisions of this part shall not apply * * * or (2) to transportation by small craft of not more than one hundred tons carrying capacity

or not more than one hundred indicated horsepower, or to vessels carrying passengers only and equipped to carry no more than sixteen passengers. * * *

Such sizable gaps in legal jurisdiction as represented by the above and other exemptions raise a serious question as to the practicability of Government regulation in the field of domestic water transportation.

Federal regulatory policy as reflected in part III of the Interstate Commerce Act and administration thereof by the ICC with respect to entry into and expansion of business conditions of service, for water carriers subject to ICC jurisdiction.—The Transportation Act of 1940 transferred to the Interstate Commerce Commission the jurisdiction over domestic water transportation formerly vested in the United States Maritime Commission under the Shipping Act, 1916, and the Intercoastal Shipping Act, 1933, both as amended, and in addition provided for more comprehensive controls by the Interstate Commerce Commission over water carriers upon the inland waterways. One important new control was the requirement that common and contract carriers by water, under the Commission's jurisdiction (except as otherwise provided) obtain either an operating certificate or a permit as a prerequisite to conducting interstate services. The holding of both a certificate for common-carrier service and a permit for contract service by the same party or controlling interest is discouraged by requiring specific approval of the Commission and a finding of consistency with the public interest and the national transportation policy.

To enable the provision of service for which there is an immediate and urgent need to a point or points or within a territory having no carrier service capable of meeting such need, the Commission, may, at its discretion, and without hearings or other proceedings, grant temporary authority for such service by a common carrier by water or a contract carrier by water, as the case may be. Such temporary authority shall be valid for such time as the Commission shall specify, and shall not create a presumption that corresponding permanent authority will be granted thereafter.

Except as otherwise provided, any certificate or permit may be transferred in accordance with such regulations as the Commission may prescribe for the protection of the public interest, and to insure compliance with the provisions of part III of the act.

The specification of the operating authority of common and contract water carriers under the Transportation Act of 1940 has brought into existence many types of regulatory restrictions upon water carrier operations in interstate commerce which did not exist prior to these enactments, such as restrictions on the commodities they may carry, the routes or territories they may serve, or the types of service they may render. Such restrictions have led to avoidable waste. For-hire carriers desiring to render service in interstate commerce by domestic water transportation, prior to the enactment of this act, were wholly free to select the area for their operations and the character of their service. Common carriers had only to observe the traditional obligations of the common law with respect to standards of service, liability for shipments, and reasonable rates. Water carriers were free to develop their service in any part of the country where suitable waterways existed and to serve any points in the selected

territory, and could haul in any direction all commodities in which traffic was available for which their equipment was fitted. They could offer common carrier service on some routes and contract service on others, and private carriers could engage freely in transportation for compensation on return hauls or to fill partially filled boats on out-bound hauls. They could render regular service more or less upon schedule or anywhere-for-hire service at the behest of the shipper, and were free at all times to make any adjustments in the scope of their operating territory and service which business conditions might demand. The forces controlling the development of the water carriers were principally economic, e. g., competition, character, and flow of traffic, business acumen, capital resources, and technological improvements.

Federal controls over the entrance of new water carriers and regulatory restrictions imposed on "grandfather" and new carriers have lessened their entrepreneurial freedom, and have tended to more or less freeze the operations of water carriers according to the pattern prevailing in 1940, thus retarding or entirely preventing many adjustments with respect to traffic and territories served.

The Interstate Commerce Commission exercises control over new for-hire operations of water carriers by granting to or denying to applicants the certificates of public convenience and necessity, or the permits required for lawful operations as common or contract carriers in interstate commerce, and by placing conditions and limitations upon the operating authority granted. A new common-carrier operation or an extension of an established service can be inaugurated on a permanent basis only after a certificate of public convenience and necessity has been secured from the Commission, and a new contract-carrier operation or an extension of an existing one requires a permit from the same source. The burden is placed upon common carriers to prove that their proposed operation or extension is or will be required by public convenience and necessity, and upon contract carriers that their proposals will be consistent with the public interest. Under this procedure, carriers are denied operating authority where such proof is deemed inadequate, or, if a certificate is granted, the operations permitted are limited to that extent.

Common and contract carriers in bona fide operation when the act became effective were treated differently than applicants for new or additional services. Under the provisos, known as the "grandfather" clauses, they were required to apply for and eventually to obtain certificates of public convenience and necessity and permits, respectively, as authorization for continuance of their established operations, but issuance of the necessary authorities was not made contingent upon submitting to the Commission proof of public convenience and necessity or consistency with the public interest.

By granting or withholding certificates of public convenience and necessity and operating permits to water carriers, the Government attempts to exercise positive control over the supply of transportation and the standards of competition, but has not been able to accomplish very rigid controls in the water-carrier field for the following reasons:

1. It was applied too late to affect materially the development of the operating pattern. Protection was afforded to operators in service at the time of passage of the act by the usual "grandfather" provisions. In respect of

either a common or a contract carrier, if it or a predecessor was in bona fide operation on January 1, 1940, in the service for which a certificate or a permit was sought and had continued in such operation, the Commission was required to issue a certificate or a permit without further showing of public interest, if application was made within 120 days from the effective date of the act. As illustrated above, the Commission in administering the "grandfather" clause has been far more liberal in the water-carrier field than it has been in the motor-carrier field, with respect to types of routes to be operated and cities to be served. The Commission had to start, therefore, with the existing pattern of service as a base and could not materially reduce the number of competitors even though the cost and traffic conditions might have suggested to them the desirability of such action. Its authority is essentially confined to the consideration of new applicants or the extension of new services. Part III of the Interstate Commerce Act does not provide revocation authority and procedure such as are found in part II and part IV of the act.

2. In reality, certificate and permit regulations are effective for only a small percentage of the total domestic water transportation system, since so many types of common and contract carriers and operations are exempted in whole or in part from the certificate and permit provisions of the act, and the very extensive private operations remain unregulated. "That exemption provisions of the act exempt most of the transportation by water carriers, other than the so-called package-freight carriers, that many carriers have preferred to confine their operations to such exempt traffic and have not seen fit to seek authority from the Commission to handle regulated traffic, noted" (Bartlett Line, Inc., 265 I. C. C. 94 (101)).

3. The Commission is specifically precluded from attaching to any certificates or permits, terms or conditions that would restrict the right of the carrier to add equipment, facilities, or contracts over the routes authorized as the development of the business and the demands of the public shall require. "Section 309 does not authorize the Commission to specify 'the service to be rendered,' but precludes it from attaching terms and conditions to a certificate which would deprive the public of the best type of service which could be rendered between ports by a water carrier."

Policy of ICC and Carriers With Respect to Coordination of Water Carrier Rates and Services With Other Forms of Transport.—The original Act To Regulate Commerce of 1887 authorized the Federal regulation of domestic water transportation in a limited way, by providing for the regulation of transportation partly by rail and partly by water when both forms of transportation were used under a common control, management, or arrangement for a continuous carriage or shipment. The Hepburn Act of 1906 gave the Commission authority to establish through routes and rates not only between two or more railroads, but also between a railroad and a connecting water carrier. The Mann-Elkins Act of 1910 contained a provision designed to protect the water carriers by prohibiting rail carriers from increasing rates previously reduced to meet water competition, unless the Commission found that the increase was justified by changed conditions other than the elimination of water competition.

The Panama Canal Act of 1912 broadened considerably the Commission's jurisdiction over water-rail transportation. The general purpose of the act was to prohibit or sharply restrict the ownership, operation, or control by railroads of water carriers of freight and passengers on routes with which such railroads do or may compete. The prohibition was absolute as to water carriers operating through the Panama Canal. The continuance or acquisition of such railroad ownership, operation, or control of water carriers on other routes, including all waterways, was also prohibited unless and until authorized by the Interstate Commerce Commission, after full hearings, on a showing that competition between the railroad and the water carriers would not be excluded, prevented, or reduced and that the public convenience and needs of commerce would be served thereby.

This statute gave the first indication of congressional attitude toward common ownership or control of two competing carrier agencies.

As a general rule the Commission has authorized continuance of railroad ownership, control, or operation of competing water carriers when the evidence before it affirmatively showed that such action would be in the interest of the public, of advantage to the convenience and the commerce of the people, and would neither exclude, prevent, nor reduce competition on the route by water.

The Federal Control Act of March 21, 1918, the Transportation Act of 1920, and the Denison Act, 1928, all continued the program of coordination of rail and water transportation similar to that established by the Panama Canal Act of 1912, in which routes and interchange of traffic were required. Common carriers by water may establish through routes and fares, charges, and classifications applicable thereto with common carriers by motor vehicle.

The ICC has about the same authority over rates, fares, and through routes and joint rates for water common carriers as for the railroads. It also has the authority to establish reasonable differentials between all-rail rates and joint rail-water rates or joint water-motor rates.

Joint Rail-Barge Rates.—In ICC docket 26712, the key issue was whether point rail-barge rates should be established in the Mississippi Valley at levels somewhat lower than the through all-rail rates. The existence of a lower rate for shipments jointly by rail and by barge, is, of course, necessary if the barge lines are to obtain any business from inland points which do not have direct access to water transportation. Where the rates are no lower than the all-rail rate, shippers will route their shipments by rail and the barge lines will be unable to obtain any of this traffic. The railroads established a limited number of joint rates under compulsion but in recent years have refused to establish any more and have challenged the existing differentials on the grounds that joint rail-barge transportation is now more expensive than all-rail transportation. In reaching its decision the ICC recognized the validity of the railroads' argument with respect to cost but concluded, nonetheless, that the continuing policy of the Congress toward waterway operations indicated the legislative intent for the establishment and maintenance of joint rail-barge rates, and accordingly ordered that differentials should be maintained on class rates and on commodity rates.

The Commission did not prescribe the new set of rates, but issued a finding that the suggested differentials were reasonable. It then left the record open for the actual establishment of rates by negotiation between the barge lines and the railroads which would substantially conform to the proposals of the Commission. It has been 2 years since the Commission issued its order in this case, and because of a suit in court to set aside the order, it has been continually postponing the effective date of the order, which presently is postponed to December 31, 1950.

This decision in the rail-barge case, which had been under consideration for approximately 13 years, unfortunately comes to them at a time when it is not likely to do them much good, as now the terminal costs of the water carriers are exceptionally high and the volume of joint rail-barge traffic has been decreasing. The net result may be to give the water carriers additional traffic, but it may also be to give them that traffic at rate levels which in many cases are no longer compensatory. In joint traffic the barge lines division may be much smaller than the revenue which it would obtain on a port-to-port traffic movement.

Extent to Which Provision of Waterway Facilities Has Fostered Competition Between the Several Modes of Transportation.—Competition fostered by the provision of waterway facilities has been primarily between carriers by water and carriers by railroad. An estimate of the complete extent of such competition would be difficult to determine. Competition between carriers by water and carriers by highway has been very limited, largely because of the marked differences in the two types of operation and the lack of adaptability of motor trucks to the transportation of the traffic that constitutes the bulk of the water movement, particularly on the inland waterways. Prior to the war there was some degree of competition between motor trucks and steamships when the latter were being operated in package-freight service along the Atlantic coast and on the Great Lakes. This service by water has not been revived to any appreciable extent since the war. To a limited extent trucks compete with railroads in conjunction with water operations through the performance of feeder or delivery service to and from interior points on traffic as to which the major portion of the transportation is by water.

It has been estimated that 90 percent of the total traffic on the inland waterways is accounted for by not more than 20 commodities, although a sizable variety of other commodities moves in comparatively small volume. On the Great Lakes, iron ore and lake cargo coal account for 75 percent or more of the total lake commerce. The transportation of these commodities across the Lakes cannot be classed as competitive with railroad transportation. Rather, the water segment is a part of a through or continuous movement by rail and water. The volume of this traffic is such, furthermore, that it is to be doubted that the railroads could handle it efficiently as a physical proposition. On the other hand, these commodities go into the production of articles which are adapted to movement by rail and so move extensively.

Other important movements on the Great Lakes are grain; stone, including sand and gravel; and iron and steel articles. The normal route for grain has been across the Lakes to eastern ports, principally Buffalo, and thence by rail. There has been some competition between this

route and all-rail routes and some of the all-rail rates are related to the ex-lake adjustment. Iron and steel articles for the most part constitute competitive traffic.

The river carriers largely have gone out of the business of handling carload and less-carload package freight because of the prohibitive cost of handling this traffic to and from barges. The Interstate Commerce Commission in its decision in *Rail and Barge Joint Rates* (270 I. C. C. 591), decided July 7, 1948, found that there were no demonstrable economies in joint barge-rail transportation on the Mississippi River and its tributaries as compared with all-rail transportation. However, it prescribed a system of differentials based upon its interpretation of the congressional policy. Its decision is now before the courts. There is not now an appreciable river movement of traffic of the type dealt with in that decision and, therefore, no competition of consequence between the river carriers and the railroads as to this traffic. Some attention is being given by water carriers to the increased use of truck-trailers on the rivers and elsewhere. This development may eventually attract a substantial volume of competitive package freight to the water routes.

The river carriers in recent years have concentrated on bargeload or large-volume types of traffic and for this traffic there is general competition between these carriers and the railroads, except probably bulk petroleum which moves largely by water or by pipeline in all areas. Railroad rate reductions or proposed reductions to meet water competition which have come to the attention of the Commission during the past year include a number of commodities in various areas as shown by table —.

There is competition between the railroads and the water lines for substantially all intercoastal traffic through the Panama Canal, and the rates of both sets of carriers reflect this competition. The general and substantial increases in railroad rates in the last 3 years between interior points and seaports have tended to exclude the intercoastal carriers from participation in traffic moving to or from interior areas that they formerly handled. There also is competition between the railroads and the Atlantic-Gulf coastwise water carriers, now few in number as compared with those in operation prior to the war. In these territories, however, the rates have reflected more standardized relationships between the rail and the water routes than generally has been true elsewhere, by reason of the prescription by the Interstate Commerce Commission of rate adjustments for both the rail carriers and the water carriers.

For many years prior to the war there was active competition between the railroads and water carriers providing regular common carriers service along the Pacific coast. The rail rates reflected this competition probably to a greater extent than was true of water-competitive rail rates in any other area, and became substantially lower than the noncompetitive rail rates in the western territory. These north-south Pacific coast water-competitive rates were continued in effect after the war, subject to some upward specific modifications and to the general increases applicable to all rates, but have been asserted by the interested water carriers as still too low to permit a resumption of the prewar common carrier Pacific coastwise service. There has been and is a substantial movement of lumber and other forest products by contract water carriers along the Pacific coast. This water move-

ment of lumber is to some extent, but not extensively, competitive with rail service.

The general conclusion is that the provision of waterway facilities has fostered competition between water carriers and the railroads in the following areas and respects:

Intercoastal, Atlantic-Gulf coastwise and Pacific coastwise, as to substantially all traffic.

Great Lakes, as to a limited amount of the total traffic; the movement of much of the remainder by water, however, being of ultimate traffic-producing benefit to the railroads.

On the inland river system, general competition as to bargeload or volume traffic, except principally bulk petroleum.

Regulatory controls, restrictions, and rate-making standards with respect to their effect on the quantity and type of waterway transportation services provided and the economic and defense objectives of waterway improvement.—The regulatory controls and restrictions as they directly or indirectly affect domestic transportation by water, have to do more particularly with the power in the ICC to prescribe minimum reasonable rates for each of the modes of transportation, and its control over the entry into the business of water carriage through the issuance or withholding of operating authority. A secondary type of control over operations is the power to specify the kind of operation, as by self-propelled vessels or by tug and barge, which was first given effect in the determination of "grandfather" applications according to the kind of service theretofore performed. Another control is that over mergers or transfers of operating authorities which the Commission may approve or disapprove as the public interest may appear. One of the principles pertaining to transfers is that transfer of a dormant water carrier operating authority will not ordinarily be approved unless the holder can show that the nonuse was due to circumstances beyond his control.

In deciding applications for water carrier operating authority, the question of adequacy of land transportation between the same points or areas has not been a controlling consideration, but such applications have been denied where it appeared there already was adequate transportation by water.

The regulatory controls over water carrier operations have not, as a general proposition, had an adverse effect on the quantity and type of waterway transportation services and the economic and defense objectives of waterway improvement. The Commission has no authority to restrict the right of a water carrier to add to its equipment, facilities, or service within the scope of its certificate or permit.

The chief controversies and criticisms pertaining to regulation as it affects water carriers have had to do with intercarrier competition between railroads and water carriers. The national transportation policy provides that all of the provisions of the Interstate Commerce Act shall be administered and enforced with a view to carrying out the policy, which declares—so far as primarily concerns the immediate questions—that the policy and the act shall be so administered as to *recognize and preserve the inherent advantages of each of the modes of transportation; promote economical and efficient service and foster sound economic conditions in transportation and among the several carriers; and encourage the maintenance of reasonable*

charges without unfair or destructive competitive practices. [Emphasis supplied.]

Generally speaking, rate issues relating to competition between water carriers and railroads have come before the Commission by way of requests for suspension and resulting suspension investigations, applications by railroads for fourth section relief, and other investigations presenting primarily the question of the minimum reasonableness of water-competitive rates of railroads. These types of proceedings involving competitive conflict raise some of the most difficult and perplexing questions that come before the Commission. They have been decided on the individual facts and merits of each case, as the Commission saw them, subject to certain general though flexible standards. One of the general standards has been to hold proposed reduced railroad rates to a level of 125 percent of the competitive water cost. But there have been many departures from this, depending upon (1) the character of the commodity and the amount of difference in rates that would affect the shipper's choice between the competing modes of transportation, and (2) the character of water competition sought to be met, such as private or other exempt operations.

A large share of the traffic of the railroads, on the other hand, is not water-competitive and from this traffic they are able to maintain their total revenues at a profitable level while carrying water-competitive traffic at rates which may yield little or no profit. Thus, the shippers of noncompetitive traffic, and the areas not affected by water competition, subsidize the railroads' water-competitive traffic; it being obvious that the railroads could not afford to handle all traffic at the levels of rates established where there is water competition. This operates, of course, to siphon off the advantages to the public which have been calculated into waterways expenditures.

The question arises whether, in the regulation of rail and water-competitive rates, sufficient attention has been given to destructive as distinguished from legitimate competition. It has been apparent in many situations of proposed reduced rail rates that shippers were playing the railroads and water carriers against each other in attempts to beat down the rates of both. In such situations regulation might well take a stronger hand than it has taken.

Reliable estimates place the volume of the exempt type of bulk traffic handled in water service at between 90 and 95 percent of the total domestic water-borne traffic. The general exemption of bulk commodities in section 303 (b) of the Interstate Commerce Act applies only in the case of commodities in bulk which are loaded and carried without wrappers or containers and received and delivered by the carrier without transportation mark or count, and is subject to the further condition that not more than three such commodities and no nonbulk commodities shall be transported in the same vessel or tow. The exemption of liquid cargoes in bulk in tank vessels, in section 303 (d), is absolute in that it applies even though a tank barge, for example, be included in a tow containing nonbulk commodities. A separate exemption, section 303 (c), applying to contract carriers of bulk commodities on the Great Lakes apparently was inserted for emphasis, since the same traffic is exempt under section 303 (b). However, removal of the section 303 (b) exemption alone would not affect the traffic now exempt under section 303 (c). Certain other types of trans-

portation which are made conditionally subject to regulation, which may be removed by the Commission, or conditionally exempt, subject to the power of the Commission to place them under regulation, are not particularly important in the consideration of the question under discussion. Principal among the commodities which may move in exempt service are ore, grains, coal and coke, petroleum and some products, sulfur, sand, gravel and stone, and phosphate rock.

The general exemption is not a complete one, and a particular bulk commodity may be exempt under one circumstance of transportation and subject to regulation under another. This is the basis of such disagreement as exists over the exemptions within the water-carrier industry. Many carriers engage exclusively in exempt transportation by conforming to the conditions of section 303 (b). They may charge such rates as they see fit and change them at will. The regulated common carriers of general commodities also handle bulk-type commodities but because they frequently must transport such commodities in vessels or tows with package or other non-exempt freight, they generally are obliged to transport the bulk commodities as regulated traffic subject to published tariff rates.

The regulated common carriers assert that this condition places them at a competitive disadvantage and has caused them to lose business. A group of these carriers operating on the Mississippi River system recently requested Congress to remove the general bulk exemption in section 303 (b). They contend that the present condition results in instability of rates and is definitely harmful to the regulated common carriers.

Exempt operators, opposing the proposal of the common carriers, claim that the absence of regulation of bulk commodities has resulted neither in excessive charges nor in a chaotic competitive condition within the bulk-carrying industry, and that additional regulation will work to the disadvantage of the public in that competition will be reduced and to a great extent eliminated. They contend that the common carriers have not undertaken to provide a true common carrier or all-purpose service, or to provide equipment adapted thereto, but instead selectively compete with the unregulated carriers. The railroads are on the side of the common carriers in opposing the exemptions.

It is difficult to appraise the effect of the unregulated portions of the water-transport industry on the regulatory controls and standards and on the quantity and type of waterway transportation services provided. Probably the regulated carriers are at some disadvantage, rate-wise, in competing with the unregulated carriers for bulk traffic. On the other hand, they have a field of operation in the handling of regulated traffic which the exempt carriers do not have and in which the latter do not compete. It would appear that on the whole the exemptions have not retarded the development of water-transportation service, but instead may have contributed to a fuller use of waterways than would be true if all domestic water transportation had been under regulation. There is, of course, competition between the railroads and the unregulated water carriers for various kinds of traffic, of which grain, sulfur, and phosphate rock may be used as representative.

Some traffic can hardly be said to be adapted to other than exempt water movement. This applies particularly

to the ore and coal movements across the Great Lakes which the railroads could hardly equip themselves to handle profitably, but which contribute greatly to the production of manufactured articles which in turn provide a heavy volume of railroad traffic. There would seem to be no need, from the standpoint of the railroads, regulated water carriers, or the shipping public, to subject this transportation to regulation.

There doubtless are competitive situations as to particular commodities, or in particular areas, where regulation instead of exemption would be beneficial to the participating carriers as a whole and therefore in the public interest, but there are other situations where this would not be true. It is plain that lifting of the exemptions in their entirety and without condition would impose an unnecessary burden on the regulatory agency and presently exempt carriers.

While it is to be doubted that sufficient experience has been gained in the regulation of domestic water transportation since the war to permit of a sound conclusion respecting the future policy toward presently exempt operations, it seems clear, as indicated, that any lifting of the exemptions should be conditional only. That is, the exemptions should remain, with power in the Commission to subject the transportation of any particular bulk traffic, or in any particular area, to the provisions of the act where competitive or other conditions appear to require regulation in the public interest.

In examining the nature and effect of conflicts between Federal promotion and regulation of inland waterway transportation the following question can be asked:

Has Federal promotion of waterways interfered with and impaired the effectiveness of regulation of the transport industry and conversely, has Federal regulatory policy lessened the effectiveness and value of Federal expenditures for waterways?

With respect to the primary proposition as to the nature and effect of conflicts between promotion and regulation of inland waterway transportation, there may be some conflict in the sense that waterway projects have been determined upon independently of the resulting effect upon the national transportation system comprising all modes of transport and for the economic welfare of each of which the regulatory agency has a responsibility under the na-

tional transportation policy and other statutory provisions. Whether a particular project would be an over-all public benefit or, on the other hand, would reduce the use and value of the existing transportation system, would seem to be a proper initial question.

In the sense that added complications and difficulties impair effectiveness, the answer would seem to be in the affirmative. The expansion of waterway and motor transportation, and the extension of regulation to these modes in addition to the railroads, necessarily has brought to regulation difficult and complex questions relating to intercarrier competition and rates. The Commission's efforts to properly discharge its equal duty properly toward each of the modes of transportation cannot be expected to satisfy all interests concerned in the complex situations with which it has to deal. In consequence the feeling may grow that regulation has not been wholly effective. In short, in many of these situations there is no answer satisfactory to all. However, the fact that growth in some of the modes of transportation has increased competition and added difficulties to regulation should not operate against further expansion which would promote the public interest.

It is to be doubted that Federal regulatory policy has materially lessened the effectiveness and value of Federal expenditures for waterways. Federal regulation, so far as it embraces waterway transportation, has existed for practical purposes only since the end of the war. In that time there has been a continual and substantial increase in the volume of traffic on the inland river system. Of course, in the various instances in which the Commission has approved reduced rates proposed by railroads to meet water competition the result has been diversions of traffic from the waterways or divisions of it between water carriers and the railroads. This has lessened to some extent the use of waterways and therefore the effectiveness and value of the expenditures therefor. But this relates more particularly to the question of rate regulatory policies. The value of expenditures for waterways must be gaged by the multiple benefits derived, including the attraction of industries seeking low-cost mass transportation, which generate traffic not only for the waterways but for the railroads as well. They are increasing in number, in volume, and in demands for reliable, low-cost transportation.

-Domestic freight traffic in the United States by kinds of transportation

[Ton-miles in millions and percent of total]

1		2		3		4		5		6	
Railways	Per cent	Great Lakes	Per cent	Inland waterways	Per cent	Highways	Per cent	Pipelines	Per cent	Total	Per cent
450,169	73.4	97,322	15.9	8,660	1.4	18,200	3.0	38,900	6.3	613,271	100
385,815	73.2	77,366	14.7	9,088	1.7	20,200	3.8	34,800	6.6	527,269	100
311,073	73.5	49,079	11.6	7,825	1.8	22,800	5.4	32,600	7.7	423,377	100
235,309	72.1	24,734	7.6	7,905	2.4	23,700	7.3	34,400	10.6	326,048	100
250,651	68.2	45,069	12.2	10,232	2.7	25,700	7.0	36,600	9.9	368,252	100
270,292	68.3	48,267	12.2	9,423	2.4	29,500	7.4	38,300	9.7	395,782	100
283,637	65.2	54,690	12.6	13,406	3.1	33,400	7.7	49,500	11.4	434,633	100
341,182	65.3	77,264	14.8	15,387	2.9	36,863	7.0	52,100	10.0	522,796	100
362,815	62.4	93,244	16.1	16,882	2.9	40,379	6.9	68,100	11.7	581,420	100
291,866	62.7	49,004	10.5	17,743	3.8	44,728	9.6	62,300	13.4	465,641	100
335,375	61.5	76,312	14.0	19,937	3.7	50,697	9.2	63,100	11.6	545,421	100
375,369	60.8	95,645	15.4	22,412	3.6	57,766	9.3	67,300	10.9	618,492	100
477,576	62.1	113,639	14.8	26,815	3.5	72,880	9.5	77,800	10.1	768,710	100
640,992	68.9	122,167	13.1	26,398	2.8	55,759	6.0	84,500	9.2	929,816	100
730,132	71.4	115,346	11.3	27,306	2.7	53,071	5.2	96,257	9.4	1,022,112	100
740,586	68.7	118,769	11.0	31,386	2.9	54,276	5.1	132,336	12.3	1,077,353	100
684,148	67.6	113,028	11.2	29,709	2.9	61,218	6.1	123,293	12.2	1,011,306	100
594,943	67.1	96,022	10.9	27,951	3.2	73,514	8.3	92,490	10.5	884,920	100
657,878	65.9	112,165	11.3	34,549	3.5	89,169	8.9	104,153	10.4	997,914	100
641,104	62.7	118,707	11.6	43,123	4.2	100,140	9.9	118,676	11.6	1,021,850	100

from ICC, Statistics of Railways. Column 1 does not include ton-miles of express, mail, and electric railway traffic. Engineers, U. S. Army. Column 3 does not include coastal and intercoastal traffic. Column 4 data for 1929-35 are from ICC, 1944; for 1936-48 from Bureau of Public Roads. Column 5 data for 1929-42 are from ICC, Postwar Traffic Levels, reports.

TABLE 5.—Summary of interstate petroleum barge movements

Louisiana, Arkansas, and Mississippi (Gulf coast) ports to Mississippi River points, by years, 1936-49

[Barrels of 42 United States gallons]

Crude oil	Gasoline	Kerosene	Heating oil	Gas oil	Fuel oil	Lube	Miscellaneous	Total
-----	4,856,545	617,427	-----	158,502	110,099	47,273	-----	5,789,846
-----	5,187,968	665,522	-----	309,910	73,800	85,520	-----	6,322,720
-----	5,691,685	716,456	-----	384,054	59,329	58,920	-----	6,910,444
-----	7,176,318	598,412	-----	569,148	76,737	84,622	-----	8,505,237
-----	7,941,044	736,032	-----	599,879	99,935	79,803	-----	9,456,693
-----	13,627,164	1,351,379	-----	874,768	553,289	81,825	-----	16,461,425
155,442	16,125,947	1,594,527	-----	2,076,032	944,023	163,755	16,496	21,076,222
878,775	21,499,954	2,872,482	-----	8,223,463	1,151,775	176,261	13,219	34,815,929
10,588,194	23,682,540	4,160,372	-----	6,277,643	1,182,619	172,653	-----	46,064,021
10,252,241	18,789,648	3,795,217	-----	7,137,216	977,786	146,076	5,399	41,103,583
8,856,678	29,120,606	2,569,748	140,499	1,822,114	641,627	178,074	8,219	43,337,565
17,354,832	32,794,294	4,666,717	946,725	3,905,038	1,020,966	200,481	12,030	60,901,083
21,983,662	40,120,635	5,342,090	793,657	4,237,337	1,057,045	195,483	57,026	73,786,935
13,690,244	44,531,800	5,783,177	2,780,827	2,015,424	1,110,588	266,691	35,398	70,214,149

a, Department of the Interior, April 1950.

TABLE 6.—Analysis of waterborne traffic on Ohio River for 1948 and computation of savings

442

Item	Commodity	Tons	Thousand ton-miles		Present rail charges	Present charges via waterways			
			Ohio River	Grand total		Barge line haul	Extra handling	Rail access and distribution	Grand total
1	Coal.....	21,032,969	1,648,726	2,670,331	\$34,704,400	\$11,778,462	\$3,091,847	\$3,742,000	\$20,612,309
2	Coke.....	296,648	77,007	93,144	940,374	393,947	24,470	64,017	492,434
3	Crude petroleum.....	4,053,452	1,454,804	2,901,082	39,846,908	21,262,973	4,310,062	2,160,712	28,733,748
4	Gasoline.....	4,842,690	1,101,773	4,600,837	55,981,496	20,999,841	4,256,724	2,121,599	28,378,164
5	Fuel, road oil.....	1,089,541	405,555	662,171	12,398,976	6,192,078	1,255,151	920,445	8,367,674
6	Refined petroleum.....	414,280	149,913	400,816	8,816,491	1,775,106	443,776	1,194,784	3,413,666
7	Sulfur.....	240,414	178,744	440,826	3,741,773	2,372,136	263,572	292,856	2,928,564
8	Iron and steel, rods, slab.....	363,661	173,501	258,100	2,251,062	648,044	120,008	432,030	1,200,082
9	Other iron and steel manufactured.....	420,895	312,793	511,179	7,388,707	2,829,176	524,014	1,886,452	8,240,142
10	Scrap iron and steel.....	348,124	272,392	343,769	2,919,876	1,261,622	182,603	215,804	1,660,029
11	All other (except sand, gravel, stone, Government).....	1,679,949	292,311	653,500	9,659,707	2,434,655	2,265,411	1,607,711	7,307,777
12	Sand, gravel, stone, Government.....	1,009,864							
13	Totals.....	42,792,487	6,067,519	13,835,755	176,347,769	72,948,040	16,747,638	18,638,411	108,334,589

Item	Commodity	Savings			Note	Differential between depressed (&) normal charges	Retail charges on normal level	Difference per ton-mile	Savings on Ohio River normal level
		Total	Ohio River	Per ton-mile (over-all)					
1	Coal.....	14,092,091	\$3,700,792	<i>Mills</i> 5.27	107	\$2,330,453	\$37,034,853	<i>Mills</i> 0.87	\$10,139,569
2	Coke.....	447,940	370,335	4.81	104	37,615	977,989	.40	401,433
3	Crude petroleum.....	10,813,160	5,422,523	3.72	104	1,581,876	41,128,784	.54	6,215,786
4	Gasoline.....	27,603,332	6,610,233	5.98	116	8,957,039	64,938,535	1.95	8,735,195
5	Fuel, road oil.....	4,031,302	2,469,021	6.08	112	1,487,877	13,886,853	2.24	2,380,290
6	Refined petroleum.....	2,402,825	898,703	6.00	112	697,979	6,514,470	1.74	1,159,760
7	Sulfur.....	813,208	329,735	1.84	101	37,407	2,779,179	.08	344,902
8	Iron and steel, rods, slabs.....	1,050,980	706,494	4.07	120	450,212	2,701,274	1.74	1,009,137
9	Other iron and steel manufacture.....	2,146,565	1,313,493	4.19	120	1,477,341	8,864,048	2.89	1,403,892
10	Scrap iron and steel.....	2,259,847	1,790,633	6.49	120	783,975	4,703,851	2.28	2,411,668
11	All other (except sand, gravel, stone, Government).....	2,331,930	1,052,020	3.59	140	2,863,882	13,523,589	5.91	2,780,337
12	Sand, gravel, stone, Government.....								
13	Totals.....	68,013,180	29,663,982	5.02	110	21,705,656	198,053,425	1.60	38,001,989

Authority for basic data.—Reports of commerce and tonnage prepared by Corps of Engineers, Department of the Army.

Authority for charges.—Tariffs of carriers lawfully on file with Interstate Commerce Commission; basic water transportation cost formulae—Board of Engineers for Rivers and Harbors, Department of the Army, and weighted average rail charges and barge charges per ton, resulting from fairly tested samples for each of the respective commodities.

Explanation of notes and reference marks:

- 1 Commerce on which no transportation benefits have been computed.
- 2 Reported by Corps of Engineers.
- 3 Reported by Corps of Engineers—6,585,854,062 ton-miles.
- 4 Computed.
- 5 Computed on all commerce except that shown in item No. 12.

Note. Factors used to adjust "Present rail charges" to what they would be if rates were on "Normal" level.

Annual charges for amortization, interest or unamortized portion of capital investment, operation, and maintenance for the fiscal year ending June 30, 1948, amounted to \$10,235,000.

7.—Analysis of water-borne traffic on the Illinois waterway for 1948 and computation of savings existing competitive rate basis, compared with estimated savings on basis of fully compensatory rates

Commodity	Tons	Thousands ton-miles on Illinois waterway	Thousands ton-miles on entire waterway system	Total present rail charges	Line-haul cost by water	Extra terminal and transfer charges	Charges for access or delivery by rail	Total charges via water route
products	5,138,717 2,468,463 971,277 373,225	960,866 795,640 112,079 119,376	1,057,007 1,689,773 147,870 575,412	13,467,261 17,502,834 3,672,955 2,762,070	4,016,627 4,379,546 617,256 1,460,759	924,969 1,487,385 571,870 67,180	2,884,993 7,206,903 1,175,892 295,212	7,826,589 13,073,834 2,365,018 1,823,151
steel manufactured	185,794 83,258	49,319 7,251	169,230 7,251	2,827,399 154,985	1,128,617 40,891	386,452 14,986	231,870	1,746,939 55,877
cake, and meal	75,486 72,788 59,017 55,314 62,038 35,667 27,669	10,207 16,450 18,660 12,210 19,322 11,605 5,713	22,264 19,216 36,021 19,459 92,705 48,939 5,713	326,353 611,419 778,020 370,591 1,480,802 413,388 69,184	175,769 215,904 381,920 235,656 429,361 244,639 15,196	47,556 104,087 34,820 100,672 78,168 52,887 11,068	164,045 275,580	223,325 484,036 692,320 336,328 1,021,494 297,526 26,264
phate	25,432 19,336 6,867 4,404	7,299 6,183 2,123 1,348	35,012 26,304 4,291 6,119	192,836 277,598 44,017 60,991	133,046 139,445 13,823 35,655	5,595 80,219 6,867 12,160	20,538	159,179 219,664 20,690 47,815
ous manufacturers merce not counted	305,294 2,286,493	50,385	179,820	1,958,808	683,316	327,412	324,675	1,335,403
Total	12,256,509	2,206,036	4,142,406	46,971,511	14,347,426	4,314,353	13,093,673	31,755,452

Commodity	Water charges on Illinois road proper	Total savings on present basis	Savings on Illinois waterway only	Differential between depressed and normal charges	Estimated rail charges on normal level	Total savings using normal rail rates	Differential applying to Illinois waterway	Estimated savings on Illinois waterway with normal rail rates
products	7,114,714 6,155,895 1,792,580 378,243	5,640,672 4,429,000 1,307,937 938,919	5,126,475 2,084,200 990,135 194,790	1,159,647	14,626,908 17,502,834 4,444,275 3,234,929	6,800,319 4,429,000 2,079,257 1,411,778	1,054,177	6,180,652 2,084,200 1,574,761 292,890
steel manufactured	509,114 55,877	1,080,460 99,108	314,885 99,108	565,480	3,392,879 154,985	1,645,940 99,108	164,800	479,685 99,108
cake, and meal	102,384 414,363 358,643 211,037 212,904 70,553 26,264	103,028 127,383 85,700 34,263 459,308 115,862 42,920	47,234 109,024 44,396 21,478 95,731 27,485 42,920	130,541 122,284 121,371 59,794 236,928 191,400 13,836	456,894 733,703 899,391 429,885 1,717,730 604,788 83,020	233,569 249,667 207,071 93,557 696,236 307,262 56,756	59,847 104,682 62,874 37,205 49,382 45,387 13,836	107,081 213,706 107,270 58,683 145,113 72,872 56,756
phate	33,184 51,634 10,237 10,536 374,176	33,657 57,934 23,327 13,176 623,405	7,016 13,622 11,664 2,903 174,492	22,369 55,520 7,043 24,396 842,287	215,205 333,118 51,060 85,387 2,800,095	56,026 113,454 30,370 37,572 1,465,692	4,663 13,050 3,485 5,374 236,006	11,679 26,672 15,149 8,277 410,498
Total	17,882,337	15,216,059	9,407,558	4,796,575	51,768,086	20,012,634	2,537,494	11,945,052

rief analysis of the Federal waterway program dated May 10, detailed distribution of commodity movements over a 20-year the Illinois waterway and its waterway connections was available through the calendar year 1947. Tonnage and ton-mileage Illinois waterway, proper, for 1948 were approximated at 12,273,000, 1,080,771,000 ton-miles, respectively, on which transportation charges directly to that waterway were computed at \$12,094,000 annual charges for interest, amortization, operation, and maintenance at \$2,128,000.

summarized in the above table have been taken from the actual individual freight movements by commodities from specific destination waterway ports. Charges for necessary additional line hauls to and from the river ports and the extra handling incurred by the barge movements have been estimated as closely as possible on the basis of available information permitted and added to the waterway line-costs for comparison with alternative rail routes to obtain the

savings. This adds 1.10 mills per ton-mile to the barge service costs to give the total unit cost of the water transportation. Savings computed on the basis of the presently depressed rail rates average 4.26 mills per ton-mile. With the competitively depressed rail charges restored to normal the savings would be at the rate of 5.42 mills, or an increase of 1.15 mills per ton-mile. These computations indicate therefore that if the rates of competitive overland carriers were restored to normal levels and the rates of water carriers increased to cover annual charges for interest and amortization of the capital expenditures for the waterway plus the operating and maintenance charges, the savings, or "spread" between the transportation charges via the water route and those via the most economical alternative route would be increased from 4.26 mills per ton-mile to 4.32 mills per ton-mile which would tend to encourage use of the waterway by a slightly greater volume of tonnage than under prevailing conditions.

TABLE 8.—Statement of selected commodity movements transported on the Upper Mississippi River and connecting waterways during 1948, showing transportation costs and rates by water and railroad

Commodity	Origin	Destination	Total tons carried (2,000 pounds)	Ton-miles (water)	Constructed water transportation costs							
					(*) Line-haul plus terminal					Line-haul port-to-port		
					Total cost	Plus public cost	(^c) Per ton-mile	Per ton	Plus public cost	Total cost	Per ton-mile	Per ton
Iron and steel products.....	All movements.....		88,630	99,357,101	\$453,961	\$9.469	<i>Mills</i> 4.569	\$5.12	\$6.06	\$269,631	<i>Mills</i> 2.714	\$3.04
Pig iron, skelp, billets, iron and steel.	do.....		47,586	81,661,053	357,349	9.276	4.376	7.51	8.47	311,191	2.811	6.54
Sulfur.....	do.....		375,577	575,801,808	2,372,911	9.000	4.100	6.22	7.28	2,136,297	2.601	5.69
Grain.....	do.....		129,586	84,838,363	295,402	8.382	3.482	2.28	3.24	219,028	2.582	1.69
Coal, bituminous.....	do.....		1,149,175	629,225,079	2,094,263	8.228	3.328	1.82	2.78	1,841,443	2.927	1.60
Total.....			• 1,790,554	1,473,883,403	5,573,906	8.682	3.782	3.11	4.07	4,777,500	3.241	2.67
Specific movements:												
Iron and steel products.....	Evansville, Ind.....	St. Paul, Minn.....	1,345	1,384,005	7,856	10.576	5.676	5.84	6.80	4,059	2.655	2.76
Do.....	St. Louis, Mo.....	Minneapolis, Miss..	1,141	767,893	5,158	11.617	6.717	4.52	2.48	2,785	2.627	2.44
Do.....	East Chicago, Ind...	New Orleans, La....	13,098	18,599,160	70,818	8.708	3.808	5.41	6.37	43,574	2.343	2.33
Sulfur.....	Port Sulphur, La....	Clinton, Iowa.....	2,352	3,393,936	14,391	9.140	4.240	6.11	7.07	12,909	2.804	5.49
Do.....	do.....	Chicago, Ill.....	93,275	140,054,650	590,012	9.113	4.213	6.19	7.15	829,969	2.784	5.56
Do.....	Galveston, Tex.....	do.....	204,669	330,745,104	1,324,546	8.905	4.005	6.47	7.45	1,195,605	2.615	5.84
Grain:												
Corn.....	New Boston, Ill.....	New Orleans, La....	1,113	1,449,126	3,842	7.551	2.651	3.45	4.41	3,129	2.159	2.81
Oats.....	Minneapolis, Minn..	Memphis, Tenn.....	1,422	1,541,448	4,542	7.847	2.947	3.19	4.15	4,031	2.615	2.83
Wheat.....	Burlington, Iowa...	St. Louis, Mo.....	4,365	977,760	5,952	10.987	6.087	1.36	2.32	2,222	2.275	.73
Coal, bituminous.....	East St. Louis, Ill..	Minneapolis, Minn..	3,233	2,175,809	7,069	8.149	3.249	2.19	3.15	6,358	2.922	1.97
Do.....	Alton, Ill.....	La Crosse, Wis....	2,469	1,222,155	4,165	8.308	2.408	1.69	2.65	3,622	2.964	1.47
Do.....	Liverpool, Ill.....	St. Paul, Minn.....	2,085	1,565,835	4,934	8.051	3.151	2.37	3.33	4,480	2.861	2.15

Commodity	Origin	Destination	Ton-miles (rail)	(*) Estimated rail transportation costs (Edward's formula)						Published common carrier rates, converted to dollars per net ton	Estimated rail transportation costs excluding passenger service and l. e. l. deficits						
				Line-haul plus terminal			Line-haul only				Water (*)	Rail		Portion		Remaining costs	
				Total cost	Per ton-mile	Per ton	Total cost	Per ton-mile	Per ton			Current	Estimated normal level (c)	Percent of total (*)	Amount	Amount	Per ton
Iron and steel products..	All movements.....		71,062,636	\$776,805	<i>Mills</i> 10.931	\$3.76	\$652,812	<i>Mills</i> 9.186	\$7.26				11.8	\$91,663	\$685,142	\$7.73	9.64
Pig iron, skelp, billets, iron, and steel.	do.....		56,449,245	554,927	9.831	11.66	484,012	8.574	10.17				11.8	65,481	489,446	10.29	8.67
Sulfur.....	do.....		475,632,772	3,924,745	8.252	10.45	3,500,441	7.360	9.32				11.8	463,120	3,461,625	9.22	7.28

.....	New Boston, Ill.	New Orleans, La.	1,196,495	10,550	8.818	9.48	9,319	7.789	8.37	3.28	7.00	8.20	11.7	1,234	9,316	8.37	7.79
Oats.....	Minneapolis, Minn.	Memphis, Tenn.	1,437,642	15,002	10.435	10.55	13,202	9.183	9.28	3.32	9.70	11.30	11.8	1,770	13,232	9.31	9.20
Wheat.....	Burlington, Iowa	St. Louis, Mo.	1,034,505	13,226	12.785	3.03	7,905	7.641	1.81	1.32	5.10	5.95	12.2	1,614	11,612	2.66	11.23
Coal, bituminous.....	East St. Louis, Ill.	Minneapolis, Minn.	2,082,052	19,689	9.457	6.09	15,701	7.541	4.86	2.15	4.46	5.23	12.2	2,402	17,287	5.34	8.30
Do.....	Alton, Ill.	La Crosse, Wis.	1,249,314	12,518	10.020	5.07	9,473	7.583	3.84	2.09	4.14	4.85	12.2	1,527	10,991	4.45	8.80
Do.....	Liverpool, Ill.	St. Paul, Minn.	1,075,860	10,738	9.981	5.15	8,166	7.590	3.92	2.35	3.44	4.03	12.2	1,310	9,428	4.52	8.76

• Constructed waterway costs were developed by Economics Division, Board of Engineers for Rivers and Harbors, Department of Army. These costs include all operating expenses and taxes, plus an amount equal to a return of 4 percent on investment after taxes. Allowance has also been made, by the addition of terminal charges, for necessary additional services required to place the traffic on a competitive basis with rail service.

• S. Doc. No. 63, 78th Cong., 1st. sess., and ICC Statement No. 2-50, May 1950. Rail costs developed by Edwards formula, as used above, include, in addition to operating expenses, taxes and rents, passenger service and l. c. l. deficits, an amount representing 4 percent on investment after taxes, plus estimated costs for loss and damage claims.

• Published Water Common Carrier rates are for line-haul only (port-to-port), except as noted, and do not include any additional terminal charges; these rates apply only to traffic subject to regulation which comprises a minor portion of the tonnage carried. Bulk commodities generally do not move at published rates.

• The costs per ton-mile do not include annual charges for interest and amortization of Federal costs, or operation and maintenance costs of the waterway. For the year 1948, such costs amounted to 4.9 mills per ton-mile on the upper Mississippi River (Federal costs of \$3,295,000 divided by 1,691,094,000 ton-miles). It should be noted that the ton-miles for the commodities shown above include ton-miles performed not only on the upper Mississippi River, but on connecting waterways as well. Any consolidation of the 2 cost factors, for any purpose, should be made with this understanding.

• The item of 1,990,554 tons represents 20.7 percent of the total 8,648,980 tons of waterborne commerce transported on the upper Mississippi River during 1948.

• Rates include destination unloading and switching charges.

• The estimated level of rail rates on particular movements obtaining in the absence of water competition; from a study of rail tariffs for equidistant noncompetitive transportation and fourth section relief granted by the ICC.

• Averages for passenger service and l. c. l. deficits are based on 9.7 percent of the fully distributed cost for the Eastern District; 13.6 percent for the Southern District; and 12.2 percent for the Western District; allowing for 4 percent return on the passenger and l. c. l. portion of the property. July 1950.

Per ton cost computed.