OXYGEN BLOCK IN THE MAIN-STEM WILLAMETTE RIVER

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OXYGEN BLOCK IN THE MAIN-STEM WILLAMETTE RIVER

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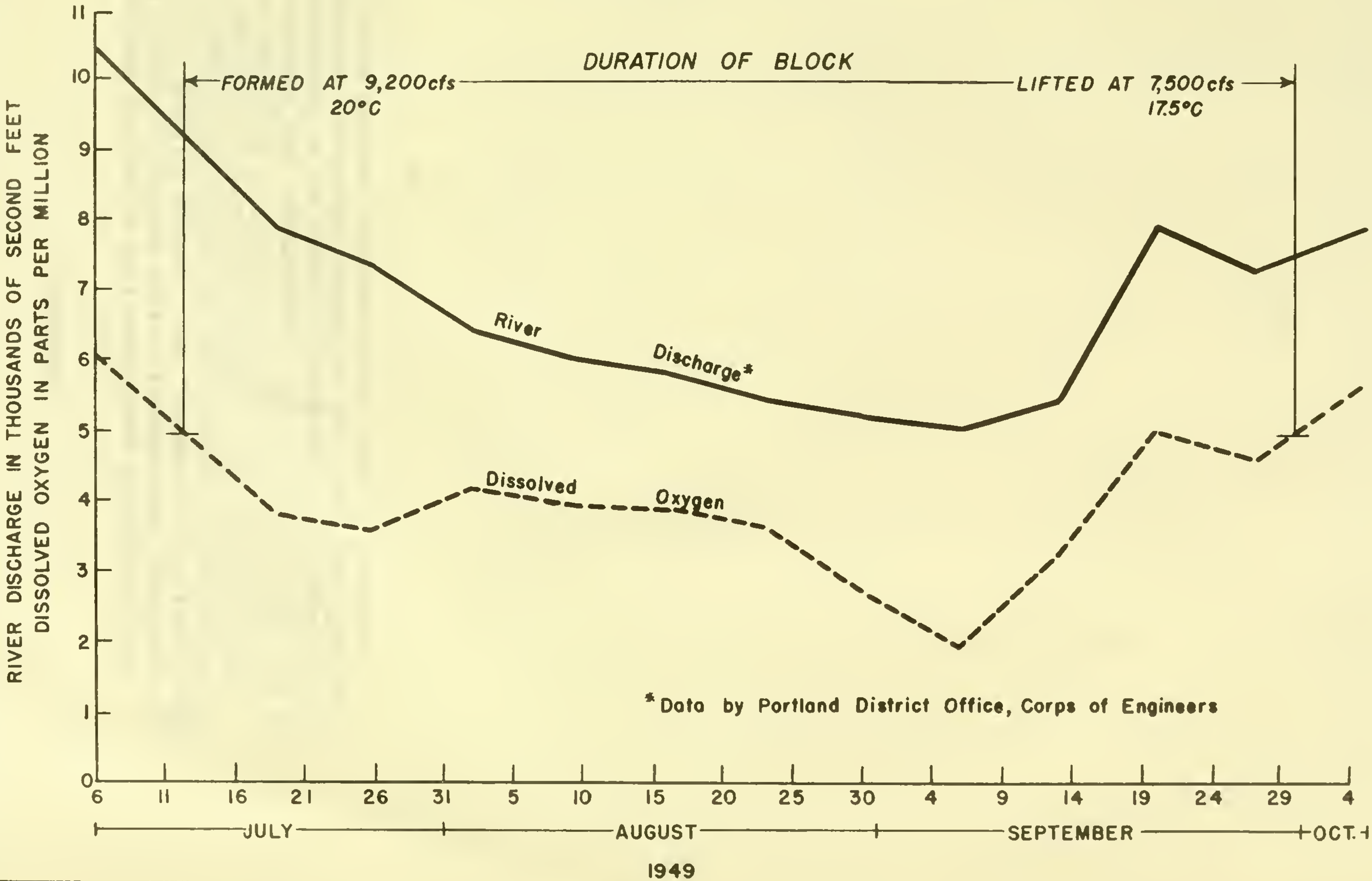
CONTENTS

Foreword

The studies included in this report were conducted at the Corvallis Laboratory, Section Western Fish-Cultural Investigation, U. S. Fish and Wildlife Service. The laboratory facilities, equipment, and supplies contributed to these studies by the Section of Sanitary Engineering, School of Engineering and Industrial Arts, and by the Department of Fish and Game Management at Oregon State College are gratefully acknowledged. The invaluable advice and interest contributed to the study by Professors R. E. Dimick and Fred Merryfield were particularly helpful as were the stream flow data provided by the Portland District Office, Corps of Engineers.

FIGURE I

OXYGEN BLOCK AT SELLWOOD BRIDGE
WILLAMETTE RIVER



INTRODUCTION

Pollution of the Willamette River of Oregon has attracted nationwide attention not only for the outstanding example of an overloaded major river that it offers but, also, because of its impact upon economically important and highly publicized run of spring-chinook salmon.

Pollution of the Willamette River is a problem that has received considerable attention over the past two decades. The initial organized studies of Willamette pollution stemmed from a conference called by the Oregon State Board of Health in September, 1926. Following that conference, the Portland City Departments of Health and Engineering routinely sampled the river in the Portland harbor area extending from the Sellwood Bridge, at river mile 16.5, to the confluence with the Columbia. These studies were conducted between October, 1926 and December, 1928 and revealed that less than three parts per million of dissolved oxygen were present in the river water during August, 1927, and during both August and September of 1928.

Rogers, Mockmore, and Adams (1930) reported more extensive studies of the Willamette pollution after surveying the main stem and major tributaries between July, 1929, and May, 1930. These authors reported an oxygen block (i.e., less than five parts per million of dissolved oxygen) existed between Wilsonville (river mile 37) and the Sellwood Bridge in Portland in August, 1929, but had disappeared by the time they next studied the river in the following October.

Gleeson (1936) made an extensive study of the pollution and tidal complex between the Sellwood Bridge and the Columbia River, September 5 to 27, 1934. Gleeson obtained no samples exceeding five parts per million of dissolved oxygen over the entire reach of river that he studied except in the extreme lower end where Columbia River backwater was involved. Gleeson also demonstrated by calculation that an oxygen block would develop in the lower Portland harbor area even though all wastes from that city were excluded from the river. He likewise determined that 7.6 days were required for the passage of water between the Sellwood Bridge and the Columbia River when the river discharge was at 4,000 second feet.

Craig and Townsend (1946) reported a series of seven spot samplings at the Sellwood Bridge and at the St. Johns Bridge, Portland, between February 4 and July 28, 1941, and four additional samplings between May 2 and August 21, 1942. Their findings indicated that the oxygen block had formed in the Willamette at the St. Johns Bridge sometime between March 18 and May 1, 1941. The oxygen block had extended upstream to the Sellwood sometime between May 29 and July 17, 1941. The oxygen block had formed at both stations sometime between May 2 and early August, 1942.

More recent studies in the Willamette River were reported by Merryfield and Wilmot (1945) and by Dimick and Merryfield (1945). Insofar as the main stem is concerned, their studies were conducted down to the Sellwood Bridge between August and December, 1944, with bi-monthly samplings at the critical stations continued until the following March. Merryfield and Wilmot demonstrated that the oxygen block extended upstream to approximately river mile 60 at the time their studies were undertaken in late August of 1944. The block had been forced downstream to river mile 44, presumably by increasing water flows, by October and it disappeared entirely sometime late in the same month.

Fish and Rucker (1950) reported a reconnaissance of the main stem Willamette from Springfield to the Steel Bridge (river mile 12) in Portland during mid-October, 1948. They obtained no evidence of an oxygen block at that time, the lowest dissolved oxygen concentration obtained on the survey being 7.4 ppm. at the Steel Bridge.

It is apparent from the studies made to date that the pollution burden of the Willamette River is of sufficient magnitude to overload the lower reaches during periods of low flows and high temperatures. The lowest reach of the river is degraded to the point where oxygen deficiency precludes any movement of migratory fishes through the affected area. Because the Willamette River currently supports important runs of salmon and steelhead trout -- fishes of high commercial and recreational value -- the impact of pollution upon the fishery resources is of considerable importance.

The impact of pollution upon the fisheries resources of the Willamette Valley is of major consequence not only under existing conditions, but it bids fair to become increasingly more so in the near future. Increasing population and industrialization of the Willamette Basin -- with an accompanying additional pollution burden to the already overloaded main stem -- appears inevitable. Some loss of potential dilution water through evaporation has accompanied the great increase in the quantity of main stem water diverted for the irrigation of croplands during the past decade. This trend undoubtedly will continue, and probably steepen, with the obvious shifting of agriculture in the Valley from grain and pasturage to truck and specialty farming.

Perhaps the greatest crisis of all, insofar as the fisheries of the immediate future are concerned, lies in the acute need for the main stem and certain tributaries of the Willamette as spawning and nursery areas for fall-chinook salmon relocated from the main Columbia River. A serious threat to the upper Columbia River salmon runs is forming in the multiple-purpose programs of water development currently in progress by the Corps of Engineers, the Bureau of Reclamation, and by private interests. The Fish and Wildlife Service, together with the fishery agencies of Oregon and Washington, are engaged in a 20-million dollar "Lower River Program" designed to perpetuate the Columbia River salmon resources despite the use of the upper river waters for purposes incompatable with the existence of the salmon. Briefly, this program proposes through various measures the maximum rehabilitation of native and/or relocated salmon runs in the lower river sections below the areas of intensive water development and utilization.

The success of the Lower River Program is predicated upon complete utilization of every available, as well as every rehabilitatable, fish-producing tributary of the Columbia River below McNary Dam. The potentialities of the Willamette River are too great to allow pollution to remain a factor limiting its full usage for fish production.

None of the Willamette pollution studies made to date reveal the circumstances under which the main stem oxygen block forms or lifts, nor do they indicate more than vaguely, the time. Until the limits of the pollution problems have been more accurately defined, it remains impossible to determine if, or under what circumstances, the Willamette can be utilized in the Lower River Program however great the need for the waters may be.

1949 Main Stem Willamette River Studies

A study of the main stem Willamette was undertaken jointly by the Fish and Wildlife Service and Oregon State College during Water Year 1949, in an effort to determine current postwar conditions. It was recognized at the outset that available funds and personnel would not permit as exhaustive a study as obviously is needed for a complete appraisal of the many facets of the pollution problem.

A series of stations was established over the length of the main stem and on each major tributary close to its confluence with the Willamette River. The geographical location of these stations is listed on Table 1. Duplicate samples were collected at half depth from a single point on the river. It was recognized that the results obtained by spot samplings would be affected by many factors but, under the limiting circumstances, it was assumed that spot sampling would prove sufficiently representative of the actual conditions to serve the intended purposes.

Each sampling station was visited periodically throughout Water Year 1949. The results obtained are listed in Table 2.

The summer of 1949 proved somewhat atypical for, as shown on Table 3, water flows in the main stem were somewhat above average and considerably above those prevailing during the 1944 survey of Merryfield and Wilmot. The July and August flows, however, were substantially equal to those of 1929 when Rogers, Mockmore, and Adams made their studies of summer conditions.

Table I

SAMPLING STATIONS FOR 1949 STUDIES.

- Main Stem Willamette -

River Mile	
185.6	Highway 28 Bridge near Springfield, 3 miles above Eugene.
178.6	Wilbur Revetment, 4 miles below Eugene
164.3	Highway 99-E Bridge at Harrisburg
122.5	Adair Village water intake, 7.5 river miles below Corvallis and 3 miles above Albany
116.5	Ufford Revetment, 3 miles below Albany
96.2	At Independence Ferry, 11 miles above Salem
72.5	At Wheatland Ferry, 12 miles below Salem
38.8	At Wilsonville Ferry
30.8	At boathouse, right bank, 4 miles above Oregon City
25.6	At boathouse, right bank, 1 mile below Oregon City
16.5	Sellwood Bridge, Portland
12.1	Morrison Bridge, Portland
	- Tributaries -
3	McKenzie River at Armitage Bridge
4	Long Tom River at Burnett Bridge
3	Luckiamute River at Davidson Bridge
5	Santiam River at Highway 99-E Bridge
5	Yamhill River at Dayton Bridge
3	Pudding River at Highway 99-E Bridge
3	Molalla River at Highway 99-E Bridge
1	Tualatin River at Athey Bridge
2	Oswego Creek at Lake Oswego outlet
2	Clackamas River at Highway 99-E Bridge

TABLE 2

D I S S O L V E D   O X Y G E N   P R O F I L E S

WILLAMETTE RIVER --MAIN STEM

- Parts Per Million -

Sampling Station	1948 10/14	1949 4/12	5/6	6/10	7/5	7/18	7/25	8/1	8/8	8/15	8/22	8/29	9/5	9/12	9/20	9/27	10/5	10/15	10/19
Springfield	9.6	11.6	10.5	9.7	9.6	8.3	8.7	8.6	8.7	8.7	8.0	9.2	8.0	8.7					
Wilbur Revet.	9.2	11.5	10.5	9.2	9.5	8.1	8.4	8.2	8.2	8.1	7.8	8.7	6.8	7.5					
Harrisburg	12.0	11.2	10.1	9.7	9.6	8.9	8.7	8.5	8.3	8.2	8.8	8.9	8.1	8.4					
Adair Intake	9.7	10.9	10.9	9.5	9.4	8.2	8.2	8.3	8.1	8.6	8.6	8.4	8.5	7.9	8.6	7.2	9.1	10.1	10.4
Ufford Revet.	9.9	10.4	9.5	9.5	8.9	8.0	8.0	8.2	8.0	7.9	8.7	8.1	8.2	8.6	8.4	8.2	9.2	10.2	10.6
Indepencence	9.6	10.7	10.2	9.4	8.7	8.0	8.1	6.7	8.3	8.4	8.1	8.3	7.4	8.9	8.8	8.3	9.3	10.3	10.6
Wheatland	9.1	10.3	9.7	9.4	7.7	6.9	7.2	6.1	7.9	8.2	6.0	8.0	7.2	8.7	8.3	7.9	8.9	10.0	10.6
Wilsonville	8.1	10.1	9.8	9.0	7.9	5.3	6.3	5.7	7.4	7.4	5.6	7.9	6.7	7.3	8.0	7.5	8.6	9.3	10.0
Above Ore. City	7.7	9.9	9.8	9.0	7.7	3.5	4.9	3.9	3.4	3.6	2.4	3.0	1.7	2.7	4.2	3.8	4.5	7.7	8.5
Below Ore. City	7.7	10.8	10.6	9.5	7.8	4.5	4.5	4.3	3.8	3.7	3.0	3.9	4.0	4.3	5.2	3.1	3.8	8.9	9.8
Sellwood Bridge	7.9	10.7	11.2	9.0	6.1	3.9	3.6	4.2	4.0	3.9	3.7	2.8	2.0	3.3	5.0	4.6	5.7	7.8	8.7
Morrison Bridge	*7.4-	10.5	10.8	8.4	6.3	3.3	3.4	2.8	2.2	2.1	1.9	1.1	0.7	1.1	3.5	2.9	3.8	7.0	8.2

* Sample collected from steel bridge.

Underlined values indicate samples collected on day following that shown at column heading.

TABLE 2

FIVE DAY B. O. D. PROFILES

WILLAMETTE RIVER -- MAIN STEM
- Parts Per Million -

Sampling Station	1948 10/14	4/12	5/6	6/10	7/5	7/18	7/25	1949 8/1	8/8	8/15	8/22	8/29	9/5	9/12	9/20	9/27	10/5	10/15	10/19
Springfield	0.7	1.7	0.9	1.3	0.8	1.4	1.3	1.4	1.7	1.8	1.0	0.7	0.5	0.8					
Wilbur Revet.		1.6	1.3	1.5	1.3	1.7	1.6	1.0	1.3	1.5	1.3	2.5	2.3	2.0					
Harrisburg	0.0	1.2	0.7	1.3	0.8	1.9	1.9	1.9	2.5	2.5	1.5	1.8	1.1	1.2					
Adair Intake	2.6	2.1	2.7	1.8	1.4	1.3	1.2	1.8	2.7	2.7	1.2	1.8	1.3	1.3	1.2				
Ufford Revet.	3.1	0.7	1.2	1.0	1.0	1.6	1.8	0.7	3.0	3.0	1.5	2.1	1.7	1.5	1.2				
Independence	2.2	1.0	1.7	1.2	1.2	1.5	1.6	1.2	2.7	2.8	1.0	2.5	0.4	1.6	1.4				
Wheatland	3.3	1.5	1.4	1.5	1.8	0.9	1.1	2.0	2.7	2.7	2.5	2.6-	+2.0	2.2	1.7				
Wilsonville	2.4	1.8	1.5	2.0	1.0	1.6	1.6	1.8	2.9	2.8	2.7	2.7	2.4	2.2	1.8				
Above Ore. City	2.5	1.1	1.2	1.8	1.5	1.0	1.6	1.8	3.6	3.2	3.0	2.3	4.0	3.7	1.2				
Below Ore. City	4.9	2.1	1.6	2.2	5.0	3.6	3.6	3.8	3.9	4.0	3.8	4.1	3.7	4.1	2.1				
Sellwood Bridge	3.6	1.5	2.1	1.6	3.4	3.1	2.9	3.8	4.1	4.1	3.8	3.1	3.9	3.8	2.5				
Morrison Bridge	*4.5	1.5	1.9	1.8	4.7	3.0	4.1	4.1	4.4	4.2	4.0	3.4	4.4	4.4	2.7				

* Sample collected from Steel Bridge

Underlined values indicate Samples collected on day following that shown at column heading.

TABLE 2

TEMPERATURE PROFILES

WILLAMETTE RIVER - MAIN STEM

Degrees Centigrade

Sampling Station	1948 10/14	1949 4/12	5/6	6/10	7/5	7/18	7/25	8/1	8/8	8/15	8/22	8/29	9/5	9/12	9/20	9/27	10/5	10/15	10/19
Springfield	13.1	10.2	11.2	17.0	15.0	20.0	21.0	21.0	21.0	20.5	18.0	22.0	19.5	18.0					
Wilbur Revet.	13.0	10.7	10.8	18.3	16.0	22.0	22.0	21.5	21.3	21.2	18.8	22.5	20.0	19.0					
Harrisburg	12.0	10.5	12.0	17.0	15.3	21.5	21.0	20.0	20.2	20.0	18.5	21.0	19.0	18.5					
Adair Intake	12.2	<u>11.3</u>	12.0	18.0	16.8	21.5	21.5	22.5	19.5	<u>21.0</u>	20.5	20.8	21.0	18.5	15.5	18.0	14.0	10.0	9.5
Ufford Revet.	<u>12.3</u>	<u>11.5</u>	12.0	18.0	17.0	21.5	22.0	24.0	21.0	<u>21.1</u>	21.5	21.0	21.7	19.0	16.0	18.5	14.0	10.0	9.5
Independence	<u>12.3</u>	<u>11.2</u>	11.5	16.3	17.3	21.0	22.0	<u>22.0</u>	21.0	<u>20.0</u>	21.0	20.5	<u>20.0</u>	19.5	17.0	18.8	15.2	10.8	10.0
Wheatland	<u>11.8</u>	<u>11.7</u>	<u>12.0</u>	18.0	<u>16.0</u>	22.0	22.5	<u>22.1</u>	22.5	<u>21.0</u>	<u>20.0</u>	<u>20.5</u>	<u>20.1</u>	<u>19.0</u>	17.5	19.0	16.5	12.0	10.0
Wilsonville	<u>13.0</u>	<u>12.2</u>	<u>12.5</u>	18.5	<u>17.5</u>	<u>21.5</u>	<u>21.0</u>	<u>22.0</u>	<u>23.0</u>	<u>22.0</u>	<u>22.5</u>	<u>21.5</u>	<u>22.0</u>	<u>21.0</u>	18.0	19.0	16.5	13.0	10.5
Above Ore. City	<u>13.1</u>	<u>12.5</u>	<u>13.0</u>	18.5	<u>17.8</u>	<u>22.5</u>	<u>23.0</u>	<u>23.0</u>	<u>23.0</u>	<u>22.7</u>	<u>22.5</u>	<u>22.0</u>	<u>22.0</u>	<u>22.0</u>	18.0	18.5	16.5	14.0	11.0
Below Ore. City	<u>13.0</u>	<u>12.8</u>	<u>12.4</u>	18.5	<u>18.5</u>	<u>23.0</u>	<u>23.2</u>	<u>23.1</u>	<u>23.0</u>	<u>23.5</u>	<u>22.0</u>	<u>21.5</u>	<u>22.5</u>	<u>21.0</u>	19.0	19.0	16.5	14.0	11.5
Sellwood Bridge	<u>13.2</u>	<u>11.0</u>	<u>12.2</u>	19.0	<u>17.8</u>	<u>22.0</u>	<u>22.5</u>	<u>21.5</u>	<u>22.0</u>	<u>21.5</u>	<u>21.0</u>	<u>21.0</u>	<u>23.0</u>	<u>20.5</u>	18.5	19.2	16.0	13.5	11.0
Morrison Bridge	*<u>13.0</u>	<u>12.0</u>	<u>11.9</u>	19.0	<u>18.0</u>	<u>22.0</u>	<u>22.8</u>	<u>22.0</u>	<u>22.7</u>	<u>21.5</u>	<u>21.5</u>	<u>22.0</u>	<u>22.8</u>	<u>22.0</u>	18.5	19.5	16.0	13.5	11.0

* Sample collected from Steel Bridge

Underlined values indicate samples collected on day following that shown at column heading.

TABLE 2

DISSOLVED OXYGEN DATA

WILLIAMETTE RIVER TRIBUTARIES

- Parts Per Million -

Sampling Station	1948 10/14	1949 4/12	5/6	6/10	7/5	7/18	7/25	8/1	8/8	8/15	8/22	8/29	9/5	9/12	9/20	9/27	10/5	10/15	10/19
McKenzie at Armitage Br.	10.3	11.7	10.6	9.9	10.3	9.3	9.0	9.1	9.2	9.1	8.6	9.4	9.0	8.4					
Long Tom at Burnett Br.		10.2	9.8	8.6	9.1	7.2	8.2	6.8	6.9	6.8	6.9	8.3	7.7	7.8					
Luckiamute at Davidson Br.		10.2	10.1	9.6	9.7	8.0	8.1	8.0	7.6	7.5	7.2	8.5	7.3	7.5	7.8	7.6	8.2	9.3	9.3
Santiam at 99-E Bridge		11.1	10.3	9.5	9.5	8.9	9.2	7.5	9.1	9.1	8.8	9.6-	8.4	9.4	7.7	8.0	8.5	9.8	9.6
Yamhill at Dayton Br.		10.2	10.1	8.6	8.6	7.0	7.0	6.2	5.3	5.3	6.1	6.5	6.2	6.9	5.4	5.5	6.0	7.3	7.0
Pudding at 99 E Bridge		10.1	9.4	8.9	8.8	*9.6	*9.5	7.6	8.0	7.8	7.4	7.6	7.6	7.6	7.8	7.7	8.4	9.0	9.8
Molalla at 99-E Bridge		11.1	10.5	9.7	9.0	8.6	8.2	9.0	9.0	8.7	8.7	8.6	8.5	9.5	9.9	9.8	10.1	10.8	11.5
Tualatin at Athay Bridge		**9.1	11.2	9.0	8.6	*9.5	*9.1	7.2	*9.7	*9.5	*10.3	*10.4	9.0	9.6	11.1	10.6	11.0	10.2	10.8
Clackamas at 99-E Bridge		11.3	11.0	10.2	9.9	9.4	9.0	9.7	10.1	9.7	10.0	9.7	9.9	10.8	11.6	10.6	11.9	12.3	12.7

* Heavy phytoplankton bloom present.

** Sample collected at Tualatin City.

Underlined values indicate samples collected on day following that shown at column heading.

TABLE 2

FIVE-DAY B. O. D. DATA

WILLAMETTE RIVER TRIBUTARIES

- PART PER MILLION -

Sampling Station	1948 9/14,15,16	1949 4/12	5/6	6/10	7/5	7/18	7/25	8/1	8/8	8/15	8/22	8/29	9/5	9/12	9/20
McKenzie at Armitage Br.	0.9	1.1	0.6	1.2	0.8	1.5	1.5	0.9	1.4	1.5	0.7	0.8	1.2	1.1	
Long Tom at Burnett Br.	1.1	2.3	1.9	2.2	1.1	2.2	1.3	2.4	2.6	2.6	1.1	1.7	2.6	2.3	
Luckiamute at Davidson Br.	0.0	1.2	1.2	1.3	1.0	2.2	1.4	1.2	2.0	2.1	0.8	1.3	1.5	1.4	0.2
Santiam at new 99-E Br.	1.2	2.7	1.6	2.9	1.3	2.2	2.2	0.5	2.2	2.3	1.1	1.7	0.7	1.2	1.1
Yamhill at Dayton Br.	1.0	1.3	1.0	1.4	2.0	1.5	1.6	1.1	2.4	2.6	1.1	1.2	1.0	3.4	1.2
Pudding at 99-E. Bridge	1.3	0.5	1.1	0.7	1.2	3.4	3.7	1.6	2.0	2.2	1.8	1.4	1.3	1.5	1.1
Molalla at 99-E Bridge	0.8	1.2	0.8	0.7	0.6	1.6	1.7	1.4	2.4	2.5	1.6	1.1	1.0	2.2	0.9
Tualatin at	*1.6	*0.5	2.1	0.6	2.7	2.5	2.6	1.6	1.9	2.0	0.6	1.4	1.5	4.0	0.5
Clackamas at 99-B Bridge	1.8	2.2	1.0	2.3	1.1	1.7	1.7	1.0	2.4	2.3	1.8	1.5	1.3	2.4	2.1

* Sample collected at Tualatin city bridge

Underlined values indicate samples collected on day following that shown at column heading

TABLE 2

T E M P E R A T U R E   D A T A

WILLAMETTE RIVER TRIBUTARIES

- Degrees Centigrade -

Sampling Stations	1948 9/14, 15; 16	1949 4/12	5/6	6/10	7/5	7/18	7/25	8/1	8/8	8/15	8/22	8/29	9/5	9/12	9/20	9/27	10/5	10/15	10/19
McKenzie at Armitage Br.	14.2	10.0	10.8	16.0	13.5	15.0	16.0	16.9	17.0	17.0	15.0	19.0	16.0	15.0					
Long Tom at Burnett Br.	21.0	17.5	17.2	21.0	19.0	22.0	22.5	23.0	22.3	23.0	18.5	23.0	20.5	20.5					
Luckiamute at Davidson Br.	19.1	12.3	13.7	18.0	17.0	22.0	23.0	23.5	21.2	21.0	21.0	21.0	21.5	20.0	16.0	18.5	14.5	10.2	9.8
Santiam at new 99-E Br.	14.0	10.6	10.5	17.5	16.5	17.5	18.0	21.0	20.5	22.0	20.5	20.5	19.5	19.0	17.0	17.0	14.0	9.5	9.0
Yamhill at Datyon Br.	17.6	12.8	11.8	21.0	17.6	22.8	23.0	22.0	22.6	21.0	20.5	21.5	21.0	20.0	18.0	19.0	16.2	14.1	11.0
Pudding at 99-E Bridge	13.8	13.0	11.8	21.1	17.5	21.2	21.2	24.1	21.3	22.0	20.9	21.0	21.1	19.0	17.2	17.5	15.0	12.0	9.5
Molalla at 99-E Bridge	14.0	12.0	11.9	17.8	16.5	18.5	19.0	22.8	21.3	22.5	21.0	20.5	21.0	19.5	16.5	17.0	14.5	10.5	9.0
Tualatin at Athay Br.	*15.0	*13.0	12.0	19.0	17.0	20.5	20.0	22.0	21.0	21.0	20.1	21.5	21.5	19.0	18.2	18.5	15.5	14.0	12.0
Clackamas at 99-E Bridge	14.7	12.0	11.5	15.0	14.0	18.0	18.5	19.5	18.8	20.0	18.5	17.1	19.2	16.9	15.5	16.0	14.0	10.0	8.5

* Sample collected at Tualatin City Bridge.

Underlined values indicate samples collected on day following that shown at column heading.

TABLE No. 3

MAIN STEM WILLAMETTE RIVER AT WILLAMETTE FALLS

Mean monthly flows in cubic feet per second *

Month	June	July	August	September
1926-1945 Mean	15,658	6,659	4,081	4,394
1929	20,410	6,830	4,110	3,640
1944	10,510	5,230	3,430	3,630
1949	14,200	7,000	4,580	5,160

* Data supplied by Portland District Office, Corps of Engineers

Interpretation of Results

Reviewing the dissolved oxygen profiles listed in Table 2, the combined effects of reaeration and dilution appeared fully adequate to maintain the quality of the main stem water above Wilsonville well within the accepted tolerance limits of cold-water fishes. Below Wilsonville, however, a rapid deterioration in water quality occurred during the low-flow period. The degradation of water culminated in an oxygen block (i.e., less than five parts per million) which appeared in the lower river between July 6 and 19, 1949. Between those dates, the block developed over its maximum range, namely upstream to a point below Wilsonville or, roughly, within the confines of the slackwater reach locally known as the "Newberg Pool". The block persisted throughout the entire lower river area until it was dissipated by increasing river flows sometime between September 27 and October 12. More than five parts per million of dissolved oxygen were found throughout the river to its confluence with the Columbia on October 12.

Patently, the formation and lifting of the Willamette River oxygen block is not a function of water flows exclusively for such factors as hours of sunshine, water temperature and turbidity, and the seasonal variations in pollution loading also play important roles. Generally speaking, however, water flows would be a -- if not the -- dominant factor.

The station at Sellwood Bridge has been selected as a reference point to illustrate the formation and lifting of the block. River flow data supplied by the Portland District Office, Corps of Engineers, and dissolved oxygen concentrations are plotted in Figure 1. These data indicate that the block formed at Sellwood Bridge about July 12 when the river discharge approximated 9,200 c.f.s. and the water temperature 20°C. They likewise show that the dissolved oxygen concentration remained below five parts per million throughout the balance of the summer and momentarily rose to that concentration with a minor crest of 7,900 c.f.s. passing the station September 19. The block lifted for the season about September 30 when river flows rose above approximately 7,500 c.f.s. and the water temperature fell to approximately 17.5°C.

The approximate picture of the formation and lifting of the Willamette oxygen block during 1949 within the reach covered by these studies can be tabulated as follows:

Location	Block Formed			Block Lifted		
	Approx. date	Approx. River Flow c.f.s.	Approx. Water Temp. °C	Approx. Date	Approx. River Flow c.f.s.	Approx. Water Temp. °C
Above Willamette Falls	July 15	7,300	21	Oct. 6	8,000	15
Below Willamette Falls	July 17	6,850	21	Oct. 4	6,700	18
Sellwood Bridge	July 12	9,200	20	Sept. 30	7,500	18
Morrison Bridge	July 11	9,500	20	Oct 8	11,600	15

One point illustrated by the data from the tributaries will be of interest to both fishery interests and sanitary engineers. Apparently none of the Willamette tributaries is a significant contributor to the main stem pollution burden in spite of the fact that certain of them--notably the Tualatin, the Yamhill, and the South Santiam--are known to be seriously polluted from the work of Dimick and Merryfield and that by Fish and Rucker.

These data indicate that, at least under the conditions prevailing during the summer of 1949, the tributaries are absorbing to an amazing degree any oxygen-consuming pollution added to their upper reaches before the water reaches the main stem. The Tualatin offers a good example of the point in question. Although pollution of the Tualatin in sufficient intensity to kill fish was reported below the cities of Hillsboro and Forest Grove during the summer of 1949, nevertheless the dissolved oxygen concentration at the Athay Bridge sampling station near the mouth remained consistently above saturation during most of the summer. This apparent anomaly stemmed in large part, no doubt, from effective reaeration by biological growth which was stimulated by the organic fertilization received in the polluted reach upstream. A very profuse phytoplankton growth was apparent in the water at the Athay Bridge station throughout the period of supersaturation. With the exception of a single sample from the Yamhill, at no time during 1949 did any tributary fail to meet the accepted criteria of a relatively clean stream (i.e., a BOD of less than 3 ppm. with a DO exceeding 5 ppm.) near its confluence with the main stem. Only the Yamhill approached, but did not exceed, these arbitary thresholds.

It would appear, therefore, that tributary pollution--however severe it may have been during the summer of 1949 and irrespective of its adverse effects upstream, was not a major factor contributing to the main stem pollution loading. The main stem pollution problem appears to be a distinct entity in itself.

The probable magnitude of pollution abatement measures necessary to eliminate the main stem oxygen block warrents consideration. At the present time, two measures of pollution abatement are in progress.

Three of the smaller impoundments of the Corps of Engineers' Willamette Valley Project are in operation which have added perceptibly to the low flows--and thus the dilution water available--in the main stem Willamette. Two major impoundments of the Project currently are under construction and scheduled for completion within four years and each of these will further increase minimum flows. Fifteen additional impoundments are scheduled for construction by the Corps of Engineers, plus several by the Bureau of Reclamation, in the program of ultimate water development within the Willamette Basin. The completed units have altered the water regimen of the main stem and the major impoundments now under construction are anticipated to increase minimum flows much more and, in addition, reduce water temperatures to some extent as well. The completed Willamette Valley Project will profoundly affect water conditions in the main stem but all effects--at least as the Project is tentatively scheduled for operation--should prove beneficial towards pollution abatement. The degree to which the changes in main stem conditions will improve water quality cannot be accurately forecast with available information.

The second corrective measure currently in progress is the demand by the Oregon State Sanitary Authority that all main stem communities must provide primary treatment of domestic wastes as rapidly as adequate plans and financing can be secured. At the present time, all wastes from these communities are discharged directly into the Willamette River without treatment. As a consequence of their action, the City of Portland is installing sewerage facilities to divert all wastes to the Columbia River. The remaining communities along the main stem have facilities for primary treatment of their domestic wastes in various stages of planning or financing. The ultimate phase of the pollution abatement program of the

Oregon State Sanitary Authority calls for the treatment of the oxygen-consuming industrial wastes, principally sulphite liquor and cannery offal, as rapidly as feasible methods can be developed.

Primary treatment of domestic sewage will reduce its subsequent oxygen demand in the order of thirty percent. When effected, this measure would improve lower river conditions materially although it still appears insufficient to lift the oxygen block all the way to the Columbia River. Insofar as the migratory fishes are concerned, an oxygen block several hundred yards in length probably would prove just as effective a barrier as one of many miles in extent.

Gleeson, it will be recalled, found that 7.6 days were required for the Willamette River water to flow from Sellwood Bridge to the Columbia when river discharge was 4,000 second feet. The assumption appears tenable, therefore, that the full oxygen demand indicated by the 5-day biochemical oxygen determination of water at the Sellwood Bridge will be consumed--at least during the low flow periods--before that water reaches the Columbia.

Using the 1949 determinations obtained at the Sellwood Bridge on August 29, September 5, and September 12 (which represent the approximate time when relocated runs of fall-chinook salmon would be entering the lower Willamette) as examples, the future river conditions between the Sellwood Bridge and the Columbia that may be grossly anticipated under conditions comparable to the 1949 river flows and temperatures and with various degrees of pollution abatement can be calculated as follows:

Date of Determination - - - - - - - - - - - - -	Aug. 29	Sept. 5	Sept. 12
River flow at Sellwood Bridge, second feet	5,260	5,080	5,476
River water temperatures (^{o}C.)	21	23	20.5
Dissolved oxygen available, 1949 conditions:			
ppm.	2.8	2.0	3.3
pounds per day	79,531	54,864	97,583
dissolved oxygen deficit, lbs/day	175,819	183,244	170,980
Dissolved oxygen available:			
with 1949 deficit reduced 30% (lbs/day)	132,564	109,837	148,897
with 1949 deficit reduced 50% (lbs/day)	167,728	146,486	183,073

Date of Determination - - - - - - - - - - - -	Aug. 29	Sept. 5	Sept. 12
Biochemical Oxygen demand, Sellwood Bridge:			
1949 conditions (lbs/day)	88,052	106,984	112,369
1949 conditions reduced 30% (lbs/day)	61,636	74,889	78,658
1949 conditions reduced 50% (lbs/day)	44,026	53,492	56,185
Anticipated minimum dissolved oxygen present below Sellwood Bridge:			
A. In terms of pounds per day:			
1949 conditions	septic	septic	septic
With O_2 deficit and BOD reduced 30%	70,928	34,948	70,219
With O_2 deficit and BOD reduced 50%	123,702	92,994	126,888
B. In terms of parts per million:			
1949 conditions	septic	septic	septic
With O_2 deficit and BOD reduced 30%	2.5	1.3	2.4
With O_2 deficit and BOD reduced 50%	4.4	3.4	4.3

Admittedly, data obtained by weekly spot samplings constitute an insecure basis, at best, for definite conclusions regarding any problem as complicated as pollution abatement. These data do strongly indicate, however, that the primary treatment of domestic wastes alone will not prove sufficient to lift the Willamette pollution block. An overall reduction exceeding fifty percent of the 1949 waste load of the river appears necessary to assure clearance of the lower reaches for the passage of migratory fishes during the low flow stages. It appears most probable, therefore, that the utilization of the Willamette River by fall-chinook salmon must await either sufficiently increased minimum river flows that may be provided by the Corps of Engineers' Willamette Valley Project and/or the effective treatment of many of the oxygen-consuming industrial wastes.

CONCLUSIONS

1. Pollution of the main stem Willamette River is a problem of long standing and one that seriously threatens the fall utilization of the river's potentialities for fish production. Above Wilsonville, the quality of the main stem water is being maintained well within the accepted tolerance limits of cold-water fishes by effective reaeration and dilution, in spite of a heavy pollution burden. Below Wilsonville, however, where the stream gradient decreases a rapid degradation in water quality develops during the low water stages. During 1949, as in earlier years, an oxygen block developed throughout the entire reach of the lower Willamette. Under the conditions prevailing during 1949, the block developed throughout its maximum range between July 6 and 19. The block persisted throughout the summer until it was dissipated by increasing river flows sometime between September 27 and October 12. More than five parts per million of dissolved oxygen were found throughout the river to its confluence with the Columbia on October 12.

2. The main stem oxygen block appears to be a distinct entity quite unrelated to the pollutional loading of the major tributaries. Whatever pollutional overloading received by the major tributaries apparently is quite well stabilized before it reaches the main Willamette.

3. To the extent that data obtained by spot sampling provide a representative base for calculations, it may be concluded that an overall reduction exceeding fifty percent of the 1949 oxygen-consuming waste loading of the main stem Willamette must be effected to maintain a minimum dissolved oxygen concentration of five parts per million throughout the river. As the primary treatment of domestic sewage will not provide the degree of pollution abatement required, the use of the Willamette River by fall-chinook salmon must await sufficiently increased minimum river flows that may be provided by the Corps of Engineers' Willamette Valley Project and/or the effective treatment of a significant fraction of the oxygen-consuming industrial wastes.

4. Available data will not permit more than an extremely gross prediction of the minimum degree of pollution abatement required to eliminate the oxygen block of the lower Willamette. This point is of considerable interest to the communities and industries of the Willamette Valley for, presumably, neither are anxious to finance a greater degree of pollution abatement than conditions warrant. A detailed study of the sources, magnitude, and subsequent effects of the pollution loading of the river, coordinated with that of the absorption capacity of many reaches of the river under varying conditions of flows and temperatures is a prerequisite to any accurate analysis of the Willamette pollution problem and its effective and most economical solution.

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