THE RETURN OF A RIVER
The Willamette River, Oregon

by George W. Gleeson

Advisory Committee on Environmental
Science and Technology

and

Water Resources Research Institute
Oregon State University
Corvallis, Oregon

Funded in part by NSF grant No. GT-14
and OWRR under PL 88-379

WRRI-13 JUNE 1972

THE RETURN OF A RIVER

FOREWORD

This writing attempts to provide a semi-historical description of the period 1926 through 1971 during which period the Willamette River was returned to the people of the State of Oregon. It is impossible to present anything but a fraction of the data from thousands of tests and river samplings. It is equally impossible to give proper credit to persons, agencies, and organizations whose collective efforts effected river improvement. More important than technical data or recognition for service is the fact that the total effort, although frustratingly slow in yielding results and in most cases very expensive, was sustained over a period of more than thirty years. The sustained effort reflected the will of the people, and the outcome is the reward for the public support. By the most widely accepted standards of water quality, the Willamette River for more than thirty years was, in the lower reaches and particularly in the Portland harbor, in about as unsatisfactory a condition as a river can be. Now, after these many years and judged by the same standards, the Willamette is once more a river of reasonable quality and an asset to the State of Oregon.

THE AUTHOR

George W. Gleeson, Dean Emeritus of the School of Engineering, Oregon State University, with other faculty members, conducted early studies of water quality in the Willamette River. These investigations documented the pollution of the river and suggested methods required to restore water quality. This pioneering work was a major factor in the enactment of the first comprehensive water pollution control laws in Oregon and establishment of the Oregon State Sanitary Authority in 1939. Dean Gleeson has actively participated in efforts to "clean up the river" since the early beginning of the program.

ACKNOWLEDGEMENTS

This study was jointly sponsored by the Advisory Committee on Environmental Science and Technology and the Water Resources Research Institute of Oregon State University.

The Advisory Committee was established in 1970 to provide a more effective interchange of information and mobilization of resources to meet environmental problems in Oregon. Faculty members of Oregon State University and representatives from State agencies and the Office of the Governor constitute the Committee. Advisors from other colleges and universities in the state are also called upon for expert assistance in the Committee's basic task of providing science advice to the State government. The Advisory Committee is funded in part by the National Science Foundation, Office of Intergovernmental Affairs through Grant No. GT-14.

The Water Resources Research Institute was established in 1960 and is funded, primarily, by the Office of Water Resources Research, U. S. Department of the Interior. Funds are authorized by the Water Resources Research Act of 1964, PL 88-379. The mission of the Institute is to encourage and help coordinate water-related research on the campuses of Oregon.

Photos are through the courtesy of the Oregon State Highway Division. Single copies of this publication are available free of charge from:

Environmental Science Information Coordinator
Room 237, Weniger Hall
Oregon State University
Corvallis, Oregon 97331

Table of Contents

Listing of Tables

Listing of Figures

Listing of Figures (cont.)

THE RETURN OF A RIVER

INTRODUCTION

The Locale

The green and fertile Willamette Valley, roughly rectangular in shape, occupies a major portion of the northwest quadrant of the State of Oregon (Figure I). The valley is approximately 150 miles long, north to south, and 75 miles wide. It is bounded on the east by the ridge of the Cascade Mountains, a discontinuous alpine zone formed by a series of perennially snow-capped peaks. The western boundary is the summit of the Coast Range of mountains of modest elevation and characterized by irregular ridges and short, steep slopes. The southern boundary is the Calapooya Mountains which separate the Willamette Basin from the drainage of the Umpqua River directly to the south. The northern boundary is the valley of the Columbia River. The basin in total occupies an area of 12,045 square miles and is drained by two major rivers, the Sandy and the Willamette. The latter drains an area of approximately 11,250 square miles.

The Willamette Valley floor which is relatively flat is made up of only about 3,500 square miles of the 11,250 total. The remainder of the area consists of the mountain slopes on three sides and a belt of mature foothills which parallels the Cascade Ridge and lies between the Cascade Mountains and the valley floor. The slopes of the Cascades and the associated foothills account for about 60 percent of the basin area. The valley floor is described as a broad, alluvial plain with areas of rolling topography and low hills. Elevations vary from about 10 feet (above mean sea level) to as high as 10,000 feet on the Cascade Ridge. The valley floor lies below an elevation of 500 feet. The Coast Range to the west attains elevations as high as 4,000 feet.

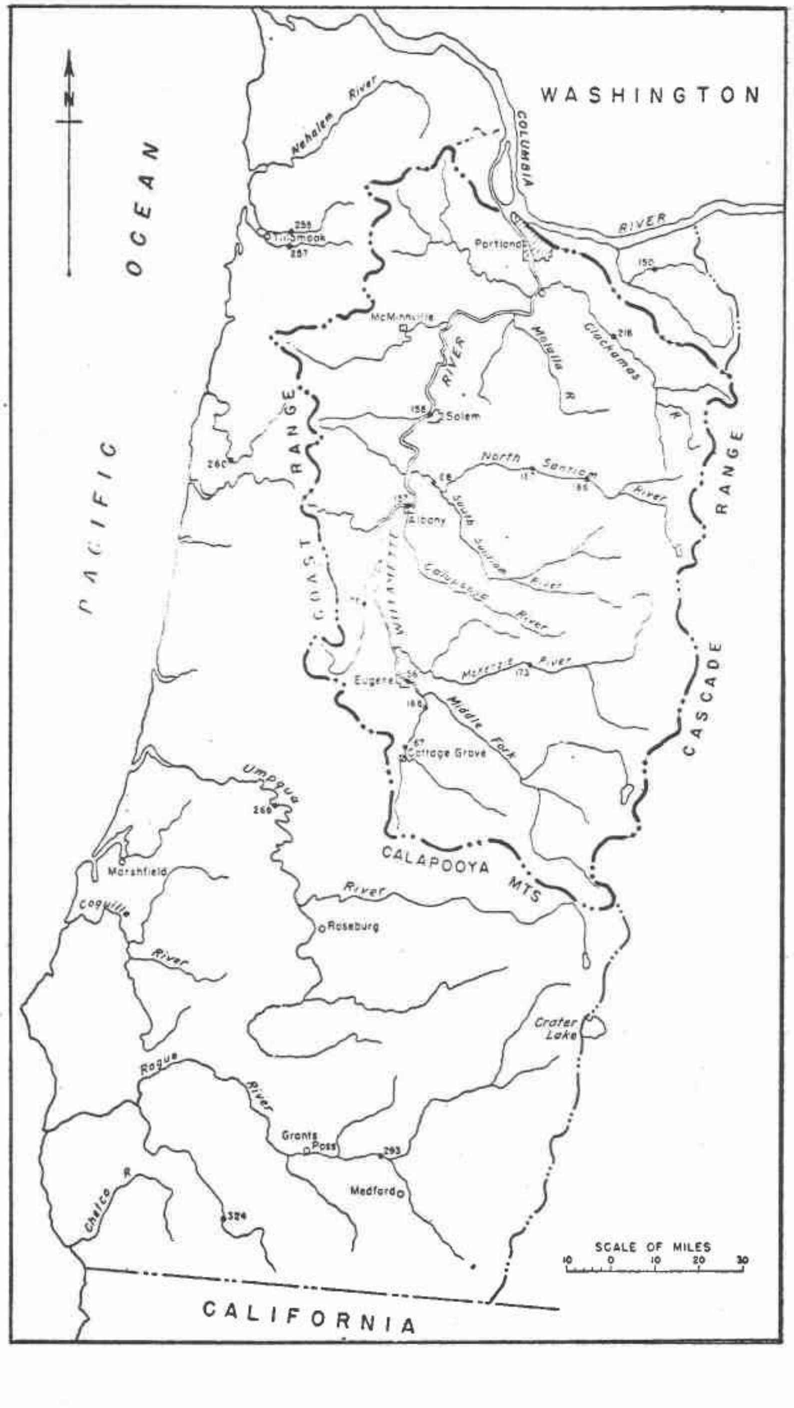


Figure I-The Willamette Basin in Relation to Western Oregon. Reference (1)

The climate of the Willamette Valley is described as Mediterranean, characterized by dry summers and wet winters (1)*, although the latitude (45°N just north of Salem, Oregon) causes the summer temperatures to be cooler than in most Mediterranean-type climates. Over 90 percent of the yearly rainfall, which averages about 40 inches per year over the major portion of the valley, occurs in the fall, winter, and spring. It is not uncommon to have from 60 to 90 days of summer without significant precipitation. Both the Coast Range and Cascade Mountains act as a barrier to storm winds, and rainfall amounting to more than double the average at the valley floor occurs at the higher elevations. There is a significant drainage from the mountains to the valley floor, particularly from the Cascade snow melt. It is not uncommon to record monthly precipitation at a number of locations in excess of 20 inches; such an amount usually occurring in November through February. In like manner, practically all records of precipitation show a very low minimum (less that 5 inches per month) for July, August, and September. In many locations, no precipitation is recorded for three months.

Salem, Oregon, the capital of the state, is situated near the center of the basin. Many records related to climate and hydrology have been maintained at the Salem site over the years. Such records will be referred to rather frequently in this writing. Figure II shows the typical yearly precipitation and river runoff for the Willamette river at Salem. The Salem record is qualitatively representative of the distribution pattern throughout the basin.

About 62 percent of the Willamette Basin is in timber land which is located largely in the tributary basins. Approximately 33 percent of the area is in farmland with 5 percent allocated to uses other than timber and agriculture. About 41 percent of the basin is in public ownership.

---

* Refers to appended bibliography.

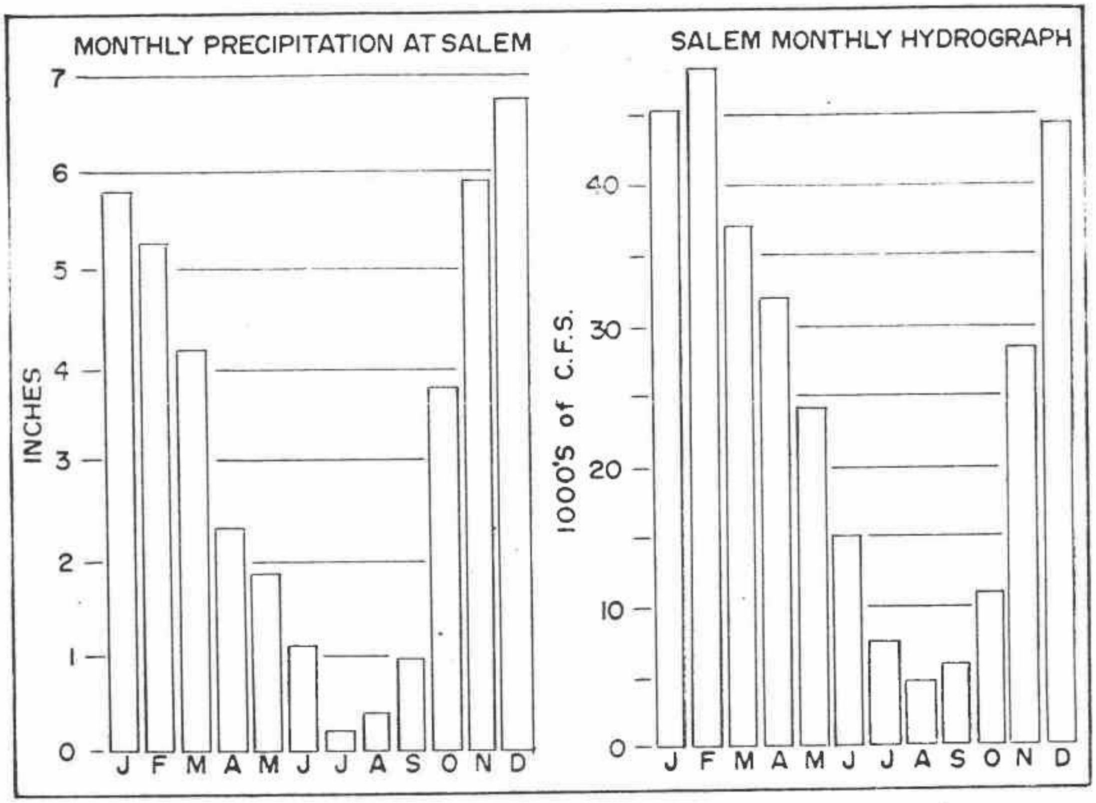


Figure II- Precipitation and Runoff at Salem, Oregon. Reference (2)

The River

The Willamette River drains the Willamette Valley and flows north to empty into the Columbia River 99 miles from the Pacific Ocean. The Middle Fork of the Willamette rises at an altitude of about 6,000 feet in the extreme southeastern part of the valley and near the summit of the Cascade Range and flows north to be joined near Eugene, Oregon, by the Coast Fork to form the main stem of the river. It is approximately 187 river miles from the junction of the forks to the Columbia, through which distance the river drops about 400 feet, with the highest velocity being in the upper half of the course.

Major tributaries of the Willamette flow westward from the Cascade Ridge (McKenzie, Santiam, Molalla, and Clackamas) and eastward from the Coast Range (Long Tom, Marys, Luckiamute, Yamhill, and Tualatin). Low summer precipitation results in extremely low summer flows in the tributaries from the Coast Range, where there is no sustaining snow pack. The mean flow of the river is illustrated in Figure III.

The Willamette ranks as the 12th largest river in the United States and has a mean average flow (natural) at the Salem, Oregon gaging station (No. 1910) of about 23,000 cfs (cubic feet per second). The drainage area of 11,250 square miles represents 11.7 percent of the area of the State of Oregon. Within this area live more than two-thirds of all the residents of the state.

The southern two-thirds of the river is in a braided, meandering channel which, prior to a degree of control by impoundment, saw yearly flooding and appreciable channel shifting. The lower one-third of the river to the falls at Oregon City is in an incised channel and relatively little shifting has taken place. (3) The maximum flood of record in December of 1861 was estimated at 500,000 cfs. Other recorded floods of large magnitude and prior to impoundment include peak flows of 428,000 cfs in January 1881, 450,000 cfs in February 1890, 315,000 cfs in November 1909, 350,000 cfs in January 1923, 243,000 cfs in February 1927, 225,000 cfs in January 1936 and others more recently.

It has been estimated that the flood conditions of 1963-64 had the potential of approximately 500 million dollars in damage were it not for regulation which reduced the peak discharges. The several major storage reservoirs which provide such regulation above the Oregon City Falls are listed in Table 1.

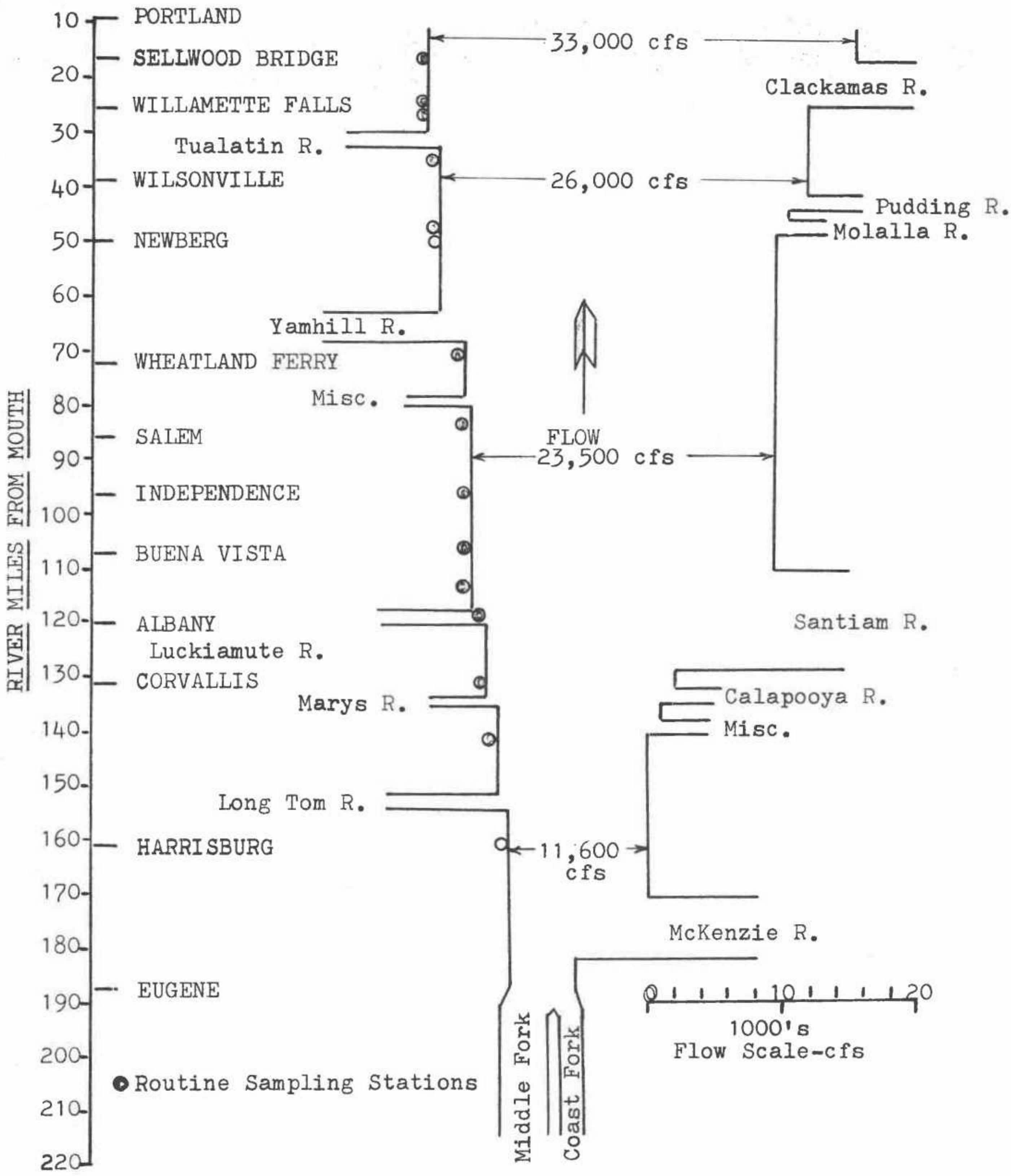


Figure III- Mean Average Flow of the Willamette River

Table 1

Storage Reservoirs on the Willamette River System above Oregon City

Reservoir	Location	Drainage Area Sq.miles	Usable Storage Acre ft.
Cottage Grove	Coast Fork	104	30,060
Dorena	Row River	265	70,500
Lookout Point	Middle Fork	991	349,400
Hills Creek	Middle Fork	389	249,000
Dexter	Middle Fork	996	4,800
Fall Creek	Fall Creek	184	115,000
Smith	Smith River	18	9,900
Cougar	McKenzie River	208	165,100
Blue River	Blue River	88	85,000
Fern Ridge	Long Tom	273	110,000
Detroit	North Santiam	438	339,900
Green Peter	Middle Santiam	277	333,000
Foster	South Santiam	494	33,600
Big Cliff	North Santiam	452	2,430

The flows of the river under flood conditions should be compared to the average, mean, yearly figure of 23,000 cfs at Salem and also with the seasonal summer lows of as little as 2,500 cfs prior to 1954. The river has had a history of periodic, heavy flood damage in the winter and low flows in the summer. Based upon flow records at the Salem gage prior to 1950, statistical analysis indicated that the most probable monthly average minimum flow would have been 3,480 cfs with a weekly average of 3,270 cfs and a minimum daily average of 3,200 cfs. The low flows from 1928 to 1950 were in the months of August, September, or October. The low flows were inadequate to handle the waste load discharged to the river and it is with this aspect that this writing is concerned.

The People

Trading posts were established in the Willamette Valley as early as 1813. Settlement in the valley dates from about 1830, primarily in the lower basin in the early days. Settlement in the upper basin did not come until about 1846. In 1856-57, steamboats started river runs from Portland to Eugene and continued such runs for about 20 years, until the north-south railroad to California was completed. The river commerce was instrumental in the establishment of a chain of settlements along the river at strategic locations. This demonstrated the Willamette to be navigable as far up river as Eugene, and it is so considered today as far as the Ferry Street bridge in Eugene. (3) It is significant that from the earliest times to the present, the major proportion of the population of Oregon has been related to the Willamette River and has resided in the Willamette Valley.

It has been said of western Oregon that it has a climate conducive to maximum mental activity in the winter and maximum physical activity in the summer. Physical activity has been largely related to the outdoors. Further, the largest industry in Oregon has always been that connected with the forest. It is natural that the people of Oregon and particularly those in the Willamette Valley would be conscious of their natural environment and concerned as changes in the Willamette River became apparent. Such concern has been a fact for almost half a century, although remedial action has many times been frustratingly slow.

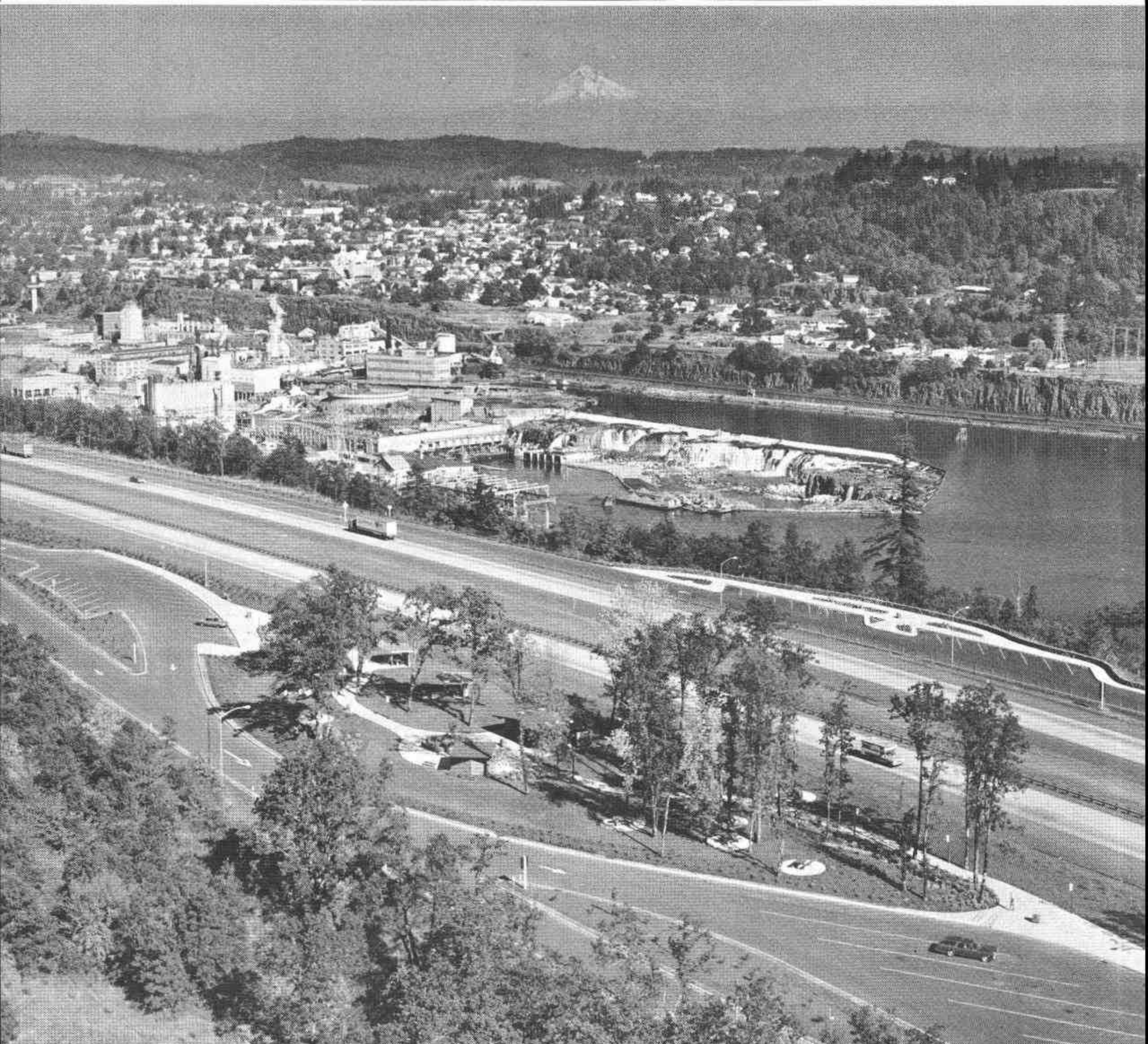
The Willamette Valley contains about 85 percent of the population of nine counties. Table 2 presents the population and area of the nine counties and the state. The significance of the valley and its river to the state is rather obvious.

The population of the State of Oregon is growing at a faster rate than that of the country as a whole or of the northwest. The population of the Willamette Valley has doubled in a period of 30 years. Such growth is of concern to the people of the state. Recently, Oregon has been criticized for lack of enthusiasm in welcoming newcomers and for being critical of the type and location of industry entering the state, particularly the Willamette Basin. The people of Oregon appreciate their heritage in the regional environment and have done so for a long time. They are, in general, aware of the potentials for environmental deterioration, and when convinced that deterioration is taking place, have been willing to act. This writing is a record of such action as related to the Willamette River which, at one time, was suggested to be an open sewer to serve the municipal and industrial needs of the Willamette Valley.

Table 2

Statistics of Counties in the Willamette Valley and the State of Oregon

County	Land Area Sq. Mi.	Population 1940	1950	1960	1970
Benton	668	18,629	31,570	39,165	53,776
Clackamas	1,884	57,130	86,716	113,038	166,088
Lane	4,562	69,096	125,776	162,890	215,401
Linn	2,283	30,485	54,317	58,867	71,914
Marion	1,166	75,246	101,401	120,888	151,309
Multnomah	423	355,099	471,537	522,813	554,668
Polk	736	19,989	26,317	26,523	35,349
Washington	716	39,194	61,269	92,237	157,920
Yamhill	711	26,336	33,484	32,478	40,213
Totals	13,149	691,204	992,387	1,168,899	1,446,638
Oregon	96,184	1,089,684	1,521,341	1,768,687	2,091,385
% of 9 Counties to Oregon	13.7	63.5	65.1	66.0	69.1



Willamette Falls, just south of Portland, site of paper mills built adjacent to the roaring cataracts. Mt. Hood, largest snow peak in Oregon, is in the background.

THE RETURN OF A RIVER

LOSS OF THE RIVER

Evaluation of the condition of any body of water to which wastes are discharged is a complex exercise. Over the years and in addition to the physical character of the body of water, certain chemical and biological quantities have been firmly established as indexes of water quality. Perhaps foremost is the dissolved oxygen (DO) in the water which is necessary to support aquatic organisms, the bacteria which effect waste stabilization, fish life, and plant life. The amount of oxygen which water will hold in solution (saturation) depends upon water temperature, the higher the temperature the lower the amount of DO. The customary quantitative expression for DO is milligrams per liter of water (mg/ℓ) or parts of oxygen per million parts of water by weight (ppm). Frequently, the DO is expressed as percentage of the amount at saturation.

The strength of a waste or the extent to which a body of water is contaminated by organic wastes is measured by the biochemical oxygen demand (BOD). Since biochemical stabilization of waste takes time, the BOD is expressed in terms of the number of days involved in the stabilization process, customarily 5 to 20 days. Increased temperature, within limits, accelerates the rate of stabilization, hence it is necessary to control temperatures during any determinations of the BOD, the customary temperature being 20°C. In any body of water, be it stream or a test bottle, the BOD is satisfied by the utilization of the DO in solution in the water.

The two quantities described above, DO and BOD, and the related temperature and time factors are perhaps the most significant indicators of water quality. In addition, the bacterial count and especially bacteria of the Coliform Group when associated with fecal sources, the hydrogen ion concentration (effective acidity or alkalinity), the dissolved and suspended solids both organic and inorganic, and the dissolved chemical substances are all indicators of water quality when properly evaluated.

The foregoing indicators of water quality are briefly described because frequent reference to them will be made in subsequent portions of this writing. Discussions of the significance of the various indicators, their application, and their inclusion in water quality standards are described in many references (4)(5)(6)(7)(8)(9)(10). A bibliography related to test data of waters of the State of Oregon are enumerated in the Water Quality Data Inventory of the Oregon State Water Resources Board (11).

In the early 1920's, water quality tests conducted by the Oregon State Board of Health in the Portland harbor area of the lower Willamette River indicated extensive pollution, a fact which should have been obvious since, at that time, all industries and municipalities on the river were dumping all of their untreated wastes directly into the stream. Both the Oregon State Board of Health and the U.S. Public Health Service were concerned with water quality, particularly from a health standpoint.

In 1926,a number of organizations insisted that laws related to pollution that had been adopted as early as 1919 be enforced. The decisions of the organized groups were communicated to city, county, and state officials, but no action resulted. In this same year, Mr. H. B. Hommon, Sanitary Engineer for the U.S. Public Health Service,suggested that a general study be made of the conditions in the Willamette Valley during the period of low water. On September 10, 1926, the Oregon State Board of Health (created in 1903) called a meeting in Salem, Oregon, to organize an "Anti-Pollution League". The League appointed a committee which was directed to prepare a report in accordance with Mr. Hommon's recommendation. The report was to indicate what steps should be taken to minimize pollution. The committee met with members of the League of Oregon Cities and advised the Oregon Legislative Assembly in the 1927 session relative to legislation to accomplish the necessary investigations. The Legislative Assembly considered the advice but failed to act (41).

The City of Portland conducted tests on the Willamette River in 1926 and 1927. The studies showed depletion of the dissolved oxygen in the lower reaches of the river even though the water entering the Portland municipal area (Sellwood Bridge) was in reasonable condition. Figure IV presents the results of the early survey (DO) for various months of the year for sampling at the Sellwood Bridge (river mile 16.5 from mouth) and at the S.P. and S. Railroad Bridge (river mile 7 from mouth). For comparison, Figure IV also presents the results of sampling at the S.P.and S. Bridge in 1963 (12). The 1927 data for the minimum DO (August) were at an average monthly river flow of 3,700 cfs, Salem gage. The monthly average (August) for the 1963 tests approximated 6,650 cfs. In the low water month for 1927, dissolved oxygen in the Portland harbor was far below any reasonable standard. The same situation was apparent in 1963, even at an appreciably augmented river flow.

In 1927 and the years immediately following, many groups, agencies, and organizations became interested in the condition of the Willamette River. One of the interested organizations was the Portland City Club which studied the subject of pollution through the Public Health Section of the Club and reported findings on April 22, 1927 (42). Among other things the report described the Willamette River as "ugly and filthy" and described conditions as "intolerable", so much so that workmen refused to work on riverside construction. The committee of the City Club conducted a survey which indicated that 48.6 per cent of the people favored anti-stream pollution legislation with 18 per cent against, and 27 per cent with no opinion. The City Club recognized that Portland was a "worst offender" and concluded that the Club should recommend legislation "in the public interest" to abate pollution. It suggested efforts to arouse public support. As a result of the City Club's action, various agencies became concerned and the interest of municipalities on the river was strengthened. The League of Oregon Cities, the League of Municipalities, and a number of sportsmen's groups became active advocates of pollution abatement.

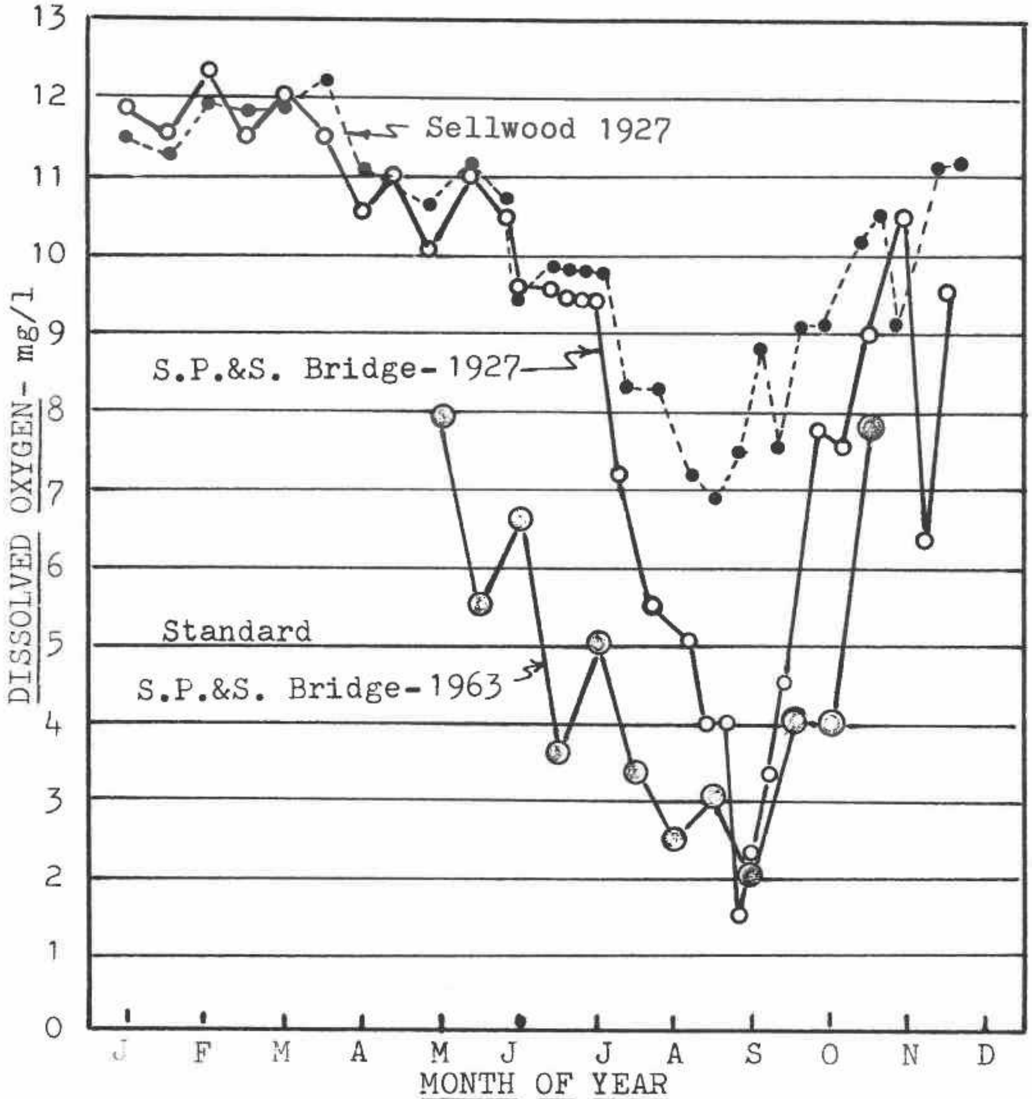


Figure IV- Variation in Dissolved Oxygen in the Lower Willamette River- 1927 Compared to 1963.

As a result of the broad interest in the condition of the river, the executive committee of the League of Municipalities requested Oregon Agricultural College (now Oregon State University) to study the condition of Oregon streams. In response to the request, a report setting forth the elements of the situation was published by the Engineering Experiment Station in early 1929 (13). This report proposed that a preliminary survey be taken as a guide for future action. The survey was to be undertaken by the Engineering Experiment Station in cooperation with the Oregon State Board of Health and the Oregon Fish and Game Commission during the low water period of the summer of 1929. The suggested program was approved and undertaken, starting July 1 and ending August 28, 1929. Data were reported for 28 sampling stations, starting with the first station at 3 miles above Cottage Grove (approximate river mile 200 from the river mouth) and ending at 0.3 miles above the Sellwood Bridge at Portland (16.8 miles from river mouth).

In addition to the river survey during the low water period of July-August 1929, sampling was continued during the year starting with the first week in October 1929 and ending with the first week in May 1930. Data were taken at 18 river stations for each month.

The river surveys of 1929-30 were very complete and are still considered to be somewhat classical, particularly because the work was done at such an early date. Results of the surveys were published by the Engineering Experiment Station in 1930 (14). The results showed the dissolved oxygen (DO) to be high in the upper reaches of the river with the first significant sag taking place below Salem, and a second significant drop below Newberg. After a slight rise due to reaeration of the water in passing over Willamette Falls at Oregon City, the drop in oxygen concentration continued to about 3.9 ppm at the Sellwood Bridge, this being 43.2 percent saturation at 20.8°C. The summary results of the survey are presented in graphical form in Figure V.

It could be inferred from Figure V that a DO content of 3.9 ppm at Sellwood would certainly result in complete exhaustion of oxygen through the Portland harbor since the upriver wastes remaining in the waters at Sellwood would continue to be stabilized, and additional demand would be encountered from the wastes of the City of Portland, all of which were discharged to the river untreated. It was a conclusion of the 1929 survey that the DO would reach less than 0.5 ppm before the waters of the Willamette reached the Columbia River.

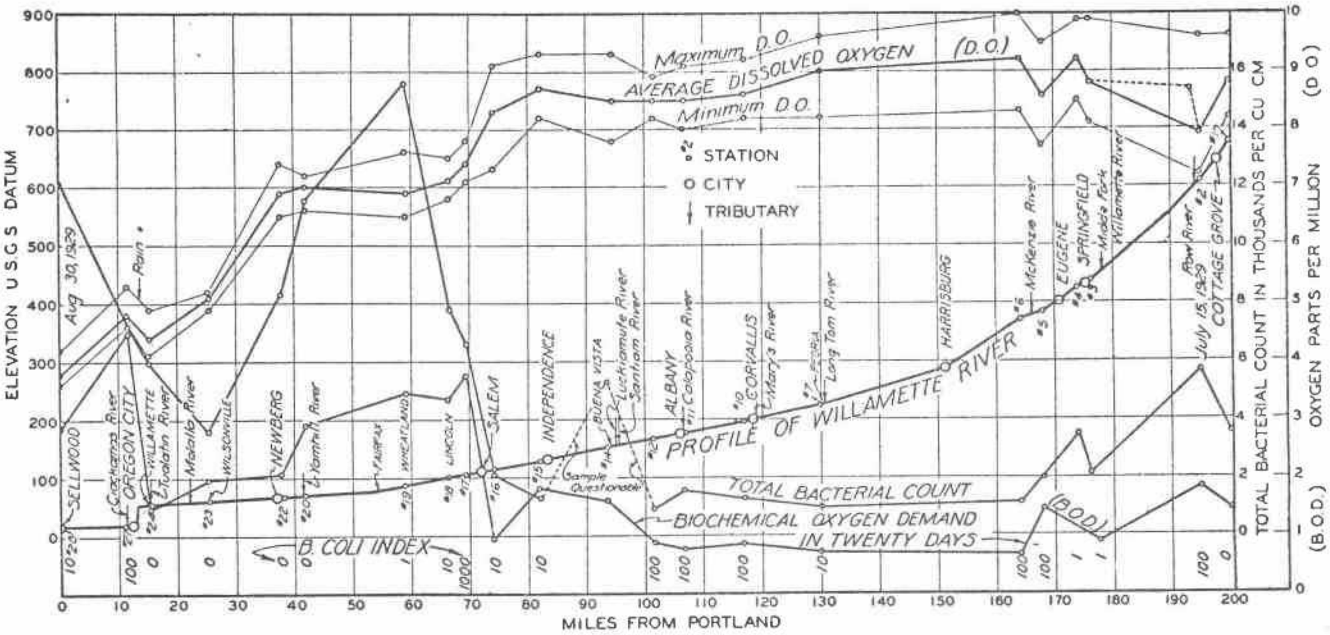


Figure V- Composite Results of the Willamette River Survey- Low Water Period July-August 1929 Reference (14)

At this point it is pertinent to mention that there is a consensus that an oxygen content of at least 5.0 mg/liter (ppm) is necessary to support a good fish fauna, and this value is generally taken as the limit below which a body of water may be considered to be polluted in-so-far as DO is an index of quality. Certainly, in 1929 the Willamette River could be considered to be polluted and grossly so in the lower reaches. The condition in the lower portion of the river at low water flow (3,800 cfs Salem) was inimical to fish life.

In early 1933, the Anti-Pollution Council was formed in Portland to promote a bond issue for sewage treatment facilities in amount of $6 million. The bond issue passed but the bonds were utility type to be paid from revenue derived from service charges. No money was immediately available, so, in 1934 a proposal was brought to vote to make the bonds general obligation. The proposal was defeated and the defeat started a long period of delay in pollution abatement by the City of Portland, a delay that was to finally culminate in the state instituting legal action against the city.

In June of 1933, Governor Julius Meier called a conference of Mayors of the cities of the Willamette Valley. The meeting was "responsive to a state-wide demand for abatement of stream pollution..." In accordance with a resolution of the meeting, the Governor appointed a committee of consulting engineers to make a study and report on the existing stream conditions. At the outset, the engineering consultants realized that they would have to separate industrial from domestic wastes. Since the pulp and paper industry was a major source of industrial wastes, a meeting of representatives of the pulp and paper industry was called in August 1933. At this meeting it became evident that there were insufficient data on the nature of paper-trade wastes as well as the extent of pollution by such wastes. Accordingly, a sub-committee was appointed by the committee of consultants to make a study of the paper industry with objectives to:

(a) Estimate the quantities of mill wastes.

(b) Determine the biochemical oxygen demand (BOD) of the wastes.

(c) Investigate possible methods of treatment.

(d) Make recommendations.

In the interim, the committee of consultants had completed the assignment regarding domestic wastes and the results were duly reported(43).

The sub-committee took appreciably longer to complete its assignment, but a rather comprehensive report was made to the parent committee and thence to the Governor. The report contained conclusions and recommendations which indicated the pulp and paper industry produced a major waste loading on the Willamette River. Due to the complicated and technical nature of the report, it was not published until 1936 and then only in abridged form by the Engineering Experiment Station, Oregon State University (15).

As recommended by the 1929 river survey (14) and by the paper-trade waste sub-committee(15), a survey of the Willamette River below the Sellwood Bridge to the river mouth was undertaken during the low water period of 1934. The survey was under contract between the City of Portland and the Charlton Laboratories of Portland, Oregon.

The circumstances in the Portland harbor are complicated by the tidal action and by back flow of Columbia River water into the Willamette River channel during low water and at certain tidal stages. River height as measured at the Stark Street gage in the Portland harbor varied as much as 3 feet. Columbia River water was encountered up-river from the mouth of the Willamette as far as 6 river miles. Being colder, the higher density Columbia River water appeared to enter the Willamette as a wedge at the bottom of the channel.

The results of the DO determinations of the 1934 survey are shown in Figure VI. As expected, complete oxygen depletion was encountered in the central Portland harbor with recovery indicated by the inflow of Columbia River water, to some degree at all depths but markedly along the bottom of the channel. Sampling was done over 5 flood tide periods and 3 ebb tide periods, hence the average effect of Columbia River water may have been somewhat more than was normally the case. The City of Portland gave the Engineering Experiment Station at Oregon State University permission to publish the results of the 1934 survey and Figure VI is taken from the publication (16).

It is pertinent to mention that the data of Figure VI were taken at a river flow at the Salem gage which approximated 3,000 cfs; however difficulty was encountered in the determination of the flow through the Portland harbor due to impoundment of water at Oregon City over weekends when power demand was low. It was finally concluded that the normal flow at the Sellwood bridge was approximately 4,000 cfs, a value that was indicated in the reporting as possibly high and which was high according to the quite rough correlation of Figure VII. It would also be high according

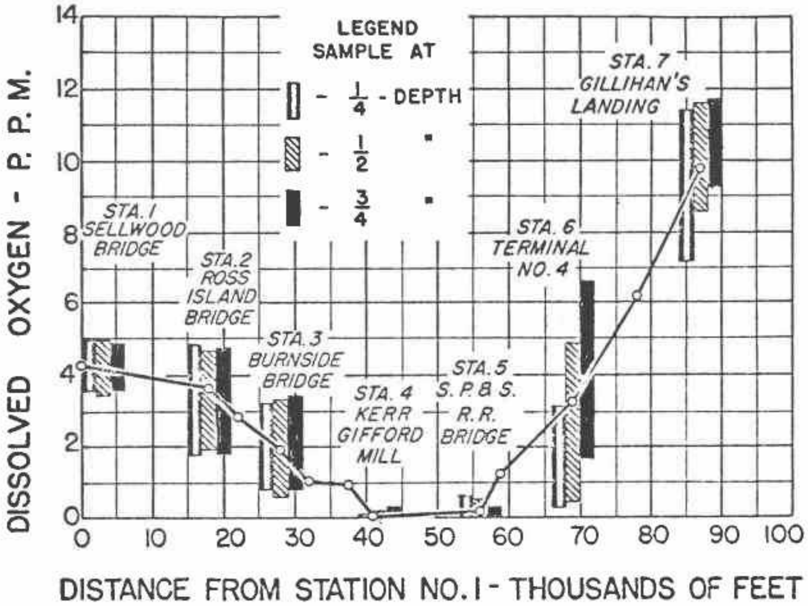


Figure VI- Dissolved Oxygen in the Lower Willamette in 1934 Showing Variation with Distance Below Sellwood Bridge and Variation Encountered at Depth

to Figure IX which gives the daily minimum average flows at the Salem gage; the 1934 daily monthly minimum approximating 2,950 cfs. Accordingly, the time of flow of the river through the Portland harbor as calculated in 1934 may have been low. A longer time would have aggravated the situation. Regardless of difficulty in the determination of exact flow, the 1934 survey showed the Willamette River through the Portland harbor to be in very poor condition and devoid of all dissolved oxygen in a stretch of several miles.

In October of 1935, the Oregon State Planning Board created a special division known as the Stream Purification Committee. The 15 man committee made studies and prepared recommendations for the 1937 Legislative Assembly. Perhaps the most important study was related to Oregon Law as it impinged upon pollution of Oregon streams. It was early determined that Oregon had too much law of a drastically prohibitory nature. For this reason as well as for lack of general public support, this law was not enforced, in spite of frequent public demand for such enforcement.

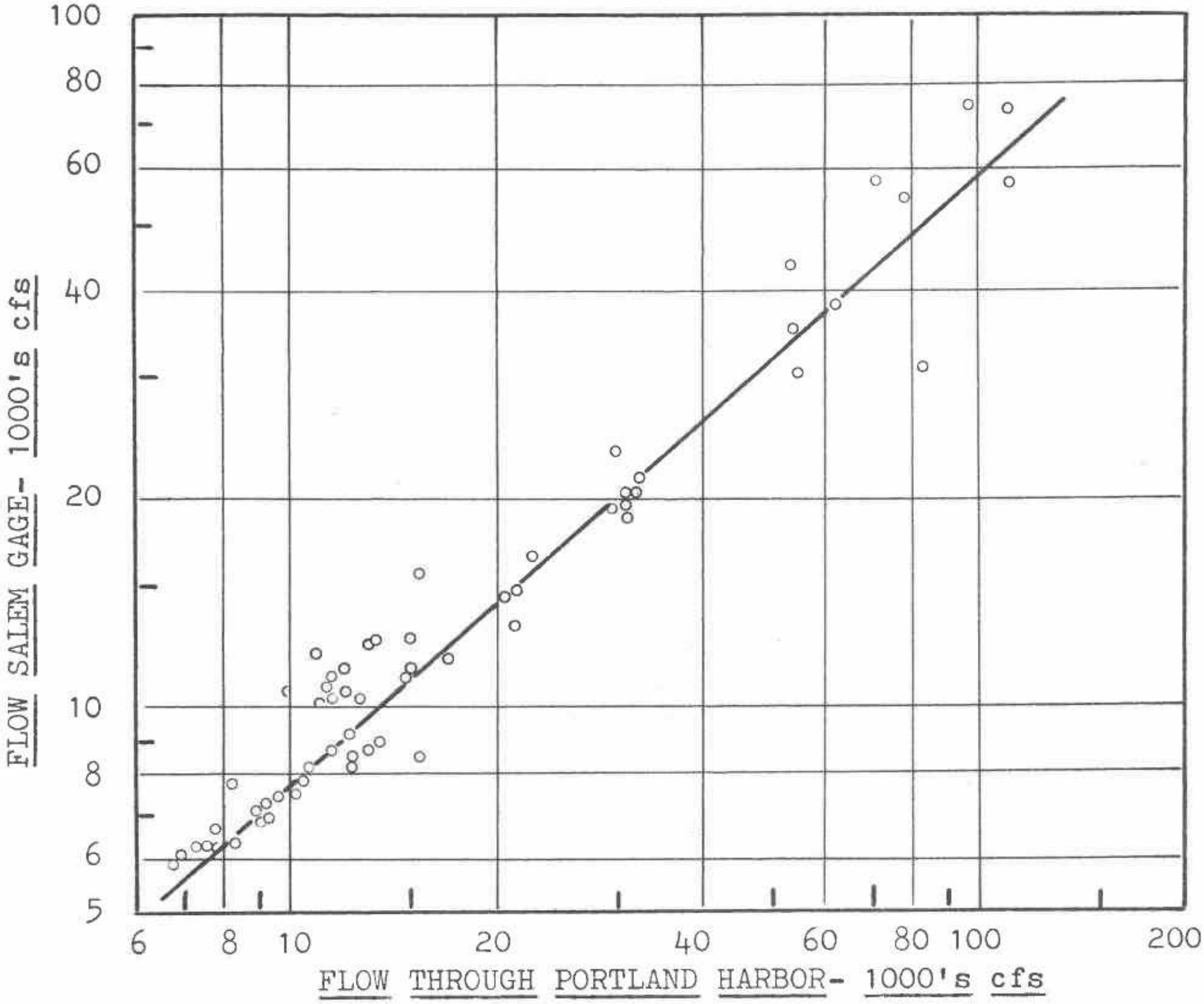


Figure VII - Correlation of River Flow

The statutes of the state were described as "Promiscuous adoption of unrelated and uncoordinated nuisance and penal statutes affords only a minimum degree of control and cannot form the basis of a concerted and direct effort to prohibit pollution of streams." The study of the statutes indicated that the State Board of Health was the dominant enforcement agency, but enforcement powers were not sufficiently comprehensive to be effective. There were, by 1935, at least 17 statutes referring to the State Board of Health, 3 referring to Fish and Game, 2 with reference to Clear Lake, 1 for Yamhill County, 2 for areas in Benton and Yamhill counties, 3 for Oswego Lake, and 7 dealt with pollution as a nuisance. The many defects in the existing statutes were enumerated as:

(a) Lack of concise coordination.
(b) Lack of direct responsibility for enforcement.
(c) Overlapping and duplication.
(d) Probable unconstitutionality of some sections.
(e) Too drastic provisions of penal sections.
(f) Practical unenforceability.
(g) Impossibility of progressive, amelioratory regulation.
(h) Lack of direct control over municipalities.
(i) Lack of proper delegation of administrative powers.

There was plenty of law but little accomplishment(44).

As a result of the 1935-36 study of the Oregon statutes related to pollution, a review was made of statutes known to be effective elsewhere. This review resulted in 17 "principles" that should be embodied in any anti-pollution legislation, if such legislation were to be effective. One of the most important "principles" involved concentration of administration and authority in a sufficiently flexible framework to permit progressive improvement of non-conforming situations rather than abrupt and drastic disruption(45). The "principles" formed the framework around which subsequent action was to take place.

The several publications to which references have been made aroused the interest of many groups of people and the period from 1936 through 1938 was one of many meetings and discussions regarding the condition of the river. There existed "undisputed evidence that portions of the Willamette River had become so polluted with municipal sewage and industrial wastes that these waters were a menace to health, destructive to fish life, and unfit for certain other beneficial uses."(12) Lacking legislative response to the situation as it existed, an initiative petition was prepared and a measure placed upon the ballot in November 1938. The measure represented a final "crystallization of sentiment" upon the part of the people of Oregon, and a desire for action that had been expressed as far back as 1926. By action of the people, a State Sanitary Authority was created by a majority vote of 3 to 1 at the polls. The Authority initiated the beginning of a pollution abatement program in 1939, but it would be quite a while before the program produced satisfactory results. Also, the war years intervened.

The initiative measure of the general election of November 8, 1938 was voted upon by 386,014 electors (57.9 per cent of those registered) with the vote of 247,685 for and 75,295 against. The measure which created the Sanitary Authority was described as, "A statute submitted by initiative petition constituted a compromise bill between Oregon industry and those groups in favor of a comprehensive program for water purification problems throughout the State." There were no arguments filed against the bill for publication in the "Voters Pamphlet".

In 1944, with the permission of Governor Earl Snell, the Postwar Readjustment and Development Committee for the State of Oregon resolved that by cooperative effort a number of State agencies would engage in a program of stream pollution studies. Such studies were initiated under the Engineering Experiment Station, Oregon State University, in July 1944. Results were published in 1945 (4). The various 1944 analyses of the Willamette River were made in August and September. At the same time that the pollutional studies were conducted, a separate study was undertaken on the fish life of the river. Thirty-four species of fish from 13 different families were collected. The publication on fish life was also printed in 1945 (5).

Figure VIII as taken from reference (4) shows that in 1944 the river condition was worse than in 1929. Although 1944 was a low water year (Salem gage showing minimum monthly average of approximately 3,180 cfs), the difference in flow would not account for the condition. The river had, obviously, not improved in the 15 year interval. Although no analyses were made, it would be expected that the oxygen in the Portland harbor in 1944 would have continued to be entirely depleted.

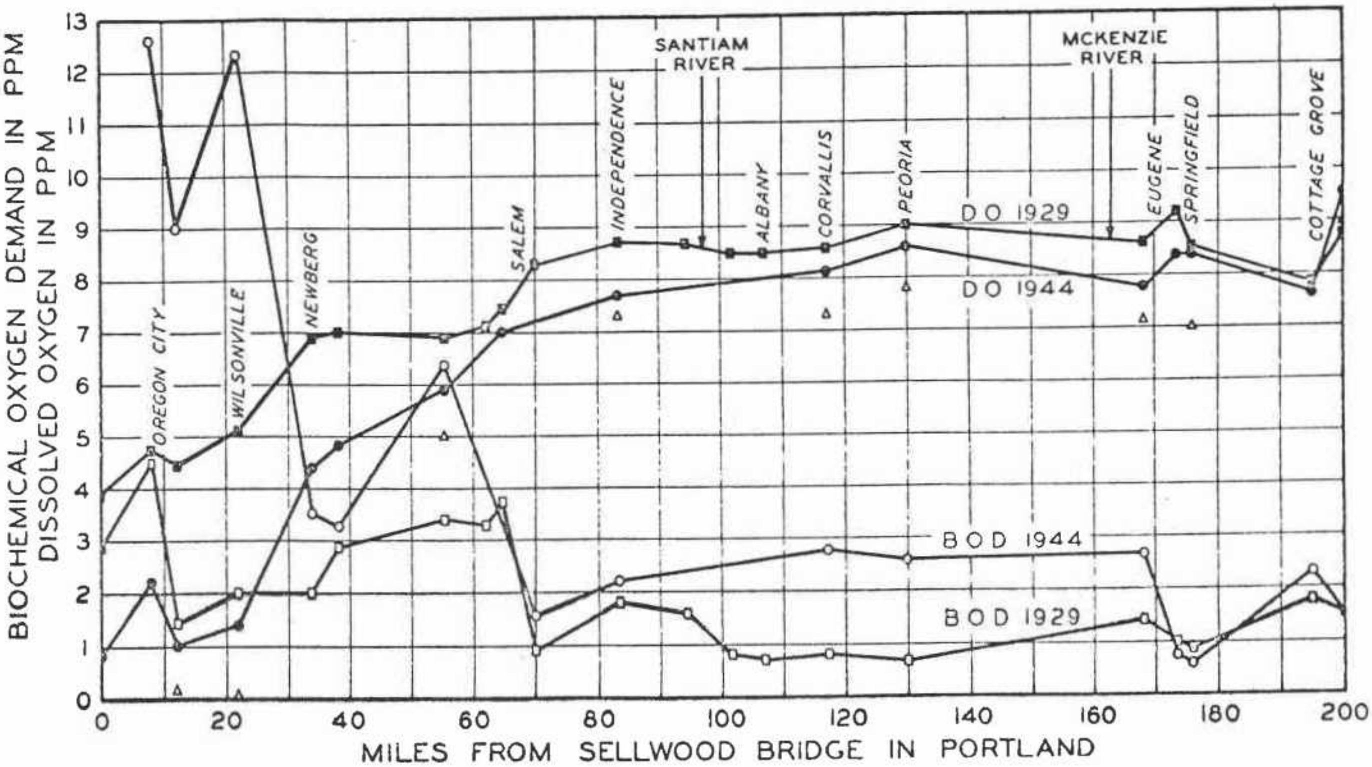


Figure VIII- **Dissolved Oxygen and Biochemical Oxygen Demand of Willamette River- 1944 Compared to 1929. Reference (4)**

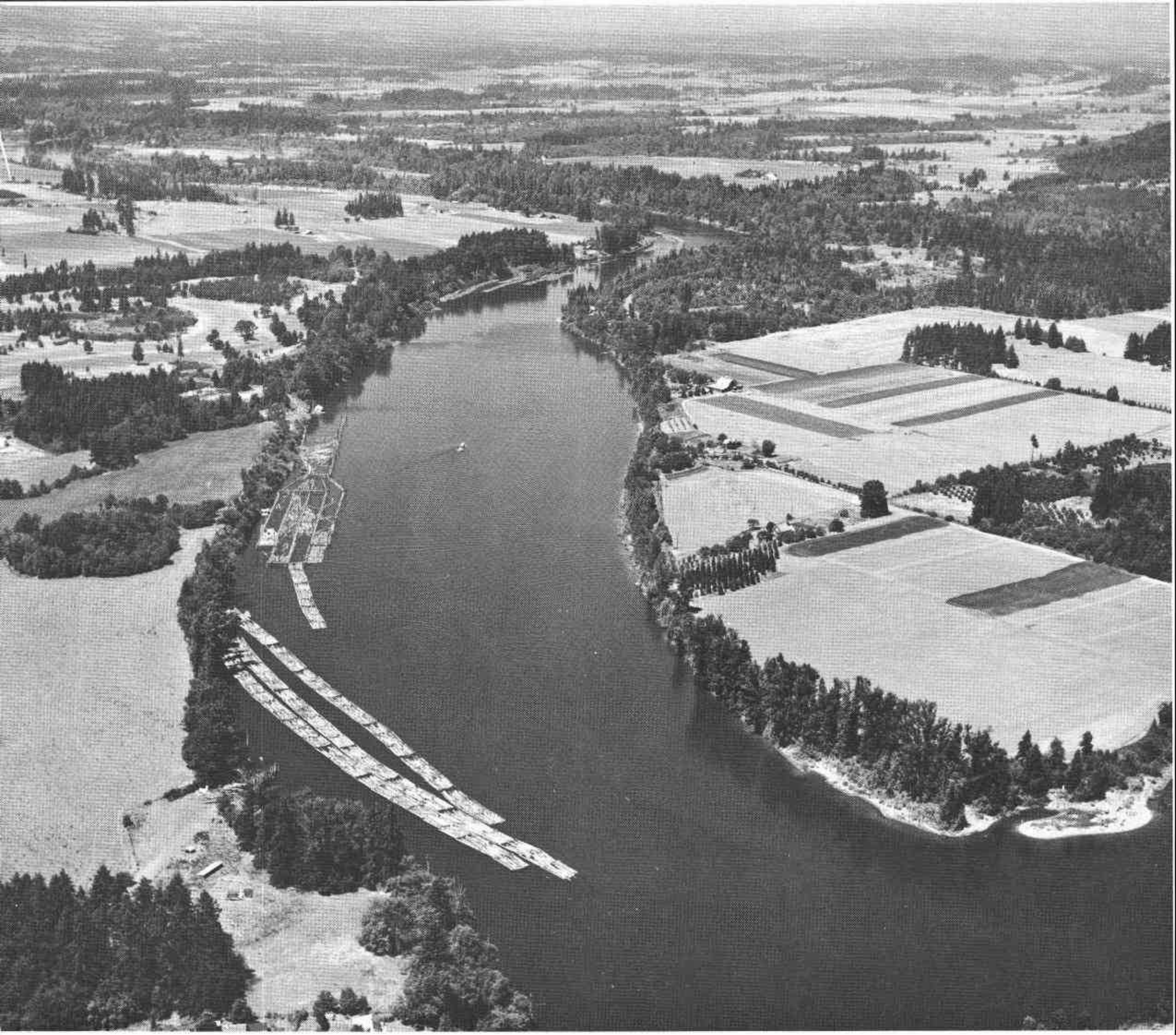
The results of the fish survey (5) can best be presented by direct quotation from that publication; "Pollution in the Willamette River system is a State shame---this magnificent river is at present in part an open sewer in which tremendous quantities of untreated human sewage and industrial wastes are disposed. Pollution in Oregon's great river, along with other detrimental activities, has depleted a world-famous commercial and game fish fauna. The Willamette River and many of its tributaries are a story of lost miles of fishing waters and of lost important spawning grounds for Chinook salmon. Not only has the fishing interest suffered in the maltreament of a natural resource, but all the people of Oregon have sacrificed a heritage in the aesthetic value of clean water." Perhaps no stronger statement than the foregoing has ever been made, a statement which reflects the condition of the river in 1944.

In 1945, additional studies were conducted on industrial and city wastes(6). These studies were an extension of the studies reported in 1936(15). The studies had limited value since they failed to provide all essentials required to make the quantitative values applicable. The studies did provide valuable comparative information.

The National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries) Inc. had become concerned with the paper trade wastes of the various northwest industries and particularly those industries along the Willamette River. In 1950 the National Council arranged with the University of Michigan, School of Public Health to make a study of the Willamette. The results of the study were reported to the National Council in 1951(7) with a supplemental report in 1961(8).

The 1950 study(7) estimated the pollutional load on the river for past years and from available data calculated the DO profile from Salem to the Oregon City falls and for the tidal area through the Portland Harbor. Results of the calculations were compared against the test results for 1929(14), for 1944(4)(5), and for 1949(17) in the upper reach and for 1934(16) in the lower reach of the river. The calculations also provided correlations for the variable stream runoff as recorded by the Salem gage. In all cases, the calculations showed remarkable agreement with the test results and, in fact, would, in most instances, serve as fair values for the test results in-so-far as DO values were concerned.

In addition to the comparison of calculated and test results for the older river surveys, the 1950 report(7) provided comparison of calculated and test results for the 1950 survey; the test results being those of the National Council for Stream Improvement-Mill Survey and of the Oregon State Sanitary Authority(18). Importantly, the results showed the river at a flow at the Salem gage of 4,900 cfs to be in as poor or poorer condition than in past years, in spite of higher runoff than in past surveys. The DO was 40 per cent saturation (3.6mg/liter) at the Willamette Falls. The DO had gone to 0 in the Portland harbor.



Log rafts line the Willamette near the town of New Era, which is upstream of Oregon City, a major pulp and paper producing area and first capitol of the old Oregon Territory.

Perhaps the opinions expressed in the 1950 report (7) are most pertinent to the condition of the river at that time. "In dealing with the non-tidal reach above Willamette Falls, it is our conclusion that under the 1950 pollution loads, oxygen depletion approaching complete exhaustion can be expected in the critical reach between Newberg and Willamette Falls at a summer drought flow of 3,000 cfs, Salem gage. Under present river regulation practice, such a drought flow as a minimum weekly average can be expected on the average in the long run once in 3 years. ....In dealing with the tidal reach below Willamette Falls, it is our conclusion that oxygen depletion approaching complete exhaustion within the City of Portland can be expected at summer drought flows at or below 7,000 cfs, Salem gage, under 1950 pollution load and production at rated capacity of the mills at Willamette Falls."

Much additional information was provided in the 1950 report, but most important was the indication that with increased river loadings, the river was in a poor or poorer shape than in any past years of record. Further, the potentially poor condition of the river, even at 7,000 cfs Salem gage was indicated. Such a flow was certainly not apparent in 1950 for the drought season and has only recently been a fact. Figure IX gives an indication of minimum river flow during the drought season over the years and indicates the remote possibility of a minimum daily drought flow of 7,000 cfs, although this might be attainable on a minimum monthly basis.

The National Council for Stream Improvement, Inc. had become sufficiently concerned with the condition of the Willamette River water to establish an engineering staff in Oregon. Staff personnel conducted a series of river samplings in 1953-54 at stations located from Newberg, Oregon to the St. Johns Bridge in the lower Portland harbor. In 1953, the river was sampled from July 23 through September 3 at 14 stations. The sampling in 1954 was not as extensive as in 1953 and extended from July 19 through August 4. Fifteen river runs were made in 1953 and six in 1954. Figure X presents the average DO and BOD results of all river runs for both years from the Sellwood Bridge to the St. Johns Bridge.

In 1953 and 1954, the BOD values were essentially equal although there was a marked difference in DO values for the two years. Also, the 1956 values fell between those of 1953 and 1954. River readings showed approximately 6,000 cfs Salem gage in 1953 and 7,000 cfs in 1954. The increased flow might have accounted for a small part of the improvement of 1954 over 1953. However, the same flow in 1956 showed no obvious improvement. These

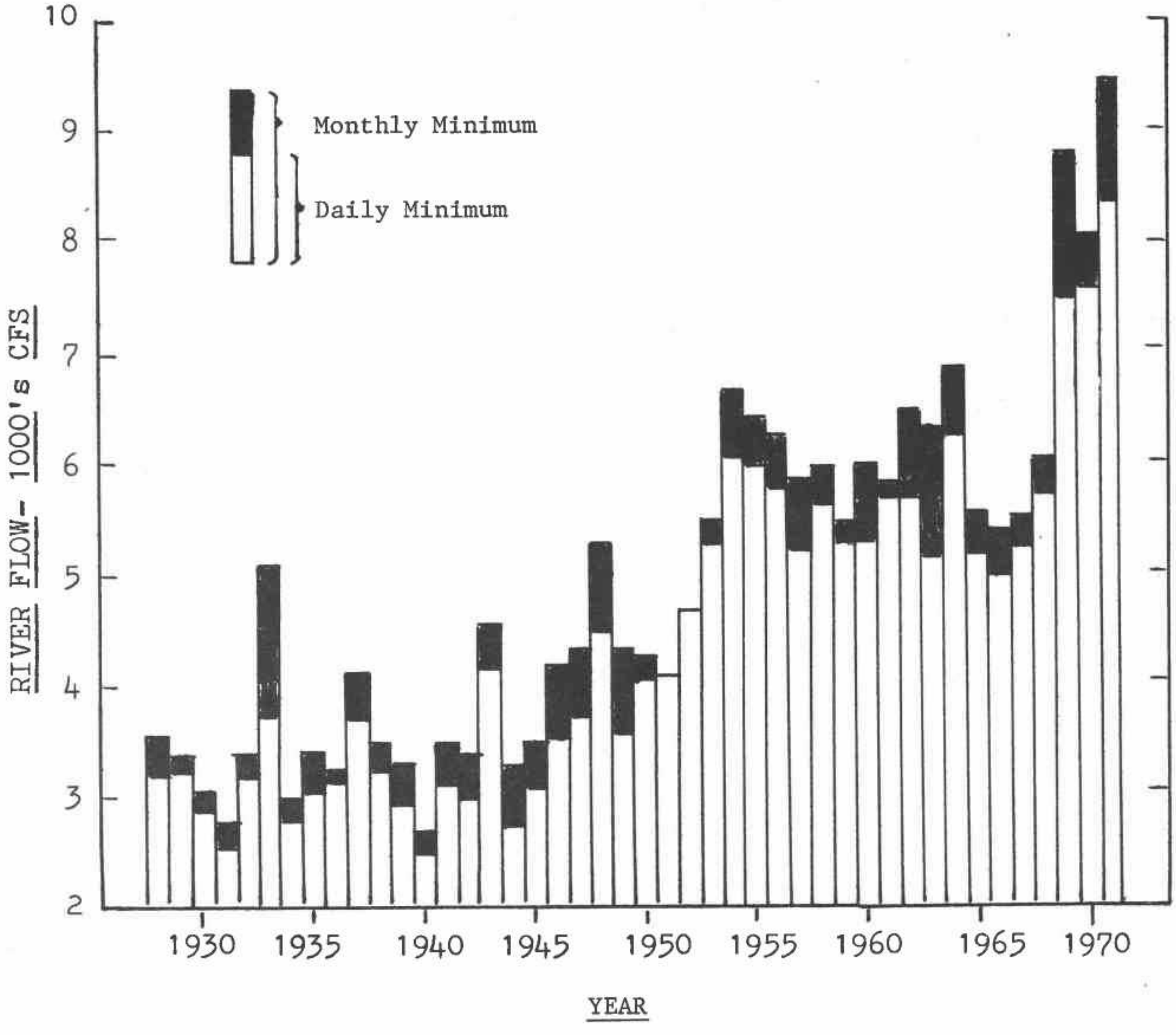


Figure IX- Minimum Daily and Monthly Average Flow of Willamette River by Years. Reference (2) (35)

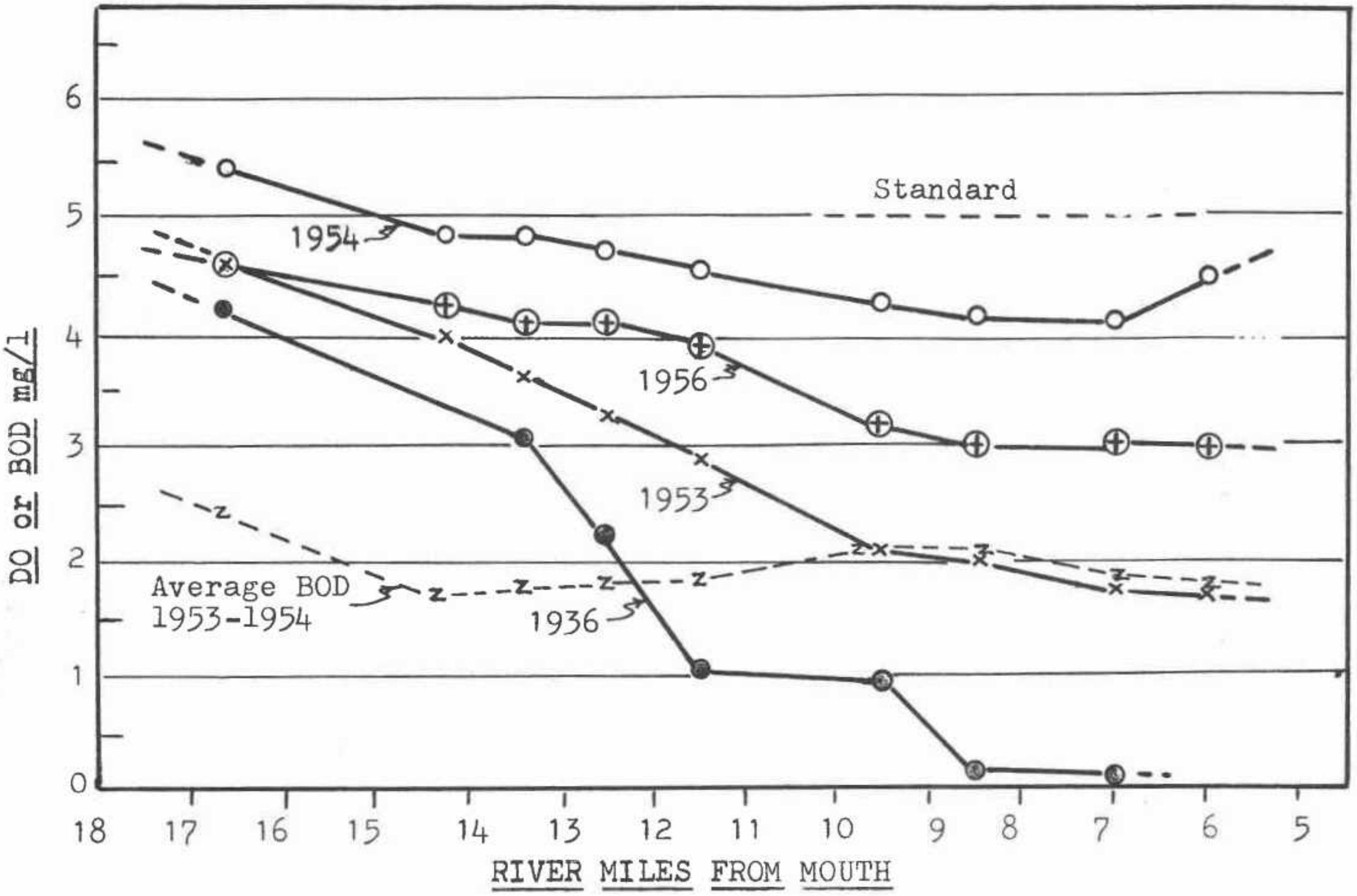


Figure X- Average of DO and BOD Determinations, Lower Willamette River in Years, 1953-54-56

facts point to the widely variable nature of river fluctuations; however, the 1953-54-56 surveys show very distinct improvement over 1936 when river flows were only about one-half as much as during the latter period (see Figure IX).

Four of the sampling stations in the 1953-54 surveys were above the Sellwood Bridge. Samplings at these same stations were available for 1952. Table 3 shows the comparative results for the three years. It will be noted that the same circumstance is reflected in the DO in 1954 in the upper reach of the river as was indicated for the lower reach by data of Figure X. Table 3 shows stabilization of wastes from Newberg to Marina

Mart with decline in the DO producing a corresponding decrease in the BOD. In passage over Willamette Falls, aeration increases the DO, but the BOD is increased by paper mill and other waste discharges at Oregon City and West Linn. Stabilization of the waste then continues to Sellwood Bridge and through the Portland harbor, where the BOD values of Figure X indicate discharge of additional wastes, since the BOD tends to increase from Ross Island to Swan Island.

There was very satisfactory agreement between the results of Figure X, Table 3, and those of the State Sanitary Authority (12) when all of the variables connected with sampling and laboratory determinations are considered.

Table 3

Average Dissolved Oxygen and Biochemical Oxygen Demand, Newberg to Sellwood Bridge for 1952, 1953 and 1954 Low Water Periods

App. Ave. Minimum Monthly Flow-Salem gage, 1952-5,200 cfs, 1953-6,016 cfs, 1954-7,000 cfs. Data from Reference (19).

Station	DO (ppm)			BOD (ppm-5 day)		
	1952	1953	1954	1952	1953	1954
Newberg	7.2	7.3	8.1	1.8	1.4	1.8
Wilsonville	4.8	6.4	7.2	2.9	1.2	1.3
Marina Mart	4.1	6.0	6.8	1.7	1.0	1.3
Gladstone	5.5	6.1	6.9	6.9	4.2	4.2
Oak Grove	5.4	5.6	6.3	3.6	2.7	2.4
Sellwood Bridge	4.3	4.5	5.4	3.0	1.9	2.4

The State Sanitary Authority made several river samplings in 1956. The results are in close agreement with those given in Figure IX, although showing a somewhat higher DO in practically all samplings.

In 1961, C. J. Velz brought up-to-date the charts and figures for the calculation of the self purification factors of the river from values for river loadings, flow, temperature, BOD, and with consideration of the tide gage in the Portland harbor as well as the back flow of the Columbia(8). Included in the 1961 supplement were the results of river samplings of 1959 from August 12 through September 2. Also included were the samplings by the Oregon State Sanitary Authority from August 11 through September 1.

The 1959 results should have been comparable to those of 1953 since the river flow was almost exactly the same for daily average minimum and monthly average minimum flows (see Figure IX). Figure XI shows the comparison. It is obvious that some improvement in the river had taken place in the six year interval although the DO was 0.3 ppm higher above Willamette Falls in 1959 as compared to 1953. This difference was small compared to the difference in the lower river where marked improvement was apparent.

Since the creation of the State Sanitary Authority in 1938, the Authority conducted test samplings of the Willamette River, many of the results being included as part of the data here-to-fore presented. In 1964, the Authority issued a summary report which indicated the condition of the river up through 1963 (12). Data presented in the summary report covered the period 1953-63 which corresponded to the period of higher river flows (10 year minimum monthly mean of approximately 6,092 cfs Salem gage). The DO and BOD results of the 1964 report are reproduced as Table 4. It should be noted that the results of Table 4 are expressed as the averages for the three months of July, August and September and are not the results when the river condition was in the most critical weekly or monthly condition. Minimum values for DO for a single test run were appreciably below the three month average.

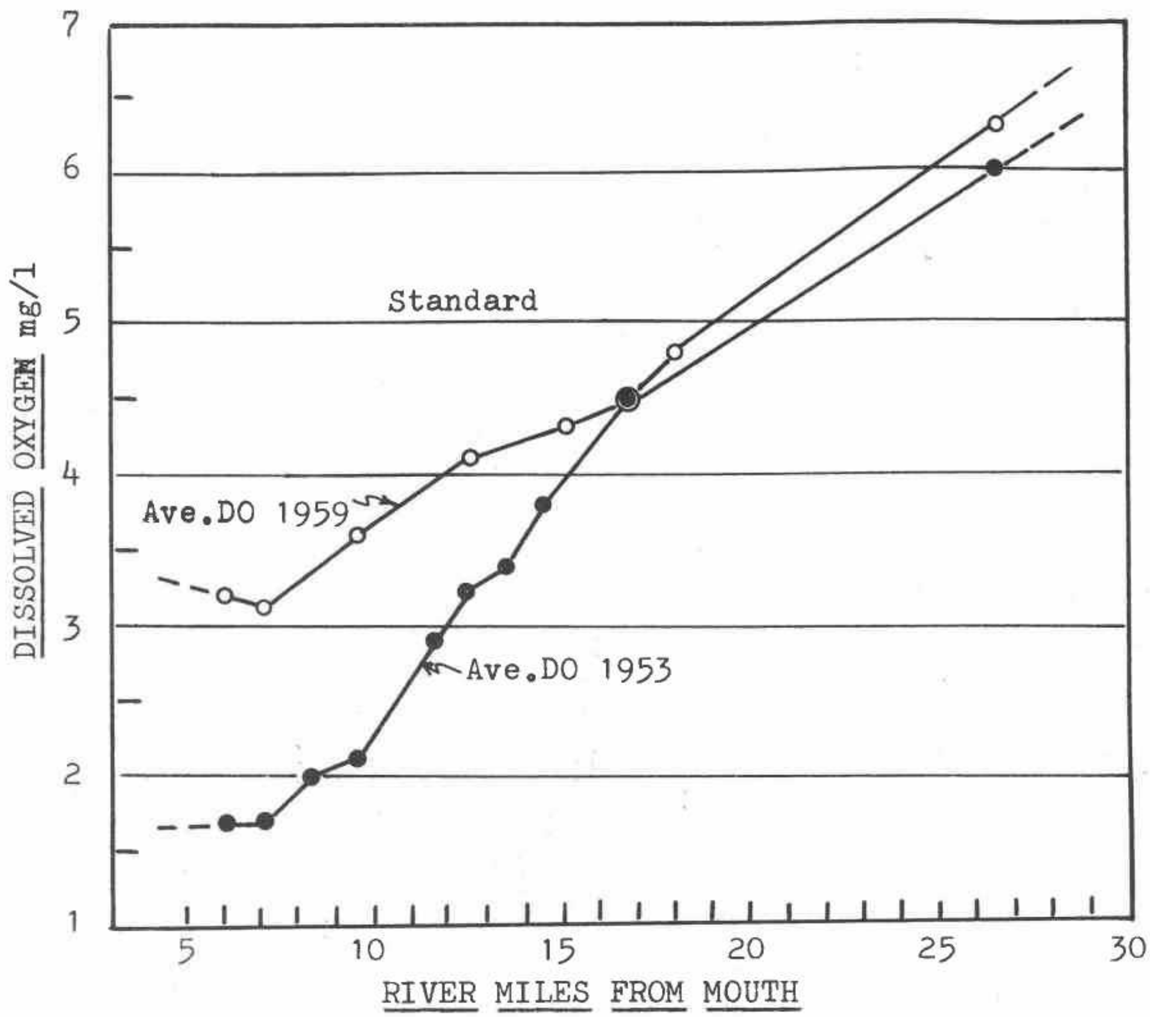


Figure XI- Comparison of Average DO in Lower Willamette River 1953 and 1959, Same Water Flow.

The results of Table 4 show remarkable uniformity over the 11 years with the condition of the river quite satisfactory in the reach above Salem (3 month average DO not falling below 90 percent saturation at Independence); it was satisfactory in the reach Salem to Newberg (not falling below a DO of 7 ppm at Newberg); it declined somewhat in some years in the reach between Newberg and Willamette Falls (less than 6 ppm at Marina Mart); but at no time during the critical months did the river contain 5 ppm DO at the S. P. & S. Bridge in the lower Portland harbor. The results for the last year given in the report (12), 1963, for the DO data by months were presented for comparative purposes in Figure IV.

Table 4

DO and BOD Data by Years as the Average for July, August and September of Each Year at Various River Stations - From Reference (12). (all values in ppm)

	Station									
	Springfield		Independence		Newberg		Marina Mart		S.P. & S. Brd.	
Year	DO	BOD	DO	BOD	DO	BOD	DO	BOD	DO	BOD
1953	9.5	2.6	8.7	0.8	7.6	1.3	6.3	1.7	2.0	2.5
1954	9.4	1.1	9.0	0.9	8.0	1.1	7.3	1.0	4.2	1.7
1955	9.2	1.1	9.0	1.0	7.6	1.0	6.7	1.5	4.1	1.5
1956	9.4	1.6	8.6	1.7	7.1	1.2	6.3	1.3	4.2	1.9
1957	9.5	1.2	8.6	1.4	7.1	1.5	5.3	1.4	2.4	1.7
1958	9.5	1.2	8.5	1.2	7.4	1.4	6.9	1.7	4.0	2.1
1959	10.4	1.2	9.2	1.3	7.7	1.4	6.6	1.2	4.3	1.1
1960	9.8	0.9	9.1	1.4	7.8	1.4	7.1	1.1	4.3	1.4
1961	9.3	0.8	9.3	1.3	7.6	0.9	6.9	0.8	3.7	1.1
1962	9.1	1.0	9.4	1.5	7.7	1.2	6.5	1.0	3.9	1.6
1963	9.4	0.9	9.2	1.5	7.7	1.2	5.6	1.2	3.6	1.2

As previously indicated, the State Sanitary Authority sampled the river on a continuous basis as a regular part of their program, making more than 35,000 analyses in 1970. Obviously, only a very small portion of the total data can be covered in this writing. To make comparison possible, Table 5 is prepared in the same general format as Table 4, giving average values for the DO and BOD for the months of July, August, and September 1967 through 1970. The Springfield sampling station is omitted. Average river flows (Salem gage) are included.

Table 5

DO, BOD, and River Flow Data by Years as the Average for July, August, and September of Each Year at Various River Stations

(DEQ Data)

(DO and BOD data in ppm - River flow in cfs Salem gage)

	Station								
	Independence		Newberg		Marina Mart		S.P. & S. Br.		
Year-Mo	DO	BOD	DO	BOD	DO	BOD	DO	BOD	River Flow
1967 July	8.0	1.3	6.9	0.8	6.4	0.6	4.2	1.1	6,300
Aug	8.2	1.9	6.7	1.3	6.0	1.2	3.3	0.9	5,900
Sept	8.0	1.5	6.7	1.1	6.4	0.8	3.8	1.2	7,600
Average	8.1	1.6	6.8	1.1	6.3	0.9	4.1	1.1	6,600
1968 July	7.6	1.2	6.5	1.1	6.2	1.2	5.2	1.3	6,100
Aug	8.3	1.8	7.1	1.2	6.5	0.7	5.2	1.0	12,000
Sept	9.1	1.5	7.6	1.0	7.2	0.8	6.8	0.8	10,400
Average	8.3	1.5	7.1	1.1	6.6	0.9	5.7	1.0	9,500
1969 July	9.0	1.8	7.7	1.1	7.4	1.4	7.2	0.9	12,500
Aug	8.6	1.7	7.4	1.2	6.6	0.9	5.7	1.3	10,400
Sept	8.8	1.4	7.6	1.2	7.2	1.0	6.9	1.1	10,700
Average	8.8	1.6	7.6	1.2	7.1	1.1	6.6	1.1	11,200
1970 July	9.1	1.4	7.7	1.5	6.9	0.8	6.0	1.2	7,100
Aug	9.1	1.2	7.9	1.2	7.1	0.8	6.2	1.0	7,100
Sept	9.8	1.0	8.6	1.1	8.0	0.8	7.4	1.1	9,500
Average	9.3	1.2	8.1	1.3	7.3	0.8	6.5	1.1	7,900

Table 5 shows failure to meet 5 ppm DO at the S.P. & S. Bridge in 1967; otherwise, all values for the DO were above standards which will be discussed in a subsequent portion of this writing.

Results are available from records of the City of Portland for river samplings in the lower reach of the river from the latter part of July through the month of August 1971. Table 6 gives the results and the average for the 5 sampling periods. River flow for August 11, 1971 was given as 7,380 cfs at the Salem gage which was translated to 9,200 cfs in the Portland harbor. This flow, if indicative of the month of August, is somewhat greater than the average monthly flow for August 1970 as shown in Table 5.

The uniformity of the average DO results through the lower reach of the river during the 1971 samplings as shown in Table 6 is surprising, the decrease in the average DO below Sellwood Bridge being insignificant as compared to any of the results of river sampling or calculation prior to 1967.

Table 6

DO in Lower Reach of Willamette River During Low Flow Period 1971

(City of Portland Data)

DO in ppm

Station	July		August			
	22	29	11	18	26	Ave
Above Tryon Cr.	6.6	6.2	6.7	7.3	7.9	6.9
Below Tryon Cr.	5.8	6.4	6.7	7.5	6.9	6.6
Sellwood Br.	6.4	6.0	6.3	6.9	7.5	6.4
Ross Island	6.0	5.8	6.3	6.5	7.1	6.3
Steel Br.	6.0	5.8	6.1	6.3	7.1	6.2
Terminal No. 2	6.2	6.0	6.7	6.3	6.7	6.4
S.P. & S. Br.	6.4	6.0	6.3	5.9	6.9	6.3
St. Johns Br.	6.4	5.8	6.1	5.7	6.3	6.0
Powerline	6.0	5.8	5.9	5.7	6.1	5.9

Mention should be made of the BOD test results over the years. In the early days, the test was usually made over a 20 day period; however, all recent test results are for 5 day determinations, the ratio between the two being taken as 5 day/20 day = 0.68. All results except where otherwise noted have been the 5 day values. The 1929 survey (14) showed BOD values in the upper river of less than 1.0 ppm subsequent to the inflow of the McKenzie River with a rise to about 1.1 ppm below Albany-Corvallis, a sudden rise to approximately 2.5 ppm below Salem and 3.1 ppm at Willamette Falls. In between the locations cited, there were declines as stabilization of organic material took place. At the Sellwood Bridge, the 1929 survey showed a BOD of 2.0 ppm, which approximates the value shown in the 1934 survey of the lower harbor (16),which averaged 2.2 ppm for four samplings. The National Council figures were 3.0 ppm in 1952, 1.9 ppm in 1953, and 2.4 ppm in 1954. The survey of 1956 (20) showed 2.4 ppm. Velz took samples throughout complete tide cycles at the Sellwood Bridge in 1950 (8) and showed BOD variations from 3.0 to 6.0 ppm with a mean of 4.5 ppm. This corresponds to Sanitary Authority samplings in 1950 of an average of 3.9 ppm and 5.9 ppm in 1949.

In general, one would conclude, from the many BOD determinations over the years, that there was some demand (0.5 - 0.7 ppm) even without any source of pollution, and that as industrial and domestic wastes were discharged into the river the BOD increased and then declined as stabilization took place only to rise again as a point of waste discharge was reached. The net effect is an overall increase in BOD as the river flows toward the mouth, with a corresponding reduction in DO. It would appear that considering the entire river in the low water periods, the BOD continued to increase over the years until some point was reached about 1960, after which there was a decline until the figures for 1967-71 averaged about 1.2 ppm, whereas 1949-50 may have averaged as high as 4.7 ppm, all values approximated at the Sellwood Bridge. Further, the BOD values in the lower portion of the Portland Harbor in 1967-71 (S. P. & S Bridge) averaged 1.2 ppm whereas in 1950 the average approximated 5.9 ppm. From 1953 to 1963, BOD averages for three month periods at the S. P. & S. Railroad Bridge varied from a high of 2.5 to a low of 1.1 ppm. The overall indication of the majority of the available data would indicate that the pollutional load on the Willamette River had peaked in the late 1950's or early 1960's and had subsequently declined at an increasingly rapid rate.

The temperature of a flowing stream relates to water quality, both because of the relationship to the amount of dissolved oxygen and to the tolerance of aquatic life. Particularly, water temperature is important in relation to sensitive fish life such as salmon and trout. The colder tributaries flowing from the snow melt of the Cascades rather than the warmer tributary streams from the Coast Range have supported the larger salmonoid populations, and temperature has probably been an important factor.

Over the years, the average temperature of the river has not changed in an amount that is significant when compared to the large fluctuations which occur between maximum and minimum. Figure XII, showing average river temperatures at Salem, is typical of fluctuations in all reaches of the river, with the temperatures being somewhat less in the upper reaches and somewhat higher in the lower reaches. Beyond a very general relationship which would be indicated by comparing the hydrograph of Figure II with the temperatures of Figure XII, there appears to be no very specific correlation between river flow and temperature. River sampling data were reviewed for thirteen different years covering the period from 1929 through 1970. In all of the thirteen years and at river flows as high as 9,900 cfs Salem gage, temperatures in excess of 70°F were encountered at one or more river stations. Records indicate that periods as long as 2.0 days above 70°F may be expected at some locations on the main stem of the river. Higher temperatures are encountered in tributaries.

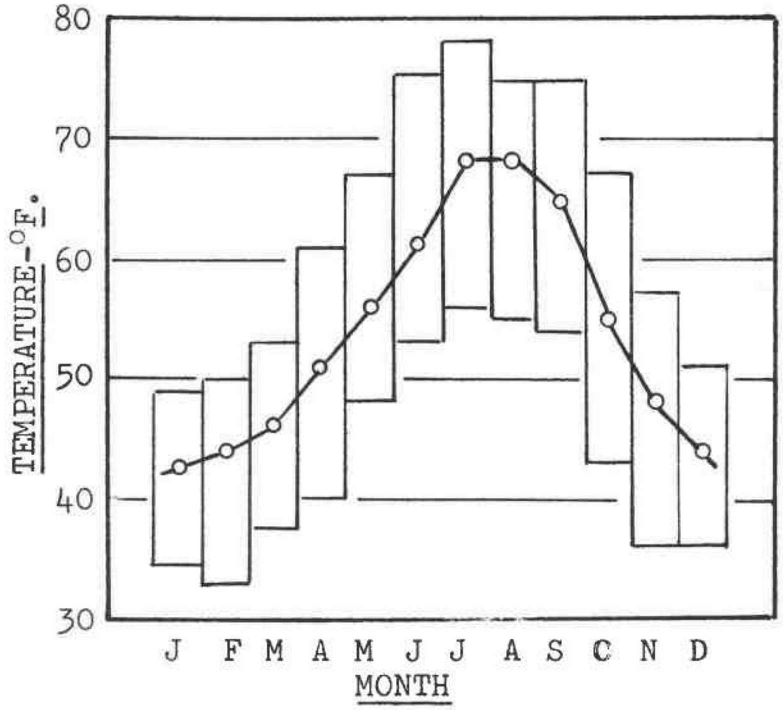


Figure XII- Average, Maximum and Minimum Monthly Temperatures of the Willamette River at Salem, Oregon- Reference (2)

Figure XIII shows the relationship over the year 1964 for river flow (Salem gage), dissolved oxygen, and temperature (21). Note the prolonged period of low water flow and the corresponding high peak temperature in the Portland harbor for July, August, September, and October. This same period of high temperature corresponded to the DO of less than 5 mg/ℓ for almost three months.

Under conditions of regulated flow and with a flow of 8,000 cfs Salem gage (9,470 cfs Portland harbor) for the month of July, the river may be expected to reach 70°F as a mean temperature in the Portland harbor and may reach a maximum of 78°F. Under the same conditions, the mean temperature

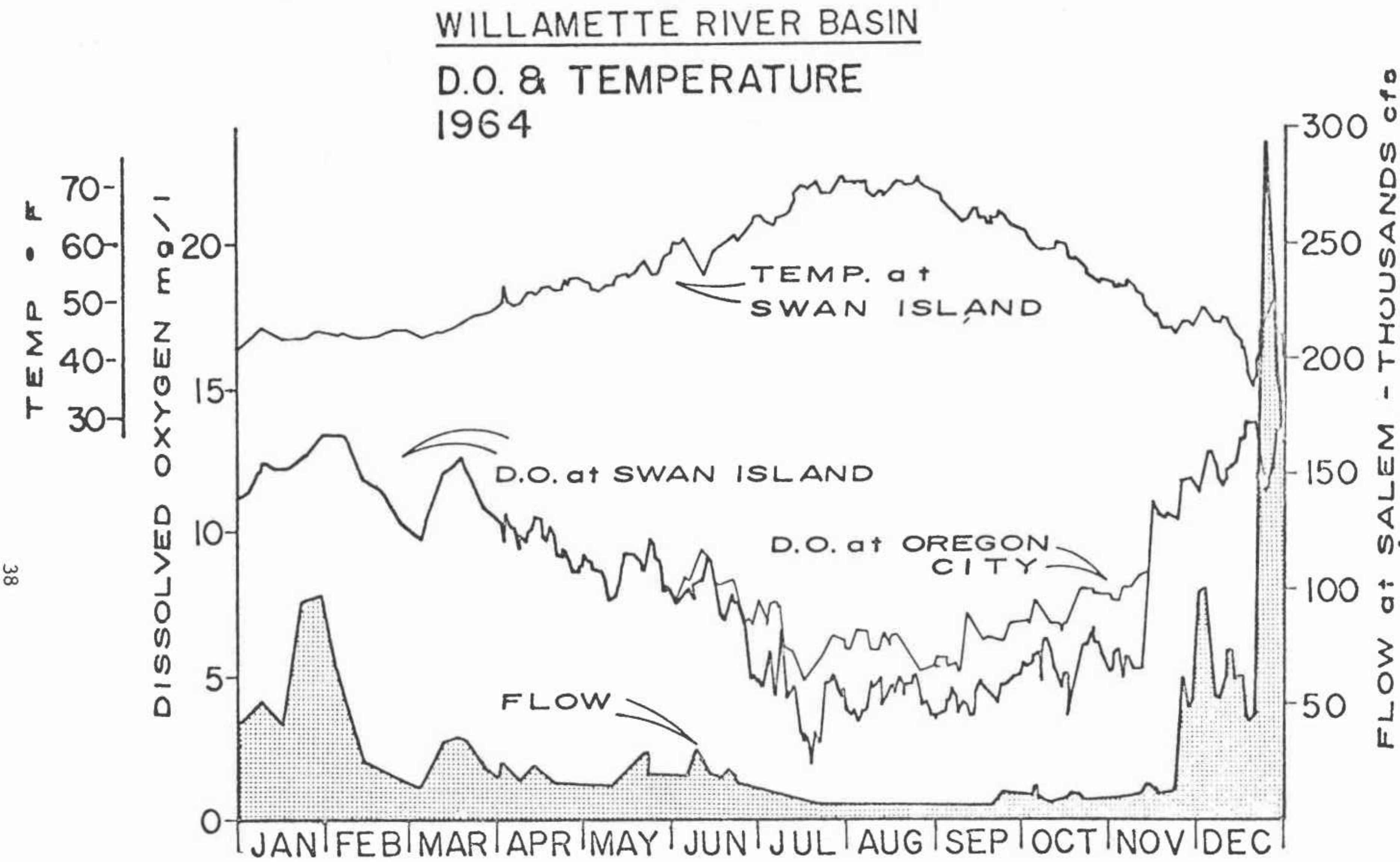


Figure XIII- Condition of the Willamette River 1964. Reference (21) of the river will exceed 65F° as far upstream as the Long Tom tributary, at approximately 146 river miles from the mouth (2). Note from Figure XII, the average temperature at Salem approximates 68°F for a 30 day period with maximums of 75°F or above for July through September. Maximum temperatures in some tributaries during July exceed 80°F with some averaging above 70°F for the entire month. Diurnal temperatures in July may fluctuate from 3 to 13°F. Of course, the winter temperatures of the river are much lower and drop down to near freezing as a minimum in some months but have an average below 50°F for 6 months of the year. Lower temperatures are experienced in the tributaries.

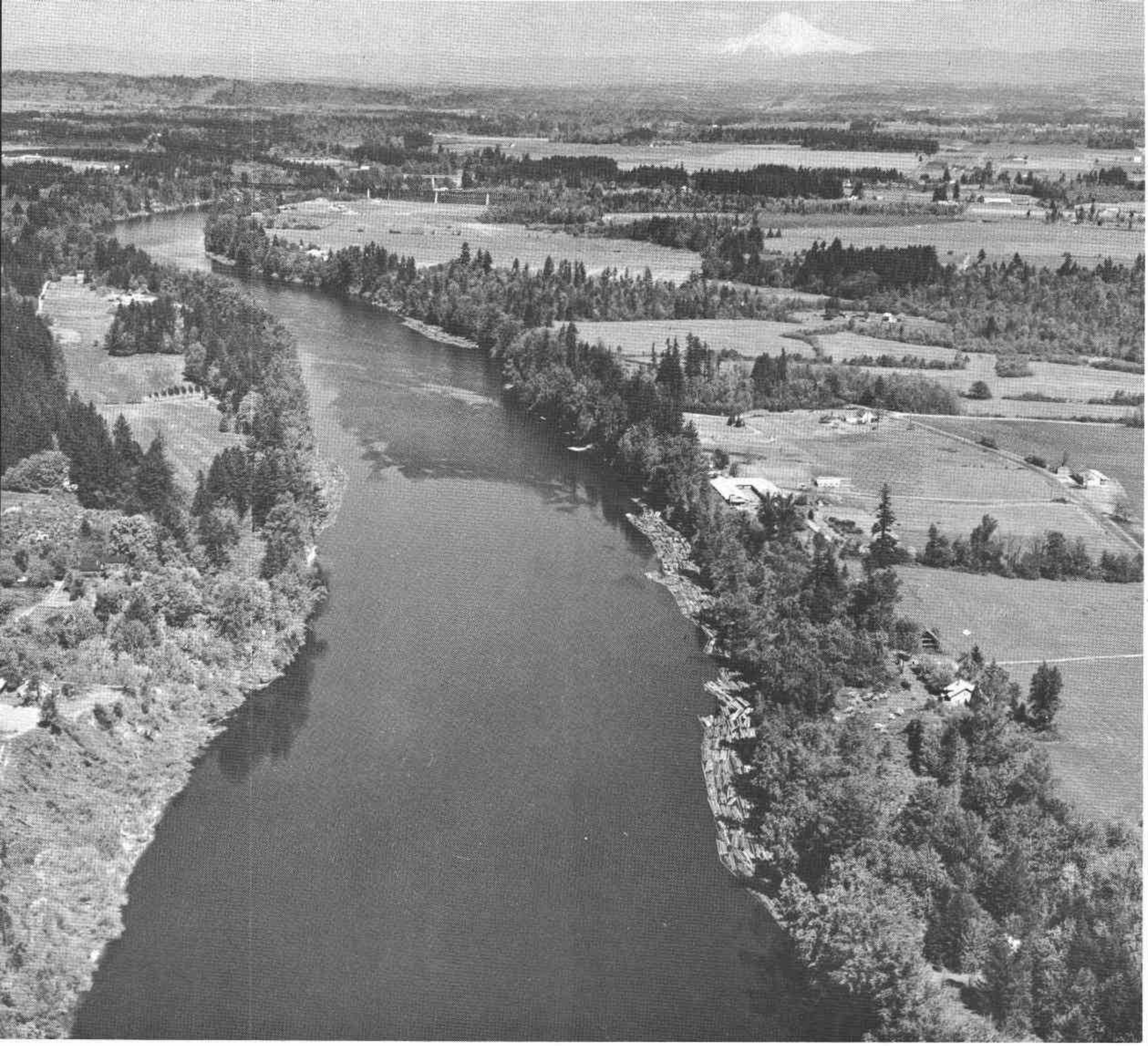
Salmon cannot survive for long periods in warm water. Comprehensive, controlled tests indicate that fish diseases increase very rapidly with increased water temperature with practically all fish afflicted in some degree at temperatures in the mid 60°F range. Exposure to a temperature of 72°F was lethal by the 10th to 12th day of exposure for all test specimens in spite of the fact that the fish had been preconditioned to the higher temperatures by a slow rise of 3.5°F/day from 50 to 72°F. Besides the ravages of disease in salmon exposed to the higher temperature, other organic difficulties were evident(22).

Certain bacterial tests measure water quality, particularly from a health or recreational standpoint. In the early days a total bacterial count was made (expressed as number of organisms per 100 milliliters) and found to be quite variable and without great significance as far as basic water quality was concerned. After a freshet and on rising water the count was high due to ground wash and run off. Temperature influences rate of bacterial growth. Available nutrients, especially carbohydrates, promote such growth. Sludge deposits from wastes promote growth. With so many variables involved, the total bacterial count became significant only if related to the specific circumstances at the time of sampling. Due to tidal action, total bacterial counts in the Portland harbor could never be related to other than the influence of tidal movement.

In contrast to total bacterial count, the count of coliform bacteria has some significance. The coliforms are associated with fecal wastes. The older tests were expressed as a B. Coli Index or the most probable number (MPN) of coliforms per mℓ expressed as multiples of 10 (1, 10, 100, 1,000 etc.). It would be expected that the discharge of raw sewage into a body of water could be detected and roughly in what amount by the B. Coli Index. In the 1929 river survey, the B. Coli Index in uncontaminated waters above Cottage Grove was 0 and immediately below was 100. Since coliforms do not survive for long under flowing stream conditions, the Index dropped to 1 then rose again to 100 immediately below Eugene. It dropped down then up to 100 below Corvallis and Albany; further down it decreased to 1, before increasing to 10 below Independence and to 1,000 below Salem. The index dropped to 0 in the Salem to Oregon City reach of the river, increased to 100 below Oregon City, and then dropped to 10 at the Sellwood Bridge. Note that below each municipality (Newberg excluded) there was an increase in the B. Coli Index roughly in proportion to the population. At this time, all municipalities were discharging raw sewage to the river (14).

In the 1934 survey, the B. Coli Index at the Sellwood Bridge varied between 10 and 100. In the lower Portland harbor it rose to as high as 10,000 and frequently was at 1,000. The increase was, of course, due to the waste discharges from the City of Portland (16).

The 1944 survey results (4) showed essentially the same as those of the 1929 survey (14), except that the values were magnified. There was a marked increase in total bacterial count and Coli Aerogenes count below Eugene; a very modest increase below Corvallis; an increase at Independence; a marked increase below Salem; a marked increase in total count but practically no increase in Coli Aerogenes below Newberg, and a marked increase below Oregon City. In between municipalities, counts were very low. It is noteworthy that from practically 0 above Eugene, the total count went to 220,000/100 mℓ and Coli Aerogenes to 60,000/100 mℓ below Eugene.



Mt. Hood continues to dominate the scene as the Willamette flows through rich agricultural land near Wilsonville, about 40 miles from the mouth.

In 1964 in the review of progress in improvement of water quality, the State Sanitary Authority concluded that, "The bacterial contamination of the river as measured by the most probable number (MPN) of coliform bacteria was, for most of the river, from 5 to 100 times the limit considered safe for water-based recreation such as swimming and water skiing." The MPN data for years 1953-63 inclusive were appended to the 1964 report (12).

There exists a question regarding what constitutes a safe or acceptable level for coliform organisms in recreational waters. It appears obvious that as the level of communicable diseases drops, the acceptable MPN might be increased. The safe level is a complex matter of probability. The Oregon Sanitary Authority has set the limit of the coliform group as associated with fecal sources to not exceed 1,000/100 $m\ell$ on the average and not more than 20 per cent of samples to exceed 2,400/100 $m\ell$.

In the recreational months of June, July, and August 1969-71, at most sampling stations, the coliforms were well below standard. This was particularly true in 1970 and 1971 even though some slight increases were still evident below population centers (23). Undoubtedly, the recent improvments were the results of efforts initiated by the Authority in 1964(12).

It should be recalled that from 200 to 600 billion coliforms per person per day are wasted to sewage systems with the results from Oregon cities being somewhat higher(24). Chlorination of treatment plant effluents provides the necessary control. For such coliforms as may not be removed by treatment, they tend to multiply and reach a maximum number in about 12 hours after discharge to the river and then die away at a rate that varies in different bodies of water. The peaking and dying being in terms of time are, of course, related to river flow in-so-far as the location of coliform numbers is concerned and such accounts for the buildup directly below population centers and the subsequent reduction in non-populated river reaches. Figure XIV taken from reference (21) shows the coliform variation in 1962. The summer of 1963 showed approximately the same configuration, but the summer of 1965 showed markedly higher peaks below Eugene and below Albany(25).

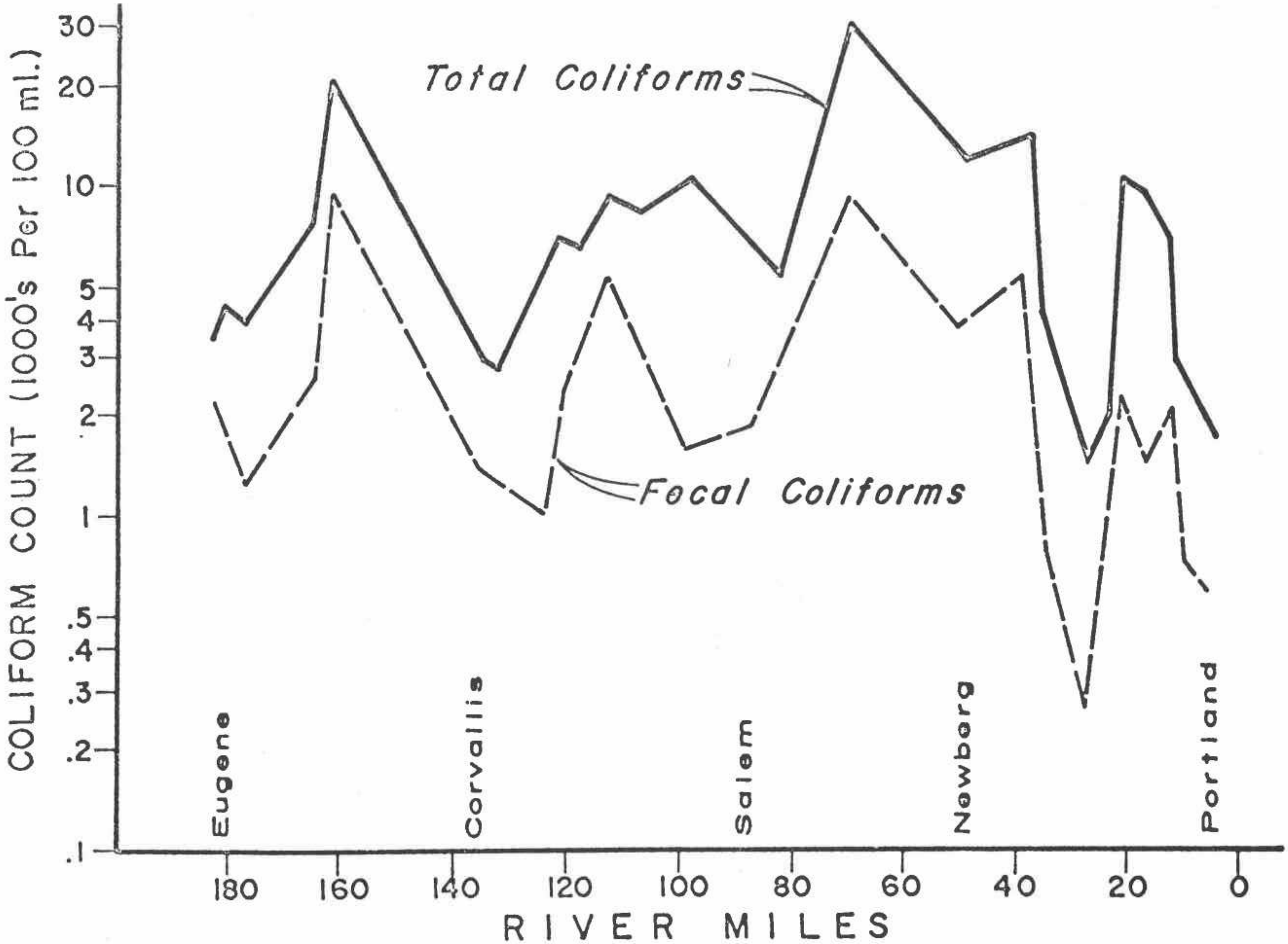


Figure XIV - Bacteriological Profile of the Willamette River in 1962. Reference (21)

As mentioned first in the 1929 survey of the Willamette River (14) and by practically all persons or agencies since, there are portions of the river where the stream velocities are so low that suspended matter settles to the bottom as sludge deposits. Since the sludge beds contain oxidizable organic matter they exert a BOD, but out of proportion to the BOD that would be experienced at the location were the sludge beds absent(26).

Velz gives the limiting velocity below which suspended organic matter settles and accumulates as 0.6 feet per second. Depending upon a variety of factors, a velocity of from 1.0 to 1.3 feet per second is required to scour such deposits (27). Based upon the critical velocity for sludge bed formation, Velz indicated potential beds at river mile 85.5, 72-75, and mile 53 to the Oregon City Falls (7).

Since river velocity is important in sludge formation, in satisfaction of BOD in relation to location in river, in die-off of bacteria in relation to location, and, in general, to all factors which relate to velocity of flow, it is important that very accurate cross-sectional information be available for the river channel from which velocities may be calculated or time of travel determined for any quantity of river flow. Times of passage in the upper reaches of the river were presented in references (14) (7) (9). More recently, velocities and travel times in the river have been measured by dye travel procedures(28). The lower reach of the river presents somewhat more difficult and different circumstances due to the tidal action and the influence of the Columbia River near the mouth of the Willamette. Circumstances in the lower reach were considered in (7) (8) (16) (29).

Figure XV shows the flow time of the river below Salem for various quantities of flow as determined at the Salem gage. The flatter the slope of the flow lines, the higher the velocity of flow. The transition from the region of higher velocity in the upper part of the river to lower velocity nearer the falls becomes much less marked as the quantity of flow increases. At low flows it would be expected that sludge build up would take place below mile 35 from Salem.

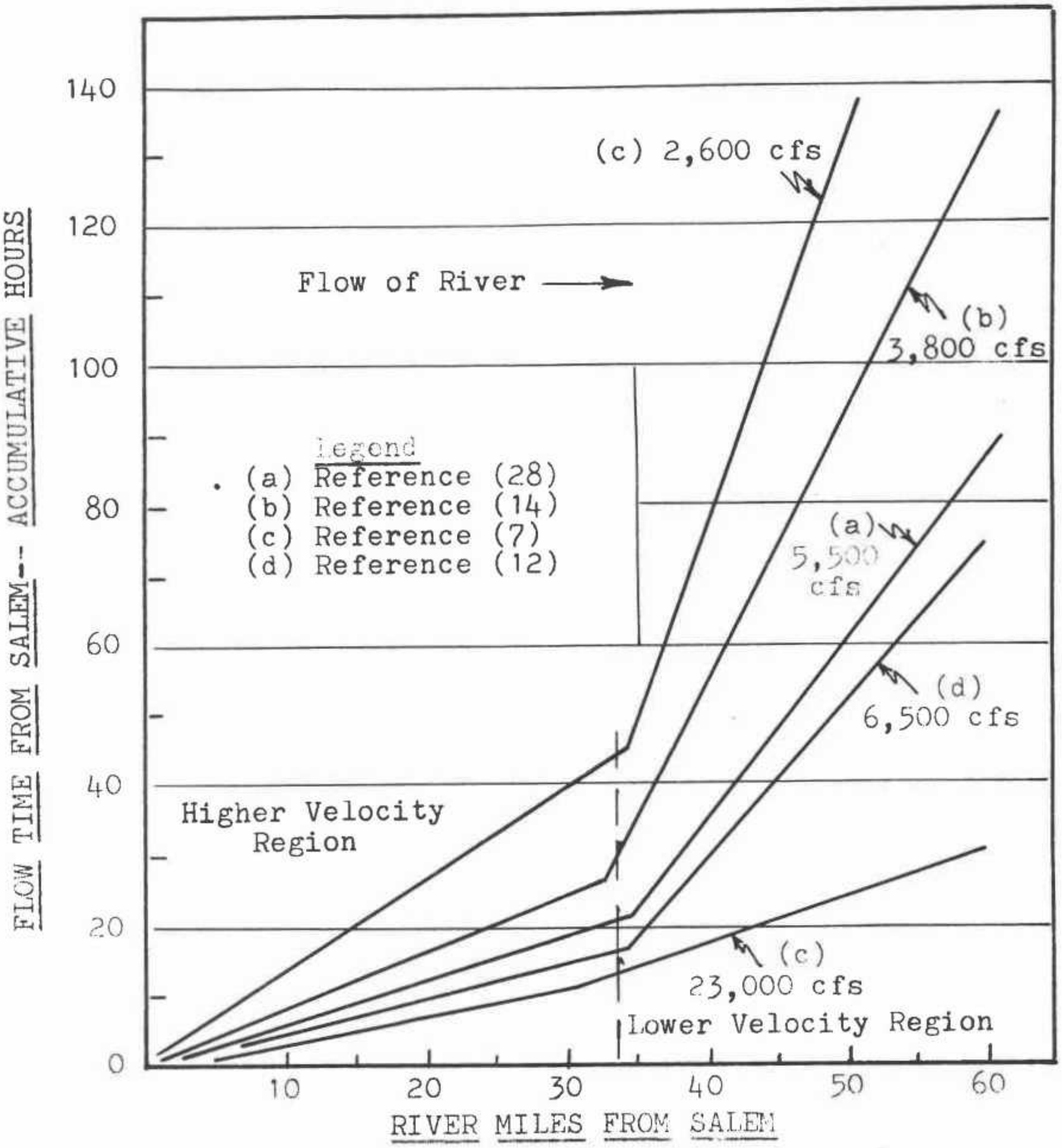


Figure XV - Flow-Time of Willamette River Below Salem

Sludge beds in the river have been investigated and found to be composed, in large part, of wood fibers(12). Frequently, in late summer as decay progresses in the sludge deposits, the gases produced buoy up sections of the sludge deposits which have been observed as sludge rafts floating in the river. It has been determined that the aquatic bacterium Sphaerotilus natans, which grows in long chains, attaches itself to floating material such as wood fibers and either floats in the stream or is deposited depending upon the water velocity. It has also been determined that the bacterium is a major constituent in the sludge beds in the river. When floating, the bacterium masses become attached to fish nets and fish lines, the cause of frequent and repeated complaints. It is believed that abatement rests in control of solid discharge to the river and particularly wood fibers. Solids, at one time discharged to the river by the pulp and paper industry, have been estimated as high as 100 tons per day (9).

As indicated before, sludge beds have a BOD out of proportion to that of the flowing stream. A lapse of time is required for a sludge bed to reach a condition of equilibrium (30-50 days) after which time a high, local BOD exists. The sludge deposit undergoes anaerobic decomposition with the soluble end products of the decomposition coming to the surface of the bed to undergo rapid oxidation at the sludge bed-water interface. This action creates a high, localized demand for the dissolved oxygen carried by the water. An unaccounted for oxygen deficit in the Portland harbor has been attributed to such sludge bed formation (29). The deficit showed as the difference between the calculated DO in the river and the DO as measured by the U.S. Public Health Service and the Oregon State Sanitary Authority in July and August 1961.

In the Willamette Basin, the transport of sediment by the rivers is a significant factor in water quality. High sediment loads, when deposited, suffocate existing aquatic fauna and flora, and tend to limit recreational sports and fishing. Removal of sediment for water supplies is expensive. Sediment concentrations in the Willamette Basin were measured in 1959 and varied between 130 and 800 ppm. Translated to the Portland harbor, the Willamette River carries about 2.3 million tons annually with the flood period of 1964 discharging an approximate 6,400,000 tons as measured at Portland (25). A very large portion of the sediment transport is related to practices of land use and would be amenable to a degree of control by proper practices.

The dissolved chemical content of water is a customary index of water quality. Large amounts of dissolved material produce the "hard water" as compared to waters in the Willamette Basin which are "soft", having as dissolved chemical solids less than 57 ppm over the years. While organic loadings to the rivers of the basin have changed markedly over the years, the chemical content of the Willamette River waters has fluctuated very little. First chemical analyses of the river waters started in 1910 and were reported in 1914(30). The water was found to be of "excellent chemical quality." Many analyses have been made since the early date including daily sampling at Salem since 1952. The uniformity of the analytical results over the years is rather remarkable.

Dissolved inorganic substances ionize and increase the electrical conductivity of water. Specific conductance (micromhos at 25°C) is proportional to the amount of dissolved ionic material. Conductivity tests have been made on river samples for some years. In general, the conductivity increased to peaks in July or August and dropped to lower values at periods of high run off. Conductivity of samples taken at Salem fell below the values of samples taken in the Portland harbor although the variation between highs and lows followed the same pattern in both locations. The range of values in 1967-70 at the S. P. & S. Bridge in the Portland harbor was from 90 to 50 while at Salem it was from 74 to 47 (2) (23).

In general, the tributaries of the Willamette River vary widely in flow as well as water quality. The tributaries flowing from the east show a consistent high quality, while those flowing from the west are not in as satisfactory condition, particularly those nearer the Portland metropolitan area. Many of the smaller tributaries have a very low summer flow ; it being said that, in some instances, the summer flow is almost entirely made up of sewage treatment plant effluent. The quality checking program of the Department of Environmental Quality has been extended to include sampling of the 41 creeks, 18 rivers, 4 sloughs or swales, and 2 ditches or canals in the Willamette Basin,in addition to the sampling of the main stem of the Willamette River.

As might be expected, the tributaries make their contribution to the condition of the main stem of the river and it is fortunate that the larger tributaries in terms of volume of flow have water of the highest quality---a condition that will undoubtedly persist since the larger tributaries flow from the least populated areas.

In summary, the Willamette River was shown to be heavily polluted in the lower reaches in the early tests of 1926-27. Subsequently, and over a long period of more than thirty five years, all significant indexes of water quality indicated a continued deterioration. The efforts which were expended in the sampling, analyses, and monitoring of water quality have been prodigious. Only in the very recent years have the tests reflected improvement in the condition of the river. How such improvements were effected is the subject matter of the following section of this writing.

ACTION

Sufficient factual data had been accumulated over the years on the condition of the Willamette River to convince even the most skeptical that the river was in exceedingly poor condition. After prolonged inaction by the Legislative Assembly of the State of Oregon, the people of the State initiated an act known as the "Water Purification and Prevention of Pollution Bill" and by vote in the general election of November 1938, by more than a 3 to 1 margin, passed the measure. No doubt remained regarding the sentiment of the people with respect to the quality of the waters of the State. The "Bill" created within the Oregon State Board of Health a division titled the State Sanitary Authority consisting of the State Health Officer, the State Engineer, the Chairman of the Fish Commission,and one member appointed by the Governor from each of the three Congressional districts of the state. The State Sanitary Engineer was designated as the secretary to the Authority. The Authority was first organized on February 25, 1939(31).

Although the original "Bill" set forth the considerations to be involved in pollution abatement, it was weak in terms of enforcement and underfunded from the standpoint of provision of adequate personnel. Nevertheless, the original "Bill" established the base from which the present statute has evolved. The current law is set forth in Oregon Revised Statutes (ORS) Chapter 449. Effective July 1, 1969, the Sanitary Authority was replaced by incorporation into the Department of Environmental Quality of the State of Oregon under a Commission known as the Environmental Quality Commission. The Water Quality Control Division is a unit under the organization of the Commission. ORS 449 deals with all of the functions of the Commission under which the sections concerned with Water Pollution start with ORS 449.075 and terminate with ORS 449.150. The following sections are particularly pertinent:

ORS 449.075	Definitions.
ORS 449.077	Policy on water pollution.
ORS 449.079	Water pollution prohibited, violation a public nuisance.
ORS 449.081	Functions of Environmental Quality Commission in relation to water pollution.
ORS 449.083	Permits required.
ORS 449.086	Standards of quality and purity of water.
ORS 449.088	Final order.
ORS 449.089	Appeal from final order.
ORS 449.092	Intergovernmental cooperation to control water pollution.
ORS 449.095	Water pollution as improper use.
ORS 449.097	Proceedings against violators.
ORS 449.100	Enjoining and abating water pollution.
ORS 449.103	Liability for injury to fish and wildlife and to their habitat.

The other sections of the statute through 449.150 deal with placement of material in water, wading and bathing, location of cemeteries near water, introduction of wastes above intakes for water supplies, sewer systems for settlements, and definitions.

ORS 449.077 expresses the policy of the State of Oregon regarding water pollution and reads:

> "Whereas the pollution of the waters of this state constitutes a menace to public health and welfare, creates public nuisances, is harmful to wildlife, fish and aquatic life and impairs domestic, agricultural, industrial, recreational and other legitimate beneficial uses of water, and

whereas the problem of water pollution in this state is closely related to the problem of water pollution in adjoining states, it is hereby declared to be the public policy of the state to conserve the waters of the state and to protect, maintain, improve the quality thereof for public water supplies, for the propagation of wildlife, fish and aquatic life and for domestic, agricultural, industrial, municipal, recreational and other legitimate beneficial uses; to provide that no waste be discharged into any waters of this state without first receiving the necessary treatment or other corrective action to protect the legitimate beneficial uses of such waters; to provide for the prevention, abatement, and control of new or existing water pollution; and to cooperate with other agencies of the state, agencies of other states and the Federal Government in carrying out these objectives."

In carrying out the objectives under the declared policy, the framework was embodied in ORS 449.086. Under subsection (1) the Commission is authorized and empowered to establish standards of quality and purity of the waters of this state in accordance with the public policy set forth in ORS 449.077 with consideration to floating solids, suspended and settleable solids, organisms of the coliform group and other bacteria or virus, the oxygen demand, the dissolved oxygen content, biological and radiological properties, exclusion of substance and the matter of schedule and time of effect of operational improvements.

Subsections of ORS 449.086 (2) and (3) refer to hearing procedures, subsection (4) to the responsibility of persons complying with standards, and subsection (5) refers to adherence to ORS 183 for filing orders with the Secretary of State.

The State Sanitary Authority and since July 1, 1969 the Environmental Quality Commission have under the statutory authority of ORS 449.086 issued Administrative Orders setting forth "Standards of Quality for Public Waters of Oregon and Disposal Therein of Sewage and Industrial Wastes". These Standards are published under Chapter 340, Oregon Administration Rules, Division 4, Subdivision 1, sections 41-005 through 41-070. Pertinent sections include:

41-005	Definitions.
41-010	Highest and best practicable treatment and control required.
41-015	Restrictions on the discharge of sewage and industrial wastes and human activities which affect water quality in the waters of the State.
41-020	Maintenance of standards of quality.
41-022	Implementation of treatment requirements.
41-025	General water quality standards.
41-030	Beneficial uses of water to be protected by special water quality standards.

Following section 41-030 is the enumeration of 14 rivers, estuaries, or river basins considered to be protected by special water quality standards, among which is the Willamette River and some of the tributaries.

Subdivision (2) of the Rules in 42-005 through 42-020 is concerned with Sewage and Waste Treatment Plant Operation. Subdivision (3) in 43-005 through 43-030 is concerned with the Disposal of Industrial Wastes. Subdivision (4) in 44-005 through 44-045 is concerned with Construction and Use of Waste Disposal Wells. Subsection (5) in 45-005 though 45-060 is concerned with Regulations Pertaining to Waste Discharge Permits. Subsection (6) in 46-005 through 46-035 is concerned with Deposit of Motor Vehicle Bodies and

Accessories into the Waters of the State, and Subsection (8) in 81-005 through 81-050 is concerned with State Financial Assistance to Public Agencies for construction of Pollution Control Facilities.

The Standards and Administrative Regulations follow closely the substance set forth in the statutes under ORS Chapter 449.

Applicable to this discussion of the Willamette River are the General Water Quality Standards and those which refer specifically to the main stem of the river. The standards and specifics are important in that they define the framework by which the condition of the river must be judged. The general Standards have been in effect for some period of time and have been modified as experiences have dictated. Currently in force is the following:

> 41-025 - General Water Quality Standards. The following General Water Quality Standards shall apply to all waters of the State except where they are clearly superseded by Special Water Quality Standards applicable to specifically designated waters of the State. No wastes shall be discharged and no activities shall be conducted which either alone or in combination with other wastes or activities will cause in any waters of the State:
>
> (1) The dissolved oxygen content of surface waters to be less than six (6) milligrams per liter unless specified otherwise by special standard.
>
> (2) The hydrogen-ion concentration (pH) of the waters to be outside the range of 6.5 to 8.5 unless specified otherwise by special standard.
>
> (3) The liberation of dissolved gases, such as carbon-dioxide, hydrogen sulfide, or any other gases in sufficient quantities to cause objectionable odors or to be deleterious to fish or other aquatic life, navigation, recreation, or other reasonable uses made of such waters.

(4) The development of fungi or other growths having a deleterious effect on stream bottoms, fish or other aquatic life, or which are injurious to health, recreation, or industry.

(5) The creation of tastes or odors or toxic or other conditions that are deleterious to fish or other aquatic life, or affect the potability of drinking water or the pallatability of fish.

(6) The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation or industry.

(7) Objectionable discolorations, turbidity, scum, oily slick or floating solids, or coat the aquatic life with oil films.

(8) Bacterial pollution or other conditions deleterious to waters used for domestic purposes, livestock watering, irrigation, bathing, or shellfish propagation, or be otherwise injurious to public health.

(9) Any measurable increase in temperature when the receiving water temperatures are 64°F or above, or more than 2°F increase when the receiving water temperatures are 62°F or less.

(10) Aesthetic conditions offensive to the human senses of sight, taste, smell, or touch.

(11) Radioisotope concentrations to exceed Maximum Permissible Concentrations (MPC's) in drinking water, edible fishes or shellfishes, wildlife, irrigated crops, livestock and dairy products or pose an external radiation hazard.

The foregoing general standards are amplified by the specific standards for the Willamette River as:

41-045 - Special Water Quality Standards for the Public Waters of Multnomah Channel and the Main Stem Willamette River. The provisions of this section shall be in addition to and not in lieu of the General Water Quality Standards contained in

Section 41-016 (sic 41-025), except where this section imposes a conflict with the provisions of Section 41-016 (sic 41-025), this section shall govern. No wastes shall be discharged and no activities shall be conducted which either alone or in combination with other wastes or activities will cause in the waters of Multnomah Channel or the Willamette River:

(1) Dissolved oxygen (DO)

(a) (Multnomah Channel and main stem Willamette River from mouth to the Willamette Falls at Oregon City, river miles 26.6). DO concentrations to be less than 5 milligrams per liter.

(b) (Main stem Willamette River from the Willamette Falls to Newberg, river miles 50). DO concentrations to be less than 6 milligrams per liter.

(c) (Main stem Willamette River from Newberg to Salem, river miles 85). DO concentrations to be less than 7 milligrams per liter.

(d) (Main stem Willamette River from Salem to confluence of Coast and Middle Forks, river miles 187). DO concentrations to be less than 90 % of saturation.

(2) Organisms of the Coliform Group where associated with Fecal Sources (MPN or equivalent MF using a representative number of samples). Average concentrations of coliform bacteria to exceed 1,000 per 100 mℓ, with 20% of samples not to exceed 2,400 per 100 mℓ.

(3) Turbidity. (Jackson Turbidity Units, JTU). Turbidities to exceed 5 JTU above natural background values except for certain short-term activities which may be specifically authorized by the Sanitary Authority under such conditions as it may prescribe and which are necessary to accommodate essential dredging or construction where turbidities in excess of this standard are unavoidable.

(4) Temperature.

(a) (Multnomah Channel and main stem Willamette River from mouth to Newberg, river mile 50). Any measurable increase when river temperatures are 70°F or above, or more than 2°F increase when river temperatures are 68°F or less.

(b) (Main stem Willamette River from Newberg to confluence of Coast and Middle Forks, river miles 187). Any measurable increase when river temperatures are 64°F or above, or more than 2°F increase when river temperatures are 62°F or less.

(5) Dissolved Chemical Substances. Guide concentrations listed below not to be exceeded except as may be specifically authorized by the Sanitary Authority upon such conditions as it may deem necessary to carry out the general intent of Section 41-010 of this subdivision and to protect the beneficial uses set forth in Table A.

		mg/ℓ
Arsenic	(As)	0.01
Barium	(Ba)	1.0
Boron	(Bo)	0.5
Cadmium	(Cd)	0.01
Chloride	(Cl)	25.0
Chromium	(Cr)	0.05
Copper	(Cu)	0.005
Cyanide	(CN)	0.01
Fluoride	(F)	1.0
Iron	(Fe)	0.1
Lead	(Pb)	0.05
Manganese	(Mm)	0.05
Phenols	(total)	0.001

Total dissolved solids		100.0
Zinc	(Zn)	0.1
Heavy metals (Totals including Cu, Pb, Zm, and others of non-specific designation)		0.5

To check compliance with standards, continuous monitoring of the river is a requirement. The Department of Environmental Quality has established designated stream surveillance stations at approximately 30 locations on the main stem of the Willamette from Springfield to the Columbia Slough at the mouth of the slough (river miles 185.6 to 0.5). Many of the stations are infrequently sampled and at 11 the sampling is routine. Data are placed in a computer data bank and consist of date, time, location, river flow, pH, temperature, DO, BOD, PBI (Perle Benson Index), and MPN. The main stem river carries computer designation 22-50 with station designations W-1 through W-26.

Eight Biological Sampling Stations are located on the Willamette exclusive of Multnomah Channel.

Four Radiological Sampling Stations are included on the Willamette.

Sixty-nine Sampling Stations are included on tributaries of the Willamette exclusive of the 42 additional stations on the Tualatin River (32).

Pursuant to ORS 449.083, the Department of Environmental Quality is empowered to issue Water Discharge Permits for which the procedures and regulations appear as sections 45-005 through 45-060 of Chapter 340 of the Oregon Administrative Rules Compilation and which became effective January 9, 1970. (Note: These rules were revised by action of the EQC on March 24, 1972) The permit system, which by statute was started on January 1, 1968, provides an effective mechanism for the inventory of all waste discharges to the waters of the state as well as a means of effective regulation in terms of time. Since 1968, there have been more than 700 applications for permits and more than 500 such permits have been issued (33). In the Willamette Basin, permits total about 313 with 80 being on the main stem of the river and 233 on tributaries. The categories of such permits appear in Table 7.

Table 7 (34)

Waste Permits in Willamette Basin

Type	Main Stem Willamette	Tributaries	Total
Domestic	21	84	105
Combined - Domestic, Industrial	6	8	14
Animal Wastes (Slaughtering, Dairy, Chickens, Dog Food, Tannery, etc.)	1	27	28
Cannery	0	7	7
Wood Industries (Pulp & Paper, Plywood, Hard-board, etc.)	14	24	38
Lumbering (Decks, Log Ponds, etc.)	3	31	34
Washing (Sand & Gravel, Cleaning, Cooling Water, etc.)	24	31	55
Agricultural Products	1	7	8
Chemicals (Metals, Glues, Adhesives, Oil, etc.)	10	14	24
TOTALS	80	233	313

Within the scope of the foregoing described statutes and administrative rules, the quality of waters of the State of Oregon and particularly the Willamette River must be judged. Essentially, the quality control program rests in the quality standards which have been formulated over a long period of time but more particularly in 1967, 1968, and 1969 to which was added the waste discharge permit program of 1968.

Directly after coming into being in 1939, the Sanitary Authority, as a first action, notified all municipalities and industries on the Willamette River of their responsibility under the law. For most of the municipalities on the river, it appeared that primary treatment of wastes followed by chlorination of effluent would be sufficient treatment. In the early 1940's, all municipalities on the river initiated plans for treatment facilities. In 1949, the first treatment plants on the main stem were completed at Junction City and Newberg. Treatment plants were completed rather rapidly thereafter, but it was not until 1957 that all municipalities and communities on the main stem of the river exclusive of Portland had complied with the original directive.

The Sanitary Authority started routine river sampling in 1950 with periodic surveys on a more comprehensive scale. The survey in the low water period of 1957 provided evidence that in terms of dissolved oxygen, biochemical oxygen demand, and bacterial contamination, the river was in no better condition than in prior years in spite of the fact that facilities for primary treatment were in operation on the entire river. It was evident that the degree of treatment was still insufficient.

In 1950, following a public hearing, the pulp and paper mills on the river were ordered to develop plans to place into operation facilities for the treatment of the sulphite waste liquors which were responsible for about 84% of the oxygen demand on the river. The restriction on discharge was for months of June through October. The several mills

In the vicinity of Wheatland, some 70 miles from the mouth, the Willamette displays its meandering characteristics.

complied with the order by evaporating, ponding, or barging the spent liquor. The 1957 survey indicated that the 1950 order was producing insufficient results in-so-far as the pulp and paper industry was concerned.

Based upon the comprehensive review of all data up to 1957, the Authority in early 1958 instructed the cities of Eugene, Salem, and Newberg to install secondary treatment facilities, the City of Portland to accelerate the program of interceptor and treatment facility construction, and the pulp and paper operations to reduce further their pollutional loads. The City of Portland had spent some $19,000,000 on construction of interceptors and treatment facilities, but was at the point of failure to make satisfactory progress and it was necessary for the Authority to take action against the City. The situation was finally resolved in 1960 by an increase in the monthly sewer charge which would yield $1,500,000 per year to complete the necessary construction.

In 1960 following another public hearing, all municipalities on the lower reach of the Willamette River from Salem downstream were ordered to install secondary treatment facilities.

In 1964 the Authority adopted a policy which set forth the requirements as:

(a) All industrial wastes from each pulp and paper mill in the Basin will receive on a year-round basis primary sedimentation or equivalent treatment for the removal of settleable solids.

(b) Each sulphite mill must, during the period June through October, effect an 85% reduction in BOD loadings of effluents from the entire mill.

(c) All other sewage or waste effluents must receive secondary treatment equal to 85% removal of BOD and suspended solids.

(d) Higher degrees of treatment may be required in some cases.

(e) A deadline for meeting requirements is fixed as December 1966(21).

Sufficient progress had been made so that by 1967, the State's water pollution control policy could shift in emphasis from pollution abatement to pollution prevention and water quality enhancement. Secondary treatment of wastes was established as the minimal treatment for any sewage wastes discharged to any public waters. All major and many minor point-source discharges of wastes had been identified and beginning in 1968 were covered by specific waste discharge permits, which permits generally contained definite limitations on amounts and strengths of wastes as gaged by the several water quality criteria. Where necessary, special and specific treatment and control were requirements of the permit with a timetable for adherence. It appeared that the policy making function and operational procedures of the Department of Environmental Quality, Water Quality Control Division had reached a point where the water quality objectives as regards the Willamette River were to be attained.

As previously indicated, the Willamette River has cyclic flow over a variable periods of years, marked seasonal variations in flow, and, in some locations, weekly or daily variation due to patterns of water use. Since water quality in the upper reaches of the river was high, for a given loading on the river, the downstream quality should be roughly proportional to river flow. Reference to Figure IX will show that starting in 1953, the flow of the Willamette River during the minimum flow period has almost doubled the average of prior years in-so-far as the minimum average monthly flow is concerned. It is believed that it would have been impossible to effect any marked improvement of water quality of the river without the augmented flow. The greater flow has been accomplished by release of water from the several upstream impoundments on a schedule of the the U.S. Corps of Engineers aimed at a flow of 6,000 cfs, Salem gage. In spite of the remarkable reduction in pollutional loadings which have been accomplished, the quality of water is dependent upon natural water flow augmentation in the summer low flow periods, now and in the future. However, it should be mentioned that in the multiple benefits attributed to the impoundments on the river system, it was anticipated that the program would provide 5,000 cfs from Albany to the mouth of the Santiam River and 6,500 cfs from the Santiam to Salem for navigation which would, of course, be the reading at the Salem gage.

Table 8 gives the release of water from impoundments for the low water months for the years 1958 - 67.

Table 8

Water Releases and River Flow, Salem Gage, For Low Water Months by Years - cfs (36)

Year		Month			
		June	July	August	September
1958	Release	0	675	1,780	3,000
	Salem Gage	13,590	7,328	5,878	7,463
1959	Release	0	890	2,010	2,590
	Salem Gage	11,200	6,158	5,472	9,190
1960	Release	0	785	1,800	2,710
	Salem Gage	15,510	6,345	5,945	6,559
1961	Release	280	1,240	2,360	2,640
	Salem Gage	11,290	6,419	5,843	6,602
1962	Release	9	705	1,800	2,630
	Salem Gage	13,300	6,543	6,435	6,886
1963	Release	0	640	2,070	2,740
	Salem Gage	9,886	7,765	6,078	7,077
1964	Release	17	530	2,100	4,030
	Salem Gage	20,000	8,318	6,873	7,786
1965	Release	60	635	1,860	3,780
	Salem Gage	7,878	5,536	5,795	6,498
1966	Release	160	930	2,580	4,120
	Salem Gage	6,849	5,415	5,342	7,694
1967	Release	25	2,050	3,090	4,260
	Salem Gage	9,234	5,967	5,459	7,193

During the 10 year period of Table 8, the average release of water from impoundments amounted to 36.7 per cent of the flow at the Salem gage. Assuming some degree of constancy of other factors over the years, it could be concluded that the augmented flow is handling about one-third of the pollutional load on the river. It has been said that, "Waste treatment alone cannot provide the level of quality that is desired in the Willamette Basin. Because of association of pollution with depleted summer flows, augmentation of flow by regulated releases from basin reservoirs is necessary for an effective pollutional control program"(37).

Releases of water from reservoirs in the basin generally provided for withdrawal in September and October with emptiness in November, December and January to care for flood control. Filling was generally accomplished in February, March, and April. Drawdown in the summer months of July, August and September is in conflict with beneficial uses of summer recreation and October-November power generation. It is fortunate that augmented streamflows for navigation correspond to needs for water quality control. Under the Federal Water Pollution Control Act, storage to provide for flow augmentation and regulation can be designated as a function of Federal reservoirs. Calculations have already been made for the necessary increases in reservoir capacity for additional storage to maintain flow requirements. Roughly an increase of 700 cfs at the Salem gage by the year 2000 will be required (24).

It should be pointed out that maintenance of 6,000 cfs Salem gage provides approximately 1.8 times the most probable, monthly, minimum, average, natural flow as indicated by the statistical study of flow data from 1928 to 1949 (7).

With reference to an editorial in the Oregon Journal in 1971, Colonel Paul D. Triem, District Engineer of the U.S. Corps of Engineers, wrote:

"There is, however, one significant contribution to the Willamette River's improved water quality which the editorial did not mention. That contribution is one of which we in the Corps of Engineers are particularly proud. That contribution is the low-flow augmentation of the river during the summer months provided by water releases from Corps of Engineers' lake projects in the middle and upper valley.

"As natural flows recede, in the period from early July to late August, the release of stored water from upstream projects amounts to as much as 1-1/2 to 2 times the natural flow. That is, if water were not withdrawn from storage during that period, and only natural flows from all of the basins streams were left in the river, the flow through the Portland harbor area could be as little as one-third of the amount we now experience during that period"(38).

Although only incidental to quality of water of the Willamette River, it is noteworthy that the impoundments on the river have prevented flood damage all out of proportion to the costs of the structures. The flood period of January 1972 was mild compared to other periods such as 1964. Still, the damage prevented by control of the more than 1.1 million acre-feet of storage amounted to in excess of $66 million. This is between 7 and 8 times the estimate of the actual damage. Without the control in the 11 flood control projects, river peaks would have been from 7 to 13 feet higher than occurred. The increase would have been on top of flood stage runoff or somewhat higher flows.

More than 240,000 acres in the Willamettte Valley are irrigated from the main stem or the tributaries of the Willamette River. In 1965, the water requirement for irrigation approximated 569,000 acre-feet. The flow of some tributary streams is nearly depleted during the irrigation season which corresponds to the period of low flow(2). The withdrawal for irrigation does not of itself pose a problem, but it does reduce the flow at locations where it is then impossible to maintain water quality. In 1965 there were holders to 28,970 cfs of water in the Willamette Basin.

Because of withdrawals for irrigation, pollutional loadings on the river and tributaries, and the potential of minimum water years, the Oregon State Water Resources Board under authority specified in ORS 536.200, set minimum stream flows at 96 gaging points in the Willamette Basin. Some of the minimum flows are a combination of natural runoff and storage release. In many of the tributaries there is over-appropriation of water rights. At such a time as the minimum specified flows are reached, the State Engineer can restrict water use. Table 9 gives some minimum established flows for the main stem of the Willamette.

Table 9

Minimum Specified Flow of the Willamette River (2).

Station	Specified Flow - cfs		
	Natural	Storage Release	Total
Gage 14-1740 Albany	1750	3140	4890
Gage 14-1910 Salem	1300	4700	6000
Gage 14-1980 Wilsonville	1500	4700	6200

In 1965, the 28,970 cfs of appropriated water in the Willamette Basin was comprised of 6,059 cfs for consumptive uses and 22,911 cfs non-consumptive. These rights included use classified as domestic, municipal, industrial, irrigation, power generation, mineral, fish life, recreation, and wildlife. Power had by far the longest appropriation with 22,039.724 cfs(2).

The impoundments on the Willamette River system are relatively new and the effect upon water quality is uncertain. There have been some turbidity problems as well as algal growth. At least one fish kill is recorded due to water release. It is expected that some adverse conditions may develop which may diminish the benefits of augmented water flow in minimum water periods; however, it would appear from the generally stable condition that persists in the up-river reaches, that release from impoundments has had, to date, a minimal effect upon quality(37).

Over the years, and particularly since 1948-49, there has been continual progress in the collection and treatment of municipal wastes which, in many locations, handle a heavy industrial load as well as the domestic load. For example, 17 of the major municipalities in the Willamette Valley, exclusive of Portland, have treatment plants with a domestic capacity of 412,195 population equivalents, but an industrial capacity of 1,104,340 population equivalents. The 1970 loadings on these installations approximated 68% of designed capacity for domestic wastes and 61% of designed capacity for industrial wastes. Since 1948-49, the domestic waste loading on the Willamette River has declined to the point where approximately 85% of the load is removed by secondary treatment at all installations in the basin. Since 1940 and through 1970, approximately $213 million has been spent in construction of treatment plants, waste gathering facilities, and separation of storm runoff from domestic wastes. Figure XVI gives an indication of the rate of removal of domestic (plus industrial loads carried by municipal plants) loadings from the river over the years.

In the process of construction of domestic treatment and gathering facilities, the federal and state construction grant programs have assisted by the sums of more than $32 million federal appropriation and $49 million state appropriation (33).

The wastes from the pulp and paper industry have always been a major pollutional load on the Willamette. In the early days, all wastes were discharged directly to the river and in 1948, the four sulphite mills on the main stem discharged wastes in excess of 2,500,000 population equivalent. Subsequently, additional plants were constructed at Springfield in 1949, Albany in 1955, and Halsey in 1969. One of the oldest plants in the west has been at Lebanon on the Santiam River since 1890. Accordingly, in 1970 there were 8 plants on the Willamette River above Portland, with a total potential loading on the river, had the mills continued the amount of production and type of operation current in 1965, of more than 4,490,000 population equivalent. However, by 1965 the practices of ponding, barging, or changes in process had resulted in reduction of waste by 76 per cent for the low water period. All mills had installed primary treatment of waste by 1969 and all are required to have installed secondary treatment by July 1972.

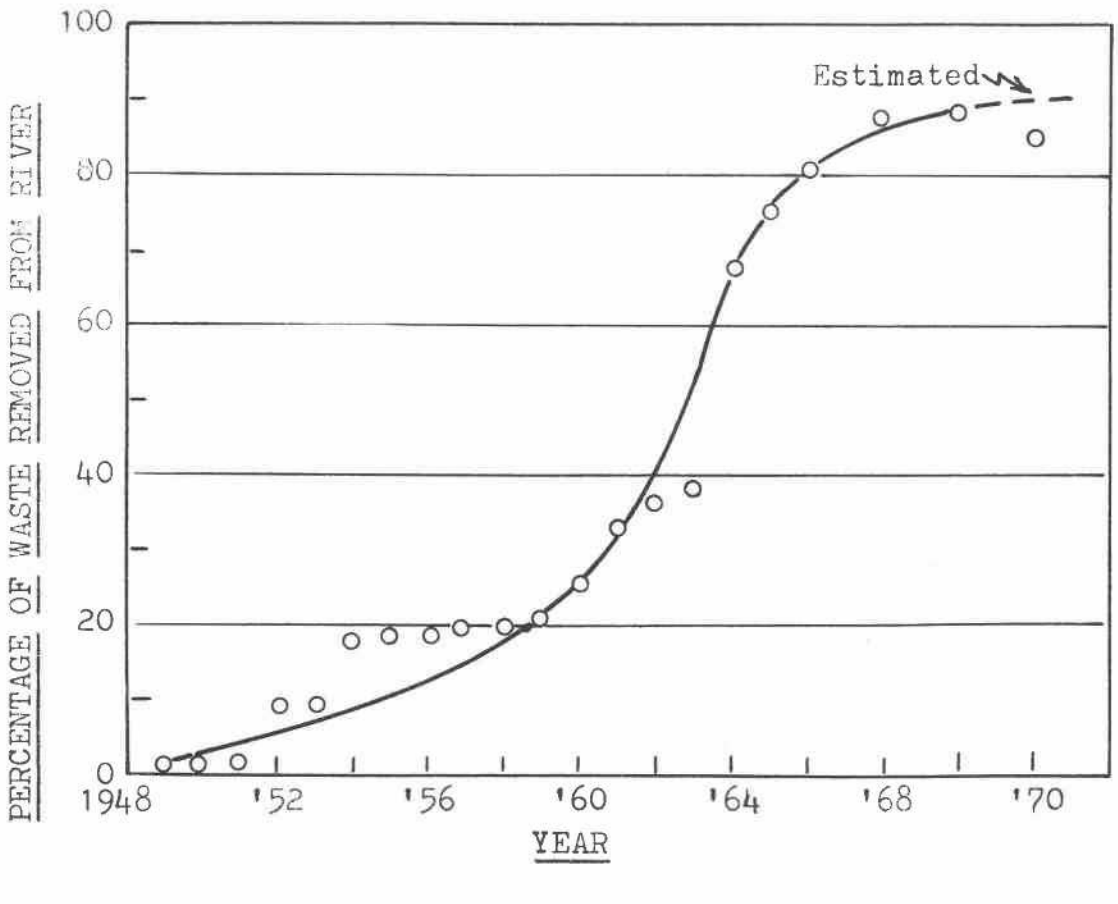


Figure XVI- Removal of Domestic Wastes from the River

Two of the mills changed operations from calcium sulphite base to ammonium sulphite base and two from calcium sulphite to magnesium sulphite. The change allowed chemical recovery. One mill abandoned pulping rather than spend the necessary sums for process change. Since 1948, the mills have spent approximately $35 million effecting the improvements which have increased the efficiency of removal of wastes from the river roughly in accord with Figure XVII

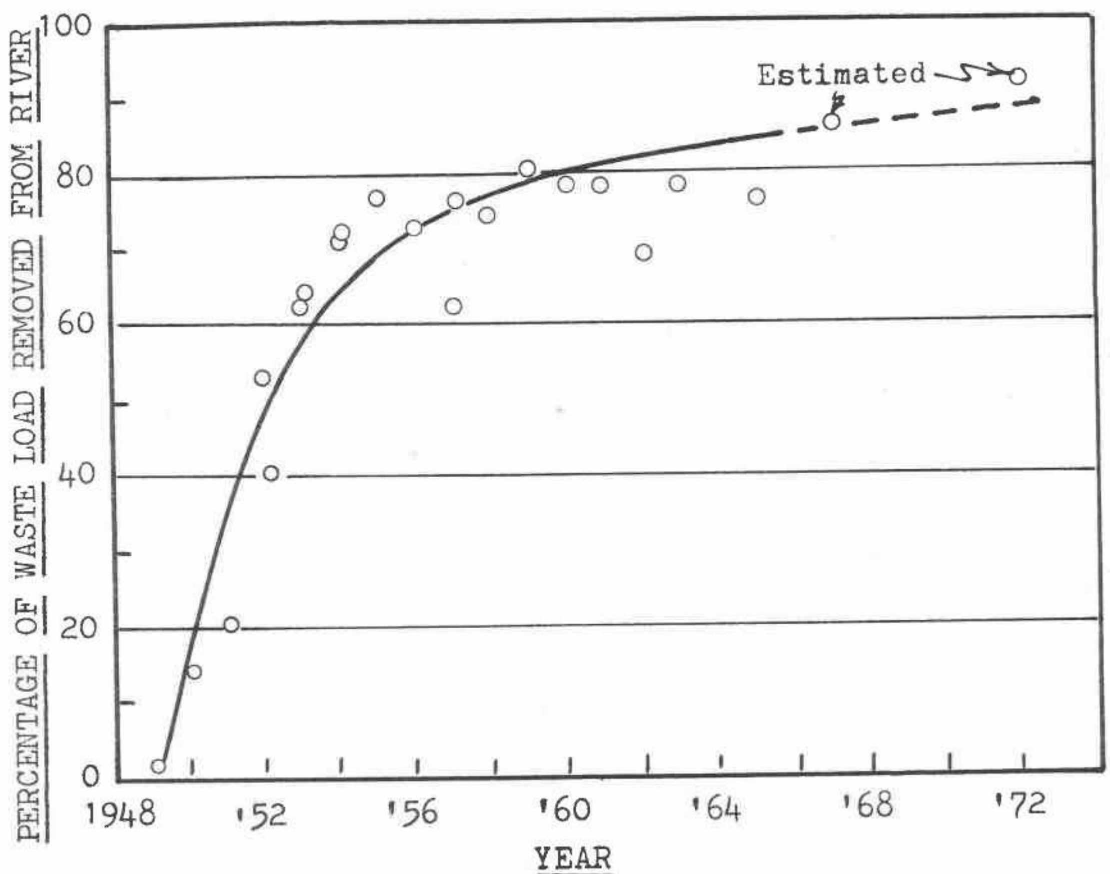


Figure XVII- Removal of Pulp and Paper Wastes from the River

A generalized indication of the decrease in waste discharge to the river may be obtained from Figure XVIII.

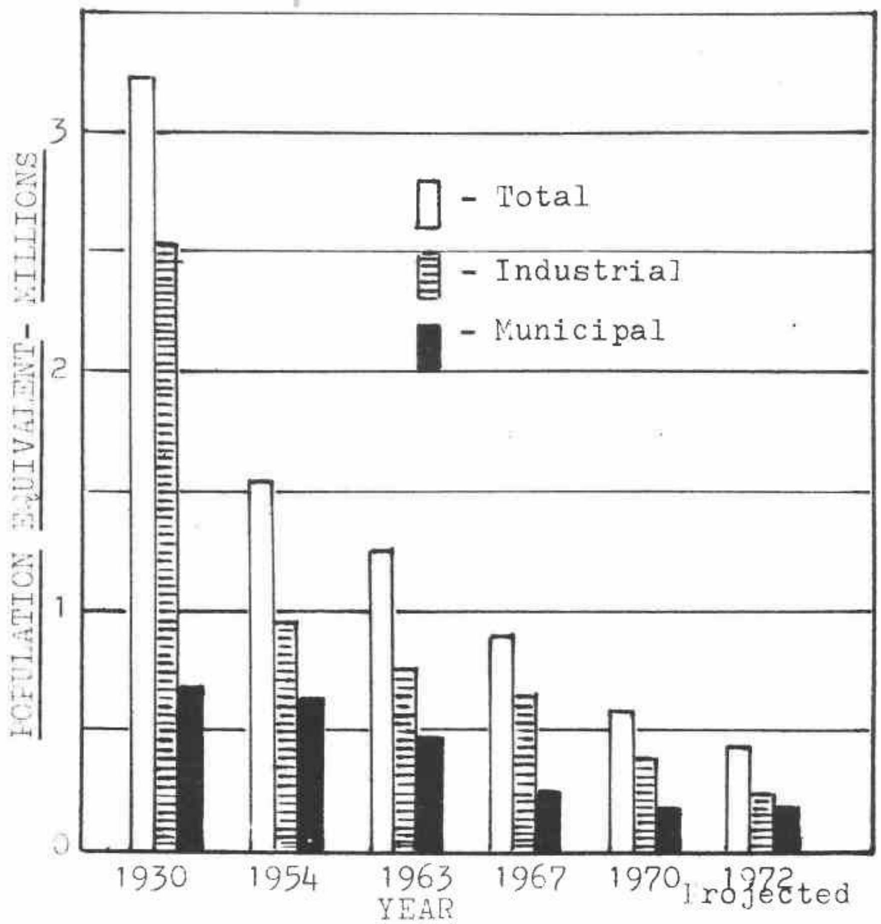


Figure XVIII - Reduction of Wastes to the Willamette River by Years

Subsequent to the difficulties encountered by the City of Portland between 1958 and 1961, the treatment of this largest domestic loading on the river has accelerated as indicated by Figure XIX. Only a very small fraction of the Portland wastes remain to be picked up and passed through treatment facilities. Only recently, the City of Portland has started construction of a secondary treatment plant. Since the Portland treatment facility was first constructed, it has operated only as a primary treatment plant with the effluent discharged to the Columbia River. The new facility, contracted to cost in excess of $16 million, is expected to be in operation by 1973(39).

Since 1954 an annual short school program has been conducted for sewage works operators by Oregon State University in cooperation with, at different times, the Oregon State Board of Health, the State Sanitary Authority, the League of Oregon Cities, the Pollution Control Federation, and the Department of Environmental Quality. Each person in attendance at the short schools is officially registered at the University and participates in a curriculum which covers classroom and laboratory study at four different levels.

As a result of the short schools, a voluntary certification program was developed. The certification program makes possible a degree of evaluation of personnel whose experience and knowledge are necessary to any successful pollution abatement program. Capability of operators is particularly important among those involved in test procedures and reporting. Table 10 provides record of short course accomplishments.

Table 10

Sewage Works Operators Short School

Year	Attendance	Certification
1956	50	17
1957	59	9
1958	72	7
1959	72	28
1960	67	33
1961	72	35
1962	89	34
1963	94	45
1964	105	52
1965	105	43
1966	105	57
1967	135	69
1968	151	70
1969	176	68
1970	186	79
1971	221	74

In summary, action to improve the condition of the Willamette River started more than forty years ago. First efforts provided factual information sufficient in scope to convince the people of the state that remedial action was required. The people responded and created the legal entity embodied in the State Sanitary Authority, now the Department of Environmental Quality, which body could formulate policy, regulations, standards, and procedures for pollution abatement and control. Although an action program was initiated immediately after formation of the Authority, progress in river improvement has been slow. Once established by action of the people, statutes were amended and authority extended until the Authority had effective regulatory powers. Regardless of such powers as resided with the Authority, river improvement has been very much a

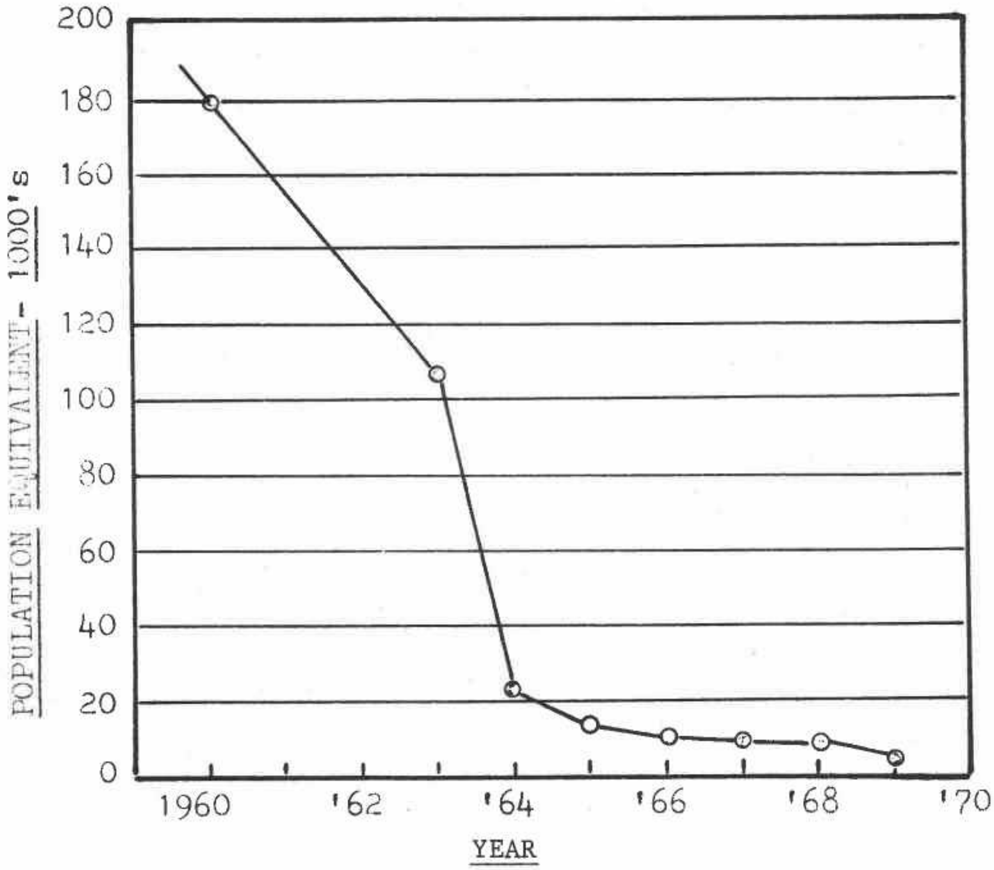
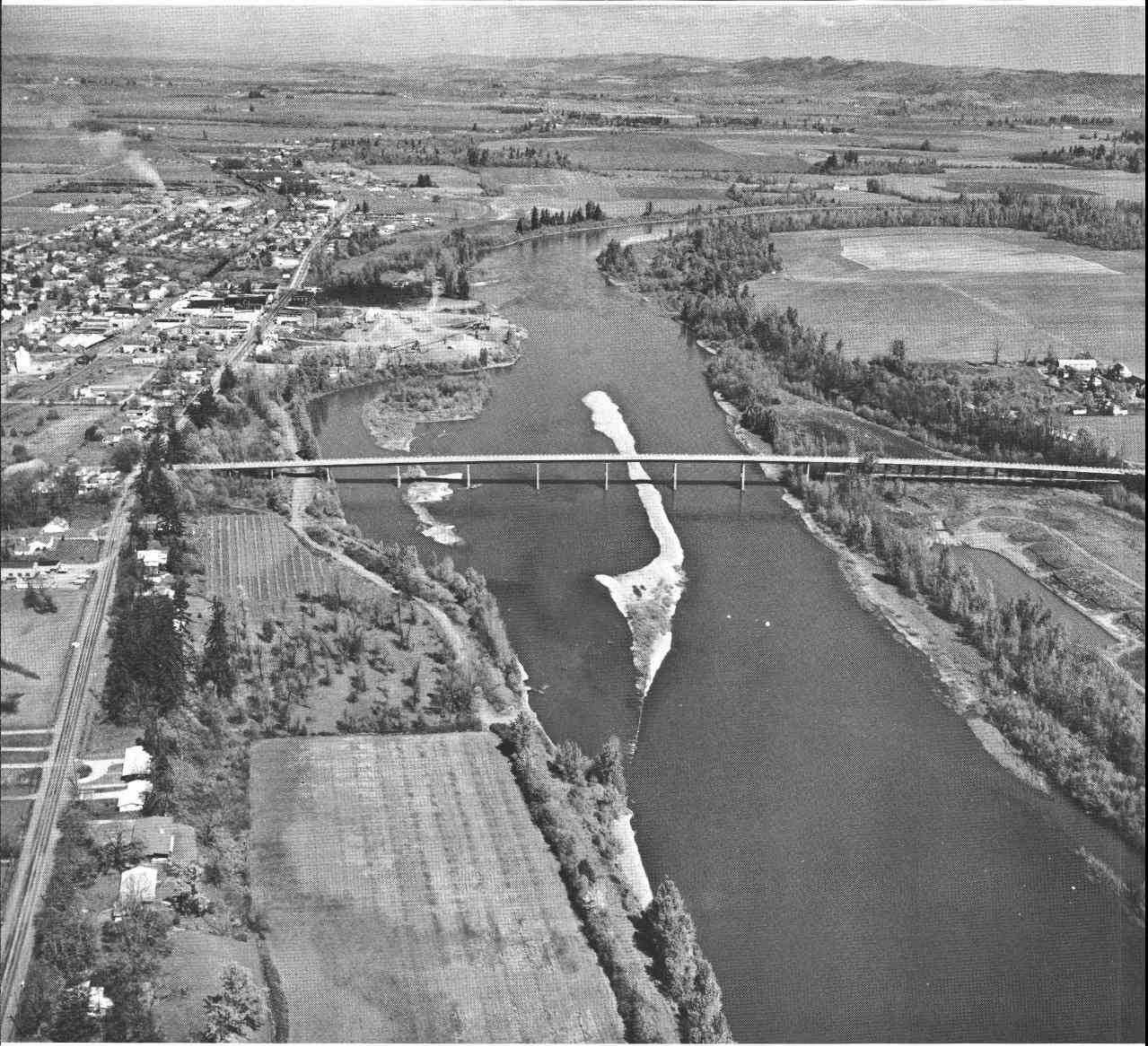


Figure XIX- Reduction of Wastes from City of Portland. Reference (40) cooperative effort. The pace of improvement has been slowed by economic consideration of very real magnitude which has probably approached $300 million over the years, by population increase, by industrial expansion, and by alteration of environment due to multiple activities including construction of the many upriver impoundments.

It was fortunate that low flow augmentation was made possible over the past two decades. It was fortunate that federal assistance was available to augment state assistance to local governments. It was fortunate that a tax relief program was initiated as well as a program of waste discharge permits. Even with all of the incentives for improvement and with even stricter regulatory control, the Willamette River, in the low water period of 1967, was below the established standards of quality. However, in retrospect, it appears that 1966-69 was an interim period when the effects of programs already initiated were not yet apparent.

Measurements of water quality, the strength and amounts of wastes, the amount and time of flow of the river; determination of the probability of extremes of flow; calculation of the required impoundment to produce given river flow augmentation; evaluation of the biological life of the river, all of these determinations and more have engaged the time and effort of individuals, industrial organizations, governmental agencies, educational institutions, county and city governing bodies and others in the many river studies which have extended over the forty year period. Final evaluation of the results of these many efforts forms the subject of the writing which follows.



The city of Independence, almost 100 miles from the mouth of the river, is located on fertile bottom lands, and was once a major hop growing center.

EVALUATION

"No one has a right to use America's rivers and America's waterways that belong to all the people as a sewer. The banks of a river may belong to one man or to one industry or to one state, but the waters which flow between those banks should belong to all the people."

Lyndon B. Johnson

River Returned

Those who had experiences on the Willamette River from 1926 until the mid-forties could have justifiably classified the river as an open sewer. Indeed, there were those who looked at the costs of improvement and suggested that the river be so classified. It is fortuitous that public opinion was for improvement; otherwise the river could easily have been lost forever because each year of neglect simply increased the magnitude of an already difficult problem. For more than forty years, the river remained in unsatisfactory condition and below acceptable standards. There had been some sporadic improvements as indicated in the prior section of this writing, but the improvements were never wholly adequate until 1968. In the low water year of 1968, the results might have been described as spectacular although no great publicity was given the fact that the river had met standards in all of the river above Newberg (33). Far less was written about the improved condition in 1968 as contrasted to the severe criticisms directed at the Authority, both locally and nationally, in 1965 when, because of necessary repair at one of the paper mills, the DO in the river was extremely low for short intervals. In retrospect, it appears that 1968 was the year of return of the river to a long anticipated condition of acceptable water quality. Certainly the quality of 1967 was unacceptable since standards were not achieved below Albany, Oregon.

The years 1969-71 showed increased improvement over 1968 with all three years showing a DO content above standards for the entire length of the river during the low water period. It has been pointed out that the improvement in the three year period was due to augmented flow which for the low water period averaged 10,400 cfs in 1969, 7,100 cfs in 1970, and 9,610 cfs in 1971, Salem gage. Although very important, it is believed that river flow was but one factor in improvement since from 1968, the domestic wastes discharged to the river had reached a point of maximum elimination as was also true of the pulp and paper wastes (see Figures XVI and XVII). Further, waste treatment was such that combined with higher water flows, it would be expected that sludge bank formation would be minimal and older deposits would have been flushed from the river or stabilized. Also, in 1968, when standards were met in all but a small part of the river, the river flow was about at the average of the prior ten years, being approximately 6,000 cfs (see Figure IX).

Figure XX shows the DO content of the river above the Willamette Falls for various selected years as compared to the 1968-70 average and to the August 1971 values. It should be emphasized that the 1968-70 averages represented 244 samplings of the river and the 1971 values, 62 samplings which in all years were over the one month period of lowest water. The improvement appeared to be decisive.

During 1971, the BOD in the low water period above Willamette Falls ranged from an average high of 1.1 mg/ℓ (river mile 83.9) to an average low of 0.6 mg/ℓ at both sampling stations at river mile 34.4 and 27.8. At no time in years 1953-63 had the average BOD values in the river been below 0.8 mg/ℓ and over the 11 year period at river mile 27.8 would have averaged 1.3 mg/ℓ. In 1967 and 1968 at river mile 27.8 the average BOD was 1.2. It appears reasonable to conclude that the waste load on the river had been materially reduced between 1967 and 1971. It is pertinent to mention that even uncontaminated water shows some BOD, depending upon the natural, organic content.

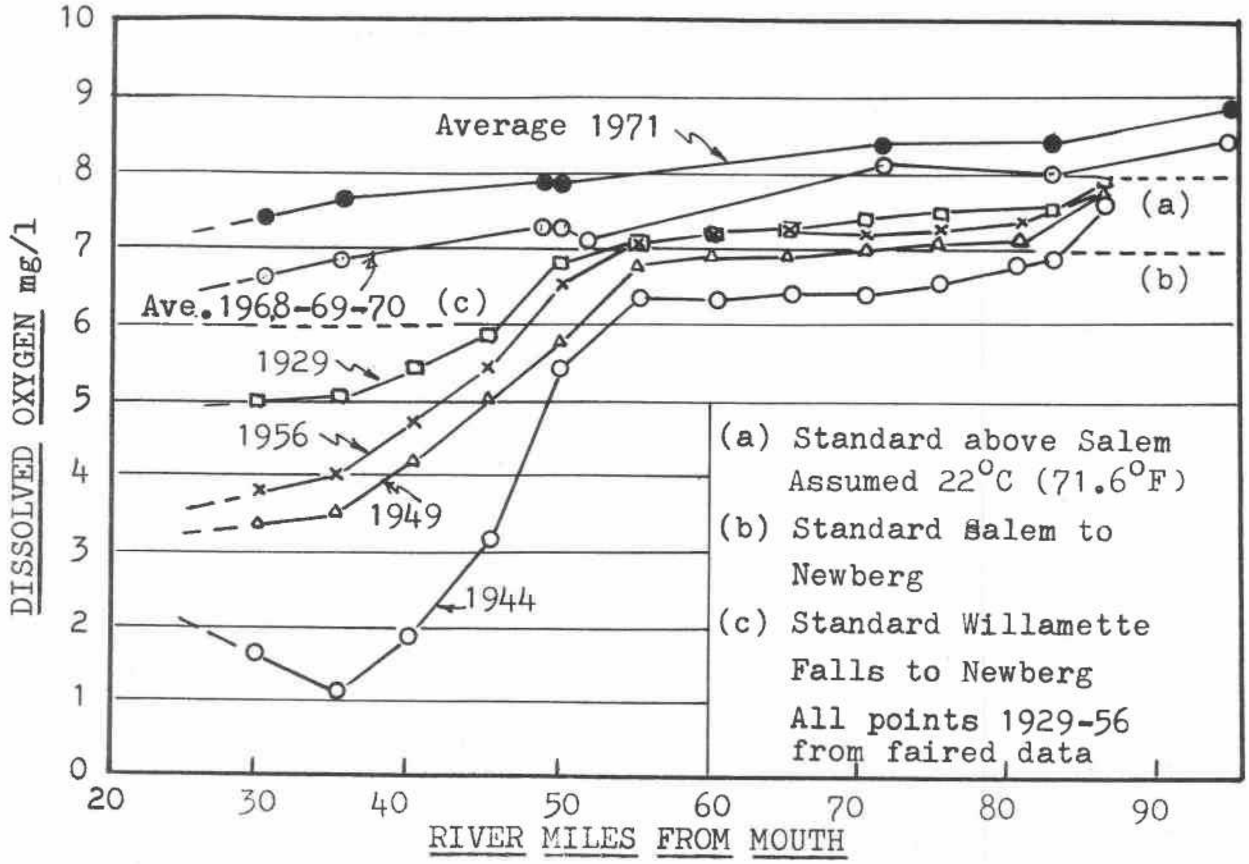


Figure XX- Up-river Data for Dissolved Oxygen by Selected Years

Even with the augmented flow in the low water period of 1971, the temperature of the river remained high with station averages varying from 20.7 to 21.6°C (69.3-70.9°F). At river mile 27.8 the temperature averaged 21.3°C in 1971 which might be compared to the range of 20-22°C with an average of 20.9°C (69.6°F) in the period 1953-63. Perhaps no significant lowering of river temperatures can be expected for the low water periods, now or in the future.

In the lower river below Willamette Falls, the improvement pattern was as satisfactory as in the upper river for the years 1968-71. Figure XXI attempts to show the improvement over the years from 1934 when the DO went to 0 compared to the 1971 results when the DO in the Portland harbor was above 6.0 mg/ℓ. Figure XXI appears typical in form to results of studies of other rivers of the country where treatment has been reasonably effective in waste load reduction (10).

The values shown in Figure XXI should be compared to those shown in Figures X and XI. In 1968-71 and for the first time in the forty year period, the DO in the lower harbor reach of the river exceeded 5 mg/ℓ standard for the low water period. This value should remove the barrier to fish passage (17). It is believed that, since the 5 mg/ℓ standard has been exceeded for four successive years, the circumstances in the lower river could be such that the standard may be maintained. Figure XXII for DO values over a long period of time at the S.P.&S. Railway Bridge in the lower Portland harbor and Figure XXIII showing average DO values by year and month of the year for the lumped lower Portland harbor values confirm the more generalized values of Figure XXI.

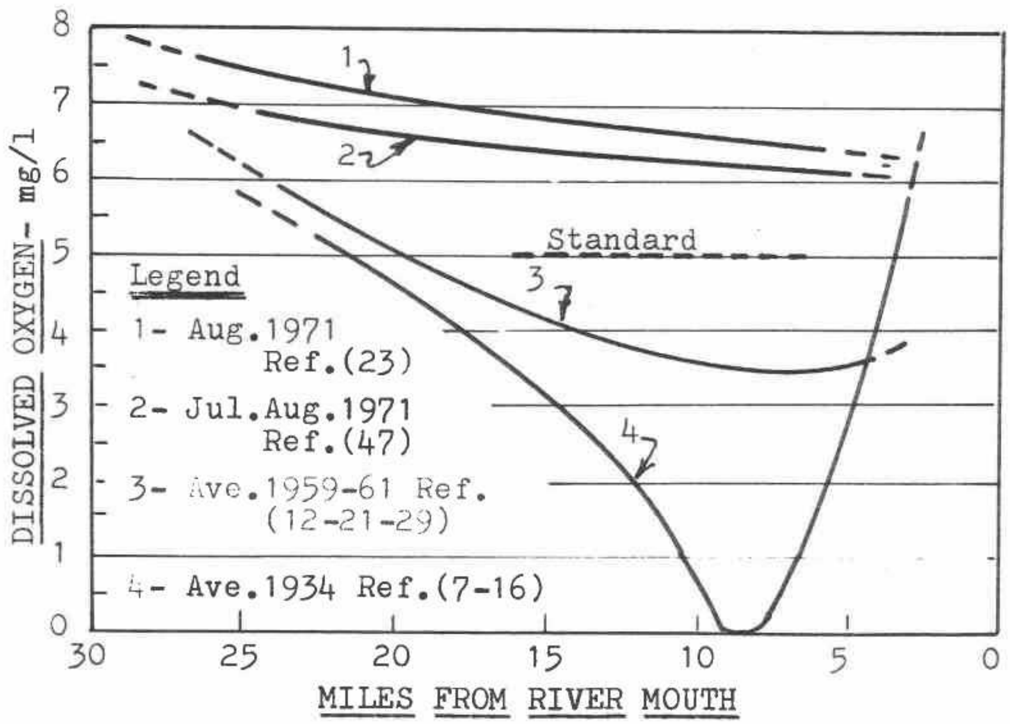


Figure XXI- Typical River Recovery Curves Applicable to Willamette River

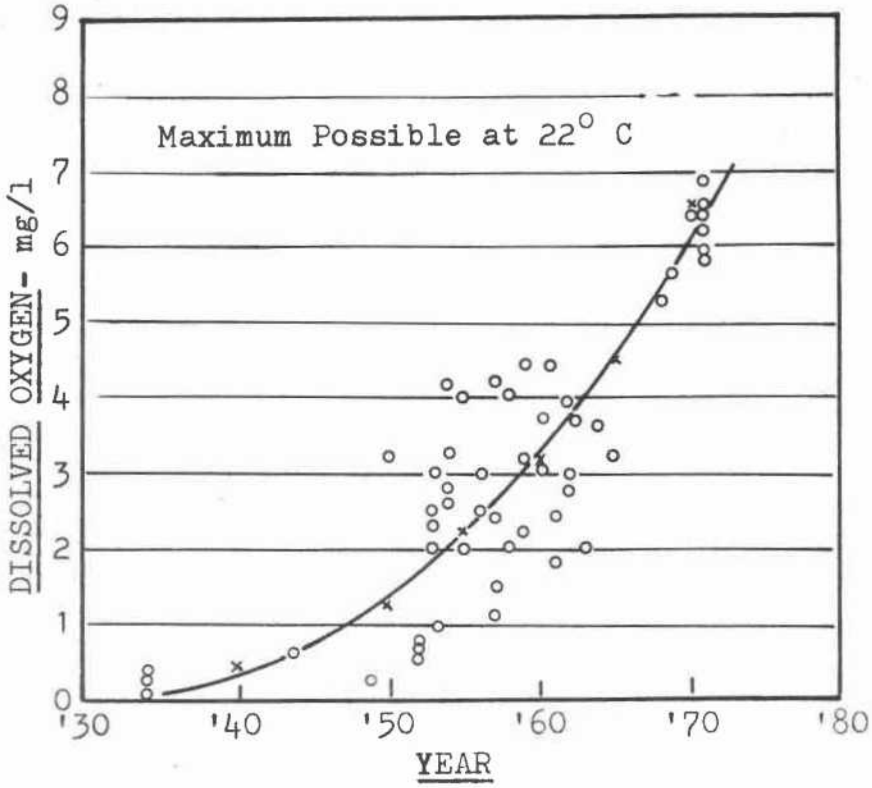


Figure XXII- Generalized Curve of Improvement at S.P.& S. Bridge in Lower Portland Harbor.

A portion of the U.S. Public Health Service data of Figure XIV is repeated in Figure XXIV to show the improvement in the fecal coliform count for the months of August-September, 1962 compared to 1970. As will be noted, the count has dropped by a factor of 10 to 100 times. Where in 1962 the highest count was approximately 9,000 and the lowest count approximately 300 coliforms per 100 mℓ, the 1970 count showed a maximum of 200 and a minimum of 45. All figures are averages for the two months. The difference between 1962 and 1970 is significant in that water quality standards from a bacteriological standpoint have been achieved.

By all customary criteria of quality, the Willamette River may be considered as having recovered from a condition where it was practically "killed" by pollution. The recovery was the result of numerous pressures, law, public opinion, recognition of responsibility, concerted effort, and cooperation.

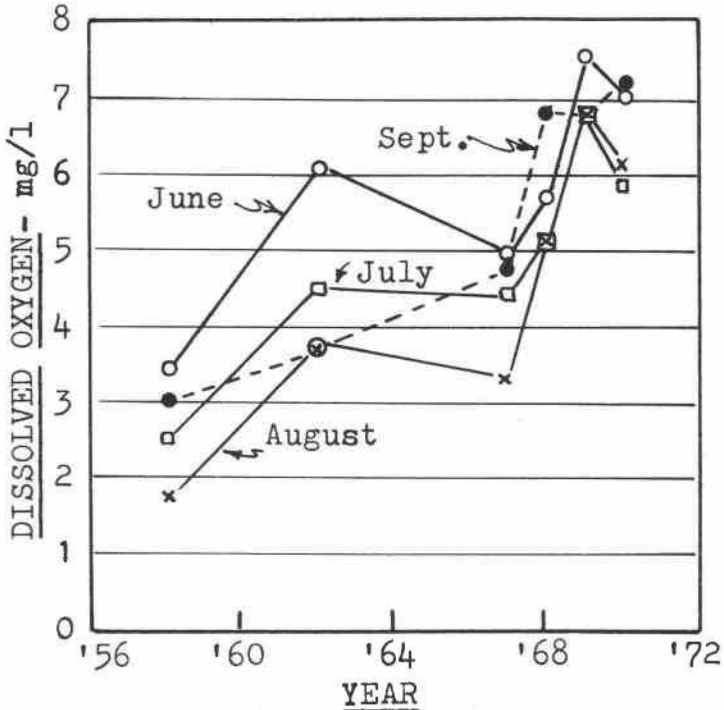


Figure XXIII- Dissolved Oxygen in Lower River by Years and Months

Known to Others

The accomplishments on the Willamette River have received attention from others whose interests center on conservation. Recently, McGraw Hill's magazine "Power" presented an award to the Publishers Paper Company at Oregon City for its participation in the reduction of wastes to the river. In an editorial entitled "Others Know About Our River," the Oregon Journal cited an editorial in the Spartanburg, South Carolina Herald which pointed to the Willamette River as an example of what can be done (48). Jules Loh in referring to the condition of the Columbia River as "quite sick" also said, "The Willamette, which joins the Columbia at Portland, at one time seemed in even worse shape, (than the Columbia) from waste pollution, but Orgonians refused to let it die. ----Today, because of the efforts of many different groups, salmon thrive in the Willamette." (49) Scheduled for publication in June 1972 in the National Geographic will be an article featuring the Willamette River's deplorable state a decade ago as compared to the present condition (50).

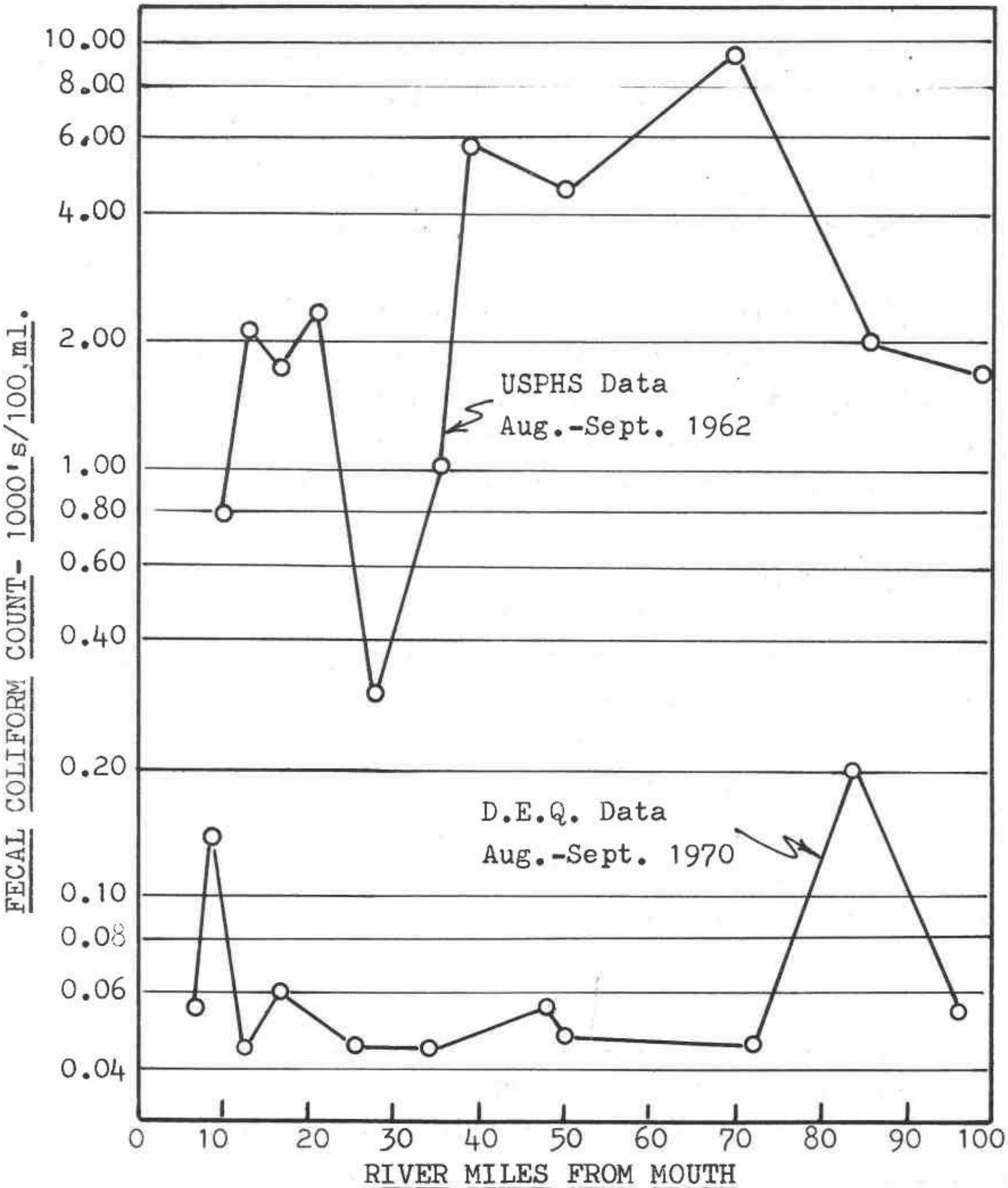


Figure XXIV - Fecal Coliform - 1962 and 1970

The Green Way

In accordance with the policy of the State of Oregon toward outdoor recreation resources as expressed in ORS 390.010, there was established the Willamette River Park System. In ORS 390.320 the policy establishing the System declared that, "in order to protect and preserve for present and future generations of citizens the natural scenic and recreational value of the Willamette River, it is in the public interest to acquire and develop along the Willamette River a recreational system to be known as the Willamette River Park System." The System is locally called the Willamette Greenway.

The Willamette River Park System was conceived in 1966 and enacted into law in 1967. The concept was to establish a green strip along each bank of the river from the Columbia River to Dexter Dam, a distance of some 255 river miles. It soon became apparent that the green strip concept was not entirely practical over the entire river distance and on both banks, so the concept was changed to the Park System which infers intermittent areas along the river. Lands acquired under the System reside with the local governments of the acquired areas and originally local government paid one-half the acquisition cost with the State paying one-half. In the spring of 1968, the Federal Government made available $1.6 million which cut the match by the State to 25% and the local government to 25%. In January of 1971 an additional allotment of $500,000 was received from the Federal Land and Water Conservation funds. Under the program up to late 1971, 32 projects had been purchased along 6-1/2 miles of river shoreline at a cost of $2,750,000, most of the projects being near centers of population and expensive.

Recently, in response to application to the Bureau of Outdoor Recreation, the Governor of Oregon announced receipt of $5 million to be matched by $5 million from State Highway funds, the new program making possible acquisition of about 156 miles of river frontage. This would advance the program to the point where the total program of some 200 miles appears to be feasible of future accomplishment.

With a clean river and the Willamette River Park System, the State will have an enviable heritage; one that has been compared to the public ownership of Oregon's beaches. With the Park System, the Willamette River will once again approximate its original usefulness, namely a major recreational resource of the Willamette Basin and, accordingly, for a majority of the people of Oregon (51).

The Fishery

It has long been recognized that the Willamette River and its tributaries are important spawning grounds for anadromous fish and have contributed markedly to the fishery of the Columbia River as well as to the off-shore catch. The exact extent of the contribution of fish spawned in the Willamette itself is uncertain, but both the Fish Commission and the Game Commission of Oregon consider the river to be an important part of the regional program of fisheries. The spring run of Chinook salmon has been the most important, since the fall run could not negotiate the Willamette Falls in any large numbers during the fall periods of low water. The falls were always a major barrier to fish passage, but particularly so since the construction of a concrete dam around the lip of the falls in 1903-4. There had been efforts to provide a fish passageway over the falls as early as 1885, but the efforts were only partially successful. Only recently, through cooperative effort under the Columbia River Fishery Development Program of the Bureau of Commercial Fisheries and the Fish Commission of Oregon, an adequate passageway has been constructed. The facility was partially operational in 1968 and in full operation in 1971.

Also, because of the kill of downstream migrants in passage through the power turbines at the falls, an agreement has been reached whereby both the power company and the paper industry have agreed to shut down units during the periods of heavy downstream migration. The combination of an adequate fishway for upstream passage, protection of downstream migration of juvenile fish, and water quality in the river at all periods should insure the continuation of the fishery resource of the Willamette River (52).

Obviously, fish spawning grounds were lost by the construction of high dams at the various impoundments on the river. To compensate for the loss of natural habitat in whole or in part, 9 salmon-steelhead hatcheries are operated in the Willamette Basin. It is the juveniles from these hatcheries which are protected by the turbine shutdown agreements of November 9, 1971.

The Future

Oregon has a right to be proud of the job that has been done in cleaning up the Willamette River. But the job is not finished. Future population in the Willamette Basin is estimated at 1,767,500 persons in 1980, 2,422,000 persons in 2000 and 3,591,000 by the year 2020. Future growth will require continuing effort to maintain water quality and at costs which will be more or less directly related to population increase. However, if water quality is maintained, the river will become increasingly important to a larger number of people.

Perhaps the most critical aspect of the maintenance of water quality is the quantity of water during the low water periods. Long range plans for the next 50 years call for 87 additional storage projects in the Willamette Basin, 52 of which should properly be designated for early action in the next 10 to 15 years. Seventeen of the early action projects would be adjuncts to the present system. The remaining 35 out of the 52 would be operated on a watershed basis and contribution to the main stem of the Willamette would be incidental. Including the proposed Dorena Dam modification and the Holley enlargement, the 17 additional impoundments would provide 1,349,000 acre-feet of storage. By such storage the future augmentation of natural flow necessary to maintain water quality can be assured. It is recognized that there is strong opposition to the construction of additional impoundments on the river, but there has been no alternative offered by which water quality can be assured.

As has already been mentioned, there are conflicts which arise when an appreciable amount of water is released from impoundments for augmentation of summer flows. Recreation suffers and future power potential is lost. If any appreciable portion of the anticipated 1,349,000 acre-feet of storage were added to the 1,897,690 usable acre-feet already available, conflicts of interests would be minimized and high summer flows could be sustained. Certainly, the plus and minus factors associated with additional impoundments should be carefully considered by all interested parties.

As far as the future is concerned, it is hoped that as population pressures increase, the quality of life in Oregon does not decline. There are mathematical models which indicate that even at a 2 percent growth rate in population and the adoption of a vigorous pollution control program, environmental deterioration cannot be prevented (53) short of control of population itself. Such control has been advocated in Oregon and in a measure is practiced; however, there is no question but that the problems of the future will depend largely upon the planning and action of today.

In Summary

It seems fair to say that over the past forty or more years the Willamette River was in unsatisfactory condition as regards water quality. At times the condition was deplorable in the low water periods. The people of Oregon acknowledged the problem and, at an early date, created an authoritative agency to effect improvement. By consistent effort and the expenditure of large sums of money, municipalities provided waste treatment facilities for both domestic and permissible industrial wastes. By equally consistent effort and expenditure the pulp and paper industry effected reduction in waste discharges to the river. Standards of water quality were established, river flow regulation was adopted for the low flow periods, limitations on water usage beyond minimal quantities were designated at specific control points, and a permit program was developed. Suddenly in 1968, past efforts culminated in water quality meeting standards in a major

This is a view north of Albany, founded in 1848 by two brothers from Albany, New York, and once a bustling river port during the early days of the state.

portion of the river and over the entire river in 1969. The quality has been maintained through 1971. Conditions are now such that the recreational potential of the Willamette River has been re-established and a Willamette River Park System is rapidly coming into being. Provisions have been made for both upstream and downstream passage of fish. Plans for the control of river water have been formulated for both the near and distant future. In brief, the Willamette River has been returned to the people of Oregon.

BIBLIOGRAPHY

(1) M. D. Brands, "Flood Runoff in the Willamette Valley, Oregon," U.S. Geological Survey Water-Supply Paper 968-A, 1947.

(2) "Hydrology", Willamette Basin Comprehensive Study, Water and Related Land Resources, Appendix B, Willamette Basin Task Force, 1969.

(3) E. A. Hoerauf, "Willamette River: River Lands and River Boundaries," Water Resources Research Institute, Oregon State University February 1971.

(4) F. Merryfield, W. G. Wilmot, "1945 Progress Report on Pollution of Oregon Streams," Oregon State University, Engineering Experiment Station, Bull. Series No. 19, June 1945.

(5) R. E. Dimick, F. Merryfield, "The Fishes of the Willamette River System in Relation to Pollution," Oregon State University, Engineering Experiment Station, Bull. Series No. 20, June 1945.

(6) F. Merryfield, W. B. Bollen, F. G. Kachellhoffer, "Industrial and City Wastes, " Oregon State University, Engineering Experiment Station, Bull. Series No. 22, March 1947.

(7) C. J. Velz, "Report on Natural Purification Capacities Willamette River," Report National Council for Stream Improvement, Inc., May 1951.

(8) C. J. Velz, "Supplementary Report on Lower Willamette River Waste Assimilation Capacity." Report National Council for Stream Improvement, Inc., March 1961.

(9) __________, "Environmental Quality in Oregon 1971 - A Summary of Current and Future Problems," Report from the Advisory Committee on Environmental Science and Technology, Oregon State University, 1971.

(10) M. Gordon Wolman, "The Nation's Rivers," Science, V. 174 No. 4012, November 26, 1971.

(11) W. C. Westgarth, M. Northcraft, "Water Quality Data Inventory," Oregon State Water Resources Board, Bull. No. 1 (no date), Bull. No. 2, June 1957.

(12) __________, "Water Quality and Waste Treatment needs for the Willamette River," Report Oregon State Sanitary Authority, May 1964.

(13) C. V. Langton, H. S. Rogers, "Preliminary Report on Control of Stream Pollution in Oregon," Oregon State University, Engineering Experiment Station, Bull. Series No. 1, March 1929.

(14) H. S. Rogers, C. A. Mockmore, C. D. Adams, "A Sanitary Survey of the Willamette Valley," Oregon State University, Engineering Experiment Station, Bull. Series No. 2, June 1930.

(15) G. W. Gleeson, F. Merryfield, "Industrial and Domestic Wastes of the Willamette Valley," Oregon State University, Engineering Experiment Station, Bull. Series No. 7, May 1936.

(16) G. W. Gleeson, "A Sanitary Survey of the Willamette River from Sellwood Bridge to the Columbia River," Oregon State University, Engineering Experiment Station, Bull. Series No. 6, April 1936.

(17) F. F. Fish, R. A. Wagner, "The Formation and Lifting of the Oxygen Bloc in the Main-Stem, Willamette River," U.S. Fish and Wildlife Service, 1950.

(18) __________ Unpublished data, Oregon State Sanitary Authority (Department of Environmental Quality), 1949-50.

(19) __________ Unpublished data, National Council for Stream Improvement, Inc. 1953-54.

(20) A. F. Gaudy, Jr., "Summary Report Willamette River Survey 1956," Report National Council for Stream Improvement, Inc., November 1956.

(21) J .E. Britton, "A History of Water Pollution Control in the Willamette Basin, Oregon." Working Paper No. 56, U.S. Dept. of Health, Education and Welfare. Public Health Service, Region IX, July 1965.

(22) M. Davenport, "Early Tests Show Salmon Can't Take Warm Water," The Oregon Journal, November 20, 1969.

(23) __________ Unpublished Data, Dept. of Environmental Quality, State of Oregon, 1968-71.

(24) K. D. Kerri, "An Investigation of Alternative Means of Achieving Water Quality Objectives," Ph.D. Thesis, Oregon State University, June 1966.

(25) "Water Pollution Control," WIllamette Basin Comprehensive Study, Water and Related Land Resources, Appendix L, Willamette Basin Task Force, 1969.

(26) C. J. Velz, "Significance of Organic Sludge Deposits," Technical Report W58-2, Robert A. Taft Sanitary Center, Cincinnati, Ohio, March 1958.

(27) C. J. Velz, "Factors Influencing Self-Purification and Their Relation to Pollution Abatement." Sewage Works Journal. V. 21, No. 2 March 1949.

(28) D. D. Harris, "Travel Rates of Water for Selected Streams in the Willamette River Basin, Oregon." U.S. Geological Survey, Hydraulic Investigations, Atlas HA-273, 1968.

(29) E. N. Kari, "An Evaluation of the Oxygen Resources in the Lower Willamette River During a Critical Low Flow Period." M.S. Thesis, Oregon State University, April 1963.

(30) W. Van Winkle, "Quality of Surface Waters of Oregon," U.S. Geological Survey Water Supply Paper No. 363, 1914.

(31) Nineteenth Biennial Report, State Board of Health of Oregon, July 1, 1938-June 30, 1939.

(32) "Implementation and Enforcement Plan for the Public Waters of the State of Oregon." Oregon State Sanitary Authority, May 1967.

(33) "Water Quality Control in Oregon," Department of Environmental Quality, State of Oregon, December 1970.

(34) Computer Read-Out, Data Bank, Department of Environmental Quality, State of Oregon, April 28, 1971.

(35) "Water Resources Data for Oregon, " Part I, Surface Water Records, U.S. Department of Interior, Geological Survey, Yearly.

(36) "Oregon's Long Range Requirement for Water," Willamette Drainage Basin, No. 2. State Water Resources Board, June 1969.

(37) "Water Quality and Pollution Control," Pacific Northwest River Basin Commission, Columbia-North Pacific Region-Subregion 9, Appendix XII, December 1971.

(38) "Corps' Role," Editorial, The Oregon Journal, December 12, 1971.

(39) "Milestone in Water Cleanup," Editorial, The Oregon Journal, January 11, 1972.

(40) __________ Private Communication, Department of Environmental Quality, December 23, 1971.

(41) Oregon State Planning Board, "Efforts to Reduce Stream Pollution in Oregon." Report to the Honorable Charles H. Martin, Governor of Oregon. February 1937.

(42). Public Health Section of the City Club of Portland, Oregon, Report "Stream Pollution in Oregon," The Pacific Engineer, V. VI, No. 5 May 1927.

(43) R. E. Koon, J. W. Cunningham, R. G. Dieck, "Report on General Survey of the Problems of Sewage Treatment and Disposl in the Willamette River Valley, Oregon." Submitted to the Honorable Julius L. Meier, Governor of Oregon and the Reconstruction Advisory Board by Board of Consulting Engineers on Sewage Disposal, August 1933.

(44) State Planning Board, "An Analysis of Stream Pollution Legislation." Report to the Honorable Charles H. Martin, Governor of Oregon and the Legislative Assembly of the State of Oregon. August 1936.

(45) J. Ronchetto, "Recommended Principles for Stream Purification Legislation." Report of Oregon State Planning Board, June 1937.

(46) J. LaPalombara, "The Initiative and Referendum in Oregon: 1938-1948." Monographs in Political Science, Oregon State University.

(47) __________ Unpublished Data, City Engineers Office, City of Portland, Oregon, 1971.

(48) "Others Know About Our River," Editorial, The Oregon Journal, November 29, 1971.

(49) J. Loh, "The Trampled Trail," Readers Digest, p. 235, February 1972.

(50) E. A. Starbird, Private Communication, National Geographic Society, December 6, 1971.

(51) "Recreation," Willamette Basin Comprehensive Study, Water and Related Land Resources, Appendix K, Willamette Basin Task Force, 1969.

(52) "More Willamette Fish," Editorial, The Sunday Oregonian, November 14, 1971.

(53) E. W. Peterson, "A Mathematical Model of the Relation Between Environmental Pollution and Population Growth," Proceedings of the Academy of Science, Vol. VI, 1970.

REFERENCES NOT CITED

The following references provide information pertinent to the Willamette River, but were not directly referred to in the foregoing text.

(A) W. J. Whitsell, "Variations in Quality of Water in a Typical River Cross-section," Thesis, Oregon State University, 1949.

(B) "Refuse Act Guidelines for 11 Industries Set," Air and Water News V.6, No.3, January 24, 1972.

Among the 19 effluent guidelines for specific industries issued by the Environmental Protection Agency is one related to the Pulp and Paper Industry for achievable effluent levels in pounds/ton of product for 9 divisions of the industry. Data on effluent includes five day BOD and total suspended solids.

(C) C. E. Warren, Biology and Water Pollution Control, W. B. Saunders Company, 1971. See p. 123-129, "Environmental Conditions Influencing Salmonoid Development."

Presents specifics for water velocities and dissolved oxygen for the survival and development of salmonoid embryos. Numerous references are included.

(D) R. E. Noble, "The Willamette River Fishes as Biological Indicators of Pollution," Thesis, Oregon State University, 1952.

(E) State Water Resources Board, "In the Matter of Formulating an Integrated, Coordinated Program for Use and Control of the Water Resources of the Lower Willamette River Basin," Report, 1965.

Also reports for the Middle Willamette River Basin and the Upper Willamette River Basin.

Presents the program which established the minimum water flows at the 96 gaging stations in the basin.

(F) Federal Water Pollution Control Administration, "Water Quality and Control and Management - the Willamette River Basin." Report. No date given. Also a summary report under the same title.

Presents a large amount of material on the Willamette River including river survey data. Points particularly to the need for flow augmentation during low water periods on the tributary streams, particularly the Tualatin and Pudding rivers, and Rickreall Creek. Comments upon storage requirements to meet specific flows at the Salem gage. Describes types of pollutants, treatment systems, impact of impoundments on water quality, and stream management practice. Discusses the procedure adopted for the 1965 low flow emergency period of approximately 60 days.

(G) Oregon State Sanitary Authority,"Stream Survey Report-Willamette River 1951." Also by the same title 1953.

Gives river loadings, river flow Salem gage, and water quality analyses in table form for several river samplings during the low water period of each year.

(H) Oregon State Sanitary Authority, "Water Pollution Control in Oregon," Annual Reports, 1957-1967.

Brings data accumulation up-to-date. Describes location of all sampling stations. Lists major sources of pollution. Lists requirements for effective improvement. Provides summary of accomplishments of municipalities, industries and the associated costs involved.

(I) F. F. Fish, R. R. Rucker, "Pollution in the Lower Columbia Basin in 1948 with Particular Reference to the Willamette Basin." U.S. Department of the Interior, Fish and Wildlife Service, Special Scientific Report No. 30, June 1950.

Gives results of river sampling of main stem of the Willamette and all major tributaries. Main stem sampled from Springfield to the Steel Bridge in Portland. Sampling in September and October 1948. All DO values were high and all temperatures low, probably due to high river flow during sampling period (above 6,000 cfs Salem gage). Cities references as in bibliography (4)(5)(14)(15) and evidently draws conclusions from references rather than results reported in the writing. This work was obviously a prelude to (17).

(J) R. E. Koon, F. Merryfield, "A Preliminary Survey of Industrial Pollution of Oregon Streams," Report to Advisory Committee on Stream Purification and Subcommittee on Present Stream Conditions to Oregon State Planning Board." May 15, 1937.

Essentially the same material in condensed form as in bibliography reference(4). No bibliography.

(K) R. E. Koon, "Stream Cleansing in Oregon, Past and Present Efforts to Reduce Pollution," Civil Engineering, V. 6, No. 10, October 1936.

Rewrite of same material as in reference (43).

(L) F. Merryfield, "Stream Cleansing in Oregon, Industrial Wastes in the Willamette Valley," Civil Engineering, V. 6, No. 10, October 1936.

Essentially abstracts from bibliography references (4)

(M) R. J. Madison, "Water Quality Data in the Willamette Basin." U. S. Department of Interior, U.S. Geological Survey Basic Data Release, 1966.

Gives chemical analyses of surface and ground waters of the Willamette Basin. Data for sampling at Salem starts in August 1910 and ends for September 1964. Analyses are also given for other sampling stations on the main stem of the river, both forks, and all major tributaries.

(N) __________, "River Mile Index Willamette River," Hydrology Subcommittee Columbia Basin Inter-Agency Committee, June, 1963.

Provides river mile distances, frequently drainage areas and elevations for locations at intervals on main stem of the Willamette River, both forks, all major tributaries and many minor tributaries. Elevations cover range from 2 feet (Portland harbor gage) to 5,414 feet.

(O) R. C. Davison, W. P. Breese, C. E. Warren, P. Doudoroff, "Experiments on the Dissolved Oxygen Requirements of Cold-Water Fishes," Technical Paper No. 1113, Oregon Agricultural Experiment Station, Oregon State University, 1959.

Describes 24 hour survival tests of juvenile coho salmon at various temperatures and various dissolved oxygen concentration. Results indicate higher temperatures require higher concentrations of dissolved oxygen for equal survival. Results for food consumption and growth are reported. Some tests made using sulphite liquor in test water. Some test results presented for sculpins. 17 citations in bibliography.

(P) J. M. Hutchison, W. W. Aney, "The Fish and Wildlife Resources of the Lower Willamette Basin, Oregon, and Their Water Use Requirements." Oregon State Game Commission Report. June 1964.

Describes the fishes of the Willamette River, Comments upon water quality in relation to fish life with particular reference to dissolved oxygen and temperature. Describes the condition at Willamette Falls with particular reference to fish passage both up and down stream. Ties future developments to improvement in water quality.

(Q) "The Willamette Valley Project," Report to the Hon. Charles H. Martin - Governor by the Oregon State Planning Board on the Development of the Willamette River Water Shed. May 8, 1935.

pp. 95-99 Sewage Treatment and Disposal in the Willamette Valley, Oregon. Describes need for action in cleaning up the river. Lists municipal facilities necessary and as recommended by the Board of Consulting Engineers. See reference (43)

(R) "Second Report on the Willamette Valley Project," Report of the Oregon State Planning Board to Hon. Charles H. Martin - Governor. January 30, 1937.

pp. 109-116 reviews in very brief form all past material related to condition of the Willamette River. For the first time in any publication, the control of pollution by regulation of river flow was suggested. No new data were presented. No bibliography.

(S) "Final Report Willamette River Basin Commission," to the Hon. Paul Patterson - Governor. December 31, 1955.

On p. 27 of this final report of the Commission there is a statement from the Oregon State Sanitary Authority which recognizes the importance of augmented stream flow in the maintenance of any dissolved oxygen in the Portland harbor.

(T) G. Eldredge, "Willamette Polluted," Oregon State Technical Record, V. 12, No. 1, January 1935.

Refers to 1934 river study, reference (16), and comments upon observations of H. B. Hommon, U.S. District Sanitary Engineer, that the condition of the river in 1934 was worse than in 1926.

(U) F. Merryfield, "Willamette Valley Stream Pollution Problems," Western Construction News V. 9 No. 10, October 1934.

A brief resume of the problems of pollution in the Willamette River with review of the results of the 1929-30 surveys of the river.

(V) J. O. Baar, "On Stream Pollution," The Pacific Engineer, V. 5 No. 12, December 1926.

Mentions the formation of the Anti-Stream Pollution League in Oregon and suggests duplicate organizations elsewhere.

(W) G. B. Thayer, "A Sanitary Study of the Willamette Valley," The Pacific Engineer V. 8 No. 9 September, 1929.

Presents a number of opinions on limits of the amount of dissolved oxygen to support fish life, numbers of bacteria, amount of suspended matter, and amount of water flow for pollution standards. Describes the wastes discharged to the Willamette River. Gives table of bacteria count in river from Cottage Grove to mouth for samples collected, presumably upon August 30 and September 7, 1928 since the writer appeared unaware of the 1929 survey.

(X) News Notes, "Willamette Valley Sewage Problems," Western Construction News, V. 8 No. 9, 1933.

Abstracts Content of bibliography reference (43).

(Y) News Notes, "Willamette Valley Sanitation Program Logs," Western Construction News V. 9 No. 2, February 1934.

Comments upon the fact that program in Willamette Valley has become dormant. Expresses hope that PWA program might give new impetus to control projects.

(Z) News Notes, "A Review of $10 Million Proposed Sewerage Improvement for Portland," Western Construction News, V. 13, No. 8, August 1938.

Describes the plans for the 28 mile interceptor system for Portland with 16 pumping plants and 4 underwater river crossings. System to all waste discharges from city. Provides location map and generalized cost figures.

(AA) News Notes, "Stream Pollution in Oregon," The Pacific Engineer, V. 6 No. 5, May 1927.

Gives the full text of the Report by the Public Health Section of the City Club of Portland.

(BB) Oregon State Board of Health - Biennial Reports

2nd report, 1907

First comments recorded on inadequacy of sewer disposal systems in the State. Gives special mention to undesirable situation in the Willamette Valley.

3rd report 1909

Points to fact that the streams of Oregon and more particularly the smaller streams should not be used as waste carriers.

4th report 1911

Emphasizes that stream pollution is of grave importance from a health standpoint. Warns that drinking from any of the streams is dangerous. Remarks that pollution in some locations makes the fish unsuitable for food.

5th report 1913

Comments upon an "active campaign against pollution of streams" and mentions that one injunction suit had been brought in circuit court to stop waste dumping.

6th report 1915

Again called attention of Legislature to Stream Pollution. Mentions a suit, described as friendly, against City of Silverton for polluting. Suit was won in lower court but reversed in Supreme Court due to weakness of law.

7th report 1917

Commends the 1915 legislative session for passage of legislation to prevent pollution of streams. Some evidence of the start on a permit system for waste disposal. System not described in detail.

10th report 1923

Again mentions permit system for waste disposal without giving details.

11th report 1925

Very complete report on Board activities but no mention of stream sanitation or pollution.

12th report 1927

A section was devoted to description of modern methods of sewage disposal and purification, but no mention is made of any actions taken. For the first time this report included a section reporting the activities of the newly created Division of Sanitary Engineering. Functions of the new division are described. Reference is made to sampling the Willamette River but no data are given.

13th report 1929

Comments upon sampling reported in the 12th biennial report with samples being analyzed for total bacteria count and B. Coli Index. Commented upon cooperative sampling with

City of Portland in 1926. It appears that the bacteriological analyses were those reported by Thayer(W). Also, the cooperative sampling undoubtedly provided the data in the files of the City Engineer, Portland, see bibliography reference(16).

Included in the biennial report is a bill to establish a special committee to study the waters of the state. The legislation failed to pass.

(CC) News Item, "Sewerage Plan Sound Policy," The Spectator V. 56, No. 12, October 27, 1934.

Reviews the results of the 1934 survey of the lower Willamette River, bibliography reference (16), and uses the survey results in support of a plea to accelerate progress in construction of the Portland disposal system.

(DD) ________"Some Aspects of Water Pollution in Washington County," Report, Oregon State Sanitary Authority, April 1965.

Concerned mainly with pollution of Rock Creek, a tributary of the Tualatin River. Gross pollution was indicated. Region one of heavy population in relatively limited watershed. Generally concluded that Washington County was one in which county-wide waste collection and treatment was a possibility.