REPORT

ON THE

RESULTS OF AN EXAMINATION OF THE CONDITIONS CAUSING THE POLLUTION OF THE MOSHASSUCK, WOONASQUATUCKET, AND PROVIDENCE RIVERS,

IN THE

STATE OF RHODE ISLAND,

MADE CONJOINTLY BY THE UNITED STATES GEOLOGICAL SURVEY AND THE RHODE ISLAND STATE BOARD OF HEALTH,

BY

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EXPLANATION.

The citizens of Providence whose duties or pleasures require that they shall pass over and remain for a short period upon any one of three bridges spanning the Providence river at Burnside bridge, at the Market square bridge, or at the Crawford street bridge, have all had opportunity to express their opinion as to the character of the effluvia or odor emanating from the stream, especially upon a warm summer night.

Time was when the citizen might inhale the salt-sea odor, calling to his senses not far distant marshes of sea-green reeds, oysters, clams, and fishing grounds. Within thirty years the citizens have been able to discern the presence of menhaden at the great bridge at Market square.

Gradually the tide of civilization with its varied industries utilized the streams which join to make the Providence river. Some would fain utilize it for power purposes, others for bleaching and cleansing of cloths and yarns, still others for the dumping or disposal of their refuse, not only human excreta, but also waste material.

The city of Providence also fell into the error common to cities and towns located upon flowing streams, and utilized its own river for the disposal of its sewage wastes by entering the numerous sewers into this stream.

The city of Pawtucket must needs dispose of the sewage wastes from a certain portion of an increasingly inhabited district. It, however, early foresaw the results which might accrue to the addition of her quota of pollution, and sought to purify her sewage wastes before delivering them into one of the tributaries of the Providence river.

The city of Providence, gradually awakening to the pollution of its own nest, sought to rectify matters by establishing a comprehensive system of drainage and sewage disposal that

would dispose of all of the sewage of a rapidly growing population.

This, by means of trunk sewers, lateral sewers, siphons under the river, pumping appliances to raise the accumulated sewage to a level whereby it might flow to the tide water, gradually succeeded in sending the sewage out to the true Providence river below Field's Point, after being treated with chemical precipitants which disposed of about one-half of its polluting material.

With the purpose of determining the amount of pollution actually present, and if possible ascertain the character and sources of the pollution, the State Board of Health availed itself of the advantages offered by the United States Geological Survey.

This department of the government, under appropriations from congress, has been able to make a comprehensive study of the amount of water available from the water sheds and rivers of many of the States, at the same time giving attention to the quality of the water in these rivers.

By a contract made with the bureau, the State board assumed one-half the expense which would accrue in the investigation, the government, through the hydrographic department, assuming an equal expenditure.

That the money so invested was successfully applied is shown in the accompanying report by Mr. Herman Stabler, who was detailed to carry on this work in conjunction with the board.

The board, having already a completely equipped laboratory for the routine chemical and bacteriological work, was not called upon to make extra expenditures beyond the cost of transportation of samples.

The report presents much data of value, aside from the general findings, which will be of interest to the several manufacturers located on the streams examined as well as to the citizens of Providence who have wondered where the fault lay that their once fair stream had become a nuisance.

While the presence of disagreeable odors may constitute a nuisance, it cannot be said that they are productive of disease or that they are dangerous to the public health.

That they should be corrected and that they can be corrrected, with time and with the coöperation of those who are parties to the cause of the pollution, is evident.

That there is a willingness for coöperation was shown by the cordial and earnest assistance afforded and given by every manufacturer approached during the investigation.

This assistance in some cases involved some considerable expense on the part of the manufacturer. Each one appeared willing to do his share towards an improvement in the disposal of his wastes so far as it might be practicable.

In some cases it would appear as if improvement of the conditions encountered were almost insurmountable, while in others a change for the better depended upon the action taken by municipalities in construction of sewers. This action in some cases depended upon engineering problems involving large expense.

While the report does not give the assurance of an immediate amelioration of the unfortunate conditions, yet it shows the cause and suggests the remedy.

This remedy must necessarily be dependent upon such legislation as would be fair to all the parties concerned and within the bounds of practicability.

It is to be hoped that a movement to this end may be inaugurated by the manufacturing interests involved.

GARDNER T. SWARTS,

Secretary, State Board of Health.

REPORT

ON THE

RESULTS OF AN EXAMINATION OF THE CONDITIONS CAUSING THE POLLUTION OF THE MOSHASSUCK, WOONASQUATUCKET, AND PROVIDENCE RIVERS.

HISTORICAL RESUME.

Providence river, the name applied to the head of Narragansett bay, is formed near the center of the city of Providence, Rhode Island, by the junction of the Moshassuck and Woonasquatucket rivers, and flows under bridges and through open channel for several hundred yards before it widens out to form the city harbor. The two tributaries named flow, in all, through some four miles of the thickly settled portion of Providence, and factories, small houses, and tenements line their banks. The Woonasquatucket, moreover, near its mouth, passes through an open parklike stretch known locally as the public gardens, fronting along the beautiful State capitol and State Normal School grounds. It will be readily apparent, therefore, that any serious pollution of Providence river and its tributaries is a matter of great importance to the public health and esthetics of the city.

From their location, these streams naturally drain a large portion of Providence, and in earlier days all domestic and manufacturing sewage, swill, and offal of all kinds was carried tideward through their channels. Beyond the city limits, neighboring towns and factories have since their origin used these streams for the disposal of their sewage and other wastes. For many years, therefore, Providence river has been a foul-smelling stream. The earliest official record of its pollution appears in connection with an investigation into the causes of a cholera

epidemic which visited the city in 1854. Providence was then a city with about 40,000 inhabitants. During the epidemic mentioned, of 159 deaths from cholera, 64 took place in the section bordering on the Moshassuck river. In a report* to the mayor, under date of January 26, 1855, Edwin M. Snow, M. D., made the following statements: "With regard to the deaths in the neighborhood of the canal (Moshassuck river) I answer unhesitatingly that the canal itself was the cause. The following are some of the reasons for this opinion: The same place was one of the principal foci of the disease in 1849. In that year there were 60 deaths from cholera there. . . . . The condition of the canal during the summer was such that the common sense of the whole city regarded it as a great nuisance. It was as filthy as any common sewer, and the stench arising from it at times pervaded the whole neighborhood. At any time during the summer numerous fishes might be seen floating on the surface which had been killed by the poisonous water. At any time dogs, cats, and hogs might be seen in the water in every stage of decomposition. At any time and everywhere large quantities of gas might be seen arising from decaying vegetable and animal substances in the bottom of the stream. The water is saturated with vegetable matter, is highly colored, and has an offensive smell from the washings of Allen's Print Works. . . . It is impossible to name a single cause of cholera in the location where so many deaths occurred, except the condition of the canal itself, which did not exist with equal intensity in other places in the city where scarcely a case of cholera was seen."

Although this report was written more than fifty-two years ago, the description of the stream as given by Mr. Snow is not very different from a true description of the conditions as they exist there to-day. The causes, however, have changed somewhat. Dead fish are now rarely to be seen; all fish in the stream have long since been killed. Dead animals and garbage are also less frequently seen, the city health department removing all such offensive matters in an up-to-date manner. The highly colored water, the bubbling gas, and the foul odor are, however, still there. Though in early days the pollution came from the city of Providence itself, it now comes largely from points beyond the city boundaries.

*City Document No. 5, 1854–55.

Although, as we have seen, the condition of the stream was made a matter of public record as early as 1854, and was further commented on in the first report of the superintendent of health of the city of Providence in 1857, it was not until 1876 that vigorous agitation for the betterment of this condition was begun. In that year the superintendent of health again called attention to the foul condition of the waters of Moshassuck river, and was directed by the board of aldermen to make an examination of the waters of the stream and ascertain if they were in any way injurious to the public health of the city. In conducting this investigation Mr. Snow made personal examinations of the river and heard statements of persons living near its banks, and also had analyses made of the river water at different points. In his report* the following is found: "This investigation soon established a very important fact, that the water of the river is polluted and rendered exceedingly foul and offensive before it reaches the limits of the city. It is so polluted that frequently at least it looks black and thick and gives off an offensive odor of sulphuretted hydrogen gas like very foul sewers and privies." He says, further, "It is certain that much filth is turned into the river from the city, and it must be still more filthy when it reaches the harbor. The water is, however, so very foul before it reaches the city that I doubt if it is made any more dangerous to the public health by the filth that it receives in the city." In his report he names the principal sources of pollution above the city of Providence, which are, slaughter-houses in the town of Pawtucket directly on the city line; Darling's tripe works, and manufactory of fertilizers, also in Pawtucket; a large woolen mill on Mineral Spring avenue in Pawtucket; and finally, Sayles bleachery in the town of Lincoln. He presents also the following table of analyses made by Professor Appleton of Brown University:

*City Document No. 33, 1877.

TABLE 1.

MOSHASSUCK RIVER ABOVE PROVIDENCE, R. I.

(Parts per Million.)

DATE.	Total Residue.	Volatile Residue.	Fixed Residue.	Albuminoid Ammonia.	Free Ammonia.	Chlorine.	LOCATION.
1877.							
Aug. 22.	54	23	31	.31	.03	3.3	Above Sayles' Bleachery.
Aug. 22.	240	88	152	.98	.12	11.5	Below Sayles' Bleachery.
July 26.	306	114	192	1.07	.08	17.7	Below Sayles' Bleachery.
July 26.	264	120	144	1.64	9.84	16.2	Below Darling's Works and Lorraine Mill.
July 26.	238	94	144	2.05	3.69	14.3	Below slaughter houses near city line

It will be seen that the stream was in very good condition above Sayles bleachery, and might well be classed among good river waters. Below this point, however, it is highly contaminated with organic and mineral matter from the bleachery and still further polluted by Darling's works, the Lorraine mill, and the slaughter-houses.

In a report* dated October 23, 1878, Mr. Snow again called attention to the condition of Moshassuck river and a large branch of the same known locally as West river, mentioning the fact that this latter stream receives large amounts of filth from woolen mills, bleacheries, and other manufacturing establishments. He also calls attention to Woonasquatucket river, which he states "is in some respects in a similar condition to the Moshassuck, though not yet as bad." In 1882 in a report† relative to the prevalence of typhoid fever in Providence, the superintendent of health makes mention of Providence river and its tributaries as a probable cause. In 1883 a joint standing committee of the engineer's department made a report‡ to the city council in relation to the pollution of the tributaries of Providence river. This committee made a thorough inspection of Moshassuck river, and was assisted in its investiga-

*City Document No. 30, 1878.

†City Document No. 24, 1882.

‡City Document No. 24, 1883.

tions by Dr. Edwin M. Snow, superintendent of health; Mr. Samuel M. Gray, city engineer; and Professor John Appleton of Brown University. A number of analyses of the water were made by Professor Appleton and are included in a table shown herewith:

TABLE 2.

STREAMS NEAR PROVIDENCE, R. I.

(Parts per Million.)

DATE.	Total Residue.	Volatile Residue.	Fixed Residue.	LOCATION.
1883.				
July 25.	66	20	46	Moshassuck river above Sayles' Bleachery.
July 26.	1320	583	737	Portion of Moshassuck river below Sayles' Bleachery, taken from Settling pond.
July 26.	878	356	522	Moshassuck river at Whelden St. (below Allen Print Works).
July 26.	5178	735	4443	Moshassuck river at mouth.
Aug. 7.	49	16	33	West river above Geneva mill.
July 26.	882	542	340	Part of West river, effluent of Silver Spring Bleachery.
Aug. 7.	509	291	218	Woonasquatucket river below Eagle street.

Commenting upon these partial analyses, it is to be noted that, as in 1877, the Moshassuck is not seriously polluted above Sayles bleachery. In this case the sample below Sayles bleachery shows an abnormal condition. The most highly contaminated waters from the bleachery were at this time passed through a small settling basin, and it is the effluent of this basin rather than the entire stream that is represented by the analyses. The sample at Whelden street includes the polluted waters of the Moshassuck after mixing with the polluted West river waters and the wastes from Allen's print works. That much pollution enters below this point is shown by the great increase in both organic and mineral matters observed in the sample taken at the mouth of the river. The conclusion reached by this committee was as follows:

"*First.* The subject of the pollution of the waters of the Cove basin, and hence of the Providence river, is one of great magni-

tude, and it is one that affects large manufacturing interests.

"*Second.* The committee find that the objectionable condition of the waters of the Cove basin and Providence river arises from the filth that is allowed to flow into and pollute them. This filth, as we have shown, flows in abundant streams from the West river, the Moshassuck river, and the Woonasquatucket river. In the case of the Moshassuck, at least, it is plain that the impurities introduced into the stream are not removed by deposition, or by any other natural influences, before they reach the Cove, for Professor Appleton finds that the foulest sample sent to him for analysis was that taken at the mouth of the Moshassuck river, where it enters the Cove basin.

"If the city government shall insist that these rivers shall be allowed to flow into and through the city in a clear and pure condition and shall take such steps as will procure this end a most valuable result will be secured. In order to bring back this state of things which once distinctly existed here, not only must continued defilement of the rivers flowing into the Cove basin and Providence river be stopped, but, moreover, the beds of the rivers should be so far cleaned as the foul materials accumulated there from past pollutions shall make necessary.

"*Third.* We detect a considerable source of pollution from outhouses, privies, and similar nuisances connected with private estates. We believe that these will be dealt with by the health officers of the city.

"*Fourth.* Another important source of defilement is referable to large manufacturing establishments. We believe that the city of Providence has clearly the right to demand of these corporations that they shall not pollute the waters flowing within the city limits to the Cove basin and thence to the Providence river. We believe that it is possible for each one of these manufacturing concerns to purify, by filtration or otherwise, its foul liquors:—in fact our investigations have shown us that many of them are doing something in this direction. We do not think that the purification of any foul water can be called an impossibility; it is merely a question of cost."

"*Fifth.* We are assured by the city engineer that the adoption of any plan for the final disposition of the sewage of the

city of Providence will involve the construction of marginal or intercepting sewers; we are of the opinion that immediate steps leading to such construction should be taken."

Recommendations for the alleviation of the conditions upon the stream were made in connection with the report, but beyond calling attention to the sources of the trouble no very material benefit was gained from it.

Previous to this time no very well-defined system of sewerage had been designed for the city. Sewers were constructed from time to time as the necessities of an increasing population required, and their outlets were always upon the nearest stream. While combating in a desultory way the pollution of Providence river and its tributaries, the city was adding to the filth of the streams by increasing the amount of sewage discharged into them. About this time, however, the design of a complete sewerage system was begun, and in 1884 Mr. Samuel M. Gray, then city engineer, reported to the city council plans for a sewerage system which included the interception of all sewage flowing into the streams and the disposal of the entire domestic and manufacturing sewage of the city by a chemical precipitation plant located at Field's Point, several miles below Providence.

The plans presented by Mr. Gray were approved by a committee of the American Society of Civil Engineers and by local sanitarians, and their fulfillment was expected to free Providence river and its tributaries from objectionable pollution. The sewers were designed to divert nearly five million gallons of manufacturing wastes from the streams, and were to be constructed upon the "combined" system, carrying street-washings in time of storms in addition to the normal flow. In a preliminary report* upon the sewage system for Moshassuck and west river drainages we find the statement: "The close proximity of each of the main branches to the rivers will make it easy to arrange for overflow and thus make the size of the mains much smaller than could otherwise be done." Again in the complete report† Mr. Gray writes: "at the junctions of the district

*City Document No. 21, 1883.

†City Document No. 25, 1884.

outlet sewers with the intercepting sewers there will be overflows into the river for the relief of the sewers from excess of rain water. These overflows will be so arranged that when the amount of rain water coming from the district sewers exceeds the amount provided for in the intercepting sewer, the excess of water will flow directly into the river." Evidently, however, it was not the intention of the designer that these overflows should constitute a serious factor in the pollution of the streams, for he states, further: "It is only by keeping all sewage and filthy liquors out of these waters, or by clarifying them before they are permitted to enter, and by thoroughly clearing the river beds from all deposits of filth, that we may look for improvement in the condition of the Providence river and its tributaries." And in another place: "It is believed that if the scheme herein recommended be thoroughly carried out, the Providence river and its tributaries may be reclaimed from their present filthy condition, and that the air which is now so often laden with foul gases rising from their waters may be preserved pure and wholesome." In the light of present conditions these statements are of great interest, and reference will be made to them later.

In July, 1887, the city council adopted the proposed plan for a sewerage system, and construction was ordered in February, 1889. Thus, at last, the city of Providence took active measures to free itself from the cesspool that had for many years been not only an unwarranted nuisance but a constant source of danger to its inhabitants.

The city officials made several efforts after this to lighten the burden of manufacturing wastes (5 million gallons in ten hours) to be carried in the sewers by treatment at the factories. None of these was successful, however, for it was found impossible to secure sufficient unanimity among the manufacturers in any one district to make the proposed plans feasible.

When called upon in 1892 to make a statement concerning the continued pollution of the streams, the superintednent of health, Dr. Charles V. Chapin,* said: "If we wish to have the river water free from nuisance, it will be necessary to remove

*City Document No. 28, 1892.

entirely the manufacturer's refuse and the house sewage. To accomplish this I have nothing better, and nothing in addition to recommend to the plan for the disposal of sewage adopted by the city council, and approved July 22, 1887," But after the completion of the sewers along the Moshassuck, the same official was forced to admit* that: "Notwithstanding the fact that the city turned all of its sewage away from the Moshassuck river, the pollution of that stream has increased from year to year, and has been greatly complained of by residents of that section of the city through which it flows."

The progress of the construction of the sewerage system has been as rapid as could be expected. With two exceptions, stream drainage areas within the city have been thoroughly covered. Nevertheless, Providence river and its tributaries remain filty streams, bubbling with gases formed by the decomposition of organic matter, and throwing off foul and noxious odors.

INVESTIGATIONS BY UNITED STATES GEOLOGICAL SURVEY AND RHODE ISLAND STATE BOARD OF HEALTH.

In 1906 an agreement was made for an investigation of stream pollution and means for alleviation of the same in Rhode Island by coöperation of the United States Geological Survey and the Rhode Island State Board of Health. The writer was assigned to the investigation, and work was begun in August, 1906.

Examination of Providence river and its tributaries was made in order to ascertain the principal sources of pollution, and investigations relative to the best economic means of treating the polluted waters were begun. It is the object of this report to present the accumulated data relative to the condition of the streams and the amount and character of the polluting wastes. Comments upon plans for reducing the pollution of the streams will also be included, but detailed studies of manufacturing wastes and methods of purifying the same will be reserved for a later report.

*City Document No. 11, 1892.

ACKNOWLEDGMENTS.

I desire to acknowledge the hearty coöperation in this work of Dr. Gardner T. Swarts, secretary of Rhode Island State Board of Health, who gave much personal attention to the investigations and assisted them greatly by his knowledge of local conditions and his long experience in sanitary work.

Much of the value of the work accomplished is due to Mr. Gilbert H. Pratt, chemist of the Rhode Island State Board of Health, under whose direction fell a very large portion of the chemical examinations. His interest in the problems encountered, coupled with indefatigable zeal, contributed in great measure to the scope and character of the investigations.

I desire to extend thanks to Mr. Otis F. Clapp, city engineer of Providence, R. I.; Mr. George A. Carpenter, city engineer of Pawtucket, R. I.; and Mr. William F. Keene, city engineer of Central Falls, R. I. for many courtesies extended, including the furnishing of data and of maps relative to the sewerage systems of the cities they represent.

I wish also to acknowledge the hearty coöperation of the gentlemen representing the manufacturing interests approached in connection with the investigation. In attacking problems relative to trades-waste utilization or treatment, little can be accomplished if the manufacturers themselves be hostile to the work. Such an attitude was not encountered in Rhode Island.

LIST OF SAMPLING STATIONS UPON PROVIDENCE RIVER AND TRIBUTARIES.

Station 1.—Woonasquatucket river at highway bridge above Greystone mill.

Station 2. Woonasquatucket river between Greystone and Centredale. Sample 2A was collected from the east side of the stream, about 200 yards above the Centredale mill. Sample 2B was collected at the highway bridge below the Centredale mill dam.

Station 3.—Woonasquatucket river from east bank, about 200 yards below Centredale mill.

Station 4.—Woonasquatucket river at head of Lymansville mill race.

Station 5. Woonasquatucket river from east bank, 150 yards below Lymansville mill.

Station 6.—Woonasquatucket river below Manton mill. Sample 6A was taken from east bank at fence line, about 300 yards below highway bridge. Sample 6B was taken at highway bridge.

Station 7.—Woonasquatucket river at Egan street, Providence (below Dyerville).

Station 8.—Woonasquatucket river opposite Bosworth street, Providence. Samples 8A, 8B, and 8D were taken from footbridge above Riverside mill. Sample 8C was taken 50 yards above Riverside mill dam.

Station 9.—Woonasquatucket river at lower side of Tanyard lane bridge, Providence.

Station 10.—Woonasquatucket river at lower side of Delaine street bridge, Providence.

Station 11.—Woonasquatucket river at lower side of Atwell's avenue bridge, Providence.

Station 12.—Woonasquatucket river at upper side of Eagle street bridge, Providence.

Station 13.—Woonasquatucket river from upper side of bridge opposite American Locomotive Motor Car Works, Providence.

Station 14.—Woonasquatucket river from upper side of and near east abutment of Acorn street bridge, Providence.

Station 15.—Woonasquatucket river from footbridge 500 yards below Acorn street, Providence.

Station 16.—Woonasquatucket river from lower side of Gaspee street bridge, Providence.

Station 17.—Providence river from lower side of Crawford street bridge, Providence.

Station 18.—Providence river at Point street. Samples of January 30, 1907, were taken from lower side of bridge. Samples of April 25, 1907, were taken 20 yards above bridge.

Station 19.—West river, from bridge over Geneva mill race outside mill enclosure.

Station 20.—West river from lower side of Douglas avenue bridge, Providence.

Station 21.—West river from upper side of Wild street bridge, Providence,

Station 22.—West river from upper side of Veazie street bridge, Providence.

Station 23.—West river from lower side of Branch avenue bridge, Providence.

Station 24.—West river from upper side of Hawkins street bridge, Providence.

Station 25.—West river from lower side of Charles street bridge, Providence.

Station 26.—West river from upper side of West river street bridge, Providence.

Station 27.—Moshassuck river from upper side of highway bridge at Sayles-ville.

Station 28.—Moshassuck river from upper side of and near west abutment of Weeden street bridge, Pawtucket.

Station 29.—Moshassuck river from upper side of Mineral Spring avenue bridge, Pawtucket.

Station 30.—Moshassuck river at Grotto avenue, Pawtucket. Sample 30A is from lower side of bridge, near east abutment. Sample 30B is from upper side of bridge, near west abutment.

Station 31—Moshassuck river from east bank, about 100 yards below Grotto avenue, Pawtucket.

Station 32.—Moshassuck river near Esten avenue, Pawtucket. Samples taken opposite and above drain from R. D. Mason & Co. establishment.

Station 33.—Moshassuck river from footbridge near R. D. Mason & Co. establishment, Pawtucket.

Station 34.—Moshassuck river from east bank, 100 yards above Cemetery street, Providence.

Station 35.—Moshassuck river from upper side of Cemetery street bridge, Providence.

Station 36.—Moshassuck river from upper side of Smithfield avenue bridge, Providence.

Station 37.—Moshassuck river from lower side of Branch avenue bridge, Providence.

Station 38.—Moshassuck river from upper side of Pettis street bridge, Providence.

Station 39.—Moshassuck river from upper side of Randall street bridge, Providence.

Station 40.—Moshassuck river from upper side of Mill street bridge, Providence.

Station 41.—Moshassuck river from upper side of Smith street bridge, Providence.

Station 42.—Moshassuck river at upper side of Promenade street bridge, Providence.

WOONASQUATUCKET RIVER.

This stream has a total length of about 21 miles and drains an area of 55 to 60 square miles. Rising in the town of Smithfield, it gathers its waters from numerous springs and small brooks in a rolling agricultural area; but almost throughout its entire length it finds use as a water supply, as a source of power, and as a sewer for numerous mills which line its banks. These mills are chiefly textile factories, and unfortunately many of them have large quantities of waste waters from scouring and dyeing which the stream must needs carry.

Beginning near the headwaters of the river, we find the Winsor mill at West Greenville and the Greenville Woolen Mills at Greenville, both small mills for the manufacture of men's wear, woolens, and worsteds. Farther on is Stillwater mill of the Centredale Worsted Co., a spinning mill for worsted yarns; the Bernon Mills at Georgiaville, making sateens, twills, and point cloth; and the Enfield Mill, a newly built structure not yet placed in operation. None of these contributes largely to the pollution of the stream, though all discharge small amounts of refuse, including sewage from a total of 600 to 700 employees. Since inspection of the stream accompanied by dissolved oxygen tests showed no undesirable conditions, no detailed examinations were made upon this section of the stream, 13 miles in length.

The next 6.5 miles may be considered, as a whole, a section open to suspicion by reason of the number of mills and comparatively dense population included. A detailed chemical survey of this district was made between August 29 and September 19, 1906. During this period the stream-flow was practically constant, there being no rainfall of consequence. The results are, therefore, comparable from station to station, without regard to date.

Occasional samples were taken at several stations from time to time, and between May 15 and June 18, 1907, a second detailed survey included the taking of samples for chemical and bacterial analysis every hour during the working day. Night samples were also taken along the lower portion of this section to ascertain whether night discharge of polluting liquor occurred to any great extent.

The results of these examinations are shown in Table 3.

TABLE 3.

WOONASQUATUCKET RIVER.

(Parts per Million.)

Sample Number.	DATE.	Oxygen Consumed.	Organic Nitrogen.	Nitrogen as Free Ammonia.	Chlorine.	Alkalinity.	Fats.	Turbidity.	Total Solids.	Loss on Ignition.	Bacteria per cubic Centimeter.	REMARKS.
1 A	9-19-06	2.5	0.30	0.05	3.4	12	......	tr.	......	......	....	Composite, 8:20 a. m. to 6:20 p. m.
1 B	5-15-07	4.2	0.21	0.05	3.6	7	1.2	tr.	38	14	300	Composite, 7:45 a. m. to 5:45 p. m.
2 A	9-19-06	4.8	0.55	0.05	3.3	11	......	5	......	......	19,000	Composite, 8:10 a. m. to 6:10 p. m.
2 B	5-15-07	4.6	0.35	0.07	3.7	7	2.4	5	40	16	9,500	Composite, 8:00 a. m. to 6:00 p. m.
3 A	9-19-06	4.6	0.55	0.05	3.7	12	......	5	......	......	28,000	Composite, 8:00 a. m. to 6:00 p. m.
3 B	5-15-07	4.5	0.35	0.07	4.1	7	3.6	5	42	18	7,600	Composite, 8:07 a. m. to 6:00 p. m.
4 A	9- 6-06	5.0	0.45	0.06	......	16	......	tr.	......	......	2,900	Composite, 11:00 a. m. to 1 p. m.
4 B	5-21-07	4.6	0.31	0.03	2.8	8	1.8	5	39	15	1,200	Composite, 7:45 a. m. to 5:45 p. m.
5 A	9- 6-06	5.1	0.40	0.07	......	18	......	5	......	......	34,000	Composite, 8:30 a. m. to 5:30 p. m.
5 B	5-21-07	4.8	0.35	0.03	3.5	8	2.6	5	39	15	2,400	Composite, 7:55 a. m. to 5:55 p. m.
6 A	9- 6-06	6.2	0.70	0.07	......	21	......	20	......	......	58,000	Composite, 8:10 a. m. to 6:10 p. m.
6 B	5-21-07	4.9	0.53	0.06	3.3	11	2.4	10	47	19	3,000	Composite, 8:05 a. m. to 6:05 p. m.
7	5-21-07	5.5	0.53	0.05	3.6	12	2.6	10	55	22	3,100	Composite, 8:20 a. m. to 6:20 p. m.
8 A	8-29-06	6.2	0.80	0.07	6.0	22	......	15	......	......	23,000	Composite, 7:55 a. m. to 6:45 p. m.
8 B	8-29-30-06	5.8	0.90	0.06	6.0	21	......	10	......	......	14,500	Composite, 7:55 p. m. to 6:40 a. m.
8 C	11-27-06	5.6	0.55	0.04	......	......	5.0	tr.	......	......	7,700	2:30 p. m.
8 D	5-23-07	5.4	0.63	0.05	4.2	12	3.4	10	52	24	6,300	Composite, 7:40 a. m. to 5:40 p. m.
9 A	11-27-06	6.0	0.75	0.07	......	......	4.0	10	......	......	9,900	2:45 p. m.
9 B	5-23-07	5.6	0.69	0.06	4.3	12	3.2	10	54	22	12,400	Composite, 7:50 a. m. to 5:50 p. m.
10 A	8-29-06	6.4	0.80	0.12	7.0	22	......	20	......	......	19,000	Composite, 7:45 a. m. to 6:35 p. m.
10 B	8-29-30-06	5.8	0.90	0.07	7.0	22	......	15	......	......	31,500	Composite, 7:45 p. m. to 6:30 a. m.
10 C	11-27-06	6.0	0.70	0.06	......	......	8.0	10	......	......	16,800	3:30 p. m.
10 D	5-23-07	5.5	0.67	0.06	4.4	12	3.8	10	54	22	11,900	Composite, 8:00 a. m. to 6:00 p. m.
11 A	8-29-06	7.5	1.10	0.03	9.0	27	......	20	......	......	54,000	Composite, 7:45 a. m. to 6:30 p. m.
11 B	8-29-30-06	5.8	0.90	0.11	7.0	24	......	15	......	......	17,000	Composite, 7:40 p. m. to 6:25 a. m.
11 C	10-30-06	7.9	0.80	0.13	7.0	17	......	10	......	......	....	Composite, 7:15 a. m. to 5:15 p. m.
11 D	5-23-07	6.0	0.82	0.10	4.9	14	3.8	10	64	24	14,300	Composite, 8:05 a. m. to 6:05 p. m.
11 E	6-18-07	5.4	0.65	0.11	5.3	14	2.4	5	61	28	16,000	6:40 a. m.
11 F	6-18-07	6.0	0.89	0.06	6.6	14	1.2	10	80	24	....	Composite, 8:50 a. m. to 6:50 p. m.

Station 1 is located just above the Greystone mill. The Woonasquatucket at this point is shown to be a clear, limpid stream, free from excessive pollution of any sort. The total amount of solid matters carried by the water is small and the percentage of this which is organic is small. The bacterial count is low, and, judged from the analysis, it would be classed as a potable water well adapted to textile or other manufacturing purposes.

The Greystone mill, operated by Joseph Benn & Sons, is an alpaca and mohair factory established in 1905, and employing between 600 and 700 persons. All wastes were at one time discharged into a small pond near the mill. The stench caused a nuisance in the immediate neighborhood, and overflow to the stream caused complaints from mills located on the stream below. As a result of these conditions the management constructed an iron pipe line six inches in diameter, through which the greater part of the wastes, including dye water, scouring-liquor, and sewage, is now forced about half a mile against a head of more than one hundred feet and discharged upon a barren hilltop, east of the Greystone village. The liquors sink into the soil, and it will be many years before the area is so saturated that a stream will be formed flowing back to the river. This is a rather expensive, but very effective, means of preventing pollution. However, as evidenced by the analyses at station 2, about half a mile below the mill, some pollution does occur at Greystone. At almost any hour a small stream of what appears to be scouring-liquor may be seen flowing into the river at the upper edge of the mill. The pollution was not considered sufficient, however, to warrant any special investigation.

Stations 2 and 3 are located above and below the Centredale Worsted Mill, a worsted yarn factory employing about 150 persons. There is a thickly settled village immediately around the mill that would be expected to contribute somewhat to the pollution of the stream. All scouring for the mill is done in Providence, and sewage of the employees is said to be the only polluting waste. The analysis shows a slight increase in

chlorine, fats, and loss on ignition, but there is no evidence of serious pollution at Centredale.

At Allendale, half a mile further down stream, is located a small silk mill operated by the Ramsay & Gore Mfg. Co. This factory employs less than 100 persons and is not operated continuously. It is not an appreciable factor in the pollution of Woonsaquatucket river.

The analyses at stations 4 and 5 show the condition of the river above and below the Lymansville mill, an establishment of 430 employees. Worsted piece goods are manufactured here. This was thought to be the chief point of pollution above Providence, and a somewhat extensive investigation of the polluting liquors was made, such an investigation being made possible through the courtesy of the Lymansville Co. Although a considerable quantity of waste liquors is discharged daily, the effect upon the stream is small, much less than could be accounted for by mere dilution. As will be observed, the analyses in table 3 show only a slight increase in organic matter, chlorine, and a somewhat greater increase in number of bacteria. Just above the mill is a large reservoir which is tapped by a mill race, through which the main portion of the stream flows. A weir overflow passes around possibly 100 yards from the mill and is joined by the waters from the tail race some distance below. The factory wastes are dye water, 3,000 to 4,000 gallons; piece scouring and rinsing water, 5,000 to 6,000 gallons; and wool scouring-liquor, 5,000 to 6,000 gallons. Piece scouring suds and dye water in intermittent flow throughout the day are collected in two 9,500-gallon brick cisterns (used alternately), where they are joined at noon and the end of the day by charges of wool scouring-liquor to which slaked lime (50 pounds per day) had been added. These cisterns serve primarily as receiving and mixing basins, but the mixed liquors are also freed there from the coarser and heavier suspended matters. The cisterns are cleaned once in three weeks, and about 9 cubic yards of sludge removed. This sludge is dumped nearby until excess of water has drained off, and is then carted away. It contains, as shown by a sample taken from the dump: Total solids, 79.7 per cent.; volatile solids, 4.5 per cent.; fixed

solids, 75.2 per cent.; fats, 1.4 per cent.; and nitrogen, 0.12 per cent. It is chiefly sand, wholly unsuitable for fertilizing purposes, and probably can not be utilized in any way.

From the receiving cisterns the combined liquors are pumped into the first of a series of four reservoirs. The sizes of these reservoirs and the periods of storage afforded by them are shown below:

No. 1,	45	ft. by	60	ft. by	4	ft.	Capacity	81,000	gal.	Storage	5.4	days.
No. 2	35	"	18	"	4	"	"	18,900	"	"	1.3	"
No. 3,	40	"	18	"	4	"	"	21,600	"	"	1.4	"
No. 4,	45	"	18	"	4	"	"	24,300	"	"	1.6	"
Total							"	145,800	"	"	9.7	"

The system is practically one of sedimentation, though the effluent from reservior No. 4 passes through a bank of coarse cinders before discharging into the river. The point of discharge is located a few yards below the weir overflow from the reservoir above the mill. Since by far the greater part of the stream-flow is by-passed through the mill, the discharge of the wastes is into a comparatively stagnant pool in which a very considerable sedimentation and a bacterial purification undoubtedly takes place. It is probably due to this condition rather than to the system of sedimentation reservoirs that the pollution of the stream at this point appears so slight by the analyses. Nevertheless much material is removed in the reservoirs. The first of these is cleaned about once in six months, and 15 cubic yards of scum and an equal amount of sludge is removed. Only slight accumulations are found in the other reservoirs. It will be seen, therefore, that in a year the following amounts of material are removed from the wastes:

Receiving cisterns	160	cubic	yards.
Reservoir No. 1	100	"	"
Other reservoirs (estimated)	10	"	"
Total	270	"	"

The scum from reservoir No. 1 contains 24.1 per cent. total solids; 15.4 per cent. volatile solids; 8.7 per cent. fixed solids; 4.8 per cent. fat; and 0.4 per cent. nitrogen. The sludge contains 29.5 per cent. total solids; 14.1 per cent. volatile solids; 15.4 per cent. fixed solids; 4.2 per cent. fat; and 0.5 per cent. nitrogen.

This material undoubtedly has considerable manurial value, but the great content of moisture (70 per cent. to 75 per cent.) renders it valueless because of cost of transportation.

Correcting for the moisture, and assuming an average weight of 80 pounds per cubic foot for the 270 cubic yards of material, it appears that a total removal of 357,000 pounds per annum is accomplished. This is a maximum figure. The waste liquors contain about 1,000,000 pounds of solid matters. A purification of upwards of 36 per cent. is, therefore, effected. It should be noted, however, that by far the greater part (about 75 per cent.) of this purification takes place in the receiving basins. In table 4 are presented analyses of the various waste liquors at Lymansville, together with analyses of the combined liquors at various stages in the sedimentation system.

TABLE 4.

WASTE WATERS AT LYMANSVILLE, R. I.

Milligrams per Liter.

Sample Number.	Turbidity.	Color.	Sediment.	Organic Nitrogen.	Nitrogen as Free Ammonia.	Oxygen Consumed.	Fats.	Chlorine.	Alkalinity.	Total Solids.		Solids in Solution.		Remarks.
										Total.	Loss on Ignition.	Total.	Loss on Ignition.	
5786	400	Black.	Cons.	7	43	364	14	5	114	700	690	700	690	Dye water.
5787	1,200	Slate.	Heavy.	60	1	560	900	100	1,990	4,810	2,140	3,960	1,510	Piece scouring-suds.
5788	22,000	Brown.	15%	663	300	5,680	14,600	1,100	8,000	45,090	24,670	31,120	13,080	Wool scouring-liquor.
5789	10,300	Brown.	7.2%	215	183	1,700	5,910	400	3,560	19,600	12,500	11,080	4,670	Inflow reservoir No. 1.
5790	9,700	Brown.	3.0%	104	160	1,600	5,430	400	3,250	16,530	9,400	11,770	5,000	Effluent Reservoir No. 1.
5791	9,700	Brown.	2.2%	104	143	1,700	4,950	400	3,750	16,010	9,140	11,600	5,050	Effluent Reservoir No. 2.
5792	8,000	Brown.	2.1%	188	145	1,680	4,380	400	3,750	15,520	8,610	11,240	4,670	Effluent Reservoir No. 3.
5793	8,500	Brown.	1.3%	184	134	1,680	5,070	400	3,750	15,730	8,760	11,590	4,920	Effluent Reservoir No. 4.
5794	9,700	Brown.	1.0%	190	133	1,700	4,850	400	3,750	15,900	8,960	11,300	4,680	Inflow to river.

From the figures there presented it appears that the entire system of reservoirs (considered aside from the receiving basins) with nearly ten days storage accomplishes a reduction of only 6.0 per cent. in turbidity, 86 per cent. in sediment, 19 per cent. in total solids, 28 per cent. in loss on ignition, 2.3 per cent. in fixed solids, 12 per cent. in organic nitrogen, 27 per cent. in free ammonia, 18 per cent. in fats, and practically nothing in oxygen consumed or filtered solids. In the first reservoir alone there is a reduction of 6 per cent. in turbidity, 58 per cent. in sediment, 16 per cent. in total solids, 25 per cent. in loss on ignition, 0 per cent. in fixed solids, 10 per cent. in organic nitrogen, 8 per cent. in free ammonia, and 9 per cent. in fats. There appears to be little gain in increasing the period of sedimentation beyond 5 days. It is even probable that a carefully constructed sedimentation basin with a 24- to 48-hour period will accomplish as much purification as the entire system of reservoirs in use at Lymansville; for it should be understood that these reservoirs are mere excavations in the earth, and no precautions were taken in their construction to produce an even flow throughout their cross sections. It is quite certain that the liquor moves through them in a comparatively narrow current, and hence is subjected to a much shorter period of sedimentation than their capacities indicate.

To sum up the situation at Lymansville, treatment of the waste liquors by lime and sedimentation, dilution and sedimentation in the stream basin, and finally dilution by the main stream, makes the pollution at that point negligible. Increase in quantity of material scoured and dyed may make this mill a factor in the stream pollution.

From an economic standpoint the method of treatment could be improved, and the valuable products (wool, fat, and potash) in the wool scouring-liquor could be made to return a substantial profit upon the cost of treatment by the Smith-Leach process.

Below Lymansville, the next probable point of pollution is Manton. Here the Manton mill of the American Woolen Co., with 700 employees, pollutes the river with dyeing, piece scouring, and sewage wastes. This mill is within the Providence city limits, and the wastes will ultimately be cared for by the city sewers, which have already been extended to within a mile of Manton station.

The present condition of the stream above and below Manton is shown by the analyses at stations 5 and 6. These samples show an increase here of 30 per cent. to 50 per cent. in the organic matter in the stream. The pollution enters in charges, and was noted by the appearance of the stream at various times during the day. On September 6, 1906, the worst appearance was at 5:00 P. M. A sample taken at that time was light blue in color; had a turbidity of 25; organic nitrogen of .70; free ammonia, 0.08; oxygen consumed, 7.0; and contained 66,000 bacteria per cubic centimeter. This analysis shows dye-water pollution distinctly. No very undesirable conditions result from the pollution at Manton.

Station 7 is below Dyerville, where the Joslin Mfg. Co. operates a shoe- and corset-lacing factory. There are about 100 employees here, and in addition to their sewage the analysis indicates slight pollution by dye water.

A similar mill with 250 employees is operated by the same company at Merino, three-fourths of a mile down stream. The water at station 8, half a mile below this mill, is not materially different from the water above. The Merino and Dyerville mills will both be reached by the city sewerage system in the course of a few years, and it is expected that their waste waters will be cared for by the sewers.

Just below station 8 lies the Olneyville mill district, a thickly populated portion of Providence, studded with large textile factories. Between stations 8 and 9, Bosworth street and Tanyard lane, are the Riverside Worsted mills, 1,700 employees, men's suitings; Centredale Combing Co., 100 employees, wool tops; C. L. Blanding Mfg. Co., 110 employees, worsted; American Multiple Fabric Co., 40 employees, cotton fabrics; Atlantic mills, 3,500 employees, cotton and woolen dress goods; Weybosset mills (American Woolen Co.), 800 employees, men's goods; Pocasset Combing Co., 40 employees, wool tops; and Crown Worsted mills, 110 employees, yarns. Formerly sewage and wastes from these mills, together with Olneyville domestic sewage, was discharged into the Woonasquatucket, a large por-

tion of the mill sewage being carried by a private sewer which discharged into the river at Eagle street. All the wastes are now cared for by the new city sewerage system, and in this district the effects of the new system are most apparent. Also between stations 8 and 9 now exist storm overflows from Hartford avenue, Manton avenue, and Plainfield street sewers; a storm drain from Olneyville Square, a fish market projecting over the stream, and by repute a few private sewers. At station 9 a considerable quantity of oily scum, presumably from condensing engines at the Atlantic mills, is noticeable upon the surface of the stream. Notwithstanding the great possibilities of pollution between these two stations, the analyses show that the contamination is very slight.

Between stations 9 and 10, Tanyard lane and Delaine street, are the Earnscliffe Worsted mills, 425 employees, spinning and weaving; and the Providence Dyeing, Bleaching, and Calendering Co., 210 employees, bleaching and finishing. These mills and the surrounding neighborhood are sewered, and there is no increase in the pollution shown by the analyses.

Between stations 10 and 11, Delaine street and Atwell's avenue, are the National and Providence Worsted mills, 2,200 employees, yarn, weaving, and finishing; and the small Queensbury mill, now closed. There are also storm sewer outlets at Delaine street, Valley street, and Atwell's avenue. This district is also thoroughly sewered. Nevertheless, some polluting matters enter between these stations, presumably from the National and Providence Worsted mills, showing an increase in both mineral and organic solids. This increase is from 10 per cent. to 20 per cent. of the organic matter in the stream during the working day, but is not noticeable at night. Occasional samples of slightly colored water were taken during the day at station 11.

Summing up the results upon this section of Woonasquatucket river, between Greystone and Atwell's avenue, Providence, a distance of 6.5 miles, the analysis figures for the stream are increased by 3.4 parts oxygen consumed, 0.7 parts organic nitrogen, 3.4 parts chlorine, 2.6 parts fats, 10 parts turbidity, and 10 parts of loss-on-ignition. The bacterial count increases from a few hundred to about 20,000. Roughly, the organic matter is a little more than doubled. This pollution does not occur at any one point, but is gradual throughout the entire distance. When it is considered that the stream passes through a thickly settled area, including a mile and a half of densely populated city; that textile mills to the number of 20, with dyeing and scouring wastes and a total of 11,600 employees are within the drainage area, such a condition is remarkable, and a cause for congratulation to the residents of Providence. The credit for this condition is due to the city engineers of Providence and to the manufacturers, lawsuits and injunctions having played no small part in maintaining the purity of the stream.

Remedial measures for the pollution that now exists are: Natural extension of the Providence sewerage system, careful trapping of oil from condensing engines, and possibly more careful treatment or disposal of waste liquors at Greystone and Lymansville.

The lower section of Woonasquatucket river, Atwell's avenue to its mouth a short distance below Gaspee street, presents a very different appearance from the section just considered. Atwell's avenue is at the head of tide water, and in addition to great pollution the rise and fall of the tides add to the nuisance caused by this portion of the stream one and three-quarters miles in length. We have seen that at Atwell's avenue, station 11, the stream is at all times in fairly good condition, though pollution is easily detected during the day. Between this point and Eagle street, station 12, a short quarter-mile below, are the following mills: Rogers Screw Co., 100 employees; Queen Dyeing Co., 470 employees, dyeing and finishing; Valley Worsted mills (American Woolen Co.), 460 employees, yarns; and the Joseph Banigan Rubber Co., 650 employees, rubber boots and shoes. A storm sewer also discharges into the stream from a point on the grounds of the rubber company. The above-named mills are very incompletely sewered and discharge their manufacturing wastes into the Woonasquatucket without treatment. The result may be seen through examination of the analyses at station 12 (see table 5), the samples at that point being taken from the upper side of the bridge, thus avoiding any wastes that enter through sewers discharging beneath the bridge.

TABLE 5.

WOONASQUATUCKET RIVER.

(Parts per Million.)

Sample Number.	Date.	Oxygen Consumed.	Organic Nitrogen.	Nitrogen as Free Ammonia.	Chlorine.	Alkalinity.	Sulphates as SO_3.	Iron.	Fats.	Turbidity.	Total Solids. Total.	Total Solids. Loss on Ignition.	Solids in Solution. Total.	Solids in Solution. Loss on Ignition.	Bacteria per cubic Centimer.	Remarks.
11 A	8-29-06	7.5	1.10	0.03	9.0	27	trace.	0.5	....	20	....	....	....	....	54,000	Composite, 7:40 a. m. to 6:30 p. m.
11 B	8-29-30-06	5.8	0.90	0.11	7.0	24	trace.	0.5	....	15	....	....	....	....	17,000	Composite, 7:40 p. m. to 6:25 a. m.
11 C	10-30-06	7.9	0.80	0.13	7.0	17	5	0.5	....	10	....	....	....	....	....	Composite, 7:15 a. m. to 5.15 p. m.
11 E	6-18-07	5.4	0.65	0.11	5.3	14	trace.	....	2.4	5	61	28	60	28	16,000	6:40 a. m.
11 F	6-18-07	6.0	0.89	0.06	6.6	14	trace.	....	1.2	10	80	24	65	21	....	Composite, 8:50 a. m. to 6:50 p. m.
12 A	10-30-06	22.0	2.50	0.03	14.0	33	17	1.0	44.0	90	....	....	....	....	50,000	Composite, 7:05 a. m. to 5:35 p. m
12 B	6-18-07	5.5	0.66	0.06	5.3	13	trace.	....	4.0	5	67	32	65	32	31,000	6:45 a. m.
12 C	6-18-07	11.8	1.25	0.03	11.6	22	5	....	2.4	20	112	38	90	26	550,000	Composite, 8:55 a. m. to 6:55 p. m.
13 A	8-29-06	12.2	2.00	0.03	15.0	42	trace.	0.5	....	55	....	....	....	....	200,000	Composite, 7:30 a. m. to 6:20 p. m.
13 B	8-29-30-06	10.0	1.30	[illegible]	12.0	31	trace.	0.5	....	20	....	....	....	....	200,000	Composite, 7:30 p. m. to 6:15 a. m.
13 C	6-18-07	5.6	0.71	[illegible]	6.1	17	trace.	0.8	4.0	5	70	35	72	35	55,000	6:50 a. m.
13 D	6-18-07	17.0	2.60	0.07	10.8	32	8	1.6	16.8	30	171	50	109	37	2,000,000	Composite, 9:00 a. m. to 7:00 p. m.
14 A	6-18-07	5.4	0.76	0.09	6.9	17	trace.	1.0	4.0	5	75	36	76	36	48,000	6:55 a. m.
14 B	6-18-07	17.8	2.55	0.07	11.4	31	8	4.4	15.2	50	175	72	110	38	3,800,000	Composite, 9:05 a. m. to 7:05 p. m.
15 A	6-18-07	6.0	0.94	0.11	7.5	19	trace.	1.8	4.8	10	89	34	84	33	70,000	7:00 a. m.
15 B	6-18-07	12.9	1.85	0.07	12.7	28	8	8.0	9.0	40	164	44	101	26	800,000	Composite, 9:10 a. m. to 7:10 p. m.
16 A	8-23-06	50.0	6.50	2.50	70.0	70	35	1.0	....	350	....	....	....	....	....	3:45 p. m. 1 hour before low tide.
16 B	8-24-06	27.0	3.30	1.40	4300.0	100	315	0.5	....	85	....	....	....	....	....	10:15 a. m. 1 hour before high tide.
16 C	8-27-06	14.5	1.80	0.40	30.0	45	20	3.0	....	125	....	....	....	....	....	11:00 a. m., mid flow tide.
16 D	8-27-06	17.5	2.50	0.35	50.0	40	trace.	2.0	....	160	....	....	....	....	....	5:00 p. m., mid ebb tide.
16 E	8-29-06	12.4	2.80	0.35	488.0	38	93	5.5	....	65	....	....	....	....	105,000	Composite, 7:20 a. m. to 6:10 p. m.
16 F	8-29-30-06	14.8	2.80	0.48	941.0	57	128	1.5	....	60	....	....	....	....	250,000	Composite, 7:25 p. m. to 6:10 a. m.
16 G	6-18-07	12.8	1.90	0.18	44.0	44	10	3.2	6.4	15	212	62	187	52	110,000	7:05 a. m., near low tide.
16 H*	6-18-07	15.5	2.30	0.07	28.0	28	10	8.0	12.0	70	208	65	145	36	3,700,000	Surface composite. 8:15 a. m. to 7:15 p. m.

* No sample taken between 1:15 p. m. and 5:15 p. m., to avoid tide water.

Although the early morning samples taken on June 18 were practically the same at the two stations, the average daily condition indicates an increase of not less than 60 per cent. in organic, and 30 per cent. in mineral, solids between Atwell's avenue and Eagle street. The samples of October, 1906, were taken at a lower stage of the stream, and indicate that the organic pollution is more than doubled at this point. The appearance of the stream at Eagle street is subject to constant change as the charges of scouring-liquor or dye water are discharged by the mills.

Below Atwell's avenue the sewers built many years ago, discharging into the stream from the south, are still in existence. The first of these empties under the Eagle street bridge, and besides the domestic sewage from a few score houses, carries all the wastes from the Providence Brewing Co. brewery on Eagle street and Harris avenue. Quite as one would expect, there is a continuous flow of filthy water from this sewer. Just across the stream in the north abutment of the bridge is the outlet of a so-called storm sewer. Contrary to expectations, this sewer is found to flow in the dryest weather, and while the flow is not continuous, there are many days that about noon one can see a considerable flow of filthy soapy water, apparently colored by dyes. Sometimes this flow continues for only an hour or two, while on other occasions its period may cover practically the entire day. Examinations of the city sewer maps developed the fact that at Eagle street there is an overflow from the Valley street intercepting sewer, which carries the drainage of the entire sewered portion of the Woonasquatucket drainage area above Eagle street. This Valley street sewer is a 60-inch circular brick sewer with a grade of 0.0005. Such a sewer should be able to carry, flowing full, not more than 1,365,000 gallons per hour. The writer has been credibly informed that the water used in three of the large Olneyville mills and diverted to the sewers amounts to 7,000,000 gallons in ten hours. If this statement is correct, 1,000,000 per hour is a conservative estimate for the day mill sewage of the district drained by the Valley street sewer. Assuming the mill sewage to be discharged uniformly throughout the working day, this leaves

but 365,000 gallons per hour for all other sewage. Actually, the mill sewage is by no means uniform in flow, the greatest discharge generally taking place just before noon and just previous to the close of the day. It is by no means inconceivable, therefore, that at times the Valley street sewer is overloaded. A natural consequence would be overflow at Eagle street, as noted. The pollution at Eagle street was brought to the attention of the city engineer, who stated that the overflow at Eagle street is controlled by a gate, and that this gate is opened when it becomes imperative to relieve the flow in the Valley street sewer when repairs are being made upon some part of the system below. This explanation would account for the conditions found only in case of a defective gate. If so, repairs to the gate are certainly needed. In either case the matter is one that should receive attention from the city sewer department. If the sewers are in reality already overtaxed, the question is a serious one. Further extensions of the sewerage system in the Woonasquatucket valley, to reach the Merino, Dyerville, and Manton villages, will naturally drain into the Valley street sewer, and pollution by storm overflows will inevitably increase unless the least objectionable mill wastes are thrown into stream direct or additional intercepting sewers are constructed.

It should be remembered that in the original plans* for the new Providence sewerage system, only 2,088,000 gallons of mill wastes were estimated as flowing into the Woonasquatucket. This estimate, while probably correct for 1884, is absurdly low for present conditions, and it may be true that an enormous increase in quantity of manufacturing wastes from the Olneyville district in the last twenty years is chiefly responsible for the overflow at Eagle street.

About 100 yards below Eagle street is a tile drain carrying sewage from the collection of small mills at Eagle street and Kinsley avenue. A short distance below this, at Sims avenue, a city sewer discharges. Still further down, a tile drain from Norcross Bros. stone works discharges about 20,000 gallons daily of a very turbid yellowish liquid. Analysis of this liquid from the composite of two samples taken in the morning and in

* Providence City Document No. 25, 1883, page XI.

the afternoon shows in milligrams per liter: Total solids, 8,192; loss-on-ignition, 134; solids in solution, 122; loss-on-ignition of solids in solution, 46; total iron, 100; iron in solution, 0.08; alkalinity, 850; alkalinity of filtered portion, 68. The water is used in connection with the cutting, grinding, and polishing of marble and other stones, and produces a suspended mineral pollution. The suspended matter is coarse and heavy. It settles out rapidly on standing, leaving a clear supernatant. Although the pollution produced is not objectionable from a purely sanitary viewpoint, it is undesirable, rendering the stream unsightly for a considerable distance and depositing some 1,300 pounds of matter upon the bed and banks of the river every day.

A storm sewer enters the stream from the north, nearly opposite the Norcross drain.

Station 13 is located a short distance below the Norcross Bros. drain, the samples being taken from the bridge leading to the American Locomotive Motor Car works. Comparison of the analyses at stations 12 and 13 will show the effect upon the stream of the polluting liquors which enter in the quarter-mile below Eagle street. Unfortunately the samples taken on June 18, 1907, are alone available for comparison. These show slightly worse conditions at the lower station in the early morning. The average condition for the day shows an increase from station 12 to station 13 of 44 per cent. in oxygen consumed, 108 per cent. in organic nitrogen, 45 per cent. in alkalinity, 50 per cent. in turbidity, 53 per cent. in total solids, 32 per cent. in loss on ignition, 182 per cent. in suspended solids, and 260 per cent. in number of bacteria. This is by no means a pollution to be neglected. The figures probably overestimate the increase of pollution between stations 12 and 13, imperfect mixing of wastes with stream water tending to reduce the figures for station 12.

Station 14, the upper side of Acorn street bridge, is about 150 yards below station 13. Between these points several drains enter on the north from the American Locomotive works, the chief discharge being condenser water. A tile drain also discharges from the south, just below the railroad track

leading to the locomotive works. No great change in the water is noticeable between these stations. The increase in iron may be due to any one of three causes: (1) a more thorough mixing of the water from Norcross Bros. drain; (2) discharge of iron-bearing water from some of the drains above mentioned; or (3) contamination from the drain of the Nicholson File Co., which enters near station 14. The last-named cause is the most probable one, and it will be assumed that the increase in iron between stations 13 and 15 is due to the discharge from the Nicholson File Co. drain.

Station 15 is a footbridge over the steam about a third of a mile below Acorn street. Just above Acorn street the main drain from the Nicholson File Co. enters from the south. This drain carries condenser water, 240,000 gallons daily, and water from grindstones, 120,000 gallons daily, making a total of 360,000 gallons in ten hours. A composite of two samples (morning and afternoon) taken from this drain in May, 1907, gave the following analysis in parts per million: Iron, 440; total solids, 1,846; loss on ignition, 84. A filtered portion showed: Iron, 1.3; total solids, 118; loss on ignition, 38.

A composite of ten hourly samples on June 18, 1907, gave the following analysis: Turbidity, 450; iron, 136; alkalinity, 56; total solids, 990; loss on ignition, 76. The filtered sample showed 126 parts of total solids and 28 parts of loss on ignition. The liquor is reddish-brown in appearance, discolors the stream and its banks for several hundred yards, and has an oily odor. Much of the suspended matter subsides rapidly, and after sixteen hours' sedimentation the supernatant is clear.

Using the last analysis as the best basis for conservative estimates, we find that the discharge here contains in suspension 400 pounds per day of iron and 2,130 pounds per day of other mineral matter (undoubtedly powdered standstone, since this is the material of which the grindstones are composed). The first analysis presented indicates a daily discharge of 1,300 pounds of iron and 3,700 pounds of other suspended matter.

In the south abutment of the Acorn street bridge is the outlet of a combined city sewer which carries, among other wastes, the sewage of the 900 employees of the Nicholson File Co. and

the waste pickling-liquor (one to two hundred gallons of weak sulphuric acid and iron sulphate) from that establishment. Upon the north side of the stream at Acorn street is the outlet of a small storm sewer which drains Hemlock street. A few yards below is a large storm sewer which carries the flow of the small stream passing through Davis Park and storm sewage from Valley and Orms streets. A few yards further down stream is a storm overflow from the large Valley street intercepting sewer, which from this point follows the Woonasquatucket, being laid under Promenade street. Unlike the overflow at Eagle street, this channel carries no flow in dry weather.

Comparing the analyses at station 14 with those at station 15, we find that in the early morning the results are higher at the lower station. These samples were taken a short time before low tide, and the increase noted is probably due to a lack of removal of the previous day's pollution rather than to pollution entering on the day the samples were collected. The composite samples, covering a period of twelve hours, include all stages of the tide. Fortunately, on June 18, a wind down stream reduced the tidal flow greatly. To eliminate this influence still further, the samples on that date were taken close to the surface.

Examining the composite samples, we find a substantial reduction in organic pollution, but an increase in iron content at the lower station. The cause for this is easily apparent, for the chief addition to the stream between these stations is the waste water from the Nicholson File works. Evidently the comparatively heavy mineral solids, in subsiding, carry down with them much organic matter. The precipitating effect of the pickling-liquor may also be a factor.

Between station 15 and Gaspee street (station 16) are a number of storm sewers and a few combined sewers on both sides of the stream. On the south side the Merchants' Freezing & Cold Storage Co. has a condenser water drain. On the north side are the Laureldale Chemical Works, Brown & Sharpe Mfg. Co., and the Wm. A. Harris Engine Co. All of these have drains entering the river, but the flows from them are largely, if not entirely, condenser water. Changes in the character of

the water as shown in the analyses at stations 15 and 16 cannot well be assigned to any one cause. High solids, chlorine, and sulphates are due to the tidal influence, and other changes are not very marked.

A short distance below Gaspee street, after receiving the flow of about half a dozen storm sewers or overflows, the Woonasquatucket unites with the Moshassuck to form Providence river.

Summing up the results upon the section of the stream below Atwell's avenue, we find a serious mill pollution at and near Eagle street and mineral pollution by Norcross Bros. and Nicholson File Co. to be the matters most worthy of special attention. Remedial measures for the mill and sewage pollution are already, in a sense, under way. Plans have been prepared for an intercepting sewer in Kinsley avenue, following the south bank of the stream from a point near Gaspee street to Eagle street, and thence in the bed of the river to Atwell's avenue. This sewer is intended to divert all mill wastes and sewage from the Woonasquatucket below Atwell's avenue.

There seems to be no valid reason why such mineral wastes as those of Norcross Bros. and Nicholson File Co. should be discharged into a sewer where the sedimentation of heavy suspended matter would be sure to cause trouble. The simplest means will purify these wastes so that they will be suitable to enter the stream. At Norcross Bros.' establishment a sedimentation basin with a few hours' period will suffice. At Nicholson File works, separation of condenser water from grindstone water and sedimentation of the latter for about twelve hours will accomplish satisfactory results. If desired, over 60 per cent. of the iron in the grindstone water may be recovered by passage through a simple form of magnetic separator.

Oil in condenser water makes the Woonasquatucket more or less unsightly throughout its entire length below Greystone. More careful trapping of this oil would be highly desirable.

FLOW OF WOONASQUATUCKET RIVER.

The Woonasquatucket flow is very irregular, and to a considerable extent under control. Near its headwaters, Waterman, Slack, and Sprague reservoirs, shallow ponds of considerable area, are used to store a part of the flood water, this being allowed to escape in time of lowest flow in order to give a more uniform supply to the mills. In addition, nearly every mill has its own small reservoir formed by damming the stream, in which during the dry season water is collected at night for use during the following day. The largest of these reservoirs are at Georgiaville and Lymansville, where the ponds are a mile in length.

At Lymansville, just above the Providence city line, the flow varies between a maximum of about 100 second feet and a dry-season minimum of about 10 second feet. The average flow is probably not far from 50 second feet. These figures are significant in connection with the quantities of water taken from the stream and discharged into the sewers in the Olneyville district. It sometimes happens for a few weeks in midsummer that the stream bed is dry at Atwell's avenue. At such times the effect of pollution is much greater than the figures in this report indicate, and mill men on the lower portion of the stream make vigorous complaint against the condition of the water. The autumn samples were taken during a 10 to 15 second foot flow at Atwell's avenue, while the samples of the spring of 1907 were taken at higher stage.

It will be seen, therefore, on rare occasions the Woonasquatucket below Atwell's avenue contains practically no flow except undiluted factory wastes. If, as is now contemplated, these wastes are diverted to the sewer, there may be times when the stream bed, at low tide, may be dry for a considerable distance. This condition may be obviated by a project, promoted by some of the manufacturers, to construct such a large reservoir above Stillwater that a much greater flow can always be maintained in the dry season. This project should receive the hearty support of all interested in the sanitary condition of the stream.