NITROGEN SUPERSATURATION—COLUMBIA AND SNAKE RIVERS—STATE OF WASHINGTON

(92-41)

HEARING

BEFORE A

SPECIAL SUBCOMMITTEE

OF THE

COMMITTEE ON PUBLIC WORKS
HOUSE OF REPRESENTATIVES

NINETY-SECOND CONGRESS

SECOND SESSION

MAY 6, 1972, AT RICHLAND, WASHINGTON

Printed for the use of the Committee on Public Works

80-152

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1972

COMMITTEE ON PUBLIC WORKS

JOHN A. BLATNIK, Minnesota, *Chairman*

ROBERT E. JONES, Alabama
JOHN C. KLUCZYNSKI, Illinois
JIM WRIGHT, Texas
KENNETH J. GRAY, Illinois
FRANK M. CLARK, Pennsylvania
ED EDMONDSON, Oklahoma
HAROLD T. JOHNSON, California
W. J. BRYAN DORN, South Carolina
DAVID N. HENDERSON, North Carolina
RAY ROBERTS, Texas
JAMES KEE, West Virginia
JAMES J. HOWARD, New Jersey
GLENN M. ANDERSON, California
PATRICK J. CAFFERY, Louisiana
ROBERT A. ROE, New Jersey
GEORGE W. COLLINS, Illinois
TENO RONCALIO, Wyoming
NICK BEGICH, Alaska
MIKE McCORMACK, Washington
CHARLES B. RANGEL, New York
JAMES V. STANTON, Ohio
BELLA ABZUG, New York

WILLIAM H. HARSHA, Ohio
JAMES R. GROVER, Jr., New York
JAMES C. CLEVELAND, New Hampshire
DON H. CLAUSEN, California
FRED M. SCHWENGEL, Iowa
GENE SNYDER, Kentucky
ROGER H. ZION, Indiana
JACK H. McDONALD, Michigan
JOHN PAUL HAMMERSCHMIDT, Arkansas
CLARENCE E. MILLER, Ohio
WILMER D. MIZELL, North Carolina
JOHN H. TERRY, New York
CHARLES THONE, Nebraska
LaMAR BAKER, Tennessee

Professional Staff

Richard J. Sullivan, *Chief Counsel*
Lloyd A. Rivard, *Engineer-Consultant*
Lester Edelman, *Counsel*
Carl H. Schwartz, Jr., *Consultant—Projects and Programs*
James L. Oberstar, *Administrator*
Henry G. Edler, *Project Coordinator*
Clifton W. Enfield, *Minority Counsel*
Richard C. Peet, *Assistant Minority Counsel*
Gordon E. Wood, *Minority Professional Staff Assistant*

Staff Assistants

Dorothy A. Beam, *Executive Staff Assistant*
Erla S. Youmans, *Minority Executive Staff Assistant*

Meriam R. Buckley
Sterlyn B. Carroll
William M. Corcoran
Ruth S. Costello
Beth Kiley
Machele Miller

Peggy McCarthy
Toby J. Stein
Cynthia J. Van Sant

Richard C. Barnett
Ludie DeCourcy
Brenda G. Jones

Joseph A. Italiano, *Editorial Assistant*
Robert F. Loftus, *Technical Staff Assistant*

CONTENTS

TESTIMONY

MATERIAL RECEIVED FOR THE RECORD

NITROGEN SUPERSATURATION, COLUMBIA AND SNAKE RIVERS, STATE OF WASHINGTON

SATURDAY, MAY 6, 1972

House of Representatives,
Special Subcommittee of the
Committee on Public Works,
Richland, Wash.

The special subcommittee met at 9 a.m. in the Federal Building Auditorium, Hon. James J. Howard, presiding.

Also present: Representative McCormack.

Mr. Howard. The hearings of the special subcommittee of the Committee on Public Works will please come to order. I am very happy to be here this morning. I especially am very happy to be in this area of the country for the first time in my life. Coming from the State of New Jersey, I never realized that one could see so far in the distance. My district in New Jersey has a high point of about 23 feet above sea level.

We are here today to hear from interested parties and to gather information concerning nitrogen supersaturation, among other things, and other problems that may confront the people of this area, as well as the country, concerning our river systems to see how we can make the proper blend of progress with protection of our environment—wildlife—and our fish. Serving an ocean coastal area, we are going through growing pains to find solutions to problems we have had which have been damaging our area, such as dumping of sludge barges off the New Jersey coast, creating areas of dead seas in our oceans, and we are happy to come here to get a view of the Northwest, to receive recommendations and, also, I would like to state that although we will be here for only 1 day, there will be a record kept open for the other members of our subcommittee and the full committee to read and consider. Anyone who will not testify today and would like to speak to the subcommittee or the full committee, if you would care to send your views to us, they will be made a part of the committee file on this subject. Mail them to the Committee on Public Works, House of Representatives, Washington, D.C., mentioning the hearings here today, and it will become an official part of the file of the committee on this subject. We will appreciate hearing from you.

We are indeed fortunate that the Public Works Committee has seen the addition of the only scientist in the Congress of the United States, someone who is familiar with this problem and with this area, our colleague from Washington, Congressman McCormack. I am happy to have been invited here, and I am especially happy that our chairman has seen this is an important enough problem to have the subcommittee hold hearings here in the State of Washington. We also have

Mr. Robert Spence, Mr. Rick Barnett, and Mrs. Ruth Costello of the staff who are with us and will be working with us. The Chair recognizes the gentleman from Washington, Mr. McCormack.

Mr. McCormack. He did not tell you that his district is 25 by 30 miles in size, and has 600,000 people in it. I told him we could lose the State of New Jersey a number of times in my district. I should like to recognize the presence of State Senator Dan Jolly who is with us today. Dan, thank you for coming. Also to express regrets of Governor McCall of Oregon who wrote he would be with us but at the last minute was unable to come. We have a number of letters and telegrams from other public officials in the Northwest, among them Congressman McClure, Senator Packwood of Oregon, Senator Church of Idaho, Congresswoman Edith Green of Oregon, and several others who sent regrets they could not join us today.

Mr. Chairman, I would like to comment on another interesting visit to the Northwest. We hope to bring the entire Committee on Public Works back this summer. Congressman Blatnik, our chairman, had an unfortunate heart attack this winter which limited his ability to make plans, but I am encouraging him to make a trip down the Salmon River with the whole committee, so that maybe we all can get a greater appreciation of the Northwest.

Multipurpose hydro projects on the Columbia River and its tributary streams are providing electricity, recreation, irrigation, and flood control in the Pacific Northwest. These benefits have great economic value to the people who live in this part of the Nation and to others who live elsewhere.

The whole Nation shares because the projects create agricultural crops, a healthy atmosphere for growing families—not to mention energy for homes, industries, and cities. As the late President John F. Kennedy said when he visited the Hanford project in 1963, "A rising tide lifts all boats."

Within the lifetimes of many of us in the auditorium, the land around us has been transformed. It was not long ago that the Columbia River Basin had no great reservoir of electrical power, no great reservoirs of irrigation water to turn desert lands green with growing farm products, and no great water-based facilities for recreation.

Instead, there was an arid land, little known and only sparsely populated because of its lack of amenities. It was a far different country from what we see today.

More than a million acres of land in the State of Washington are under irrigation. We have stopped the serious floods such as the one in 1948 which wiped out the city of Vanport and which threatened other cities along the Columbia River. We have great manmade lakes, and we have new parks for recreation. We also have inexpensive and inexhaustible supplies of electricity generated by the dams on the Columbia and Snake River system.

And, finally, we have problems. When man disturbs the natural balance, he creates problems. Nature creates problems also, but, even before the famous television commercial was created, we all knew that "it's not nice to fool Mother Nature."

Mother Nature takes millions of years to solve her problems. We do not have that time. We cannot wait millions of years for new types of aquatic life to evolve and adapt to the new environment. We have to give Mother Nature a helping hand.

There is a delicate ecological balance in the marine world as well as on the land, and the aquatic organisms are, of course, endangered when the balance in their world is upset.

Men gave Mother Nature a boost when fish-passage facilities for dams were developed and built. Otherwise, the tremendous runs of anadromous fish already would be only history.

Now, we find there is a new problem, and that it seems to be associated with nitrogen supersaturation.

Probably everyone in the audience today knows more about this subject than the committee does. I certainly hope that many of you do. We made this trip to this area to obtain factual information pertaining to nitrogen supersaturation and the problems that may be relaed to it. We are interested in finding out about nitrogen suepraturation and the extent of the threat—if any—to the salmon and steelhead and other fish which inhabit the rivers.

There are observations this year that the runs of salmon are exceptionally great despite the high levels of nitrogen in the river and 2 and 3 years ago, when these fish were migrating to the ocean as smolts. We hope there will be testimony to this point.

There are those who say that the Corps of Engineers and the public utility districts should demolish the existing dams and return parts of the river to a free-flowing state. This, it is suggested, would eliminate any nitrogen supersaturation problems.

There are others who insist that the benefits of multipurpose hydro projects outweigh the costs, and that every possible site should be dammed.

I might interject here that my own views are that some sites must be preserved because of other values they possess.

Since the Public Works Committee must make some of the basic decisions affecting the rivers, and must comment on the activities of the Corps of Engineers in attempting to correct this phenomenon, we want to learn what the facts are. We would like to learn what problems are capable of solution, and what is necessary to implement programs to correct the problems that may be established as falling within the jurisdiction of the corps.

With the witnesses here today, I feel certain that we will go back to our full committee with a great deal of useful information for consideration by the members who cannot be present with us today.

Mr. Howard. We will proceed with our witnesses now. The first witness will be Mr. Howard Copp, associate head, Albrook Hydraulic Laboratories, Washington State University, Pullman, Wash. He has been with the Department of Engineering at WSU since 1960. He received his master's degree from WSC in 1960 and did graduate study at the Stanford University on water resources. We are very happy to have you here this morning, and appreciate your taking the time to appear before the committee.

STATEMENT OF HOWARD COPP, ASSOCIATE HEAD, ALBROOK HYDRAULIC LABORATORIES, WASHINGTON STATE UNIVERSITY, PULLMAN, WASH.

Mr. Copp. Mr. Chairman, I would like to provide for the record a statement, "The Columbia River Basin—A Description of the River System," prepared by myself and Allen F. Agnew, director, State of Washington Water Research Center, Washington State University, Pullman, Wash.

Mr. Howard. Without objection, the statement will appear at this point.

(The statement referred to follows:)

The Columbia River Basin—A Description of the River System

(By Howard D. Copp[1] and Allen F. Agnew[2])

THE LAND AREA

The Columbia River is the second largest river in the United States as measured by average flow rate at its mouth. The river drains some 260,000 square miles. All of Idaho (with exception of a small southeastern area), large portions of Washington and Oregon, and segments of Montana, Wyoming, Utah and Nevada are in the watershed. Approximately 15 percent of the basin (39,000 sq. mi.) lies in British Columbia. The river system is illustrated in Fig. 1; some of the larger tributaries are designated thereon and quantitative basin description is tabulated in Table I. The largest tributary basin is, of course, that of the Snake River.

---

[1] Associate Hyrdaulic Engineer, Albrook Hydraulic Laboratory, College of Engineering Research Division, Washington State Univ., Pullman.

[2] Director, State of Washington Water Research Center, Washington State Univ., Pullman.

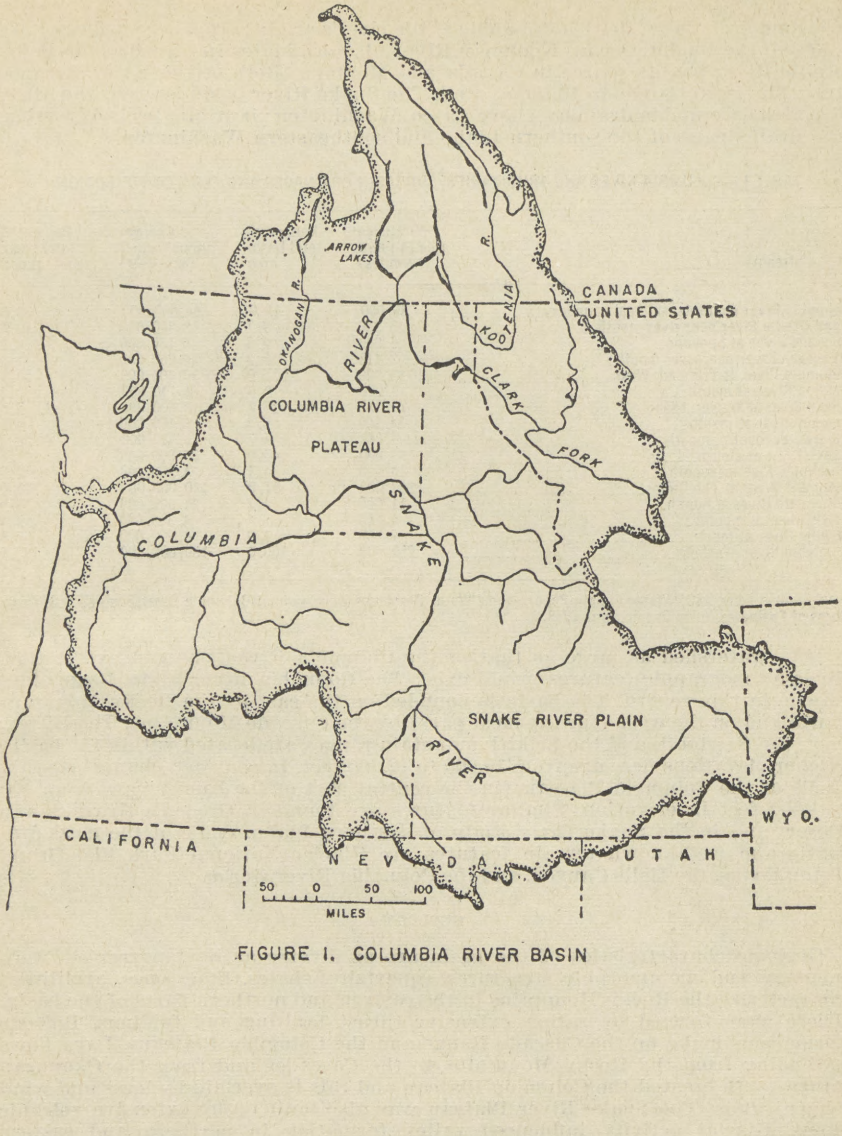


FIGURE I. COLUMBIA RIVER BASIN

Columbia Lake in British Columbia is the river's origin; from here it flows 1200 miles to the Pacific Ocean. Kootenay River also originates in Canada; the Pend Oreille River has its source in Canada and Montana. Both of the latter streams drain significant areas in Idaho as well. The Snake River basin is about the same size as the Columbia drainage above Pasco, Washington; it originates in Wyoming and drains most of the southern Idaho and southeastern Washington.

TABLE I.—COLUMBIA RIVER AND TRIBUTARIES, SUBBASIN DRAINAGES AND FLOW CONTRIBUTION [1]

Stream	Drainage area (square miles)	Percent of total basin area	Average annual runoff (acre-feet)	Percent of total basin runoff
Columbia River near international boundary	39,000	15.0	54,000,000	30.0
Pend Oreille River near river mouth	25,300	9.7	18,800,000	10.4
Spokane River at Spokane	6,640	2.5	5,780,000	3.2
Okanogan River near river mouth	8,415	3.2	2,260,000	1.3
Columbia River at Trinidad, Wash	89,700	35.0	90,400,000	50.0
Yakima River at mouth	5,900	2.3	4,100,000	2.3
Snake River at Weiser, Idaho	70,000	27.0	13,500,000	7.5
Salmon River at mouth	14,100	5.4	8,100,000	4.5
Clearwater River at mouth	9,640	3.7	11,300,000	6.3
Snake River at mouth	109,000	42.0	36,900,000	20.5
Deschutes River at mouth	10,500	4.1	4,200,000	2.3
Columbia River at The Dalles	237,000	91.0	140,000,000	78.0
Willamette River at mouth	11,200	4.3	25,000,000	13.9
Lewis River at mouth	1,000	.4	4,300,000	2.4
Cowlitz River at mouth	2,500	1.0	6,800,000	3.8
Columbia River at mouth	259,000	100.0	180,000,000	100.0

[1] Compiled from USGS Water Supply Papers and "Water Resources Development Columbia River Basin," U.S. Army Corps of Engineers North Pacific, June 1958.

In a watershed as large as that of the Columbia River, one can expect that diverse topographic features would exist. The Columbia River basin disappoints no one in this regard. The basin is bounded on the east by the Rocky Mountain range and on the west (for the most part) by the Cascade Mountains. The Bitterroot, the Sawtooth and the Selkirk mountain ranges are located within the basin. Higher elevations here are from 10,000 to 12,000 feet. In contrast, channeled scablands of the Columbia Plateau (in the central part of the basin) vary from 400 to 4000 feet in elevation. Similar features are found in Oregon's Great Sandy Desert and in the Snake River Plain of southern Idaho. Some of the most dramatic and well-known terrain features are Glacier National Park, the Grand Teton Peaks, the Hells Canyon, and the Columbia River Gorge.

GEOLOGY

Geologic characteristics of the basin are as diverse as its topography. Sedimentary and metamorphic structures (quartzite, shales, limestones, argillites) characterize the Rocky Mountains in the eastern and northern parts of the basin. These were formed by rather extensive thrust faulting and foldings. Igneous formations make up the Cascade Range and the Columbia Plateaus. Lava flows extending from the Rocky Mountains to the Cascades and from the Okanogan range south created the Columbia Plateau and this is overlaid by loess and wind blown sands. The Snake River Plateau was also built up by extensive volcanic flows. Glacial activity influenced valley formation in northern and eastern parts of the basin.

Outcroppings are abundant throughout the basin where precipitous topographic features exist. Adequate soil exists on more mildly sloping terrain to support native vegetative growth. Valley floors and lower terraces created by alluvial or glacial deposits and the loessal soils in east-central Washintgon and southern Idaho support extensive cultivated agriculture.

CLIMATE

A diverse and varying climate exists over the basin; moderate temperatures predominate coastal zones while temperatures from subzero to over 100°F occur inland. Similarly, precipitation varies from less than 10 inches per year in the Columbia Plateau, in the Oregon Great Sandy Desert, and in the Snake River Plain to more than 100 inches annually in the Cascade and Selkirk Mountains (see Figs. 2 and 3).

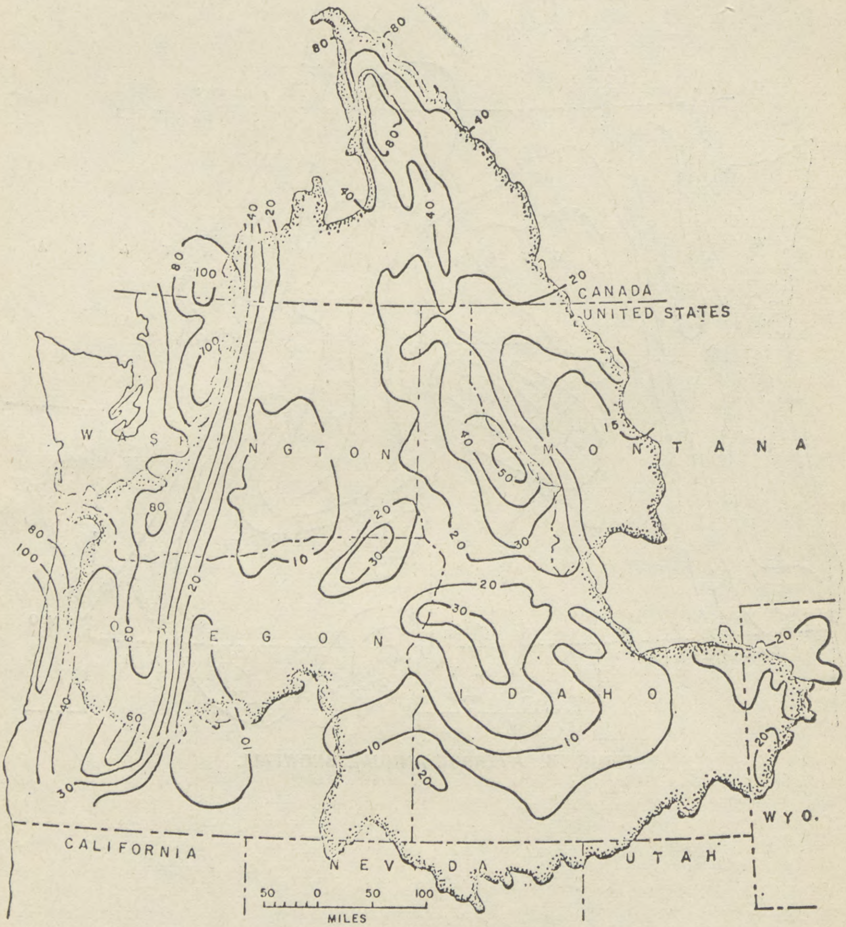


FIGURE 2. AVERAGE ANNUAL PRECIPITATION

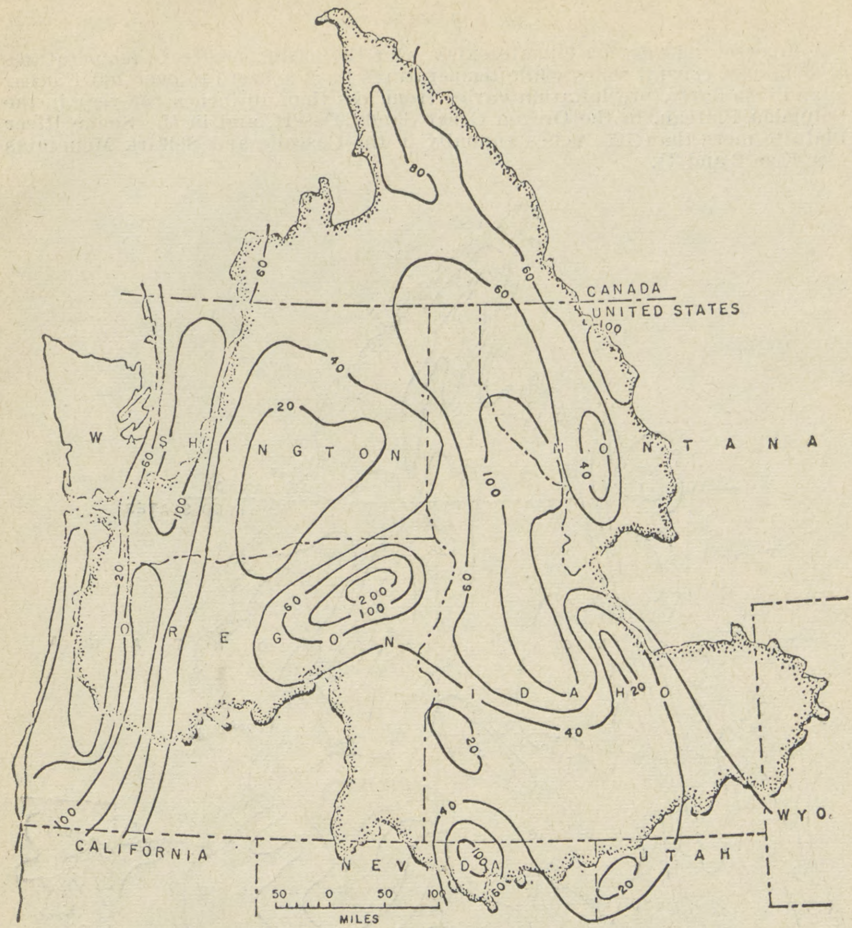


FIGURE 3. AVERAGE ANNUAL SNOWFALL

WATER RESOURCES

The variation in precipitation naturally produces runoff variation from the basin, Fig. 4. Table I provides quantitative runoff data. The largest portion (65 percent approximately) of runoff west of the Cascades occurs during October through March, about half of it from rainfall and half from snowmelt. East of the Cascades, most runoff occurs from April to September as a result of snowmelt.

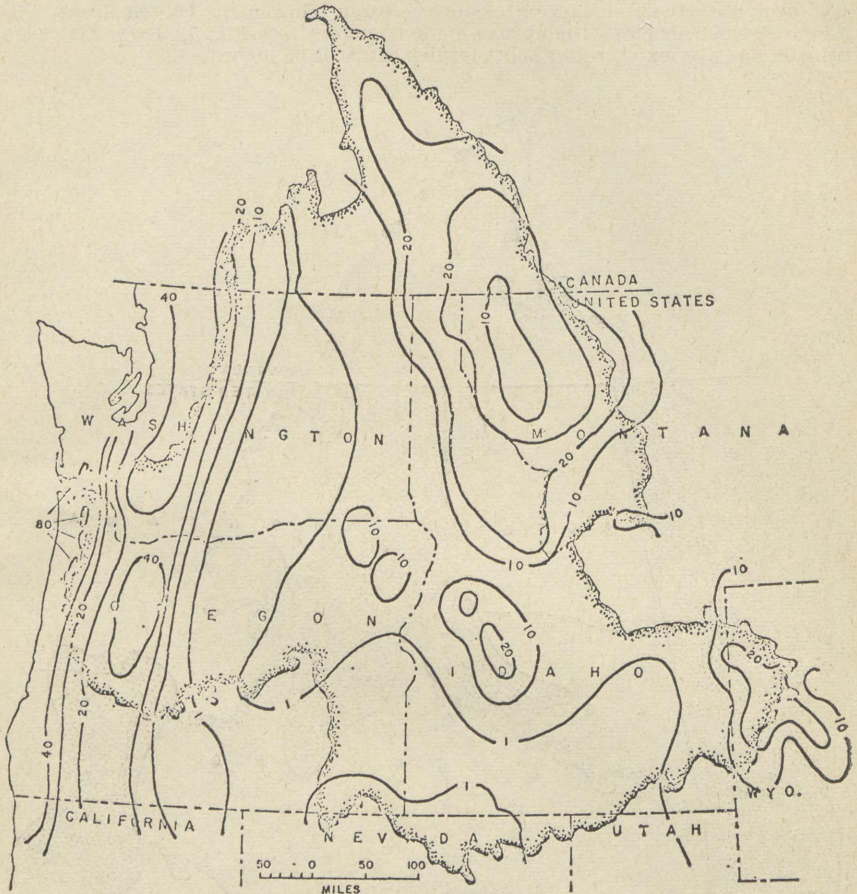


FIGURE 4. AVERAGE ANNUAL RUNOFF

Long term average annual runoff from the Columbia River Basin at The Dalles is approximately 140,000,000 acre-feet (or its equivalent of almost 11 inches of water from the entire basin). About 25 percent of this comes from the Snake River basin above Lewiston, Idaho, and slightly more than this flows out of Canada. Maximum annual runoff at The Dalles was 224,000,000 acre-feet (in 1894) ; the lowest runoff was about 87,000,000 acre-feet and has occurred several years in the late 1920's and early 1930's.

Runoff cited above would imply that the basin would have abundant water for whatever use. However, large areas of the basin lying in the United States witness water deficiencies without man-made transfers (see Fig. 5). Even with such transfers as now exist, water-short locales can still be identified.

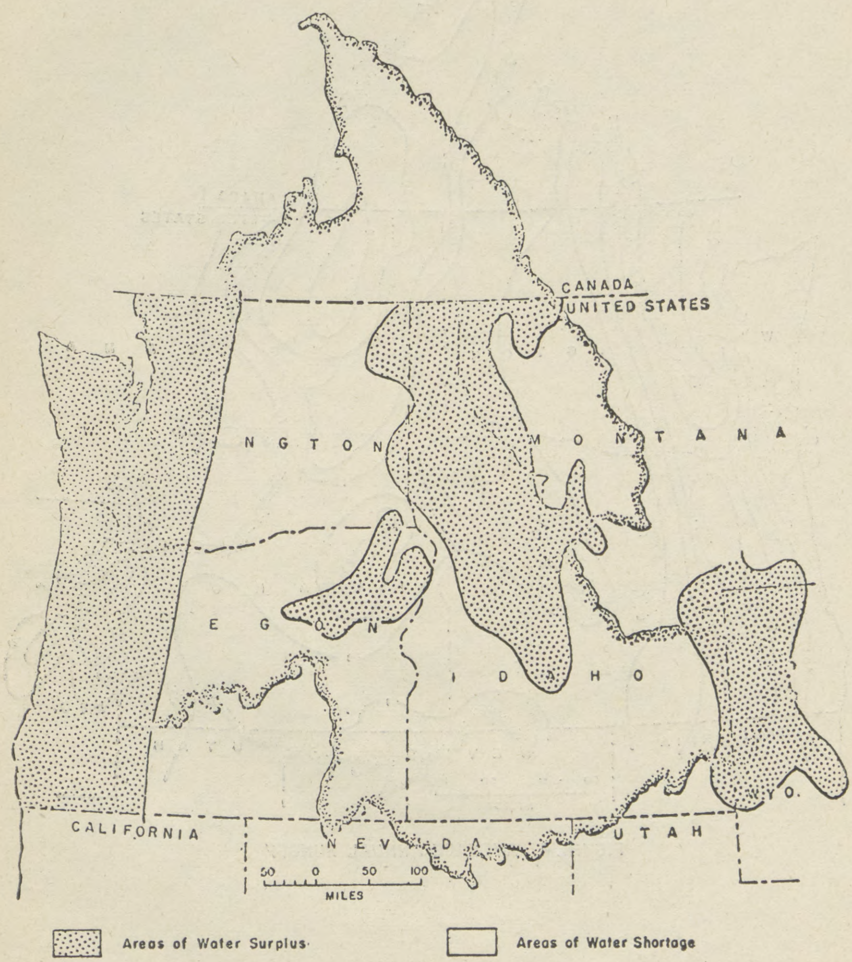


Figure 5. Areas of Water Deficiency & Surplus

With the exception of parts of the Columbia Plateau area, groundwater resources in the basin are abundant. Recent years have seen increased use of groundwater for irrigated agriculture in the Big Bend area (east of the Columbia Basin Irrigation Project) of Washington State—to the point where aquifers may have been permanently damaged, even for domestic use. As a result, the Washington State Department of Ecology has closed that area to further, additional groundwater withdrawals. Groundwater levels in southeastern Washington have been declining rather markedly for several years because of continuously increasing withdrawals for domestic use. This situation is being constantly monitored and studies are ongoing to locate other sources of water to replace or augment groundwater sources as needs arise.

POPULATION AND ECONOMY

The water resources of the Columbia River basin have played a very significant role in population and economic growth in the basin and in the Pacific northwestern United States. Table II shows population statistics for the basin. At the present time, average population density is about 23 persons per square mile; projected density in 1985 is near 30 per square mile. Major population centers in the basin are Portland, Oregon, Spokane and Yakima, Washington, and Boise, Idaho.

TABLE II.—COLUMBIA BASIN POPULATION[1]

[In thousands]

Year	Washington	Oregon	Idaho	Montana	Total
1930	1,150	940	445	158	2,693
1940	1,200	1,000	525	173	2,898
1950	1,750	1,500	589	185	4,024
1960	1,900	1,700	640	230	4,470
1985	3,200	3,000	940	295	7,435
2010	4,500	4,500	1,350	400	10,750

[1] Compiled from various sources; includes some estimates and excludes Puget Sound, Wash., area populations.

Approximately 45 percent of the basin area (115,000 sq mi) is forest covered. Open range lands occupy about 22 percent of the area with nearly the same percentage being used for crop and other agricultural activity. Cities, highways, waterways and lakes, and other miscellaneous uses occupy the remaining 11 percent.

Economy of the basin is geared primarily to manufacturing, agriculture, and associated industry. Lumbering and related pulp and paper industries create about one-third of basin employment; food processing, including that of marine fisheries, is the second most "active" manufacturing entity. Mining, mineral, and chemical industries are prevalent in northeastern Washington, north Idaho, Montana, and British Columbia. Agriculture is prevalent in Washington and southern Idaho. Hydroelectric power from basin streams provide essentially all of the energy needed by the economy. Much of the production from basin activity is exported from the basin.

The natural and man-made features of the basin provide a wide attraction for recreation and sport by persons living in the basin as well as by persons from all parts of the world. Fishing, hunting, camping, boating, hiking, and other leisure time activities are "big business" in the basin. A quantification in monetary terms or in man-hours spent in these activities would, at best, be difficult, but they are becoming one of the most significant attributes of the Columbia Basin.

BASIN DEVELOPMENT

Initial river system development was prompted by irrigated-agriculture interests near the turn of the century in the Yakima River Basin and in southern Idaho. Hydroelectric power development began in earnest during the 1930's on the Lewis, Snake, and Columbia Rivers. Development in the 1930's and 1940's began to take on multipurpose concepts with flood control, hydroelectric power, irrigation, and navigation interests being prime purposes. Some 17 major dams and impoundments were completed during the 1950 decade, hydropower being the major impetus. These were located on the Columbia, Snake, Pend Oreille, Deschutes, Williamette, and Lewis Rivers or their tributaries. Ten similar projects were completed during the 1960's. Seven major dams are now under construction including those in British Columbia.

Currently, there are operating projects having more than nine million kilowatts of hydroelectric generating capability in the Columbia basin that are federally owned. About the same capacity are either under construction at existing plants or are authorized (federal and nonfederal) and an added 14,000,000 kilowatts are in various stages of consideration.[1]

The Flood Control Plan developed by the Corps of Engineers[2] for the Columbia River Basin involved reducing flood peaks by reservoir storage and constructing levees along the lower reaches of the Columbia River. Flood storage reservoirs would reduce the 1894 peak flow rate of 1,240,000 cfs to 800,000 cfs at The Dalles. This would have required about 10,500,000 acre-feet of usable storage volume. Upon completion of Dworshak Dam in Idaho and Libby Dam in Montana, over 17,000,000 acre-feet of storage will be available for flood control in the United States (see Table III). In addition to this, approximately 8,000,000 acre-feet of usable flood control storage is to be provided in reservoirs located in British Columbia. 25,000,000 acre-feet of total storage would theoretically control flood flows to about 650,000 cfs at The Dalles. However, one must recognize that timing of runoff events from different subbasins may create significant departure from the theoretical.

TABLE III.—FLOOD CONTROL STORAGE[1]

Project	River	Usable flood control storage (acre-feet)
Hungry Horse	Flathead	1,830,000
Grand Coulee	Columbia	5,230,000
Priest Rapids	do	170,000
Palisades	Snake	1,150,000
Anderson Ranch, Arrowrock, and Lucky Peak	Boise	240,000
Deadwood and Cascade	Payette and tributaries	420,000
Brownlee	Snake	1,000,000
John Day	Columbia	500,000
Wanapum	do	330,000
Dworshak	Clearwater	2,000,000
Libby	Kootenay	5,010,000
Total		17,910,000

[1] Data taken from "Water Resources Development, Columbia River Basin," USCE, North Pacific, June, 1958, and other sources for more recent verification

At the present time, slack water navigation occurs along the Columbia and Snake Rivers some 430 miles upstream from the Pacific Ocean. Upon completion of Lower Granit Dam, Lewiston, Idaho will become the head of such navigation. In 1968, 2,415,000 tons of goods were transported on the waterways upriver from Portland, over 50 percent of it being grain and the remainder being petroleum products, chemicals, sand and gravel, forest products, and other goods. Just under 80 percent of this tonnage moved downriver.[3]

Columbia River development holds certain interregional and international obligations in the form of product and electric power export and import. Formal agreement with the Pacific Southwest for electric power transmission must be honored and, if course, responsibilities for water regulation and power transfers under the United States and Canada treaty need be met. The Pacific Intertie provides for transmission of surplus capacity and energy to and from regions outside the Pacific Northwest, while the Columbia River Treaty calls for planned developments in Canada and the United States to create greater use of available waters, to enhance flood damage alleviation and to further develop and utilize potential energy in the basin. These agreements are integral parts of resource management of the Columbia River Basin.

CURRENT WATER AND LAND PROBLEMS

The Columbia River Basin is not without problems that relate to water and land management. Groundwater depletions in certain areas have already been mentioned. Local flooding situations still persist; these problems might best be addressed through land use regulation. Water quality can certainly be upgraded in many parts of the basin although it is reasonable to state that water quality degradation has not occurred to the extent witnessed in other parts of the United

---

[1] Data in this paragraph taken from "Review of Power Planning in the Pacific Northwest, Calendar Year 1969," Pac. N.W. River Basins Commission, Jan., 1970.

[2] See H.D. 531.

[3] "Innovations in Barge Transportation on Columbia River," W. E. Torget and R. Funston, *Journal of Waterways and Harbors Div.*, American Society of Civil Engineers, May, 1970.

States. However, the nitrogen supersaturation aspect is apparently of critical importance now. Land erosion occurs in many areas particularly in dry farming zones on rolling terrain. Certain logging practices are currently being examined to assess their effects on erosion and water yield. Aesthetics and outdoor recreation activities are likely to be affected by current land and water development practices. This suggests that land use regulation (or zoning), on a broad scale, ought to be considered. Such consideration has not occurred until just recently.

WATER PLANNING

Many water and related land use planning efforts in the Pacific Northwest are currently being expended. The Pacific Northwest River Basins Commission has several plans underway, at various levels of detail and in many fields of specific interest. Individual states are developing their own water plans. A Western States Water Plan is being drawn under the direction of the U.S. Bureau of Reclamation. The U.S. Army Corps of Engineers is beginning a review study of the Columbia River and tributaries. Many other governmental and interinstitutional agencies, including counties and municipalities, are planning for land use, water availability, power supply, sanitary and solid waste disposal, water and air quality, and economic growth. Thus, there are a myriad of plans being made—one can only urge that they will be objective, rational, and truly in the public interest. Crises will probably never be obliterated, but society together with technology hopefully can foresee problems before they occur to avoid needless investment for costly, and oftentimes, ineffective solutions.

Brief Biographical Résumé of Allen F. Agnew

Present Position (since July 1, 1969).—Director of the State of Washington Water Research Center, and Professor of Geology at Washington State University.

Education.—University of Illinois; AB, MS in Geology, 1940, 1942; and Stanford University, Ph. D. in Geology, 1949.

Previous Professional Experience—Hydrogeology, Economic Geology, Environmental Geology.—

Illinos State Geological Survey, 1939–42 (oil, coal).

U.S. Geological Survey, 1942–47, 1955–63 (lead-zinc mining, water).

Taught Geology at the University of Alabama, 1948–9; University of South Dakota, 1955–63; Indiana University, 1963–69; Washington State University, 1969—.

State Geologist of South Dakota and Director of South Dakota State Geological Survey, 1955–63.

Director of the Water Resources Research Center, and Professor of Geology, Indiana University, 1963–69.

Director of the State of Washington Water Research Center, and Professor of Geology, Washington State University, 1969–.

Certification.—Certified Professional Geologist No. 240 of the American Institute of Professional Geologists.

Scientific Publications.—Approximately 30 significant ones (about equally divided among general geology, mining, and water resources).

Professional Societies.—Member or Fellow of a dozen; active on numerous committees; and Vice Chairman, Technical Division and member of Board of Directors of National Water Well Association.

Honors.—Who's Who in America—last four editions; other Who's Whos; Phi Beta Kappa, 1940; graduated with Highest Honors in Geology, 1940, at the University of Illinois; Sigma Xi (honorary scientific society), 1941; and Robert Peele Award for Technical Writing, American Institute of Mining Engineers, 1955.

Administrative Activities.—Directed bi-university (WSU and UW) water research center and its activities, with a total operating budget of about $400,000; 1969– .

Communication.—Presented talks and panel discussions on water-related topics before numerous groups across the state of Washington.

University Activities.—Member, Committee on Water Resources, National Association of State Universities and Land-Grant Colleges, 1969—; Chairman, 1970—; Member, Executive Board, Universities Council on Water Resources, 1968–71, Chairman, 1969–70; Member of faculty of Environmental Sciences Program, WSU; and, Member and officer of numerous committees and organizations on diverse subjects over the past several years.

State Activities.—Member, Chairman and Governor's Representative on several State and Interstate committees and commissions in South Dakota, 1957–63; Member of two committees advisory to the Washington Department of Ecology—Water Rights & Water Law, and Water Resources, 1971– ; Trustee of oceanographic Institue of Washington; Worked closely with committee of Washington State Legislature on matters relating to water, environment, and land use.

National Activities.—Member of several national organizations including two on water resources; active on committees.

Industrial Activities.—Worked with industrial organizations on environmental problems through committees, conferences and consulting arrangements; Member, Bonneville Power Advisory Committee, 1970– .

Research Activities.—Conducted and supervised applied research dealing with environmental problems of selected industrial activities (such as mining and thermal power plants) and more basic or academic studies (such as mining and thermal power plants) and more basic or academic studies (such as groundwater movement). Current interests; interstate ground-water problems; mining hydrology; interdisciplinary water studies; and Supervised theses and dissertations.

Teaching Activities.—Organized and presented courses for nongeologists in subjects of water resources and mineral deposits (including fuels); Presented lectures and seminars in courses of other departments than geology.

Service Activities.—Consultant to numerous State and Federal agencies; testified before U.S. Congress.

Other Interests.—Communication with young people; music; sports.

Family.—Married—wife is homemaker, secretary, bowler, and musician; 4 children (1 boy, Indiana University—geology student and volley ball enthusiast; 1 boy, Yakima Green Valley Cab Vo.; 1 girl, University of Washington freshman; 1 girl, Pullman High School junior).

Significant Publications

1. 1955, "Application of Geology to the Discovery of Zinc-lead Ore in the Wisconsin-Illinois-Iowa district": *Mining Engineering* (*Trans. A.I.M.E.*, v. 202), p. 781–95, 16 figs.
2. (with A. V. Heyl, Jr., E. J. Lyons, C. H. Behre, Jr.), 1955, "Zinc-lead-copper resources and general geology of the Upper Mississippi Valley District"; *U.S. Geol. Survey Bull. 1015–G*, p. 227–45, pls. 25–6, figs. 33–4.
3. 1955, "Facies of Middle and Upper Ordovician rocks of Iowa": *Bull. Amer. Assoc. Petroleum Geologists*, v. 39, p. 1703–52, 13 figs.
4. 1956, "Facies of Platteville, Decorah, and Galena rocks of the Upper Mississippi Valley": *Gdbk, Field Trip No. 2, Geol. Soc. America, Minneapolis meeting*, p. 41–54, figs. 9, 10.
5. (and A. V. Heyl, Jr., C. H. Behre, Jr., and E. J. Lyons), 1956, "Stratigraphy of Middle Ordovician rocks in the lead-zinc district of Wisconsin, Illinois, and Iowa": *U.S. Geol. Survey, Prof. Paper 274–K*, p. 251–312, figs. 31–54.
6. 1957, "Ostracodes of the Paleozoic": *Geol. Soc. America, Memoir 67*, p. 931–5.
7. 1957, "Geology of the White River Quadrangle, Mellette and Jones Counties, S. Dak.": *S. Dak. Geol. Survey, Geol. Quad.*, map and text.
8. 1959, "Student Report Writing Must Be Improved": *Jour. Geol. Education*, v. 7, no. 1, p. 29–32, Spring 1959 (Reprinted in *Oil and Gas Jour.*, Nov. 30, 1959, p. 118–19).
9. (with A. V. Heyle, Jr., E. J. Lyons, and C. H. Behre, Jr.), 1959, [1960]: "The Geology of the Upper Mississippi Valley Zinc-Lead District": *U.S. Geol. Survey, Prof. Paper 309*, 310 p., 101 illust.
10. (and J. P. Gries), 1960: "Dig Deep for South Dakota Pays": *Oil and Gas Journal*, v. 58, no. 12, p. 160–162, 164, 167, 169, 170, 172, 7 illust. Also "South Dakota Oil—Past, Present and Future" (Abst): *Bull. Amer. Assoc. Petroleum Geologists*, v. 44, p. 953, 1960; full text in 1960 *Geological Record*, p. 85–94, Aug. 1960.
11. 1960, "Ground Water in South Dakota": *Hearings, Select Committee on National Water Resources, U.S. Senate, 86th Cong. 1st Sess., S. Res. 48, pt. 6*, March, p. 1040–1047, map (p. 968).

12. 1961, "Possible Underground Storage of Natural Gas in South Dakota"; *S. Dak. Geol. Survey, Misc. Invest. 2*, 15 pp., 3 figs.
13. 1963, "Geology of the Platteville Quadrangle, Wis.": *U.S. Geol. Survey Bull. 1123–E*, pp. 245–277, pl. 19, figs. 38–42.
14. 1963 [1964], "Geology of the Mission Quadrangle," *S. Dak. Geol. Survey, Geol. Quad.*, map and text.
15. 1964, "Water: The First of Things": *The Review (Ind. Univ. Bull., Alumni Assoc. Coll. of A & S—Grad. School)*, v. 6, no. 3, pp. 13–24, May 15.
16. (and P. C. Tychsen), 1965, "A guide to the stratigraphy of South Dakota"; *S. Dak. Geol Survey, Bull. 14*, 195 p.
17. 1966, "A Quarter to Zero—Surface Mining and Water Supplies": *Mining Cong. Jour.*, v. 52, p. 29, 32–34, 38–40, October.
18. (ed), 1967, "Water, Geology, and the Future—A Conference; April 1964": *Indiana Univ., Water Resources Research Center*, 117 p.
19. 1968, "The geological profession and ground water": *Ground Water*, v. 6, no. 1, pp. 5–9, Jan.–Feb.
20. (with Y. M. Sternberg), 1968, "Hydrology of surface mining—a case study": *Water Resources Research*, v. 4, pp. 363–368, April.
21. 1968, "State and Federal Geological Surveys—Their History and Growth": *State Geologists Jour.*, v. 20, pp. 32–35, October.
22. (with Don M. Corbett), 1968, "Hydrology of the Busseron Creek Watershed, Indiana": *Indiana Univ., Water Resources Research Center, Rept. Inv.* No. 2, 234 p., July.
23. (and Don M. Corbett), 1969, "Hydrology and Chemistry of Coal-Mine Drainage in Indiana": *Amer. Chem. Soc., Preprint Ann. Meeting, Minneapolis, Minn.*, April 14, 1969, 16 p.
24. (and Max Katz), 1970, Review of "Engineering Aspects of Thermal Pollution" and "Biological Aspects of Thermal Pollution," both edited by Fran K. L. Parker and Peter A. Krenkel: *EOS (American Geophys. Union Trans.)*, v. 51, no. 9, pp. 645–649, Sept.
25. (and Don M. Corbett), 1971, "Hydrology of a Watershed Containing Flood-Control Reservoirs and Coal Surface-Mining Activity, Southwestern Indiana": *(International Symposium on Ecology and Revegetation of Drastically Disturbed Areas, Aug. 3–16, 1969, Pennsylvania State University)*: 18 manuscript pages; to be published by Gordon and Breach Science Publishers.
26. March, 1971, "After Six Years—The State of Washington Water Research Center": Pullman, Washington, *State of Wash. Water Research Center, Rept. No.* 7, 21 p.
27. June, 1971, "Coal Mining Hydrology and the Environment, or Give the Devil His Due": pp. 157–164 of *AIME Environmental Quality Conference*, June 7–9, 1971: New York City, AIME, 448 p.
28. August, 1971, "Solutions to Water Problems—The Time is Now," pp. 52–63 in *Proceedings of the Sixteenth Annual Water Conference*, March 25–26, 1971: Las Cruces, New Mexico, Water Resources Research Institute, 197 p.
29. November, 1971, Review of "A paleoaquifer and its relation to economic mineral deposits; the Lower Ordovician Kingsport Formation and Mascot Dolomite"; (in *Econ. Geol.*, v. 66. pp. 695–810, Aug. 1971): *EOS, (Amer. Geophys. Union Trans.)*, v. 52, pp. 781–782.
30. September, 1971 (February, 1972). "Interstate Ground-Water Aquifiers of the State of Washington; Physical and Legal Problems—A Preliminary Assessment; Part A—The Physical Situation": *State of Washington Water Research Center, Rept. No. 8*, pp. 1–66.

BIOGRAPHICAL OUTLINE OF HOWARD D. COPP, ASSOCIATE HYDRAULIC ENGINEER, ASSOCIATE PROFESSOR, CIVIL ENGINEERING, WSU REGISTERED PROFESSIONAL ENGINEER (CIVIL), STATE OF WASHINGTON

EDUCATION

Washington State University—B.S. Civil Engineering, 1957.
Washington State University—M.S. Civil Engineering, 1960.
Stanford University—Graduate Study in Water Resources, Department of Civil Engineering, 1963–1964.

EXPERIENCE RECORD

August, 1968–Present: Assistant Head, Albrook Hydraulic Laboratory, Washington State University, Pullman.
July, 1966–Present: Associate Hydraulic Engineer, Washington State University, Pullman.
July, 1960–September, 1963; September, 1964–July, 1966: Assistant Hydraulic Engineer, Albrook Hydraulic Laboratory, Washington State University, Pullman.
July, 1966–Present: Associate Professor, Department of Civil Engineering, Washington State University, Pullman.
July, 1957–June, 1960: Junior Engineer, Albrook Hydraulic Laboratory, Washington State University, Pullman.
Summer, 1966: NSF Participant in Water Resources Institute, New Mexico State University.

MEMBERSHIPS IN SOCIETIES

American Society of Civil Engineers.
American Society for Engineering Education.

SELECTED PUBLICATIONS

Copp, Howard D., and Tinney, E. Roy, "Spillway Model Studies for the Oxbow Hydroelectric Development," Technical Report No. 7, Washington State Institute of Technology, Washington State University, March, 1958.

Copp, Howard D., "Laboratory Investigations of Trajectories from Segmental Flip Buckets," Master of Science degree thesis, Department of Civil Engineering, Washington State University, June, 1960.

Copp, Howard D., "Hydraulic Model Studies of Spillway Capacity, Rocky Reach Hydroelectric Project," Research Report No. 61/9–63, Washington State Institute of Technology, Washington State University, June, 1961.

Copp, Howard D., "Hydraulic Model Studies of the Rocky Reach Hydroelectric Power Project—Part IV," Technical Report No. 9, Washington State Institute of Technology, Washington State University, Aug., 1964.

Johnson, C. W., Copp, H. D., and Tinney, E. R., "Drop-Box Weir for Sediment Laden Flow Measurement," *Journal of the Hydraulics Division* ASCE, Vol. 92, No. HY5, Sept., 1966.

Copp, Howard D., "Final Report on Thermal-Hydraulic Model Studies of the Columbia River," Research Report 67/9–67, College of Engineering Research Division, Washington State University, June, 1967 (Classified).

Copp, Howard D., "Predicted Outflow Temperatures from the Proposed Pleasant Valley Reservoir with Selective Withdrawal from the Brownlee Reservoir," Research Report 69/9–57, College of Engineering Research Division, Washington State University, June, 1969.

Copp, Howard D., "Water Temperature Predictions for Turtle Rock Island Fish Rearing Pond Columbia River Near Wenatchee, Washington," Research Report 69/9–67, College of Engineering Research Division, Washington State University, Oct., 1969.

Copp, Howard D., "Hydraulic Model Studies of the Ross Dam Spillway," Bulletin 320, College of Engineering Research Division, Washington State University, Aug., 1970.

Contributor to: "Guidelines for Establishing Economic and Engineering Flood Criteria," Report No. 4, State of Washington Water Research Center, June, 1970.

PROFESSIONAL PAPERS PRESENTED

"Snake River Development," Inland Empire Chapter, American Society of Agricultural Engineers, Garfield, Washington, May 8, 1970.

"Flood Damage Alleviation, Engineering or Education?", American Society of Civil Engineers National Meeting on Water Resources Engineering, Phoenix, Arizona, January 11–15, 1971.

"Flood Plain Management in Pullman, Washington," American Society of Civil Engineers National Meeting on Water Resources Engineering, Phoenix, Arizona, January 11–15, 1971.

ADDITIONAL ACCOMPLISHMENTS

December, 1967: Member of Water Quality Task Force, Middle Snake River (Task Force for Federal Power Commission).

January–May, 1968: Member of Technical Committee for Evaluation of Water Temperature Influences of Ben Franklin Dam (Columbia River).

September, 1968: Appeared as Expert Witness at High Mountain Sheep Hearing, Federal Power Commission, Portland, Oregon.

January, 1970: Appeared as Expert Witness at High Mountains Sheep Hearing, Federal Power Commission, Washington, D.C.

CURRENT ONGOING RELATED RESEARCH

Model Development and Systems Analysis of the Yakima River Basin (OWRR matching grant project).

Columbia River as a Resource (Washington State Department of Ecology, Sponsor).

Mr. HOWARD. Thank you very much, Mr. Copp, for your statement. I am very happy to have you here to present this statement by Dr. Agnew and yourself concerning the area of the Columbia River Basin. The numbers are certainly profound. You stated that the population which is now at 23 persons per square mile will be increased to 30 per square mile in 13 years, which will over that time represent about a 30-percent increase. Can you see the needs of this 30-percent increase in some way affecting what must be done, and would this 30-percent increase, considering the needs of these additional people who will be living in the area, create more severe problems for the river basin, or do you feel that they can, with proper planning, be able to preserve the fine area that you have, and yet meet the needs?

Mr. COPP. My reaction to that question is I am confident the needs can be met by various activities in the basin. There is no question that that can be done. One has to look beyond, however, because much of the goods created are exported. There may have to be some new balances in the imports and exports to handle all the needs of the citizens in the area. With that constraint, there is ample possibility to meet the needs of the people. How they will be met will be determined by planning. I am not sure that planning responds to needs. I think there will be changes made in the basin, both in economy and needs, and again I think the basin can be responsive to the needs.

Mr. HOWARD. Thank you, and I agree with you in that any planning that will be responsive to the wishes of the people in the area should proceed in the coming years with all areas of interest being involved in the planning, both with the governmental agencies, local lenders, and environmentalists, as well as business interests; and I feel that one of the best ways to do that is to make all stages of planning public as much as possible, such as public hearings.

Mr. MCCORMACK. I want to congratulate you on a very fine statement. I may want to plagiarize some of it in the future. I was particularly interested in your statement calling land use planning a necessity. This is an excellent point, and I hope that it can be a criterion in the future for this committee.

Mr. Copp, to change the subject, may I ask what the States have done concerning maximum concentration of nitrogen in the river?

Mr. COPP. I am not sure I am close enough to give you a good answer. Washington State has held hearings relative to nitrogen concentrate, and there have been talks about proceeding along this line. But just where that is I am not sure. I think you should ask others this question.

Mr. HOWARD. Thank you. I hope that later your associates at the university are brought into the planning for the future. That would be a great benefit.

The next witness will be Mr. Richard T. Pressey, of Portland, Oreg. Thank you, Mr. Pressey, for taking the time to appear before the subcommittee. We are delighted to welcome you. Please proceed.

STATEMENT OF RICHARD T. PRESSEY, NATIONAL MARINE FISHERIES SERVICES, PORTLAND, OREG.

Mr. PRESSEY. Thank you. Since I am to cover namely the history of the Columbia River fisheries, I have to go all the way back to Lewis and Clark to the present day, and I beg your indulgence since it will be a little sketchy.

Lewis and Clark found the economy and mode of life of the Columbia River basin Indians depended heavily on salmon and steelhead. At this time, the population of Indians living on this "salmon economy" is established by anthropologists at about 50,000 people. Craig and Hacker [1] estimated that the total annual catch of salmon by the Columbia River Basin tribes approached 18 million pounds. This figure is based on the consumption of 1 pound of salmon per day per person.

It was not until the late 1870's that commercial catches of salmon equaled the amount caught by the original Indian population. The river was remarkably productive for salmon and steelhead before the turn of the century, and although catch records are not well documented, the river was probably capable of yielding 50 million pounds. The first settlers quickly undertook to divert the tributary streams for irrigation, to dam and divert water for power, to use the waters and stream gravels for mining operations, and to utilize the system as primary means of waste disposal.

By 1915, the river fisheries were still producing nearly 40 million pounds, but had changed from a catch in earlier years of nearly all spring run chinook salmon to one utilizing all races including the more mature and less desirable fall run fish. This change in racial composition of the catch was brought about by the sagging populations of upriver runs that were feeling more severely the detrimental impact of manmade habitat changes.

At this time also, man had begun to harvest a great quantity of salmon from the waters of the ocean in which many Columbia River fish were undoubtedly present.

By the 1930's, the river fisheries had further declined to about 20 million pounds, although ocean catches continued to rise.

By 1950, the catches had shown a further decline and had sagged to 15 million pounds, with the majority of the fish coming from the lower river races. At this time it was apparent that all races of salmon and steelhead were definitely being hurt by the impact of environmental changes. Fisheries agencies had long been concerned about the future of the Columbia River salmon and steelhead, and had sought funds to help mitigate these losses, but no adequate funding was obtained until 1949. The Mitchell act of of 1938 authorized this work.

---

[1] Craig, Joseph H., and Robert L. Hacker. 1940. "The History and Development of the Fisheries of the Columbia River." U.S. Bur. Fish., Bull. 49 : 133–216.

Under these appropriations, in 1949 the State and Federal fisheries agencies initiated a concerted effort to restore the salmon and steelhead fish runs of the Columbia. By 1960, they had constructed or enlarged 21 fish hatcheries and had built 80 fish ladders over natural barriers to open up spawning and rearing areas formerly never available to salmonids for spawning and rearing. Efforts were also directed to clear and improve over 1,300 miles of stream and to screen over 500 water diversions to prevent small seaward migrants from entering and being lost in the irrigation systems.

It should be pointed out the Columbia River fishery development program focused its major restoration effort in the lower 200 miles of the river. All of the 21 hatcheries are located below the Dalles Dam. This program was executed in this manner as the river from the Dalles Dam upstream was still being intensely developed for power, irrigation, flood control, and navigation. The problems surrounding these developments were complex, and large investments in fish restoration projects were thought to be risky. Specific projects where fish could definitely be helped in the upper river were undertaken. These projects included the installation of over 220 fish screens in Idaho and the construction of several major fishways over natural falls. A large number of fish screens were also installed in the diversions of eastern Oregon and Washington.

Today in the Columbia drainage, there is no major water diversion important to large numbers of seaward migrants that has not been screened. There are also no major natural falls or rapids that have sizable areas of good spawning or rearing above the barrier that have not been provided with a fishway.

The impact of this program was not felt immediately and the catches of salmon and steelhead coming from both the upper and lower river continued to decline until they reached an alltime low in 1960 when only 5,219,000 pounds of all species were landed by the river commercial fisheries.

Sport fishing for salmon and steelhead had also suffered accordingly by this time and catches were dropping although good statistics of sport fishing are not available for earlier years. By 1960 sport and commercial fishing were feeling the effects of this decline, although ocean sport fishing for salmon was becoming more popular.

After the low production year of 1960, the work done under the Mitchell Act began to show encouraging results and catches coming from principally lower river stocks started a rapid rise. In 1970 coho landings in the river were the best in 40 years and ocean troll landings of coho off the coast of Oregon were at an alltime high in 1971. Sport fishermen fishing in the lower Columbia made their best catch in history taking over 300,000 coho at the mouth of the river in 1971. The hatchery program in the lower river showed its impact to steelheaders by producing a record winter steelhead catch.

By 1970 we estimate the Columbia River was producing a catch to all fisheries, ocean and river, commercial and sport, in excess of 30 million pounds. Approximately 75 percent of these fish were taken by commercial fishermen and 25 percent by sportsmen.

Although this resurgence of salmon and steelhead runs was gratifying to the lower river and ocean fishermen, the upper river runs continued their downward trend that began in the early part of the century.

Sport catches of salmon and steelhead in Idaho and the upper Columbia are generally decreasing. It is apparent the Snake and upper Columbia River runs of salmon and steelhead are having difficulty in maintaining their numbers when faced with the mortalities suffered by passage at dams both upstream and downstream, and the problem has now been compounded with mortalities suffered by fish from water supersaturated with nitrogen.

These highly prized fish are undoubtedly in jeopardy unless present research being carried out by the Army Corps of Engineers and the fisheries agencies to alleviate the losses is successful.

We are optimistic these investigations will prove beneficial. Screening of the turbine intakes on an experimental basis has shown large numbers of seaward migrants can be diverted from the danger areas. Several techniques of alleviating the nitrogen problem have been tested by the Army Corps of Engineers and also appear to be promising. It should be pointed out that with eventual completion of upriver storage dams the spill at lower river dams will be curtailed and thereby greatly alleviating the nitrogen problem.

Assuming these programs are successful and no further deterioration of the upriver habitat occurs, the salmonid runs to the upper river should eventually increase. A strong hatchery program on the upper river would materially accelerate the recovery.

SUMMARY

1. Indian catches in the Columbia River in the early 1800's approximated 18 million pounds annually.
2. In the late 1800's commercial catches of principally spring run Chinook exceeded 40 million pounds. The river at this time was probably capable of producing 50 million pounds.
3. Catches by 1915 were still in the magnitude of 40 million pounds but had shifted to harvest all races of salmon and steelhead due to decline of spring fish.
4. Fisheries, both sport and commercial, dropped to an alltime low in 1960 due to the decline of all races of Columbia River salmonids.
5. Record catches by both sport and commercial fishermen have been recorded in recent years mainly composed of lower river fish revitalized by hatchery and stream improvement programs. Today's catch is in excess of 30 million pounds.
6. Races of fish to the Snake and upper Columbia have continued to decline and the depletion has been compounded by mortalities suffered by passage at dams and from water supersaturated with nitrogen.
7. If present research on solving the passage of fish through turbines and alleviating mortalities resulting from water supersaturated with nitrogen is successful, we can expect larger runs of salmon and steelhead to the Snake and upper Columbia Rivers. A strong hatchery program would accelerate the recovery of these runs.

Mr. Howard. Thank you very much. We are certainly impressed with your testimony and the history of the fish catch in the Columbia. To someone who is not that familiar, what are the implications? The fish catches are rising in one area but not in another. Should that be corrected?

Mr. Pressey. I feel that more effort should be made in the upper area to conduct a similar program in both upper and lower. The upper area can be reclaimed with our modern technology. The two problems of nitrogen, and the passage through the turbines, if these were solved, it would be a good program to bring the upper Columbia River runs back as has been done in the lower. This would be an absolute gain.

Mr. McCormack. Thank you, Mr. Chairman. Mr. Pressey, I think your testimony was excellent. I have three or four questions. First, you mention the downstream migration—are we trucking fingerlings downstream to McNary at this time?

Mr. Pressey. That is true.

Mr. McCormack. Do you have a comment on this program?

Mr. Pressey. It is a little bit early to determine the success of it. We are concerned about taking a fish at an upper dam and placing him downriver. He might not return to where he came from. But from the recent returns back to Ice Harbor, it appears they still may be able to find the Snake River, and so this junction taken out of their migratory returns did not bother them too much. This is still in a research stage. It would be desirable not to talk, because you could be talking for the rest of the time and they could swim downstream on their own. This research is aimed at keeping fish in the stream.

Mr. McCormack. What controls do we have? Is there a successful program for controlling the path of downstream migrants to keep them out of turbines?

Mr. Pressey. Yes, there is a procedure to deflect fish in a bypass, delivering them below the dam and keeping them out of the danger area.

Mr. McCormack. Now, about the nitrogen supersaturation problem, and the experiments underway, do you have any other recommendations for a way to solve the nitrogen supersaturation problem?

Mr. Pressey. I think these hold the greatest promise at the time, and what I would like to urge is that funds continue to be made available for this work because in the future we may come up with a better idea.

Mr. McCormack. Do you have any comment for suggested allowable nitrogen concentration in the river?

Mr. Pressey. The State of Washington has set the maximum concentration at 110 percent and the State of Oregon at 105 percent. We support that 110 percent would be all right because we have not received an indication of serious problems in concentrations of this nature.

Mr. McCormack. Some analyses indicate concentrations have exceeded 115 percent in upstream areas where there were no dams at all. Do you have any comment on that?

Mr. Pressey. Some data was through faulty sampling. If you have a river below the falls, fast flowing, or rocks, the nitrogen is removed. Where the nitrogen is poured into a pool, the dispersion does not occur, so it distributes very quickly below falls but not in the more calm areas.

Mr. McCormack. You mention spawning areas; do you have any comment on this stretch of the Columbia River from Richland through the Hanford Reservation, and to Priest Rapids Dam?

Mr. Pressey. This surely is a good spawning area and runs have increased in recent years. I would hate to see it lost because it is one of the major areas left. Fish do not spawn in flat rivers. Some of this is a relocation. We are operating a small hatching stage in that area and some of the fish in the small water supply stay in the river and spawn.

Mr. McCormack. The hatchery at the mouth of the North Fork of Clearwater, would you comment on that as an upstream hatchery?

Mr. Pressey. This is what we want to do—to put a model installation in the upper river to keep them going back. It is expensive—about $8 or $9 million. It uses new methods of technology.

Mr. McCormack. We do not have data yet on how successful it will be.

Mr. Pressey. It takes about 4 years to get a migrant back from the ocean. This is in its third year now.

Mr. Howard. Thank you, Mr. Pressey, we appreciate your testimony. Our next witness is Dr. Perry, Bureau of Sport Fisheries and Wildlife, Portland, Oreg. We are pleased to welcome you. Please proceed with your testimony.

STATEMENT OF DR. L. EDWARD PERRY, DEPUTY REGIONAL DIRECTOR, BUREAU OF SPORT FISHERIES AND WILDLIFE, PORTLAND, OREG.

Dr. Perry. Perhaps the most serious problem has faced the salmon and steelhead of the Columbia River in recent years has been the occurrence of supersaturated nitrogen. This problem seems to be unique to the Columbia River although conditions in the Columbia are not greatly different from those at other locations in the United States and it is expected it occurs elsewhere but it is not recognized. Where the fishery is of such tremendous importance as in the Columbia and every effort is being made to preserve the resource, there is, of course, scrutiny of the factors affecting this production. Hence, we recognize the significance of the nitrogen problem.

Supersaturated nitrogen has been recognized among fish culturists for many years under the name of "gas bubble" disease. Hatcheries have fought this problem in water supplies. It is quite common that hatchery water coming from cold springs would be saturated with nitrogen gas as it emerges from the ground. Many hatcheries' water supplies must be aerated to release any undesirable gases.

In the Columbia River the problem is created by spilling of water at the dams during the spring flood season and the entrapment of air as the water is plunged into the stilling basins. The gas is forced into solution under the pressure of great depth. High concentrations are recognized in the Columbia, sometimes exceeding 140 percent saturation.

The plunging water at natural waterfalls normally entraps air and sometimes supersaturation occurs but cascading streams usually release the excess gas as the water flows downstream. Normal capacity of the water under atmospheric pressure is called 100-percent saturation. It can be created by merely shaking water in a bottle with free access to air. Problems occur when the dissolved gas reaches higher quantities such as 120 or 130 percent.

Although supersaturated gases are the cause of gas bubble disease, the primary problem seems to be associated with nitrogen. Air, of course, consists of approximately 80 percent nitrogen and 20 percent oxygen. The oxygen is not a significant problem because the hemoglobin in the blood can remove the oxygen and use it for normal metabolic processes of the animal. Nitrogen is not used but it is no problem as long as it remains in solution in the blood. When it separates as bubbles it can be a serious problem.

Fish as cold blooded animals maintain a constant balance between their blood and the watery environment they live in. As they move from one area to another there is a tendency for the blood supply to maintain a balance with the concentration in the water they live in.

If the fish has been living in water that contains 120-percent saturation of nitrogen the blood supply contains the same concentration and the fish has no problem as long as it remains at this level or it passes to an area of greater pressure and greater concentration. But when the fish moves to lower pressure, as occurs when it rises to the surface of the water, there is a natural release of the excess gas. Bubbles are formed in the blood and cause a physical impairment of the circulation of the blood. The result is known as embolism or bends.

If the fish is able to descend hurriedly to deeper water where the pressure is greater this gas can go into solution again.

The extent that a fish can voluntarily make such adjustments is not fully understood but it is known that some are able to recover. This is probably related to the length of time that the fish is subjected to this embolism and the tissue damage that may be caused.

Temperature also pays a vital part in the way a fish reacts to this problem. Cold water will hold a greater quantity of gas than warm water. At warmer temperature the excess gas is released. Consequently fish that are accustomed to the gas supply of water at 40° are in distress when they move to water of 50° or 60° and the gas is released because of the change in solubility of the water. This, of course, applies to the blood as well as the water. It is easily recognized that fish that might move from the bottom water, which is cold, to the surface, would experience both changes in pressure and temperature. Also fish that would migrate from a cool stream to a warm tributary would have problems as the surplus gas in the blood escapes.

In the Columbia River the continuous quiet water in the many impoundments prevents the necessary agitation to release gases that are absorbed at spillways of the dams. It is even noted that the content of dissolved nitrogen will increase to some extent from one dam to the next. The Columbia River is also reasonably calm from Bonneville Dam to the mouth at Astoria. Hence, we have observed a high concentration of nitrogen remaining in the water all the way downstream.

Historically nitrogen was not recognized in supersaturated quantities in the Columbia River until casual observances were made by the Washington Department of Fisheries less than 10 years ago and, when these observances were made the significance of them was not fully appreciated for some time. There was no outward evidence of mortality among the fish. It is really not surprising that no dead fish were seen. The river is large and dead fish are hard to find. Even now when heavy mortality is known to exist through intensive study of fish passing the dams, there is little evidence in the presence of dead specimens.

Fortunately research in the Columbia during the past several years has been intensive for many purposes. As a result there has been more frequent study of individual fish and high incidence of gas bubble disease has been observed. This has led to further research and resulting evidence that the impact is great—much more so than anticipated.

The visual appearance of gas bubbles in fish is often conspicuous although fish can be in distress without outward physical evidence. Gas bubbles are often found in the bloodstream of fish when examined with a microscope. Bubbles are easily seen with the naked eye, however, in the body cavity and on the surface of the fish. When the diesase concentration is high, bubbles are noted under the skin around the body, on the head, and in the mouth. Sometimes it will cause rupture of the eye and hemorrhaging. This is true of juvenile fish as well as adults.

Detectable symptoms quickly disappear in dead fish, or in fish transferred to water that is not supersaturated with nitrogen. This makes diagnosis difficult. However, fish surviving gas bubble disease are more sensitive to the effects of a second exposure and are more likely to die. It is suspected that tissue damage is involved. Since the disease has a generally debilitating effect the fish also may be subjected to greater predation. Their tolerance to temperature changes is also reduced.

These ruptured bubbles destroy the protective surface of the skin and lead to secondary infection. Such has been noted among spawning fish in the streams in Idaho. The abundance of affected fish has reached as high as 50 percent. In the last few years many have been observed to die without spawning in Idaho, mostly attributed to the nitrogen problem. A conspicuous picture of affected adult fish occurred when John Day Dam was closed in 1968 and a number of adults were found in distress below the dam.

Fish do not have conspicuous problems when they remain in water below 8 or 10 feet, even when nitrogen levels are high and would well exceed 100 percent saturation if this water were brought to the surface. We have no evidence, however, that fish will independently seek deeper water to avoid the impact of the gas.

Studies have been made of fish confined to large screened cages. Those held at shallow depths in the reservoirs were unable to acclimate to the high nitrogen problem. On the other hand, fish in deep cages were able to compensate for the problem and their mortality was lessened. They were apparently able to avoid serious trouble by seeking lower levels at greater depth.

The exact level at which nitrogen affects salmon is not clearly understood although research on various forms of fish has investigated gas bubble disease for at least 70 years. The excitement over the Columbia River problem has intensified studies on salmon and steelhead during the past few years. Harmful effects have been noted by some workers from concentrations as low as 103 percent, although generally most studies indicate severe problems begin at 115 percent. The variation between these results depends somewhat on the species of the fish, the age at which they are studied, and the physical conditions of the laboratory equipment. There are some indications that very small salmon are more susceptible than larger migrants. Most of the work at the present time is being done by the research laboratory of National Marine Fisheries Service in Seattle. Some is being conducted, however, by the Washington Department of Fisheries, Environmental Protection Agency, and the Bureau of Sport Fisheries and Wildlife.

As you are probably aware, the department of environmental quality in the State of Oregon has considered a limit of 105 percent saturation as the desirable threshold that can be permitted. In the States of Washington and Idaho there has been some indication that they would accept a limit of 110 percent saturation.

The problem in the Columbia River has drawn together many agencies and industries in a concerted effort to preserve the salmon and steelhead. During the spring when the spill is high at the dams, frequent discussions and continual observations are an accepted procedure. Full cooperation of the Corps of Engineers, Bonneville Power Administration, and private and public utilities is appreciated in order to control the spill at critical times.

During the past 2 years the spill has been significantly reduced during 1 week each spring to provide the most satisfactory quality of water for the release of fish from the hatcheries. As many fish as possible have been released at this time. In 1972 this occurred during the week of April 23. Nitrogen content was generally reduced to levels below 110 percent.

Many other ideas for such coordinated effort have been adopted and are being put into effect by the Corps of Engineers and the fishery agencies. These will undoubtedly be discussed later.

With the research evidence both in the laboratory and in the field, nitrogen has been considered to be the most serious problem in the Columbia at the present time. Although we recognize that some individual fish may recover from a gas bubble problem, the evidence of research in the river is that the total mortality is high.

Experiments of the National Marine Fisheries Service in the river demonstrated in 1970 after completion of Lower Monumental and Little Goose Dams in the Snake River, that fish passing through this area suffer an estimated 70 percent mortality, largely caused by nitrogen. Other marked fish experiments by National Marine Fisheries Service and Oregon Fish Commission indicated an accumulative mortality in excess of 50 percent in passing over three dams between the mouth of the Snake River and Bonneville Dam and losses of a similar magnitude below Bonneville.

There are many things that can be done to ameliorate the nitrogen problem. They nearly all involve the reduction of spill at all dams during the migration period of salmon and steelhead. This, of course means greater passage through the turbines and in turn directs attention to the protection of fish from injury at this point. Consequently, as additional turbines are brought on the line and the spill is reduced it is foreseen that effort should be placed on the screening of turbines.

If it were not for the strenuous effort and close cooperation of all concerned in the last 2 or 3 years we suspect the fish runs would have suffered severely. With the program of study that is presently at hand and the means that are being incorporated in the dams of the Columbia River, we anticipate reasonable success. Nevertheless there is still concern about the results that can be expected and we urge continued effort to protect these fish.

Mr. Howard. Thank you very much. We certainly appreciate your testimony. I believe from your statement I understand that there is not yet a clear indication of the problem of nitrogen supersaturation, as it is just where that problem begins, and there should be more research to find out how much is necessary for harmful effects.

Dr. Perry. That is true. There is a serious problem, but we need to define it more precisely.

Mr. Howard. In your report, you state that harmful effects have been noted, et cetera—and that there are some indications showing that it seems to be a question as to amounts.

Dr. PERRY. This is true.

Mr. HOWARD. We also have a situation somewhat disturbing. Oregon—105 percent, Idaho—110 percent—this is a confusing area I agree, and we should keep up the studies to find out how much can be tolerated. Also, tests have shown that nitrogen levels of 110 percent is high enough to cause some disease. It does not say by whom or how, but it would indicate that the States of Oregon and Idaho are in favor of disease of the salmon, which of course is not true. I guess about 10 years ago it was noted in the Columbia as a real problem. So I would hope that more continuing research funds on the problem by experts would give us a clear indication of where the problem starts and where it ends. We do have so many levels being testified to, some qualified, others flatly stated, in magazines, et cetera, and may lead us down the wrong path, or at least in a wrong direction. Thank you for a comprehensive statement concerning the problem of nitrogen supersaturation.

Dr. PERRY. May I comment more? The approach is faulty. You can take the safest level indicated and permit nothing beyond and then modify it as research shows it can be modified. Others can take another level on the Columbia River, and then shut it down tighter. This is the difference between the levels established by the States. They all have the same research. I lay on the table charts showing good research on different levels. Some are dealing with small fish, some with adults, and to lump it all together is difficult, so you have to qualify it. Also, dealing with different types and percentage of water.

Mr. HOWARD. I agree. Obviously, we are still in the discovery stage.

Mr. MCCORMACK. Thank you for appearing before us. You mention a mortality rate difference in your testimony. Are you speaking of downstream migrants?

Dr. PERRY. Yes.

Mr. MCCORMACK. How?

Dr. PERRY. Fish were captured at one dam and released, and at one stream downstream and marked, and an analysis of the catch leads to this conclusion. This figure of 70 percent was challenged by some, and a committee was established to look at it, and they came back and said that it looked like a good study. This was repeated the following year and results found to be not quite that high but continually observed.

Mr. MCCORMACK. May I be the devil's advocate for a moment? To what degree do we know that nitrogen supersaturation is causing the deaths?

Dr. PERRY. Because fish are seen with bubbles in them. Lab experiments show that fish do not survive with that, and so you relate one to the other.

Mr. MCCORMACK. The fish tend to remain on the surface, don't they?

Dr. PERRY. Relatively speaking, on the surface. At night they come up.

Mr. MCCORMACK. If they were on the top, would they be susceptible to nitrogen supersaturation problems, too?

Dr. PERRY. Yes.

Mr. MCCORMACK. May I be the devil's advocate again on the other side. I am disturbed by the charts here showing that peaks for nitrogen supersaturation concentration and the migration happened to coincide. Can you comment?

Dr. PERRY. Work is based on what is in progress. Studies indicate we can drop the level of nitrogen by reducing the spill, and this is encouraging.

Mr. McCORMACK. Do you feel as a representative of Fish and Wildlife that everyone is cooperating?

Dr. PERRY. I think it has been marvelous. When this problem was recognized, there was close scrutiny for the first few years, and everyone could see the same problem, and they all knuckled down and got to work. The Corps of Engineers was very helpful, and other agencies were very helpful, too. Last year, we had a coordinating committee to regulate flows; and this year, everyone wants to get involved. I think it is an effort to do whatever they can.

Mr. HOWARD. The next witness is Dr. John Sheppard, member of the board of directors of the Washington Environmental Council. We certainly wish to welcome you, and are very happy that you are here. It is an environmentalist problem that we have, so we will be glad to hear your remarks.

STATEMENT OF DR. JOHN C. SHEPPARD, A DIRECTOR OF THE WASHINGTON ENVIRONMENTAL COUNCIL

Dr. SHEPPARD. Thank you for the opportunity to present this testimony.

There is little doubt that the sportsmen and conservationists of the Northwest are concerned about the adverse impacts of hydroelectric projects on the salmon and steelhead runs of the Snake and Columbia Rivers. If you want to get an idea of the depth of feeling on the "nitrogen supersaturation problem," I suggest that you read "River on Its Deathbed" in the April Outdoor Life.

The Washington Environmental Council has urged the Environmental Protection Agency to take strong action on interstate pollution problems resulting from Federal activities. Nitrogen supersaturation caused by federally constructed dams on the Snake and Columbia Rivers is one such pollution problem.

Why are environmentalists concerned about the adverse environmental impacts of hydropower projects? Sport salmon fishing in the State of Washington has grown at the rate of 10 percent per year over the past 20 years. Any loss of salmon and steelhead represent lost recreational opportunities. Since the Columbia River contributes about 60 percent of the salmon caught off the Oregon and Washington coasts, the "nitrogen disease" represents a serious threat to the existence of this valuable fishery.

Furthermore, the nitrogen supersaturation problem can be considered in the context of "social costs" generated by these hydropower projects. Salmon and steelhead killed by the nitrogen disease represent lost income for the commercial fishermen and those who cater to the sportsmen of the Northwest.

These potential social costs are not negligible. In 1969, anglers caught 876,000 salmon off the Oregon and Washington coasts. Remembering that 60 percent of these fish come from the Columbia River, assuming that two salmon are caught per trip, and using Mathews and Brown's value of a sport salmon day of $27 to $63, the annual economic value of the Columbia River sport salmon fishery is calculated to be between $7 and $17 million. Steelhead increase this by an unknown amount. University of Washington Prof. James Crutchfield conservatively estimates the value of the commercial salmon fishery at $5 to $10 million. So the Columbia River salmon and steelhead fishery has an annual economic value greater than $12 to $27 million. To place this in perspective, the value of the Columbia River fishery is 10 to 20 percent of the Bonneville Power Administration's net annual revenue. The fate of this fishery deserves your serious attention.

The past is prolog. Technological fixes, like slotted gates, may give the salmon and steelhead of the Snake and Columbia Rivers a temporary reprieve. But what about the environmental impacts of the hydrothermal plan? Does the Corps of Engineers have sufficient data available to manage the Columbia River of the future? Or will we go from one technological fix to another? Perhaps some of these questions will be answered by the current study of the Columbia River and tributaries.

We need a basinwide NEPA statement that carefully examines the various environmental impacts of the hydrothermal plan. Part of the statement should consider the environmental impacts of peaking operations of the Snake and Columbia River dams. If dams on the Columbia River and its tributaries are going to be used as a coordinated system to generate peaking power, it makes little sense to examine the system on a piecemeal basis. Your committee should be asking for this statement.

Thank you for the opportunity to testify.

Mr. Howard. Thank you for your testimony, Dr. Sheppard. I am sure the corps will be involved in the long-range future of the Columbia River. In your first paragraph you suggested that we read "River on Its Deathbed" in the April Outdoor Life. I have not read it. There must be a pipeline through to Congressman McCormack. As we left Dulles Airport yesterday, there was a hijacker wanting $300,000 for it, so we did not read it. We would certainly point out the fact that we must do more than just go at the problem when it begins to overwhelm us. That is why we are fortunate in the Congress to be the committee that deals most closely with the Corps of Engineers. The Committee on Public Works is also the environmental committee. We caused the establishment of the Environmental Protection Agency and put it in other developments in the country such as the Highway Act. We write the water pollution legislation. I remember several years ago getting interest in the Water Quality Act of 1965, the first major program, and that we did not have the advocates around the country and did not realize the crisis of the situation. Now we recognize problems, and most States are preserving and reclaiming our environment. I think we are fortunate in the present setup in the Congress where one committee has jurisdiction over both areas. We are tying in much more closely with EPA, and corps and the Committee on Public Works. And we feel it is just as important in rural areas such as this that we do have the cooperation and coordination of people of all interests, including those who speak for the environmentalists. So I thank you for your testimony. Your main point at not being satisfied with stopgap measures, and that we should develop a long-range program, will, I believe, be adopted.

Mr. McCormack. Thank you. I want to comment on the remarks that you just made. It is the Public Works Committee that is taking steps in the environmental pollution control and I am proud to have the opportunity to serve on this committee. Three quick points: The article you recommend we read was rather theoretical and inflammatory and did not carry a rational theme. I would wish that such articles would be less inflammatory, more objective, and use fewer scare words.

Dr. Sheppard. I was not endorsing the article, only pointing out the concern. Looking at the nitrogen problem is an orderly planning process which in this case did not take place, and hopefully in the future we will do better. There are a lot of people very concerned and emotional and you should at least be aware of how some people feel.

Mr. McCormack. Thank you. Now another question: Are you suggesting that we request an environmental impact statement for the entire hydrothermal electric plan for the Northwest?

Dr. Sheppard. Yes; we are.

Mr. McCormack. Now to another subject. I have recently been involved in discussions involving an irrigation project which might be combined with a large industrial complex in northern Washington. One concept is that electric power would be obtained by damming one of the dry coulees in northern Washington and using it for pump-storage. Such filling and flushing of this reservoir would obviously make it useless for recreational purposes. However, if we were to start with a completely isolated dry coulee and designate it for such industrial use, do you think that the environmental interests in the Northwest would accept such a concept?

Dr. Sheppard. I do not know for sure; we would want to look into it. We would certainly feel apprehensive about any such project.

Mr. McCormack. I want to congratulate Dr. Sheppard for his dedication and hard work, particularly with respect to protecting the rivers in the Northwest. Very few persons have been as dedicated or as rational as he has been and I think we all owe him a debt of gratitude.

Mr. Howard. The next witness will be Col. Richard M. Connell, of the U.S. Army Corps of Engineers. We are very anxious to receive your testimony, Colonel, please proceed.

STATEMENT OF COL. RICHARD M. CONNELL, DISTRICT ENGINEER, DEPARTMENT OF THE ARMY, WALLA WALLA DISTRICT CORPS OF ENGINEERS

Colonel Connell. It has been clearly established that nitrogen supersaturation is directly related to the discharge of water over the spillways at dams. This process entrains air in the plunging flows and subjects it to pressures at the bottom of the stilling basins which force the gases into solution and causes supersaturation. A number of studies have been conducted, particularly at Little Goose and Ice Harbor Dams and below Bonneville Dam, in which downstream migrants have been held in holding pens in surface waters with high gaseous supersaturation. Tests on exposure of adult salmonids have also been conducted, particularly at Oregon State University, to determine the effects of exposure to supersaturated water.

These tests have established that death or serious damage may occur to fish which remain in highly supersaturated waters, the severity of loss increasing with increased exposure. Research leading to the estab-

80-152—72——5

lishment of these relationships was pioneered by the Washington Department of Fisheries and National Marine Fisheries Service in the late 1960's. Since that time, the Corps of Engineers; the State fish and game and environmental quality agencies of Washington, Oreg., and Idaho; the National Marine Fisheries Service; the Bureau of Sport Fisheries and Wildlife; Bonneville Power Administration; Bureau of Reclamation; Environmental Protection Agency, and the mid-Columbia Public Utility Districts have joined efforts to determine the specific source and scope of the problem, the impact on fish resources, and to develop and implement methods of control. A task force composed of representatives of these agencies, endorsed by the Governors of Washington, Oregon, and Idaho meets regularly to coordinate research, river management, and structural modification programs aimed at the ultimate and complete solution of the supersaturated gas problem in this region.

ACTIONS

Observations in the spring of 1965 by the Washington Department of Fisheries and the Bureau of Commercial Fisheries showed that dissolved nitrogen concentration at some sites in the Columbia River was as high as 125 percent of the saturation value. Levels of this magnitude had produced gas bubble disease in juvenile salmon in hatcheries. Additional surveys were made in 1966–67 to attempt to determine how this supersaturation occurred and whether high levels of dissolved nitrogen might be responsible for losses of adult and juvenile salmonids in the main rivers. The studies in these years, while not conclusive, did strongly indicate a potential problem to fish and did demonstrate that the supersaturated conditions were related to heavy spill periods at the dams.

It was not until the raising of the pool behind John Day Dam in 1968, however, that the seriousness of the problem became fully recognized. Heavy spillway discharges at that project caused nitrogen supersaturation conditions of 123 to 143 percent, and symptoms of gas bubble disease and mortality were found in both juvenile and adult salmon. An extensive dissolved gas measurement program was initiated and a substantial amount of inriver sampling has been conducted to determine the degree and extent of the problem, the individual input of each project, the carryover between projects, and background levels found in undeveloped streams and below natural waterfalls. Actual sampling and analysis have been done largely by Washington Department of Fisheries, Fish Commission of Oregon, and National Marine Fisheries Service.

The Corps also contracted with the Water Research Engineers of Walnut Creek, Calif., in 1970 for $20,000 to develop a mathematical model that will permit prediction of gas saturation values of various operating conditions of its projects. The sampling and analysis for gas saturation levels has until recently been a complex and difficult task that restricted the amount of coverage that could be made of the area involved. Recently, however, EPA has been instrumental in developing a new, inexpensive saturometer that essentially permit a "dip stick" type measurement of gas levels in a few minutes by an easily trained technician. This instrument measures the total dissolved gas content by diffusion through a permeable tubing and the value is read from a dial. Dissolved oxygen content is determined by a simple method requiring a few minutes and this is subtracted from the dial reading. Since nitrogen and oxygen make up approximately 99 percent of the total gas, the nitrogen content can be determined quite accurately in about 15 minutes. Over 50 of these instruments have been built to date at a cost of $160 each and many of them are now in service. I have one of these test instruments here with me for you to take a look at. EPA has conducted training courses so that all involved agencies can do their own sampling. This is in contrast to the old method which required central testing stations with equipment costing several thousand dollars and requiring about an hour per test. All data collected are placed into automatic data processing systems of Environmental Protection Agency and the Corps and are available for anyone to use.

Following the disclosure in 1970 by National Marine Fisheries Service of high probable mortalities to juvenile fish in the lower Snake River, the corps has funded the monitoring and testing of nitrogen supersaturation for a total of about $75,000 to date. Washington Department of Fisheries has conducted additional studies in the mid-Columbia region with funds largely provided by the Washington State public utility districts. Holding pen studies have been conducted in all reaches of the river to determine relationships between gas concentrations, exposure times, water depth, and effects on fish.

The National Marine Fisheries Service is currently conducting studies on the effects of nitrogen supersaturation on salmonid eggs, fry, fingerlings, adults, fish food organisms, and nonsalmonid fish by in-river and laboratory tests at Prescott, Oreg., and the National Marine Fisheries Service laboratory in Seattle, Wash.

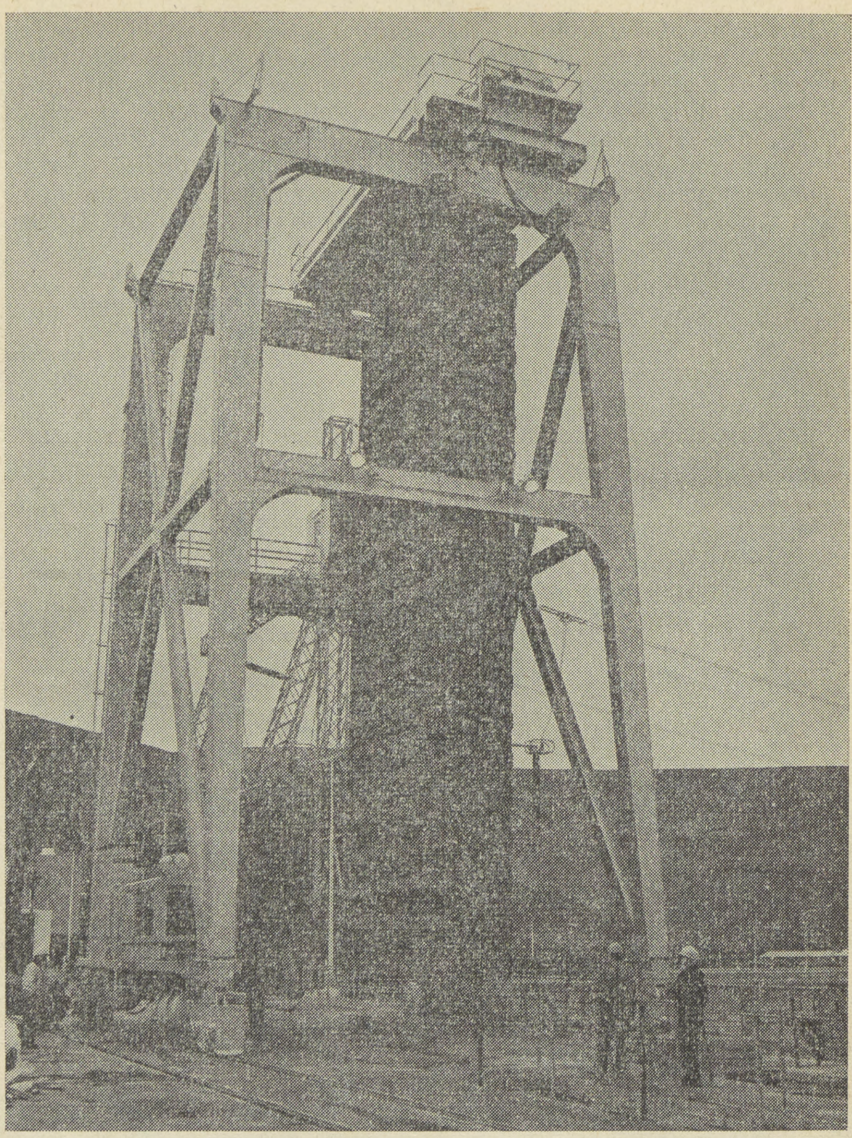
In the past 2 years since the National Marine Fisheries Service research indicated a high loss rate to seaward migrants in the Snake River, the corps has taken a number of actions involving plant operations, structural modification, research, and design studies aimed at reducing or eliminating supersaturated nitrogen or minimizing the exposure of fish to excessive concentrations.

In 1971, limited nitrogen supersaturation control was achieved by a modified reservoir system operation and to some extent by individual project operational revisions. Through close coordination with the fishery agencies, EPA, Bonneville Power, Bureau of Reclamation, and the mid-Columbia public utility districts, a plan of water storage, select turbine loading, and power transfers was planned by the North Pacific Division of the Corps of Engineers and executed in the Pacific Northwest and western Canada to curtail spill at lower Columbia River projects. During this period, State and Federal hatcheries on the lower Columbia made their annual releases of some 40 million young fish. Nitrogen levels during this time were near the 110 percent level and sampling of the fish movement indicated that these fish had migrated into the estuary before limited storage capacities and high runoff necessitated resumption of spill at all projects with resultant high nitrogen levels. In 1972, this was again accomplished in the last week of April and some 18 million fish were released. Though the numbers of fish released in 1972 were less than in 1971, the total poundage was greater because data indicates that fish reared to a larger size for release have a much better chance for survival.

Ongoing construction will also materially improve nitrogen conditions in the Columbia River system in 1972 and 1973. During the spring of 1972, two additional large storage projects will be storing runoff flows. These are Dworshak Dam on the north fork Clearwater River in Idaho and Libby Dam on the Kootenai River in Montana. Mica Dam on the upper Columbia River in British Columbia will be completed by spring 1973. Together, these three projects will add 19 million acre-feet of active storage to the Columbia River system. This storage will do much to reduce spill and nitrogen supersaturation. In a median year, they will reduce the flood peak and spill at The Dalles Dam by about 100,000 c.f.s. or about a 20-percent reduction in total flow. Even though Dworshak Dam is not yet completed, floodwaters are being stored this year. With the extremely heavy snow cover in the north Fork Clearwater drainage, it is predicted that the project may reduce the flows in the Snake River by as much as 40,000 c.f.s. Overall, the peak flows will be reduced by varying amounts for about 95 days.

In the lower Snake River, where the most immediate and critical problems existed, substantial relief from nitrogen supersaturation by foreseeable additional storage and River control is not forthcoming. At projects in the lower Snake, a great amount of effort was expended on structural changes to reduce or eliminate nitrogen. Hydraulic and mathematical model studies were conducted to develop possible solutions through modifications to powerhouses and spillways. One of the most promising results of this work is a structural modification that permits the passage of substantial amounts of water through skeleton bays constructed for future power units at many of our projects. In February 1971, the division engineer approved the recommendation of the Walla Walla District to install a prototype slotted bulkhead in one bay of the skeleton powerhouse at Little Goose Dam. Design and model studies were undertaken simultaneously on this program. On March 12, 1971, an invitation for bids was issued. On March 16, the bids were received, and notice to proceed was given on March 23. The first bulkhead was placed on April 10, 1971, and all three bulkheads were in place by May 10, 1971.

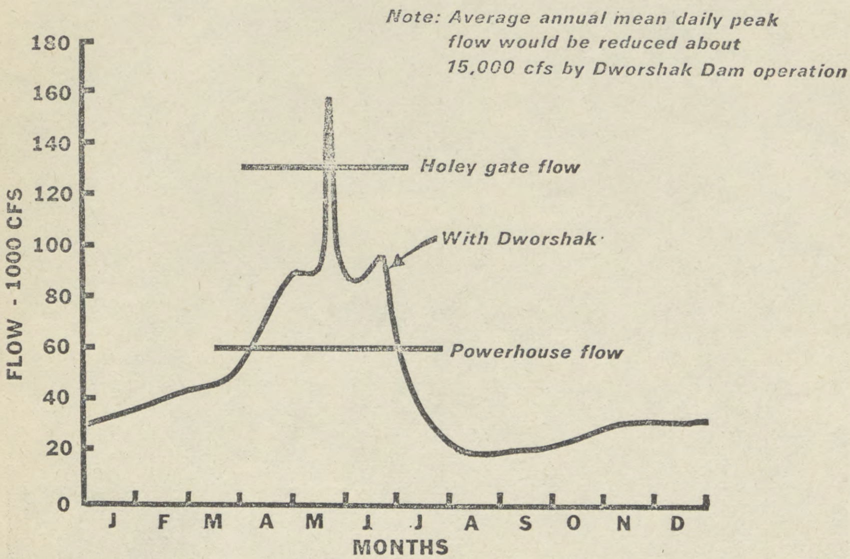
Testing of the prototype began on May 10, 1971, and observations of the resulting flow conditions in the skeleton bay and downstream area indicated successful operation.



Holy Gate

This is a picture of one of the three bulkheads. Note that it is a solid steel gate fitted with narrow slots to limit the passage of water through the gate. We will see one of these at Lower Monumental Dam this afternoon. These slotted bulkheads permit passage of approximately 21,000 c.f.s. per skeleton unit without entraining air and increasing the nitrogen level. Nitrogen sampling above and below the project did not indicate any increase in nitrogen supersaturation.

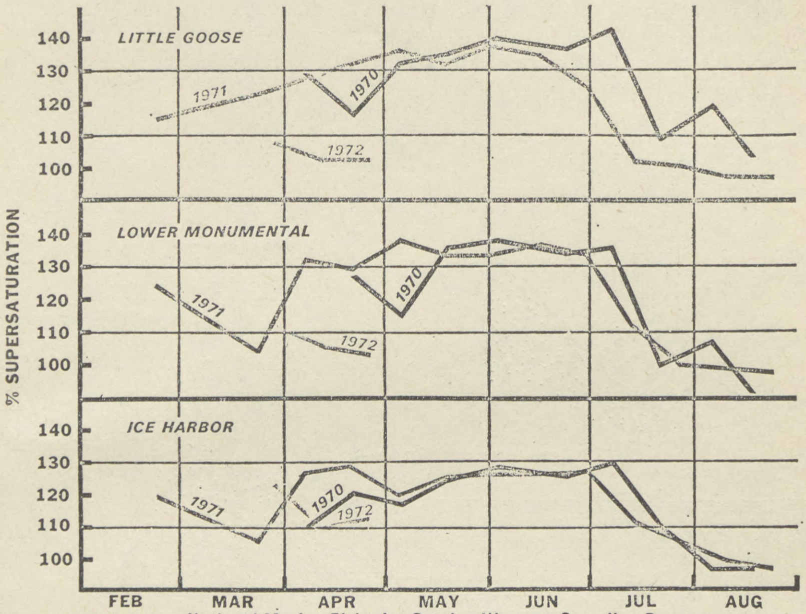
As a result of the prototype tests, contracts were awarded in the fall of 1971 to permit installation of the slotted gates in all the skeleton bays at each of the three lower Snake River projects (Little Goose, Lower Monumental, and Ice Harbor) prior to the spring freshet period of 1972. These contracts have now been completed, and the skeleton bay diversion is in operation at all three dams. Completion of this installation increases the powerhouse flow capacity at the two upper dams from about 66,000 c.f.s., with just the power units, to about 130,000 c.f.s.



AVERAGE ANNUAL FLOW SNAKE RIVER
CLARKSTON, WASHINGTON

This chart shows the effect of the slotted gates on the flow at Little Goose Dam. Note that on an average flow year, the spill period would be reduced from over 80 to 15 days or less.

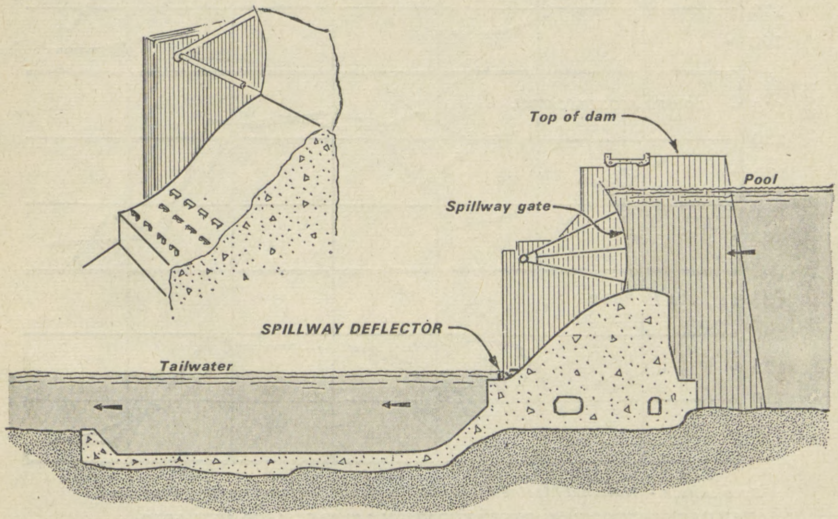
Nitrogen levels resulting from the spillway flows would be further reduced because of the higher dilution from powerhouse flows. Funds for this program were provided by supplemental congressional appropriation in fiscal year 1972.



Data source - National Marine Fisheries Service Nitrogen Sampling Program

TAILRACE NITROGEN SUPERSATURATION LEVELS - 1970 1971 1972

To show you some idea of what we see of the effect of the slotted gate program, I would like to show the effect on nitrogen saturation levels below each project on the Snake River this year, as opposed to the levels of previous years. The Corps is also investigating modification of spillways to handle water that cannot be bypassed through the project powerhouse. This might be called a ski jump or flip lip. Since the air and nitrogen are normally entrained in the plunging and rollback action of a conventional stilling basin, this modification would direct modest amounts of spill downstream on the surface where there would be no pressure and supersaturation. This device was modeled at the Corps' Bonneville Hydraulic Laboratory, and results were encouraging.



CROSS SECTION - LOWER MONUMENTAL SPILLWAY

This chart shows a diagram and cross section of the flip lip. On the basis of the model work, we constructed a flip lip in one bay of lower Monumental Dam and one bay of Bonneville Dam this past winter to test in prototype its capability for passing water without creating supersaturation. The Lower Monumental installation was completed by April 1. Initial tests look promising, but further work is necessary before large sums of money are committed for such an installation in the many spillway bays in the Columbia River system. The Walla Walla District is currently supplying funds to NMFS to determine the possibility or extent of mortality to downstream migrant salmonids passing through the slotted gates or over the flip lip. These studies will be completed in the spring of 1973. The results of these studies will influence greatly the decision to install flip lips in the project spillway bays.

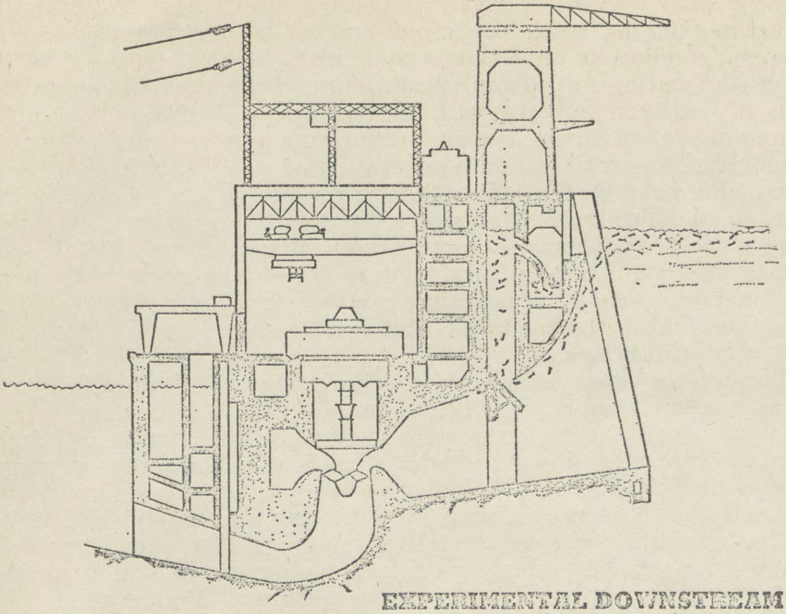
In addition to passing water through skeleton bays, the slotted bulkheads show promise of usage in connection with power units.

In the spring when the river is flooding and the seaward migrant fish are moving to the sea, powerloads are at their seasonal lows, while electrical generation potential is at a maximum. Thus, we have a problem of keeping all of our powerhouses fully operable at a time we most need to keep water out of the spillways. To resolve this problem, we are investigating the passing of maximum amounts of water through turbines with minimal generation of electricity. This is done by reducing head on the units through use of the same slotted gates ahead of the turbines. Prototype tests recently conducted at Little Goose project show that this can be done. Normal flows of water can be passed through the unit, producing only 7 or 8 megawatts of power compared to about 150 megawatts when the unit is operated normally. We have further testing to do, but are most encouraged with the potential of this system.

Although the Corps is dedicated to eliminating or minimizing nitrogen supersaturation to the extent possible, I should mention efforts to bypass fish around high concentration areas. The trapping and hauling of seaward migrants around dams has been under study for many years by the National Marine Fisheries Service. The studies have concentrated on methods of effectively deflecting and trapping juvenile fish from the turbine intakes and on the effect of transporting fish around long segments of river on the homing instinct of returning adult fish. The application of such a program, if successful, was intended primarily to mitigate known losses through turbines and unknown predation losses in the reservoirs. There are two ways to solve the fish mortality problem from nitrogen supersaturation: either prevent supersaturation from occurring in the river or remove the fish from the supersaturated water. Obviously, fish so transported have reduced exposure to water supersaturated with nitrogen, and such a system offers a possible contingency method for protecting a portion of the fish runs while ways of eliminating nitrogen supersaturation are devised and implemented.

In 1971 the National Marine Fisheries Service, under a $544,000 contract with the Walla Walla district, Corps of Engineers, tested a prototype deflection, trapping, and transport system at Little Goose Dam on the Snake River. The large, complex, traveling deflection screens were installed ahead of one of the three turbine units to determine the efficiency of such a system in deflecting fish and to test the structural and operational capability of the equipment.

80-152—72——6



EXPERIMENTAL DOWNSTREAM
PASSAGE OF MIGRANT FINGERLINGS

This shows a cross-sectional view of the powerhouse unit with the traveling screen in place. Note the diversion of fish into the gate well and into the bypass system to be discharged into the river below or collected for transporting. The National Marine Fisheries Service marked the fish trapped at Little Goose so that they could compare the return survival of fish hauled with that of control groups released below the dam and allowed to migrate to sea in the normal manner. As with most any new equipment, they had some mechanical difficulties but proceeded through a debugging process. These problems have since been largely solved according to National Marine Fisheries Service and they are looking forward to greater trapping success in 1972. Despite the problems, the deflector screens operated much of the time in 1971 and the system offers much promise for accomplishing its originally intended purpose.

Tests have shown that when the screens are operating, about 90 percent of the fish entering a turbine can be trapped and safely handled. Such a system, when installed in the full complement of turbine units at a project, would in effect be capable of collecting 90 percent of the migrating population. We in Walla Walla district are continuing to support these experiments financially for future application as necessary to maintain the anadromous fish runs in the Columbia Basin. In the meantime, in 1971 some 350,000 juvenile salmon and steelhead were trapped, transported, or otherwise handled as a part of this endeavor. With these tools I have described, we should be able to protect against critical loss of fish in the Snake this season with even greater improvement of survival in the subsequent 1 or 2 years. We do have several projects on the Columbia where the nitrogen problem may persist to some degree for years to come. At Chief Joseph Dam considerable spilling is occurring now and the situation will be aggravated further with the completion of the new powerhouse upstream at the Bureau of Reclamation's Grand Coulee Dam. The corps is seeking funding for the early installation of the 11 additional power units at Chief Joseph which will serve to reduce nitrogen in the Upper Columbia River. If we achieve our recommended schedule, the new units would be available for diverting additional water from the Chief Joseph spillway between 1976 and 1978.

At Bonneville, hydraulic capacity of the powerhouse is the most limited on the river and there are no skeleton units to use as bypass systems. The "flip lip" and upstream storage should provide substantial relief; however, additional powerhouse capacity is needed to take water away from the spillways, and studies for a second powerhouse at Bonneville are nearing completion. At best, it will probably be at least a decade before such a second powerhouse can be funded and constructed. A second powerhouse is also being studied for McNary Dam but it will be many years before such an addition would be available.

In summary, while there are several problem areas that may persist for some years, we are making deliberate considered efforts with all other agencies to solve the nitrogen supersaturation problem in the most reasonable and expeditious manner. I feel confident that we now have a good handle on the problem on the Snake River and that our continued efforts will bear timely fruit to protect the fishery resources of the area.

Colonel CONNELL. I have here a saturometer which is being used regularly.

Mr. HOWARD. Excuse me; I do not want to interrupt, but will you explain the 110 percent sampling? Also, was this damaging?

Colonel CONNELL. Mr. Chairman, I did turn back to the National Marine Fisheries Service sampling program, and would say we would have to rely on the return run. This was the best that could be achieved during that season and the limited sampling to date at that time failed to show any effect on the fish. The real result will be when the fish return to spawn.

(Slides shown.)

Mr. McCORMACK. While you are there—it is in spite of Dworshak we are getting this peak.

Colonel CONNELL. It is taking something like 40,000 off the Snake River alone.

Mr. HOWARD. From the chart, it seems that with the slotted dam at Ice Harbor where you have a higher level, the other will be at that same place, and it is lower, so it is not a proportionate thing. Could you tell us why?

Colonel CONNELL. The flows going over the dam in some instances, the limited storage behind each dam, might affect the sampling at each point. You will notice that the 72 points were higher, and then it dropped down. Part was caused by higher flows. Another aspect is that Ice Harbor has smaller flows through the powerhouse than the other two dams on the Snake River.

Mr. HOWARD. This would seem to be an indication of more of a success.

Mr. McCORMACK. What is the peak period this year on the Snake?

Colonel CONNELL. It will be about the 20th of May. It is a very heavy year.

Mr. HOWARD. Thank you very much, Colonel, for your testimony. This other operation you have is making water run through the empty turbine, what results do you get from that?

Colonel CONNELL. We have three gates, skeleton units, where units will be placed.

Mr. MCCORMACK. You mention the cooperation of other organizations. Do you feel you are getting all the cooperation you should be getting?

Colonel CONNELL. I feel most encouraged, and this is one of the most rewarding experiences of my life. The challenge is there, and seeing the job that needs to be done, everyone there helps.

Mr. MCCORMACK. One other thing, how long does it take the fish to get downstream to escape?

Colonel CONNELL. We are talking in terms of several weeks or longer, depending on the flow of the water in the river at the time, as well as how far we are talking about. Most of the releases were made from downstream hatcheries. We are talking in terms of about 7 to 14 days for the fish from Dworshak to get down to Little Goose. If you multiply that three times you can tell how long it takes to get the steelhead to sea.

Mr. HOWARD. But with the information you are gathering, in cooperation with the other agencies, I have been familiar with the Army Experimental Station in Vicksburg, Miss., do you feel you can do all the studying you need here without the need for a model? Would that be of any help to you?

Colonel CONNELL. The expertise we have developed is on Bonneville, itself, where the North Pacific Division has its own models. This is in fact where we developed the model of the slotted gates. You cannot, of course, model supersaturation. To find out if you are solving the problem of nitrogen supersaturation, you have to build a prototype.

Mr. MCCORMACK. I would like to commend Colonel Connell for his outstanding leadership here in the Northwest in carrying out the projects of the Corps of Engineers and in helping to do everything possible to preserve and develop the river for recreation and beauty, and to help preserve the fish runs. It has been under his leadership that the old hostilities between the corps and environmentalists have started to disappear, and have been replaced by responsible dialog and intelligent programs to do everything possible to help preserve the finest aspects of the river, including the fish runs, while carrying out the directives to build the dams and provide for navigation, flood control, and hydroelectric power. I believe that everyone, no matter how he looks at the river, can be proud of the work that Colonel Connell has done and the leadership he has provided.

Colonel CONNELL. Thank you.

(The following was subsequently received for the record:)

DEPARTMENT OF THE ARMY,
WALLA WALLA DISTRICT, CORPS OF ENGINEERS,
Walla Walla, Wash., May 15, 1972.

HOUSE COMMITTEE OF PUBLIC WORKS,
Rayburn House Office Building,
Washington, D.C.:

During my testimony at the House Committee on Public Works Hearing on Nitrogen Supersaturation at Richland, Washington, on May 6, 1972, I was asked a question concerning the length of time it required for the downstream salmonid migrants to reach the ocean. I requested a time extension on my answer until I could provide detailed information. I now wish to submit my answer and have it included in the Congressional Record of that hearing.

Travel time for juvenile salmonids is influenced greatly by the velocity of water through the river system. Creation of reservoirs on the river has reduced the velocity of flow even though the volume of flow remains the same. According to research conducted by National Marine Fisheries Service prior to construction of John Day, Lower Monumental, and Little Goose dams, the travel time from the Salmon River in Idaho to Bonneville Dam ranged from 18 to 32 days, depending on high or low river flows. Since construction of these projects, the migration time has extended about 18 days, for a travel time of 36 to 50 days for high to low flow years. About equal time is required for the fish to migrate from the Salmon River to the mouth of the Snake River as from the Snake River to Bonneville Dam. During the period of flow regulation in 1971 and 1972 when flows were reduced in the river system to permit hatchery releases in the lower Columbia River to migrate out under low nitrogen level conditions, these fish moved downstream to the estuary in less than one week. In 1971, this low flow was maintained for one week and in 1972 the period was maintained for about 10 days because of lower river flows at that time.

I appreciate the opportunity to delay my answer until I could obtain this information, and I hope it will satisfactorily answer the question of the Committee.

Sincerely yours,

RICHARD M. CONNELL,
Colonel, CE, District Engineer.

Mr. HOWARD. Our next witness is Mr. Robert Stockman, from the Washington State Department of Ecology. You are most welcome today, and please proceed. In the interest of time, I would hope that the balance of the witnesses will summarize their remarks, and in this way we will be able to keep our schedule.

STATEMENT OF ROBERT L. STOCKMAN, EXECUTIVE ASSISTANT DIRECTOR OF THE WASHINGTON STATE DEPARTMENT OF ECOLOGY

Mr. STOCKMAN. I have testified before you in many other situations.

Mr. Chairman and members of the committee, I am Robert L. Stockman, executive assistant director of the Washington State Department of Ecology. It is a privilege to be here today to express our views on the nitrogen saturation problem and water quality standards for nitrogen saturation.

On April 24, 1972, the Department of Ecology adopted amendments to its water quality standards to establish the criteria for nitrogen saturation and to provide an implementation and enforcement plan. In addition, Director John Biggs, on behalf of the Department adopted a "statement of intent" which clearly expressed the need for a system of river management and the need for viable working agreements among the State environmental agencies together with arrangements for full participation by the fisheries agencies and the operators of hydroelectric and water control and utilization projects.

I will discuss the background leading to the adoption of the standards and implementation plans, review their major elements and present our view on moving ahead from here.

Governor Tom McCall, of Oregon, called a tristate Governor's meeting on November 12, 1971, to establish action steps to meet this problem. Governor McCall chaired the meeting. Governor Andrus of Idaho was represented by his administrative assistant, Edward V. Williams. I had the privilege of representing Governor Dan Evans of Washington. British Columbia was represented by Mr. Walter Raudsepp, Deputy Minister for Water Resources of the Ministry for Lands, Forest, and Water Resources. Progress reports were presented by the National Marine Fisheries Service, the U.S. Corps of Engineers and the Environmental Protection Agency. Views on nitrogen standards were presented by the Fish Commission of Oregon, the Oregon Department of Environmental Quality, and, through a joint preservation, by the Washington Department of Ecology and the Idaho Department of Health. Response to comments and recommendations were made by the Bonneville Power Administration, the Bureau of Reclamation, and the Chelan County Public Utility District.

In the joint presentation by Idaho and Washington, the following basic points were made:

1. Nitrogen supersaturation caused by the spilling of excess water over spillways at hydroelectric projects on interstate waters is considered by the State environmental agencies to be a violation of the State-Federal standards and a serious threat to the fishery resource of these river systems:

2. A specific criteria or level for nitrogen saturation was not currently identified in the water quality standards;

3. Since a substantial natural resource is being jeopardized, Idaho and Washington declared their intent to establish a maximum level of nitrogen saturation on interstate waters and particularly those areas of the Columbia and Snake Rivers utilized by commercial and game fish species for spawning, rearing, or migration;

4. A maximum level of 110 percent of saturation was recommended, however, in keeping with the policies of the State and Federal environmental agencies, water project owners should apply all known and reasonable methods to achieve the lowest possible nitrogen supersaturation level;

5. Research funds should be made available to determine whether maximum supersaturation values of less than 110 percent are desirable to protect fisheries resources indigenous to the Columbia River system and other interstate waters;

6. A plan for implementation and enforcement of the standards should be developed in cooperation with the State and Federal fisheries and pollution control agencies and the project owners;

7. The plan should include a summary of all known and potentially feasible methods of reducing supersaturation of atmospheric gases, a priority schedule listing each project and the gas reduction method to be employed and a time schedule for completion.

In presenting the statement, great emphasis was placed on the idea that the real practical standard was the utilization of all known and reasonable methods of control applied at the earliest possible time. Recognizing that a number standard was no doubt needed for legal enforcement purposes, I stated that the number selected should be based on all available scientific information and should be supportable in court. In other words, every effort should be made to avoid the numbers game in setting standards.

As an outcome of this tristate Governor's meeting, a joint resolution was adopted which:

1. Provisionally endorsed the recommendations of the Federal and State fisheries agencies of Idaho, Oregon, and Washington, calling for a nitrogen standard not to exceed 110 percent of saturation and calling for fishery research to confirm future needs;

2. Directed the environmental control agencies of the three States to immediately initiate proceedings to adopt and implement uniform water quality standards for nitrogen;

3. Urged the appropriate Federal agencies to authorize funds sufficient to conduct needed fisheries research;

4. Agreed to request the President and Congress of the United States to authorize funding of Federal project modifications as necessary;

5. Directed the existing nitrogen task force consisting of Federal and State fishery and environmental control agencies of the three States, together with owners and operators of public and private dams and the power supply and distribution agencies, to seek overall coordination of the nitrogen control program for the Columbia and Snake Rivers.

A copy of this resolution is attached.

(The resolution referred to follows:)

Joint Resolution of the Governors of Oregon, Idaho, and Washington

Whereas, runs of anadromous fish in the Columbia River system contribute millions of fish each year to sport and commercial fisheries in Washington, Oregon and Idaho, and in the ocean from California to Alaska; and

Whereas, nature will bear much of the cost of maintaining upriver runs if given the chance and not excessively interfered with by man's encroachment on the environment; and

Whereas, spilling of large amounts of water at many main stem Columbia and Snake River dams causes nitrogen supersaturation in the water resulting in extremely high mortality to young and adult salmon and steelhead and other species; and

Whereas, chinook salmon downstream migrant losses between only two dams, Little Goose and Ice Harbor, approached 70 percent in 1970 and 52 percent in 1971 and there are many more dams in the system where losses occur; and

Whereas, such losses threaten the very survival of certain upriver runs which have been using these waters for centuries; and

Whereas, steps can be taken to reduce significantly these catastrophic losses,

NOW, THEREFORE, Governor Tom McCall of Oregon with Governor Cecil Andrus of Idaho and Governor Dan Evans of Washington concurring through their general representatives does hereby resolve to:

1. Provisionally endorse the recommendations of the federal and state fishery agencies of Idaho, Oregon and Washington which unanimously agree that nitrogen standards not to exceed 110 percent of saturation be adopted for the interstate waters of the Columbia and Snake Rivers, provided that fishery research be carried out to determine if more restrictive standards are necessary.

2. Direct the environmental control agencies of our three states to immediately initiate proceedings to adopt and implement uniform water quality standards for nitrogen gas in the above interstate waters.

3. Urge the appropriate federal agencies, particularly the Environmental Protection Agency and the Corps of Engineers, to authorize funds sufficient to conduct fisheries research to:

(a) Define with bioassay techniques the effects of lower levels of nitrogen supersaturation on fish, with emphasis on eggs, yolk-sac fry and food organisms.

(b) Continue development of spillway modification and other devices to reduce nitrogen supersaturation.

(c) Develop techniques for getting juvenile salmonids down and adults up the Columbia and Snake Rivers with minimum mortalities during the next several years before nitrogen goals can be attained.

4. Request the President and the Congress of the United States to authorize funding of federal project modifications sufficient to satisfy nitrogen standards set by the states of Idaho, Oregon and Washington, such modifications to be consistent with the results of current Corps of Engineers research and development projects.

5. Direct the existing Nitrogen Task Force consisting of federal and state fishery and environmental control agencies of Idaho, Oregon and Washington; owners and operators of public and private dams in these states; and power supply and distribution agency to expand its present jurisdiction to include overall coordination of the nitrogen control program for the Columbia and Snake Rivers.

(S) Tom McCall,
Governor, Oregon.
(S) Edward Williams,
(For Governor Cecil Andrus, Idaho).
(S) Robert L. Stockman,
(For Governor Dan Evans, Washington).

Mr. Stockman. As a followup to the resolution directive, the State of Washington arranged a meeting of the environmental and fisheries agencies of the three States on January 19, 1972, to lay the groundwork for developing common standards, implementation plans and monitoring programs, and to define further research and development needs. We also organized a public meeting on February 17, 1972, in Vancouver, for the purpose of placing on the record, all of the available information on the effects and control of nitrogen supersaturation. At this meeting there was a very substantial input from the recognized experts in the Federal agencies and the State agencies of the three States.

In an effort to assure compatibility among the three States and the Environmental Protection Agency, a meeting of the three States' environmental agencies and the EPA was held on March 22, 1972, in Boise.

During the course of these meetings, the following significant factors became very clear:

1. There was clear scientific evidence to support a standard of 110 percent of saturation;

2. A management program for the entire Columbia and Snake River system is essential to the success of controlling the nitrogen problem;

3. Special attention must be paid to insure that corrective measures by physical changes or operational procedures to meet the nitrogen standard do not, in themselves, result in significant damage to the fisheries. Such damage could potentially occur with downstream migrants passing through turbines or slotted gates or in slowing fish passage.

The first formal public hearing by the department of ecology, leading to the adoption of the nitrogen standard, was held in Olympia on April 10, 1972. Precedent to this hearing, the department had reviewed the available information and had relied heavily upon information provided by the fisheries resource experts at the State and Federal level. These are the people we feel should be most knowledgeable and most concerned about the problem. At the hearing, the Environmental Protection Agency commended the department of ecology for its leadership in developing a standard and implementation plan, explained the procedure for review and adoption of State-interstate standards under the Federal Water Quality Act and spefically stressed the need for a systemwide management program in the interestate waters to control the nitrogen problem.

The president of the Tri State Steelheaders urged that the proposed criteria be made more stringent.

The Corps of Engineers outlined the work that it already has underway and the work proposed to control the problem. The Washington Department of Fisheries spoke in support of the nitrogen standard and urged that it be included in developing and approving procedures for implementation.

Spokesmen for the Douglas Country Public Utility District, the Grant County Public Utility District, and the Chelan County Public Utility District, together with a spokesman for the Northwest Electric Light and Power Association generally indicated that we do not have sufficient data at hand to realistically set a standard and that the proposed timetables may be too stringent.

Based upon the testimony at the public hearing and upon information and evidence submitted earlier, the Department of Ecology proceeded with the adoption of the water quality standard and the implementation and enforcement plan with final adoption occurring on April 24, 1972. The amendment becomes effective May 24, 1972.

I believe that the wording of the water quality standard, together with the statement of intent by the Department of Ecology, clearly expresses the view of this department with respect to managing the nitrogen problem. The State adopted the standard as applicable to both interstate and intrastate waters. I am including the standard and the statement of intent verbatim at this point in my presentation and will discuss the highlights.

(The standard referred to follows:)

Water Quality Standard Concerning Dissolved Nitrogen Gas Saturation

CRITERIA

The concentration of dissolved nitrogen gas shall not exceed 110% of saturation at the point of sample collection due to non-natural causes.

GENERAL CONDITIONS

The dissolved nitrogen criteria shall be referenced to the water temperature of the sample collected and the ambient atmospheric pressure at the water surface.

The Director may specify the applicability of the dissolved nitrogen standard with respect to excess stream flow conditions, direct that all known and reasonable measures be taken to assure protection of the fishery resource and require that operational procedures or project modifications proposed for compliance for dissolved nitrogen criterion shall not contribute to increased mortalities to juvenile migrants nor impose serious delays to adult migrants. In making these determinations, he may seek and enter into agreements with adjoining state environmental regulatory agencies.

Implementation and Enforcement Plan

Nitrogen gas supersaturation caused by the excessive spilling of water over spillways at hydroelectric and water control and utilization projects has been demonstrated to be a serious threat to the fishery resources of these river systems. The anadromous and resident fish resources of the Columbia and Snake Rivers are of special concern and in danger of extinction due to nitrogen gas supersaturation. The nitrogen gas saturation criteria and the following plan of implementation and enforcement has been developed in order to protect this valuable beneficial use of the waters within the State of Washington.

In keeping with the policies of state and federal environmental regulatory agencies, all hydroelectric and water control and utilization project owners and operators shall employ at the earliest possible date all known and reasonable methods, including facilities operation, as well as structural modifications and other methods of control to assure protection of the fishery resource and to achieve the established dissolved nitrogen criterion.

Each project owner or operator shall submit to the Department of Ecology within 60-days a proposed dissolved nitrogen monitoring and reporting program. The proposed program shall be subject to revision and approval by the Director, including revisions at annual or such other intervals as the Director may designate.

Each project owner or operator shall submit to the Department of Ecology by September 1, 1972, their conceptual program, including time schedules for facility construction, modification and operation to comply with the dissolved nitrogen standard. After reviewing the proposed compliance schedule, and such comments as are submitted, the Director shall issue a regulatory order establishing a compliance schedule, the progress reporting requirements and such other conditions as he determines necessary.

Each project owner or operator shall according to an approved compliance schedule, but no later than April 1, 1975, complete construction, modification of procedures, and place into full operation all facilities and methods necessary to comply with the dissolved nitrogen standard.

Statement of Intent, Water Quality Standards for Nitrogen Supersaturation, State of Washington, Department of Ecology

In adopting amendments to the state water quality standard to establish criteria for dissolved nitrogen gas, and to provide for the implementation and enforcement plan, the Department of Ecology is fully cognizant that:

1. Dissolved nitrogen supersaturation conditions during the spring and summer runs of salmon and steelhead in the Columbia and Snake Rivers are threatening the very existence of this valuable natural resource.

2. A cooperative system-management approach to the construction, modification and operation of hydroelectric and water control and utilization facilities on the Columbia and Snake Rivers and major tributaries is essential to the solution of the unique and complex problem of nitrogen supersaturation.

3. Agreement and cooperation among the official environmental agencies of the states of Oregon, Washington and Idaho is essential to such a management system together with participation in such a management system by facilities operators, fishery resource agencies and others.

4. In carrying out modifications of facilities and their operation, extreme care must be exercised to insure against physical or other types of damage to fish.

5. A river-system wide program or surveillance and monitoring of water quality and fishery conditions is essential.

6. A well-conceived and implemented plan of compliance and improvement, taking into account all aspects of fisheries resource protection, is a priority concern over the application of a numerical standard. However, the development of an enforceable standard must, for legal purposes, be based upon and reflect available scientific information.

In keeping with the spirit and directive of the joint resolution entered into on behalf of the Governors of Oregon, Idaho and Washington on November 12, 1971, it is the intent of the State of Washington to:

(*a*) Seek and enter into cooperative agreements with the environmental agencies of its sister states and to seek and assist in bringing about the optimum arrangement among appropriate federal, state and private participants such as to attain an optimum system of river management as related to the nitrogen and associated fisheries resource problem.

(*b*) Encourage needed nitrogen research programs to provide information for the further optimization of fishery protection.

Washington State Department of Ecology Statement of Intent Concerning the Implementation of the Water Quality Standards for Nitrogen Supersaturation

In adopting amendments to the state water quality standard to establish criteria for dissolved nitrogen gas, and to provide for the implementation and enforcement plan, the Department of Ecology is fully cognizant that:

1. Dissolved nitrogen supersaturation conditions during the spring and summer runs of salmon and steelhead in the Columbia and Snake Rivers are threatening the very existence of this valuable natural resource.

2. A cooperative system-management approach to the construction, modification and operation of hydroelectric and water control and utilization facilities on the Columbia and Snake Rivers and major tributaries is essential to the solution of the unique and complex problem of nitrogen supersaturation.

3. Agreement and cooperation among the official environmental agencies of the states of Oregon, Washington and Idaho is essential to such a management system together with participation in such a management system by facilities operators, fishery resource agencies and others.

4. In carrying out modifications of facilities and their operation, extreme care must be exercised to insure against physical or other types of damage to fish.

5. A river-system wide program of surveillance and monitoring of water quality and fishery conditions is essential.

6. A well-conceived and implemented plan of compliance and improvement, taking into account all aspects of fisheries resource protection, is a priority concern over the application of a numerical standard. However, the development of an enforceable standard must, for legal purposes, be based upon and reflect available scientific information.

In keeping with the spirit and directive of the joint resolution entered into on behalf of the Governors of Oregon, Idaho and Washington on November 12, 1971, it is the intent of the State of Washington to:

(*a*) Seek and enter into cooperative agreement with the environmental agencies of its sister states and to seek and assist in bringing about the optimum arrangement among appropriate federal, state and private participants such as to attain an optimum system of river management as related to the nitrogen and associated fisheries resource problem.

(*b*) Encourage needed nitrogen research programs to provide information for the further optimization of fishery protection.

Adopted this 24th day of April, 1972.

John A. Biggs, *Director*.

Mr. Stockman. Mr. Chairman and members of the committee, it has been a pleasure to appear before you today. We believe we have developed a viable program plan. It is a complex problem and its solution will be complex. The best effort by all concerned is required. We will immediately take further steps to develop the necessary working agreements and arrangements among the regulatory agencies, fisheries research groups and facility operators.

Mr. Howard. Thank you very much. I have one question. Does the State consider nitrogen a pollutant, or only above a certain percentage?

Mr. Stockman. Above a certain percentage it becomes a pollutant.

Mr. Howard. I was wondering if you feel there might be some difficulty in your attempts to improve this situation to see that there is no excess that might get tangled up with nitrogen in other areas.

Mr. Stockman. You mean other than water? No, sir, this is impossible. This is simply water quality standard.

Mr. Howard. Thank you very much.

Mr. McCormack. I have two quick qusetions. I will be the devil's advocate again. What do you do if you find upstream concentrations exceedings 110 percent? Do you have a jurisdictional problem between the States and EPA with respect to operation of the dams?

Mr. STOCKMAN. I do not think that we would sit in the working group as we are the operators. We are taking the position that this is something with which the Federal agencies must comply. You realize that this will be adopted by EPA and they will become a Federal document.

Mr. HOWARD. We would like now to welcome Colonel Marshall to present his testimony.

STATEMENT OF COL. A. R. MARSHALL, NORTH PACIFIC DIVISION, CORPS OF ENGINEERS, U.S. ARMY

Colonel MARSHALL. Congressman McCormack, Mr. Chairman, committee members, ladies, and gentlemen. I am pleased to have the opportunity to participate in this hearing. The Corps of Engineers desires to keep you and the public informed of our continuing efforts to maintain and improve the anadromous fish runs in the Columbia and Snake Rivers and, especially, to reduce the nitrogen supersaturation which has been damaging these fish.

Colonel Connell has summarized our current programs for nitrogen reduction. I would like to elaborate a bit on the need for and potential for additional measures, beyond those already on the drawing boards, for further reduction of nitrogen supersaturation.

NEED

The Columbia River Basin is one of the most important producers of anadromous fish in the world. In 1970, the estimated value of the commercial and sport fish produced by the Columbia River amounted to $26 million. There is no question as to the need for preservation and enhancement of this valuable fishery resource. Our total expenditure of about $200 million on fish facilities since 1938 attests to our awareness and complete commitment to satisfying this need. In addition, our nitrogen reduction program has involved an expenditure of over $12 million during the past 2 years. In fiscal year 1972 we have supported various research projects at a cost of $900,000.

POTENTIAL

With regard to nitrogen reduction our present program is considered to be only a first step toward a permanent, satisfactory solution to the nitrogen problem. Exact definition of the future most effective courses of action is dependent upon completion of current and future research work.

Slotted bulkheads for skeleton bays, while proven structurally, still need to be tested for safety of fish passage. Successful tests have been conducted previously at our Bonneville Hydraulic Laboratory using fish ejected from a high velocity nozzle into a tank. Based on these tests, we are optimistic that survival rates will be high through the actual bulkheads. The National Marine Fisheries Service has already commenced fish passage mortality studies on the prototype bulkheads, which will give us positive answers to this question. High mortalities could necessitate more studies and perhaps even a reorientation of some nitrogen reduction work.

We are testing the use of slotted bulkheads in front of operating generators, to rob energy from the water and let it pass through generators without making electricity. If successful, this will permit water to go through the powerhouse rather than over the spillway, even when the demand for electricity is low. Initial results are promising, but further tests have to be made for possible detrimental effects of such sustained operation on the turbines and the dam structure itself. Completion of the testing and final assessment of this concept is forecast for the summer of 1973.

The first tests of spillway flow deflectors (the so-called flip lips) in single bays at Bonneville and Lower Monumental Dams are most encouraging, but further tests are required to confirm the efficacy of this concept. Preliminary data indicate that the increase in nitrogen supersaturation in water going over the Bonneville spillway will be only about one-half the value developed without deflectors. The Lower Monumental deflector appears even more effective. Fish safety tests have not yet been initiated with the deflector. The deflector at Lower Monumental has a series of dentates or roughness blocks on the surface which increase the efficiency of the deflector but may be detrimental to fish passing over them. Tests are being accomplished this spring on the effect of this modification on fish survival. If significant mortality to juvenile fish is found to occur, further tests will be made without the dentates on the deflectors. We will have a good idea this fall concerning the overall feasibility of deflectors as a remedial measure for existing spillways.

With regard to fish screens, we are checking the desirability of installing these traveling screens in the other two turbine intakes at Little Goose. The fish screen system has demonstrated a good capability of bypassing around the dam about 90 percent of the migrating juvenile fish that would otherwise have passed through the turbines. We plan to include these screens in the construction of Lower Granite Dam.

WATER QUALITY STANDARDS

Water quality standards for nitrogen are also important to the future program. We are in full accord with the general proposition of taking what actions are necessary to protect fish from nitrogen. For regional compliance, we have asked the Director of region X, EPA, to coordinate an acceptable interstate standard applicable to all reaches of the river. Past studies on which to base standards do not conclusively establish tolerance and lethal limits of dissolved gas on fish by using actual river water during spring flood conditions. The National Marine Fisheries Service, with cooperative funding from the Corps, has recently undertaken this study at their floating laboratory on the Columbia River at Prescott, Oreg. Juvenile fish are held in tanks containing continuously flowing Columbia River water. They are observed regularly for symptoms of gas bubble disease and mortality. Information from this study is of paramount importance, since it will tell us what levels a juvenile fish can actually tolerate and for how long. It will also provide the necessary scientific basis for establishing workable water quality standards. National Marine Fisheries Service in Seattle is also studying the tolerance of fry and eggs to various levels of dissolved nitrogen.

With regard to direct effects of dissolved gas on adult fish, there has been little experimentation. There are some indications from spawning ground surveys of spring and summer chinook that some nitrogen damage may be occurring to adult fish. The Environmental Protection Agency will be starting a 3-year laboratory study this fall on the effects of dissolved gas on adult salmonids. Preliminary results of this study may be available in 1974. We expect that standards for nitrogen levels will be set by EPA this fall and will actually serve as goals until adequate tolerance studies are completed and better knowledge exists on what the needs of the fish are.

Another interesting phenomenon which needs further investigation in order for a full understanding of the nitrogen problem is the fact that there are at times appreciable nitrogen levels in natural undammed streams. An Environmental Protection Agency report on nitrogen supersaturation cites supersaturation values of 110 to 114 percent in the Salmon River and 112 percent in the Clearwater River in April and May 1971. These two rivers are the home target of host anadromous fish runs coming into the Snake River. The Salmon River has no dams on it. The Clearwater has no dams on its main stream above Lewiston, and has only Dworshak Dam on its North Fork, which had not been closed at the time the measurements were taken. Other measurements in past years have shown values ranging between 116 to 130 percent upstream of several uppermost dams, and 115 percent below Willamette Falls. More data will be collected this spring to verify such conditions, but these few measurements cited do seem to indicate that relatively high supersaturation levels do exist at times at a number of locations on undammed rivers during the spring runoff season. Answers are necessary to evaluate the need for additional measures to reduce nitrogen supersaturation.

FISH MORTALITY STUDIES

The most significant information to date concerning the impact of nitrogen supersaturation has come from the various National Marine Fisheries Service studies that have been concentrated in the Lower Snake River. Their study for 1970 concluded that: "Approximately 90 percent of the juvenile migrants died between little Goose Dam and the estuary largely because of supersaturated nitrogen in the river. Four years of 90 percent mortalities would nearly destroy the Snake River anadromous fish runs which are valued at about $2.6 million annually to commercial and sport fishermen." The 1971 studies by National Marine Fisheries Service indicate a less severe but still substantial loss of about 50 percent. These estimates were based on extrapolations from releases and small sample recoveries of test lots of fish that were handled, marked, and reexamined in surface water where gas supersaturation effects are greatest.

There have been some encouraging signs that at least the seaward migrants may not be as hard hit as earlier studies have indicated. The seaward migrants for the Chinook which returned in 1971 passed downstream in 1969, when all present dams were generating high nitrogen levels, except Little Goose. About one-half of those adult steelhead returning in 1971 had migrated downstream as juveniles in 1969, and one-half had migrated as juveniles in 1970, the year of high estimated mortality. We are cautiously encouraged because, despite the heavy mortality of juveniles, the 1971 returning adult runs of spring and summer Chinook and steelhead to the Snake River were about the average number for the last 10 years.

1972 RETURNING RUNS

The runs in 1972 will reflect the return of adult Chinook whose juvenile migrations occurred in 1970, when conditions were thought to be at their worst. And we will see 4- and 5-year-old steelhead which, as seaward migrants, were considered to have been exposed to the worst possible nitrogen conditions. The 1972 returning runs of adult fish are those whose parents were subjected in their upstream migrations to heavy nitrogen supersaturated waters created when it was necessary to pass the entire river flow over the spillway at John Day Dam during its first year of operation in 1968. Subsequent runs of adult fish in 1973 and 1974 will reflect the effects of Lower Monumental and Little Goose Dams on both seaward migrants and returning adults.

The present count for the 1972 run over Bonneville Dam of returning adult spring Chinook is well above the 33-year average for this date. The total count for April 1972 is 154,443 Chinook as compared to a 33-year average of 45,532 for the same month. The daily count of 19,200 Chinook crossing Bonneville Dam on April 26, 1972, far exceeded the previous alltime record for a single day's count (14,735).

Substantial numbers of mostly native steelhead are now in the holding ponds at the Dworshak National Fish Hatchery. As of May 2, 1972, 1,796 returning adult steelhead had been gathered there. Enough eggs are now available to maintain the hatchery's schedule of production. Next year, in 1973, we will see the first substantial return of steelhead planted by this most modern hatchery, which should result in a great improvement to the run.

We all hope that our joint efforts to maintain the anadromous fish runs on the Columbia River system are achieving success. In reviewing the work accomplished in conjunction with the fisheries agencies since our first dam was raised at Bonneville, we have reason for guarded optimism since the trend of returns has been increasing. However, even in this day of advanced science and technology, it is vital that all of us continue to press the state of the art, to identify more ways with which to insure the continuation of these unique natural runs.

SUMMARY

In summary, we are doing everything we presently know how to do to correct the nitrogen problems associated with our dams. We have had the full support and cooperation of the Federal and State fishery agencies and of those departments concerned with ecology, as well as the Governors of the several States and the Congress of the United States. We have taken short-term corrective measures in the areas of river flow, power management, and structural modifications. Further improvements through increased storage and installed power capacity are imminent. We have developed a comprehensive program of research and arranged to finance it. Our continued research is fundamental and vital to attaining continued success. We expect that by this fall, our cooperative research program will begin to identify what further is needed to solve the nitrogen supersaturation problems, and to continue our improvement of the anadromous fish runs in the Columbia River system. The Congress has invested very heavily in these runs and we seek to find new ways in which to continue our improvement of this investment.

Mr. HOWARD. Thank you very much for your statement. You did mention early in your statement that tests should be done concerning several things, among them damage to fish and damage to the turbines—are these planned or do you need to request funds?

Colonel MARSHALL. They are under way. We are doing our own work on it, too.

Mr. MCCORMAK. We enjoyed your testimony. My question would be, do you suppose it is reasonable to have variable maximum levels depending on the location, say one upstream in the mountains and another, depending on the characteristics of the river, downstream?

Colonel MARSHALL. I do not feel qualified to answer that. I would say that it would be extremely hard to determine and to try to enforce. I would like to have someone else answer that question.

Mr. HOWARD. The final witness is Mr. Arthur Solomon, national director for Trout Unlimited.

STATEMENT OF ARTHUR SOLOMON, NATIONAL DIRECTOR FOR TROUT UNLIMITED, SPOKANE, WASH.

Mr. SOLOMON. I am Arthur Solomon, Jr., a national director for Trout Unlimited. Trout Unlimited is a conservation organization specifically concerned with watershed management.

On behalf of Trout Unlimited I would like to thank this committee for the opportunity to be allowed to present testimony.

The subject of nitrogen supersaturation and its related problems in the Columbia and Snake Rivers and their tributaries is little understood by the general public, but it is well documented by the National Marine Fisheries Service, and therefore I do not intend to describe the basic cause and effect of nitrogen supersaturation. The anadromous fish runs of the Columbia River watershed, the Snake River and its tributaries, are in danger of being destroyed from nitrogen supersaturation. Those fishes involved include the several varieties of salmon that frequent these waters, the steelhead (migratory rainbow trout) together with bass, shad and other less valuable species.

As a private citizen involved with the nitrogen problem for over 2 years, I have concluded after consulting with several and various Federal and State biologists from different departments within their governmental structures, that the nitrogen tolerance upper limit, based on the available study materials and evidence known at this time, should not exceed 110 percent supersaturation. Ongoing studies may prove this figure to be too high or too low, but the indepth material available from the National Marine Fisheries Service indicates that 110 percent is the most reasonable and realistic figure.

The cause of nitrogen supersaturation is excess spill over the top of the dam installations in the Snake and Columbia Rivers during the high water runoff period in spring and early summer. The U.S. Army Corps of Engineers has sought to bring some relief to the nitrogen levels by constructing and inserting what they call "slotted bulkheads" (holy gates) into the empty generator bays at Little Goose Dam, Lower Monumental Dam and Ice Harbor Dam on the Lower Snake River. These installations were hoped to be the corrective procedure necessary to reduce nitrogen and thus allow the passage of downstream migrants in the most advantageous water conditions possible. Unfortunately, the slotted bulkheads constructed by the Corps of Engineers have proved to be more damaging to the anadromous fish runs than it would have been to have left the dams and empty generator bays alone. The National Marine Fisheries Service estimates that the loss of spring Chinook smolts caused by the slotted bulkheads at each of the three dams on the Lower Snake River has been 40 to 60 percent of the downstream migrants at each dam during the 1972 migration period (April and May).

On May 11, 1972, the Columbia River Technical Committee advised that a partial shutdown of the slotted bulkheads should be immediately implemented. The Corps of Engineers shut down six of the nine slotted bulkheads at Little Goose Dam, three of the nine slotted bulkheads at Lower Monumental Dam, and all of the nine installations at Ice Harbor Dam. Finally, on May 23, 1972, all slotted bulkheads were ordered shut down.

It was obvious that by implementing this order the spill would be increased over the top of the dam, and higher nitrogen levels would thus result, but in spite of this it was felt that the danger from nitrogen supersaturation was less than the danger of pushing at least 25 percent of the total downstream run of fish through these slotted bulkheads. The sheering force effect to those fish being subjected to the slotted bulkheads is like that of being squirted through a narrow passageway of water at 70 feet per second, and being instantaneously stopped in still water. Below the slotted bulkhead downstream migrants were discovered during May 1972 (approximately 1,500) with torn and inverted gill plates, torn throat areas, missing scales, missing eyes, and even missing heads. Controlled recovery tests recently concluded indicate an alarmingly high percentage of the run was being destroyed.

The slotted bulkheads are a cure worse than the nitrogen disease. It is evident that it now becomes necessary to control the nitrogen saturation to tolerable levels if we are to sustain and nurture the anadromous fish runs on the Columbia and Snake Rivers. The severity of the problem today cannot be underestimated. The value of the fish run cannot be overestimated.

Fish runs produce millions of dollars in commercial and sports catch to the economy of the Northwest. It is a natural resource that does replenish itself. As a result of incomplete, and in some cases total lack of advance study and research, the problems created for the anadromous fish have been allowed to continue.

New control methods are being studied now. Until these studies are completed, no dams should be built on the Snake and Columbia Rivers.

The Environmental Protection Agency in a report released in September 1971, recommended that no construction (Lower Granite Dam) be allowed to continue until nitrogen supersaturation levels can be controlled at 110 percent. By concensus, those agencies vitally concerned with maintaining the anadromous fish runs at both the State and Federal levels, have jointly and separately concluded that the nitrogen supersaturation problem is serious and a continuing threat.

For the information of this committee, the nitrogen supersaturation condition that existed on May 23, 1972, in the Lower Snake and Columbia Rivers exceeded 120 percent, a nitrogen level toxic to the fish. (The entire May 23, 1972 National Marine Fisheries Service Nitrogen Survey Report is attached hereto.)

In conclusion, I would like to suggest that existing State and Federal regulations, when appropriate, be enforced; that new laws and/or regulations needed to strengthen and safeguard the 110 percent nitrogen supersaturation level be immediately executed by either the legislative or administrative process. Most important, all regulations should carry strong and meaningful enforcement provisions.

Thank you for your time.

NATIONAL MARINE FISHERIES SERVICE COASTAL ZONE AND ESTUARINE STUDIES COLUMBIA RIVER AND TRIBUTARIES GAS SATURATION DATA—MAY 23, 1972 FLIGHT SAMPLES

Location	Time	Depth, feet	Temperature, Centigrade	Oxygen		Nitrogen		Hourly flow KCFS	
				MG/L	Percent saturation	ML/L	Percent saturation	Spill	Total
Snake River above Clearwater	0730	0	12.0	10.6	98.5	15.2	106.2		
Clearwater River ¼ mile above mouth	0800	0	7.6	12.8	106.8	17.6	112.0		
Snake River above Salmon River	0945	0	15.2	10.3	101.0	14.8	111.1		
Salmon River ¼ mile above mouth	1005	0	9.7	11.6	102.6	16.4	109.7		
Lower Granite site prior to operation	1102	0	10.7	11.3	101.9	16.0	109.1		
Little Goose Forebay ¼ mile up center	1127	0	10.7	11.1	100.1	15.7	107.0	81.1	176.5
Do	1127	33	10.8	11.1	100.4	15.6	106.3	81.1	176.5
Little Goose Tailrace ¼ mile down spill site	1150	0	10.8	13.5	122.4	18.9	129.1	81.1	176.5
Palouse River ½ mile above mouth	1209	0	14.0	10.6	103.0	15.1	110.2		
Lower Monument Forebay ¼ mile up center	1230	0	11.1	13.4	121.9	19.2	132.3	72.8	174.0
Do	1230	33	11.2	13.3	121.4	18.8	129.5	72.8	174.0
Lower Monument Tailrace ½ mile down spill site	1243	0	11.2	13.8	125.8	19.3	132.8	72.8	174.0
Ice Harbor Forebay ¼ mile up center	1312	0	11.3	12.8	117.0	18.1	125.0	131.2	180.6
Do	1312	33	11.3	13.2	120.2	18.6	128.1	131.2	180.6
Ice Harbor Tailrace ½ mile down spill site	1325	0	11.2	13.8	125.9	19.2	131.9	131.2	180.6
Columbia River above mouth Snake	1340	0	11.3	12.7	115.7	17.5	120.9		
McNary Dam Forebay ¼ mile up spill site	1408	0	11.6	12.4	113.7	17.2	119.5	267.4	489.2
Do	1408	33	11.6	12.4	114.2	17.4	120.9	267.4	489.2
McNary Dam Forebay ¼ mile up powersite	1420	0	11.6	12.0	111.0	17.2	119.5	267.4	489.2
Do	1420	33	11.4	12.4	113.7	17.5	121.1	267.4	489.2
McNary Tailrace ¼ mile down spill site	1425	0	11.6	14.1	130.0	19.8	137.6	267.4	489.2
McNary Tailrace ¼ mile down powersite	1443	0	11.4	12.4	113.7	17.5	121.1	267.4	489.2
John Day Forebay ¼ mile up center	1640	0	12.2	11.5	107.4	16.8	115.4	163.6	497.8
Do	1640	33	12.5	11.7	110.3	16.8	119.3	163.6	497.8
John Day Tailrace ½ mile down spill site	1646	0	12.2	14.1	131.7	19.4	133.6	163.6	497.8
The Dalles Forebay ¼ mile up center	1705	0	12.2	12.6	117.2	18.0	124.0	333.1	494.5
Do	1705	0	12.3	12.4	116.0	17.7	122.2	333.1	494.5
The Dalles Tailrace ½ mile down spill site	1713	0	12.3	12.9	120.7	18.2	125.3	333.1	494.5
Bonneville Forebay ½ mile up spill site	1749	0	12.4	11.8	110.6	17.2	119.4	355.8	485.9
Do	1749	33	12.5	11.9	111.8	17.0	118.2	355.8	485.9
Bonneville Tailrace ¼ mile down spill site	1755	0	12.4	13.3	124.6	19.0	134.5	355.8	485.9
Columbia River Prescott Center	1832	0	12.6	11.6	109.2	17.2	119.9		

Mr. Howard. Thank you. We certainly want all groups to be involved and to be considered in connection with everything done in connection with the Columbia River Basin and the Snake River, and we hope that your group will be active with the other groups. I would make only one comment regarding your statement. There is some doubt in your mind whether the desires of the Corps are honorable. I assume that they are. Just as you debate, yours are equally honorable. We could be much more cooperative in what we are trying to do. We will be pleased to have this a part of the permanent record.

This is the end of our list of witnesses. I have been asked for permission for a 1-minute statement by Mr. Ray Weis.

STATEMENT OF RAY WEIS. PRESIDENT OF THE TRISTATE STEELHEADERS, WALLA WALLA, WASH.

Mr. WEIS. Mr. Chairman and all other distinguished guests, ladies, and gentlemen. I am Ray Weis, president of the Tristate Steelheaders, headquartered in Walla Walla, Wash. I come before you as the representative of one of the strongest and most active sportfishing clubs in the Northwest.

At our most recent executive board meeting March 27, 1972, all aspects of nitrogen supersaturation were analyzed, the figure of 105 percent was the maximum allowable, which was deemed necessary to sustain the existing species of fish and the anadromous steelhead and salmon. On April 3, 1972, 1 week later at our general membership meeting, the 105 percent maximum allowable of nitrogen supersaturation was presented and passed as well as an amendment to it to add a penalty. As to the severity of the penalty, I shall bring that up later.

For the present I wish to regress and refresh your memory on what man has selfishly done to the environment and I shall try to confine it to fish and water, although it will be extremely difficult, and the Pacific Northwest.

In the early thirties Bonneville Dam was completed. While man had tremendous knowledge to build this huge structure, he was very ignorant in the ways of migrating fish, and because of the inadequacies of the fish ladders tens of thousands of steelhead and salmon were lost, yes to this very day, 46 years later, the fish ladders are still not efficient as they should be. This dam happened to be a Corps of Engineers project.

Now the Bureau of Reclamation started to get in the act, the time was middle thirties. Using tremendous public relations effort Coulee Dam was conceived and built, and with the greatest hush program ever planned and promoted, there was almost no publicity, when the tremendous run of tens of thousands steelhead and salmon died when they could not migrate above this huge structure. The Bureau of Reclamation had now established a precedent. Hundreds of miles of fishing and spawning areas wiped out.

Now the Corps of Engineers follows suit—downstream from Grand Coulee Dam we have Chief Joseph Dam—no fish ladders. A precedent established by Bureau of Reclamation, now followed by the Corps of Engineers.

Dams start being placed everywhere; public utility districts are formed and they get into the act of building dams. Private power companies expand and build dams—then they combine forces and continue building.

Hells Canyon Dam is built on the Snake River by Idaho power—the precedent set by the Bureau of Reclamation and the Corps of Engineers, the Idaho power people said no fish ladders.

But also; this time the people became aware of what happened at Hells Canyon and the public was informed as to what was happening to the tens of thousands of salmon and steelhead. Every conceivable method of transportation was used to get the dead and dying fish out of the river, but it was a very futile attempt. The memory of that tragedy is still very vivid in the minds of millions of people. It was given nationwide publicity. You must realize we now have a bottleneck in the Snake River.

What had been tremendous steelhead and salmon streams, the Columbia and the Snake, and these are the two largest, hundreds and hundreds of miles were wiped out to fishing and spawning. This same fate has happened to countless dozens of other streams in the Pacific Northwest.

Suddenly McNary, The Dalles, John Day, Priest Rapids, Wanapum, Rock Island, dams—and I could go on, now are in the Columbia River and the lower Snake River has Ice Harbor, Lower Monumental, Little Goose, and Lower Granite is well on its way to being completed and it will put slackwater to Lewiston, Idaho, approximately 400 miles from the ocean.

Now we have Dworshak Dam, approximately 40 miles upstream from Lewiston on the north fork of the Clearwater. The dam is 1.9 miles from the stream's confluence with the main stem of the Clearwater.

At the confluence is a structure which was built and is advertised as the world's largest steelhead hatchery. This facility was placed at this location so that it could utilize the water from the dam, but more important, to capture all of the steelhead that can no longer migrate up the North Fork. As a steelhead rearing facility, it must release approximately 3 million smolts 6 to 9 inches in length annually in order to maintain a return of approximately 3,500 adults.

Sunday, March 12, 1972, the Corps of Engineers began discharging water from Dworshak Dam. By Thursday, March 16, 1972, the discharge had increased to 12,000 cubic feet per second. This increase put the nitrogen up to 119 percent; now understand this, this is the stream the Dworshak Hatchery gets its water from.

The report and facts are this, for I made a personal investigation, taking with me one Mike Shockman, a member of the Washington State Game Department.

Water samples were taken from Dworshak Hatchery Tuesday, March 14, 1972, to Little Goose Dam to be analyzed, using the Van Slyke equipment. The measurement of nitrogen was 109. This being under your so-called safe figure two aerators were used to bring it down to 100 to 101. I will add that the hatchery is using the raw river water. Wednesday, March 15, 1972, at 10:30 p.m., the fish were checked visibly and all seemed well, but when the employees came early Thursday, March 16, 1972, they found the dead fish. Death came silently to 43,000 20-month-old steelhead, 30,000 10-month-old steelhead and 12,000 five-to-the-pound trout.

Water samples were flown to Little Goose Dam and the nitrogen was 119. In the meantime eight aerators were put into operation and the nitrogen was brought down to 100 and 101 percent.

Needless to say, as of now, a man is qualified to take readings at the hatchery and it is monitored daily—both outside from the river and inside the hatchery. Mr. Parvin, hatchery manager, told me when I called him by telephone Saturday, March 25, 1972, that the river had reached 128 percent nitrogen on Thursday, March 23, 1972, but with eight aerators it was never higher than 101 inside the rearing ponds, and that it (North Fork Clearwater) was presently 124 percent; and this was Saturday, March 25, 1972.

So much for tragic historical facts—now to the nittygritty and my challenge to anyone who wants to establish the polluted nitrogen saturated water of 110 percent. The main stem of the Clearwater flowing past the hatchery is 100 percent of nitrogen. Fish live and survive and multiply in it; but look what the North Fork is trying to do to it.

The Congress of the United States says you shall not pollute. The State department of ecology says you shall not pollute. Everyone is told use the air, but when you return it, it shall be clean; use the water, but when you're through, return it pure.

We are told if you do not do these things we shall penalize you and shut your operation down. How can you condone pollution? Why must you try to set the lethal poison so high that the fish in the rivers will soon be decimated. Do you realize what is happening and has happened in the short period of less than 50 years when Bonneville was started? How many fish will survive 400 miles of polluted water of 110 percent or more? I want facts—not assumptions or a laboratory test under ideal conditions. What paths do downstream migrants travel? We know that adults travel one side, maybe mill around the reach of a 2-mile pool area, then back and forth across to each bank, trying to home; and move upstream then cross over again. We have migration study tracks to prove adults erratic movements—what of the downstream? Have you tracked them. If so, in the reaches in what pools and what was the nitrogen level? Have you tracked these smolts for 30 miles? 100 miles? 400 miles to see how many survived, or are you guesstimating? Were any of the smolts under any duress after exposure for 400 miles?

Where are the water samples going to be taken? What distance apart? What depth? How often will the monitoring be done? Who will be doing this? Are you going to set this level so all shall abide in every stream that has fish life—or is it OK to pollute in some streams and not in others?

And finally, what happens if the figure is exceeded and we lose millions of fish as has been happening? What have you established as a penalty? How shall the penalty be collected and who will be the recipient?

I want answers and the proof of these answers to these questions. When you answer them, I want your qualifications and what studies you made and what the locations were.

I have been asked by agency people to be tolerant and reasonable.

If I fail to pay for my water—it will be turned off by the city. If I fail to pay my taxes, the county will take my home. If I fail to pay sales tax, the State will fine me. If I fail to pay my Federal income tax, the Government will jail me. Plus, each one will make me pay a penalty if I am late in my payment. Are they all tolerant and reasonable?

You may rest assured now I am going to fight for one of the few resources left that belongs to the people. I plan to leave something for the next generations. It is no wonder the younger generation is disgusted with the establishment.

Can you really blame them?

We, the executive board, and the general membership of this Tri-State Steelheaders, are telling you to establish a safe 105 percent nitrogen pollution for all water. We demand this 105 percent pollution be made mandatory immediately and without any delaying tactics. Remember this nitrogen is as lethal a poison to fish as cyanide gas is to man.

I sent copies of this to all the major papers and TV outlets in the Pacific Northwest, as well as Congressmen. Thank you.

Mr. HOWARD. Thank you very much for your appearance today.

Mr. MCCORMACK. I would like to pay tribute to a lady who is sitting in the audience—Mrs. Annettee Cussing. She has probably done more than any other living American to save Hells Canyon.

Mr. HOWARD. I am very pleased to be here from New Jersey to meet with other people from other parts of the country. A local television man talked with me this morning and asked if I could make some comment, and since I have been on the Public Works Committee for 8 years. I said I am here from New Jersey to learn of your problems. I would like to get away from that description about our State. That seems to be what catches the eye in newspaper articles, and the good remains hidden.

I want to thank you for your courtesy here today. In developing any kind of legislation, we gather knowledge and good ideas when we hold public hearings. And we hold them some time before we pass any meaningful legislation. We get a better feeling by going out to the States than having them come to Washington. The conference report on the water pollution bill will be out in a matter of weeks. We have had thousands of pages of testimony, and this is the kind of thing I believe shows what America is like and what our form of Government is like when the Government comes to the people, and their views are heard and considered and their views do make a difference. Mr. McCormack and I will be able to go back to the Congress with a great deal of knowledge of the Subcommittee on Rivers and Harbors.

That concludes the hearings. Any additional correspondence received will be placed in the record at this point.

(Whereupon, at 12:15 p.m., the special subcommittee adjourned.)

(The following were subsequently received for the record:)

[Telegram]

PORTLAND, OREG., *May 5, 1972.*

Hon. MIKE MCCORMACK,
U.S. Federal Building,
Richland, Wash.:

Recognizing the urgency of the nitrogen super saturation problems in the Columbia and Snake Rivers, State of Oregon has recently amended water quality standards to limit concentration to 105 percent saturation. State will soon issue waste discharge permits to operators of hydroelectric projects located in Oregon establishing deadlines and other requirements for effecting necessary controls. Co-operation of Congress in providing timely and adequate funding for required modifications of Federal projects respectively requested.

TOM MCCALL, *Governor.*

[Telegram]

WASHINGTON, D.C., *May 9, 1972.*

Hon. MIKE MCCORMACK,
Federal Building, Richland, Wash.:

Welcome invitation to express my longstanding grave concerns. You deserve our commendation for providing additional focus on the critical problem of nitrogen supersaturation in the Columbia and Snake Rivers. Nitrogen supersaturation, caused by spillage of water of the dams on the Lower Snake and Columbia, has been identified as a major killer of salmon and steelhead. An estimated 70 percent or more of the anadromous fishery resource has been killed by nitrogen supersaturation. I am deeply distressed by such deterioration. We must move fast and effectively in order to restore the fish runs. For some time I have been insisting that emergency actions be taken to solve this problem. Clearly, the faster we move, the better the chance to remedy the situation. An in-depth discussion describing the need for action appears in the appendix of hearings held by the Senate Interior Committee's Subcommittee on Parks and Recreation on Hells Canyon Snake National River legislation on September 16, 17, and 30 of 1971. Best wishes to all of you, public officials and private citizens alike, as you gather in Richland to make further inroads on the problem.

FRANK CHURCH,
U.S. Senator.

STATEMENT OF THOR C. TOLLEFSON, DIRECTOR, WASHINGTON DEPARTMENT OF FISHERIES

The Washington Department of Fisheries appreciates the opportunity to comment at the hearing being held by the Public Works Committee of the U.S. House of Representatives on the nitrogen supersaturation problem in the Columbia and Snake Rivers. We are pleased at the interest being shown in the fisheries resources of these important salmon-producing streams and the efforts undertaken to date to solve the problem.

For the past 25 years, significant economic development in the Columbia Basin and the Pacific Northwest has resulted from the construction of dams, water diversion and irrigation developments, flood control measures, and other projects that have encroached upon the natural habitat of salmon. These factors and others such as pollution have contributed to a general decline in the value of the Columbia River as a salmon producer. Only through a vigorous program of fish passage research, hatchery production, and intensive management by this and other fisheries agencies in the Northwest have the anadromous fish runs been maintained at productive levels.

Today as a direct by-product of dam construction, the resource faces yet another threat to its existence in the form of nitrogen supersaturation. This water quality problem primarily affects fish and is one that must be solved, otherwise the efforts and expenditures of the past several years to preserve the salmon and steelhead runs of the Columbia River will have been in vain.

The Department of Fisheries has been cognizant of the nitrogen problem since 1965 when our scientists first noted its occurrence in the Columbia River from water samples collected below Chief Joseph Dam. Since then we have conducted numerous studies on the effects of nitrogen supersaturation on salmon juveniles and adults. These studies, along with those performed by the National Marine Fisheries Service, have contributed greatly to the general knowledge of the problem and to the establishment of parameters for nitrogen standards.

As active participants in the Nitrogen Task Force established by resolution of the governors of the states of Washington, Oregon, and Idaho, we have contributed by formulating required research priorities and through participation on the committee assigned to regulate river flows to attain the best water quality conditions possible during the migration of adult and juvenile anadromous fish. We have and will continue to vigorously support the water quality standards for nitrogen as set forth by the Washington Department of Ecology.

In our opinion, additional studies are required to further define the effect of nitrogen on fish and to aid in the design of control features. Further, every effort should be made to procure funds for the installation of proven control methods at dams on the Columbia and Snake Rivers if we are to maintain this important source of protein food for present and future generations.

We are appreciative of the interest of the committee in this important matter and the efforts being expended by you and others to seek solutions to the problem.

Statement of Bernie Leman and Mike Erho

(Representing: Public Utility District No. 1 of Chelan County, Wenatchee, Washington; Public Utility District No. 1 of Douglas County, East Wenatchee, Washington; Public Utility District No. 2 of Grant County, Ephrata, Washington)

This is a statement for the record of the hearing conducted by the Public Works Committee of the U.S. House of Representatives. This hearing to be held on May 6, 1972 in the Federal Building in Richland, Washington.

The purpose of this testimony is to provide the committee and the public with factual information on nitrogen supersaturation and its effects on fish in the mid-Columbia area. This statement is the joint combined opinions of the three mid-Columbia Public Utility Districts, Public Utility District No. 1 of Douglas County, Public Utility District No. 1 of Chelan County and Public Utility District No. 2 of Grant County. Hydroelectric projects owned by these organizations are Wells, Rocky Reach, Rock Island, Wanapum and Priest Rapids Dams. These five dams are represented by stars on the map (Figure 1).

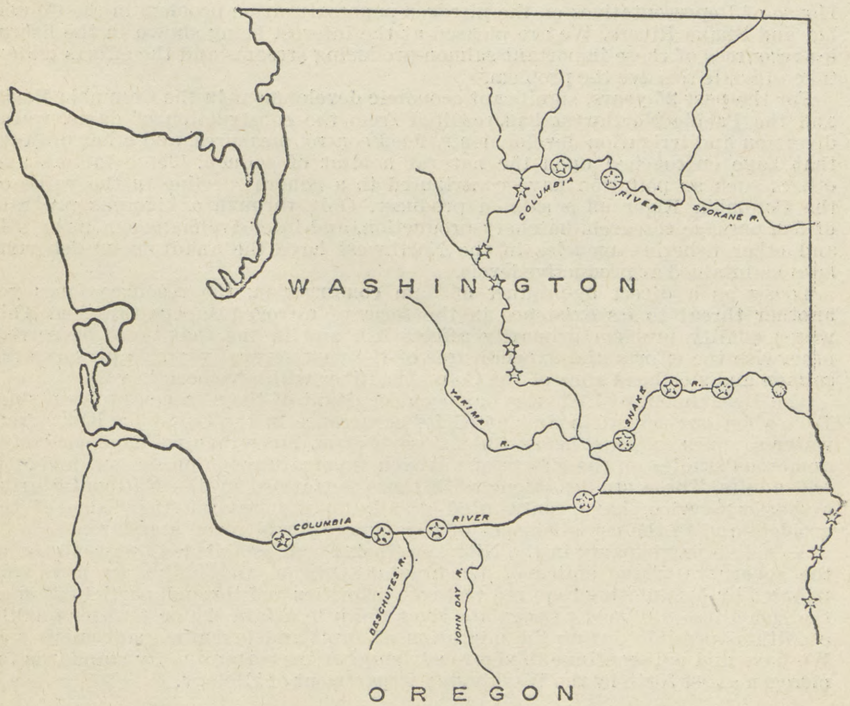


FIGURE 1

Federal dams are represented by a circle and star. The five PUD dams are the only non-Federal projects on the Columbia River.

Much of the following discussion was included in testimony before the State of Washington's Department of Ecology Hearing on Proposed Nitrogen Standards held in Lacey, Washington on April 10, 1972.

The problem of supersaturated nitrogen gas on the Snake River in 1969 and 1970 has received widespread publicity. This wasthe result of two dams in similar stages of construction which required the entire flow of the Snake River to be spilled at both projects. This resulted in extremely high concentrations of supersaturated gases for a long distance downstream. These conditions apparently extended on into the lower Columbia. Our projects have cooperated in controlling the river to reduce spill and in turn reduce the concentration of dissolved gases. This was done to facilitate the downstream movement of hatchery released fish through these problem areas.

In the mid-Columbia we are not aware of a severe dissolved gas problem. The only recorded instance of salmonid mortality in the mid-Columbia, in relation to gas bubble disease, occurred below Chief Joseph Dam which is the uppermost limit of anadromous fish migration. It is normal for maturing adults to hold in the area downstream of Chief Joseph until the physical maturation of the fish and water quality conditions in the Okanogan River become favorable for them to move upstream and spawn on their ancestral spawning grounds. Unfortunately, there is a high concentration of supersaturated dissolved gases in this area during spill operations at Chief Joseph.

Recently, there have been insinuations that the mid-Columbia River area also had dissolved gas supersaturation problems similar to those experienced on the Snake and Lower Columbia. We reject these insinuations and believe strongly that they have no basis in fact. This belief is supported by the historic record of adult salmon and steelhead passage in the mid-Columbia area. Our only apparent problems occured when we used Columbia River water in a shallow situation such as in aquaria and spawning channels. These, of course, in addition to the previously mentioned experience below Chief Joseph Dam. We, subsequently, re-examined the record to try and further define the situation and this is what we found.

Rock Island Dam was the first dam constructed across the Columbia River and began operation in 1933. Fish counting in the mid-Columbia began at this time. The actual counts of salmon and steelhead at Rock Island Dam for the period 1933 through 1966 is shown in Table 1 along with the Priest Rapids count from 1967 through 1971. These counts are plotted on a three-year moving average to smooth the curve in Figure 2. (There are no major tributaries between Priest Rapids and Rock Island.) Runs in the early thirties were extremely low, with sockeye runs being the highest in the neighborhood of 20,000 per year, although in 1941 less than 1,000 were counted. Chinook numbered less than 10,000, and steelhead less than 1,000. These runs remained at about this level through the mid-forties although Bonneville and Grand Coulee projects had been constructed during this period. McNary was completed in 1954; the Dalles and Chief Joseph in 1958; Rocky Reach and Priest Rapids in 1961; Wanapum in 1963; Wells in 1967 and John Day in 1968. While there have been highs and lows in the fish count record, it is obvious that the salmon and steelhead runs counted past the mid-Columbia dams have not decreased in recent years.

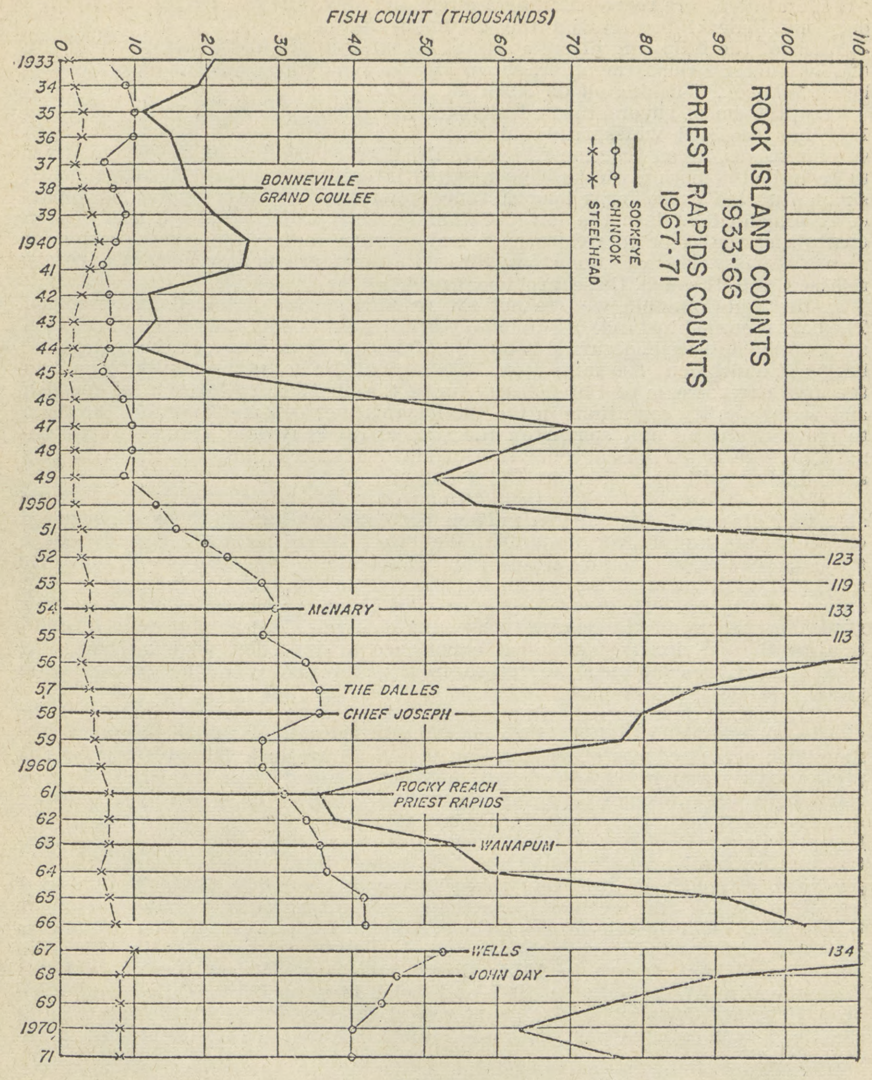


FIGURE 2

Historically, these dams have been spilling water each spring-flood period of each year. Supersaturated gas conditions have obviously been in the river for many years. During the early part of this era, because of the distances between dams, high dissolved gas concentration areas would have been quite spotty. Since the completion of Chief Joseph in 1958, there, undoubtedly, has been a solid section of supersaturated river extending from Chief Joseph Dam downstream past Rock Island. Yet, when you look at the fish count record, the runs over Rock Island Dam have not deteriorated.

It is recognized that many factors influence the fish-count picture. Regulation of commercial and sports fisheries to meet management goals do influence the number of fish migrating past Rock Island Dam as do many other factors.

Regardless of the factors that influenced these fish counts, this is the historical record. These are the numbers of fish that passed over Rock Island Dam. If the same problem existed in the mid-Columbia area as has been indicated for the Snake River, where agencies tell us downstream migrant salmon and steelhead have suffered a 70% mortality, it would be reflected in reduced runs of salmon and steelhead in the mid-Columbia. (Recent fish counts at Bonneville Dam indicate a near record run of spring chinook and cast serious doubts on the validity of the estimated mortality figure.)

TABLE 1.—ROCK ISLAND DAM FISHWAY COUNTS, 1933–66; PRIEST RAPIDS DAM FISHWAY COUNTS, 1967–71

Year	Chinook	Sockeye	Steelhead
Rock Island Dam Fishway counts:			
1933	5,668	40,737	1,055
1934	6,482	2,227	583
1935	16,310	14,013	5,412
1936	7,396	16,501	2,369
1937	5,133	15,087	2,214
1938	5,803	17,123	2,400
1939	11,206	19,591	5,427
1940	9,492	26,894	5,550
1941	2,571	949	3,561
1942	6,814	16,282	3,586
1943	11,145	17,665	2,249
1944	3,375	4,932	1,329
1945	5,696	7,142	1,121
1946	9,992	46,563	1,761
1947	11,786	79,834	2,115
1948	7,095	84,627	2,319
1949	12,358	18,682	2,460
1950	8,292	50,059	1,846
1951	18,794	102,724	2,932
1952	20,114	113,703	3,015
1953	30,908	152,013	4,071
1954	33,261	91,184	5,400
1955	25,733	155,782	3,902
1956	24,910	92,209	1,780
1957	50,745	71,267	4,013
1958	32,981	97,947	6,121
1959	23,344	72,251	4,145
1960	26,535	60,341	6,216
1961	33,077	19,233	7,042
1962	34,155	29,252	7,605
1963	34,688	64,750	7,078
1964	39,951	69,411	5,016
1965	36,407	42,380	6,062
1966	48,553	164,547	9,734
Priest Rapids Dam Fishway count:			
1967	48,918	123,653	7,354
1968	48,314	107,532	10,524
1969	40,786	39,240	6,650
1970	43,802	77,419	5,558
1971	36,158	73,837	11,102

The obvious question is why has nitrogen supersaturation not been a serious problem in the mid-Columbia where the records show that these conditions have been present throughout the mid-Columbia since at least 1958. One factor may be the timing of the fish runs past this section of the river. Figure 3 illustrates the timing past Rock Island Dam of the three salmonid species—sockeye, chinook, and steelhead. This figure is based on the record year 1966; however, historically, timing of the runs over Rock Island Dam has remained the same.

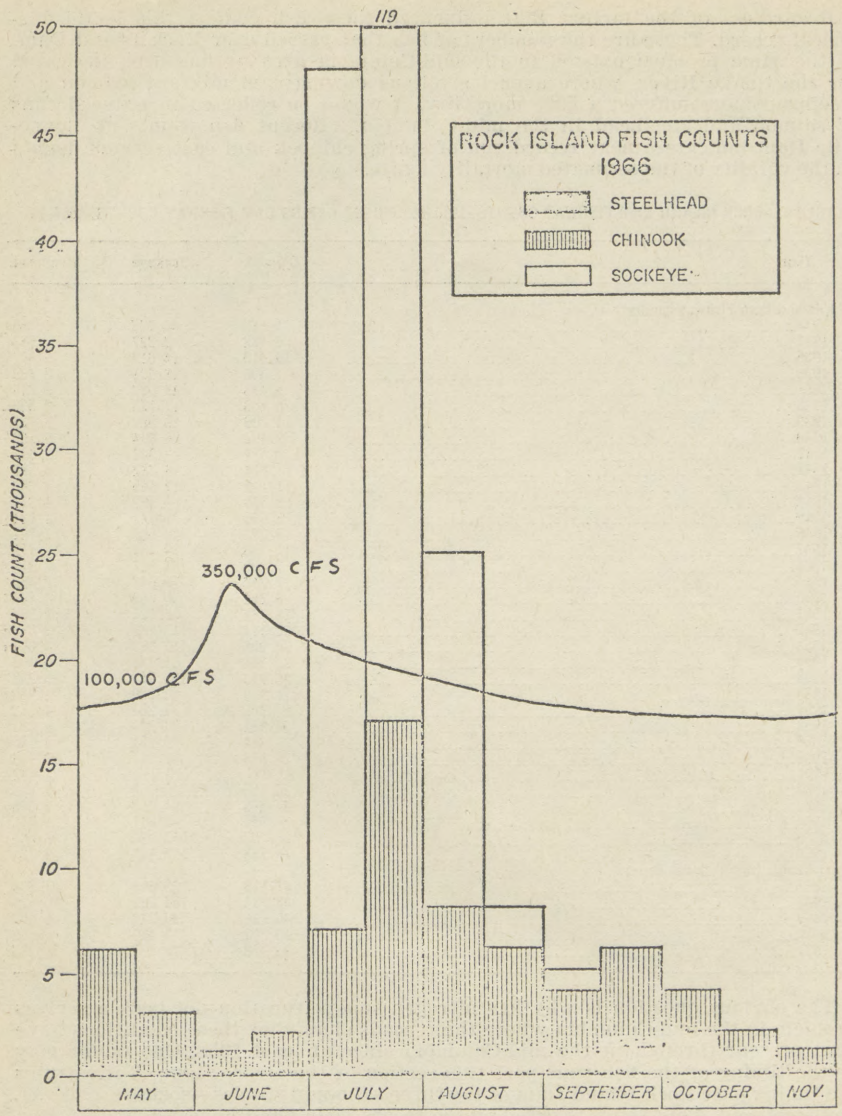


FIGURE 3

The steelhead run begins in mid-July, peaks in late September and early October. The fish migration stops and the fish winter over after about November 15. The over-wintering population then begins to move again in the early spring, and we have a little burst over Rock Island in early May. The mid-Columbia supports three basic runs of chinook salmon. The spring runs, which comes to us in early May, peaks in late May and ends about June 23. The summer run begins at this point, peaks in late July and is over by September 1. After this date any chinook passing the dam is considered to be a fall-run fish. The sockeye approach our area in a compact population. They begin to arrive in early July, peak in early August and are pretty well gone by mid-September. Observe in Figure 3 the relationship between the movement of adult fish at Rock Island and the river hydrograph. The hydrograph illustrated in this figure represents a median year. The high-flow period occurs about mid-June. This, then, is when most water is spilled at the hydroelectric projects. Dissolved gas monitoring data shows that the highest concentration of dissolved gases occurs during this period of highest spill.

The timing of downstream salmonid migration at Rock Island Dam is shown on **Figure 4.**

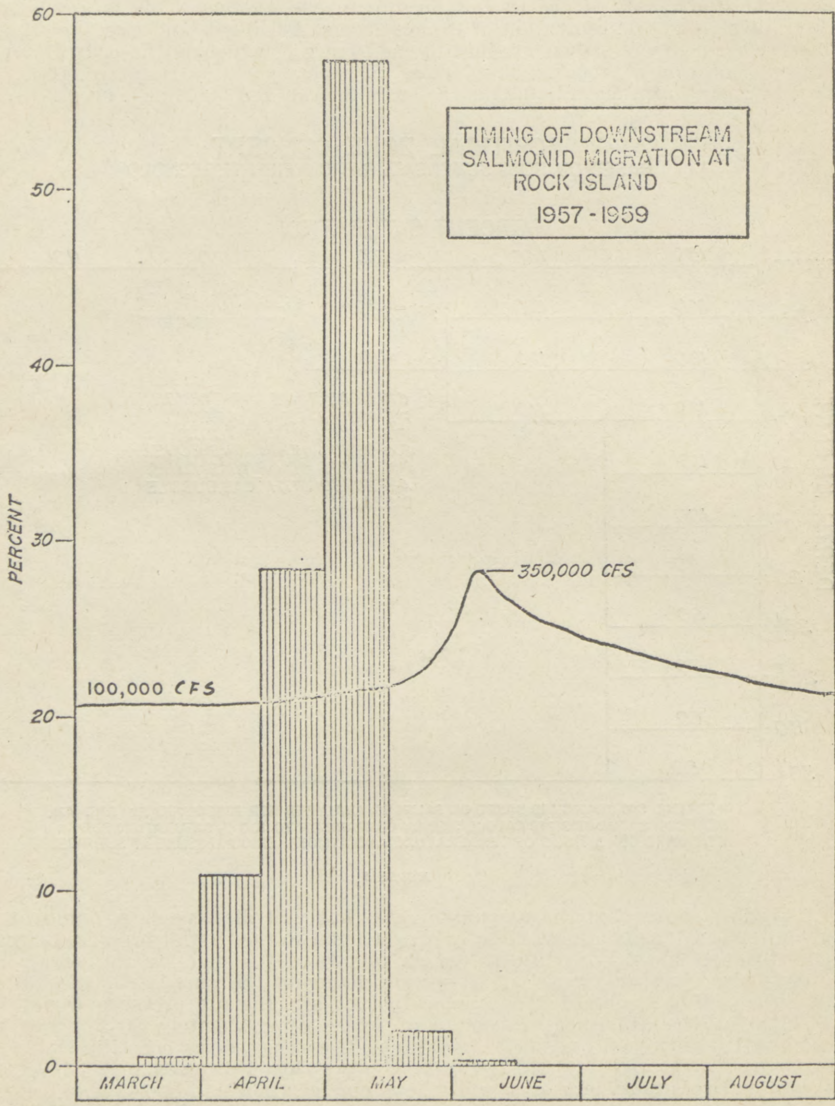


FIGURE 4

This figure represents studies conducted by the Chelan County Public Utility District and the Department of Fisheries from 1957 through 1959. The downstream migrants begin to move in late March, peak the first half of May. In relation to the hydrograph, the downstream migration, for the most part, is past our dams before the river reaches its peak flows and spilling is at its greatest. Nitrogen monitoring records also show that the highest concentrations occurring in our region of the river normally are less than 130%; although through much of the high water period, we do experience concentrations in the area of 120%.

High concentrations of dissolved gases do not become a problem until we have fish and dissolved gas in relationship to one another. This is a relative thing involving a concentration of dissolved gas, fish depth and exposure time. This relationship is shown graphically in Figure 5, which is the critical zone concept based on a proposed 110% nitrogen supersaturation standard. Henry's Law on gas absorption in liquids is the basis for this critical zone concept.

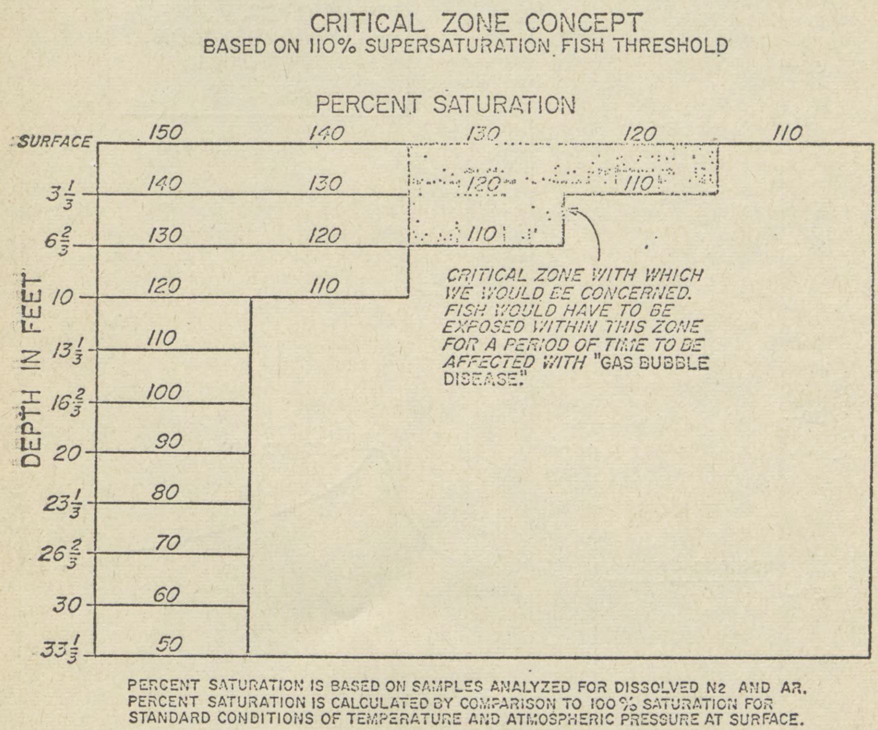


FIGURE 5

This law states that the amount of gas that will dissolve in a liquid at a given temperature is almost directly proportional to the partial pressure of that gas. Briefly, this may be illustrated as follows: If a bell jar full of air at atmospheric pressure were placed upside down on the surface of the water and the bell jar contained one cubic foot of air, the air pressure would be 14.7 psi or one atmosphere absolute of which approximately 80% would be composed of nitrogen and 20% of oxygen. The other gases constitute only a small portion of the total. If the bell jar were then depressed to a 33⅓ foot depth, or two atmospheres absolute, the volume of air would be ½ cubic feet or one-half the surface volume. However, the pressure would be doubled, or 29.4 psi. Therefore, according to Henry's Law, the amount of gas that would go in solution would be twice what it was at the surface. In other words, if a volume of liquid were saturated with all the gas that it would hold at 33⅓ feet, it would be 100% saturated for that depth and temperature. If it were brought to the surface, it would be 200% saturated. In nature this 100% saturation in relation to depth is rarely attained. According to the physical laws of gases, fish need only submerge one meter or 3⅓ feet below the surface to compensate for 10% supersaturation (Figure 5). Saturation of 150% measured at the surface becomes 110% at 13⅓ feet in depth, saturation of 140% at the surface becomes 110% saturation at 10 feet in depth; 130% becomes 110% at 6⅔ feet in depth and 120% saturation becomes 110% at 3⅓ feet.

Thus during most of the fish-run year in the mid-Columbia, fish need only be swimming 3⅓ feet below the surface of the water or have intermittent exposure above that depth to be safe from the effects of gas bubble disease. One thing that should be pointed out is that the 110% saturation standard has been established using constant exposure of the fish to that concentration of dissolved gases. While in nature this is more naturally an intermittent exposure. (For example; a diver, in a 12-hour period, can safely [without getting the bends] make a single time limit dive to a given depth, or he can make a number of repetitive dives to the same depth separated by intervals of surface time and increase his total dive time significantly.) The safe length of exposure time and even the concentration of exposure are significantly greater for intermittent exposure than constant continuous exposure. This would result in a higher dissolved gas standard or threshold level.

We feel that 40 years of record cannot be ignored. An examination of these records leads us to the conclusions that: The mid-Columbia has experienced high nitrogen concentrations in the past. The fish count records establish the fact that the runs have not decreased in relationship to the dissolved nitrogen gas. The critical zone concept illustrates conclusively that the depths at which fish move in relation to dissolved gas concentrations is of utmost importance. There is a difference in the situation which existed on the Snake and lower Columbia and that experienced in the mid-Columbia. As members of the Nitrogen Task Force Committee, we know that numerous studies are being conducted to gain factual data to define and solve the dissolved gas problem. Many facets of the problem have not at this point been investigated and other investigations already begun, are not completed. Until these studies can be completed and more is known, it is not possible to fully understand the complex nature of the dissolved gas situation. Attempts to reduce nitrogen supersaturation by means such as river-flow control without full consideration of all related ecological factors may have serious ramifications.

STATEMENT OF CARL W. BLAKE, BRANCH OF POWER, SUPPLY AND SCHEDULING, U.S. DEPARTMENT OF THE INTERIOR, BONNEVILLE POWER ADMINISTRATION, PORTLAND, OREG.

The Administration has been cooperating in every way possible the past two years to achieve a minimum saturation of nitrogen in the Columbia and Snake Rivers during the critical fish migrating period. In 1971, during the period April 26–30 a little over 12 million kilowatt-hours of energy was delivered to utilities under a special "in lieu" arrangement. In addition a little over 4 million five hundred thousand kilowatt-hours was delivered to utilities for immediate spill. Also, 250,000 kilowatt-hours was delivered to B.C. Hydro for storage in their Peace River Project. The total energy transferred under these special arrangements was about 17 million kilowatt-hours. It is estimated that these transactions reduced the spill on the Lower Columbia river plants by about 80,000 acre feet.

These special transactions totaled 124,297,000 kilowatt-hours for the period April 3–30. It is estimated that the total reduction in spill in the Lower River plants was 590,000 acre feet as a result of these special operations.

In addition to the special cooperations mentioned above, generation was shifted to the maximum extent from the upstream Federal plants (Grand Coulee, Chief Joseph, Boundary and Hungry Horse) to the Lower Columbia River plants McNary, John Day and The Dalles.

The two a-c Interties to California were loaded to their scheduled capacity of 1600 megawatts throughout this period except for a few short periods when line capacity was reduced because of maintenance requirements. The d-c line between Celilo and Los Angeles was not available during the fish migration season in 1971 because of the damage done to the southern terminal by the earthquake in February 1971.

Bonneville Power Administration has again been cooperating with the Corps of Engineers and Federal and State fishery agencies this year in planning the river operation so as to enhance the probability of safe downstream passage of hatchery fingerlings released during the week of April 23–28. Operational planning was carried out through the Nitrogen Control Task Force consisting of representatives from State, Federal Fishery Agencies, the Corps of Engineers Bonneville Power Administration, EPA, Bureau of Reclamation, Federal Power Commission and owners and operators of the non-Federal dams on the Columbia and Lower and Middle Snake Rivers.

The goal of this operation was to control the flow of the Columbia River at Bonneville Dam to about 200,000 cfs during the fish release period. Essentially all spill was eliminated at McNary, John Day, and The Dalles projects during this week. It was not possible to completely eliminate the spill at Bonneville Dam, however the spill is expected to be substantially reduced. The spill at Bonneville Dam for the week ending April 21 averaged 140,000 cfs. For the week ending Friday, April 28 the spill at Bonneville will be only about 60,000 cfs. All spill was eliminated at McNary, John Day and The Dalles as well as the three Lower Snake projects, Ice Harbor, Lower Monumental and Little Goose. This regulation was accomplished primarily by holding back water at the Bureau of Reclamation's Grand Coulee project on the Columbia River, and at the Idaho Power Company's Brownlee project on the Snake River.

The Bonneville Power Administration scheduled special power exchanges with the owners and operators of the mid-Columbia non-Federal plants; the Douglas, Chelan and Grant Counties' PUDs. About 6,000 000 kilowatt-hours was programmed for exchange each day during this critical week. The actual exchanges varied somewhat from these programmed values in response to the weather conditions occurring from day to day.

Another factor contributing to a reduction in the nitrogen super-saturation is the return to service of our d-c Intertie with Los Angeles. As mentioned earlier, this Intertie was knocked out of service by the earthquake in 1971. It is now back in service and operating at partial load up to 680,000 kilowatts for 14 hours on weekdays and all day on Saturday and Sunday. This line was loaded to the maximum extent during the week when hatchery-produced fish were released. This increased the load on electric generators, thereby decreasing the risk of spill.

In both 1971 and 1972 nature cooperated well with us during the period when hatchery fish were released. Streamflows were at a level that could be controlled within the limits requested by the fishery agencies. We may not always be so fortunate. The spring runoff could reach magnitudes during the latter part of April and early May which could prevent suitable regulation. The addition of extra units at John Day and Rocky Reach this past year has provided additional ability to divert water through turbines rather than over the spillway which tends to reduce the nitrogen saturation. The completion of additional generating units at The Dalles and at Chief Joseph and Grand Coulee will also assist in the nitrogen control program. In addition the Mica, Libby and Dworshak Reservoirs will provide upstream storage which will be helpful in reducing the nitrogen saturation. These new reservoirs and additional generating units give flexibility to the power system and permits generation to be shifted from one area of the river to another in order to shift any spill requirements to the least damaging portion of the river.

The Bonneville Power Administration heartily endorses the Corps of Engineer's program for installation of slotted gates at empty bays such as has been accomplished this spring on the Lower Snake River projects as well as slotted gates ahead of generators not needed to serve load. We further endorse the prototype studies of the so called "flip lip" spillway modification. These programs should help materially in meeting any standards or goals established by responsible State and Federal agencies.

U.S. Department of the Interior,
Bureau of Reclamation,
Boise, Idaho, May 2, 1972.

Chairman, Public Works Committee,
House of Representatives,
Washington, D.C.

Dear Sir: This letter relates to the hearing on nitrogen supersaturation problems on the Columbia and Snake Rivers which will be held at Richland, Washington, on May 6, 1972, by the House Public Works Committee. A letter of April 14, 1972, from Mr. R. F. Nowakowski invited a written statement for the record. In response, we submit the following:

The Bureau of Reclamation, like other Federal and non-Federal agencies operating facilities on the Columbia and Snake Rivers is aware of the nitrogen supersaturation problem and is cooperating in seeking a solution. We are financing extensive tests to determine what changes could and should be made to bring about improvements. Our effort is directed primarily toward the situation at Grand Coulee Dam and Franklin D. Roosevelt Lake. Grand Coulee Dam is the only dam operated by the Bureau of Reclamation on the main stem of the Columbia River. The Bureau of Reclamation has not constructed, nor does it operate, any dams on the middle or lower Snake River.

Franklin D. Roosevelt Lake, the reservoir behind Grand Coulee Dam, has been partially evacuated in preparation for what might appear to be a record spring runoff. The storage space made available, in addition to providing downstream flood protection, will provide temporary reduction in flows on the Columbia River to avoid spills and thereby lower the nitrogen concentration so that young salmon released from hatcheries will have a better chance to migrate seaward successfully.

Under present operating conditions, we are investigating the influence of releases through the turbines, releases from the two rows of outlet tubes under different hydraulic head conditions, and use of the spillway on nitrogen concentrations in the tailwater. We are also investigating nitrogen concentrations in Franklin D. Roosevelt Lake, particularly at locations where tributary rivers enter the Lake.

By selecting certain outlet tubes to discharge water as necessary and by studying the settings of spillway gates, we hope to alleviate in some degree the downstream nitrogen levels on a short-term basis during the spring high flow periods. It is unlikely that the proposed water quality standards for nitrogen can be fully met in this manner. The primary cure, in large part, appears to be to allow no discharges except through powerplants. The completion of the Third Powerplant now under construction at Grand Coulee Dam will go far in reducing spills and their effect on nitrogen increase. We are attempting to get these generating units on the line at the earliest possible date. All six units currently authorized should be operating by the latter part of the 1970's.

We are cooperating with all agencies involved with the nitrogen supersaturation problem. In addition to the Grand Coulee Dam and Reservoir investigation program mentioned above, we have contributed $30,000 during the current fiscal year for bioassay fish studies to learn more about the actual effect of nitrogen supersaturation on fish. We are also closely following nitrogen supersaturation investigations and experiments being carried out by the Corps of Engineers at its dams. We meet with all interests to discuss the problem and to chart courses on action for temporary relief, and we hope ultimate solution of the problem.

Our Assistant Regional Director, Norman Moore, plans to attend the May 6 hearing as an interested observer.

Sincerely yours,

E. F. Sullivan,
Regional Director.

Olympia, Wash., May *2, 1972.*

Hon. Mike McCormack,
House of Representatives,
Washington, D.C.

Dear Congressman McCormack: First, I wish to express my personal thanks for this opportunity to comment on the nitrogen problems in the Columbia and Snake Rivers. I believe the public hearing approach on the part of the Public Works Committee of the U. S. House of Representatives is most appropriate, and I wish to have this letter included in your hearing record.

I also would point out that while all fisheries agencies of this region have been concerned with and have studied nitrogen gas supersaturation since the mid 1960's, it is only in the last few years that the most complete information on the nitrogen problem has been accumulated.

Our position has been that nitrogen gas supersaturation is a cause of resident and anadromous game fish mortality. The most severe losses were noted in spring and summer of 1970 and 1971; these losses were attributed, primarily, to spilling at dams on Lower Columbia and Snake Rivers. Excessive spill in 1972 will also kill fish. We lost 43,000 resident game fish in 1970 and another 11,000 in 1971 in Lower Snake River. These resident species were primarily bass, crappie, catfish, and whitefish; salmon and steelhead losses are not included here.

As members of the Columbia Basin Fisheries Technical Committee, as well as the Corps of Engineers Fisheries-Engineering Research Technical Advisory Committee, we and other fisheries agencies have worked very closely with owners of projects causing these unusually high nitrogen gas levels. The coordinated effort to reduce spilling during critical migration periods in 1971 and 1972 was a commendable step in the proper direction. However, this effort is not of enough duration to help both upstream and downstream migrating salmonids throughout the spill season.

We commend the efforts of the Corps of Engineers to modify spillways, pass surplus water through perforated bulkheads in skeleton turbine units, fund studies to capture and/or bypass fish at each of their projects, and monitor nitrogen levels within the basin. However, unless or until all Columbia and Snake River project modifications are completed, the nitrogen gas supersatuation problem will remain.

Based on examination of existing data on the nitrogen problem and mortalities occurring to fish life, it is the recommendation of this Department that a nitrogen standard not to exceed 110% saturation be adopted by the Washington Department of Ecology for interstate and intrastate waters of Washington. Further, if additional research provides sufficient justification for modification of this standard, it would be considered and implemented as necessary. We also believe the proposed 110% saturation level to be realistic and achievable through a planned program of storage and modification of facilities at dams creating the problem.

In instances, it is possible that project operation or flow regulation to decrease nitrogen supersaturation could result in a significant loss of fish, especially adults. Since protection of fish life is the primary objective of establishing a nitrogen standard, we feel the input that can be made available with additional research by fisheries agencies should be included when determining specific project operation criteria.

An additional danger is the impact power peaking will have on anadromous and resident game fish in the Columbia system. Power peaking is the program which will provide hydropower as a supplement to the basic power needs during peak demand periods. The present ability to handle widely-fluctuating flows (which accompany peaking) depends on the capacity of a particular plant to handle the flows released from an upstream project. If the plant capacity is too small, spilling and high nitrogen levels will occur. Research associated with peaking flows must be done also and is recommended.

We believe the nitrogen problem can be solved and that differences of opinion can be resolved with adequately-funded research. In the interim, it is our belief that every effort should be made to use known methods for reducing nitrogen supersaturation to an acceptable level.

If our staff can be of further assistance to you or your committee, please do not hesitate to let me know.

Very truly yours,

THE DEPARTMENT OF GAME,
CARL N. CROUSE,
Director.

WASHINGTON GAME DEPARTMENT STATEMENT TO LEGISLATIVE INTERIM COMMITTEE ON FISHERIES, GAME AND GAME FISH

THE NITROGEN PROBLEM IN COLUMBIA RIVER SYSTEM AND ITS FUTURE AS VIEWED BY STATE FISH AGENCIES

First, we thank your Committee for taking time to hear about nitrogen supersaturation conditions, problems and actions taken in the Columbia River System. Because the most critical area is the lower Columbia and Snake Rivers, our comments emphasize Corps of Engineers projects. Not precluded are the contribution of Public Utility Districts, Bureau of Reclamation or private power company structures to the problems on this system.

Simply stated, the problem is that there is too much water over too many spillways during the anadromous fish migration periods, and we see no immediate relief.

The coordinated effort to reduce spilling during critical fish migration periods in 1971 was a step in the proper direction. However, it was only done during periods of high power demand during the day, but not at night nor on weekends. Unless power can be generated full-time, and storage can regulate flow throughout the high runoff period, this program provides only temporary relief. Too many fish pass these facilities when reservoir control and power demand does not exist.

Effort is being made by Corps consultants to construct models of spillway design and flow control potential. Results of this computer model study hopefully will point to methods for relief. But we believe much will depend on the possibility of altering existing spillway sections and coordinating of storage and generation at projects throughout the northwest and Canada. Unless spillway modification or methods to waste surplus power are implemented almost immediately, fish runs will continue to decline. Also essential is modification of spillways and coordinated power releases at projects under construction or proposed. If another dam is completed without these provisions, the nitrogen problem will be further compounded. We know of no plans to alter "new" projects, nor have we seen any plans which show that spillways will be altered.

Even if we assume that future construction will not add to the nitrogen problem, we have still another construction problem; this is the need for repair or additional construction at existing projects. At times, this work prohibits or at least restricts integrating efforts required to reduce nitrogen at specific dams and those downstream. This has already happened on upper Columbia River in Washington and may be a problem at a lower river project. Only if projects controlled water flows to the point that nitrogen supersaturation is below accepted limits will future water quality be guaranteed. This includes mixing of spill and powerhouse releases as well.

It has been proven that fish are more sensitive to a second exposure to nitrogen and that related tissue damage makes them more susceptible to infection. Because nitrogen has a general debilitating effect, fish may also be subjected to greater predation. Predation losses already occur at every dam: the impoundment and tailwater area is very desirable habitat for competitive and predator fish species and birds.

Along with efforts to store and release water for fish passage is the potential for losses to wildlife. This occurs when reservoir levels are altered during waterfowl nesting. Lowering or raising a reservoir only a few feet in spring could expose or flood nests. If, for example, Canada geese chose to nest on an island under a certain water stage and the reservoir is dropped, the island may become a part of the mainland and available to predation. If the reservoir level is down and then raised, the nest will be flooded. The most critical period for waterfowl nesting corresponds to the need for reservoir storage . . . April and May. Future manipulation of reservoirs must be a part of overall environmental management . . . including wildlife resources.

It has been shown that spilling at dams causes nitrogen supersaturation of water. Supersaturation can also occur with heavy algal blooms and warming of water without adequate circulation and exposure to atmosphere. Although this facet has not been emphasized, the possibility for nitrogen supersaturation exists. Unless we are assured that such a condition will not occur, the guarantee of nitrogen-free reservoirs does not exist.

We already mentioned that juvenile fish losses occur with continued exposure or second-time exposure to nitrogen, and the effects of tissue damage making them susceptible to infection. Because adult salmon and steelhead also remain in high nitrogen exposure areas for long periods, these fish also suffer mortalities. We have noted dead adults below dams and lack of adults in spawning tributaries after they have passed fish counting stations. This has been particularly obvious in Idaho's Salmon River. The present status of adult salmon and steelhead runs, as well as resident game fish populations, indicates they cannot stand nitrogen conditions that have prevailed since the late 1960's and particularly those existing in 1970 and 1971. We see no immediate, nor complete, relief. The question is not so much how soon can we expect water quality correction, but how long can these populations persist under these conditions.

The overall success of fingerling collection and transportation from gatewell slots and slotted intake gates is covered in other presentations. Until the results of collection and transportation studies have been analyzed, we are not certain that this procedure is the most desirable. There remains the need to capture wild, as well as hatchery steelhead fingerling migrants (smolts). There also remains the need to evaluate the adult steelhead returns to point of origin. Results have been encouraging. We believe the future lies with collecting and transporting around dams free of nitrogen problems, not with transport programs, in the face of high nitrogen levels, into the estuary of Columbia River.

We do not know the impact that power peaking will have on anadromous fish in the Columbia system. Power peaking is the program which will provide hydropower as a supplement to the basic power production during peak power demand periods. In the future, much of the basic power will probably be provided by hydroelectric, fossil fuel and thermo-nuclear plants. Peaking power is certain to come from hydro projects. The present ability to handle widely-fluctuating flows (which accompany peaking) depends on the capacity of a particular plant to handle the flow released from an upstream project. If the plant capacity is too small, spilling and high nitrogen levels will occur. Changes in reservoir temperature may also take place. We do know that fish subjected to nitrogen while in higher water temperatures do not survive as well as those exposed at lower water temperature; mortality occurs in either case. Completion of projects to ultimate size will not occur in the near future, but only when power demand dictates. Until all projects are completed to ultimate size, we cannot afford to have high nitrogen levels associated with peaking flows.

In summary, the nitrogen problems of today are also those of the future. Hopefully those of today will be reduced. At the same time, however, there may be added problems. The problems, expressed as needs, are as follows:

1. The need to provide regulated flow and spill control on a 24-hour basis every day during high flow period.
2. The need to modify spillways so nitrogen levels do not exceed water quality standards (or as an alternative, provide a means to waste surplus power).
3. The need to insure that future projects, as well as modifications at existing projects, do not cause nitrogen supersaturation during or after construction.
4. The need to eliminate injury to fish which results in increased predation loss.
5. The need to insure that wildlife losses will not occur as a result of water storage or drawdown procedures.
6. The need to eliminate the possibility of any other nitrogen-related condition (such as that which could occur with algae and non-circulation of reservoir waters).
7. The need to protect and eventually increase the runs of salmonids and resident game fish.
8. The need to fund projects that sustain anadromous fish runs until nitrogen saturation is eliminated, as well as to maintain these facilities where necessary after elimination of nitrogen problems.
9. The need to provide for non-nitrogen producing conditions with the advent of power peaking.

STATE OF WASHINGTON,
INTERIM COMMITTEE ON FISHERIES, GAME AND GAME FISH,
Olympia, Wash., May 4, 1972.

Hon. MIKE MCCORMACK,
Washington State Congressman,
Richland, Wash.

DEAR CONGRESSMAN MCCORMACK: This is in regard to your up-coming meeting relative to the nitrogen supersaturation problem we are experiencing in the rivers of this state.

I had planned to attend the hearing but due to unforeseen circumstances I cannot be there.

I am enclosing herewith copies of testimony presented last summer at a meeting of the Interim Committee on Fisheries, Game & Game Fish. I hope that this material will be of some use to you at Saturday's meeting.

If my committee can be of further assistance, please feel free to contact me.

Sincerely yours,

Senator LOWELL PETERSON,
Committee Chairman.

STATE OF WASHINGTON, DEPARTMENT OF FISHERIES, FISHERIES INTERIM COMMITTEE MEETING

NITROGEN SUPERSATURATION VS. FISH IN THE COLUMBIA RIVER

I. Its causes and remedies

Supersaturated nitrogen in water can be produced by both natural and artificial means. It does occur as a natural phenomenon and has been studied by many investigators in the past. The two main causes of nitrogen supersaturation in nature are (1) by the effects of solar radiation on deep bodies of water such as lakes (2) its formation at waterfalls and (3) in well water supplies.

Heating of the deep layers in very clear lakes through solar radiation causing nitrogen supersaturation has been measured by various investigators, predominantly in the clear deep lakes of British Columbia. The lethal effects of this supersaturation nitrogen on trout populations in the lakes has also been observed.

The occurrence of supersaturated nitrogen immediately below waterfalls has been documented by many investigators. In deep plunge basins below certain waterfalls, air bubbles may be carried to depth through the action of the waterfall itself, forcing nitrogen into solution and thus supersaturating the water.

The main cause of man-made supersaturation of nitrogen is produced by spillways at dams and is closely related to the mechanism found at natural waterfalls.

Denitrification or equilibration of gases in water is accomplished in nature and can be artificially accomplished by man in some instances. In nature, the most common method for equilibration occurs in shallow, free-flowing river sections where there is a maximum exposure of the water-gas solution to the atmosphere. This method is primarily responsible for the denitrification of natural waterfalls and, as a result, measurable damage to the fish stocks below such natural obstructions is, in most instance, not considered serious.

Supersaturated nitrogen can also be artificially denitrified when small quantities of water are involved. For example, hatchery and artificial spawning channel water supplies are routinely denitrified by the use of a very simple mechanism. The water supplies are passed over flat screen sections and the water is allowed to drop vertically through the screen baffles. This in effect breaks the water into small droplets, exposing the water particles to the greatest amount of air surface, allowing the dissolved gas solution to be dissipated into the air and thus equilibrate the water supply. This method in principal is very similar to that found in nature of water moving over a shallow free-flowing stream section. However, only relatively small quantities of water can be treated in this manner because of the size of the screen installation needed. For example, the Department of Fisheries' Cowlitz Hatchery denitrifies approximately 165 cfs of water continuously in order to perform this function. A tower was constructed that is 37 ft x 37 ft and 6 stories high. Because of the quantity and veloctiy of water passing over a single spillway bay on any main stem Columbia or Snake River dam the denitrifying tower method described above is a physical impossibility.

II. Its effects on fish

Nitrogen in solution is passed into the fish's blood supply during its normal breathing process by means of the gills. Therefore, the blood of a fish tends to come to equilibrium with the environment. Dissolved nitrogen in the blood vessels and tissues can come out of solution and produce gas bubbles as a result of (1) fishing at depth and suddenly rising to near the surface, allowing the gas in solution to form bubbles, or (2) by a change in temperature which allows nitrogen in solution to form bubbles. "Gas bubble disease" in fish can be likened to a common malady of divers called the "bends". In a diver, or a fish, the blood media becomes saturated with nitrogen under pressure, at depth. As soon as pressure decreases and/or a temperature increase occurs, the nitrogen turns from a soluble solution to a gas, forming bubbles in the tissues and bloodstream. In fish, these bubbles commonly occur in the head region, at the base of the fins, in the eye, and sometimes on the sides of the body. In addition, bubbles in the blood supply commonly cause internal hemorrhaging and in severe cases cause death by embolism.

As can be seen from the lab tests in Section IV, Juvenile salmon held at depth more than 8–10 feet, appear to be able to withstand high nitrogen supersaturation levels. The natural inclination, however, for juvenile salmon and steelhead smolts migrating down the Columbia River to sea is to remain near the river surface. Thus, unless the gas bubble disease actually produces discomfort in the animal, which would wake it sound and stay at depths, it is very likely to feel the full and drastic effects of the disease. Likewise, adults ascending the river on their spawning migration, are usually found fairly near the surface and, indeed, when approaching the fishways at any of the projects, must ascend to relatively shallow depths to pass safely up the fishway system.

Temperature also affects nitrogen's ability to remain in solution in the water mass and/or fish's blood supply. As the temperatures increase, a fish's tolerance to supersaturated nitrogen diminishes. Increased temperatures reduce the amount of nitrogen that can be held in solution and thus produce gaseous nitrogen and bubbles in the fish's blood and tissues. Laboratory experiments on salmon juveniles have confirmed this fact, namely, the higher the temperature the less tolerance salmon will have to supersaturated nitrogen.

III. History in the Columbia River

The first published occurrence of nitrogen affecting salmon in the Columbia River was reported in 1962 at the McNary Spawning Channel by the Washington Department of Fisheries. Excessive mortalities occurred to the adult fall chinook from gas bubble disease in September. However, it was determined that the causative agent for the supersaturated nitrogen was not the Columbia River water itself, but rather a faulty intake system which allowed the water to plunge into the channel, much like a waterfall.

In 1963, gas bubble disease was noted in the Rocky Reach Spawning Channel operated by the Washington State Department of Fisheries. In 1965, in an effort to solve the problem at the Rocky Reach Channel, Thomas Meekin of our Department began a systematic sampling of the upper Columbia River between Grand Coulee and Priest Rapids dams. He established that (1) supersaturated nitrogen was present in the upper Columbia River, (2) its occurrence was correlated with spill activity at the various dam projects, and (3) equilibration or denitrification was not occurring in the deep, slow-moving reservoir pools between the projects. As a result of his work, denitrifying structures were placed on all three spawning channels (Wells, Rocky Reach, and Priest Rapids) in order to assure the safety of the adult spawners and juvenile salmon populations. In addition, his work firmly established the fact that excessive adult mortality to summer-run chinook was ocurring during the times of heavy spill and high nitrogen supersaturation below Chief Joseph dam on the upper Columbia.

In 1966, the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) and Washington Department of Fisheries began routine nitrogen sampling of the Columbia River from Grand Coulee to Bonneville on a monthly basis. This has been expanded over the years until at present nitrogen sampling is carried out every two weeks during the spill season by NMFS and the Washington Department of Fisheries in the Snake River from Little Goose to Ice Harbor and in the Columbia branch from Grand Coulee to Astoria.

In the spring of 1968, with the completion of John Day Dam, supersaturated nitrogen effects on fish became a visible problem in the lower Columbia River. Extremely high concentrations of supersaturated nitrogen were expected since the John Day powerhouse was still under construction and all river flow was thus passed over the spillway. In the preceding three years, saturation in the entire lower river downstream of Priest Rapids Dam was near equilibration with the atmosphere (100%) from late fall to May when none of the dams discharged water from the spillways regularly. Immediately after the closure of John Day Dam on April 20, concentrations of nitrogen were recorded over 125% of saturation throughout the Dalles' impoundment. These concentrations were considerably higher than those in 1966 and 1967 and remained high during the entire salmon migration. In September they still exceeded 125%, long after concentrations at other dams had dropped to less than 105% of saturation. Nitrogen concentrations in the tailrace immediately below John Day ranged as high as 145% saturation because of the heavy discharge over the spillway. Supersaturated nitrogen reached levels of over 130% saturation at Astoria during the month of July. NMFS personnel examining juvenile salmon and steelhead at the Dalles dam, noticed unusually high mortalities among fish held for inspection. During one weekend in late May, 25% of the juvenile steelhead, 46% of the chinook salmon, and 68% of the coho salmon inspected had obvious external symptoms of gas bubble disease.

Three incidents of substantial mortality to adult salmon and steelhead were recorded downstream from John Day dam in 1968. Passage problems over the project caused delay in the upstream migration and it was estimated that over 20,000 summer chinook salmon were missing between Bonneville and McNary dams. Gas bubble disease was in part responsible for these mortalities. Several sockeye salmon captured at the entrance to the John Day ladders exhibited obvious external gas bubble symptoms.

IV Nitrogen Fish Losses

A. Experimental Tests

1. Tests were conducted from 1968 through 1971 by the Washington Department of Fisheries (WDF) in order to determine the effects of nitrogen supersaturation on anadromous juvenile migrants. Some of the more important findings are as follows:

(a) Chinook have a higher tolerance threshold than coho salmon and steelhead trout.

(b) Larger migrants are more susceptible to nitrogen gas.

(c) Migrants can survive in nitrogen levels of 132% saturation for 18 hours, and in 119% for 68 hours (3 days) for large fish (100 mm), and 140 hours (7 days) for smaller fish (50 mm).

(d) When given a choice, chinook migrants will choose water of 100% saturation.

(e) Migrants retained in live boxes at the surface of the Columbia River died in the time of 3 to 7 days, depending on the size, in nitrogen levels of 122% to 130%

(f) Migrants held at a 3 to 5 foot depth survived for 7 days before mortalities occurred in nitrogen levels at 122% to 130%.

(g) No mortalities occurred on migrants held at depths of 5 to 10 feet for 17 days in saturations of 120% to 130%.

(h) The nitrogen level that migrants can tolerate without mortality was concluded to be less than 115%.

2. Experimental tests conducted by the National Marine Fisheries (NMFS) and Oregon Fish Commission (OFC).

(a) The NMFS found 100% mortality of fish held at the surface of the Columbia River with mortalities decreasing as the depth increased.

(b) The NMFS reported that mortalities of 6–16% occurred if fish were held in deep live boxes which permitted fish to seek their own depth.

(c) The OFC reported no mortalities occurred if fish were held in live boxes which permitted fish to seek their own depth.

B. Snake River and Columbia River juvenile loss.

1. In 1970 the migrant loss in the Snake River from Little Goose Dam to Ice Harbor Dam was calculated by a mark recovery program to be 70% chinook and 30% steelhead by NMFS. Additional loss in the Columbia River would be additive to those figures.

2. The Washington Department of Game (WDG) valued the steelhead loss at $226,000.

3. An estimate has not been calculated for the 1971 Snake River migrant loss but preliminary reports indicate it will be of similar magnitude.

4. During 1968 the NMFS found symptoms of nitrogen gas in juvenile migrants at John Day Dam. During one week in late May, 25% of the steelhead, 46% of the chinook and 68% of the coho salmon examined had external symptoms.

5. The WDG estimated that ⅔ of the 325,000 steelhead trout planted in the Washburn Island rearing facility, upstream from Wells Dam, were killed during a 5-day period in July 1970 because of high nitrogen levels.

C. Wells pool adult summer chinook loss.

1. The WDF investigated summer chinook and sockeye salmon prespawning mortalities in the Columbia River downstream from Chief Joseph Dam during the years 1965 through 1970. Mortalities occurred during the spill season at Chief Joseph and Grand Coulee dams, but ceased after the spill period. Mor-

talities were significant during 1965 through 1969 and were caused by high nitrogen levels ranging from 120 to 135%. During 1970 with reduced spill volumes and nitrogen levels less than 117% the mortalities were minimal. Following are the calculated mortalities for adult summer chinook:

Year	Run size	Mortality	Percent mortality
1967	9,164	5,400	59.3
1968	6,550	2,457	44.3
1969	3,597	2,000	55.6
1970	5,600	309	5.5

Sockeye salmon also succumbed to the lethal effects of nitrogen supersaturation but estimated mortalities are not as precise.

2. Adult chinook mortalities have also been found between Wells Dam and Rocky Reach Dam from 1967–1970 by the WDF and in the McNary pool during 1968–1969 by NMFS.

3. In 1968 the WDF, OFC and NMFS participated in surveys below John Day and The Dalles dams and found significant numbers of chinook salmon carcasses. The OFC estimated that 20,000 summer chinook salmon were missing between Bonneville and McNary dams and that nitrogen levels were in part responsible for these mortalities.

D. Resident fish

1. In 1970 the WDG estimated that 43,400 crappie, bass and catfish were killed downstream from Little Goose Dam in the Snake River. The monetary value of this loss was calculated to be $710,000.

2. Preliminary data collected by the WDG indicate significant mortalities are also occurring during 1971.

3. During the Wells pool study, 1965–1970, the WDF found dead whitefish, trout, carp, suckers, squawfish, shiners and chub in the Columbia River during periods of high nitrogen levels (120% and higher).

4. Experimental tests by the WDF show that squawfish will die in 48 hours in nitrogen levels of 130%. They will not die in levels of 119.5% but become very lethargic.

CONCLUSIONS

1. Mortalities of adult anadromous fish are occurring in the Columbia River between Wells and Chief Joseph Dam during the spilling season. The cause of this mortality is supersaturated nitrogen levels above 120%. Furthermore, losses of adult fish have been documented in other sections of the Columbia River and nitrogen gas is undoubtedly a contributing factor.

2. Anadromous juvenile migrants are definitely affected by high levels of nitrogen gas, over 115%, but a reliable estimate of the overall mortality occurring throughout the Columbia River cannot be calculated without mark recovery data.

3. Resident fish are also affected by supersaturated nitrogen.

4. Even though the precise extent of nitrogen induced mortalities of adult and juvenile fish cannot be calculated, this factor is undoubtedly contributing to the decline of the Columbia River anadromous fish runs. If these runs are to be maintained, even at their present level, a decrease in the nitrogen levels will have to be accomplished at the earliest possible time by the first available means.

V. Status of Columbia River Salmon and Steelhead

Historical records show that salmon and steelhead once utilized extensively the Columbia River and its tributaries, Chinook salmon migrated nearly 1,200 miles up the Columbia to Lake Windermere, Canada and 600 miles up the Snake River to Shoshone Falls, Idaho.

The construction of dams has gradually reduced areas accessible to anadromous fish, especially in the valuable salmon-producing tributaries of the upper watersheds. Early in the 20th century irrigation and hydroelectric dams were built on upriver tributaries, but hydroelectric development of the mainstem Columbia and Snake rivers did not begin until Rock Island Dam in 1933. Since then dams have been built in the drainage at an increasing rate. As of today the upstream limit of salmon and steelhead in the Columbia River is Chief Joseph dam while in the Snake River, less than 50% of the salmon and steelhead environment is available.

Prior to 1938 no meaningful estimates were available of the size of salmon and steelhead runs entering the Columbia River. Completion of Bonneville Dam in 1938 provided a means of counting all species passing upstream. A substantial portion of the spring chinook, summer steelhead, and essentially all of the summer chinook and sockeye migrate upstream past this structure to spawn. Other races and species also utilize upstream spawning grounds but, because of timing, are not as seriously affected by dam construction.

Spring and summer chinook, sockeye, and summer steelhead runs have suffered from loss and deterioration of spawning and rearing areas, delay in migration and predation, and more recently, gas bubble disease resulting from accelerated construction of dams on the mainstem Columbia and Snake rivers beginning in the 1950's.

Upriver spring chinook runs have ranged from a low of 56,300 fish in 1944 to a high of 281,000 fish in 1955, averaging about 162,000 fish since 1938. Catches over the long period have been approximately 85,000 fish annually. During the past 10 years, however, the average annual run increased to about 172,000 fish while the catch declined to approximately 64,000 fish annually. Part of the reduction in catch resulted from fishery regulations imposed to enhance escapement. Prior to 1960, the number of days open to fishing for spring chinook averaged about 22. Since 1960 the average number of days dropped to 18 but often the season opening was delayed because of passage problems at upstream dams. Sport fishery seasons have also been curtailed on this run.

Summer chinook runs have ranged from 53,000 fish in 1945 to 207,000 fish in 1957, averaging about 110,000 fish. During the mid and late 1950's, the run increased to about 183,000 fish on the average. Since 1960, however, the runs have ranged from 70,000 to 143,000 fish and stabilized at below 100,000 fish annually. Because this run migrates upstream during peak freshet conditions and is most severely affected by passage conditions, fishing time has been curtailed drastically. In 1963 an escapement goal of 80,000–90,000 fish was established for this run. Beginning in 1964, no specific commercial fishing seasons have been permitted on this stock (some summer chinook are taken incidental to fisheries for other species, however). The sport fishery also has been curtailed on this run, limited to "jacks" only, or completely closed.

Sockeye runs to the Columbia have fluctuated more than any other salmon species. Catch records indicate this run may have exceeded 1 million fish prior to 1900, however, the largest run recorded since 1938 was 335,000 fish in 1947. The smallest run of about 11,000 sockeye occurred in 1945. The peak period of abundance in recent years occurred in 1950's when the run averaged over 220,000 fish annually. During the past 10 years, the run has averaged only 95,000 fish annually with 80,000 fish needed for escapement. Drastically restricted summer fishing periods have been permitted (these seasons have ranged from 1 to 8 days) with mesh restrictions designed to reduce the catch of both chinook and steelhead.

Upriver summer steelhead runs have ranged from a high of 423,000 fish in 1940 to a low of 139,000 in 1970. During 1938–63 the run size averaged 259,000 fish but decreased to 180,000 during the 1964–70 period. This reflected a decrease in the production and survival of juveniles in recent years. Commercial fishing regulations are designed to minimize the catch of steelhead during legal seasons for other species. Prior to World War II, catches exceeded 200,000 fish annually. In recent years the incidental commercial catch has averaged about 35,000 fish. Besides mesh restrictions to protect this species, a delayed commercial season during August also reduced the catch.

The sport catch for 1965–69 in the Snake River in Washington as measured by punch card returns was approximately 12,000 fish annually. In 1970 the catch head dropped to approximately 7,000 fish.

VI. Results of 1971 N_2 reduction studies

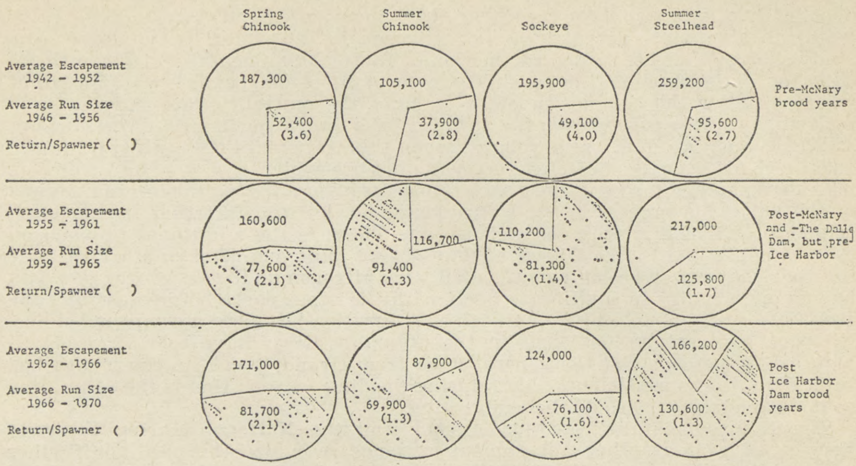
Several measures were undertaken in 1971 in an attempt to alleviate the nitrogen superation problem. These included test structures to pass water through the skeleton turbine bays at Little Goose Dam to reduce the amount of spill, the transportation of Snake River downstream migrants around problem areas, and a water control program aimed at regulating generation and spill at the Columbia and Snake River dams to produce the best conditions possible for natural and hatchery-produced migrants.

The Corps of Engineers was requested by State and Federal fisheries' agencies to explore the possibility of passing water through the skeleton units at Corps' dams and this has become known as the "slotted bulkhead" program. The term is derived from the fact that it is necessary to control the flow of water through the skeletal bays to prevent structural damage and this is provided by slots or openings in a steel bulkhead located at the turbine intake. There are three intakes for each turbine and each of the three dams on the Snake River will require nine slotted bulkheads. The first installation was made at Little Goose in mid-May and subsequent installations at Little Goose, Lower Monumental, and Ice Harbor Dams will depend on appropriations. The Governors of Washington, Oregon, and Idaho have directed a resolution to the President and Congress requesting funds for installation at these dams.

A program to collect and transport Snake River migrants from Little Goose dam around the trouble areas for release below Bonneville dam was initiated by the National Marine Fisheries Service. The program is financed by the Corps and it is estimated that 20% of the Snake River migrants could be collected at Little Goose Dam. The biological considerations involved are numerous but studies conducted by NMFS suggest that transportation may be a partial interim solution to the problem. The program was initiated this spring and by June 1 approximately 250,000 migrants were transported below Bonneville.

Early this spring, a committee of biologists was appointed by the Columbia Basin Fishery Technical Committee to work with the Corps to determine if generation and spill manipulation could be used as a tool to alleviate the nitrogen problem. This group was soon expanded to include Bonneville Power Association, Bureau of Reclamation, the eastern Washington PUD's, and other power producers and eventually became international in scope when power was sold to Canada in order to keep the generators loaded at mainstem dams. The role of the fisheries' agencies was to advise the Corps and BPA on the time and location of hatchery releases and the timing of the natural downstream migration. The Federal agencies endeavored to conduct power production operations in such a manner as to reduce spill in the critical areas. The program was extremely complex and it was impossible to satisfy all the fisheries requirements. The work was complicated by the abnormally large runoff this season and it is believed that in a medium or below average water year, considerable relief could be achieved with this approach. Despite the above normal water year, river regulation was achieved to the extent that spill was almost completely eliminated at the lower Columbia River dams during the period of the release of 40 million fall chinook salmon in late April by the fisheries' agencies. It is believed that without the flow regulation, significant losses would have occurred to these fish from nitrogen supersaturation. We received excellent cooperation, particularly from the Corps and BPA, and we expect that this approach will be continued until permanent solutions to the nitrogen problem are found. The measures described above are of an emergency or stop-gap nature and, although they offer some relief to the problem, they are not considered permanent solutions.

Columbia River Adult Salmon and Steelhead Runs



NOTE: All circles are based on 100%. The Large Number represents the average run size for the years shown. The Smaller Number represents the average escapement which produced the run. The number in (·) represents the return per spawner, i.e.,. The number of fish in the returning run produced by each brood year spawner.

NORTHWEST CONSERVATION REPRESENTATIVE,
CONSERVATION CENTER,
Seattle, Wash., May 10, 1972.

CHAIRMAN,
Public Works Committee,
U.S. House of Representatives,
House Office Building, Washington, D.C.

DEAR MR. CHAIRMAN: Unfortunately, we were unable to attend the Public Works Committee hearing held in Richland, Washington on May 6, 1972. The purpose of this hearing, as we understand it, was to provide information on nitrogen supersaturation and its effect on fish in the Columbia and Snake Rivers both to the committee and the public as well as providing information on measures being taken to solve the problem. We are extremely concerned about this current threat to the already depleted fishery resource of these rivers and we feel that we must express our views on this issue. We are requesting that this letter be made a part of the official hearing record.

The nitrogen supersaturation problem in the Columbia and Snake Rivers has reached crisis proportions and is expected to become worse if nothing is done. Fish kills from bubble disease are well documented and the evidence clearly points to abnormal concentrations of nitrogen in the water as the cause. One study showed that before the completion of Lower Monumental and Little Goose dams on the Columbia the mortality rate of anadromous fish was 5 percent where as after the completion of these dams the mortality rate jumped to 70 percent. As water passes over the spillway of a dam it picks up a large amount of nitrogen gas from the atmosphere; when this water hits the stilling basin the entrained nitrogen is subjected to great pressure which forces it into solution. The nitrogen then forces its way back into a gas after entering the internal organs of the fish. This process is not well understood, but the fact that it can blind, cripple or kill fish is only too well known. There is the additional problem on the Columbia and Snake Rivers of dams being built one after another so close together that water becoming saturated with nitrogen as it passes over one dam has no opportunity to equilibrate itself with the atmosphere before reaching the next. The result is not only a maintained saturation level, but a compounded one. Nitrogen supersaturation levels in the Columbia River have been recorded as high as 145 percent and the general level from Grand Coulee to the mouth has been found to be consistently high during flooding season; this is the same time as most anadromous fish do their migrating.

The Environmental Protection Agency and the National Marine Fisheries Service as well as other government agencies recognize the need for further research into the nature of bubble disease and the development of a standardized method of measuring dissolved nitrogen levels. We strongly support this type of research and support the EPA attempts to reduce nitrogen levels in the Columbia and Snake Rivers through a coordinated effort by state and federal agencies involving operational and structural modifications of existing dams and fish hatcheries. However, in considering overall solutions to this problem, we feel it is appropriate to reflect on the short sighted planning and lack of understanding some of the basic laws of nature which are responsible for today's environmental problems of which nitrogen supersaturation is only one. Although the mistakes of the past are painfully obvious and can teach us what not to do in the future, we must keep in mind that there are still a multitude of things we do not understand and we are capable of making mistakes today that could cause environmental problems tomorrow that we have not yet imagined. This possibility must be considered before technological solutions are applied to problems originally caused by technology itself.

Since nitrogen in supersaturation is toxic to aquatic life, its presence violates the Interstate Water Quality Standards pursuant to the Water Quality Act of 1965. This means that a standard for the amount of nitrogen allowable in the water can and must be set and enforced. Page 12, paragraph 5 of *WORKING PAPER, Nitrogen Supersaturation in the Columbia and Snake Rivers* published by the Environmental Protection Agency makes the following statement:

> "Nitrogen supersaturation levels above 105 percent produce symptoms of gas bubble disease in fish, and levels above 120 percent are lethal."

This strongly suggests that, since the purpose of establishing a standard is to protect fish from gas bubble disease, the obvious and necessary standard would be 105 percent. However, under *Recommendations* on page 14, paragraph 1a, the publication states the following:

> "The standards criterion should establish a maximum allowable concentration of dissolved nitrogen in the Columbia and Snake Rivers at 110 percent of saturation based on analytical procedures presently being followed by the National Marine Fisheries Service."

We can only conclude that this contradiction is attributable to disagreement among researchers as to what level of nitrogen concentration begins to produce harmful effects on fish. More research is necessary to clear up this disagreement and a device must be developed to efficiently test for dissolved nitrogen levels. However, until such time as this is accomplished, we strongly recommend adoption of a standard of not equal to or more than 105 percent in any cross section of the Columbia and Snake River systems. Not only is there doubt as to what level of nitrogen supersaturation begins to cause visible damage, but it has been shown that fish exposed to various concentrations of dissolved nitrogen can develop conditions that do not become apparent until after the fish are transferred into equilibrated water. This is particularly apparent when the equilibrated water is at fairly high temperature. In other words, the sensitivity of fish to rising temperatures becomes more acute and the ability to endure temperatures decreases after exposure to water supersaturated with nitrogen. It has been shown that the life expectancy of jack salmon is greatly shortened by exposure to dissolved nitrogen. These factors must be considered when setting a standard for the amount of nitrogen concentration allowable. It is conceivable that levels of 110 percent could cause decreased life spans and other detrimental effects upon fish after they have gone out to sea. This would be extremely difficult to detect. Even a standard of 105 percent does not assure us that this will not occur. Although nitrogen supersaturation does occur in a natural environment, it would be difficult to find a natural example of continuous dissolved nitrogen exposure throughout the greater part of a river system such as occurs as a result of the many dams on the Columbia and Snake. Most waterfalls will create some nitrogen supersaturation, but there will usually be enough turbulence downstream to allow the water to equilibrate itself. We feel that an allowable level 105 percent is a calculated risk and is the absolute maximum that should be considered.

Although we favor structural modifications to existing dams to protect fish from the turbines as well as from nitrogen concentrations we note that the EPA requires all new projects to be equipped with structures to prevent supersaturation of nitrogen from occurring. We flatly oppose any new dam project on the main stem of the Columbia and Snake Rivers. Dams are responsible for much of what is wrong with many of our river systems today affect fish in many ways. Change of flow configuration affects water temperatures, destroys spawning grounds and sometimes makes it impossible for fish to survive because of lack of sufficient flow. The dam itself blocks the passage of the fish and necessitates such measures as fish hatcheries, trucking fish around dams and fish ladders, none of which can equal the efficiency of the original rivers capacity to produce fish runs. Wildlife habitats are lost to reservoirs and recreational and asthetic values are greatly diminished. To approve new projects now would be to continue the same short-sighted approach as has been taken in the past.

Only since recent attempts at calculating the dollars lost from depleted fish runs and some estimates as to the value in economic terms the Columbia Basin fishery have been made has the deplorable condition of these rivers become public knowledge. It is unfortunate that the economic value which is great provides the motivation for improving conditions and that so much damage has to occur before it is noticed. We urge immediate action to lower nitrogen levels in the Columbia River system and recommend that no concentration of nitrogen equal to or greater than 105 percent be allowed to occur in any cross section of that system. We also oppose any new projects regardless of the requirements imposed by on them by the Environmental Protection Agency. We thank you for this opportunity to express to you our recommendations and evaluation of this serious problem of mutual concern.

Sincerely,

BROCK EVANS.

CONGRESS OF THE UNITED STATES,
HOUSE OF REPRESENTATIVES,
May 3, 1972.

Hon. MIKE MCCORMACK, M.C.,
Congressional District Office,
Federal Building,
Richland, Wash.

DEAR MIKE: Enclosed you wil find my statement concerning nitrogen supersaturation problems in the Columbia and Snake Rivers for inclusion in the May 6 hearing record.

I'm sorry that I cannot attend in person, since I'm greatly concerned about the outcome. I had made earlier commitments in the Coeur d'Alene area, and the Sunshine Mines disaster now makes it imperative that I be there. I'm sure you understand.

I would appreciate having a full transcript of the proceedings when it becomes available.

Best regards.

Sincerely yours,

Jim
JAMES A. MCCLURE,
Member of Congress.

Statement of Hon. James A. McClure, a Representative in Congress From the State of Idaho

NITROGEN SUPERSATURATION

Mr. Chairman and members of the committee, one look at your impressive list of witnesses discourages me from attempting to provide technical data on the alleviation of nitrogen supersaturation in the Columbia and Lower Snake Rivers. I am not a scientist or a hydraulic engineer, and the problems we face lie primarily in those areas. But I am an Idahoan, representing that area where most of the Columbia Basin anadromous fish find their spawning grounds, and I am greatly concerned. As Congressman for the First District of Idaho, I know that my constituents share this concern and give their full support to effects to solve the problem.

It is essential that we protect our anadromous fish runs if we are to prevent yet another member of earth's community from becoming an endangered species. Thousands of sportsmen are vitally concerned, too, that one of nature's most spine-tingling experiences be preserved—that of a fighting steelhead or salmon on the end of a taut line. From an economic standpoint, it is essential, too, that we protect the salmon. The Pacific Northwest derives great revenue from its commercial fishing industries. We have a lot at stake and an overriding environmental responsibility to meet.

There are several steps necessary to any finalization of this situation. To begin with, we must fully understand the nitrogen problem and its effects on fish. We have come a long way in understanding the problem. Historically, reference to gas bubble disease is documented as early as 1890. The implications, though, were largely ignored until the early 1960's when large-scale fish kills in the Columbia River pointed a finger to the disease once again. The full implication was not recognized until 1968.

Even today, though, there is some indication that we may have overestimated the deadliness of this disease. I emphasize "may" because I do not wish to be identified as one who would have us ignore the problem. It is essential that we act, but a recent development warns us that we must not act unwisely.

In 1970, fisheries biologists warned that downstream migrations of fingerlings were suffering a 90 percent mortality. It was a "doomsday" prophesy and the public reaction was immediate and emphatic. Such overwhelming kill figures would lead one to expect that that generation of salmon is the weakest link now in the reproductive chain. Not so. That generation is now passing through Bonneville on its way upstream to spawn, and they are passing in overwhelmingly big numbers. As of May 1, approximately 155,000 chinook had been recorded—a figure exceeded only once in the past 10 years. The recorded high for that period is 173,000.

So something was apparently wrong with the earlier predictions of a 90 percent kill rate. What was it? We really don't know, but we must find out. Could it be that these fish automatically sink to deeper levels when nitrogen content becomes uncomfortably high? That's a possibility, but we must positively identify that factor which saved the 1970 fish generation. I believe it is clearly illustrated that such a factor exists, and we could harness it to our advantage in solving the overall problem.

A second step in this program is to monitor the levels of saturation. Generally, we have found that saturation increases with each dam spillage operation. Because the Snake and the Columbia are no longer free-flowing rivers, the problem becomes cumulative as waters pass each dam. We have already made some advances in developing the technology and tools of monitoring the rivers. We must complete this phase of work rapidly in order to move on.

The third phase is a difficult one—that of testing and proving out devices or methods of alleviating the supersaturation. Much has already been done, and I think we are on the right road with a number of ideas that have come forward.

I am particularly pleased with the initial test results on the slotted gate devices, although they are only useable on those dams where skeleton bays are yet available. I at least will strongly recommend it to you as an excellent stop-gap measure until we make some longterm decisions.

An obvious answer to at least part of the problem is increased use of the turbines—perhaps to the extent that more turbines be added quickly to the skeleton units of various partially-powered dams. In order to make this move, we need new power customers and new interbasin exchange plans. My experience on the

Task Force has clearly demonstrated the need for new thinking and new sources of power. The thinking, at least, must begin now, and perhaps it is appropriate that it begin in this Committee.

As a legislator dealing on a day-to-day basis with the nation's irrigation problems, I know that where you begin the tricky process of regulating dam flows, you affect irrigation. You also affect erosion of the river embankments, and it is to this point that I address one question. In simple terms, it levels off spillway water before it can plunge to great depths and contribute additional nitrogen. I am concerned that in solving the problem in this manner, we create another. What effect does the deflector have in creating turbulence and eroding embankments?

The final step, of course, is implementation of our findings. And here, for a moment at least, I want to assume the role of the devil's advocate.

How much saturation is "normal"? Studies I have reviewed indicate that in nature we find levels exceeding 100 percent—often markedly higher. While I strongly support the work we have finished and the work we are about to begin in alleviating supersaturation—let's not overreact to the importance of the program. In nature, nitrogen supersaturation occurs naturally to some extent along any undammed, but turbulent stream. Fish populations apparently adjust easily to what occurs in nature. Let's not adopt an arbitrary standard of improving upon nature.

Nevertheless, your Committee has my full support and cooperation in your efforts to end this unnecessary loss of fish below our dams. I wish to add my thanks for these efforts, and my promise to assist in any way I possibly can.

RICHLAND, WASH., *May 21, 1972.*

PUBLIC WORKS COMMITTEE,
Congress of the United States,
House of Representatives,
Washington, D.C.

(Attention: Rep. Mike McCormack, Federal Building, Richland, Wash.)

GENTLEMEN: The following comments are submitted as part of the record, with your permission, of the Hearing of the Public Works Committee of the U.S. House of Representatives on nitrogen supersaturation problems in the Columbia and Snake Rivers, Saturday, May 6, 1972.

I had occasion to attend this hearing and listen to a number of speakers on various aspects concerning dams on the Columbia and Snake Rivers. My reaction to the various speakers was one of disappointment.

I found the people speaking in favor of the dams and dam projects were well prepared, and the people speaking against dams and selected dam projects were not as well prepared. This difference is of course easily explained when one realizes that the U.S. Corps of Engineers, Power People, etc. have staffs and funds available to help prepare for such hearings; while most people who have concern for natural, undammed rivers, natural salmon runs, etc., are not as well organized and financed but are generally run on small donations and volunteer help and time.

So I believe the subcommittee has heard a rather slanted story at this hearing.

I, for one, would like to go on record as being vigorously opposed to dams and the mess they make of a natural, free-flowing river. Further, I advocate the removal of as many dams as possible as soon as possible and the restoration of natural salmon runs. I realize there are great problems involving power and dam removal, but the value of having a free river is great. I'm sure you also realize that I am not alone in my desire to see a free Snake River and a free Columbia River again.

Yours very truly,

W. P. METZ.

STATEMENT OF JOHN F. STREIFF, CHAIRMAN IDAHO WATER RESOURCE BOARD

The Idaho Water Resource Board, the state's water planning and development agency, appreciates the opportunity to present a statement to the Public Works Committee of the U.S. House of Representatives concerning nitrogen supersaturation problems in the Columbia and Snake rivers.

The Board recognizes the importance of the anadromous fishery resource to Idaho and will continue to support efforts to minimize problems, such as nitrogen supersaturation, which could raise havoc with this valuable resource. The emergency measures taken by the Corps of Engineers and the U.S. Bureau of Sport Fisheries and Wildlife to overcome nitrogen supersaturation are endorsed and supported by the Board.

At the request of Idaho, a new report is being prepared under the auspices of the Pacific Northwest River Basins Commission (PNWRBC) on the status of the anadromous fish in the Columbia River System and tributaries. This report is to be prepared annually and will provide accurate and up-to-date information to federal, state, and local groups on the status of the anadromous fish runs. In the past, conflicting statements by various public and private entities have served to confuse the public as to the seriousness of the problems confronting the anadromous fish.

Although the PNWRBC report will provide general basic information, until water quality and other problems are solved, it would be well if monthly reports of fish runs including an analysis of the impact of the Lower Snake and Columbia dams on the runs into Idaho were provided to concerned state and local agencies. Information should also be provided to concerned state and local agencies. Information should also be provided on release dates of hatchery fish in Idaho and nitrogen conditions at each dam on days the young fish are proceeding downstream. Surveys should be conducted during the spawning season of redds on the Snake River and tributaries. The Board would benefit by having annual reports on operation and production results from the five hatcheries located on the Snake, Salmon, and Clearwater rivers which have been established to maintain and enhance anadromous fish runs. In addition, we would like to receive fish passage figures for Ice Harbor, Little Goose, and Lower Monumental from the times they become operative until the present time.

Monitoring of water quality in the Salmon, the Clearwater, the Middle Snake, and Lower Snake rivers is important to determine what impact pollution is having on the fish runs.

Until current problems are resolved, there possibly should be a change in fishing regulations to allow additional escapement of juvenile steelhead trout and chinook salmon. If nitrogen supersaturation continues to be a serious problem, we would recommend a reevaluation of escapement goals and commercial fishing in the Columbia River.

The people of Idaho share the concern of our neighboring states in the importance of maintaining a quality anadromous fishing resource. We hope that your committee will be instrumental in providing funds necessary to see that this objective is carried out.

JOINT STATEMENT OF THOMAS G. BELL,[1] AND R. KEITH FARRELL,[2]
WASHINGTON STATE UNIVERSITY

GAS BUBBLE DISEASE: LABORATORY STUDIES ON GAS EMBOLI FORMATION AND MORTALITY IN STEELHEAD

Mr. Chairman, members of the committee, ladies and gentlemen, when we first became interested in gas bubble disease, I asked the question, as did I suppose everyone else, can it be possible that fish are getting the bends?

I think you will agree that field studies run, thus far, characterize a considerably different disease:

(1) Fish restricted to very shallow water are affected. There appears to be no need for a depressurizing episode, as is the case in aviators or divers that get the classical Casson's disease, nick-named the "bends" because of the posture they assume thereafter.

(2) The disease occurs primarily in the northwest in salmonoids, even though other fish in the river system are exposed to the same supersaturation conditions.

(3) The presence or absence of bubbles in fish does not appear to correlate well with mortality.

---

[1] Assistant Professor, Department of Pathology, College of Veterinary Medicine, Washington State University, Pullman, Washington.
[2] Veterinary Medical Officer, Veterinary Sciences Research Division, Agriculture Research Service, U.S. Department of Agriculture, Pullman, Washington.

The first experimental question we asked was, "is the supersaturated gas passing directly into the fish and causing the disease?" Since all fish in a given body of water may be equally exposed to the supersaturation, an experiment designed to compare different species of fish appeared to be a good starting point.

Running immature steelhead (approximately 20 grams) along with young channel catfish (approximately 35 grams) under identical conditions in the environmental chamber (10° C., 1.5 atmospheres partial pressure of dissolved air in water equivalent to approximately 130% nitrogen [1] in open tanks), we found that:

(1) Both steelhead and catfish showed decreased respiratory rates and efforts (See Chart I).

(2) Both groups evidenced decreased circulation.

(3) Only the steelhead demonstrated loss of co-ordination and heaviness in the water.

(4) Only the steelhead developed gas emboli in the tissues and blood.

(5) Only the steelhead developed muscular rigor of some degree prior to death.

(6) The steelhead all died between 90 and 160 minutes after introduction into the testing chamber. No catfish succumbed. In fact, certain catfish were administered six steelhead lethal exposures in six days without showing ill effect. It is to be noted, however, that catfish have been reported to die with a gas bubble disease like syndrome where water temperatures are 25° C. or more.

Other observations were recorded. Both species of fish showed discomfort at being exposed to the test environment, even though there was no change in other factors (temperature, location, lighting, etc.). In laboratory test chambers, generation of supersaturated gas solutions by air injection under pressure always resulted in increases in the amount of carbon dioxide. Since carbon dioxide is a very small portion of atmospheric air, the total partial pressure contribution is small, that is, around 1 mm Hg. However, in repeated trials, the contribution of carbon dioxide in the water appears to be significant in terms of mortality. This can be understood by a careful study of work reported by Herman Rahn, 1971. Whether the same hold true for generation of gas solutions in the river remains to be seen. The Corps of Engineers have indicated they will attempt carbon dioxide measurements during 1972 in the Columbia and Snake River systems.

In addition, we noted that a relatively stable supersaturation condition was achieved in water only if none of the solubility maximums of the gases being dissolved were exceeded. For example, if the alpha for nitrogen is taken at 16.4 ml/liter and for oxygen at 31.0 ml/liter, one could put that much into solution and, judged by measurements of gas content with blood gas analysis (gas electrodes), the situation was relatively stable. The total partial pressure of such a solution, of course, exceeds one atmosphere, since each gas contributes one atmosphere of partial pressure at its maximum solubility. This is to be expected since gases dissolve independently of one another in a solution.

As far as the situation relates to the fish, however, it is to be noted that contact with any surface caused a bubbling out of gases in this metastable solution. Therefore, it became hard to understand how the transfer of supersaturation from water to blood could occur across the gill membrane. In fact, measurements of blood never revealed more than a saturation with any gas.

Bubbles which form on a surface can transfer only a partial pressure equal to the ambient pressure; therefore, the formation of a bubble on the gill surface would prevent the transfer of supersaturated solutions across that membrane.

Incidently, the above phenomena is the cause for a minor problem concerning the use of the Weiss Saturometer demonstrated earlier today. It is used to measure *total* partial pressures of *dissolved* gases in water. The surface of the membrane, across which these gases must pass, causes bubbling out of gases, just as the fish or any other surface does. If the Saturometer is not shaken violently during use, it will give a low reading. This is true because, as explained above, the bubbles on the membrane of the device can transfer only a partial pressure equal to the ambient water pressure (nearly equal to one atmosphere near the surface of the water).

We are in the process of developing a "model" fish based on the structure of the Saturometer invented by Dr. Ray Weiss. It will enable us to pass blood of various species through water and make direct observations on the formation of gas emboli in blood.

---

[1] Knowing that the alpha for N_2 in water is about 17 ml/L.

Well, this first set of experiments, as you can see, did not answer very many of our questions. How do gas emboli form in the blood and tissue if it is not entirely due to a simple transfer and bubbling out of a supersaturated solution?

We looked to the red blood cell for the answer to that question, because published reports indicated clearly that there are major differences between species in the functional capabilities of hemoglobin contained in the cell. First of all, an experiment which blocked the ability of the red blood cell to pick up oxygen was designed and accomplished. Both control and test steelhead were exposed to carbon monoxide. The control fish survived well (See Chart II) as long as the water was oxygenated and maintained at 5°C. Under identical conditions, the test fish exposed to gas bubble disease conditions as described before, formed *NO* gas emboli in blood or tissues. They still died, however, exhibiting the other signs of the disease.

The obvious procedure to attempt next was to expose fish using only oxygen, rather than air. This was done using total partial pressures of 1.25 atmospheres oxygen dissolved in water with other conditions the same as in previous tests.

In this case, steelhead reacted by forming many emboli in the tissue, but there was no mortality in the experiment. The fish literally looks like a sponge, but he does not die.

The formation of massive emboli in supersaturated oxygen water is not surprising. It has been known for many years that the fish, particularly salmon and trout, can unload oxygen from the red blood cell in this manner. What is happening is the exaggeration of the normal oxygen unloading process in the presence of acid to form free gas. The fish does this every day, in fact, as a means of adding gas (oxygen) to his swim bladder. The blood filled spaces around the bladder concentrate lactic acid and carbon dioxide causing the red cell to give off gas. This gas is then taken into the bladder.

The gas formed in bubble disease is abnormal, of course, and because of the saturation of gases in the blood stream, the micro-oxygen emboli increases in size as a function of the total partial pressure of various gases in solution in the blood. Thus, the bubble's final composition reflects the content of dissolved gas in the blood.

As demontrated in the pure oxygen trials, blood and tissue air emboli do not appear to be the cause of death since fish were able to survive twenty hours or so with obvious signs of tissue emboli. After that period, the fish appeared to be normal for up to 10 days. Further observations were not made. Whether the emboli cause narcotic skin lesions frequently observed in returning migrants, we do not know. This would seem likely.

If the tissue and blood gas bubbles are not the immediate cause of death, then what is? The answer apparently lies in the way the fish perceive his environment with respect to gas content. Several recent investigations in other laboratories have shown that the fish probably only responds to the level of oxygen in water and blood. Mammals, on the other hand, regulate their respiratory and circulatory rates by measuring carbon dioxide levels in air and blood.

Our preliminary studies indicate also that the fish (see Chart II), having checked only the level of oxygen in the water during exposure to gas bubble disease conditions, makes an inappropriate response. Since oxygen levels are elevated, he slows his respiratory and circulatory efforts even though his tissues are accumulating lactic acid and carbon dioxide from metabolic activity. This is a normal, constant production and is increased during violent exercise and when water temperature increases. This accumulation of acid products in the tissue causes the formation of gas emboli in the fish when gas bubble conditions exist, just as the swim bladder organ does normally. What is more important, however, the accumulation of acid products in the tissue with high oxygen levels and air emboli eventually results in a shock like syndrome, varying degrees of premortal rigor, and death of the fish.

A similar toxicity in humans or animals exposed to high partial pressure of oxygen is explained by a mechanism which involves a direct inhibition of central nervous system respiratory centers. The resulting muscular twitchings and coma are said to result from the build-up of carbon dioxide and metabolic end products. In this instance, also, physical labor and other stress speeds the death of the animal or human involved.

In summary, the animal calculates, because the oxygen is very adequate, that he needs make only a minimal respiratory and circulatory effort. It appears to be a fatal mistake on his part.

How should one interpret the preliminary findings I have reported today? Very carefully.

First of all, the work was done entirely in the laboratory. Secondly, only two species of fish were utilized. Finally, the exact cause of death is still being investigated. We need to know just how important the presence of gas emboli in the tissue and blood are. We also must demonstrate directly the accumulation of lactic acid and other metabolic products responsible for death. This is being accomplished presently by measurement of lactacidemia and specific histochemical examinations of increases in glycerophosphate dehydrogenase and lactic dehydrogenase levels in muscle. It may also be possible to detect uncoupling of oxydative phosphorylation by demonstration of myosin ATPase activity. A useful diagnostic procedure should arise from studies such as these.

What tentative conclusions might we make from the data? I believe that mortality results from the combination of dam induced stress and high partial pressures of gas in water. The mechanisms involved have been previously discussed, but we do not know how to balance the importance of the stress in relation to high partial pressures.

It has become apparent that, in the laboratory, one can alter the susceptibility of fish to gas bubble disease. Knowing the following:

(1) that stress increases the mortality and emboli formation, and

(2) that, the higher the water temperature, the more energy expenditure required per unit time (aside from the decreasing solubilities of gases as temperature increase, the susceptibility therefore would increase absolutely as a function of elevating water temperature), one can suggest that reducing the stress that the fish undergoes while going over a dam, or through a slotted gate, or turbine would reduce the mortality.

One could also suggest that earlier release in the spring when water temperatures are colder may reduce the mortality.

Perhaps examination of existing field data could confirm or refute the value of these suggestions. For instance, the finding of nitrogen levels above 110% in the undammed portions of the Clearwater River unassociated with fish mortality would tend to strengthen the above theory, since the missing element is dam induced stress.

We would like to join Colonel A. R. Marshall of the Corps of Engineers in voicing the need for continued research, and to congratulate those who have already contributed much energy and time towards a solution of the problem. Thank you for your attention!

CHART I—*Effects of Exposure to 1.5 Atmospheres Dissolved Air in Water at 5°C. at Standard Pressure*

Steelhead	*Catfish*
Decreased respiratory rate and effort	Yes.
Decreased circulatory effort	Probably.
Loss of coordination	No.
Development of gas emboli in tissues and blood	No.
Muscular rigor prior to death (premortal rigor)	No.
Death within 90 to 160 minutes	No, even after repeated exposures (Reports of gas bubble disease at 25° C+).

CHART II

SOME FACTORS INFLUENCING GAS EMBOLI FORMATION IN GAS BUBBLE DISEASE

Experimental manipulation	Influence on gas emboli formation	Mortality
Standard exposure	Present	High.
Red blood cell not functional (carbon monoxide tie up)	None formed	Do.
Pure oxygen at 1.25 atmospheres	Many emboli	Low.
Low oxygen (e.g., 6 p.p.m.) with 120 percent sat. of nitrogen	Few or none	Do.
15-min. exercise period prior to exposure	Many emboli	High.
Equal number of controls for each experimental group	None formed	Low.