Water Resources Planning and Development

Seminar Conducted by

Oregon State University
WATER RESOURCES RESEARCH INSTITUTE

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Corvallis, Oregon

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Preface

An important function of the Water Resources Research Institute is to provide for training of students in the many aspects of water resources. Members of the Institute supervise the research efforts of graduate students and teach both undergraduate and graduate level courses applicable to water resources.

A water resources minor is offered under the guidance of the Institute for master of science or doctor of philosophy degree candidates in established disciplines. Courses offered in this minor cover all catagories of water knowledge and include, as a requirement, a water resources seminar which is conducted by the Institute each quarter except summer session.

This publication is the proceedings of the Spring 1964 seminar series, which was designed to provide the participant with a general understanding of the entire field of water resources planning and development, and to illustrate the complexities and interdisciplinary nature of comprehensive planning. Guest lecturers were from many of the federal and state agencies active in the field of water resources planning in Oregon.

Corvallis, Oregon
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Malcolm H. Karr

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* Manuscript not available

Presented April 1, 1964 by MALCOLM H. KARR, Executive Secretary, Water Resources Research Institute, Oregon State University, Corvallis, Oregon.

Introduction to Comprehensive Planning

Since water resources planning is a broad, complex subject, highly interdisciplinary in nature, we have designed the seminar sessions for this quarter as an integrated series in which each week's topic will be an important facet in the comprehension of the entire problem.

We will devote the first seven sessions to a general discussion of the nature of each of the beneficial uses of water, as recognized by both federal and state law, and the interrelationship and conflicts between these uses. The eighth session will bring out the aspects of water control; specifically the problems associated with flooding, erosion, and drainage. Session nine will explore ways in which a state can provide leadership in guiding the development of its water resources. The tenth, and final, session will discuss that most important first step in comprehensive planning – integration of basic data collection.

Today I will give a general introduction to the entire subject and will begin by reviewing, chronologically, the growth in water resources planning to the comprehensive approach that is recognized today.

First, let us compare federal laws relating to water project functions with Oregon laws relating to beneficial uses of water and water control, as depicted in the table below.

LEGISLATION FOR

WATER RESOURCES PLANNING AND DEVELOPMENT

Name and Date of Oregon Law Defining BENEFICIAL USES AND WATER CONTROL	ITEM	Name and Date of Federal Law Authorizing PROJECT FUNCTIONS
1909 Surface Water Code	DOMESTIC	1958 Water Supply Act
	MUNICIPAL	
	INDUSTRIAL	
	MINING	1962 Senate Document 97
	IRRIGATION	1902 Reclamation Act
	POWER	
1955 Surface and Ground Water Acts and creation of State Water Resources Board	RECREATION	1962 Flood Control Act
	WILDLIFE	1958 Revised Fish and Wildlife Coordination Act
	FISHLIFE	
	POLLUTION ABATEMENT	1960 Water Quality Control Act
	FLOOD CONTROL	1936 Flood Control Act
	EROSION	
	DRAINAGE	1944 Flood Control Act

It can be noted that for many years following passage of the 1902 Reclamation Act, federal interest was limited to developing water for irrigation and power. As early as 1909, however, Oregon recognized that water supplies must be developed and protected for domestic, municipal, industrial and mining purposes as well as for irrigation and power.

Federal legislation was expanded so that federal projects also encompassed flooding and erosion problems, starting in 1936, and drainage problems in 1944.

The Oregon Legislature came to the decision in 1955 that the development of the state's water resources would soon become chaotic unless a single agency was given the responsibility to establish state water policy and resolve conflicts regarding use of water, under the authority of strong, broad legislation. Accordingly, the 1955 surface and ground water laws were passed which gave recognition to the need for water for recreation, wildlife, fishlife, and pollution abatement in addition to uses identified by state law in 1909. The 1955 surface water law also created the State Water Resources Board as a single agency delegated to serve as the final authority on all matters pertaining to the use and control of the state's water resources.

It was not until 1958 that federal water project planning was authorized to give consideration to domestic, municipal and industrial water supply and fish and wildlife enhancement as project functions. And it was as late as 1962, with the acceptance of Senate Document 97, before federal legislation and Oregon law regarding water use and control became completely compatible. This lag created some problems between state and federal planning and resulted in some projects being constructed with less functions than those desirable and possible. However, steps are now being taken to review existing projects with a view towards possible modifications in order to more fully realize their potential. Perhaps the most important point is that water resources planning today can be, and is in Oregon at least, truly comprehensive and multi-purpose in nature.

I would like to illustrate the complexity and interdisciplinary nature of water resources planning and development by calling attention to the listing below of federal and state agencies active in Oregon in some phase of the field of water and related land resources.

AGENCIES ACTIVE IN OREGON
IN
WATER RESOURCES PLANNING AND DEVELOPMENT

STATE

* Water Resources Board

Fish Commission

Game Commission

Sanitary Authority

Oregon State University

University of Oregon

Highway Department

Parks and Recreation Division

Marine Board

Board of Forestry

State Engineer

Department of Agriculture

Department of Geology and Mineral Industries

Committee on Natural Resources

Department of Planning and Development

Board of Census

Soil Conservation Committee

Mapping Advisory Committee

FEDERAL

* Department of Army

Corps of Engineers

* Department of Interior

Bureau of Reclamation

Geological Survey

Bureau of Commercial Fisheries

Bureau of Sport Fisheries and Wildlife

Bonneville Power Administration

Bureau of Outdoor Recreation

National Park Service

Bureau of Land Management

Bureau of Mines

* Department of Agriculture

Soil Conservation Service

Economic Research Service

Forest Service

Agricultural Stabilization and Conservation Service

Farmers Home Administration

Rural Electrification Administration

* Department of Health, Education and Welfare

Public Health Service

* Department of Commerce

Weather Bureau

Bureau of Census

* Department of Labor

* Federal Power Commission

* Member of Willamette Basin Task Force; coordinating body formed under auspices of Columbia Basin Interagency Committee.

A major significance of this list is that all of these agencies (nearly 40 in number) are currently participating in a comprehensive study of the water and related land resources of the Willamette River Basin, Oregon. Cordination of this mammoth effort is not being left to chance, but rather is being effected by a Task Force made up of a representative from each of the seven federal departments involved and one from the State of Oregon, the latter serving as chairman. This Task Force was formed under the auspices of the Coordinating Subcommittee of the Columbia Basin Inter-Agency Committee.

A coordinated study of this scope and magnitude has never been undertaken before and would not now be possible if the state did not have both the desire and ability to participate and to provide leadership in guiding the development of its water and related land resources.

A number of the guest lecturers who will appear later in this seminar series are members of the Willamette Basin Task Force: Don Lane represents the State of Oregon and is Chairman; James Agee represents the Department of Health, Education and Welfare; John Mangan, the Department of Interior; and Henry Stewart, the Department of Army.

Since my work is now primarily in the field of water oriented research, and research is vital to the successful solution of many of our problems, I will further illustrate the interdisciplinary nature of water resources development by discussing research in the field of water currently underway at Oregon State University as part of the activities of the Water Resources Research Institute. The listing below shows the many departments of the University that are contributing to water and related land resources planning and development through research in eight general subject areas; biology of water, meteorology, oceanography, plant ecology, soil physics, water economics, watershed management, and food science and technology.

There are more than 80 projects currently underway involving 16 departments and about 100 Water Resources Research Institute scientists and engineers.

OREGON STATE UNIVERSITY DEPARTMENTS
CONTRIBUTING THROUGH RESEARCH
AS MEMBERS OF
WATER RESOURCES RESEARCH INSTITUTE

GENERAL SUBJECT AREA	CONTRIBUTING DEPARTMENT
BIOLOGY OF WATER	Fish and Game Management Civil Engineering Entomology Botany Chemistry Microbiology Oceanography Agricultural Engineering Agricultural Chemistry Soils * U. S. Public Health Service * National Council for Stream Improvement * Oregon State Game Commission
METEOROLOGY	Physics Meteorology Statistics
OCEANOGRAPHY	Oceanography
PLANT ECOLOGY	Soils Agricultural Engineering Mechanical Engineering Meteorology
SOIL PHYSICS	Soils Agricultural Engineering
WATER ECONOMICS	Agricultural Economics Civil Engineering Fish and Game Management
WATERSHED MANAGEMENT	Forest Management Fish and Game Management * Oregon State Game Commission
FOOD SCIENCE AND TECHNOLOGY	Food Science and Technology Agricultural Chemistry * Fish Commission of Oregon

* Off-campus agency maintaining research staff and facilities at OSU

It is important to note that these studies are nearly all interdisciplinary, requiring that several departments join their special talents together as a team to attack the problems. As a specific example, an ecological study of an experimental stream, under the general heading of biology of water, is currently being conducted jointly by scientists and engineers from the departments of Fish and Game Management, Civil Engineering, Entomology, and Botany.

I am sure that the need for and importance of coordination, cooperation, and communication between the many disciplines involved in water resources planning and development will be mentioned many times by subsequent speakers in this seminar series.

Let me conclude by stressing one point—in the time available (ten one-hour sessions) we will not begin to make water resources planners out of any of you who attend this seminar series. However, we hope that each of you will gain a general understanding of the entire field of water resources planning and development, including the complexities and interdisciplinary nature of comprehensive planning. And perhaps most important, we hope each of you will become fully aware of the pressing need for communication with other disciplines regardless of what aspect might be your specialty.

Presented April 15, 1964 by JOHN F. MANGAN, Area Engineer, U. S. Bureau of Reclamation, Salem, Oregon.

Irrigation

Gentlemen, it is a pleasure to participate in your Water Resources Seminar. The subject that Mal Karr has assigned to me is "Irrigation". This is a subject as old as recorded history, and probably even older, yet it is continually changing and to those of us closely associated with it, it is a most challenging field of endeavor.

Historical Development

Some 2300 years B. C. in Mesopotamia, the Code of Khammurabi of the Babylonian era provided, "If anyone opens his irrigation canals to let water in, but is careless and the water floods the field of his neighbor, he shall measure out grain to the latter in proportion to the yield of the neighboring field."

There is reference to a form of irrigation in the Bible. In China and India, irrigation systems have been in use for hundreds of years. Roman aqueducts are still in use.

In the United States we find that there were crude irrigation works built in the southwest by the aboriginal Indians. These were improved upon by the Spanish Conquistadores and the colonists coming from Mexico and Spain and later by homeseekers who began to settle the western expanse of our country.

Modern Development

The beginning of modern irrigation as it is practiced today was July 23, 1847, when Mormon pioneers built a diversion dam on City Creek in what is now Salt Lake City. The first record of irrigation in Oregon is in the early 1950's in the Rogue River Basin where cattle ranchers irrigated their pastures. Beef was produced for gold miners in nearby Jacksonville or driven overland several hundred miles to San Francisco. In the Baker Valley of Oregon early irrigation dates back to about 1865, also for pasture.

Here in the Willamette Valley the first record of commercial irrigation dates back to 1890. In that year water pumped from a 16-foot well was conveyed by ditches to a half-acre of celery in the Eugene-Springfield area.

Although the United States did not take a census of irrigation until 1890, it was established that there were 1,000,000 acres being farmed in 1880 in the river bottoms of western streams.

The first census of irrigation in 1890 showed some 178,000 acres irrigated in Oregon. This increased to 440,000 acres in 1902 and 1,004,000 acres by 1939. The 1959 census of agriculture listed 1,384,000 acres under irrigation in Oregon.

The first irrigation enterprises were generally simple diversions in crude ditches. In contrast, today one of the most modern of pressure sprinkler systems is under construction near The Dalles, Oregon. Here water will be lifted a total of about 1,100 feet from the Columbia River for sprinkler irrigation of some 5,000 acres of cherry orchards. Between these two extremes are the many individual pumps, private ditches, ditch companies, water associations, district improvement companies, water control district systems, and irrigation districts of Oregon. On the drawing boards of the Bureau of Reclamation and the Department of Agriculture are a number of future irrigation developments that are responsive to the rapidly increasing interest in irrigated agriculture.

Irrigation development throughout the west to 1880 was mostly small ditches financed by individuals and associations of farmers. In the 1880's there was a substantial expansion of irrigation of a speculative type. Sales of stocks and bonds were used to finance the projects. Many of the projects initiated in this manner had considerable merit and after the speculative profit had been eliminated through foreclosure of mortgages and with new financing, they succeeded.

To about 1900 irrigation developments were entirely by private enterprise. There were several legislative steps taken by the Federal Government to encourage private enterprise.

Federal-State Relationship in Western Development

The first step taken to ensure that the Federal Government would not become the sole owner, operator, and developer of public lands for agriculture was the Act of July 26, 1866 which is of major importance with relation to the 80 years of irrigation development that was to follow. This act left "to local customs, laws, and decisions of courts" the development of irrigation. It provided that all irrigation must be carried on under state laws. This law has since guided development of western agriculture.

Desert Land Act of 1887 — This act provided that title to 640 acres of arid land could be procured by conducting water upon it and reclaiming the land within three years from time of filing and by payment of $1.25 per acre. In 1890 congress reduced the amount of acreage which could be patented to 320 acres. This act continued in force to 1949. In Oregon about 357,000 acres were entered by this means.

The Carey Act of 1894 provided for land grants to Western states who would in turn grant the lands to settlers for irrigation development. This act was intended to be an aid to the public land states in reclamation of desert lands. It granted not to exceed 1,000,000 acres of federal land to each of the states and directed that the state cause it to be irrigated, reclaimed, and occupied and that 20 acres out of each 160 acres would be cultivated by settlers within 10 years of the passage of the act. On the whole, the Carey Act did not measure up to expectations, but development under its provisions proved highly effective in Idaho and Wyoming. The high cost of reclamation soon discouraged applicants from initiating or proceeding with construction. The Carey Act is still in effect and some irrigation development under its provisions continues. As of June 30, 1949, about 73,500 acres had been patented under this act in Oregon.

Although the Federal Government had resisted efforts to bring about its participation in financing Western development, there were financial limits beyond which private and state resources could not go.

The Reclamation Act of 1902 established the Federal Government in planning and developing irrigation in the West. The Reclamation Service was established by this act as a part of the Geological Survey. In 1923 it became the Bureau of Reclamation—a separate Bureau in the Department of Interior. This Bureau now has authority and responsibility in the 17 Western States, and to a limited extent in Alaska and Hawaii, for the planning, construction, and operation of water resource developments.

Subsequent to 1902 various amendments to the Reclamation Act and other legislation establishing full multiple-purpose water resources planning have been passed. Today multiple-purpose and river basin water resources development is standard practice for the Bureau of Reclamation and for other responsible agencies within the Federal Government.

Problems of Irrigation Development in Oregon

Early irrigation developments were beset with many difficulties. Land speculation was one. The settlers were unable to meet the payments on the high land costs charged by the speculators within the period specified for repayment. Not enough study had gone into problems of water supply, soil properties, crop adaptation, and subsurface geologic conditions, to name just a few of the other associatd problems in irrigation development. Storage of flood flows to permit sustained high stream flows in summer months became essential at an early date. Storage Development sometimes met with difficulty. The State of Oregon has had its share. At least one reservoir in Eastern Oregon failed to fill and store water as expected because of excessive leakage in the reservoir basin itself. On another stream in Oregon, a small reservoir completely filled with silt within a few years and had to be breached to prevent flooding of a main line railroad.

In other early projects the water requirements of the crops and the land were underestimated. This coupled with excessive losses in long canals caused projects to be cut back in size from original plans.

As the amount of irrigation increased, the appropriation doctrine of first in time, first in right was applied in most parts of the West. This principle, which is now backed by statute in many states, opened the way for large scale irrigation development because it did not grant water-use priority to riparian landowners, particularly those upstream, unless they were also first in time. The appropriation doctrine originated in the West when miners developed it to meet their needs for water in areas that often did not abut on the streambank. Implicit in the appropriation doctrine is the idea of beneficial use. The individual who could show that he could put the water to beneficial use had a right to it. Under appropriation doctrine, a water right may, under certain conditions and provisions of the law, revert back to the control of the state if the water can no longer be put to beneficial use, either through process of abandonment or forfeiture.

The Oregon State Water Code of 1909 established the appropriation doctrine as law in Oregon. Since that time, water rights on many Oregon streams have been adjudicated and priorities established. But because the adjudication proceedings do not generally take place until there is a conflict in demands to make them necessary, most of the streams of the Willamette River basin have not yet been adjudicated. The Tualatin River is an exception.

Research and Technology

Many problems of past irrigation developments are still with us, but modern technology and research such as you are doing here at Oregon State University are providing many answers in the field of irrigation.

We know a great deal more now about silt measurement and deposition. We anticipate problems now on the basis of past experience and study the water holding ability of reservoir basins as well as the damsite.

In recent years there has been considerable knowledge gained through research on lower cost canal lining.

Studies are underway at the present time searching for a means of eliminating excessive evaporation losses from reservoirs, particularly in the southwest.

Sprays and weedicides are being used on salt cedar and other water-loving plants, also in the arid southwest, to minimize water losses.

Research continues on methods of application of water. Sprinkler irrigation has come into the picture since World War II. This permits controlled application of water, reduction of distribution losses, and minimizes drainage problems.

Work is continuing on providing adequate drainage for irrigation projects, both "on the farm" and as a part of the project system.

Comparisons of Eastern and Western Oregon

The climatic differences between eastern and western Oregon have had a profound effect on the importance and development of irrigation in the two areas. In the Vale-Ontario area, the rainfall averages about nine inches annually. This occurs generally in the period of October to May. The summer months have practically no effective precipitation season. The growing season averages 138 days.

An average hay and pasture crop plant has a consumptive use of about two acre-feet per acre in addition to transportation losses to the plant. Unless irrigation is provided, only dryland pasture grasses can exist. Under these conditions, water becomes the very life blood of the area economy.

The availability of a water supply is a critical factor. Generally speaking, in eastern Oregon there is more irrigable land than we can possibly provide water for, even by long-term carryover in the reservoir sites that are, by the nature of the topography, limited in size and extent.

In the Willamette Basin the situation is quite the reverse. There is adequate rainfall to support many crops. Salem has an annual rainfall of about 38 inches. This is distributed through the months of October to June. Only in mid-July to mid-September is there a shortage of natural rainfall to meet the consumptive use of the plant. The growing season runs to about 200 days.

Although irrigation development was rather slow, now there is a growing interest, due to changing economic conditions. In the past the farms produced an adequate family living under natural rainfall conditions. Reduced farm income associated with increased population and subdivision of holdings directs the farmer's interest to more intensive type of agriculture and to crops that must be irrigated to be competitive with outside areas. The Blue Lake bean has become an important crop in the valley, but it is only being raised where irrigation water is available. Local processing outlets will not contract for most row crops unless they are being irrigated.

In eastern Oregon, almost all land that can be irrigated by present systems and existing water supplies has been developed on a large scale.

In western Oregon, by contrast, only in the Rogue River Basin has project-type irrigation been developed to a significant degree. About 70,000 acres are being irrigated. In the Willamette Valley 180,000 acres are being irrigated, but most of this is being done on an individual basis, with farmers pumping directly from the Willamette River or one of its tributaries. In all, about 1-1/2 million acres of land can ultimately be brought under irrigation in western Oregon. At present not over a fifth of this potential has been realized.

Role of Oregon State University

The University has a common responsibility and a unique place in future development of irrigation as it has had in the past.

We have many problems that can only be answered by continued research and by dissemination of the results of this research.

We need better data on irrigation water requirements, particularly on the west slope. We need to know what crops can best be grown in the Willamette basin under irrigation. Through the Extension Service, the University can help the farmers in the changeover from dryland to project-type irrigation.

The University has underway at the present time a very good study on the Dayton soils at the Jackson farm. Preliminary results, I am told, show terrific increases in production of corn, for example, but on these soils the harvesting becomes a major problem because of irrigation—clearly the study is not complete.

The University has the opportunity to do basic research in many fields—fields that are beyond the means of individuals and more time consuming and costly than the Federal Agencies can undertake individually under present staffing, program scheduling, and financing methods.

In the past, many studies by the University have been related to irrigation in some manner. An example of a type of study particularly useful in the changeover from individual to project-type irrigation on the west slope was a paper by Caldwell and Castle entitled "Economics of Supplemental Irrigation on Polk County Farms." This study provided a great deal of information to support a federally financed project investigation. We need more like it.

Irrigation Projects—Existing and Planned

Existing irrigation projects in Oregon range from small farm ditch company-type developments, making direct diversions from streams without storage, to the federally constructed projects of varying complexity.

As I described earlier, easily constructed diversions were within the scope of private enterprise. Oregon has many privately constructed projects such as the Central Oregon Irrigation District which provides water to about 44,000 acres of land.

The Ochoco Irrigation District was a privately constructed project which in recent years received federal funds for a rehabilitation and enlargement of its system and storage reservoir and the construction of additional new storage on Crooked River.

The North Unit of the Deschutes Project is a Bureau of Reclamation constructed project of 50,000 acres, now operated by the water users.

In the Rogue Basin we have the Talent Irrigation District—an old established district that sought federal assistance for a rehabilitation and enlargement program that included improved and enlarged canals, storage reservoirs, and a unique hydroelectric plant that develops 16,000 kilowatts of electric energy from a 2,000-foot drop in the irrigation supply system. The revenue from this plant assists in the financing of the irrigation features.

The Bureau of Reclamation has in the planning stage the Tualatin Project near Forest Grove and the Red Prairie Project near Sheridan which would have storage reservoirs to meet irrigation and other related water functions. The Bureau has also developed plans for the Monmouth-Dallas Project which would secure a water supply by pumping from the natural flow of the Willamette River.

The Bureau also has responsibility for sale of irrigation water stored in the Corps of Engineers' constructed upstream reservoirs in the Willamette Basin.

The Soil Conservation Service of the Department of Agriculture has a number of projects under study on a "technical assistance to local group basis" throughout Oregon, and some under construction. These are generally smaller than those previously described. One of their better known projects is Lake Labish Pumping project on the Little Pudding River. The Department of Agriculture's program known as Public Law 566 provides technical assistance to local groups for small irrigation developments. This program covers developments on drainage areas of less than 250,000 acres. Any single storage structure cannot have a capacity of more than 2,500 acre-feet or a federal contribution to construction costs in excess of $250,000, unless approved by an appropriation committee of the Senate and the House.

The Bureau of Reclamation's Small Reclamation Projects Act of 1956 is a loan program to assist smaller projects. The loan is limited to $5,000,000. The total project cannot cost more than $10,000,000. The work can be done by the sponsor or its engineer, with review by the Bureau of Reclamation. Irrigation allocations must be repaid in 50 years without interest.

The conventional Bureau of Reclamation project has no cost limitation, except that each and every function must be financially feasible. The part of the project construction cost allocated to irrigation and within the water users' ability to pay is repaid without interest over 50 years. The lands must be able to pay operating cost and part of construction. That part of the construction allocation beyond the ability of the water users to repay is repaid by power revenues—in this area by the power revenues from the Federal Power System of the Columbia River Basin. The basic requirement in this program is that water will not be provided to more than 160 acres of irrigable land in any individual ownership.

Irrigation Water Supply, Quantity and Quality

Determination of the amount of water available for a project is made by analysis of streamflow records and ground water yields. Most projects utilize stored surface water, although there are some ground water developments, notably on the Snake River Plain. About 200,000 acres are irrigated from ground water in Oregon.

Water to be utilized for irrigation must also be of good quality, of low mineral content, and free of silt or other suspended material. If the water is of high mineral content, its relation to the soils on which it is applied must be known. This is not a problem in western Oregon because the waters are low in mineral content. In some areas of eastern Oregon the quality of the soil is a serious consideration.

Silt control is also another important factor in irrigation. The most significant problem area for silt is, as you might expect, in the lower Colorado River basin. Hoover, Glen Canyon, and other dams in the Colorado basin have done, or are doing much to alleviate this problem, but it is still necessary to remove silt from Colorado River water at Imperial Dam, near Yuma, Arizona. Here desilting facilities remove silt and discharge 15,000 cfs of irrigation water into the All-American Canal. Here in Oregon the silt load of the stream must be determined; generally it is not serious.

Once the quantity and quality of water available for irrigation are known, determination of the acreage that can be irrigated is made.

The first step is to compute the amount of water that is required to be delivered to the farm turnout. By analysis of rainfall patterns, soil types, and water demand by crops that would likely be raised under irrigation, this quantity is established within reasonable limits.

To determine the amount of water that must be taken from the stream or reservoir for irrigation, losses in transmission from the water source to the farm are added to the farm delivery requirement.

In some cases, for example, on the Columbia Basin Project in eastern Washington, there is opportunity to use return flow from irrigation of higher lands on lower-lying lands in the project. This reduces the diversion requirement that would otherwise be necessary to irrigate an area.

In western Oregon, and in the Willamette Valley in particular, we are dealing with an area that is rather unique in that water supply generally exceeds that required for irrigation, so the problem is not one of obtaining sufficient irrigation water, but rather development of plans to make the best overall multiple-purpose use of water.

Conflicts with Other Uses of Water

Use of water for irrigation in many cases conflicts with other possible uses. There are many factors that induce conflict, but several or primary importance are:

1. Season of use
2. Consumptive vs. non-consumptive use
3. Point of diversion
4. Streamflow cycle
5. Existing water rights

There are obviously many examples of conflict that could be cited, but I will illustrate each of the examples given above.

Season of Use. In the Willamette Valley, irrigation and flood control are very compatible. In flood control operation, reservoirs are drawn down during the rainy winter, or the non-irrigation season. The high probability of rains and considerable snowmelt in the late winter and early spring guarantees that reservoirs will be filled in most years by the start of the irrigation season. The reservoirs need not be drawn down very far as the irrigation season approaches because the probability of heavy prolonged rain is low. On the other hand, irrigation and lake recreation are highly incompatible. As drawdown commences during the summer dry season for irrigation, exposed mudflats, shallower water, and decreased water skiing area result.

Consumptive and Non-Consumptive Uses. Irrigation and municipal and industrial water are two important consumptive uses of water. Flood control, power generation, minimum flows for fishlife and water quality control, and recreation, constitute non-consumptive uses. Obviously water removed from the stream for irrigation or domestic use cannot be used in the stream for other purposes. If there is a considerable fish population in a drainage system, fish and wildlife interests are extremely interested in the proposed plan for developing irrigation on what has heretofore been a "fishin' stream."

Points of Diversion. If water is taken from a stream at a given point, other functions of use immediately downstream may be adversely affected. If the point of diversion is further downstream, considerable use of water may be made in the intervening stretch. Releasing stored water downstream through generators before diverting it for irrigation is one means of making it do double duty, but also power needs are not always compatible with irrigation demands. Heavy power use is in winter—maximum streamflow is in early spring.

Streamflow Cycle. As I mentioned previously, flood control and irrigation are very compatible alternative uses of water in the Willamette Basin. However, such is not the case throughout most of the Columbia River Basin. The period of maximum flow on the Columbia occurs about two months after the start of the irrigation season. While some of the high inflow can be diverted, most of this water is not available for irrigation unless it is stored. While there are many dams in the Columbia Basin, they have not completely alleviated this problem, although the river is now highly controlled. Upstream storage in Canada will go a long way to stabilizing the streamflow of the main Columbia River.

Existing Water Rights. In some cases previously existing water rights preclude irrigation development, particularly in those areas where it is not feasible to build storage facilities. Use of natural surface flows or ground water for irrigation may not be possible because previous water right holders preempt all the water during periods of low flow.

Let me summarize the conflicts inherent in a water resource development by an illustration.

Imagine, if you will, a fairly large reservoir with a powerplant, recreation facilities, anadromous fish runs, a sport fishery, and a demand for municipal water for a nearby city. This stream can do substantial flood damage if allowed to run uncontrolled. In addition, it is located above a large body of irrigable land that is unproductive without irrigation.

The water resource engineer must recognize that:

(1) The flood control interests seek flood protection on the river—vacant space in the reservoir to catch the "big flood."

(2) The irrigation farmers want the reservoir full when irrigation season starts.

(3) Local power demands are greatest in late fall or winter.

(4) Fluctuation of reservoir flows will seriously affect the sport fishery in the reservoir and on the stream below the dam.

(5) Anadromous fish must be allowed to pass the dam on their upstream migration and downstream migrants must pass the dam and powerplant unharmed.

(6) From a domestic water supply standpoint, the reservoir and the stream must not be a source of pollution.

(7) Finally, the recreationists—the water skier and boat enthusiasts want the reservoir to remain full—at least until Labor Day.

Gentlemen—it is a most interesting problem—it requires the patience of Job, the wisdom of Solomon, the hide of an elephant, and the poise of a high wire circus performer.

Presented April 29, 1964 by HAROLD SCHICK, State Parks Superintendant, Parks and Recreation Division, Oregon State Highway Department, Salem, Oregon.

Water-Based Recreation

The boom toward outdoor recreation has been rapidly increasing the past several years and is anticipated to spiral to even new heights during 1964 and the years to come.

In the May 5, 1964 issue of LOOK it was estimated 23 million cars will travel over the United States in 1964, there will be 64 million tourists spending $13 billion on trips upwards to 600 miles. They will sleep in 85, 000 hotels, motels – or in tents and trailers. There will be an estimated 40 million at the New York World's Fair.

Oregon is no exception to this outdoor recreation boom. The attendance was over 13 million visitors in our Oregon State parks during 1963. We were 6th in the nation in state park attendance. This indicates the rapid movement toward the Northwest and Oregon. We have 188 State park areas, with a budget slightly over four and one-half million for the biennium. You can imagine the amount of maintenance and operation involved of these areas with over 7, 500 picnic tables, as only a part of the facilities needed for this recreational impact.

Recreation is a big business in Oregon, and is attracting tourists to its increased use.

Oregon State parks are under the State Highway Commission, who has legal jurisdiction to acquire, develop, and maintain State parks and waysides. These areas all promote travel and the motorist's desire seems to be increasing for this service.

Approximately thirty-three of our major parks are oriented toward water recreation, and water attractions are the main features in a number of waysides and park areas. I have with me four master plans. They are of The Cove Palisades, Bullard's Beach, Wm. M. Tugman and Nehalem Bay state parks, and are representative examples of areas that are under construction with a major part of their activities oriented toward water use. At the Cove Palisades Park we will have spent about 1/2 million dollars before it is completed. This will include camping, picnicking, two large boat launching ramps, bath houses and swimming areas.

At Nehalem Bay Park we are in the process of completing a road to the sandspit for better access to the beach and to the Nehalem Bay area. Here there will be camping, picnicking, swimming and other water-front activities.

The William M. Tugman Park has been completed, and has a large area for boat parking, picnicking and swimming. This area is eight miles to the south of Reedsport on Eel Lake, and is already filled to capacity with day recreation users.

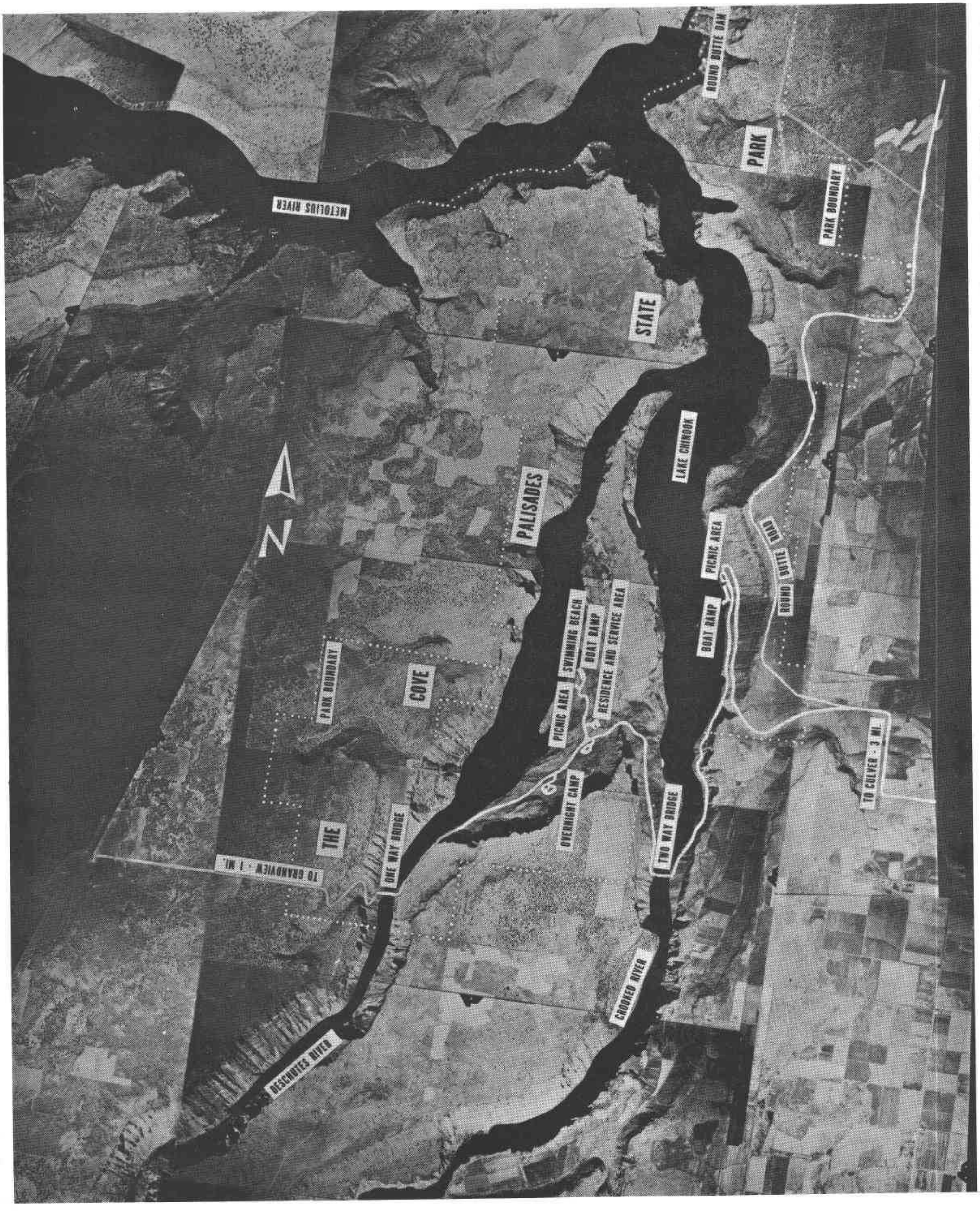
Bullard's Beach Park is located just north of Bandon. A new road is in the process of construction into the park. There will be a boat launching ramp, access to the beach and picnicking area.

It is estimated there are over 8 million recreational boats in existence on all waters in the United States. The State Marine Board's Oregon pleasure boat registration in 1961 totalled 45,628 boats, with 150,000 predicted by 1972.

The total U. S. recreational boating business was over $2.5 billion, a fourfold increase in the past 9 years.

According to the Outdoor Recreation Resources Review Commission report, boating is normally done in combination with other activities, such as fishing, picnicking, and sightseeing; also, 83% of all boating is done in connection with fishing, while cruising and sightseeing is the main activity of large boats. These figures may vary from lake to lake, depending on many factors, including the reputation of the lake as a source of fish or for boating. Water skiing, swimming, sunbathing, picnicking, sightseeing, and camping also are often done in combination with boating. Racing, both sailboats and motor boats, is a popular sport, but one in which a small percentage of boaters participate.

The use in water-oriented recreation activities is constantly changing. We think that swimming will be more important in the


ROUND BUTTE DAM
PARK
PARK BOUNDARY
METOLIUS RIVER
STATE
LAKE CHINOOK
PALISADES
N
PICNIC AREA
ROUND BUTTE ROAD
BOAT RAMP
SWIMMING BEACH
BOAT RAMP
RESIDENCE AND SERVICE AREA
PICNIC AREA
PARK BOUNDARY
COVE
OVERNIGHT CAMP
TWO WAY BRIDGE
TO CULVER - 3 MI.
THE
ONE WAY BRIDGE
TO GRANDVIEW - 1 MI.
CROOKED RIVER
DESCHUTES RIVER


NEHALEM BAY STATE PARK
day use area
boat ramp
boat camp
airstrip
overnight camp

future. There may be other changes in use that we cannot determine at this time. This can be obtained through research and surveys determining changing demand of our park users.

Arizona, one of the driest states in the union, now has more boats per capita than any other state. In the first six months of 1959 boat sales in California exceeded car sales, and a milestone was reached in New York when, according to estimates made by Time-Life, Inc., more people were killed over the Fourth of July weekend in boating accidents than in car accidents.

In California the average one-way distance from home to water for day-use boaters is about 25 miles, typical averages for weekend-overnight is 75 to 175 miles and for vacation boaters 135 to 250 miles.

Paralleling closely the tremendous boom in boating is the increase in water skiing. On certain lakes and in certain areas some 60% of the boats are towing skiers.

In 1958 in California they were in need of 50% more access units than were available, and there were about 1.3 million actual acres of boating waters in California. The effective or usable supply was much less, only about 200,000 acres, owing to lack of access.

There is usually more of a deficiency in the access to lakes than in lakes themselves. On lakes where construction of boat ramps and other recreational facilities depends on congressional appropriation funds, the result is long lines of boaters waiting sometimes for hours on end for their turn to launch their boats. Private enterprise is more sensitive to the demands of the boater. However, even here there is considerable lag in time between supply and demand.

The most intensively used portion of a lake is the area around an access point, with boats going in and out of the water at all times of the day. Next might be picnic areas where families enjoy their picnicking between boating, skiing or fishing expeditions out into the lake. More remote sections of shorelines also offer picnic sites, swimming, water skiing, and general enjoyment of the water away from the crowds. The least intensively used portion of the larger lakes is the area in the center, a mile or more from shore.

Water reservoirs are becoming more important toward supplying the recreational needs in Oregon and other states. The following are some of the federal agencies administrating reservoirs.

The Corps of Army Engineers has 250 reservoirs, with 23,000 miles of shoreline, or 3 million water acres, plus 3 million acres of project lands. There were 109 million visitors in 1960 to these areas; since 1947 there has been an increase of 15% annually.

The Bureau of Reclamation has 174 reservoirs in the western United States with 1-1/2 million acres of water and 7,000 miles of shoreline. There were 24.3 million visitors during 1960, which increased four times in ten years.

The Soil Conservation Service is limited under watershed protection and flood prevention Act to lakes of 5,000 acre-feet for flood prevention. They have 25,000 acre-feet for all purposes. There have been 1,802 watershed structures built since 1959.

There are a number of other federal agencies administrating water recreation areas, such as the U. S. Forest Service. It is primarily concerned with the high Cascade mountain and coastal areas in Oregon.

The Bureau of Land Management is concerned with the valleys and foothills. Many of their areas are located on streams and provide a variety of recreational activities.

The National Park Service has several monuments and Crater Lake National Park in Oregon.

There are a number of private agencies administrating recreation areas, such as utility companies and timber companies.

There are 27 out of the 36 counties in Oregon which have some form of water recreation. The counties are doing an outstanding job in providing water-oriented recreation at a local level.

Taken from the ORRRC report, conclusions are that where water occurs, it is not necessarily the volume of water, the surface area, or the miles of shoreline per unit area that limits recreational use. We are forced to conclude that water quality is one of the most important limiting factors in recreational use. Quality of water exercises this control through its effect on the quality of the experience. It is the quality of the experience that makes outdoor recreation one of the important pursuits in a civilized existence.

Further, in problems of water recreation there is conflict over existing areas between sailboats, fishermen, skiers, and swimmers. More zoning and limitation is needed. The uses are changing—more swimming is predicted, such as skin diving.

Research is needed for development of new procedures for making economic and monetary evaluation for the use of water-oriented recreation.

From a survey made by the State Marine Board in 1961 it was found that the most needed types of improved boating facilities as indicated by owners of smaller pleasure boats are (1) more launching ramps, (2) paved or improved launching ramps, (3) camping areas near mooring or launching sites, and (4) sanitary facilities.

The owners of larger pleasure boats indicated that the most needed boating facility improvements were (1) overnight mooring facilities, (2) more piers and docks, (3) improved law enforcement and safety regulations enforcement, and (4) breakwaters to shelter mooring areas.

Oregon has 240 boat access areas developed on its 112,000 miles of streams and 2,000 lakes and reservoirs, and other accesses to the Pacific Ocean along the 350 miles of public ocean ownership.

Oregon has a great water resource, but problems exist and will increase with competition in the future. These problems as mentioned earlier are water quality, water access, zoning and research to meet the changing needs.

Presented May 6, 1964 by P. W. SCHNEIDER, Director, Oregon State Game Commission, Portland, Oregon.

Fish and Wildlife

The discussion of fish and wildlife as a part of a water resources seminar is a fundamental approach to a discussion of the future welfare of this important segment of our state's renewable natural resources. A glance at the prededing five sessions of this seminar indicates that some of the basic background material of a legal, policy, and historical nature has by now been discussed. Considerable within these categories remains yet to be reviewed. I will attempt to comment on fish and wildlife within the scope of the outline prepared by Mr. Karr and within applicable state laws.

Perhaps the best point to begin is to refer to certain significant sections of the 1955 Act establishing the current law pertaining to surface water for this state. Chapter 707, Oregon Laws 1955, laid down a new code. ORS 535.210 through 536.590 embrace several matters significant to fish and wildlife.

Section 10, subsection (1) states: "The board shall proceed as rapidly as possible to study: existing water resources of this state; means and methods of conserving and augmenting such water resources; existing and contemplated needs and uses of water for domestic, municipal, irrigation, power development, industrial, mining, recreation, wildlife, and fish life uses and for pollution abatement, all of which are declared to be beneficial uses, and all other related subjects, including drainage and reclamation." The specific mention of fish and wildlife and the declaration of beneficial use of water was a milestone in western water law.

Subsection (2) states: "Based upon said studies and after an opportunity to be heard has been given to all other state agencies which may be concerned, the board shall progressively formulate an integrated, coordinated program for the use and control of all the water resources of this state and issue statements thereof."

Subsection (3)(g) of Section 10 states further: "The maintenance of minimum perennial streamflows sufficient to support aquatic life and to minimize pollution shall be fostered and encouraged if existing rights and priorities under existing laws will permit."

It will be noted from the above that prior vested rights are not invaded and, therefore, correction of problems incurred to fishery resources, particularly through diversion of flows from natural stream channels, was left unsolved with the enactment of this law.

Subsection (3)(l) states: "When proposed uses of water are in mutually exclusive conflict or when available supplies of water are insufficient for all who desire to use them, preference shall be given to human consumption purposes over all other uses and for livestock consumption, over any other use, and thereafter other beneficial purposes in such order as may be in the public interest consistent with the principles of this Act under the existing circumstances."

In previous and subsequent sections of the Act, fish and wildlife are specifically recited as beneficial uses, in common with all other uses other than human and livestock consumption. Herein lies an extremely significant feature of the Oregon surface water code from a fish and wildlife standpoint which, insofar as I know, is singular to Oregon among all of the states who operate under the doctrine of appropriation.

Section 11, wherein the Water Board upon issuing a statement of policy pertaining to a given stream, section of stream, or other surface water supply, and delivering said statement to affected agencies, imposes the following: "In the exercise of any power, duty, or privilege affecting the water resources of this state, every state agency or public corporation of this state shall give due regard to the statements of the board and shall conform thereto. No exercise of any such power, duty, or privilege by any such state agency or public corporation which would tend to derogate from or interfere with the state water resources policy shall be lawful."

Further definition and procedural requirements are spelled out in preceding and subsequent sections of the Act. Suffice it to say that once the Water Resources Board makes its finding of fact, use, and policy and complies with appropriate procedures required under the Act, the policy then becomes binding upon the agency involved, including the agencies dealing with fish and wildlife resources.

The aforementioned citations of law enunciate, among other things, three basic facts germane to fish and wildlife:

1. Fish and wildlife are declared to be beneficial uses of water.

2. Except for domestic and lifestock use, fish and wildlife have been placed upon the same basis as other uses in the initial process of establishing policy.

3. There is no invasion of the integrity of prior vested rights.

Now with regard to the fish and wildlife resources of the State, there are certain fundamental factors to recognize. The three basic constituents for maintaining fish and wildlife consist of food, water, and cover. These factors in relation to each other, in relation to quality and quantity, and in relation to their stability in the environment dictate in a fundamental way the ability to produce and maintain fish and wildlife. This wild resource, as a dynamic renewable one, exists because of the presence of water, along with food and cover, in its environment.

It is from our aquatic environment, whether it be a fresh-water stream, lake, marsh, or the marine environments of our coastal estuaries or oceanic areas, that the diversified and abundant fauna of Oregon springs in great array and abundance. All species with which my organization deals depend upon water and certain of these forms discriminatingly so. Quality as well as abundance becomes compellingly important with such forms as the salmonid fishes and even such species as certain aquatic mammals, as for example the otter. A running stream, a stable natural lake or a pulsing tidal estuary manifest a fauna reflective of the ecology demanded by species and subspecies and perhaps even races delicately tuned over many generations to specific conditions to be found in each of these varying aquatic environments.

No discussion with regard to indigenous forms can overlook the tremendous importance of the relationship of food, water, and cover to their maintenance. Oregon is blessed with one of the most diversified fish and wildlife resources of the continent. The extent to which water plays a prominent role in their maintenance is reflected by the great array of both terrestrial and aquatic forms typical of the peculiar ecology present across our state from west to east and north to south. The wide variation of land and water areas, along with climate and elevation, makes this possible.

With regard to big game, we have, for example, two subspecies of elk—the so-called Rocky Mountain form adapted to that part of the state east of the Cascades, and the Roosevelt elk which finds its most suitable habitat in our Coast Range.

Antelope is a species confined pretty much to the southeastern quarter of the state. Although it thrives in a relatively arid area, water is important as a part of its environmental requirements.

Our deer are represented by three subspecies—the blacktail from the crest of the Cascades west, the mule deer east of this area, and certain remnants of whitetail in two or three localized areas of both eastern and western Oregon.

Except to the extent that water is necessary in proper location but in minimal amounts for the maintenance of normal life activities, the most important contemporary function this ingredient appears to have is its use in bringing about more desirable distribution. Perhaps in a few localized areas if more water were available, it would be possible to sustain higher populations than is now the case. However, free water is not, in most instances, a limiting factor.

With regard to upland birds, both native forms and the several species which have been introduced and successfully established, water seasonally appears to be a critical factor even within the flood plain of the Willamette River. Bottlenecks in the seasonally dry areas have been overcome by the employment of small cisterns. The provision of water has made it possible to extend the range or carry higher populations of several of the so-called upland bird forms.

The several aquatic or semi-aquatic mammals, particularly among the commercially important furbearers such as the beaver, otter, and mink, have a strong dependence upon an aquatic environment. Current patterns of water use have not, except in a few instances, affected their environment. They are more effectively influenced by related water development activities such as channelizations which alter the related habitat or sufficiently change the hydraulic character of river channels to reduce the carrying capacity for certain of these species.

It is primarily with our fishery resources and with waterfowl, found in natural streams and in so-called wetland or marsh areas of the state, that massive influence has been felt. The splendid sea-run stocks of salmon and steelhead, all of our fresh-water resident fishes, and the waterfowl as well as other marsh-dependent birds have been influenced in varying degrees, but generally unfavorably. All five of the Pacific salmon as well as the coastal sea-run cutthroat trout are fishes which are extremely sensitive to changes in their environment. In addition, since about 1000 repeated introductions, a number of so-called warm-water fishes, not originally native to our state, have in varying degrees become well established in many of our waters. The fish resource represents one which is incredibly productive if afforded the proper environment and management, and water is the obvious key to their existence.

A great deal of effort and money are currently going into fishery programs with fruitful results. For example, the recent upsurge in winter runs of steelhead in the Alsea River manifests the remarkable opportunities facing us in taking advantage of biological knowledge and applying management procedures where the combination of fresh-water stream environments and oceanic feeding areas produce phenomenal yields. Our fresh-water lakes have the potential of yielding heretofore unrealized tonnages of desirable fish resources. To cite one example, last year's angling season at Diamond Lake yielded to the angler in excess of 256,000 trout, weighing about 243,000 pounds, for an annual yield of 84 pounds per surface acre.

The composite of resident, anadromous, warm-water, and coastal marine fishes represents a value inherent in our water resource not realized by the average citizen. We possess over 750 lakes and 51,000 miles of streams which are currently under varying degrees of management.

The fish and wildlife management field is developing a technology and science at a very rapid rate. The application of this knowledge presents many opportunities. However, the great challenge lies in the area of coordination between the adjudications of water for its many and necessary purposes and the recognition of all values including fisheries. A recitation of the major management and enhancement problems would be too numerous to discuss at this time. There are, however, certain basic examples which could be used to demonstrate what lies ahead of us in the field of fish and wildlife in relation to water. Part of these rest in the field of public policy and part within the innumerable and related disciplines of knowledge and technology.

First with regard to public policy. We in this state are blessed, I feel, with a fortunate organic act under which all values must be recognized and in which each recognizable value, at this point at least, has been afforded an opportunity to receive its day in court before a final water use decision is made. In my judgment each use of water to the extent that it is competitive with other legitimate demands may document its case. It fosters the concept that the development of the water resource should be so prosecuted that as new values are exploited, existing values are exposed to a minimum of damage or opportunities of both their mitigation and enhancement are recognized and utilized.

Many of our serious contemporary problems, particularly from a fishery standpoint, reflect development practices which have occurred over the past half century. It is in this aspect of reflection, identification, and analysis of existing problems that there is revealed abundant opportunity of recovering values which once existed but which have been destroyed. This would entail deep and painful policy decisions, which may or may not ever come about, in an era of more exploitive development of residual water resources. I have in mind, for example, and this has greatest significance to the fishery resource, such problems as over-appropriation of important stream systems by diversion and use of normal streamflows for important and legitimate areas of our economy. The early development of irrigation at a time when economic necessity and the lack of recognition of inherent values prevailing in a stream was not as important then as it is today.

Another example arising from early day lumbering activities was the employment of splash dams for many years on certain streams. Splash dams were brutally destructive to anadromous fish resources. It has been only in recent years that the last remaining of these once important adjuncts to timber harvest were removed from important coastal streams. As a general policy and in part because of their destructiveness to fishery values, it is, in my opinion, improbable that the use of splash dams for transportation of wood fibre from the woods will occur again.

Specific management and enhancement problems can be pretty well reduced to a few basic areas.

1. Fish passage. This involves assuring the continuation of both upstream and downstream migration of fish over physical structures constructed or diversions created in any stream system.

Suffice it to say that these are obvious problems, each individual instance having peculiarities to itself which demand study. These include not only size of the structure and protection from operating elements of that facility, but methods of passing migrants both upstream and downstream through extensive areas of slack water which represent in some instances violent alterations of the natural environment to which these fish are adapted. It has only been in most recent years that the effect of the slack water areas themselves have been recognized as a substantial problem to the movement of fish destined either to spawning grounds or to rearing areas at sea.

Some of these changes are even at this time obscure. However, such basic factors as temperature, water chemistry, changing aquatic fauna, and hydraulic characteristics have apparently in some instances had profound effects upon the successful movement of both adult and juvenile fishes.

2. The loss of spawning and rearing areas through inundation. This physical removal of necessary natural spawning areas in certain of the larger stream systems reflects net losses in the capacity of a stream system to accommodate adult spawning fish.

3. Water quality. The problems of pollution, violent changes in the character of the water environment itself, and the reduced volume of water at certain times of the year are simply examples of the numerous aspects related to the continuing problem of water quality.

4. Rough fish problem. The normal pattern of fish production in a river system, basically changed in character through impounding and creation of large expanses of slack water, is that of a gradual increase in so-called rough fish. These fish at varying rates normally usurp the productive capacity of these sections of a stream system. The rapidly developing techniques of rough fish control of the past couple decades and the adoption of this function as a routine in freshwater fisheries management are manifestations of this situation.

5. The continued reduction of natural flowing streams as a part of the angling opportunity. Here we have a question of quality to be considered in the long range planning of fisheries development of our state. Although we have an increasing amount of impoundment water to be enjoyed by the average angler, in most instances these

have been accompanied with a net loss of stream environment which is in ever increasing demand by the angling public. It is here that long range planning should recognize the importance of retaining a minimum of natural flowing streams intensively managed both for the direct utilization of the fishery resource in angling and as production areas for sea-run stocks of fish. The current "Wild River Study" of the federal government is in part responsive to this need.

Trends in Angling and Hunting

One of the criteria which can be employed in examining the trend in hunting and fishing is reflected through the issuance of hunting and angling licenses. In 1950 there were slightly over 388,000 licensed hunters and anglers in the State of Oregon. In 1963 there were about 731,000 people licensed to directly use our fish and wildlife resources, an increase of about 45 per cent. Recently we had occasion to project the probable trend in this demand into the future. Our best but most conservative estimate indicates that by 1972 we can expect a minimum of one million people in this state who will be licensed to hunt and fish.

Whether or not these projections are within the area of precise accuracy is perhaps beside the point. We can detect no factor which would indicate that interest in hunting and fishing in this state will decline over this period of time. Furthermore, by virtue of our geographical location—immediately north of the most populated state in the Union, California—and with the current popularity of emphasizing the importance of outdoor recreation in general, it is quite probable that we will be faced with an explosive demand for hunting and fishing not recognized by any of us at this point.

Contributions of OSU

Present-day fisheries and wildlife management as we know it from a professional standpoint is relatively new. Most of the basic principles and technology have evolved within the relatively short time of the past 25 years. Throughout this quarter century, there has been a continuous and close association between the Oregon Game Commission and Oregon State University.

The Department of Fish and Game Management, particularly, but also other academic disciplines on the campus have been associated with us on many of the complicated problems involved in applied management which we today carry out in the field. This contribution is reflected both through the training of the bulk of our present professional staff, who are graduates of the Fish and Game Department, and through the continuous yield of scientific and technical knowledge from OSU. It has involved such wide ranging contributions as a study of culvert design for road construction with hydraulic criteria which meet fish passage problems by the School of Engineering to a problem of parasitology in a big game herd in Veterinary Medicine. I can think of no field of current resource management in which liaison between the operating agency and the academic community is more necessary. It is for this reason that our entire Research Division is physically and officially headquartered on this campus.

Activities and Authorities of State and Federal Fish and Wildlife Agencies

Not only many governmental agencies but a number of segments of private enterprise today are directly participating in one or more phases of the state's fish and wildlife affairs. However, the direct accountability to the people of the state, except for certain migratory birds and oceanic mammals, rests specifically with the Oregon Game and Fish Commissions.

The Department of the Interior through the U. S. Fish and Wildlife Service properly has responsibility for migratory birds, whales, sea otter, and certain other elements of the oceanic fauna usually through the device of international treaties. In addition, a host of other federal agencies in varying degrees are engaged directly with us and with other states in prosecuting cooperative projects which are directly tied to the management of fish and wildlife resources. We work very closely and actively with the two major federal land management agencies—the U. S. Forest Service and the Bureau of Land Management.

With exception of the migratory groups previously mentioned, all fish and wildlife are common properties belonging to all of the people and are simply held in trust by the appropriate state agencies. This is a unique legal characteristic of fish and wildlife in North America which goes back to colonial times in our country and which is generally unlike the legal status of fish and wildlife in many other parts of the world. Legislative and judicial treatment of this question has been repeatedly enunciated throughout the history of our country.

The recent availability of federal funds as supplemental to state funds has brought about greater activity on the part of the federal establishment in this field. In addition, and I think here in part because of increasing recognition of the value of fish and wildlife as well as certain economic problems confronting water or land oriented segments of private enterprise, you have seen industry recruit trained fish and wildlife personnel. For the hydroelectric power industry, the lumber industry, and even in some segments of agriculture this has become normal procedure.

The effectiveness of a program can perhaps best be assessed by reflection on annual yields of the various categories of a resource of this type. Suffice it to say that the following trends, in my opinion, justify a great deal of optimism for the future of the fish and wildlife resource as a continuing part of the social and economic life of our great state. Using the period from 1950 through 1963, the following is indicative:

Big Game

Elk - annual yield doubled.
Deer - annual yield trippled.
Antelope - static.

In addition, California bighorn sheep and Rocky Mountain goat established.

Fisheries

With minor exceptions of certain stocks of salmon, the annual aggregate production has continued to increase. In addition, completely new resident fisheries, including new species such as the Atlantic salmon in controlled environments, have been established.

Upland Birds

Annual aggregate yield perhaps doubled, partly through careful management of species present in the state by 1950 and partly due to introduction of certain species such as the chukar partridge which is utilizing a habitat type not previously producing significant numbers of birds.

In conclusion, then, although urgent and compelling problems confront us in the enhancement of this resource and in some instances we are failing to achieve the desired improvement of a given species, the picture of the past decade or so is one of spectacularly increased opportunities and yields for hunting and fishing. These are the direct result of close cooperation with other major land and water user interests and the diligent application of research findings and scientifically proven techniques. In spite of the formidable problems, particularly within the field of water resource development confronting the fishery agencies over the next decade, I am convinced that we will continue to make gains in a gratifying way.

Presented May 13, 1964 by CURTISS M. EVERTS, Director, Pacific Northwest Water Laboratory, Division of Water Supply and Pollution Control, U. S. Public Health Service, Corvallis, Oregon.

Water Quality Control

One observer in Portland just before the turn of the century noted that sawdust floating on the surface of the Willamette river in the vicinity of the city's water supply intake in upper Portland harbor appeared to move upstream on flood tide. He wondered whether domestic sewage discharged into the river from a sewer immediately downstream followed the same path. The city had by this time already made plans to abandon the river as a source of water supply and it is well that they did for it was not until almost 50 years later that treatment of sewage was provided by Portland and by neighboring communities upstream.

These upstream cities also had their problems for the State Board of Health, in reports issued shortly after it came into being in 1903, warned of the dangers of any city using the river as a source of water supply as long as untreated sewage was being discharged into the stream above their water supply intakes.

Almost three decades passed, however, before the first factual information was obtained on pollution in the lower Willamette. This showed what most conservationists already knew; that the stream was almost devoid of oxygen during the summer season and that it harbored a bacterial load that could only exist as a result of its use as a receptacle for most of the sewage from cities along the lower river. By this time the valuable fall run of salmon had disappeared, recreational use of these waters had become a hazard to health, and most cities had abandoned the river as a source of water supply or were making plans to do so.

While the job of cleansing the river of its filth had proceeded with rapid strides, additional reductions in the amount of sewage and other wastes entering the harbor and in upstream industrial waste loadings are essential if desired objectives are to be attained.

This is only one river but failure on the part of its stewards to recognize the importance of this resource and husband it properly is a lesson that can well be remembered over and over again for other streams throughout the state and nation.

How do the waters of such an important river become so defiled, and what measures have been undertaken to prevent this condition from recurring in Oregon in the future? These are subjects that I should like to discuss with you this afternoon.

Water as one of the essential elements for survival has many important uses. These include:

1. Water supply for domestic, industrial, and agricultural use.

2. A resource to sustain fish, shellfish and other aquatic life, and to support commercial and sports fishing.

3. Recreation, such as swimming, water skiing, boating, camping, and hunting.

4. Water power and navigation.

Almost any substance added to water is a potential pollutant. If, for example, the commonly known substance sodium chloride is sufficiently concentrated it can adversely affect one or more uses of the body of water into which it is discharged. Where concentrations are low or where sufficient dilution takes place, this same substance may be relatively harmless. Pollution could be defined, therefore, as any impairment of the usefulness of natural waters.

Substances that pollute water may be classified into nine general categories, each of which is somewhat unique in its pollutional characteristics and effects. These categories are as follows:

OXYGEN CONSUMING WASTES - Such as the traditional organic wastes contributed by domestic sewage and industrial wastes of plant and animal origin. These substances are subject to biological degradation and when oxygen is present it will be consumed whether it is supplied artificially as in a waste treatment process or naturally as dissolved in a stream. Since fish and aquatic life depend on dissolved oxygen, oxygen demanding wastes are a detriment to their environment.

INRECTIOUS AGENTS - Consist of the pathogenic or disease producing bacteria, protozoa, and viruses carried into surface and underground water by sewage or by certain industrial wastes such as those from tanning and meat processing plants. Water contaminated with such wastes is unsafe for human consumption, and for swimming and other water contact sports. Shellfish taken from such waters are also rendered unsafe for human consumption.

PLANT NUTRIENTS - These are substances which support and stimulate the growth of aquatic plant life. Nitrogen and phosphorus are the two principal minerals involved but other trace elements are important. These minerals are usually present in small amounts in natural waters, but much larger amounts are contributed by sewage, certain industrial wastes and drainage from fertilized lands. Nutrients are fertilizers and stimulate intensive and extensive growths of water plants which interfere with water treatment processes, and cause unpleasant and disagreeable tastes and odors. When these plants die and decay they cause secondary oxygen consuming and taste-odor producing pollution.

SYNTHETIC ORGANIC CHEMICALS - Are the relatively new pollutants resulting from new chemical technology. They include detergents, all the new synthetic organic pesticides, solvents, synthetic industrial chemicals of a wide variety and the wastes from their manufacture. As pullutants they are characterized by their toxicity or potential toxicity to fish and aquatic life and possibly to humans, their extreme stability and persistence in the water environment, their resistance to removal by conventional water and waste treatment processes, their ability to cause taste and odors, and their interference with other water uses.

ORGANIC CHEMICALS AND MINERAL SUBSTANCES - Include a wide variety of mineral and inorganic chemical wastes from mining and manufacturing processes, oil field operations, agricultural practices, and natural sources. They may interfere with natural stream purification, destroy fish and aquatic life, cause excessive hardness of water, corrode steel and concrete structures, increase maintenance costs for commercial and recreational watercraft and increase the cost of water treatment. Certain of the metals and their compounds, such as lead and chromium, are known to be toxic.

SEDIMENTS - Are generally considered to be those inorganic particles of soils, sands and mineral matters washed from the land or from the hard surfaced areas of communities. They fill stream channels and reservoirs, erode power turbines, blanket nests, spawn and food supplies of fish, reduce sunlight penetration of waters required for green aquatic plants to produce the oxygen necessary for normal stream balances.

RADIOACTIVE SUBSTANCES - Result from mining and processing of radioactive ores; from the use of refined radioactive materials in power reactors and for medical, industrial and research purposes and from fall-out from nuclear weapons testing. Since radiation is cumulative in humans, controls must be provided for the total exposure potential in the human environment–from water, food, air, occupation, and medical treatment.

HEAT - Tremendous volumes of water are used for cooling purposes by steam electric power plants, steel mills, petroleum refineries and other industries. Most of this water is returned with added heat to the surface water body from which it came. Increased temperatures reduce the solubility of oxygen in water, are detrimental to fish and aquatic life, and reduce the usefulness of the water for further cooling purposes.

OIL AND GREASE - These are the petroleum oils, and the animal and vegetable fats and greases from both domestic sewage and industrial wastes originating from agencies engaged in the production, transportation, handling and use of oils. Such wastes spoil beaches, destroy or injure waterfowl, foul boats and fishing gear, damage marine flora and fauna, create fire hazards in harbors, and cause taste or odors in water supplies.

Traditionally, domestic sewage and industrial waste waters have been the principal causes of pollution. In recent years, however, more attention is directed to both the existing and potential effects of storm water runoff, irrigation return flows, radionuclides, agricultural chemicals, wastes from timber processing, and the construction of highways and dams, as well as some of the natural phenomena that result in conditions detrimental to surface and underground waters.

To enumerate the characteristics of each waste water responsible for pollution would be a time-consuming task and would result in a discussion too detailed and lengthy for the purposes of this seminar. Sufficient to say, therefore, that pollution in surface waters of the state result from the discharge thereto of waste waters from the following sources:

Domestic sewage

Industrial waste waters from:
- Manufacture of pulp and paper
- Food processing
  - Fruits and vegetables
  - Meat
  - Milk
  - Poultry
- Tanning
- Mining
  - Minerals
  - Gravel and sand
- Manufacture of chemical products
- Lumbering
  - Timber harvesting
  - Manufacturing

Agriculture
- Erosion
- Irrigation
- Chemicals
  - Pesticides
  - Fertilizers

Construction
- Highways
- Housing development
- Dams

Transportation
- Wastes from vessels
- Accidental spills of chemicals in transit by land or water

Natural
- Gonyaulex catenella in shellfish
- Arsenic in ground water

Pollution has no respect for the boundaries of political subdivisions. Lack of attention in the past has caused this whole matter to become a national problem, and its solution generates the need for action at all levels. This results in a sharing of responsibility along broad lines as follows:

The State has the primary responsibility for water pollution control. The agency in Oregon is the State Sanitary Authority. It establishes standards for water quality within its area of jurisdiction, conducts surveys and investigations, collects and evaluates data, provides technical assistance to local government and industry, supports research, and applies its laws and regulations, including enforcements.

Local governments construct and operate municipal sewage treatment works, provide consultation and technical assistance to the industries they serve and enforce their own regulations and ordinances.

Industries are responsible for control of their own pollution. They institute inplant measures for waste reduction, and construct and operate waste treatment or disposal facilities if they are separate from a municipal sewer system. They conduct research to develop or improve waste treatment methods or to reduce or eliminate pollutants.

Universities are responsible for conducting research and training scientific manpower needed by other jurisdictions. They also provide technical services and consultation.

The Federal Government has a leadership role to play in water pollution control. It supports and supplements the programs of the other four levels. It conducts research and investigations, collects and analyzes data on a nationwide basis, and provides technical assistance and training to State and local governments and to industries, including training. It develops comprehensive water supply and pollution control programs and coordinates these with the States and with the water resources programs of other federal agencies. It carries out the enforcement provisions of the Federal Water Pollution Control Act. It provides grants for State program development, for incentives to municipalities for the construction of sewage treatment works, and for research, demonstrations, and training.

While the fundamentals of these program responsibilities have remained essentially unchanged, increases in urban population, new and expanding industry and the development of new chemical products have required the initiation of more sophisticated techniques and the adoption of stronger laws. More emphasis is now being placed on research, special studies, and enforcement.

For example, in the early stages of a control program, it is essential to recruit and train a highly qualified technical staff to discharge both legal and administrative responsibilities. Today's problems of water quality management can become quite complicated with conflicts of interest in the areas of both quality and quantity. This has made it increasingly necessary to assemble personnel from almost every scientific resource and can involve a whole regimen of disciplines from those trained in computer techniques to those skilled in resolving socio-economic problems to aid in reaching reasonable and equitable solutions.

Unless those engaged in pollution control activities are backed up by competent laboratory support for field studies, demonstrations, and research, the whole program will suffer. No longer is it sufficient to rely entirely on gravimetric and colormetric chemical determinations or on biochemical analyses for the data required to undertake a decisive program. To our already formidable search list of physical, chemical, and bacteriological contaminants that we have named as potential pollutants, we now add such elements as plankton population, synthetic organic chemicals, radionuclides, and trace amounts of metals and other elements. The array of exotic equipment for such analyses and the assembly of a staff competent to operate it are enough to stagger the imagination of the water pollution control pioneer of 30 years ago.

Any program for water quality control should be based on a comprehensive plan which takes into account all beneficial water uses and provides for the treatment of wastes and the regulation of streams for water quality control to meet both present and future requirements.

While many of the early plans were developed on the basis of a river basin system, more often than not the basin was small and frequently tributary to a stream not within the jurisdiction of the State control agency. Since it was unlikely that an acceptable plan would evolve from a number of unrelated programs developed on a local or subregional basis, it soon became evident that a correlated plan was needed which included an entire river system. This meant that a cooperative working relationship had to be established with other agencies, both State and Federal, having primary interests in water resources management. This is being achieved by the creation of State and Interstate Committees or Commissions, Interstate Compacts, and by the Federal agencies acting under their respective statutory responsibilities. Under such an arrangement, a plan can be devised which recognizes the effect that all watershed activities, including water resource development, will have on the quantity and quality of water in a river basin. It develops compatible and cooperative working relationships, and finally if the plan's authors are sincere, the plan can be made to work.

Once a plan for pollution control has been devised, the next step is to inform the public of the nature and extent of the problems, what is being done and what needs to be done to correct them, and what legislative and fiscal support is required to accomplish desired objectives. Originally only the press and radio were available to assist in this marshaling of public support. Now a rather formidable ally, television, supports the effort on both a local and national basis.

There are always problems in water quality control for which current technical knowledge does not provide the answers. Initiation or support of research in these areas has become an important part of the control effort. Advanced waste treatment, removal of refractories, the development of mathematical models, the refinement of existing laboratory techniques to provide more rapid analyses methods, and efficient and effective automatic monitoring and telemetering devices are only a few of the tools that we must provide for space age water pollution control programs.

And finally, we come to the matter of enforcement. On occasions a point is reached in which enforcement proceedings must be initiated to obtain correction. Statutes adopted a quarter of a century ago were quite adequate for their time. Improvements, advances, and changes have occureed in the judiciary just as they have in the executive arm of government. The competent water pollution control administrator must be prepared, therefore, to have the statutes under which he operates brought up-to-date from time to time to meet these changing conditions if he expects support from the courts. For example, administrative hearings and orders supplemented by the threat of court action formerly sufficed to gain abatement of pollution. In today's rapidly moving industrial and urban environment, provision must be made in the law for a water pollution control agency to move decisively to stop promptly the discharge of any waste water that is inimical to human health, that would destroy animal or aquatic life, or otherwise seriously impair water for other important uses.

Of particular significance in water quality control are the provisions of the Water Supply Act of 1958 and the 1961 amendments to the Federal Water Pollution Control Act. Both the Corps of Engineers and the Bureau of Reclamation are authorized under the Water Supply

Act to plan for anticipated future municipal and industrial water supply requirements in any reservoir they may propose for construction.

Provision is made in the 1961 amendments to the Water Pollution Control Act that, "in the survey or planning of any reservoir by the Corps of Engineers, Bureau of Reclamation, or other Federal Agency, consideration shall be given to inclusion of storage for regulation of stream flow for the purposes of water quality control" and that "the need for and value of storage for this purpose shall be determined by these agencies with the advice of the Secretary of Health, Education and Welfare, and his views shall be set forth in any report or presentation to the Congress proposing authorization or construction of any reservoir" including storage for low flow augmentation.

In 1947, long before either of these acts was adopted, provision was being made for both water supply and stream flow regulation for pollution abatement in some of the Willamette river basin projects proposed by the Corps of Engineers. Natural flow in the river during the late summer and early fall reached lows of 2,500 cubic feet per second at Salem. Wastes discharged into the stream included untreated domestic sewage and industrial waste waters from pulp and paper production, meat packing, and food processing. To further complicate the problem, low flows coincided with the peak of food canning operations. Early estimates anticipated that storage releases from the proposed reservoirs to increase the flow at Salem to 6,500 cubic feet per second would provide dilution for existing and future wastes as well as supply a substantial amount of additional dissolved oxygen. At the same time it was also anticipated that this additional flow would provide sufficient dilution to permit cities in the basin to use primary sewage treatment instead of the secondary treatment facilities that would otherwise have been required.

All of the storage projects have not yet been completed, but the releases that have been made from storage at Cottage Grove, Dorena Lookout Point and Detroit dams have sometimes supplied as much as 40 to 50 per cent of the Willamette's flow during the dry season. While these additional flows have proven most helpful, a stable minimum of 6,500 cfs. has not yet been achieved at Salem and even though it had, other unanticipated factors have prevented the original program from achieving the objective of maintaining at least 5.0 parts per million of dissolved oxygen throughout Portland harbor.

Significant increases have occurred in industrial waste loads due to expansion of the pulp and paper, and food processing industries. This, coupled with a formidable increase in urban population, and extensive use of the river for every conceivable form of water-based recreation, has required a complete re-evaluation of the waste treatment-stream flow regulation relationships. It is now reliably estimated that even when flow regulation has provided the 6,500 cfs at Salem, a reduction of at least 85 per cent in all waste loads, domestic and industrial, will be required to meet established water quality standards in the lower reaches of the Willamette River.

In the near future an even greater effort will be required. Our technical knowledge in the field of waste water treatment has not reached a point where removal of all pollutants is economically feasible. The treatment or disposal of both domestic sewage and industrial waste waters must be programmed, therefore, to remove as much as possible of the pollutants they contain. During this interim period when new waste treatment methods are being explored, stream flow regulation will be of great assistance as an alternate means of water quality control. It cannot be looked upon or accepted, however, as a substitute for adequate treatment of sewage and industrial wastes.

In spite of existing scientific resources, there are still areas in which we do not possess sufficient knowledge of the behavior of some pollutants, or the characteristics of others, to intelligently assess their importance. This is particularly true of some of the synthetic organic pesticides. Our colleagues at the colleges and universities have been exploring with us some of these fundamental problems of water quality control for a good many years. The product of these efforts has been a valuable contribution to the art and has provided some of the guide lines now used by our profession. There remains, however, a great need to translate some of this research into useful practice through the media of demonstrations, field studies or pilot plants. Research under field conditions is also needed to complement our laboratory and field activities as well as the work of others.

As part of the Federal effort in this program, the Congress in 1961 authorized the Department of Health, Education, and Welfare to establish field laboratories and research facilities to conduct research, investigations, experiments, field demonstrations and studies, and training relating to the prevention and control of water pollution. One of these laboratories is to be located in each of the following geographic areas, Northeast, Middle Atlantic, Southeast, Midwest, Southwest, Pacific Northwest, and Alaska. Construction of the laboratory authorized for the Pacific Northwest will begin in July of this year on the campus of Oregon State University, Corvallis. This facility will serve the six state areas of Idaho, Montana, Oregon, Utah, Washington, and Wyoming. In addition, the laboratory is to serve California and Nevada to the degree necessary and possible.

The Pacific Northwest Water Laboratory will consist of a two-story reinforced concrete structure having some 50,000 square feet of floor space. It will contain modern laboratories in chemistry, microbiology, radiation-physics, biology, and engineering which will be especially equipped to tackle the job of water pollution control research in this region. This building has been planned to house an ultimate staff of 150 chemists, physicists, microbiologists, aquatic biologists, engineers, and other scientific and supporting personnel whose primary mission will be to untangle the thorny problems of water pollution control in the Pacific Northwest so that everyone can proceed with the "clean up" effort at a much more rapid pace.

We expect that most of our work will consist of field studies and investigations with the laboratory serving as a strong right arm to support this effort. In this way, we hope to develop a better knowledge and understanding of the characteristics and behavior of natural and man-made pollutants under the physical, chemical, and biological conditions that exist in the region's inland, coastal and estuarial waters. Some of the areas we expect to explore are: (1) the effects of watershed activities and multiple purpose impoundments on water quality in the Pacific Northwest; (2) problems of waste disposal into estuarine and coastal waters; (3) requirements for the protection of water resources from industrial wastes; and (4) the control of artificial eutrophication of surface waters. The Willamette river basin, among others, will provide an ideal setting for such an undertaking.

To provide these services, the laboratory staff will initially be organized into major units of chemistry-physics, biology, microbiology, and engineering. From these units, teams or groups will be established with representation from as many scientific, engineering, and socio-economic disciplines as may be required to mount a multidisciplinary attack on any problem we seek to solve. It is anticipated that this same procedure will be used to discharge our responsibilities for demonstrations and pilot plant studies, for training and to fill requests for technical assistance.

In keeping with the philosophy of a strong field research effort, it is anticipated that some of the laboratory staff will be located at field study sites throughout the area. For example, when Oregon State University completes its Marine Sciences Center at Newport, we expect to initially locate a few key staff members in that city to cooperate with the university staff in studies of waste disposal in coastal waters and tidal estuaries. Subsequently, the staff at this station would be increased commensurate with the field studies and research to be done. Field studies will be initiated in other appropriate problem areas as the need develops.

Not all of the work can or will be done by the laboratory. There are many basic research problems that we feel can essentially be explored better by others. Moreover, the pressure for solutions to problems directly associated with our Federal responsibilities are so great that we could not hope to undertake all of the fundamental research that universities are so well qualified to do. Consequently, by continuing and extending our present program of research grants and research contracts, the Public Health Service hopes to continue researching the neglected areas as rapidly as facilities and manpower are available.

Research will be but one activity of the Public Health Service's Corvallis Laboratory. As a field facility, it will be our responsibility to provide technical assistance and training in the areas of competence we develop and to initiate demonstrations and pilot plant studies to translate basic research knowledge into useful practice. We will also furnish such support as may be required for the discharge of other Public Health Service responsibilities in water pollution control, such as the water pollution control surveillance system, comprehensive planning for river basin development and enforcement.

An extremely important function of the laboratory will be to provide training opportunities designed to meet the needs of the Pacific Northwest. These will probably fall into several categories.

Initially, short courses on water quality control, similar to those now offered at the Taft Sanitary Engineering Center in Cincinnati, will be developed covering subjects applicable to this region. Specialized training in specific areas of applicant interest or in new procedures may also be available on an individual or group basis. As new techniques and procedures are developed, they will be promptly shared with other agencies, and with industry.

One of the most exciting training possibilities lies in our plans to make the laboratory facilities available to graduate students from the Pacific Northwest colleges and universities who wish to undertake their masters or doctoral research work in areas allied with water pollution control. This same opportunity may be afforded others whose qualifications and interest in the field would enable them to make a worthwhile contribution to the research effort.

It is fortunate indeed that provision was made to locate these laboratories near institutions of higher learning in which graduate training in water pollution control research might be carried out. The opportunities for complementary research activities, for training, and for the exchange of scientific and technical competencies are unlimited. When the Pacific Northwest Water Laboratory becomes functional, every effort will be made to extend this partnership throughout the entire area we serve.

Finally, the symposia have been permanently transferred to the Pacific Northwest Water Laboratory, and depending on progress made, will be conducted annually or semi-annually in the future. In this fashion we hope to keep abreast of developments and to continually evaluate critical research needs so that we may fulfill our share of the responsibility for making water safe and suitable for all beneficial uses.

It may appear to many of you that reasonably good progress has been made in the control of water pollution, and this is true. On the other hand, in spite of everything that has been done, new problems, the need for an accelerated research and training effort, and the almost daily requests for technical assistance coupled with insufficient support are a frustrating experience for those who dare to meet the challenge of water quality control with the zeal and fervor it deserves. The speed with which these regional objectives are attained will depend upon the ability of State, and Interstate agencies, and the Federal government to provide a sufficient staff of competent engineers, scientists and administrators who can be dedicated to the task of providing a supply of water suitable for all beneficial uses.

Presented May 20, 1964 by W. H. STEWART, Chief of Basin Planning Branch, Portland District, U. S. Army Corps of Engineers, Portland, Oregon.

Flood Control, Drainage, and Erosion

My talk will cover most of the points listed by Mr. Karr in the seminar announcement, but in a slightly different order. I will discuss causes of floods and flood damages; the types of solutions available, with some examples; the position that flood control seems to occupy in the water resource development field; and some of the conflicts and opportunities inherent in flood control activities. I will emphasize the need for cooperation and coordination in planning for flood control.

The basis for a discussion of flood control, drainage, and erosion must be a definition of flooding and the causes and effects of flooding. One definition of flooding can be stated as follows: "The occasional occurrence of conditions under which runoff from a watershed utilizes more of its traditional waterway than the usual and well-defined permanent stream channels."

In order to accept that definition, we must look at the annual sequence of precipitation —the cause of runoff — and the overall runoff picture. Willamette River Basin is a good example. It has an annual dry season, generally June through September, during which only about 10 per cent of its average annual precipitation occurs. It has an annual season of heavy precipitation, generally November through February, when about 60 per cent of its annual precipitation can be expected to occur. October and March through May are transition periods between the wet and dry seasons. The normal runoff pattern coincides closely with the seasonal precipitation pattern — maximum streamflows during the wet season and minimum flows in the dry season.

During the years before the white man came to the valley, the streams used as much waterway as was appropriate to the runoff — wide floodways in the winter and smaller permanent channels during the summer. There was available then a total channel, or flood plain, adequate for whatever runoff might occur. A part of that channel was continuously used. A much larger part was flood plain, covered with grass and forest and used for runoff only as necessary; it was available most of the year for use by wild game and the red man. The occasional inundation of part or all of the total channel beyond the permanent streambed was flooding—caused by a combination of meteorologic, hydrologic, and topographic conditions which produced runoff in excess of the capacity of the permanent channels.

Conditions are much the same today—with one major exception. The normal runoff pattern of the basin still requires the continuous availability of a system of permanent channels plus the periodic availability of additional capacity to carry runoff from storms. The major difference is that since the first settlers entered the valley, man has been encroaching on the waterway. Flooding and flood damages have become a matter for concern. Wild game, the Indians and their lodges—all of these could and did move out of the waterway when it was needed for flood runoff. They could stay out until flood stages receded and the land had drained. If they suffered damage, it was not of a nature or extent to cause them to decrease in numbers or to leave the valley. The flood plain was used by them but in a manner consistent with the normal runoff pattern. If runoff from major storms eroded banks and carved new channels, it was not then flood damage—it was part of the ages-long process of shaping Willamette Valley as the first settlers found it.

With the settlers came changes—changes that have not yet run their course. The permanent stream channels were the first main avenues of transportation. Homes, communities, towns, and cities developed along those transportation routes—in the flood plain. As land transportation developed, roads and railroads were constructed in and across the flood plain. So, too, were farm homes and buildings. None of these developments were readily movable. There was no longer the flexibility in which joint use of the flood plain by runoff and man was compatible. Thus, there were flood damages—caused by man's permanent invasion of an area suited for only transient or periodic use. As time has gone on, flood plain lands—runoff waterway areas—have been further invaded and developed until not only inundation and ponding of water but also erosion—the natural shaping of the land—causes major damage to man and his works.

Before the first settler came, periodic inundation of flood plain lands, ponding and slow drainage on some of those lands, and the natural process of erosion and valley shaping were not matters of concern. Now they are major problems.

Methods of Preventing Flood Damage

Several methods are available for prevention of flood damage. Each has advantages and disadvantages. Whenever a flood problem is to be solved, we must select a solution with a view to the needs of the area involved, so as to get the benefits of flood control with a minimum of disadvantages—or, preferably, in a way which will be of advantage to other interests.

1. The simplest method of preventing flood damages probably would have been to stay out of the flood plain. Even today it would be possible to get out of the flood plain—but totally impracticable! It appears both possible and practicable, however, to limit flood damage by regulating the future use and development of flood plain. The suburbs of many cities—and even whole new residential communities—are developing into the flood plain. We can only assume that such development is occurring because of lack of knowledge or understanding that the flood plain is a part of the stream system, or a lack of knowledge as to the extent of the flood plain. In some cases, the construction of storage reservoirs and other flood-control works may have led to the development of a false sense of security.

   Where developments in the flood plain exist, particularly residences, industries, and related improvements, removal is generally out of the question because of costs. There is, however, much relatively undeveloped flood plain on which it may be practical to restrict or regulate development.

   The power to adopt and enforce flood plain regulation—flood plain zoning—lies with local governing bodies. Cities and counties, possibly even states, can adopt and enforce zoning ordinances and regulations. To do so, they must know the extent of the flood plain and the frequency of flooding.

   Section 206 of the 1960 Flood Control Act authorizes the Corps of Engineers, at the request of a responsible local governmental unit, to make studies and prepare maps and data to show the extent of a flood plain, the frequency of flooding, and the degree of hazard involved in using the flood plain. Such a study now is being made for Lane County. Also, the Metropolitan Planning Commission is about to publish a report containing flood data for Tualatin River Basin. Decisions as to how and to what extent to use the resulting data will be the responsibility of the two counties and the cities and communities therein.

2. A second method of preventing flood damage is to increase permanent channel capacity. This can be done by clearing, straightening, deepening, leveeing, or a combination of those items. Work of this nature is for a single purpose—reduction of overflow damage—and may result in detriment to other interests. For example, channel deepening and straightening may increase velocity of flow enough to cause erosion and land loss which did not exist before. It may also be highly detrimental to fish and wildlife, as well as to agriculture, because of overdrainage and lowering of water tables. It has the advantages of relatively low cost and ease of accomplishment. It can be done by individuals, groups, local governments, or the Federal Government, depending on the size of stream and other conditions involved. In many cases, if all related factors are considered, some means of increasing channel capacity can be shown to be a proper approach to the prevention of flood damages, either through prevention of flooding or through drainage—more rapid removal of accumulated runoff.

3. A third method of preventing one phase of flood damage is control of bank erosion. This is a single-purpose approach, which does not directly reduce flooding, but which acts to prevent horizontal movement of the permanent stream channels. In that it modifies the natural process of valley forming, its total effect may not be known for years to come. To date, however, it has proven to be beneficial to the adjacent landowner and generally nondamaging to other interests. Because of the cost of reasonably permanent bank protection facilities, such work usually is done by the Federal Government or a State agency.

4. A fourth method, and one which can reduce inundation, drainage, and erosion problems, is to reduce or regulate flood runoff. Our first opportunity would be to regulate precipitation, which is the source of runoff. To go to the source, we would have to be able to modify the timing and/or areal distribution of precipitation. While study and experimentation are going on in that field, it does not appear to offer an immediate practicable solution to the problem. In addition to questions as to ability to effect any

major modification in the precipitation pattern, there are questions of overall physical effects and the possibility of major legal problems of local, national, or even international scope.

Once the precipitation has occurred, we must work on the ground or in the streams. Two tried and proven methods of reducing or regulating runoff are watershed management and reservoir storage.

Watershed management can be accomplished at every level from the small individual tract of land up to a total watershed or a National Forest embracing several watersheds. It includes preservation, modification, and improvement of vegetative cover; land treatment by contouring, ditching, and check dam construction; and a multitude of related items. It has been a focal point of widespread and vociferous discussion as to its relative merits, particularly as compared to major storage reservoirs. That discussion apparently has ended in general agreement that watershed management is an effective tool—one of several tools required for the overall job of water resource control and development. Most Federal watershed management activities have been under the jurisdiction of the Department of Agriculture, particularly through the Public Law 566 and related programs, which combine the abilities and skills of Federal and local levels to do the job on both Federal and private lands. The Department of Interior's Bureau of Land Management is taking an increasing part in improved watershed management and interest and activities along that line seem to be increasing at all levels. I repeat—it is one of a set of essential and generally compatible tools to do the job of flood control and water resource development.

Reservoir storage for flood control includes everything from the beaver dam on the upper watershed to the individually or group-constructed small reservoir, such as are being constructed under the Public Law 566 program, to the major reservoirs such as Detroit, Lookout Point, and Cougar in the Corps of Engineers' Willamette Basin Project. Of the man-made reservoirs, some were planned for single purposes, and some as multiple-purpose projects. Regardless of how or why they were planned, they usually serve other incidental purposes or have a significant effect on other resources or other phases of water resource control and use. For that reason we must come to the conclusion that the best—sometimes the only—way to consider or achieve flood control, drainage, and erosion control is as a part of a larger picture. Before discussing that larger picture, I have some data on flood control effect of existing projects.

Project Effects on Floods

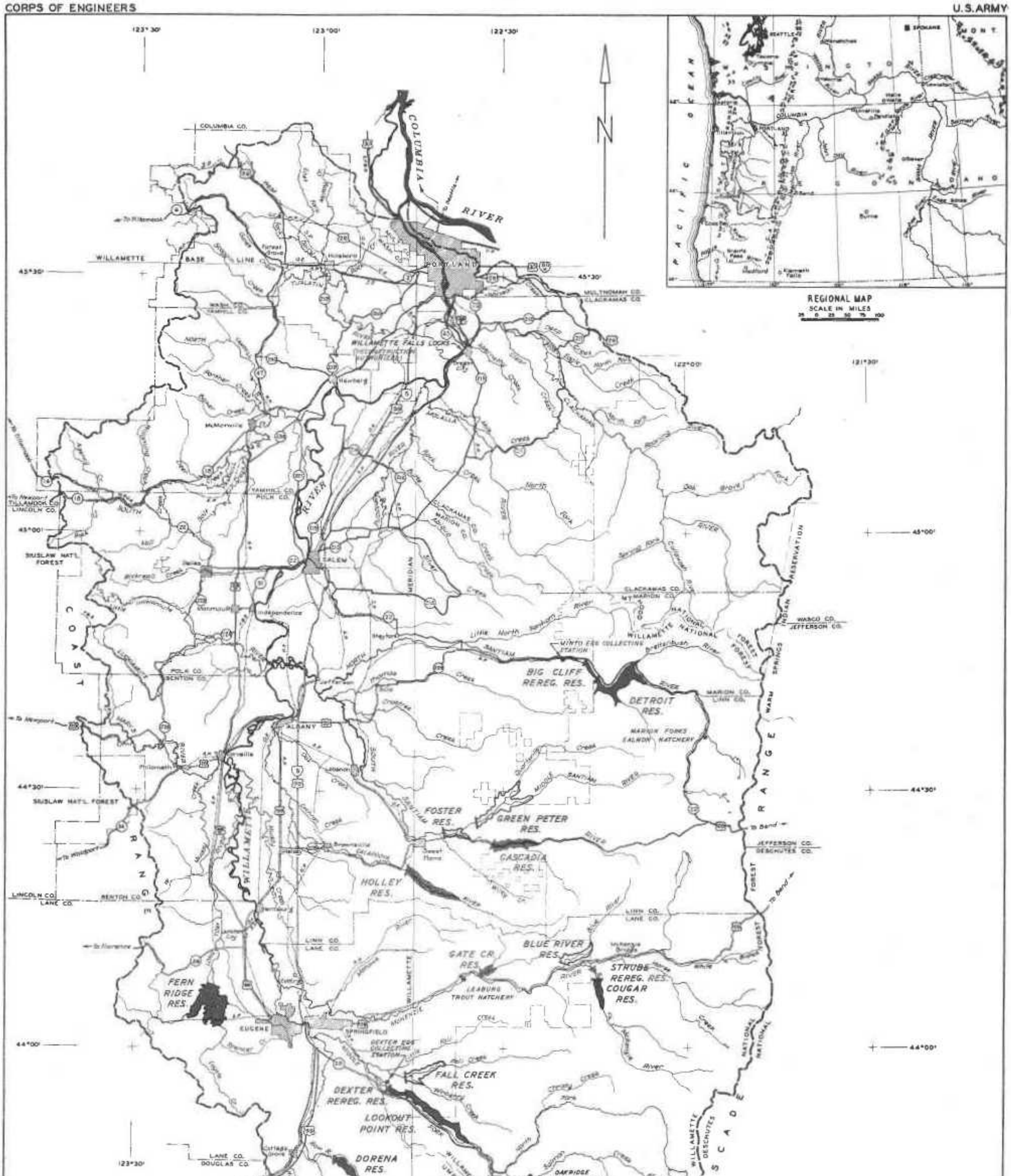
Projects to reduce flood stages, increase channel capacity, and prevent erosion can do much to reduce flood damages. The Willamette Basin system of multiple-purpose reservoirs, shown on the next page, will accomplish major reductions in flood stages and frequency of recurrence. The table, page 58, shows the bankful and major flood stage at locations from Eugene to Salem, and on McKenzie and Santiam rivers. It also shows, for the 1861, 1943, and 1955 floods, the natural stage (stage had no reservoirs been in operation), the controlled stage for such a flood with all presently authorized Willamette River Basin reservoirs in operation and the resulting stage reduction. It is interesting to note that the regulated stages shown generally exceed bankfull stage, and, in some cases, exceed major flood stage. Thus, there will remain a substantial flood problem to be solved. As of 1948, it was shown in the Corps' report published as House Document 531, 81st, 2nd, that based on the 1948 price levels and developments forecast for 1970, an average annual Willamette Valley flood damage of $12,000,000 under natural conditions would be reduced by about $10,000,000 by reservoirs and related works. Incidentally, rapid development in the flood plain probably has resulted in the existence of more residual damage than was then anticipated. Zoning or flood plain regulation could limit further development of damage potential.

The shading on the map on page 59 shows the area inundated in 1943, to the east and downstream from Corvallis. With the limited storage then available (Cottage Grove and Fern Ridge Reservoirs) such a degree of flooding could be expected to recur once in about 20 years, on an average. With the entire authorized storage plan in operation, this extent of inundation can be expected to occur only once in more than 100 years.

So far as bank erosion is concerned, there are now about 75 miles of bank revetment constructed at about 171 locations. A good example of bank revetment is the work along Willamette River and U. S. Highway 20 immediately north of Corvallis.

Resource Conservation and Development

The Willamette Basin projects are an example of flood control by projects for resource conservation and development. Even there,



WILLAMETTE RIVER BASIN
RESERVOIR SYSTEM
CORPS OF ENGINEER PROJECTS

SCALE IN MILES

U.S. ARMY ENGINEER DISTRICT, PORTLAND
CORPS OF ENGINEERS

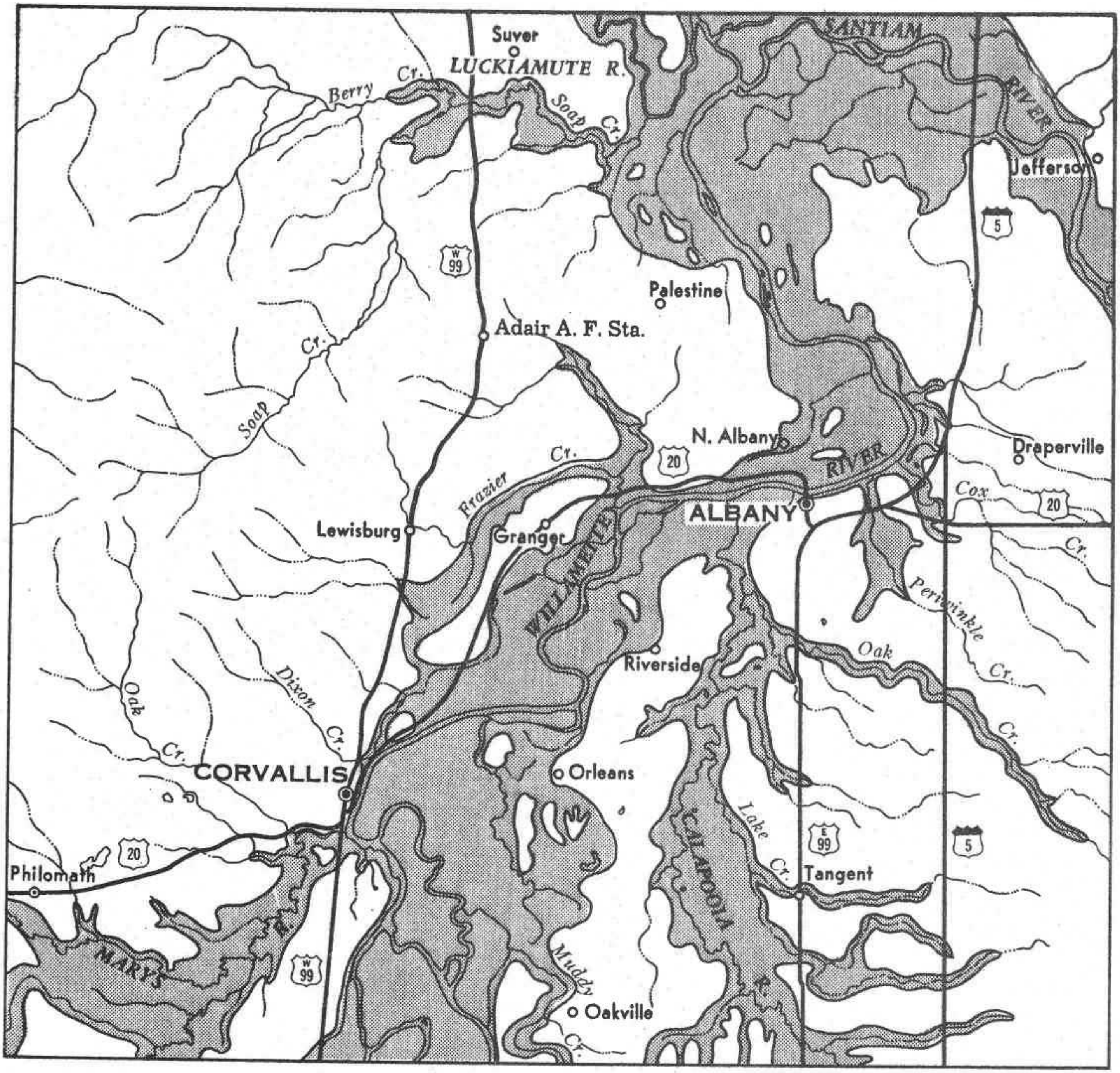
APRIL 1964

FLOOD STAGE REDUCTIONS - MAJOR FLOODS
WILLAMETTE RIVER BASIN

April 1964

Item	Willamette River					McKenzie R.	Santiam R.
	Eugene	Harrisburg	Corvallis	Albany	Salem	Coburg	Jefferson
Bankfull stage, feet	20.2	10.0	16.0	16.5	16.0	8.0	13.0
Major flood, feet	29.0	17.0	26.0	27.0	25.0	13.0	20.0
1861 FLOOD							
Natural stage, feet	37.2	20.5	32.2	36.0	39.2	18.2	25.0
Regulated stage, feet	23.8	17.4	25.9	27.6	28.0	14.2	19.7
Stage reduction, feet	13.4	3.1	6.3	8.4	11.2	4.0	5.3
1890 FLOOD							
Natural stage, feet	36.0	20.1	30.7	33.9	36.5	17.8	23.4
Regulated stage, feet	21.9	16.4	24.6	26.0	24.8	13.9	19.6
Stage reduction, feet	14.1	3.7	6.1	7.9	11.7	3.9	3.8
1943 FLOOD							
Natural stage, feet	31.5	19.1	28.5	31.0	29.4	16.1	21.2
Regulated stage, feet	18.9	13.9	22.6	23.4	20.5	11.7	16.4
Stage reduction, feet	12.6	5.2	5.9	7.6	8.9	4.4	4.8
1945 FLOOD							
Natural stage, feet	35.0	19.7	28.1	30.4	26.9	17.4	22.6
Regulated stage, feet	21.3	16.5	22.4	23.2	16.4	13.8	18.3
Stage reduction, feet	14.7	3.2	5.7	7.2	10.5	3.6	4.3
1955 FLOOD							
Natural stage, feet	32.8	19.3	28.7	31.2	29.5	16.3	22.1
Regulated stage, feet	21.3	14.8	23.2	24.2	18.9	13.0	17.5
Stage reduction, feet	11.5	4.5	5.5	7.0	10.6	3.3	4.6
1961 FLOOD							
Natural stage, feet	33.0	19.2	28.4	30.9	29.6	16.1	23.6
Regulated stage, feet	22.9	15.7	23.7	24.9	19.5	13.7	19.9
Stage reduction, feet	10.1	3.5	4.7	6.0	10.1	2.4	3.7

Note: Based on present river conditions with 14 reservoirs in operation.



FLOOD OF JANUARY 1943

however, we find opportunity for improvement. Some background information will show why that is true. Up to the time the first settlers arrived, Nature's plan of resource conservation apparently was adequate. There was generally enough of everything that the Indian tribes needed, and they were not so numerous or so confined and controlled by traditions, developments, and worldly goods as to be unable to adjust to Nature's regime. The first settlers found too much of some things—flood waters, trees, animals—but enough land, fish, waters, and other necessities so that they could use the valley without major problems.

Today we have a Willamette Basin population in excess of 1,200,000 people and a projected year 2010 population of about three times that many. Our needs for flood control are great and rapidly growing. But so are our needs to conserve and develop water and related resources for the best use of a majority of our people. Already, in the opinion of many, we have reduced to too little the remainder of some of our resources—fish, wildlife, scenic and recreational opportunities. If we continue with single-purpose development—flood control alone, power alone, industry alone, or any of a multitude of others—we will further reduce, or even possibly eliminate, the extent and usability of some resources.

On the other hand, proper planning for resource conservation and development can give us flood control as part of a package including many other benefits, even enhancement and increase in some or our renewable resources. We can't expect to reach a Utopian state in which there are no floods, all the water that could be used for any purpose by any person in any place, all the hydro-electric development to satisfy ultimate power demands, or enough fish and wildlife to make us all capable of emulating Isaak Walton or Nimrod. We can hope and strive to have some of all those things—enough of each to provide the maximum overall benefit to the general public. Even though that day may be far in the future, we can and must plan for it now.

If what I have said sounds too much like a sermon, let's look at what has happened and what is happening. We have moved from an era of single-purpose development to the beginning of an era of multiple-purpose development.

Where the first settlers cut and burned trees to clear the land, we now harvest timber as a sustained yield crop to serve a multitude of needs for wood products and by-products. In addition to wood products and by-products, managed forests tend to reduce flood runoff, conserve the soil, sustain low-water flow for many uses, and make habitat for wildlife.

Where man originally built reservoirs for flood control, or irrigation, or power, he now builds them for several purposes. For example, the Willamette Basin reservoirs now serve four primary purposes, but additional functions have been recognized since those projects were planned. All told, the Congress now recognizes eight potential primary functions for Federal water resource projects. These are:

Flood Control	Water Supply
Irrigation	Water Quality
Navigation	Fish and Wildlife Enhancement
Power Generation	Recreation

Planning for all those purposes, and evaluating benefits therefrom, will permit continued development of projects which would not be justifiable for a single purpose such as flood control or power generation. It is not, however, as simple as planning for a single purpose. It involves consideration of more area—whole watersheds or basins, instead of a single site or tributary. It involves consideration of interrelated effects—conflicts and compatibilities which I will mention later. It involves agencies and interagency relationships—more than 30 Federal and State agencies in the case of a review study now being made for Willamette River Basin. It involves people—all the people of a stream basin and possibly many from outside the basin who rely, directly or indirectly, on some of its resources for income, food, or recreation. And finally, it involves time, money, and patience to collect the necessary data, develop satisfactory and justifiable plans, and gain public understanding of what is being proposed, and why.

On the plus side, it can provide for the best use of water and related resources in the interest of the general public. I believe that most of any future works for reduction of flood stages will be planned as elements of overall water resource development projects.

Areas, Problems, Interrelationships

Willamette Valley provides an excellent example of flood areas, areas needing drainage for improved agricultural use, and of the interrelationship between those problems and existing and potential projects for flood control. Those of you who have been here during the school year know that the area east of Corvallis is subject to periodic flooding. Conditions in that area are typical of much of the area along Willamette River from the mouth of McKenzie River downstream about 125 miles to Newberg.

Tualatin River Valley, or East or West Muddy Creek areas south of Corvallis, are areas where reduced flood stages and improved drainage would be of benefit from an agricultural standpoint. Tualatin River, in particular, is an area where reduction in flood stages would be essential to continued good drainage. Other areas where flood control and drainage go hand in hand are those along the tidal reaches of lower Coquille River. In those areas, the long-continued process of upstream erosion and downstream deposition has created stream banks which are substantially higher than the adjoining lands—in effect, natural levees. Without flood stage reduction or some type of work to increase channel capacities, drainage pumps and tide boxes already installed cannot function effectively for more than a few months per year. The question of how to accomplish a reasonably adequate, and yet economically justifiable, job of reducing flood stages or increasing channel capacities now is under study by the Corps in cooperation with local people and other agencies.

As far as bank erosion is concerned, Willamette Valley also affords many examples, both of continuing erosion and works to prevent it. As of 1948, when the last careful study of the overall problem was made, there were known to exist about 50 miles of eroding banks along the main stream and tributaries. Erosion is a natural process, which changes the location of the stream and eventually leaves new land, often of a different composition and at a different elevation, to replace that which has been removed. The present valley floor apparently is the result of long-continued erosion and deposition. The trouble is that we are not flexible or patient enough to live with the natural process. When erosion removes all or parts of cultivated fields, the property owner involved can't wait a few hundred years for an equal amount of tillable land to build up on the opposite shoreline. And even if he could, the new land probably would be a part of the property of someone on the other bank! When his home or farm buildings set on land which is washed into the stream, there is no natural process to replace them. These are things which make erosion a matter of consequence. Further, flood stage reduction and increased channel capacity are not necessarily an answer to the problem. In fact, increasing channel capacity by straightening and enlarging tends to increase velocity of flow and possibility of erosion. Also, when reservoir operation for flood control involves emptying of storage space after one flood, to be prepared for a subsequent one, the period during which erosion can take place is prolonged. Whether or not the result is more, less, or an equal amount of erosion is a moot question.

Conflicts and Opportunities

As you can deduce from what has been said, both by me and at previous sessions, reduction of flood crests by storage results in both conflict and opportunities. Fortunately, in this area, flood control by storage and conservation of water for other purposes are compatible because we have a well-defined flood season and a well-defined dry season. Thus, the same storage space can be used for flood control and for water conservation. This is not the case in areas where flood-producing storms can and do occur during the season when stored water is needed for irrigation and other purposes. In such areas, flood control space must be provided in addition to space for water conservation. Thus, the economic, and sometimes the physical, feasibility of providing flood control by storage is difficult to show in those areas—and easier to show in our area.

There are several items of mixed opportunity and possible conflict of uses. These include flood control and power generation; storage development as related to fish and wildlife; and recreational use as related to other uses of storage.

Using Willamette Basin storage projects as an example, power generation and flood control by storage are not completely compatible, but we can and have developed a workable approach. Willamette Basin is a part of Columbia Basin, which in turn is part of the Pacific Northwest Power Pool area that Mr. Marple discussed on April 22. Columbia River generating plants provide a large part of the electric power for the total area. But Columbia River power is not available at a uniform annual rate, because of the Columbia's annual runoff pattern. Looking at power needs of the area, without reference to other water and related resource needs, the flow regimen of the Willamette is ideal to provide power to supplement Columbia River generation. That is, the season of maximum Willamette River runoff is the season of low runoff and reduced power generation on the Columbia. To take full advantage of the Willamette's power potential, we would have to keep the Willamette reservoirs as nearly full as possible during the winter. Flood control, however, requires that reservoir space be empty at the beginning of the flood season. Also, irrigation water supplies and increased low-water flows for navigation can be provided only by withdrawing water from storage, which results in lowering of pool levels before the beginning of the critical power season on the Columbia. What we do, in order to provide the most benefit for the most people, is to make withdrawals from storage first from those Willamette Basin reservoirs which do not include generating facilities. So far, in the absence of a major irrigation demand on storage, we have been able to hold the pools at the power reservoirs at or near full level until about September 1. We then withdraw storage at those projects at a rate which can be used by the turbines and which will empty the pools to required flood control levels by early November. Thus, we fill in a part of the Columbia River deficiency and permit Columbia River storage to be saved for use later in the critical period. At the same time, we serve irrigation and navigation needs and provide for full reservoir use for flood control.

Fish and wildlife is another, and extremely important area of mixed conflict and opportunity. I must emphasize that the opportunity side of the picture is fairly new—only since late 1958 has there been congressional recognition of the propriety of planning Federal projects to benefit fish and wildlife.

The conflict side of the picture is obvious. Migratory fish and resident game fish use the streams for highways, for spawning areas, and for rearing areas. Game birds and animals use the stream and land along the stream for the same purposes. Dams block migration routes, inundate areas used by fish and wildlife, and change the whole character of the environment for fish and wildlife. Prior to 1958, and the passage of Public Law 85-624, the Revised Fish and Wildlife Coordination Act, the only action which could be taken by Federal construction agencies as a part of project construction was to provide mitigation for losses to fish and wildlife. In practice, this generally meant fish ladders, or similar passage devices, and/or fish hatcheries. In many cases, as at Grand Coulee Dam on Columbia River and at all of the early Willamette dams, it meant only fish hatcheries, with no further access to upstream fish spawning and rearing areas. As Mr. Schneider told you on May 6, Willamette Basin projects recently constructed or under construction include fish-passage facilities as a mitigation measure. Even with mitigation measures, the conflict side of the picture is obvious.

The opportunity side of the picture is newer, and possibly less obvious. The possibility of improving fish and wildlife habitat, or enhancing the resource, as one of the functions of a Federal water resource development project has existed only since August, 1958, when Public Law 85-624 was approved. That Act did not automatically change the picture at projects authorized or constructed prior to Public Law 85-624. It did specify that, in all future study or water resource development, full consideration be given to the possibility of including fish and wildlife enhancement as a primary project purpose. I am not aware that any projects have been constructed which include such provisions. Initial appropriation has been made and detailed planning is underway on a reservoir project on Rogue River which will include fish and wildlife enhancement as a major project purpose. That enhancement will be obtained by providing some 150,000 acre-feet of stored water to be released in controlled amounts, at selected times and temperatures, to approximately triple the low-water flow of Rogue River and reduce temperatures in critical reaches from the high 80's to not more than about 68° F. Further, planning now underway, and which may lead to recommendation for additional project authorization in Willamette, Umpqua, Coquille, Nestucca, and Nehalem River Basins and on some of the five streams tributary to Tillamook Bay, includes full consideration of possible fish and wildlife enhancement. In several cases, the only apparent possibility of project justification lies in providing a maximum of fish and wildlife enhancement. In other cases, there is a possibility that modification to structure or operation of existing projects can be justified by potential fish or wildlife benefits. The Willamette review study will cover the possibility of such modifications to projects now including only mitigation features.

A final example of conflict and opportunity is Fern Ridge Reservoir. It now is used heavily (391,000 attendance in 1963) for recreation. As soon as irrigation demands develop, the project authorization will require early withdrawal of storage. After about 1-1/2 feet of drawdown the pool loses most of its recreation potential. Thus a potential conflict of major proportions is in the offing. The same sort of conflict, of varying degrees, can be expected wherever satisfaction of downstream uses involves reduction of pool levels during the summer months. Where such conflicts would exist, a possible solution may be the provision, if justifiable, of additional storage; either at the original site, so as to reduce the rate and amount of drawdown, or at other sites so as to permit the fullest recreational use of the original site. In either case, the additional storage may afford opportunities for joint use and additional benefits in categories other than recreation.

SUMMARY

To summarize, floods are caused by the natural sequence of meteorologic and hydrologic events; flood damages occur, or are known and evaluated, only because man has need for, and uses, the flood plain which is a part of the natural channel through which runoff moves to the sea. Flood damages can be reduced by keeping man away from the water, or by keeping water away from man. The first method is best suited to local accomplishment. The second usually is accomplished by State or Federal agencies, using public funds.

When water is kept away from man by increasing channel capacity, the benefits usually are from flood control alone. When storage reservoirs are used, other benefits, as well as possible major conflicts, enter the picture. Because of our growing need for some or all of the potential additional benefits, it has become desirable—almost essential—that flood control be accomplished as a function of a multiple-purpose plan.

In order to provide for multiple-purpose water resource control and development, including flood control, extremely careful planning and full consideration to <u>all</u> needs and potentials are required. Such planning can be done only by achieving coordination, understanding, and cooperation between agencies with various responsibilities and interests, and between those agencies and the general public. The interest expressed so far in the seminar, as well as my own experience in the last several years in working with other agencies on Rogue, Umpqua, and Coquille Basin studies, and now with the Willamette Task Force, indicates the probability that increasing cooperation and coordination can be realized.

Presented May 27, 1964 by DONEL J. LANE, Executive Secretary, State Water Resources Board, Salem, Oregon.

The Role of the State of Oregon

The State of Oregon has accepted the responsibility of planning for full multiple-purpose development of its water resources.

In 1909 the basic surface water code of Oregon was enacted. The state's primary interest was in the areas of identification of water resources, the administration of those resources, and in the early part of the present century developing plans and proposals to meet specific needs, particularly for irrigation.

Prior to World War I the state, through the office of the State Engineer, undertook numerous investigations and studies to determine means and methods by which the waters of the state might be developed and utilized. This activity on the part of the state was an outgrowth of the Federal Reclamation Act of 1902.

The unappropriated waters of all or parts of river systems were withdrawn by the State Engineer, under the authority of the 1913 Act, for domestic, power, and irrigation purposes. The purpose of this action again was to foster and encourage development of waters under the authority of the Reclamation Act.

Subsequent to the 1909 Surface Water Act, the Legislature created a number of additional agencies including the Hydroelectric Commission, Sanitary Authority, and organized and reorganized the Fish and Game Commissions. In so creating and organizing agencies, the Legislature established state policies which at times had the effect of developing basic conflicts in responsibility. For example, the Legislature had enacted a policy of encouraging development of water for power, domestic, and irrigation use. Yet the Legislature also passed an act giving the Fish and Game Commissions the authority to veto projects which in the opinion of those commissions were detrimental to fish life. This conflicting authority actually provided the basis for the now famous Pelton Decision by the United States Supreme Court in the case of the Federal Power Commission versus Oregon.

As a result of these conflicts the Oregon Legislature enacted Chapter 658, Oregon Laws, 1953, authorizing the establishment of a Water Resources Committee for the purpose of making a comprehensive study of the water resources of this state. The committee was directed to undertake:

a. Evaluation of existing and contemplated needs and uses of water.

b. A study of existing water resources.

c. A study of means and methods of conserving water resources.

In making this study the committee was directed to consider water for recreation and scenic attractions, water supplies for domestic and municipal uses, irrigation and drainage of agricultural land, fish and wildlife propagation, power development, pollution abatement, farm ponds or storage of water for beneficial use, and such other subjects as the committee might determine.

The committee was further directed to prepare a report to the 48th Legislative Assembly. This report was to include:

a. A critical analysis of the water resources of this state and the extent to which such resources are presently being utilized and developed.

b. Specific recommendations regarding the formulation of a statewide coordinated system of water resource development accompanied by the facts and reasons upon which the recommendations were based, including specific proposals and bills for legislative action based upon the committee's findings.

The committee, after two years study, recommended that there be created a State Water Resources Board composed of seven members appointed by the Governor for staggered terms with the appointments to be confirmed by the Senate. The committee recommended that this board formulate and carry out, under standards prescribed by the Legislature, a statewide coordinated plan and policy for the development and conservation of the water resources of the state. The board should have the power to forbid and enjoin and otherwise control uses and proposed uses of water in conflict with that plan; to review and set aside or modify the decision of any other state agency in conflict with such plan or policy; to cooperate with the United States and its agencies in carrying out said plan and bringing about the highest and best utilization of the waters of the state; to formulate independently its own plans and recommendations; to withdraw from appropriation unappropriated waters for any beneficial purpose including maintenance of minimum flow for public health and preservation of aquatic life.

These recommendations were enacted by the Legislature in the form of Chapter 707, Oregon Laws, 1955. In enacting this law the Legislature approved the following policy statement contained in ORS 536.220:

"(1) The Legislative Assembly recognizes and declares that:

"(a) The maintenance of the present level of the economic and general welfare of the people of this state and the future growth and development of this state for the increased economic and general welfare of the people thereof are in large part dependent upon a proper utilization and control of the water resources of this state, and such use and control is therefore a matter of greatest concern and highest priority.

"(b) A proper utilization and control of the water resources of this state can be achieved only through a coordinated, integrated state water policy, through plans and programs for the development of such water resources and through other activities designed to encourage, promote and secure the maximum beneficial use and control of such water resources, all carried out by a single state agency.

"(c) The economic and general welfare of the people of this state have been seriously impaired and are in danger of further impairment by the exercise of some single-purpose power or influence over the water resources of this state or portions thereof by each of a large number of public authorities, and by an equally large number of legislative declarations by statute or single-purpose policies with regard to such water resources, resulting in friction and duplication of activity among such public authorities, in confusion as to what is primary and what is secondary beneficial use or control of such water resources and in a consequent failure to utilize and control such water resources for multiple purposes for the maximum beneficial use and control possible and necessary.

"(2) The Legislative Assembly, therefore, finds that it is in the interest of the public welfare that a coordinated, integrated state water resources policy be formulated and means provided for its enforcement, that plans and programs for the development and enlargement of the water resources of this state be devised and promoted and that other activities designed to encourage, promote and secure the maximum beneficial use and control of such water resources and the development of additional water supplies be carried out by a single state agency which, in carrying out its functions, shall give proper and adequate consideration to the multiple aspects of the beneficial use and control of such water resources with an impartiality of interest except that designed to best protect and promote the public welfare generally."

In carrying out this policy the board recognizes that the state does not have full, complete and absolute legal jurisdiction over all waters within the state. The board's experience to date shows, however, that the state in assuming its responsibility in comprehensive planning can be an effective mechanism in the formation and establishment of federal actions and policies.

This type of result can best be illustrated by three examples:

1. Snake River Power Development

Application for license, Pacific Northwest Power Company, for the Low Mountain Sheep and Low Pleasant Valley projects, Federal Power Commission License No. 2173, had been filed with the Federal Power Commission and the Hydroelectric Commission of the State of Oregon.

The Governor of Oregon requested the Hydroelectric Commission to refer these applications to the State Water Resources Board and asked the board to undertake its own independent study to determine the project or projects, Middle Snake Basin, that were in the best interests of the State of Oregon.

The board's study published as Snake River Study, Interim Report No. 1, evaluated the physical effectiveness of 20 combinations of projects. In this evaluation full consideration was given to the effect of the various combinations on navigation, recreation, fish life, wildlife, municipal and industrial uses of water, water quality, irrigation, power, and flood control. After full consideration of staff findings, the board concluded that construction of the combination projects including High Mountain Sheep would be in the best interests of the State of Oregon.

In the meantime a review study of the Corps of Engineers of the entire basin had neared completion. The Division Engineer with the approval of his advisory committee had removed from further consideration the High Mountain Sheep Project. The board, as a result of its own findings, requested the Division Enginer to reexamine the High Mountain Sheep Project. This was done and as a result of this reexamination the High Mountain Sheep Project was recommended by the Corps of Engineers for construction.

In the meantime the applications for Low Mountain Sheep and Pleasant Valley Projects had been denied by the Federal Power Commission on the grounds that these projects were not best adapted to comprehensive planning. Pacific Northwest Power Company amended its application to include the High Mountain Sheep Project. Following extensive hearings, the Federal Power Commission Examiner recommended and the Commission ordered the issuance of a license to the Pacific Northwest Power Company for High Mountain Sheep Project. In the meantime the Pacific Northwest Power Company had received a state license from both Idaho and Oregon for the High Mountain Sheep Project.

2. At the time of the formation of the State Water Resources Board, the Eugene Water and Electric Board had received a Federal Power Commission license, Beaver Marsh Project, McKenzie River, as well as a license from the state. In spite of the two licenses, serious controversy over the utilization of the waters of the Upper McKenzie continued. The voters of the City of Eugene turned down authority for a bond issue to construct the Beaver Marsh Project.

In the meantime the State Water Resources Board had undertaken its own study and as a result had issued a program which found that the waters of the Upper McKenzie above Middle Falls were best adapted to utilization for recreation and compatible uses and that any power development should be constructed in the area between the mouth of Smith River and Middle Falls. The Eugene Water and Electric Board withdrew its application for license, Beaver Marsh Project, and submitted an application for the Carmen-Smith Project located in the area approved by the State Water Resources Board in its program.

The Federal Power Commission in its order issuing a license to the Eugene Water and Electric Board for a project at the new location stated, "The Licensee shall comply in all respects with the aforementioned resolution of the State Water Resources Board of Oregon, dated July 17, 1958, which resolution, embodying a program for the development of the water resources of the McKenzie River from Clear Lake .... is approved and adopted as the Federal Power Commission's own determination in the matter, and the Licensee shall construct, operate, and maintain the project in accordance with the provisions of the resolution subject to further order of the Federal Power Commission."

3. In November of 1961, the Senate Public Works Committee authorized the Corps of Engineers to undertake a review study, Willamette Basin. At the time of the authorization the State Water Resources Board had been undertaking its own investigation in the basin to inventory the water resources of the area to determine existing and future requirements and other functions necessary for the formulation of a state policy leading to the allocation or classification of unappropriated water for future beneficial use and the guidelines for a developmental program.

It seemed apparent to the board at that time that full participation in the review on an adequately funded basis of all agencies was necessary if a truly comprehensive report was to be developed. The board was aware of examples in the past where agencies' responsibilities for development of a portion of a plan or project had been handicapped because they had not been adequately staffed or funded to provide information necessary for the development of the best possible plan. It was the board's opinion that on a simultaneous basis with the Corps of

Engineers' review, adequate determination of irrigation potentials and solutions, for example, should be undertaken by the Bureau of Reclamation; evaluation of municipal and industrial requirements as well as water quality factors by the Department of Health, Education and Welfare.

The board's own investigations had indicated that many of the problems and possible solutions were primarily localized in area, thus showing the need for simultaneous studies by the Department of Agriculture, particularly the Soil Conservation Service.

In addition there was need to bring into the development of a plan the interest and recommendations of state agencies and local citizens. Through all this it became apparent that there was need for some type of coordinating mechanism. The belief was concurred in by the Columbia Basin Inter-Agency Committee when in December of 1962 that Committee by formal action authorized the establishment of the Willamette Basin Task Force to coordinate planning activities.

The Task Force is composed of representatives of the Departments of Army, Agriculture, Commerce, Health Education and Welfare, Interior, and Labor, the Federal Power Commission, and the State of Oregon. In its action the Columbia Basin Inter-Agency Committee determined that when a basin being studied lies wholly within one state, the state representative shall serve as chairman. The Governor has designated the State Water Resources Board as the state's representative on this Task Force, and, in addition, coordinator of state participation.

The Task Force is operating without precedent inasmuch as no similar type of coordination has been undertaken in any other river basin in the country. It involves participation by more than 30 state and federal agencies. In addition the state is endeavoring to secure full and active participation by local governmental agencies and other groups. It is anticipated that recommendations to be submitted in a report in 1969 will include a number of factors such as recommendations for federal authorization of projects, recommendations for state or local action which may require legal actions, local funding requirements, furnishing easements or rights-of-way, relocations, assurances, cost sharing, etc.

The report will delineate and recommend measures to meet the water and related land resource needs for a period of at least 10 to 15 years and will provide a framework plan that can be utilized in meeting long-range water and related land resource problems.

The jurisdictional argument of who has legal responsibility for the water is not a major deterrent at this time to the development of this type of plan. Rather, the important factor is recognition on the part of all concerned that strong and effective state participation is necessary if a plan is to be developed that encompasses all aspects of state authority and state interest.

In order to implement and carry out state responsibility it is evident that a state agency must possess:

1. Legal authority to develop information and take action on all aspects of local use, development, and control of water.

2. Adequate funding to implement its legal authority.

3. The initiative to undertake investigations on behalf of the state and to transmit its recommendations to those that have the final determination of how the plan will be implemented, including both the State Legislature and the Congress.

While additional examples can be cited, the foregoing represents a strong argument for the need for adequate and qualified state participation in comprehensive development of water and related land resources.

Presented June 3, 1964 by ROY B. SANDERSON, District Engineer, Surface Water Branch, U. S. Geological Survey, Portland, Oregon.

Integration of Basic Data Collection

During the past eight weeks at seminar sessions such as this, you have been exposed to the numerous problems inherent in water resources planning. You have heard of the many conflicts over uses of water, and of the need for comprehensive planning prior to any decisions regarding development of our water resources. In fact, by this time you may have already decided to devote your talents to some other, less controversial field. There is no denying that there are problems and controversies, and we might as well face the cold facts of life: The per capita use of water has doubled with each generation, and there is no reason to assume that this trend will diminish. The solution of problems related to floods and droughts, upstream and downstream interests, water supply and pollution, high dams versus low dams, power versus fish, and irrigation demands versus recreation will become increasingly difficult. What, then, is the first step in meeting this prodigious responsibility of supplying the solutions to such problems? The answer, of course, is by providing the foundation for any planning effort–basic facts. During the next hour I hope I can contribute to your appreciation of the need for and knowledge of the most common types of basic hydrologic facts used in water resources planning, and, to a lesser extent, acquaint you with the techniques of obtaining, storing, and retrieving these data.

Background

Some of the earliest works of man were hydraulic structures designed toward better utilization of the earth's water resources. To name a few, the floodways constructed in 2278 B.C. to help control "China's Sorrow," the Hwangho River; the extensive irrigation systems of Central Asia, Egypt, Peru, and Mexico; the Roman aqueducts; and the underground cisterns of Alexandria.

Just as ancient man-made structures reflect the never-ending need for water resources utilization and control, many written records, such as the Bible, describe man's continuous effort toward understanding and applying hydrologic principles. The Biblical quotation "All the rivers run into the sea, yet the sea is not full; unto the place from whence the rivers came, thither they return again" (Ecclesiastes 1:7, King James version) is presumed to be an early statement of the hydrologic cycle. Typical of many erroneous hydrologic assumptions was an early Greek theory relating to the flow of springs and streamflow. The Greeks believed this water originated from extensive underground caverns fed by the sea and then by some mystical process appeared as fresh water at the land surface. The belief was accepted as fact by many hydrologists until as late as the end of the 17th century. Historians report that throughout the ages many of the greatest philosophers and scientists such as Plato, Aristotle, Leonardo da Vinci, Bernoulli, and others groped for a better understanding and delved deeply into complex hydrologic principles.

The ancient hydraulic structures, when compared with our giant hydraulic complexes of today, seem insignificant, and, similarly, the ancient hydrologic hypotheses appear to be more fumbling in the light of our present understanding of hydrologic concepts and principles. However, we do have one thing in common with our ancient counterparts in the field of hydrology, and that is the need for basic data. There is absolutely no substitute for facts and the ability to apply these facts toward the understanding and solution of a problem. Without the basic water facts (meager as they were) upon which the first water-supply works, irrigation systems, and flood-control works were based, whole civilizations might have perished. In fact, ancient history shows that some civilizations did perish because of inability to gain sustenance from, and control the distribution of, their water resources. Just as those ancient works reflected the available data, the great hydraulic structures of today reflect the availability of basic water facts.

Basic Data

What do we mean by the term "basic data"? To the early hydraulic engineer this may have meant only a record of river stage. Records of stage of the Nile date back to the reign of the Pharaohs in Egypt (4400-332 B.C.). In fact, the Egyptians considered the stage of the Nile so important they developed remarkable gages called nilometers and assigned priests to supervise their operation. Today our river stages are not observed and recorded with such religious fervor but are just as essential for planning river development. The early Romans recognized the need for streamflow measurements, and developed a crude technique for measuring flowing water, and as the demand for more and better water has increased throughout the centuries, man has learned to appreciate the importance of basic water facts. In fact, the collection of basic data necessarily precedes and to some extent controls the development of water resources. Today our programs of basic data collection reflect the need for sophisticated, complex water resources planning. Thus, to the present-day hydrologist the term "basic data" means an integration of related hydrologic facts into readily understandable and usable forms geared toward supplying answers to immediate and anticipated problems. For example, to the trained hydrologist, data on precipitation, runoff, soil moisture, evapotranspiration, and ground water levels (which frequently have little significance when considered as single entities) can be combined to portray a complete water budget. These data as a water budget prove to be valuable tools to the planning and development agencies.

Data — Its Interdependence and How it can be Used

The following outline shows some of the most common hydrologic data, and to some extent how these data can be used. The interdependence of hydrologic data will be apparent as we run through the outline. In fact, without integration of the various types of data collection programs, in many instances the answers required for specific problems will not be forthcoming.

Precipitation Data

Knowledge of the quantity and character of precipitation over an area or basin would provide:

1. An index of available surface and ground water.

2. A guide to the prediction of runoff volume and flood peaks.

3. A basis for development of a water budget for the area or basin.

4. A generalized indication of the potentials of future agricultural, industrial, and municipal development.

5. A means for determination of orographic influences.

Streamflow Data

Evaluation of amount and seasonal variability of streamflow aids in:

1. The delineation of surface supplies for municipal, industrial, and agricultural activity.

2. The design of dams, reservoirs, and spillways; bridges and culverts; canals, aqueducts and ditches; dikes and levees; hydropower installations.

3. The solution of hydrologic studies such as flood magnitudes and frequency; flow duration; low flow and high flow analyses; sediment transport determinations; pollution analysis; flood plain inundation maps; water budget determinations; ground water and surface water interchange and relationships; channel geometry.

4. The monitoring of hydrologic changes, both natural and man-made.

5. Helping courts to make legal decisions (water rights and lawsuits).

Water Temperature Data

Temperature records of ground water and surface water are essential to:

1. Determination of suitability of water for industry, domestic use, fish habitat and propagation, air conditioning and heating, pollution control, and recreation.

2. Determination of thermocline in lakes and reservoirs.

3. Evaporation and evaporation suppression studies.

4. Location of subsurface spring inflow to rivers, lakes, and reservoirs.

5. Determination of influence on biologic community.

Chemical Quality of Water Data

Knowledge of chemical quality of both ground and surface water provides:

1. A basis for determining suitability of water for industrial, agricultural, domestic, recreation, and fish habitat and propagation uses.

2. A means of detecting changes in water quality caused by various water uses.

3. The ability to trace the natural movement of water, both underground and on the land surface.

4. A basis for determination of treatment necessary for various uses.

5. A method of defining ground water aquifiers.

6. A means for determining points of introduction and movement of contamination such as factory wastes.

7. For continuous monitoring of salt water encroachment on fresh water supplies.

8. A method of tracing the movement of radioactive isotopes.

Sediment Load Data

Records of total and suspended sediment load and variability of concentration would provide:

1. A monitor and guide for land use and forestry practice.

2. An index for reservoir design and expected useful life.

3. A guide for determining suitability of potential water supplies.

4. An index to stability of upstream watershed.

5. A guide for harbor design and maintenance.

Evaporation and Transpiration Data

Evaluation of amount and variability of evaporation and transpiration will aid in:

1. Development of a water budget for river basin or reservoir.

2. Determination of water used by phreatophytes, crops, etc.

3. Determination of the effectiveness of evaporation suppression techniques.

Ground Water Data

Knowledge of ground water levels and fluctuations provides:

1. An index to amount of water in a ground water reservoir.

2. The tools for development of water table maps used in delineating areas of inflow or outflow of an aquifer and amount of overdraft or recharge.

3. An index to infiltration capacity and permeability of earth materials.

4. Clues to causes of subsidence and swelling.

Geologic Information

Understanding of the geology of a region or basin is essential in order to:

1. Delineate the types and hydrologic properties of various rock units, thus permitting the prediction of infiltration and runoff characteristics.

2. Define areas of actual and potential ground water storage.

3. Delineate areas of unstable ground.

4. Provide an indication of potential sediment yields.

Soil Moisture

Evaluation of amount and variability of soil moisture aids in:

1. Defining of soil properties.

2. Establishment of irrigation practices.

3. Forecasting of runoff.

4. Development of water budget for a basin or area.

Synthetic Records; Long-term and Short-term Data

Obviously, if we had all the data we needed, water resources planning would be greatly simplified. However, the amounts and types of water facts are in many cases inadequate, and the collection of hydrologic facts is expensive. Furthermore, as our needs for more and more comprehensive data increases, the costs rise accordingly. Therefore, through established procedures and new techniques, we must develop synthetic records of sufficient accuracy to meet the exacting demands of the planners and developers. Some of the most fertile minds in the field of hydrology are now engaged in studies along these lines, and their accomplishments have been many.

Correlation techniques probably are the most common means of developing synthetic data and are, of course, used extensively. The key to successful correlations is an understanding of all parameters affecting the particular data being analyzed. Thus, just as a comprehensive basic data program requires collection and integration of related hydrologic facts, a program of synthetic record development requires knowledge of, and the ability to use, all pertinent parameters. The importance of evaluating all variables was apparent in a simple but interesting correlation of water temperatures made recently by the Geological Survey.

During the summer of 1963, water temperature records were obtained on both the North and South Forks of Trask River. At the time the records were begun, a local resident pointed out that North Fork was preferred over South Fork as a "swimming hole" because it was warmer. The first records in July showed that North Fork was indeed 4° to 8° F. warmer than South Fork. The latter was tested with a hand thermometer for several miles upstream to see if there was evidence of any cool springflow contributions. None was found.

Evidently the difference was caused by the north-south orientation of South Fork and the east-west orientation of North Fork. This conclusion was further supported when cloudy days resulted in closer agreement between the temperatures of the two streams. In fact, when cloudy weather continued for two or three consecutive days, the temperature of the two streams became practically identical. The point is that without the whole picture—water temperatures, stream orientation, and weather records—the correlation would have been written off as poor, while in fact it was excellent.

Use of long-term and short-term data in the development of synthetic records by correlation undoubtedly is the most common of all procedures, and many data collection programs are designed along these lines. It is important, however, that the collection of short-term data can and should be discontinued after it has served its purpose, whether that purpose be to solve a specific problem or to synthesize a long-term record.

The backbone of any hydrologic fact finding program is its long-term records. These long-term data not only portray past hydrologic events, but are essential to present and future predictions as well. The multitude of uses for long-term records include integration with short-term records to develop synthetic data, as well as to monitor man-made or natural changes in the hydrologic system.

A good example of long-term data in Oregon is the record of water surface elevations of Crater Lake. Although intermittent during the early years, records on the lake date back to 1878, and they all have just recently been adjusted to the same datum. The lake acts as a giant precipitation gage, and the fluctuations mirror quite closely those of Weather Bureau precipitation records on the rim. As might be expected, the yearly changes in lake elevation also show good correlation with yearly variations of nearby streamflow. Study of the first year of record after installation of a continuous water stage recorder permitted a determination of both the rate at which Crater Lake leaks and its annual evaporation loss, although the record was not obtained primarily for those purposes. Because of the long-term nature of the records, and because the lake and its surroundings will probably remain unaffected by man's activities, Crater Lake has been selected as a National Bench Mark station by the Geological Survey. These stations are established primarily to monitor long-term changes in the hydrologic system.

Data Storage and Retrieval

One of the biggest problems encountered by our present-day hydrologists is that of data storage and retrieval. Obviously, data are of no value unless the nature of available data, where the information is stored, and how it can be retrieved are known. Within this state alone, a tremendous amount of hydrologic data has been collected through the combined efforts of many agencies. Unfortunately, much of it is unpublished and forever lost in the files of the individual organizations. Agencies such as the Geological Survey, with their regular data-collection programs, usually release their data in the form of annual reports or in other publication media best adapted to the type of data and their potential uses. But even with planned data publication series, these agencies are often guilty of storing data in a form that is not easily retrievable.

Probably few river basin planning committees or task forces have come to grips with this problem of data storage and retrieval to the extent that the Willamette Basin Task Force has. Within the Task Force, a Data Storage and Retrieval Team has been established whose primary function is to determine and make available information as to what data exists and where, and in what form it is stored. The team has just recently completed this data catalog.

The most recent problem of the Data Storage and Retrieval Team stems from use of electronic computers. Many agencies have their own computer programs, and few of the programs are compatible. Some data are stored on cards, whereas others are on tape, both paper and magnetic. Magnetic tape for one computer cannot be used for another, thus adding to the complexity of the problem. The crux of the problem is lack of coordinated planning when these computer programs were initiated. Whether anything can be done toward coordinating and making these various programs compatible at this late date remains to be seen.

Conclusion

Many of you are presently engaged in studies in the field of hydrology or related sciences, and others of you probably have plans along these lines. In any event, in the not too distant future the responsibility of wise planning and development will fall upon your shoulders. The burden of collecting, interpreting, publishing, and using basic hydrologic and related data will be yours. Remember that a gifted investigator can breathe life into raw facts, but the facts must encompass the entire problem and not consist of a hodge-podge collection of unrelated, unreliable, non-coordinated information. Your project or study—and possibly even your professional reputation—will either flourish or wither on the vine depending on your ability to collect, interpret, and apply basic data pertinent to your problem.

I would like to leave you with this closing thought, a paraphrased statement by the founder of the Geological Survey, Major John Wesley Powell: "The unwise indiscriminately collect data, the wise select data."