Summary Report

of the

ADVISORY BOARD ON WATER POLLUTION,
RAINY RIVER AND LAKE OF THE WOODS
to the

INTERNATIONAL JOINT COMMISSION
UNITED STATES AND CANADA

on the

POLLUTION OF
INTERNATIONAL BOUNDARY WATERS

1960-1962 INVESTIGATIONS

RAINY RIVER AND LAKE OF THE WOODS
MINNESOTA AND ONTARIO

APRIL 1963

Printed in the United States for Public Health Service by General Services Administration.
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FOREWORD

This summary report is prepared for general public purposes. Detailed information and technical data on studies and investigations made are contained in the "Report of the Advisory Board on Water Pollution, Rainy River and Lake of the Woods to the International Joint Commission, United States and Canada, on the Pollution of International Boundary Waters, 1960-1962 Investigations, Rainy River and Lake of the Woods, Minnesota and Ontario, April 1963."

The latter report is available through the offices of the International Joint Commission in Ottawa, Canada and Washington, D. C. in the United States.
LETTER OF TRANSMITTAL
(Rainy River and Lake of the Woods Section)

To: International Joint Commission,
United States and Canada


Pursuant to the appointment of the Advisory Board on October 8, 1959, technical investigations and studies over a three-year period have covered those aspects of pollution deemed necessary for the Commission to answer the questions contained in the reference referred to them from the Governments of Canada and the United States.

In this report, the Advisory Board has endeavored to present, for general public purposes, certain factual information, its findings and recommendations and technical data by means of tables, charts and illustrations.

Respectfully submitted,

ADVISORY BOARD ON POLLUTION OF BOUNDARY WATERS - RAINY RIVER AND LAKE OF THE WOODS

United States - L. F. Warrick
Chairman

Canada - W. R. Edmonds
Chairman

United States
L. F. WARRICK, Chairman
H. C. CLARE
S. A. FREILSEN
H. G. ROGERS (1959 - March 9, 1962)
L. H. SMITH

Canada
J. R. MENZIES, Chairman (1959 - December 9, 1961)
W. R. EDMONDS, Chairman
R. E. TAIT
A. E. BERRY
F. A. VOEGE

May 8, 1963
ACKNOWLEDGMENTS

Valuable assistance has been rendered during this investigation, by the various municipalities and industries as well as several State, Provincial, and Federal agencies on both sides of the boundary. Special acknowledgment is made to the following:

On the United States side to:

Minnesota Department of Health
Division of Environmental Sanitation
Section of Water Pollution Control
Section of Engineering Laboratories

Minnesota Department of Conservation
Division of Waters and
Division of Game and Fish
Section of Research and Planning

Minnesota Department of Agriculture

City of International Falls, Minnesota

Minnesota and Ontario Paper Company
International Falls, Minnesota

Otto W. Kuehne, Chief Operator,
Waste Treatment Plant
International Falls, Minnesota

Owen Charlton, Operator,
Waste Treatment Plant
Williams, Minnesota

and on the Canadian side to:

Laboratory of Hygiene
Department of National Health & Welfare
Ottawa, Canada

Water Resources Branch
Department of Northern Affairs & National Resources
Ottawa, Canada

Town of Fort Frances

Ontario Department of Agriculture

Ontario Department of Health

Ontario Department of Lands and Forests
For Canada

William R. Edmonds (Chairman), Department of National Health and Welfare, Ottawa

Robert E. Tait, Department of National Health and Welfare, Ottawa

For the United States

Louis F. Warrick (Chairman), U. S. Public Health Service, Washington, D. C.

Herbert C. Clare, U. S. Public Health Service Regional Office, Kansas City, Missouri

For Ontario

Albert E. Berry, Ontario Water Resources Commission, Toronto

Fred A. Voege, Ontario Water Resources Commission, Toronto

For Minnesota

Lyle H. Smith, Water Pollution Control Commission, Minneapolis

Sidney A. Frellsen, Minnesota Department of Conservation, Division of Waters, St. Paul
FINDINGS AND RECOMMENDATIONS

The investigation of pollution of the boundary waters of Rainy River and Lake of the Woods extended over the period from June 1960 to September 1962. In that time a comprehensive examination was made of many phases of pollution, and relevant information was obtained from many sources. These data were studied and conclusions reached on the questions contained in the terms of reference to the International Joint Commission by the Governments of Canada and the United States.

This study involved unique and complex problems. A previous investigation in 1913 was a pioneering effort in the evaluation of bacteriological pollution. In the intervening years these waters assumed an important role in serving numerous uses on a boundary between two countries where healthful living, commerce, and recreation have attained a high level of development. These activities focused attention on two necessities: first, the recognized need for clean waters, and secondly, the serious problem of attaining this objective. The steady increase in urban population, the marked increase in production of paper products, and the prospects for future industrial and recreational development gave rise to involved and complicated requirements both for the investigation and solution of this situation. The cost is high for correction, but it is higher for continuance of the defilement of these waters.

The investigation enabled the Advisory Board on Water Pollution, Rainy River and Lake of the Woods, to reach certain conclusions on the findings and to offer recommendations to the Commission for remedial measures. The findings of the Board are summarized herewith.

Findings

1. These waters are seriously polluted in many places on both sides of the boundary. Serious pollution exists in the entire river downstream from Fort Frances and International Falls.

2. There is a transfer of pollution from each side of the boundary to the other. This has been demonstrated by float studies and by analytical results.

3. Conditions conducive to injury to health and property exist on both sides of the boundary. This has been manifested in the following ways:

   a. Health - A potential menace is present where waters polluted to the extent of these are used for domestic purposes. The extent of pollution of these waters is such that they cannot be safely used as a potable water supply without complete and continuously effective treatment.
Furthermore, they are so polluted in most areas so as to render them unsafe for recreational bathing purposes.

The pollutants present in these boundary waters must be considered an actual and potential health hazard, whether they be transmitted through public water supplies, bathing beaches, or by other means. If the 1913 to 1962 trend in bacterial pollution is permitted to continue, the time will come when conditions will reach a point where it will be impossible to use these waters safely for domestic purposes.

b. Property - Injury to property has been illustrated in an increase in the cost of water supply for municipalities and in lessened attractiveness of bathing beaches which may result in lower valuation of water-front and resort properties.

c. Industry - There is evidence that these waters are polluted to such a degree that their use in certain industries may be affected. An economic loss to the community, and to industry as well will occur when a plant is unable to locate in an area because of inability to secure a satisfactory water supply.

d. Recreation - These waters are polluted to such a degree that they are unsafe for bathing, unsuitable for fishing, detrimental to fish propagation, unsatisfactory for general recreational purposes and are aesthetically offensive.

Biological characteristics of the river have been altered by waste discharges. Changes in plankton, benthos, fishes and slime growths are related to specific waste effects and river discharge patterns.

Wood sugars discharged in the pulping process are a major source of nutrients for slime growths. Fiber, bark, and chips released from the pulp and paper mills create bottom deposits which rise and cause malodorous conditions along the major portion of the river, and impairment of fish propagation.

4. Some progress has been made in control or elimination of pollution during the period of this investigation. Municipal progress has been confined to the planning stages, with the exception of sewerage facilities and sewage stabilization ponds recently completed at South International Falls. Industrial progress has been confined mainly to in-plant controls and partial segregation of domestic sewage from industrial wastes.

5. Conferences by the Commission and the Advisory Board show a reasonable appreciation by village officials and industrial management of the need for correction of existing conditions. Financing of the necessary remedial work was indicated to be the principal hindrance to correction.
6. The condition of these waters requires that remedial measures be undertaken as early as possible.

Recommendations

The Advisory Board respectfully offers the following recommendations to the Commission:

1. Remedial measures for the abatement and control of pollution in the Rainy River section of the boundary waters should be undertaken at the earliest possible date. These measures should be sufficient to restore and protect the uses of these waters to which the people of both countries are rightfully entitled. Major consideration should be given to uses of water for domestic and industrial supplies, recreation, fish and wildlife, sanitary purposes, and navigation.

2. The "Objectives for Boundary Water Quality Control", currently applying to boundary waters under Reference, as suitably modified to meet water quality needs in the Rainy River-Lake of the Woods public water areas should be recognized in the development of remedial and pollution-preventive measures by municipalities and industries. These objectives should apply to both existing and new sources of wastes.

3. Treatment of municipal wastes by sedimentation and disinfection of the effluent should be undertaken by all communities as the initial step; and a program of more efficient or secondary treatment should be inaugurated at as early a date as possible. Need for more efficient or secondary treatment will be most urgent near large centers of population or where much industrial waste is involved. It is recognized that local conditions on either side of the boundary may give additional emphasis to the need for this higher degree of treatment. The estimated cost for installation of intercepting sewers and primary treatment works for municipalities in this section is $2,384,500 of which none is for United States communities. For the additional cost of secondary treatment of municipal wastes the estimate is $708,000 of which $200,000 is on the United States side and $508,000 on the Canadian side. These works must be financed through public funds.

4. Industrial wastes should be utilized, controlled, or treated to comply, as soon as possible, with the "Objectives for Boundary Waters Quality Control" interpreted as recommended by this Board. The cost estimated by the industries involved for industrial waste treatment works exceeds $11,000,000.

5. Appropriate action should be taken to accomplish reduction of slime growths such as by reduced discharge of nutrients.
6. It is recommended that the Commission review its order of June 8, 1949, as amended by its order of October 1, 1957, governing the regulation of the levels of Rainy Lake and other boundary waters in the Rainy Lake watershed with the view of eliminating the extremely low flows in the Rainy River now prevalent on weekends below the outlet of Rainy Lake.

7. Boats should be equipped with effective devices for treatment of sewage and pollutional matter. No refuse or other waste should be discharged overboard in boundary waters.

8. Definite plans for financing and constructing municipal works needed to remedy pollution should be formulated.

9. Definite time schedules for abatement of industrial waste pollution should be established and followed.

10. Continuing surveillance over pollution control progress should be maintained through a technical committee or board, with representation from both countries including Federal, state, and provincial governments.

11. The Commission should take such measures as may be legally available to it to have the pollution abatement and prevention program herein outlined initiated, promoted and effectively prosecuted.
The Pollution Problem

The waters between the United States and Canada are vitally important to health, recreation, and the national economy of both countries. In the Rainy Lake, Rainy River, and Lake of the Woods section of the boundary the pulp and paper industry, recreation, and agriculture have developed to a considerable degree. The success of these developments, and indirectly the welfare of larger areas of both countries, is influenced in no small measure by maintenance of these waters free from objectionable pollution.

Pollution control is an ever changing problem. At one time the major source of contamination was human sewage, and the degree of bacterial pollution was the primary concern. This continues to be an important health problem, but industrial developments in both countries have added new factors. Their wastes produce effects additional to and different from those created by the concentration of sewage bacteria. These industrial wastes may have a deleterious effect on the aesthetic qualities of the water as well as on its physical and chemical properties. Their health significance is secondary to sewage, but they may seriously impair the use of water for domestic, recreational, industrial, and other purposes. The development of new products, the expansion of industrial activity, and modification of industrial processes all cause variations in wastes which intensify the problems of water pollution control. These problems are further aggravated in this area by the demand of large sections of population of both countries for the preservation of these extensive recreational resources.

The Previous Investigation

The pollution of boundary waters between Canada and the United States has been of concern to both countries for more than half a century. Interest has been manifest in the extent, nature, and dispersion of pollution from each side of the boundary to the other. An answer to this question was first sought when the initial survey of these waters was undertaken in 1913 by the International Joint Commission. The "Progress Report of the International Joint Commission"(1) in 1914, emphasized the extent of bacterial contamination at that time.

In the interval between 1913 and 1962 the population, the use of the area for recreation, and the volume of industrial wastes have increased greatly. Some waste treatment facilities have been built, but continuing efforts will be required to insure that these waters will be maintained in a satisfactory state for the use of the people of both nations.
Authorization of Survey

"The Governments of the United States and Canada have been informed that the waters of the Rainy River and the Lake of the Woods are being polluted by sewage and industrial wastes emptied into these waters. Having in mind the provisions of Article IV of the Boundary Waters Treaty signed January 11, 1909, that boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other side, the two Governments have agreed upon a joint Reference(*) of the matter to the International Joint Commission, pursuant to the provisions of Article IX of said Treaty. The Commission is requested to inquire into and to report to the two Governments upon the following questions:

"(1) Are the waters referred to in the preceding paragraph, or any of them, actually being polluted on either side of the boundary to the injury of health or property on the other side of the boundary?

"(2) If the foregoing question is answered in the affirmative, to what extent, by what causes, and in what localities is such pollution taking place?

"(3) If the Commission should find that pollution of the character just referred to is taking place, what measures for remedying the situation would, in its judgment, be most practicable from the economic, sanitary and other points of view?

"(4) If the Commission should find that the construction or maintenance of remedial or preventive works is necessary to render the waters sanitary and suitable for domestic and other uses, it should indicate the nature, location, and extent of such works, and the probable cost thereof, and by whom and in what proportions such cost should be borne.

"For the purpose of assisting the Commission in making the investigation and recommendations provided for in this Reference, the two Governments will, upon request, make available to the Commission the services of engineers and other specially qualified personnel of their governmental agencies, and such information and technical data as may have been acquired by such agencies or as may be acquired by them during the course of the investigation.

"The Commission should submit its report and recommendations to the two Governments as soon as practicable."

Advisory Board on Water Pollution

Pursuant to the reference of the two Governments the International Joint Commission appointed an Advisory Board on Water Pollution for

(*) May 30, 1959
Rainy River and Lake of the Woods and issued a directive dated December 15, 1959, as follows:

"1. The Advisory Board on Water Pollution--Rainy River and Lake of the Woods was established by the International Joint Commission on 8 October 1959, and the following were appointed to serve on the Board:

United States Section:

Mr. L. F. Warrick (Chairman)
Mr. H. C. Clare
Mr. S. A. Frellsen
Mr. H. G. Rogers*

Canadian Section:

Mr. J. R. Menzies (Chairman)**
Dr. A. E. Berry
Mr. R. E. Tait
Mr. F. A. Voege

"2. The Board will carry out the technical investigations and studies necessary to enable the Commission to prepare and submit its report and recommendations to the Governments of the United States and Canada, as requested by the two Governments in a Reference to the Commission dated 30 May 1959. A copy of the said Reference is attached hereto.

"3. Field investigations should be directed initially to pollution of the waters of Rainy River, of tributaries of Rainy River insofar as the quality of the tributary waters affects the quality of the waters of Rainy River and of Lake of the Woods insofar as the quality of its waters are affected by the quality of waters discharged to it from Rainy River. The Board will advise the Commission if it appears that more extensive investigation of pollution of the waters of Lake of the Woods would be desirable.

"4. The Board will furnish a preliminary report to the Commission on or before 31 March 1960 containing a general outline of the existing situation as regards pollution in the area under reference, and of the procedure proposed for carrying out the investigation.

*The late Harvey G. Rogers retired from the Board March 9, 1962, and on that date was succeeded by Mr. Lyle H. Smith.

**Following the death of Mr. J. Ross Menzies on December 9, 1961, Mr. William R. Edmonds was appointed on March 8, 1962, to the Board as Chairman of the Canadian Section.
"5. The Board is authorized to establish such committees and working groups as may be required to effectively discharge its responsibilities, to enlist the cooperation of technical officers of other Federal, Provincial or State Departments or agencies in the United States and Canada and to make such expenditures for travel as may be found necessary.

"6. The Board is requested to carry out its investigation as expeditiously as possible and to keep the Commission currently informed of developments and progress. To this end, the Board will prepare and submit semi-annual progress reports to the Commission on or about 31 March and 30 September of each year and such other reports from time to time as the Commission may direct or as the Board may consider desirable."

Organization of the Survey

Field work on the survey of these boundary waters was initiated in June, 1960. The personnel was supplied by the United States Public Health Service, the Canadian Department of National Health and Welfare, the Ontario Water Resources Commission, and the Minnesota Department of Health. Work in the field and laboratory was carried out on a joint cooperative basis under the general direction of Dr. Gerald W. Lawton, Special Consultant, U. S. Public Health Service. During the summer of 1961, Mr. Orlando Ruschmeyer took over the direction of the field and laboratory work due to the unavailability of Dr. Lawton during the early part of the summer. Dr. Alan D. Tennant, Bacteriologist, Canadian Laboratory of Hygiene organized the program of bacteriological studies. Dr. Joe K. Neel, Biologist of the U. S. Public Health Service, and John Neil, Biologist of the Ontario Water Resources Commission organized the biological studies program. Dr. Theodore A. Olson and Dr. Lloyd L. Smith, Jr., served as special consultants on the biological program.

Field work was carried out from June through September, 1960. In 1961 field work was carried out from mid-June to mid-September. In addition a winter survey of two weeks was conducted in January, 1962, by the Minnesota Department of Health and the Canadian Department of National Health and Welfare. Special field studies, mainly biological, were made during the summer of 1962, including fishery studies conducted by the Minnesota Department of Conservation, under contract with the U. S. Public Health Service, and the Ontario Department of Lands and Forests.

A research project under a grant by the U. S. Public Health Service, directed by Dr. Lloyd L. Smith, Jr. (*), of the University of Minnesota,

Winter sampling through the ice during Rainy River - Lake of the Woods boundary water survey, January, 1962.
studied the effect of wood fibers on the various stages of fish development. This project consisted of laboratory studies at the University of Minnesota and field studies at a temporary camp on Rainy River near the mouth of the Big Fork River. These wood-fiber studies continued from early 1961 through 1962.

General Procedure

The Advisory Board was responsible for the general organization of the field work and made arrangements for the use of necessary laboratory and field equipment. Laboratory headquarters was established at the International Falls municipal waste treatment plant. Facilities included a complete mobile bacteriological laboratory supplied by the Canadian Department of National Health and Welfare, a trailer laboratory supplied by the U. S. Public Health Service, and the main chemical laboratory located in the treatment plant. Field studies included sampling and analyses of the boundary waters and tributaries, float tests for determining the direction of currents, visual and microscopic examination of the water and benthological samples, and investigation of industries and other sources of waste.

Selection and Designation of Sampling Points

The sampling points selected corresponded approximately with those previously used jointly by the Departments of Health of the State of Minnesota and the Province of Ontario. The selection of these points was influenced by the location of known sources of waste, characteristics of stream flows, locations of tributaries, accessibility, and location of sampling points used during the 1913 International Joint Commission survey. The known waste sources included municipal and industrial sewer outlets along the shores of Rainy River and its tributaries. Stream flow characteristics were considered significant in relation to dispersion of wastes throughout these boundary waters. The diluting effect of the tributaries influences the pollution pattern in the stream. To facilitate comparison of results with those of the 1913 survey, many of the same sampling points were used in the 1960-62 investigation.

To identify the location of sampling ranges, sewer outlets, and other important points on the river, a mileage index system was used. Each sampling range on Rainy River was identified by reference to one or two international boundary markers (IBC). The zero mileage point is located at the mouth of Rainy River as indicated by a line through boundary marker number 51 and turning point number 38. All ranges were identified by numbers which represent the distances in river miles above the zero point at the Lake of the Woods. One sampling point was located on each tributary and indicated by a mileage number only.
Table 1. Ranges and Stations of the Rainy River Survey 1960-62

<table>
<thead>
<tr>
<th>Range Number</th>
<th>Boundary Marker Numbers</th>
<th>Station Numbers</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U. S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Canada</td>
<td></td>
<td></td>
</tr>
<tr>
<td>86.4</td>
<td>266</td>
<td>265</td>
<td>1+00, 2+00, 3+00, 4+00</td>
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<td>83.5</td>
<td>254</td>
<td>256</td>
<td>0+35, 2+35, 4+35, 5+35, 6+35</td>
</tr>
<tr>
<td>83.3</td>
<td>255</td>
<td>253</td>
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</tr>
<tr>
<td>82.2</td>
<td>-</td>
<td>250</td>
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<td>240</td>
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<td>71.2</td>
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<td>-</td>
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<tr>
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<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>68.0</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>64.8</td>
<td>-</td>
<td>212</td>
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</tr>
<tr>
<td>63.8</td>
<td>-</td>
<td>-</td>
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<td>60.2</td>
<td>204</td>
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<tr>
<td>60.1</td>
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<tr>
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<tr>
<td>41.2</td>
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<td>-</td>
<td></td>
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<tr>
<td>36.4</td>
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<td>-</td>
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<td>119</td>
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<td>1+00, 2+00, 3+00, 4+00, 5+00</td>
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<td>19.9</td>
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<td>17.2</td>
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<td>-</td>
<td></td>
</tr>
<tr>
<td>13.8</td>
<td>-</td>
<td>92</td>
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</tr>
<tr>
<td>12.2</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
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<td>89</td>
<td>87</td>
<td>1+00, 3+00, 5+00, 7+00, 9+00</td>
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<tr>
<td>10.9</td>
<td>86</td>
<td>-</td>
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</tr>
<tr>
<td>9.3</td>
<td>80</td>
<td>-</td>
<td>1+00, 3+00, 5+00, 7+00, 9+00</td>
</tr>
<tr>
<td>7.8</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>52</td>
<td>53</td>
<td>1+00, 2+00, 3+00, 5+00, 7+00</td>
</tr>
</tbody>
</table>
Each range on Rainy River consisted of four to eight sampling points designated as stations. Each station was defined by distance in hundreds of feet from the U. S. shore. Table 1 gives the ranges, stations, and general locations.

The river mileage system was not adaptable for Lake of the Woods or Rainy Lake. Sampling points on Lake of the Woods are shown on Figure 11.

**Laboratory Determinations**

Routine determinations on water samples included coliform organisms, pH, temperature, dissolved oxygen, biochemical oxygen demand, turbidity, total solids including volatile, suspended solids including volatile, color, and lignin. In addition, chemical oxygen demand, phenol, calcium, alkalinity, conductivity, and hardness determinations were made on certain samples. Bottom samples were taken at all ranges where obtainable and examined for bark, chips, fibers, and types of soil. In general, the analytical procedures conformed to those given in the current edition of "Standard Methods". (2)

Samples for biological examination were taken separately at several times during the course of the survey. These samples were examined for bark chips, fiber, and numbers and types of organisms.

A close approximation of the number of samples collected and analyses made during the course of the survey is presented in Table 2.

<table>
<thead>
<tr>
<th>Source</th>
<th>Bacterial Examinations</th>
<th>Chemical Examinations</th>
<th>Examinations Determinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainy Lake</td>
<td>48</td>
<td>26</td>
<td>276</td>
</tr>
<tr>
<td>Rainy River</td>
<td>2,978</td>
<td>2,407</td>
<td>20,791</td>
</tr>
<tr>
<td>Rainy River Tributaries</td>
<td>139</td>
<td>107</td>
<td>963</td>
</tr>
<tr>
<td>Lake of the Woods</td>
<td>65</td>
<td>65</td>
<td>705</td>
</tr>
<tr>
<td>Pulp and paper mills</td>
<td>84</td>
<td>304</td>
<td>3,468</td>
</tr>
<tr>
<td>Totals</td>
<td>3,314</td>
<td>2,909</td>
<td>26,203</td>
</tr>
</tbody>
</table>

During 1961, some samples were specially preserved and sent to the Minnesota Department of Health laboratories for phenol determinations. The winter survey of January, 1962, also made use of the laboratories of the Departments of Health of Ontario, Minnesota, and Manitoba for determinations other than those made at the point of sampling.
GENERAL DESCRIPTION

The 1931 Report of the International Boundary Commission states that "From the northwesternmost point of Lake of the Woods to Lake Superior the boundary follows an almost continuous system of waterways broken only at three places by short portages whose combined length is less than one mile. The line follows the old canoe route of the early fur traders which traversed a region of irregularly shaped lakes joined by streams comprising, as a rule, a series of ponds or pools connected by rapids or falls."

The Ontario-Minnesota Rainy River Pollution Survey of 1937 states that "The Rainy River comprises a part of one of the most imposing water systems of the North American continent. It flows out of Rainy Lake whose watershed is a vast forested lake country beginning at North Lake about 40 miles west of Lake Superior and extending westward approximately 200 miles to Rainy Lake itself. The watershed drains areas from both sides of the International Boundary. The water collected in Rainy Lake flows down the Rainy River, through Lake of the Woods, the Winnipeg River and Winnipeg Lake, finally reaching Hudson Bay via the Nelson River."

Headwaters

More than two-thirds of the Rainy River watershed lies above Rainy Lake. What is considered to be the main stem rises in North Lake on the International Boundary and consists mainly of a series of lakes connected by short streams. Available maps indicate that the main stem leaves the boundary and courses into Ontario at two points, one between Saganaga Lake and Lac La Croix where it enters as the Maligne River, and the other as the Namakan River between Lac La Croix and Namakan Lake.

In Minnesota the Rainy River headwaters watershed area comprises 4,489 square miles and includes parts of Koochiching, St. Louis, Lake, and Cook Counties. The area of that part of the watershed in Ontario is about 10,000 square miles, and includes parts of Rainy River, Kenora, and Thunder Bay Districts.

Rainy River and Tributaries

The watershed boundaries are shown in Figure 1. Rainy River above its mouth in the Lake of the Woods drains an area of 20,850 square miles, 10,850 square miles in the Province of Ontario, and 10,000 square miles in the State of Minnesota. The stream is about 86 river miles in length, flowing from east to west along a fairly direct course. There are several bends in the stream but the channel is far from being torturous. The stream is wide at practically all points, and the depth seldom exceeds 20 feet. The stream is further characterized by several wooded islands which divide the water into definite channels.
The current is normally strong except in the lower portion of the stream. However, controlled outflow flow in accordance with the regulations established by the I.J.C. frequently produces very low flow on week-ends. Frequently on Sunday and early Monday the effects of the controlled flow are evident in the area from International Falls to Manitou Rapids, and at many locations large portions of the usual river bottom are exposed to view. From the Baudette-Rainy River area to Lake of the Woods, the current is slow. In this reach of the river the effect of the week-end reduction in flow at International Falls is not apparent.

Tributaries to the Rainy River proper enter from both sides of the stream. The drainage area on the Canadian side approximates 600 square miles and on the United States side about 5,700 square miles. The principal streams on the Canadian side are the La Vallee, Sturgeon, and Pine Rivers. On the Minnesota Side the Little Fork, Big Fork, Black, Rapid, Baudette, and Winter Road Rivers are worthy of note. The Little Fork and Big Fork Rivers drain the greater part of the area with 1,849 and 2,063 square miles in their respective watersheds. The mean flows in these two rivers are 972 and 653 cubic feet per second (cfs), respectively.

Lake of the Woods

Lake of the Woods, including Shoal Lake, is an irregular lake with an area of 1,485 square miles of which 470 square miles are within Minnesota. The lake is relatively shallow, with a major portion ranging from 25 to 35 feet in depth. In Canada the greater portion lies in western Ontario, with only a few small areas extending into Manitoba. The total watershed of the lake covers 11,235 square miles in Minnesota and 15,515 square miles in Canada. Of these areas 5,900 square miles drains directly into the Lake of the Woods. In the southern and western parts of the lake the shoreline is fairly regular, but in the northern and eastern sections the shoreline is extremely irregular. Many large and small islands are found in the Ontario section of the lake. This area is widely used for fishing and hunting by people from many sections of the United States and Canada.

Topography

The topographic features of the watershed have been shaped largely by the heavy sheet of ice that covered the region during the glacial period. The leveling action of the ice resulted in a terrain characterized by relatively small differences in elevation.

In Ontario the average slope of the upland bordering the river proper is less than one foot per mile. The general slope in a southwesterly direction towards Rainy River is somewhat greater, but is interrupted by isolated areas at times several hundred feet high.
The maximum relief of the area is 300 feet but the average is very much less.

Rainy River is a remarkable river in that it nearly fits its banks and has few meanders. Throughout much of its course the banks rise abruptly on both sides. The banks have generally rounded, smooth, grass covered slopes. In the upper part of its course the immediate banks are generally 25 to 35 feet high. At many points the river valley is not greater than two or three times the width of the river itself. The river has very little flood plain even in its lower portion.

The average width of the river is approximately 200 yards, and its depth in mid-channel generally varies from 10 to 20 feet. Downstream from the dam at Fort Frances there are two rapids influencing the flow in the stream. The first occurs at Manitou Rapids, 35 miles downstream from Fort Frances, where a rocky barrier causes a constriction of the channel of the river to about half its normal width. The fall here is about 1.5 feet. Seven miles farther downstream the Long Sault Rapids begin. They are caused by boulders in the bed of the stream, and extend for about two miles with an estimated total fall of 5.5 feet.

The average gradient for the surface of the water is 2.5 inches per mile from Fort Frances to the Rainy River-Baudette area. Disregarding the rapids this is reduced to 1.5 inches per mile. Below Baudette the gradient is approximately one inch per mile.

Lake of the Woods is naturally divided into two distinct portions, a northern portion characterized by a very irregular, rocky coast line and having its surface thickly dotted with islands, and a southern portion generally free from islands and bounded by low, sandy or marshy, shores with gently curving outlines. The southern portion of the lake is for the most part shallow and represents a flooded portion of the deeply drift-covered plain. In the northern part of the lake the greatest depth is reported to be 84 feet.

Southwestward from the Lake of the Woods the summit of the divide separating the waters which drain westward to Red River and those draining into the Lake of the Woods is generally composed of drift deposits, is swampy in character, and for some distance is not over 30 feet above the lake. Hence the wooded plains of Rainy River district and the southern portion of Lake of the Woods are practically continuous with those of northern Minnesota and southeastern Manitoba.

Lake of the Woods in 1913 was found to have an altitude of 1,061 feet, with a maximum variation at that time of about five feet. Since 1925, the lake levels have been controlled by I.J.C. regulations.
Geology

Johnston(5) notes that the Rainy River District of Ontario lies just at the margin of the great Laurentian Plateau region of Canada. This district for the most part is underlain by Pre-Cambrian rocks, but is generally deeply covered with glacial and lacustrine deposits. The waters of pro-glacial (glacial marginal) Lake Agassiz at their maximum extension covered nearly the whole area, and the deposition of lacustrine sediments lessened the relief and gave part of the surface the character of a plain. A large part of the area, however, where till or boulder clay forms the surface, is gently undulating, but even in these areas the relief is slight. Notable features in the character of the surface (along Rainy River) are the general absence of lakes due to the evenly aggraded character of the drift deposits, and the large swampy areas where drainage is poorly or not at all developed.

A considerable portion of the superficial deposits of the region consists of calcareous till or boulder clay containing a large proportion of limestone, similar to that which outcrops near Winnipeg, Manitoba. The till sheet occupies large areas in the southern portion of the region, along the Rainy River, but is entirely absent in the northern portion, and in the eastern part does not extend beyond Fort Frances. The calcareous or gray till is underlain in places by "red drift", consisting of a non-calcareous till and fluvio-glacial sands and gravel derived from an ice sheet advancing from the northeast, across a region underlain by Pre-Cambrian crystalline rock. Hence the red drift contains no limestone.

At one locality the red drift was found to be underlain by a still older deposit of calcareous drift which was, presumably, derived from the northwest. Later than all the above deposits are the lacustrine and littoral deposits of pro-glacial Lake Agassiz. They occupy considerable areas in the district and occur through a range of altitudes of nearly 100 feet. Their maximum thickness is, in places, at least 30 feet.

The Rainy River watershed in Minnesota consists almost entirely of a gravelly, clayey subsoil covered with sandy or clayey loam with portions of the area covered with peaty material. An exception to this is a band along the extreme south edge of the watershed in Itasca and St. Louis Counties, which is the uppermost section of the watersheds of the Big Fork and Little Fork Rivers. The eastern one-third of this band is clay with boulders and the remainder gravelly, sandy loam. There are also scattered small islands of gravelly, sandy loam in Koochiching County. In a few areas the Pre-Cambrian crystalline rock crops out at the surface along the Rainy River.
Climate

Long term climatological records of the United States Weather Bureau Stations at Baudette, Tower, and International Falls, and the Canadian Meteorological Branch Stations at Atikokan, Fort Frances, Mine Centre, and Upsala provided the data summarized in Table 3.

Table 3 (2a)*. Climatological Data Summary

<table>
<thead>
<tr>
<th></th>
<th>U. S. Weather Bureau Stations</th>
<th>Canadian Meteorological Branch Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (inches)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean annual</td>
<td>24.63</td>
<td>24.75</td>
</tr>
<tr>
<td>Mean October-March</td>
<td>6.54</td>
<td>7.10</td>
</tr>
<tr>
<td>Snowfall (inches)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean annual</td>
<td>60.1 (Int. Falls)</td>
<td>60.6</td>
</tr>
<tr>
<td>Range</td>
<td>----</td>
<td>40-107</td>
</tr>
<tr>
<td>Temperature (degrees F.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean annual</td>
<td>37</td>
<td>36</td>
</tr>
<tr>
<td>Mean October-March</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>Mean April-September</td>
<td>57</td>
<td>55</td>
</tr>
<tr>
<td>Highest</td>
<td>106</td>
<td>108</td>
</tr>
<tr>
<td>Lowest</td>
<td>-53</td>
<td>-57</td>
</tr>
</tbody>
</table>

The watershed is characterized by warm pleasant summers and cold snowy winters. The direction of the prevailing wind varies from month to month and from year to year. During the winter the winds are generally from the west, northwest and north. During the spring months easterly and northeasterly winds occur more frequently than at any other season, but there is also great variation. During the summer southerly and southwesterly winds more commonly occur, and during the autumn months southwesterly and westerly winds prevail. Destructive windstorms rarely occur in this region.

Population

The population in the area based on the census years of 1960 and 1961 totaled approximately 47,000. Five communities have populations in excess of 1,000. Their combined total equals 42 percent of the population in the watershed. Population growth was

*Table numbers in parentheses correspond with those in the Board's full report.
moderate up to 1940 and since has declined slightly. Recent increases in urban population have been more than offset by declines in rural population. Population density expressed in persons per square mile is approximately 27 in Ontario and slightly over 5 in Minnesota. Figure 2 shows population trends since 1910-1911. Changes in urban population are shown in Table 4.

Table 4 (3). Urban Population Changes

<table>
<thead>
<tr>
<th>Municipality</th>
<th>1910</th>
<th>1920</th>
<th>1930</th>
<th>1940</th>
<th>1950</th>
<th>1960</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort Frances, Ontario</td>
<td>2,780</td>
<td>2,818</td>
<td>5,003</td>
<td>5,410</td>
<td>8,114</td>
<td>9,481</td>
</tr>
<tr>
<td>Rainy River, Ontario</td>
<td>1,572</td>
<td>1,404</td>
<td>1,680</td>
<td>1,150</td>
<td>1,348</td>
<td>1,168</td>
</tr>
<tr>
<td>International Falls, Minn.</td>
<td>1,487</td>
<td>3,448</td>
<td>5,036</td>
<td>5,626</td>
<td>6,269</td>
<td>6,778</td>
</tr>
<tr>
<td>South Int. Falls, Minn.</td>
<td>-----</td>
<td>283</td>
<td>939</td>
<td>1,299</td>
<td>1,840</td>
<td>2,479</td>
</tr>
<tr>
<td>Baudette, Minnesota</td>
<td>1,565</td>
<td>1,531</td>
<td>1,036</td>
<td>1,459</td>
<td>1,349</td>
<td>1,577</td>
</tr>
<tr>
<td>TOTALS</td>
<td>7,404</td>
<td>9,484</td>
<td>13,694</td>
<td>14,944</td>
<td>18,920</td>
<td>21,503</td>
</tr>
</tbody>
</table>

Land Use and Development

The Rainy River watershed in both Canada and the United States is devoted mainly to agricultural, silvicultural, and recreational uses. Fur farming, forest products industries, and commercial fishing also exist. In International Falls and Fort Frances extensive pulp and paper manufacturing facilities have developed. The large peat deposits in the swampy areas may have future potentialities for commercial development. In the early days, lumbering was the outstanding industry, but presently it is of lesser significance.

Recreational facilities such as summer cottages, resorts, fishing areas and bathing beaches are widely scattered in the Rainy River watershed and in the area adjacent to Lake of the Woods. On Rainy River proper from Fort Frances to Baudette limited recreational facilities have been developed. In this section of the river very few summer homes, practically no bathing areas, and few boats are encountered. In the lower part of the river, especially near the Sioux and Manitou Rapids, there is a limited amount of sport fishing. Along the reach of the river from Baudette to the mouth there has been extensive development of recreational facilities and there is considerable sport fishing.

Practically all of the farming in the Minnesota section of the watershed is found in Koochiching and Lake of the Woods counties. Approximately 864 farms comprising 213,500 acres are included in the two counties. The principal crops are hay, grains, and potatoes. Table 5 indicates the acreage of the important crops.
Figure 2
POPULATION TRENDS 1910-1961

DATA FROM CANADIAN AND U.S. CENSUS BUREAUS

- 20 -
Table 5 (6). Crop Distribution in Rainy River Watershed (Minnesota)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Acres</th>
<th>Crop</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oats</td>
<td>14,397</td>
<td>Winter Wheat</td>
<td>499</td>
</tr>
<tr>
<td>Barley</td>
<td>1,756</td>
<td>Potatoes</td>
<td>1,374</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>3,679</td>
<td>All hay crops</td>
<td>31,518</td>
</tr>
<tr>
<td>Flax Seed</td>
<td>5,372</td>
<td>Rye</td>
<td>688</td>
</tr>
</tbody>
</table>

In Ontario the general flat topography and accompanying poor drainage tended to restrict early settlement to narrow strips parallel to the bank of Rainy River. The heavily forested area created difficult problems in the clearing of land for agriculture. It was not until artificial drainage measures were taken that large areas could be brought under cultivation. Even today, farming is restricted to a strip of about five to seven miles in depth back from the river. The soil in the area being of lacustrine origin, enriched by the humus formed through centuries of forest growth, continues to support mixed farming, particularly the cultivation of forage and root crops. Livestock and dairy farming are important along the Rainy River.

An economic survey of the area showed that there are 1,371 farms with 90,294 acres of improved land in the Rainy River District in Ontario. The improved land is about 5.9 per cent of the total land area. According to the 1956 study, 14,799 acres were in spring grain with the largest portion of this acreage, 8,200, in oats. The total number of acres in hay was 44,558. Livestock is the main enterprise on most farms, the total number of cattle being 16,148. Sheep are also a good source of revenue, with a total number of 6,265.

A large number of farmers, it was stated, do not have sufficient livestock and acres of land under cultivation to provide a sufficient income. Many supplement their income by cutting pulpwood or timber during the winter months. A number of farms are no longer used for agricultural purposes.
Sources of Information

Hydrometric data presented in this report were obtained from available records and reports of various governmental agencies.

Flow records of Rainy River at International Falls-Fort Frances have been recorded since October, 1917, by the Water Resources Branch, Canadian Department of Northern Affairs and Natural Resources. Records from October, 1905, to October, 1917, were furnished by the International Joint Commission.

Flow records at Manitou Rapids on Rainy River have been recorded by the U. S. Geological Survey since November 10, 1934. From June, 1928, to November, 1934, flows were measured by the U. S. Corps of Engineers at a site near Birchdale, seven miles downstream from Manitou Rapids.

Flow recording stations are maintained on the Little Fork and Big Fork, and Warroad Rivers, at Little Fork, Big Falls, and Warroad, respectively. Flow data on other tributaries on the U. S. side are not available.

In Ontario flow recording stations are maintained on the Pine, Sturgeon and La Vallee Rivers at Pinewood, Barwick and Devlin, respectively.

Flow Characteristics

Rainy River at International Falls - Fort Frances

The watershed above this station is approximately 14,900 square miles, of which 10,360 square miles are in Ontario and 4,540 square miles are in Minnesota.

Discharge and runoff data: (Discharge records, 56 water years, October 1, 1905 to September 30, 1961; runoff records, 45 water years, October 1, 1905 to September 30, 1950).

(Maximum daily - - 47,900 cfs (July 7, 1950)
Flow (Minimum daily - - 40 cfs (April 20, 1941)
(Mean - - - - - - 9,100 cfs

(Maximum - 19.05 inches - (1950)
Annual runoff (Minimum - 2.94 inches - (1924)
(Mean - - 8.24 inches

Monthly runoff - maximum 3.86 inches (June 1950)

Data above is based on unadjusted records.
Flow duration data: (Records available from October 1, 1909 to September 30, 1961)

Exceeded 99.8 per cent of the time - - 1,000 cfs daily flow
Exceeded 50 per cent of the time - - 8,000 cfs daily flow

The flow duration data, because of the regulation of upstream reservoirs for power development, do not reflect natural conditions. The outflow from Rainy Lake is controlled by the Minnesota and Ontario Paper Company at the dam at International Falls-Fort Frances subject to the regulations of the International Joint Commission.

Rainy River at Manitou Rapids

The watershed above this gaging station is about 19,400 square miles. It includes, in addition to the headwaters area, the watershed of the Big Fork and Little Fork Rivers comprising 3,900 square miles, and 600 square miles tributary to minor streams entering the Rainy River.

Discharge and runoff data: (Complete records available for 34 water years, October 1, 1928 to September 30, 1962)

(Maximum - - - - 71,600 cfs (May 12, 1950)
Flow (Minimum daily - 928 cfs (Dec. 26, 1929)
(Mean - - - - 11,800 cfs

(Maximum - 16.31 inches - (1950)
Annual runoff (Minimum - 3.13 inches - (1931)
(Mean -- 8.26 inches

Monthly runoff - maximum 3.15 inches (May 1950)

Flow duration data (Complete records available from October 1, 1933 to September 30, 1962)

Exceeded 99.6 per cent of the time - - 3,000 cfs daily flow
Exceeded 50 per cent of the time - - 10,000 cfs daily flow

Figures 3 through 5 show the flow characteristics of Rainy River at International Falls-Fort Frances and at Manitou Rapids.

Time of flow studies made by the Minnesota and Ontario Paper Company(6) indicate that approximately 14 days are required for water to travel the 70 miles from International Falls to Baudette. Their studies were made during a period in which the flow ranged from 3,500 to 4,700 cfs. Additional flow times are given in Table 6.
Table 6 (7). Time of Passage of Water Down Rainy River
(Based on an Average Flow of 4,000 cfs)

<table>
<thead>
<tr>
<th>Location</th>
<th>Miles Downstream from International Falls</th>
<th>Time of Passage from International Falls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Little Fork River</td>
<td>12</td>
<td>16 hours</td>
</tr>
<tr>
<td>Below Manitou Rapids</td>
<td>36</td>
<td>44 hours</td>
</tr>
<tr>
<td>Below Sault Rapids</td>
<td>44</td>
<td>52 hours</td>
</tr>
<tr>
<td>Above Rapid River</td>
<td>62</td>
<td>11 days (approx.)</td>
</tr>
<tr>
<td>R. R. Bridge at Baudette</td>
<td>70</td>
<td>14 days (approx.)</td>
</tr>
</tbody>
</table>
Rainy River at Manitou Rapids

Figure 3
Figure 4

Duration curve of daily flow
Rainy River at International Falls

Maximum daily flow 47,900 cfs
Minimum daily flow 40 cfs
Median daily flow 6,000 cfs

Percent of time indicated discharge was equalled or exceeded
Duration curve of daily flow
Rainy River at Manitou Rapids
Compiled from U.S.G.S. records

Maximum daily flow 71,600 cfs
Minimum daily flow 2,200 cfs
Median daily flow 10,000 cfs

Percent of time indicated discharge was equalled or exceeded
Figure 4

Duration curve of daily flow
Rainy River at International Falls

Maximum daily flow 47,900 cfs
Minimum daily flow 40 cfs
Median daily flow 8,000 cfs

Percent of time indicated discharge was equalled or exceeded
Percent of time indicated discharge was equaled or exceeded

Division of Waters

Median daily flow 10,000 cfs
Minimum daily flow 2,200 cfs
Maximum daily flow 71,600 cfs

Fig. 2

Discharge, cubic feet per second

Compiled from U.S. G. S. Records
Oct. 1, 1933 - Sep. 30, 1962
Rainy River at Manitou Rapids

Duration curve of daily flow
USES OF BOUNDARY WATERS

Domestic Water Supply

Municipal and industrial water supplies for International Falls and Fort Frances are obtained from surface waters. Rural domestic and farm supplies are obtained mainly from wells.

Fort Frances pumps water from Rainy Lake through an intake a short distance above the outlet of the lake. It is chlorinated only. The Minnesota and Ontario Paper Company obtains water from the Rainy River just above the International Bridge. Its modern water purification plant, which includes flocculation, sedimentation, filtration and chlorination, processes water for the cities of International Falls and South International Falls, as well as for the mill manufacturing processes.

In the lower watershed on the Ontario side the town of Rainy River obtains water from the river with chlorination as the only treatment. There is no public supply at either Emo or Barwick. On the Minnesota side the Villages of Baudette, Big Falls, Big Fork, Cook, Little Fork and Warroad have municipal water systems, and all obtain water from wells in the glacial drift. Most of the rural domestic and farm supplies are secured also from wells in the glacial drift.

A large number of people temporarily residing in the resort areas during the summer months obtain their domestic water from wells. There may be instances in which some individuals outside the resort areas use untreated surface waters.

Sewage Disposal

The sanitary wastes from all sewered communities in the watershed ultimately reach the Rainy River. International Falls has secondary treatment facilities and South International Falls has recently constructed sewage stabilization ponds to provide adequate treatment. Other sewered communities on the Minnesota side of the drainage basin have primary treatment facilities. On the Ontario side only the Towns of Fort Frances and Rainy River have public sewers. Fort Frances has no treatment and Rainy River has only sedimentation facilities which are inadequate.

Domestic wastes from approximately 23,000 persons enter the Rainy River directly or indirectly. The most concentrated sewage loading occurs in the Fort Frances-International Falls area where the untreated wastes from approximately 9,500 people in Fort Frances and
the satisfactorily treated wastes of nearly 9,000 people in the International Falls area are added to these waters. Other communities along the river are relatively small. Presently Fort Frances, Rainy River, and Emo are planning the construction of treatment facilities.

Navigation

At present the Rainy River is little used for navigational purposes. Log rafts are towed across Rainy Lake to the mills at Fort Frances and International Falls during the summer. The dam at the mills, the two rapids, and modern land transportation facilities tend to discourage the use of the river for navigation for commercial purposes.

Power and Irrigation

At International Falls-Fort Frances the Minnesota and Ontario Paper Company uses water from Rainy Lake reservoir for the operation of a steam and hydroelectric plant. The hydroelectric plant at Big Falls in the Big Fork basin is the only source of water power from tributaries of Rainy River proper on the United States side.

Three hydroelectric stations are located at the outlet of Lake of the Woods in Canada. These stations are important in controlling the water level in Lake of the Woods.

No irrigation is carried on in the Minnesota section of the watershed or in the Rainy River District of Ontario.

Industrial Uses

The pulp and paper mills at Fort Frances and International Falls are the main industrial water users in the watershed. Large quantities of good quality water are essential to their operations. Essentially all of the used water is returned directly to the river. In some operations the water is not appreciably changed while in other operations the character is altered. The Minnesota and Ontario mill at International Falls processes approximately 1,000 cords of pulpwood daily requiring about 55 million U. S. gallons (46 million Imperial gallons) of water per day. The Ontario and Minnesota mill at Fort Frances processes approximately 500 cords of pulpwood daily using about 23 million Imperial gallons of water (28 million U. S. gallons) per day.

- 30 -
Industrial users of water of lesser magnitude include a brewery, a railroad tie plant, two milk plants and two soft drink plants in Fort Frances. Their water is obtained from the municipal supply. A creamery in the Village of Rainy River is the only other industrial water user of importance on the Canadian side.

Three slaughtering plants, three soft drink plants, and a milk plant are located in International Falls. Their water is obtained from the municipal supply.

**Recreational Uses**

Rainy River from International Falls-Fort Frances to Baudette is little used for recreational purposes. The high levels of color, turbidity, bacterial count, and suspended solids, render this reach of the river generally unattractive for bathing, boating, and fishing. Some sport fishing is done in the Long Sault and Manitou Rapids areas.

The section of Rainy River adjacent to Lake of the Woods has a well developed resort area and attracts a considerable number of people interested in fishing and boating. Boats are available in this area for transportation to various sections of Lake of the Woods. Canoeing in the lake areas has been popular for many years.

Estimates based on a 1958 Vacation Travel Survey(7) indicate that approximately eight per cent of the resort facilities in Minnesota are located in the Rainy River Watershed, and the amount spent by travelers and vacationers in this area is about $2,500,000 annually.

**Fish and Wild Life**

Sport fishing is carried on extensively in much of these boundary waters. In Lake of the Woods, commercial fishing is permitted. Muskellunge, lake trout, small mouth bass, wall-eyed pike, great northern pike, crappies, rock bass, whitefish, bullheads, perch and sturgeon are common to this area. Rainy River above Baudette is not widely used as a fishing area. In autumn duck and geese hunters flock to the area, where wild rice feeding grounds attract thousands of migratory wild fowl.

Nute(8) states that in the Rainy River Country "one may still see ruffed, pinneated, spruce, and sharp-tailed grouse, timber and brush wolves, bear, lynx, snowshoe hares, mink, otter, marten, beaver, and a few other rarer animals." Deer are still common in the area, and moose are occasionally noted.
Commercial Fishing

No commercial fishing is permitted in the Rainy River. Lake of the Woods has an extensive and valuable fishery, and commercial fishing licenses are issued by both the State of Minnesota and the Province of Ontario.
Rainy River Watershed

In Rainy River domestic and industrial wastes are prevalent. The situation for the entire watershed is as follows:

**Domestic wastes.** Many small communities are located in the watershed on either side of the border, but relatively few have sewer systems or treatment facilities. Generally, the domestic wastes in these communities are disposed of by soil absorption, thus they do not necessarily constitute a problem of river pollution.

The sewered communities in the area and data pertaining to the treatment methods used are shown in Table 7. Of the 47,266 estimated population in the watershed only about 23,800 live in sewered areas. Of those in the sewered area approximately 60 per cent have some form of waste water treatment with about one-third having secondary treatment facilities. When Fort Frances, Emo, and Rainy River complete their current construction plans all of the sewered area will have treatment facilities.

Minor sources of waste exist outside the communities listed in Table 7. Among these are three Minnesota schools adjacent to Rainy River, located at Border, Indus, and Loman. The three schools, with a combined daytime attendance of 217, discharge their waste to septic tanks which drain to the river. In addition, residences, summer cottages, resorts, motels, trailer establishments, and a few small communities are located on Rainy River. In some instances their sewage may be discharged into the boundary waters, but ordinarily it passes through septic tanks and into some form of soil absorption system. The transient summer population directly on Rainy River is estimated to reach 800 at times.

**Industrial wastes.** Industry contributes the greatest volume and strength of waste water to Rainy River. These wastes affect the water mainly from a physical and chemical rather than a bacterial standpoint. The chief objections to industrial wastes are the taste and odor producing compounds, the high oxygen demand, the high solids content, the color, and the toxic and physical effect on fish and other biological life.

In planning the survey, various types of substances were anticipated in the domestic and industrial wastes discharged to Rainy River. Coliform organisms are contributed chiefly by domestic sewage rather than by industrial wastes. Highly toxic substances were not
<table>
<thead>
<tr>
<th>Community</th>
<th>Flow - Design</th>
<th>Gals./Day Present</th>
<th>Population 1960-61</th>
<th>To stream lbs./day</th>
<th>Receiving Stream</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort Frances, Ont.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>9,481</td>
<td>1,580*</td>
<td>Rainy R.</td>
<td>(1) None</td>
</tr>
<tr>
<td>International Falls, Minn.</td>
<td>714,000</td>
<td>800,000</td>
<td>6,778</td>
<td>250</td>
<td>Rainy R.</td>
<td>Secondary</td>
</tr>
<tr>
<td>South Int. Falls, Minn.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>2,479</td>
<td>38*</td>
<td>Rainy L.</td>
<td>Oxidation ponds</td>
</tr>
<tr>
<td>Emo. Ont.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>630</td>
<td>100*</td>
<td>Rainy R.</td>
<td>(2) None</td>
</tr>
<tr>
<td>Rainy River, Ont.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>1,168</td>
<td>140*</td>
<td>Rainy R.</td>
<td>(3) Primary</td>
</tr>
<tr>
<td>Baudette, Minn.</td>
<td>200,000</td>
<td>331,000</td>
<td>1,597</td>
<td>480</td>
<td>Rainy R.</td>
<td>Primary</td>
</tr>
<tr>
<td>Little Fork, Minn.</td>
<td>30,000</td>
<td>N.A.</td>
<td>805</td>
<td>90*</td>
<td>Little Fork R.</td>
<td>Primary</td>
</tr>
<tr>
<td>Cook, Minn.</td>
<td>33,000</td>
<td>50,000</td>
<td>527</td>
<td>60*</td>
<td>Little Fork R.</td>
<td>Primary</td>
</tr>
<tr>
<td>Williams, Minn.</td>
<td>60,000</td>
<td>120,000</td>
<td>317</td>
<td>17</td>
<td>Zipple Creek</td>
<td>Primary</td>
</tr>
<tr>
<td>U. S. Air Force A.C.W.</td>
<td>32,000</td>
<td>5,000</td>
<td>50</td>
<td>4*</td>
<td>Baudette R.</td>
<td>Secondary</td>
</tr>
<tr>
<td>Station, Minn.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>23,832</strong></td>
<td><strong>2,759</strong></td>
<td><strong>N.A.</strong></td>
<td><strong>N.A.</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N.A. = Not Available
* Estimated
(1) Presently under construction (1963)
(2) Presently planning sewers and treatment works
(3) Presently planning secondary treatment (oxidation pond)
expected in appreciable amounts from the industries located in the watershed. Cyanides and various heavy metals were not considered of enough importance in this area to be included in the list of materials investigated. Phenols or phenol-like compounds were found in appreciable quantities in a few areas of the river adjacent to the mills and at times in some pulp and paper waste sewers. Some of the high phenol concentrations were found in the sewers from the debarking and grinding operations, indicating that natural wood contributes substances that react as phenols.

Wastes creating a biochemical oxygen demand (BOD) in the stream are common to nearly all industries in the area. Wastes from milk plants, food processing, breweries, and pulp and paper mills, all contain relatively large amounts of fats, proteins, or carbohydrates that are readily degraded by biological life in the stream with a consequent depletion of dissolved oxygen. Wood sugars from the pulping process have especially high oxygen demand. Biological sewage treatment ordinarily reduces the BOD of wastes by 70 to 95 per cent. Primary treatment may accomplish reductions up to about 35 per cent.

Suspended solids are present in most industrial wastes, but milk plant and soft drink processing wastes normally have very low concentrations. The other industries in the watershed discharge considerable quantities of suspended solids. Reduction of these solids by waste treatment may be very effective. Primary treatment is expected to obtain suspended solids reductions up to about 60 per cent and additional treatment may accomplish up to 95 per cent removal. With the exception of some pulp and paper wastes nearly all the industrial wastes receive at least primary treatment.

Lignin is a common constituent in streams flowing through wooded and swampy areas. Pulp and paper wastes usually exhibit high concentrations of lignin as a result of the separation of wood fibers and a liberation of lignin in the pulping process. Other industries in the area normally discharge little or no lignin.

Oils and greases present little problem in this river. With the exception of slaughtering plants little grease is expected from the industries. All the slaughtering wastes undergo at least primary treatment which removes the bulk of these substances. The two wood treating plants use creosote or similar materials, but there was no evidence that these substances were being discharged into the river. Occasional findings of wax, grease, or similar materials in the river or on the shore have been reported.

Taste and odor were not determined on waste samples or river water because there has been no history of a problem of this nature.
The source and estimated amount of industrial wastes not receiving treatment in municipal waste treatment plants are given in Table 8. It may be noted from this table that the bulk of the industrial waste discharge occurs in the Fort Frances-International Falls area. The wastes originating in Fort Frances are discharged to Rainy River without treatment either through the municipal sewerage system or directly, in the case of the Ontario and Minnesota Paper Co. Ltd. At International Falls all wastes, with the exception of the pulp and paper wastes, are discharged to the municipal sewers and consequently are given biological treatment. The pulp and paper wastes are discharged directly to Rainy River. Approximately 60 per cent of the domestic sewage from the Minnesota and Ontario Paper Company is included with their industrial wastes. The remaining 40 per cent is segregated and diverted to the International Falls municipal sewer system.

The Ontario and Minnesota Pulp and Paper Co. Ltd. at Fort Frances is located on the north bank of the Rainy River at the end of the power and control dam. The production of pulp is based entirely on the groundwood process, supplying the needs for newsprint and specialty paper production, as well as supplying a portion of the pulp required for the International Falls operation. Sulfite pulp used in the production of paper is pumped in a pipeline as slush stock from the U. S. Mill. Kraft pulp that is used is trucked in from the International Falls plant. Average wood consumption is approximately 500 cords per day and the average paper production approximates 400 tons per day. The total mill employment averages about 640 persons. The mill waste waters are conveyed directly to the river through five sewers.

The Minnesota and Ontario Paper Company at International Falls is located on the south bank of the Rainy River, opposite the Canadian Mill, at the end of the power and control dam. Pulp is produced by the groundwood process, the sulfite process, and the kraft process. A portion of the pulp from the latter two processes is supplied to the Fort Frances mill for its paper production. The wood delivered for sulfite, Kraft and Insulite pulp production averaged approximately 340, 240, and 170 cords per day, respectively, in 1960 and 330, 290, and 410 cords per day in 1961. Finished products averaged approximately 320 and 330 tons of paper in 1960 and 1961, respectively, and 440 and 710 tons of Insulite board daily in 1960 and 1961. The total mill employment averages about 2,000. The mill waste waters are conducted to Rainy River through 11 sewers. (See Appendix for schematic diagrams of pulp, paper, and paper board manufacturing processes.)

Pulp and Paper Mill Surveys

Waste surveys of the mills of the Minnesota and Ontario Paper Company and of the Ontario - Minnesota Pulp and Paper Company Ltd.
<table>
<thead>
<tr>
<th>Location and Name</th>
<th>Process or Product</th>
<th>BOD lbs/day</th>
<th>Waste Treatment and Control</th>
<th>Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MINNESOTA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>International Falls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minnesota &amp; Ontario Paper Co.</td>
<td>Groundwood, kraft and sulfite pulping, bleaching, manufacturing of paper and various board</td>
<td>1960 - 162,000, 1961 - 232,700</td>
<td>Save-all, bark recovery plant, settling pond, foam barrier, sulfite liquor for road binder</td>
<td>Rainy River</td>
</tr>
<tr>
<td>Grabills Farm Market</td>
<td>Slaughtering</td>
<td>25*</td>
<td>Septic tank, drain tile to surface</td>
<td>Soil or Rainy River</td>
</tr>
<tr>
<td><strong>Big Fork</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Big Fork Valley Coop Creamery Association</td>
<td>Butter</td>
<td>5*</td>
<td>Septic tank. Buttermilk sold</td>
<td>Rice River to Rainy River</td>
</tr>
<tr>
<td><strong>Loman</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loman Co-op, Creamery Association</td>
<td>Butter</td>
<td>15*</td>
<td>Septic tank</td>
<td>Soil or Moose Creek to Black R. to Rainy R.</td>
</tr>
<tr>
<td><strong>Williams</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Williams Cash Market</td>
<td>Slaughtering</td>
<td>15*</td>
<td>Septic tank, solids and blood hauled out, sanitary sewage to municipal system</td>
<td>Zipple Creek to Lake of the Woods</td>
</tr>
<tr>
<td><strong>ONTARIO</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fort Frances</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fort Frances Brewing Co. Ltd.</td>
<td>Beer</td>
<td></td>
<td>Septic tank</td>
<td>Rainy River</td>
</tr>
</tbody>
</table>

Table 8 (11). Industrial Wastes Not Receiving Treatment in Municipal Waste Treatment Plants
<table>
<thead>
<tr>
<th>Location and Name</th>
<th>Process or Product</th>
<th>BOD lbs/day</th>
<th>Waste Treatment and Control</th>
<th>Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ONTARIO -- Cont'd.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fort Frances</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borden Dairy</td>
<td>Milk products</td>
<td></td>
<td>None</td>
<td>Rainy River</td>
</tr>
<tr>
<td>Fort Frances Dairy</td>
<td>Milk products</td>
<td></td>
<td>None</td>
<td>Rainy River</td>
</tr>
<tr>
<td>Beck's Beverage Ltd.</td>
<td>Soft drinks</td>
<td></td>
<td>Septic tank</td>
<td>Rainy River</td>
</tr>
<tr>
<td>Ontario Minnesota Pulp &amp; Paper Co. Ltd.</td>
<td>Groundwood pulping and paper manufacturing</td>
<td>1960 - 23,300</td>
<td>Save-alls, bark recovery plant, screens</td>
<td>Rainy River</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1961 - 22,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1962 - 12,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rainy River Dairy</td>
<td>Milk products</td>
<td></td>
<td></td>
<td>Rainy River</td>
</tr>
</tbody>
</table>

* - Estimated
were made during the summer periods of 1960 to 1962. The surveys of the Minnesota mill were made in 1960 and 1961 under the supervision of members of the staff of the Section of Water Pollution Control, Minnesota Department of Health. The surveys of the Ontario mill were made under the supervision of members of the staff of the Ontario Water Resources Commission in 1960, 1961, and 1962.
M&O Plant Sulfite Sewer basin - only one left intact after high water of May-June, 1962

POLLUTION EFFECTS ON BOUNDARY WATER QUALITY

The effects of pollution in Rainy River have been measured by chemical, bacteriological, biological and physical examinations. In the present investigation, the analytical results show that pollution is due to both domestic and industrial wastes. Sampling covered Rainy Lake near its outlet, Rainy River, streams tributary to Rainy River, Lake of the Woods near the mouth of Rainy River and various pulp and paper mill sewers.

Comparison of 1913 and 1960-61 Bacteriological Results

A comparison of the bacteriological quality of the water in various sections of the Rainy River watershed in 1913 with that found in the 1960-61 survey is made in Table 9 (41). The 1913 findings, based on B. Coli expressed in terms of the "Phelps Index", are compared to the present findings based on MF coliform counts. Not all ranges and stations in the two surveys are identical, but those included in the table are. All coliform values shown are mean values for each range under consideration. The table indicates the number of samples on which each mean is based.

Coliform levels near the outlet of Rainy Lake have slightly increased since the original survey, reflecting the increased use of the lake. In Rainy River at ranges 86.4 and 83.5, both upstream from the main sewer outfalls of Fort Frances and International Falls, there has been no appreciable change in coliform density over the years. At all Rainy River stations below the International Falls-Fort Frances area a highly significant increase in coliform numbers has occurred. The present bacterial load in Rainy River below the mills ranges up to 55 times greater than in 1913. At that time the overall increase in B. Coli from Rainy Lake to Rainy River was approximately 10 fold as compared to a 500 fold increase in coliform organisms at the present time. Bacterial levels in tributaries to Rainy River show only moderate changes over the years. The effects of this increased bacterial contamination in the river are not evident in the Lake of the Woods.

The median coliform concentrations found during the 1960 - 1962 investigation for Rainy River are shown graphically in Figure 6.

Rainy River

Water of good quality entered Rainy River at Ranier. The bacterial quality decreased appreciably from Ranier to the International Bridge but the chemical and physical characteristics changed only slightly. At the first two ranges below the pulp and paper mills, ranges 83.3 and 82.2, dramatic changes in the water quality were found.
Table 9 (41). Comparative of Coliform Numbers 1913 and 1960-61

**Rainy River**

<table>
<thead>
<tr>
<th>Location</th>
<th>Comparable Ranges</th>
<th>1913</th>
<th>1960-61</th>
<th>No. Average</th>
<th>No. Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Samples</td>
<td>B. Coli/100 ml</td>
<td>Samples</td>
<td>MF Coliform/100 ml</td>
</tr>
<tr>
<td>Rainy River Outlet</td>
<td>26-31</td>
<td>86.4</td>
<td>60</td>
<td>39</td>
<td>63</td>
</tr>
<tr>
<td>International Bridge</td>
<td>38-43</td>
<td>83.5</td>
<td>60</td>
<td>145</td>
<td>87</td>
</tr>
<tr>
<td>Below Int'l Falls</td>
<td>50-55</td>
<td>82.2</td>
<td>60</td>
<td>269</td>
<td>226</td>
</tr>
<tr>
<td>Near Little Fork R.</td>
<td>59-63</td>
<td>71.2</td>
<td>50</td>
<td>374</td>
<td>198</td>
</tr>
<tr>
<td>Near Black River</td>
<td>70-74</td>
<td>60.2</td>
<td>50</td>
<td>357</td>
<td>121</td>
</tr>
<tr>
<td>Near Emo</td>
<td>75-79</td>
<td>53.4</td>
<td>50</td>
<td>292</td>
<td>161</td>
</tr>
<tr>
<td>Above Rainy River</td>
<td>80-84</td>
<td>13.8</td>
<td>40</td>
<td>228</td>
<td>138</td>
</tr>
<tr>
<td>Below Baudette</td>
<td>85-89</td>
<td>10.9</td>
<td>39</td>
<td>331</td>
<td>181</td>
</tr>
</tbody>
</table>

**Tributaries to Rainy River**

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. Average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Little Fork River</td>
<td>56-58</td>
<td>70.8</td>
<td>30</td>
<td>287</td>
<td>17</td>
</tr>
<tr>
<td>LaVallee River</td>
<td>64-65</td>
<td>68.0</td>
<td>20</td>
<td>375</td>
<td>9</td>
</tr>
<tr>
<td>Black River</td>
<td>68-69</td>
<td>60.1</td>
<td>20</td>
<td>390</td>
<td>15</td>
</tr>
</tbody>
</table>

**Rainy Lake**

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. Average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Outlet</td>
<td>1-25</td>
<td>R1-R22</td>
<td>249</td>
<td>18</td>
<td>72</td>
</tr>
</tbody>
</table>

**Lake of the Woods**

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. Average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Mouth of Rainy River</td>
<td>210-314</td>
<td>1A-4E</td>
<td>105</td>
<td>19</td>
<td>38</td>
</tr>
</tbody>
</table>

|                 |                   |               |               |             |             |
|                 |                   | No. Average   |               |             |             |
|                 |                   | MF Coliform/100 ml |            |             |             |
|                 |                   |                 |               |             |             |
At the former range the effects of the Ontario mill discharges and the Fort Frances domestic wastes were evident. On the Minnesota side of this range no appreciable changes were found in the physical and chemical characteristics of the water, but the coliform count increased from about 150 to 500 per 100 ml. At 50 feet from the Ontario shore at range 83.3 the coliform counts ranged up to 140,000 per 100 ml, the DO dropped by about 0.5 mg/l, and the BOD increased three to fourfold.

At range 82.2 the effect of the discharges from the Minnesota mill became evident. The coliform count near the Minnesota shore ranged up to 36,000 per 100 ml. The BOD at station 1+00 averaged approximately 15 mg/l, a tenfold increase. The average DO dropped to 6.0 mg/l, down from 7.7 mg/l in Rainy Lake outlet. The suspended solids increased 300 to 400 per cent and the lignin content increased nearly sixfold. Near the mid-point of the river at this range the average values of the chemical tests were not greatly changed from those found above the mill sewers, indicating channeling of the flow, with the strong wastes concentrated near each shore. The coliform count is a sensitive indicator of pollution, and near the mid-point of range 82.2 the count was approximately 12 to 15 times that at International Bridge. The changes are illustrated in Figures 6 through 10.

At range 77.5 the wastes had spread appreciably across the river, but the concentrations remained high near each shore.

At ranges 71.2 and 64.8 the spread of the wastes across the river became more apparent, and at range 60.2 the BOD and DO levels were nearly uniform across the river, with values of about 3.0 and 6.0 mg/l, respectively. The turbidity, color, and lignin were also moderately uniform across the river at this range. The suspended solids and coliform count were somewhat higher in midstream than near the banks.

At range 36.4, below the Manitou and Long Sault Rapids, there were no appreciable differences in values at all sampling stations across the river. Essentially complete mixing had been attained. Sedimentation and bacterial stabilization had reduced the BOD to approximately 2.0 mg/l, and the turbidity to about six units. The volatile solids content at this range was approximately double that found at the International Bridge.

As the water progressed downstream the DO dropped slowly to a level of about 4.0 mg/l near Baudette. In the Baudette-Rainy River area a slight increase in BOD and suspended solids, and a slight decrease in DO were noted, due to the presence of wastes from the two communities. A short distance downstream an appreciable rise in DO occurred, perhaps due to greater concentration of algae in slow moving water in this area.
At range 1.3 (Wheeler's Point) just above the mouth of Rainy River the channel is wide. Near the Ontario shore the water is shallow, heavy weed growths are present, and the flow is low. In the main channel adjacent to the Minnesota shore DO levels of 4.0 to 5.0 mg/l were noted while near the Ontario shore DO values ranged from 6.0 to 7.7. Temperature, pH, color and BOD were also higher along the Ontario shore.

The changes occurring in DO, BOD, lignin, and suspended solids throughout the river are shown graphically in Figures 7 to 10.

Lake of the Woods

The analytical summary for samples taken from Lake of the Woods near the mouth of Rainy River is presented in Table 10 (44). Figure 11 shows the approximate location of the sampling points in this section of the watershed.

The water from Rainy Lake undergoes appreciable changes as it passes down Rainy River. A comparison of the characteristics of Rainy Lake water with those of Lake of the Woods water shows that the pH has increased 0.4 units and the hardness, calcium and alkalinity have nearly doubled. The coliform density in Lake of the Woods water showed a remarkable recovery from the highly contaminated condition in the upper reaches of Rainy River. The dissolved oxygen deficiency noted in the lower section of Rainy River disappeared and the DO level approximated those found at Rainy Lake outlet.

The lignin content of Lake of the Woods is about 50 per cent higher than in Rainy Lake but much lower than the average content in Rainy River. The color shows but little change from Rainy Lake to Lake of the Woods.

The BOD in Lake of the Woods was somewhat higher than that found in Rainy Lake. The turbidity and suspended solids values were higher than those found in Rainy Lake outlet. The total solids content showed an increase of approximately 50 per cent from Rainy Lake to Lake of the Woods, reflecting the effect of mill discharges and tributary water.

The overall picture of Lake of the Woods' water quality is satisfactory. Bacterial contamination is low, the oxygen demand is moderate, the DO is high, and the concentration of other substances is normal for a lake of this region.

Biological Features

Data concerning the biological features of these waters were secured from two rather exploratory surveys in 1960 and 1961.
INTERNATIONAL JOINT COMMISSION
BOUNDARY WATERS POLLUTION INVESTIGATION
LAKE OF BIRCHDALE
BOUND.
SCALE:
HORIZONTAL - DISTANCE FROM UNITED STATES SHORE,
AS INDICATED
VERTICAL - NUMBER / 100 ML.

MEDIAN COLIFORM CONCENTRATION

Figure 6
View showing scum floating down river past International Falls waste treatment plant. 1962

Member of field crew holding scum taken from river near International Falls waste treatment plant. 1962
Sludge bank of bark, fiber and chips. 1962

Floating mat of bark, fiber and chips with paddle supported on it. 1962
Rainy River sampling. Left to right, Lawrence A. Schmid, U. S. Public Health Service; Thomas Shelton, Minnesota Department of Health; Richard Klippel, U. S. Public Health Service. August 1962. (International Falls Daily Journal Photograph)
<table>
<thead>
<tr>
<th>Sta. No.</th>
<th>Temp. °C</th>
<th>pH</th>
<th>DO mg/l</th>
<th>BOD mg/l</th>
<th>Turbidity mg/l</th>
<th>Lignin</th>
<th>Color</th>
<th>Total Susp. mg/l</th>
<th>Hardness mg/l</th>
<th>Alkalinity mg/l</th>
<th>Calcium mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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Figure 11 - Lake of the Woods Sampling Stations 1960-1962
(plankton and benthos) and a more intensive study of two and one-half months duration in 1962. The latter phase included fishes, plankton, and benthos. Aims of the plankton and benthos programs were determination of the influence of discharged wastes upon the composition, concentration, and distribution of each population, assessment of pollutional changes affecting their physical and chemical environment, and delineation of indirect effects via stimulation of normally sparse organisms.

In this particular report, only the summary and conclusions of the biological findings are herewith presented.

Biologically, Rainy River appeared to be most affected by wood fiber and associated materials discharged from the pulp and paper mills. Nutrient elements contained in municipal sewage effluents and industrial wastes contributed to algal and slime growth. Studies completed have provided basic information on the abundance and distribution of the majority of organisms under present conditions. These data, when compared with future conditions and biotas, will allow estimation of benefits accruing from improved waste treatment, or other effects related to industrial and municipal development and growth.

**Suspended Fiber**

Fresh suspended wood fiber was associated with *Sphaerotilus* (slime) growths. The fiber often served as a substrate, both when suspended and caught on obstructions, and *Sphaerotilus* growth generally declined in reaches where wood fiber disappeared. Fresh wood fiber deposits were unfavorable to the majority of bottom animals. In the main path of wood fiber flow, finer fibers occurred near the river surface and coarser fibers near the bottom. Weight per volume also increased with depth. Freshly discharged fibers were eventually lost to sedimentation, but river deposits were reduced or removed by a number of actions and no continuous year to year buildup was noted. The most permanent deposits of any consequence were laid down in Four Mile Bay, Lake of the Woods. Experiments with line sets indicated fiber entanglement at a rate that would seriously interfere with angling and other fishing methods. Higher river stages slowed sedimentation of fresh wood fiber and maintained its suspension over greater stream distances.

**Slime (Sphaerotilus) Growth**

This filamentous bacterium began proliferation in reaches below entry of the pulp mill wastes. Areas containing materials conducive to its growth were rather sharply delimited by the presence of fresh suspended wood fiber. It formed slimy coating on various obstructions, including trapped wood fibers, in the upper river. Experiments
indicated complete coatings were developed from a few initial fibers within 72 hours in late summer. Dislodged filaments were more concentrated than algae in a number of plankton samples.

Growth rates noted in summer would appear to make slimes a nuisance only in covering objects that remain submerged or largely submerged for at least two or three days. Slime masses attached to various obstructions contribute to unsightly conditions.

**Plankton**

Diatoms, blue-green algae, and green algae were the most important planktons in that order. Rainy Lake populations that entered the river were stimulated to greater growth by nutrients contained in wastes discharged from the Fort Frances-International Falls area, but these substances did not markedly affect the composition of the plankton assemblages. Plankton algae have created no known nuisances to date in Rainy River.

**Benthos**

Bottom animals were eliminated from areas that were exposed by weekly regulated declines in water level in 1960 and 1961. The great majority of organisms avoided fresh wood fiber deposits (they were tolerated by sludge worms, some midges, and some snails) but aged fiber mixed with natural materials had no marked deleterious affects on other common groups. In many instances varied and comparatively concentrated populations resided in bottom deposits that contained aged wood fiber. Higher river stages (increased dilution) contributed to greater variety of organisms in 1962. Forms most tolerant of wood pulp fiber and associated industrial waste products were the only ones found in any great concentration. A number of forms avoided the upper river entirely, and others seemingly may live there only in areas right of center during years of normal river stages. With the exception of sludge worms and some midges, concentration of organisms was less than would normally be expected for a stream environment of this type, and it may reasonably be assumed that benthos development was generally impeded by the waste complex entering the river from the Fort Frances-International Falls area.

A number of the more desirable fish food organisms were evidently unable to contend with conditions developed during summers with normal river stages. Animals that offered greatest quantities of fish food were crayfish, fingernail clams, and midges.

**Fishes**

Collecting operations netted 44 species of fish that may normally be expected in this general area. The sturgeon, *Acipenser fulvescens*,
was not taken in nets, but specimens inadvertently caught on set lines were observed and photographed by survey personnel. Abundance of fish in terms of pounds per unit area or annual harvestable crop could not be determined. Angler records were lacking and collection difficulties occasioned by high water and wood fiber fouling of nets prevented comparison of catches with those obtained by similar methods in other waters. Large numbers of certain species and a wide spectrum of age groups indicate substantial populations of larger species. The river environment seemingly imposed limitations on the number of species only in the upper 11 miles where six indigenous forms failed to occur. A number of species reproduce in Rainy River. The walleye population appears to be augmented by migration from Lake of the Woods or tributary streams. Independent studies conducted at the University of Minnesota (in press) indicate that Sphaerotilus growth on walleye eggs reduces their per cent hatchability.

Angler utilization is considerably less than the indicated fish population would sustain. Attraction for anglers is reduced by accumulation of wood fibers on fishing lines and unsightly Sphaerotilus growths. The fishery survey was carried out during a year of abnormally high water, and it is possible that greater dilution so afforded allowed greater than usual survival of spring-spawned fish. Younger age groups of game fish were less numerous than normally anticipated. The fish population was similar on both sides of the river and fishing opportunity appeared to be equally divided. Fishing sites and access routes are more numerous on the American shore.

Lake of the Woods

Four Mile Bay received and held most of the wood fiber, chips, and bark load discharged by Rainy River. Such materials have settled out in a definite pattern that appeared to be established by diminishing river velocity and southeast water movement through Oak Point Inlet. Thickness of such deposits exceeded three feet in some areas. Distribution of benthic animals was markedly affected by the pattern of sedimentation of the wood waste materials. Areas with this cover contained much smaller numbers of benthic groups than unaffected regions. Plankton in this bay had no apparent relationship to any class of pollutants.

Very little fiber was carried into the main body of the lake and it had no demonstrable effects upon distribution of bottom organisms therein. This fauna exhibited distributional patterns that were largely induced by variation in natural bottom materials. A rich and varied plankton population occurred when studies were made in July 1961. Blue-green algal components were drifted into numerous long southwest-northeast windrows. No relationships to pollution or other human activities were discernible.
Suspended matter adhering to fishing line. 1962

Suspended bark, fibers, and chips adhering to tree. After high flow in spring of 1962. (Elm Island, July 23, 1962)
Views showing bark, fiber, chips and slime adhering to nets. Summer of 1962. One and a half miles below Ontario and Minnesota mills.
TRANSBOUNDARY MOVEMENT OF POLLUTION

In the Treaty of 1909 between the two countries it was agreed that "the boundary waters shall not be polluted on either side to the injury of health or property on the other". In the reference for this investigation an answer was sought to the question of whether transboundary movement of pollution was taking place, to what extent, and in what localities. The information utilized in answering these questions in the present investigation was obtained from float studies, and a review of the analytical data compiled during the survey periods.

Float Movements

It is apparent from float studies conducted that transboundary currents occur at various places in the Rainy River. In the International Falls-Fort Frances area 55 floats were released. Of these, 31 crossed the International Boundary line and ten recrossed it within four miles of the point of release. Seven crossed from the Canadian to the United States side and 24 from the United States to the Canadian side.

In the vicinity of range 77.5, approximately six miles below the outlet of Rainy Lake, 11 of 17 floats released in the river crossed the boundary line from the Canadian side to the United States side. In the Rainy River-Baudette area the current is slow and ill-defined. Twenty-one floats released in this area showed only six crossings of the boundary, all from the Canadian to the United States side.

Other Studies

Limited conductivity studies in the Fort Frances-International Falls area indicated the pattern of transboundary movement of pollution in the river. A great increase in conductivity occurred along the United States shore just below the pulp and paper mill in Minnesota, due to the addition of quantities of inorganic wastes. The increased conductivity gradually spread across the river as the water moved downstream. By the time the water reached the junction of the Little Fork River (approximately 11 miles) the conductivity was uniform three-fourths of the distance across the stream from the United States shore.

Coliform organism concentrations at the outlet of Rainy Lake were very low, about 35 per 100 ml. A very significant increase in numbers occurred along the Canadian shore just below the Fort Frances mill and the municipal sewer outfall. In this area the average coliform concentration approximated 36,000 per 100 ml.
A lesser but substantial increase occurred along the United States shore below the International Falls mill, with concentrations averaging about 6,600 per 100 ml. These high concentrations gradually spread across the river and became moderately uniform approximately 20 miles downstream. At range 64.8 the average coliform concentration ranged only from 10,400 to 11,500 per 100 ml across the stream.

Biochemical oxygen demand, lignin, color and suspended solids increased sharply along the United States shore just below the mills. As the water moved downstream there was a gradual spread across the river of the aforementioned constituents and their concentrations became uniform approximately 25 miles downstream from the mills. BOD values at the outlet of Rainy Lake averaged about 1.6 mg/l. Just below the mills on the United States side the BOD averaged 14.8 mg/l, on the Canadian 5.3 mg/l, and in midstream about 2 mg/l. At range 60.2 the BOD values were nearly uniform, ranging only from 2.5 to 3.1 mg/l across the stream. The transboundary spread of pollution is shown clearly in the charted data, Figures 6 through 10.

In the vicinities of Manitou and Long Sault Rapids the flow is spread uniformly across the channel with very thorough mixing of the water and pollutional matter.
DISCUSSION OF FINDINGS AND REMEDIAL MEASURES

Data presented in this report summarize through tables, charts and illustrations the results of the investigation of pollution in the Rainy River - Lake of the Woods section of the boundary waters. They indicate, in accordance with the terms of reference to the Commission, the extent, nature and sources of pollution, and in what localities such pollution occurs. The Advisory Board has examined and evaluated these various data. From this analysis certain conclusions have been reached, and remedial measures are recommended. The findings and conclusions are discussed herewith.

Canada and the United States jointly possess an unparalleled natural resource in these boundary waters. Because they vitally affect the health, economy and recreation of both countries it is essential that the waters be so safeguarded from pollution that their use will be in the best public interests. The importance of maintaining these waters in a satisfactory state is evident in the action taken by the two governments on two separate occasions, in requesting that the International Joint Commission make an investigation of pollution.

The 1913 Investigation

The pollution problem in 1913 was appreciably different from that of today. The earlier investigation was concerned primarily with bacterial pollution from domestic sewage. No municipal sewage treatment plants were in operation in the area in 1913, hence the bacterial load on the stream was of primary importance. Records are not available, but apparently the industrial wastes were not of such volume or strength that the investigators were much concerned about their effect on the condition of the water in Rainy River.

The 1913 report stated that "In general the Rainy River shows serious pollution throughout its length, but in an increased degree below Fort Frances and International Falls to the Lake of the Woods, making this whole river an unsafe source of water supply without very careful purification. The tap water of the Towns of Fort Frances, International Falls and Rainy River was examined and shown to be of the same character as that of the river, the source of supply."

The International Joint Commission, following the 1913 investigation, recommended to the two governments that, for the boundary waters as a whole,

"It is feasible and practicable, without imposing an unreasonable
burden upon the offending communities, to prevent or remedy pollution, both in the case of boundary waters and waters crossing the boundary.

"(a) In the case of city sewage, this can best be accomplished by the installation of suitable collecting and treatment works, the latter having special reference to the removal of bacteria and matters in suspension.

"(b) In the case of vessel sewage, a feasible and inexpensive remedy lies in the employment of recognized methods of disinfection before it is discharged. In the case of water ballast suitable rules and regulations should be prescribed with a view of protecting the water intakes.

"(c) The discharge of garbage and saw mill waste into boundary waters should be prohibited, and industrial and other wastes, which are causing appreciable injury, should be discharged subject to such restrictions as may be prescribed."

Changes in Period 1913-1962

Many changes have taken place in the period from 1913 to 1962 which have affected the pollution problem. Two factors which have contributed adversely to this situation are the increases in population and industrial activities. Comparative populations in the Rainy River watershed in 1913 and 1961 are shown in Table 4.

The total population of the watershed has increased from about 25,000 to 47,000, but the urban population adjacent to Rainy River has approximately tripled, to a present population of nearly 22,000.

Industries were small and few in number in 1913. The paper mill on the Minnesota side had been in operation for only three years, and production was relatively low. The mill on the Ontario side started operation in 1914. Production has greatly increased during the intervening years. Many new products are now produced, resulting in appreciable changes in the characteristics of waste flow. Several small industries have been founded and now discharge their waste directly or indirectly to the river.

Several municipalities have constructed sewage treatment plants that reduce the solids and bacterial content of the waste discharge. International Falls has a modern well operated secondary treatment plant. South International Falls recently completed waste stabilization ponds. Baudette, Williams and Rainy River have primary
treatment plants. These sewage treatment facilities provide secondary treatment for the domestic wastes from 43 per cent of the urban population, and primary treatment for an additional 13 per cent.

In this same period science has made important contributions toward solving pollution problems. Research in analytical procedures and treatment methods has made it possible to define more clearly, both qualitatively and quantitatively, the nature, extent, and effects of pollution and to apply corrective measures.

The science of water purification in 1913 was in the initial stages of development. While filtration had been developed it had not been employed anywhere along these boundary waters. Chlorine was added to the water in the form of hypochlorite, but the method of application was crude and often ineffective. Present day methods in chlorine application and control for disinfection were unknown.

Corresponding advances have been made in the technology of sewage and industrial waste treatment. New and improved processes have made possible greatly increased efficiencies in the removal of objectionable polluting substances.

**Extent and Effects of Pollution in 1960-1962**

The 1960-1962 investigations revealed that the major pollution occurs in the Fort Frances-International Falls area and only relatively minor pollution occurs in other areas of this watershed. The analytical data derived from bacteriological, chemical, physical, and biological examinations are a measure of the extent and effects of the pollutants on Rainy River water. The kind, degree, and location of pollution are summarized under "Sources and Character of Pollution" and "Pollution Effects on Boundary Water Quality". The findings are reviewed here in the light of their effects on the waters and in relation to the questions contained in the terms of the reference.

**Transboundary Movement**

In the Treaty of 1909 between the two countries it was agreed that the waters on either side of the boundary should not be polluted to the injury of health or property on the other side. The first question asked in the present reference to the Commission involves this transboundary aspect of the pollution problem.

The data presented under "Transboundary Movements" have shown clearly that there is a transboundary crossing, both of flows and pollutants, from each side to the other. Since waste discharges tend to diffuse and become diluted in the receiving waters, it is
difficult to trace a specific effluent over the distance required to dissipate its potency. Added dilution through travel downstream and the admixture of similar or other deleterious materials further complicate this difficulty. The intermingling is also influenced by winds, bends in the river, islands or other obstructions, and navigation channels. These effects may not be constant. Under these circumstances it is not feasible to state, in exact terms, the amount of pollutants which crosses from each country to the other.

Injury to Health

The danger to health in the use of these waters is measured most readily by the coliform determinations, although constituents of a chemical nature are also of sufficient importance to warrant consideration. Major purposes for which these waters are used include domestic water supply, bathing, and recreation. All of these uses are closely allied to public health and may be injuriously affected by the discharge of bacterial and chemical wastes. Limits of pollution beyond which a health menace may exist are not universally accepted. Several standards have been formulated from time to time to apply to specific areas and requirements. In the final report on the 1913 investigation the Commission stated that "the standard of purification required of these communities should be such that the streams after receiving their treated sewage would have a mean annual cross-sectional average of B. Coli not exceeding 500 per 100 c.c." A more recent standard for raw waters, acceptable for treatment and use as public water supplies, is that recommended by the U. S. Public Health Service in 1946. In this recommendation, waters which have an average monthly coliform content of not more than 5,000 per 100 ml and exceeding this number in not more than 20 per cent of the samples examined in any month are acceptable for treatment by complete rapid sand filtration and continuous postchlorination. In cases where the coliform bacteria exceed 5,000 per 100 ml in more than 20 per cent of the samples examined during any one month and do not exceed 20,000 per 100 ml in more than five per cent of the samples examined during any one month the waters shall be acceptable when given auxiliary treatment in addition to complete rapid sand filtration and continuous postchlorination. Waters containing coliform bacteria in excess of the above figures are considered unsuitable for use as a source of drinking water supply unless brought into conformance by means of prolonged preliminary storage or some other satisfactory measure.

All sewage pollution must be considered as a potential health hazard. Pollution also may add an extra burden in the form of higher costs for water purification, necessitated by the failure of some upstream user to treat adequately the wastes produced. Similarly, many riparian owners who may wish to use these waters are not in a position to secure the protection provided by modern
and properly controlled purification processes that can be installed by municipal bodies. Some municipalities are deprived of the right of developing public water supplies within economical limits.

Coliform pollution in Rainy River rises sharply below the cities of Fort Frances and International Falls and is sustained throughout the length of the river. The median coliform density in the river during the 1961 summer survey did not drop below 1,600 per 100 ml from Fort Frances to range 9.3, several miles downstream from Baudette. The median density at the mouth of Rainy River approximated 400 per 100 ml. In most areas of the river the coliform figures were in excess of those considered suitable for a raw water to be treated even by modern purification methods. The maximum counts reached excessive values and thereby imposed a severe load on water purification processes.

Tastes and odors in water supplies may be caused by industrial wastes, and particularly by phenolic compounds. In water supplies which are chlorinated to protect against bacterial pollution, phenols react with chlorine and may produce intensely odorous compounds. These compounds, even when highly diluted, give to the water tastes and odors which are variously described as medicinal, chemical, or iodoform. Two parts of phenol in one billion parts of chlorinated water may be sufficient to cause objectionable taste and odor. This condition can cause the public to resort to other water supplies which may be palatable but dangerously contaminated.

Presently the polluted section of Rainy River is little used as a source of water supply. Only Rainy River Village now uses the river water for domestic purposes. It is supplied to the water mains following chlorination only. Small communities along the river are discouraged from using the water because of its polluted condition. International Falls and Fort Frances take water from the watershed upstream from the major sources of pollution.

The presence of sewage pollution in bathing areas located in these waters also constitutes a health hazard. The coliform data show that Rainy River below the International Falls-Fort Frances area is heavily contaminated all the way to the Lake of the Woods. Standards of bathing water quality vary greatly. A study by Garber (9) in 1956 indicated that the bathing water bacteriological quality standards of various governmental units were so varied and complex that it was difficult to compare them. The U. S. Public Health Service studies (10, 11) on Lake Michigan and Ohio River concluded that swimmers in waters with median coliform densities as low as 100 per 100 ml had a greater incidence of eye, ear, nose, throat, skin, and gastrointestinal illnesses than did non-swimmers. Based upon the American Public Health Association recommendations, many governmental units have indicated that suitable
bathing water shall have a coliform density of less than 1,000 per 100 ml.

Rainy River water has limited use for recreational bathing at the present time.

Effects Upon Aquatic Life

Recent studies (1960-62) showed that aquatic life was influenced by wastes discharged at the Fort Frances-International Falls area, and by declines in river stage that were periodically occasioned by suppression of flow at the paper mill dam. Reductions in flow intermittently expose large bottom areas in upper Rainy River and tend to prevent development of an abundant aquatic life in such areas.

Proliferation of phytoplankton and the slime bacterium *Sphaerotilus* were stimulated by nutrients contained in municipal and industrial wastes. The latter normally grows attached to various submerged objects. It often makes certain substrates uninhabitable for other forms of life; it may become affixed to various invertebrates and destroy them by suffocation or smothering; and its dislodged filaments often create nuisances by fouling fishing lines. Experiments carried out during the spawning seasons of 1961 and 1962 have indicated that *Sphaerotilus* growths inhibit hatching of walleye eggs, seemingly making it very difficult for the embryo to leave the egg. Dense phytoplankton concentrations may induce unpalatable tastes and odors in surface water supplies and increase the cost and difficulty of water treatment.

Wood fiber, wood chips, and bark discharged by the paper mills affected bottom organisms (benthos) in most river reaches below their points of entry, and in Four Mile Bay, Lake of the Woods. Fresh wood fiber begins to settle as soon as it reaches the river, but some is carried in suspension for a number of miles. Settled wood fiber forms rather thick deposits, patches of which frequently break away and form floating "islands" which may drift for varying distances dependent upon their points of origin. Disintegration of the "islands" temporarily returns wood fiber to suspension, and secondary settling may form wood fiber mats on remote bottom areas. Most wood fiber presently being carried into Four Mile Bay probably arrives as floating "islands". Fresh wood fiber deposits (most concentrated along the left bank in the upper river) restrict benthos to some midge larvae, sludge worms, and other forms that are very tolerant of such pollution. These organisms are much less desirable fish food resources than intolerant organisms, such as mayflies, that are eliminated. Wood fiber and/or other wastes components have apparently made the entire Rainy River intolerable.
Fibrous sludge deposits along shore of Rainy River at International Falls, Minnesota. August, 1962.
Typical accumulation of wood slivers and fibrous material observed along U. S. shore of Rainy River, August 4, 1962.
for some important benthic groups that have been found in unpolluted tributaries. A number of other species found in limited areas in the lower river were missing in reaches containing fresh wood fiber deposits. Quantities of the more desirable organisms that were found in lower reaches indicated that individuals were widely dispersed in what appeared to be naturally productive areas.

Fouling of fish lines with wood fiber and Sphaerotilus discourages angling in many reaches so that utilization of the Rainy River for sport fishing is far below its potential.

**Injury to Property**

Discharge of sewage and industrial wastes into these waters is a deterrent to potential development of property and the use of this water for municipal purposes along this river and adds to the cost of water supply. Suspended fiber, bark, chips, and foam carried by the water frequently cause deposits along shores of the river. The deposits are unsightly and often highly odorous. Similar deposits are common on the river bottom.

During the summer season decomposition liberates gases from these deposits which often lift sections of the deposits to the water surface. Obnoxious odors are released from the floating masses, and bottom deposits. Such conditions adversely affect the use of these waters for recreational bathing purposes.

**Sources of Pollution**

Pollution of these waters is due to the discharge of domestic sewage and industrial wastes, principally from the municipalities and pulp and paper mills. Most of the small industries discharge their wastes into municipal sewers, but the pulp and paper mills have outlets direct to the boundary waters.

**Sources of Domestic Waste**

On the United States side the City of International Falls represents the major portion of the sewered population. This community has secondary treatment facilities and its BOD load to the stream represents approximately nine per cent of the entire domestic waste load. Baudette, with only primary treatment, discharges a domestic BOD load of approximately 18 per cent of the total.
On the Canadian side Fort Frances, which presently provides no
treatment, discharges an estimated domestic BOD load of about
58 per cent of the total. Emo is only partially sewered and
provides no treatment. At present it contributes a small BOD
load. Rainy River Village has only primary treatment. Its waste
load contributes about five per cent of the total domestic BOD
to Rainy River. The remaining domestic BOD is contributed by
villages located on tributaries of Rainy River. The data show that
the domestic BOD load to the river from each of the tributaries
is relatively light and insignificant.

It is expected that the coliform load on the river from each
community, except where chlorination is practiced, is approximately
proportional to the domestic BOD load. It is of interest to note
that the entire domestic BOD load is about one per cent of the combined
domestic and industrial BOD load.

Sources of Industrial Waste

A summary of industrial waste discharges in the Rainy River
watershed below Rainy Lake is given in Table 8. Almost the entire
waste load is discharged from the outlets of the two pulp and paper
mills.

The total daily volume of mill wastes is approximately
77,000,000 U. S. gallons. This volume includes condenser and cooling
water as well as process wastes. These effluents contain large
quantities of pollutants which have an adverse effect on the
receiving stream.

The BOD load contributed to the stream daily by the two mills
in 1961 totalled about 255,000 pounds. This oxygen demand is the
equivalent of that from the domestic waste of a city of one and
one-half million people.

The suspended solids load, including bark, fiber, chips, and
lime sludge, discharged from the mill outlets exceeded 100 tons/day.
Of these suspended solids, woody materials amount to 61.5 tons/day
or about four per cent of combined net production of both mills.
Suspended matter of this type is the cause of deposits along the
shore and on the river bottom. These deposits are unsightly and
often produce obnoxious odors.

Sources of Other Wastes

Wastes from navigation and careless dumping of refuse along the
shore and from other sources are relatively negligible in Rainy River.
Remedial Measures

It has been shown that stream pollution exists in Rainy River. Its nature, extent, and sources have been presented in detail. This pollution has an injurious effect on actual or potential uses of these waters for domestic and industrial water supplies, bathing, recreation, and fish life. Pollutants cross from each side of the boundary to the other. A further question in the terms of the reference concerns the measures for remedying the situation. If such measures are to be effective, they must raise the quality of the waters to the point where they can be used satisfactorily for these various purposes.

Objectives for Boundary Waters Quality Control

Remedial measures involve the treatment or control of all sources of pollution reaching the boundary waters and their tributaries. Information acquired prompted the Advisory Board to recommend interpretative modifications of the "Objectives for Boundary Waters Quality Control" for application in the Rainy River and Lake of the Woods area.

Water quality objectives are essential for determining the remedial measures necessary for correcting pollution. Objectives may be established in two ways: (1) through limitation of the quantity of deleterious substances allowed to enter the receiving streams, or (2) through limitation of these substances within the receiving waters. Whichever type of objective is used, the end result must be the same, namely maintenance of the water in a condition suitable for all appropriate uses.

Objectives adopted for boundary waters quality control establish the ultimate aim of corrective measures. Objectives must be defined if water quality is to be improved and maintained, and they must be impartial in setting goals for all uses. Each purpose will require a specific quality of water. In the majority of cases, the uses of any one watercourse are varied, and complex interrelationships must be considered in objectives consistent with all uses. These principles have been adhered to in the following objectives:

These objectives are for the boundary waters in general, and it is anticipated that in certain specific instances, influenced by local conditions, more stringent requirements may be found necessary.

General Objectives

All wastes, including sanitary sewage, storm water, and industrial effluents, shall be in such condition when discharged into any stream that they will not create conditions in the boundary waters which will adversely affect the use of these waters for the following purposes: source of domestic water supply or industrial water supply, navigation, fish and wild life, bathing, recreation, agriculture and other riparian activities.

In general, adverse conditions are caused by:

(A) Excessive bacterial, physical or chemical contamination.

(B) Unnatural deposits in the stream, interfering with navigation, fish and wild life, bathing, recreation, or destruction of aesthetic values.

(C) Toxic substances and materials imparting objectionable tastes and odors to waters used for domestic or industrial purposes.

(D) Floating materials, including oils, grease, garbage, sewage solids, or other refuse.

Specific Objectives

In more specific terms, adequate controls of pollution will necessitate the following objectives for:

(A) Sanitary Sewage, Storm Water, and Wastes from Water Craft

Sufficient treatment for adequate removal or reduction of solids, bacteria and chemical constituents which may interfere unreasonably with the use of these waters for the purposes aforementioned. Adequate protection for these waters, except in certain specific instances influenced by local conditions, should be provided if the coliform M.P.N. median value does not exceed 2,400 per 100 ml at any point in the waters following initial dilution.

(B) Industrial Wastes

(1) Chemical Wastes - Phenolic Type

Industrial waste effluents from phenolic hydrocarbon and other chemical plants
will cause objectionable tastes or odors in drinking or industrial water supplies and may taint the flesh of fish. Adequate protection should be provided for these waters if the concentration of phenol or phenolic equivalents does not exceed an average of 2 p.p.b. and a maximum of 5 p.p.b. at any point in these waters following initial dilution. This quality in the receiving waters will probably be attained if plant effluents are limited to 20 p.p.b. of phenol or phenolic equivalents. Some of the industries producing phenolic wastes are: coke, synthetic resin, oil, creosoting, wood distillation, and dye manufacturing plants.

(2) Chemical Wastes, Other than Phenolic Adequate protection should be provided if:

(a) The pH of these waters following initial dilution is not less than 6.7 nor more than 8.5. This quality in the receiving waters will probably be attained if plant effluents are adjusted to a pH value within the range of 5.5 and 10.6.

(b) The iron content of these waters following initial dilution does not exceed 0.3 p.p.m. This quality in the receiving waters will probably be attained if plant effluents are limited to 17 p.p.m. of iron in terms of Fe.

(c) The odor-producing substances in the effluent are reduced to a point that following initial dilution with these waters the mixture does not have a threshold odor number in excess of eight due to such added material.

(d) Unnatural color and turbidity of the wastes are reduced to a point that these waters will not be offensive in appearance or otherwise unattractive for the aforementioned uses.

(e) Oil and floating solids are reduced to a point such that they will not create fire hazards, coat hulls of water craft, injure fish or wild life or their habitat, or will adversely affect public or private
recreational development or other legitimate shore line developments or uses. Protection should be provided for these waters if plant effluents or storm water discharges from premises do not contain oils, as determined by extraction, in excess of 15 p.p.m., or a sufficient amount to create more than a faint iridescence.

Some of the industries producing chemical wastes other than phenolic are: oil wells and petroleum refineries, gasoline filling stations and bulk stations, styrene co-polymer, synthetic pharmaceutical, synthetic fiber, iron and steel, alkali chemical, rubber fabricating, dye manufacturing, pulp and paper mills, and acid manufacturing plants.

(3) Highly Toxic Wastes

Adequate protection should be provided for these waters if substances highly toxic to human, fish, aquatic, or wild life are eliminated or reduced to safe limits. Some of the industries producing highly toxic wastes are: metal plating and finishing plants discharging cyanides, chromium or other toxic wastes; chemical and pharmaceutical plants and coke ovens. Wastes containing toxic concentrations of free halogens are included in this category.

(4) Deoxygenating Wastes

Adequate protection of these waters should result if sufficient treatment is provided for the substantial removal of solids, bacteria, chemical constituents and other substances capable of reducing the dissolved oxygen content of these waters unreasonably. Some of the industries producing these wastes are: tanneries, glue and gelatin plants, alcohol, including breweries and distilleries, wool scouring, pulp and paper, food processing plants such as meat packing and dairy plants, corn products, beet sugar, fish processing and dehydration plants.

The methods of determination of the chemical constituents referred to in the preceding objectives are as given in "Analytical Methods for
Boundary Waters Quality Control," as prepared by the Board of Technical Advisers. Bacterial determinations are to include the presumptive and confirmed tests, or the M.F. procedure, for the coliform group of bacteria as given in "Standard Methods for the Examination of Water and Sewage".

Application of These Objectives - Rainy River and Lake of the Woods:

The Advisory Board recommends in the application of these objectives for the Rainy River and Lake of the Woods area that the following interpretations apply:

(1) The provision (B) (4) of the Objectives, pertaining to dissolved oxygen reduction, would be met if the dissolved oxygen does not fall below 5 mg/l at the monthly average flow which is exceeded 95 per cent of the time in the critical month, nor fall below 3 mg/l at the minimum daily flow that is exceeded 95 per cent of the time in the critical month.

(2) The provision (B) (2) (e) of the Objectives pertaining to "floating", or suspended, solids will be met for pulp and paper wastes if facilities that effect substantially complete removal of all suspended solids are provided by the mills.

(3) The provisions of (B) (1), (B) (2) (a) and (B) (2) (c) would be applicable when and if the need for the same is demonstrated or develops in these waters.

(4) The provision (A) as applied to public recreational bathing areas would be met if median coliform values do not exceed 1,000 per 100 ml.

The Board recommends the adoption of the following specific objective:

The discharge of nutrients, including wood sugars, shall be controlled or reduced to the extent necessary to prevent nuisance growths of Sphaerotilus or other slimes in the river.

Pollution Control Program

It is apparent, from the data presented in the foregoing, that a comprehensive waste treatment program is required. Two methods for dealing with water pollution problems are commonly advocated. One viewpoint advocates the utilization of the stream for carrying away as much waste as it can tolerate without interfering too seriously with normal stream uses. The other would exclude all
impurities from watercourses. Between these conflicting views is a course which the Board feels will meet the situation. This course has been followed in developing the "Objectives for Boundary Waters Quality Control." No tolerance limit, whether for the effluent or for the stream, can be expected to remain fixed. It must change with changing conditions and each change should be in the public interest.

The large volume of water flowing between the United States and Canada should be regarded as a natural resource to be shared by both countries. It should not be wantonly destroyed by pollution from municipalities, from industries, or from any other source. An intelligent policy of safeguarding these waters from gross pollution should be fostered and encouraged so that they will be used for the highest public good and not exploited by selfish interests. While the boundary waters should not be regarded as public sewers for carrying away wastes of all kinds, their reasonable utilization for the disposal of effluents may be permitted as long as other water uses are not impaired.

The pollution problem must be considered not only on the basis of present-day conditions but also in terms of the future. Facilities for the treatment of municipal sewage must incorporate sufficient flexibility to permit ready expansion to satisfy future demands. Industrial waste disposal programs must not only provide for adequate treatment for the present, but must insure that new industries or new industrial processes which may be established will not jeopardize the rights of users of these waters. Industry must continue to assume, in cooperation with other agencies, the research and planning required for satisfactory and efficient disposal of industrial wastes.

Disposal of Municipal Wastes

Since municipal sewage carries the organisms of diseases transmissible to humans, the discharge of this waste is of major concern in these boundary waters. The large volume of municipal wastes, totalling three million U. S. (2.5 million Imp.) gallons per day, discharged into these waters adds a heavy bacterial load. About 50 per cent of this is receiving some treatment, but the treatment in some cases is primary only. In addition to the domestic sewage from the sewered population of 21,500 in the area under Reference, the municipal sewers carry a limited amount of industrial wastes.

Since 1913 the total population of this area has risen from less than 24,000 to slightly more than 47,000. The final report of the 1913 investigation pointed out that these waters were seriously polluted by sewage. It was recommended that the sewage be treated
either by fine screening or sedimentation and, when necessary, by chemical disinfection in order to secure in the receiving waters a mean annual cross-sectional average B. Coli of 500 per 100 c.c.

Since 1913 a number of sewage treatment plants have been constructed. Notwithstanding the accomplishments of these works, the bacterial load was found in 1961-1962 to be approximately 20 times as great as in 1913. The treatment of municipal wastes which has been provided has neither reduced the bacterial load below the 1913 level nor has it even kept pace with the increase resulting from expansion of municipal populations and industrial activities.

It is the opinion of the Advisory Board that satisfactory quality in these waters, as outlined in the "Objectives for Boundary Waters Quality Control", will not be obtained until all municipal wastes are given continuous treatment of a high degree, and more efficient or secondary treatment will have to be provided where this has not already been accomplished. It is recognized that local conditions on either side of the boundary may give additional impetus to the need for this higher degree of treatment. The completion of the construction of such works will require an appreciable period, but action should be taken without delay to inaugurate this program leading to the attainment of secondary treatment for all municipalities discharging wastes into these waters.

This program for the treatment of sewage will not fully accomplish the desired objective unless concurrent action is taken to deal with the overflows from combined sewers. A long term program leading to the separation of domestic sewage from storm water should be adopted. Sanitary sewage must also be segregated from mill wastes for proper treatment in municipal and treatment facilities.

The misuse or neglect of treatment facilities must be avoided at all times. Inefficient operation of a plant or unwarranted bypassing of untreated or partially treated effluent should not be permitted.

The Board is of the opinion that reasonable water quality consistent with the wide variety of uses of these waters, both present and future will be maintained if the wastes are treated to a degree which will result in a median coliform value not exceeding 2,400 per 100 ml at any point in the boundary waters following initial dilution of waste discharges and not exceeding 1,000 per 100 ml in public recreational bathing areas. It will likewise be necessary to provide sufficient treatment so that other substances which may injuriously affect the water, as defined in the objectives, will be removed.
Disposal of Industrial Wastes

The volume of industrial wastes, exclusive of that carried in municipal sewers, discharged directly into these boundary waters, is 77 million U. S. (64 million Imp.) gallons per day, nearly 30 times the volume of municipal wastes. These wastes carry large quantities of deleterious substances, which seriously affect the quality of the receiving waters and may adversely affect property values.

In contrast to the disposal of domestic sewage, industrial wastes are so varied in composition that no uniform treatment process is applicable. Each waste must be considered individually in the light of the deleterious substances present. Limits of tolerance for certain of these substances in industrial effluents have been included in the "Objectives for Boundary Waters Quality Control" as interpreted for these waters. The problem of industrial waste treatment is one for the industry involved.

When a new industry proposes to locate on a watercourse, due regard must be given to ensure that the wastes will not jeopardize the rights of other water users. The same principle must apply when new processes resulting in objectionable wastes are involved. Approval by the water pollution control public agencies is required in both Ontario and Minnesota.

One of the problems of industrial waste disposal is that of sudden or concentrated discharges, commonly known as "slugs" or "spills". By a slug is meant the release of a volume of highly concentrated polluting material over a short period of time. Slugs are intermittent, but their effects may be felt for great distances and for prolonged periods.

It is the responsibility of industry to avoid slugs and spills as far as possible. Control and monitoring programs should be instituted and maintained where there is the likelihood of such conditions occurring.

Disposal of Other Wastes

In Rainy River wastes from boating, log rafting and community and private refuse disposal present a relatively minor problem.

Progress in Pollution Control

Some progress in the control or elimination of pollution has been accomplished during the period of this investigation. While construction of sewage works has not been on a large scale there
has been much activity in the preparation of plans and initiation of projects. This activity is continuing on the part of both municipalities and industry.

**Present Status of Municipal Waste Treatment Facilities**

**Minnesota**

- International Falls: Secondary treatment, trickling filters
- South International Falls: Sewage stabilization ponds
- Baudette: Primary treatment
- Williams: Primary treatment
- Little Fork: Primary treatment
- Cook: Primary treatment
- U. S. Air Force A.C. & W. Station: Secondary treatment, trickling filters

**Ontario**

- Fort Frances: No treatment, primary treatment plant under construction
- Barwick: No sewerage system
- Emo: Partly sewered - no treatment. Plans being made for sewage stabilization ponds.
- Rainy River: Inadequate primary treatment. Plans being made for sewage stabilization ponds.

**Present Status of Industrial Wastes**

**Reduction facilities:**

- Ontario - Minnesota Pulp and Paper Company, Ltd.: Savealls, bark recovery.
Cost and Financing

The following estimates have been prepared on costs for remedial measures in answer to this question in the terms of the reference. The municipal costs are divided as follows: (1) interceptors and primary treatment, and (2) additions of secondary treatment. Industrial costs were estimated by industries involved on the basis of compliance with the "Objectives for Boundary Waters Quality Control".

Costs for municipalities (interceptors and primary treatment):

United States: None
Canadian : $2,384,500
Total Primary: $2,384,500

For the second stage or secondary treatment of municipal wastes the additional costs are estimated as:

United States: $200,000
Canadian : $508,000
Total : $708,000
Grand TOTAL: $3,092,500

Costs for industries:

United States and Canada: $11,000,000

A strong deterrent in the solution of water pollution problems has been the reluctance of some municipalities and industry to make funds available for this purpose. This may be due either to financial inability, lack of appreciation of responsibility by the polluter, or indifference on the part of the public. Accordingly, it is important to consider methods of securing funds for the construction and operation of remedial works.

Remedial works for treating municipal wastes must be constructed through public funds. These may come from any of several sources such as cash reserves, short term loans or debentures, general obligation bonds, special assessment bonds, revenue bonds, government aid, or any combination of these. The annual payments on capital debts incurred by the municipalities for such works and for their operation may come from general taxation or some form of service charge. Since the sewage works are designed for the benefit of the
entire community and are an obligation of the municipality, some municipal authorities favor paying part of the costs by general taxes. In order to apportion the remaining costs on the basis of benefits derived the practice of applying a service charge is gaining widespread use. These service charges are designated by several names such as sewer rates, sewage service rates, and sewer rentals. These rates have advantages which justify serious study by public officials confronted with the problem of financing municipal sewage treatment works.

It is a recognized fact that industrial wastes are the responsibility of the industry. Experience has demonstrated that in certain industries it is possible to reclaim from the wastes useful by-products which may partially offset the cost of treatment. The treatment or control of these wastes, however, whether profitable or otherwise, must be regarded as a part of the cost of production.

**Water Pollution Control Legislation**

Federal legislation in the United States centers about Public Law 660, as amended by Public Law 87-88, and known as the "Water Pollution Control Act". It was designed to "recognize, preserve, and protect the primary responsibilities and rights of the States in preventing and controlling water pollution, to support and aid technical research relating to the prevention and control of water pollution, and to provide Federal technical services and financial aid to State and interstate agencies and to municipalities in connection with the prevention and control of water pollution." There is also Federal legislation applicable to certain types of pollution of harbors and other navigable waters.

In Canada there is no Federal legislation which is concerned with pollution of water per se. There are, however, certain statutes which deal with this problem, particularly as applied to navigation, fisheries, and wild life.

In the State of Minnesota water pollution control is centered in the Water Pollution Control Commission. The statute creating this agency gives it authority to deal with all types of water pollution.

In the Province of Ontario, problems pertaining to water pollution and pollution control are under the jurisdiction of the Ontario Water Resources Commission.

Municipalities are authorized to enact regulations or by-laws dealing with such matters as control of local pollution, restrictions on the use of sewers, setting sewer service rates, and financing.
The Continuing Program

It is recognized that in these waters pollution control is an ever changing problem. The fulfillment of the objective will require time and continuous supervision. Technical difficulties may be expected in connection with industrial wastes. New industrial processes which will be developed may produce different wastes and complications in disposal. Past experience has shown that constant effort and attention by regulatory authorities are needed if existing pollution is to be controlled and new pollution is to be prevented.

It is believed advisable for the Commission to foster pollution abatement programs for the boundary waters through consultation and cooperation with Federal, State, and Provincial governments. The administration of such a program should be through existing pollution control authorities.

A spirit of cooperation in solving pollution problems has been evident among industries and the municipalities. Industries have formed associations primarily for the development of waste treatment methods. Of particular interest in this area is the National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries) Incorporated.

It is believed that progress in pollution abatement will be aided if a technical committee or board be established to maintain a continuing interest in the pollution problem. Such a committee would supplement and strengthen the efforts made by pollution control authorities and would permit the interchange of reports on progress. This committee should consist of representatives from the Federal, State, and Provincial governments involved in this problem.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. coli or B. coli group</td>
<td>the coli-aerogenes group as used in all editions of Standard Methods of Water Analysis prior to the sixth edition. It is equivalent to the coliform group as defined in later editions of Standard Methods and used during this investigation.</td>
</tr>
<tr>
<td>Board, Board of Sanitary</td>
<td>Board of Technical Advisers to the International Joint Commission in the investigations described in this report.</td>
</tr>
<tr>
<td>Experts, or Advisory Board</td>
<td></td>
</tr>
<tr>
<td>BOD</td>
<td>Biochemical Oxygen Demand</td>
</tr>
<tr>
<td>Boundary Waters</td>
<td>the waters from main shore to main shore between the United States and Canada, as defined in the Treaty of 1909.</td>
</tr>
<tr>
<td>cf s</td>
<td>cubic feet per second</td>
</tr>
<tr>
<td>Coliform or coliform group</td>
<td>those organisms which will ferment lactose within 48 hours at 35.5°C in the presence of brilliant green bile and in the proportions contained in standard dehydrated media of that type (tube dilution test): or those organisms which produce a dark colony with a metallic sheen in 20 ± 2 hours of incubation at 35.5°C on M-Endo-MF Broth (membrane filter test).</td>
</tr>
<tr>
<td>Commission</td>
<td>the International Joint Commission; I.J.C.</td>
</tr>
<tr>
<td>composite sample</td>
<td>a sample made up of portions collected at definite intervals and mixed before analyses.</td>
</tr>
<tr>
<td>DO</td>
<td>dissolved oxygen</td>
</tr>
<tr>
<td>fps</td>
<td>feet per second</td>
</tr>
<tr>
<td>grab sample</td>
<td>an individual sample all portions of which have been taken at the same time.</td>
</tr>
<tr>
<td>IBC</td>
<td>International Boundary Commission</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>I.J.C.</td>
<td>International Joint Commission</td>
</tr>
<tr>
<td>Imp.</td>
<td>Imperial</td>
</tr>
<tr>
<td>IMViC</td>
<td>the pattern of biochemical reactions derived from the results of the Indol, the Methyl Red, the Voges-Proskauer, and Citrate tests.</td>
</tr>
<tr>
<td>International Boundary or boundary</td>
<td>the boundary between the United States and Canada</td>
</tr>
<tr>
<td>median</td>
<td>the value which is equaled or exceeded by exactly half the values in the given list.</td>
</tr>
<tr>
<td>MF</td>
<td>membrane filter</td>
</tr>
<tr>
<td>mg/l</td>
<td>micrograms per liter (approximately equivalent to ppb)</td>
</tr>
<tr>
<td>mg/l</td>
<td>milligrams per liter (approximately equivalent to ppm)</td>
</tr>
<tr>
<td>mgd</td>
<td>million gallons per day</td>
</tr>
<tr>
<td>ml</td>
<td>milliliters</td>
</tr>
<tr>
<td>MPN or MPN Index</td>
<td>the most probable number of coliform organisms per 100 ml when calculated from multiple tube dilution tests.</td>
</tr>
<tr>
<td>No.</td>
<td>number</td>
</tr>
<tr>
<td>P.A.</td>
<td>Public Act</td>
</tr>
<tr>
<td>P.L.</td>
<td>Public Law</td>
</tr>
<tr>
<td>pH</td>
<td>hydrogen ion concentration</td>
</tr>
<tr>
<td>Phelps Index</td>
<td>the indicated number of B. coli per 100 ml when calculated from the results of single tube dilution tests.</td>
</tr>
<tr>
<td>primary or partial treatment</td>
<td>the first major step in sewage treatment works, usually screening, grit removal, and sedimentation.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>---------------------</td>
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</tr>
<tr>
<td>secondary treatment</td>
<td>the treatment of sewage by biological methods following primary treatment.</td>
</tr>
<tr>
<td>slug or spill</td>
<td>the release of a volume of highly concentrated polluting material over a short period of time.</td>
</tr>
<tr>
<td>SS</td>
<td>suspended solids</td>
</tr>
<tr>
<td>U. S.</td>
<td>United States</td>
</tr>
<tr>
<td>%</td>
<td>per cent</td>
</tr>
</tbody>
</table>
REFERENCES


3. Minnesota Department of Health, Supplementary Report on Background Information, Rainy River Watershed Between the Outlet of Rainy Lake at Ranier and Long Point of Lake of the Woods, July, 1961, and Appendices A through H.


