Preliminary reports on the disposal of New York's sewage.

NEW YORK CITY

METROPOLITAN SEWERAGE COMMISSION.

Preliminary reports on the disposal of New York's sewage.
Nos 1, 4, 5, 6 & 7.

REPORT OF THE COMMISSION INTRODUCING THE REPORTS OF MESSRS. FOWLER AND WATSON.

Honorable WILLIAM J. GAYNOR, Mayor of the City of New York:

SIR:—The reports here published represent critical studies by eminent experts who were called upon by the Metropolitan Sewerage Commission in the autumn of 1912, to examine various projects which the commission was considering for the protection of the Harlem and Lower East rivers against excessive pollution by sewage.

Preliminary plans had been prepared by this commission for the disposal of the sewage tributary to these bodies of water, but owing to the radical character of the remedies which seemed to be necessary, and the large sums of money involved, this commission considered it desirable to subject the projects to competent and unprejudiced criticism.

Messrs. Fowler and Watson were requested to come to New York and study the data which had been collected by this commission, remain long enough to become personally acquainted with the situation and to weigh the relative merits of the alternative plans which had been made to improve the situation. The two experts came to America separately and made their studies independently of one another, although, while still in New York and, later, in England, they met and exchanged opinions.

Dr. Gilbert J. Fowler, who came first, is a chemist. He is a Doctor of Science, Fellow of the Institute of Chemistry, Fellow of the Royal Sanitary Institute of Great Britain and author of numerous reports, papers and contributions to the science and art of sewage purification. The sewage disposal works of Manchester, England, of which he is superintendent, have been developed under his direction until they constitute the largest plant of their kind in the world. These works include screens, settling basins, contact beds, sludge storage reservoirs and steam vessels for transporting the sludge to the open sea.

Mr. John D. Watson, who is a Member of the Institute of Civil Engineers of Great Britain and a Fellow of the Royal Sanitary Institute, is an eminent consulting engineer and expert in sewage disposal. He is in charge of the sewage purification works for Birmingham which are as large and efficient as any of their kind. Originally consisting of farm lands, where the sewage was taken for disposal in the hope of utilizing its manurial properties, these works have been rebuilt by Mr. Watson in accordance with modern scientific principles and

include settling basins, sludge-digesting tanks, supplementary settling basins, percolating filters, screens and sludge-drying beds.

These two reports, which are of similar scope, therefor approach the subject from the separate standpoints of the chemist and the engineer. Each recognizes the necessity of stopping the existing pollution and improving the harbor without loss of time and critically discusses the nature and extent of the works which will be required. In each report the conclusion is reached that a large part of the sewage which is tributary to the Lower East river and Harlem should be collected in large sewers to be constructed near the water front and carried by tunnel to an island to be constructed in the sea at the mouth of the harbor, there to be discharged after enough of the impurities have been removed to insure that no nuisance or injury to health will result. This project was reported upon by the Metropolitan Sewerage Commission under date of January, 1913.

The standard of cleanness proposed by this commission in its report of August, 1912, is approved by Dr. Fowler and Mr. Watson as a code of minimum requirements. Mr. Watson, like some other sanitary experts who have been called upon to advise in regard to this standard, would have the harbor waters kept cleaner than the commission's requirements demand. Dr. Fowler discusses the present pollution in considerable detail and gives much attention to the need of cleanness with respect to these waters. Both experts lay emphasis upon the fact that the pollution has reached large proportions and is rapidly increasing.

The opinion is expressed by both that if the digestive capacity of the harbor for sewage is not to become overloaded to the point of nuisance, it will be necessary to carry a large part of the sewage away for disposal, it being beyond the range of practicability to purify it near where it is produced.

It is pointed out that sewage works which are capable of effecting a high degree of purification are so likely to produce odors and nuisance from flies that it is desirable to avoid the construction of such works within the city limits as far as possible. For this reason only such comparatively crude and simple processes as employ settling tanks, grit chambers and screens should be considered for installation on the shores of Manhattan Island and Brooklyn. There is no land anywhere within the limits of Greater New York upon which it would be permissible to construct works capable of purifying the sewage tributary to the Lower East river and Harlem by percolating filters, such as Mr. Watson employs at Birmingham, or contact beds like Dr. Fowler uses at Manchester, because of the nuisance which would result.

After discussing other alternatives, Messrs. Fowler and Watson arrive at

the conclusion that the proper solution of the problem is this commission's proposal to carry the sewage which is naturally tributary to the Lower East river, and eventually that which is tributary to the Harlem, to an island to be built at sea. On this island the sewage would be passed through settling basins and perhaps treated with electrolyzed sea water, in accordance with a method with which the Metropolitan Sewerage Commission has made some experiments. The effluent from the island should be discharged in such a way as to cause the organic matters present to be thoroughly mixed with large quantities of fresh sea water and, consequently, oxidized and rendered permanently harmless and inert by natural agencies.

Neither Dr. Fowler nor Mr. Watson has been dissuaded from endorsing this project on account of its cost. Their opinion is that the money for such sewage works as are necessary for the health, welfare and reputation of the port will be forthcoming, when once their necessity is understood. It is pointed out that other cities, and among them many small places, have spent much more per capita for sewage disposal than would be required here.

Mr. Watson has given considerable attention to the form of administration which is most suited for the construction and maintenance of the necessary main sewers and sewage disposal works and his experience as Chief Engineer of the Birmingham, Tame and Rea District Drainage Board, which represents a number of municipalities in addition to Birmingham, gives him special qualifications to deal with this subject. He recommends that a commission be created which shall have charge of the building and maintenance of such sewage disposal works as are necessary for New York and in this suggestion, Dr. Fowler, with a knowledge of the details of the recommendation, concurs.

The reports of Messrs. Fowler and Watson contain so much that is of value from scientific and practical standpoints and their statements seem so capable of aiding the public to understand New York's large and complicated problem of sewage disposal that their two reports are herewith published in full.

Respectfully submitted,

METROPOLITAN SEWERAGE COMMISSION OF NEW YORK,

GEORGE A. SOPER, President;
JAMES H. FUERTES, Secretary;
H. DE B. PARSONS,
CHARLES SOOYSMITH,
LINSLY R. WILLIAMS.

February, 1913.

REPORTS OF THE METROPOLITAN SEWERAGE COMMISSION.

1. Digest of Data Collected Before the Year 1908 Relating to the Sanitary Condition of New York Harbor; 87 pages; 1909;
2. Report on the Discharge of Sewage from the Proposed Passaic Valley Sewer of New Jersey; 7 pages; May 23, 1910;
3. Report on the Proposed Discharge of Sewage from the Bronx Valley Sewer; 10 pages; July 25, 1910;
4. Sewerage and Sewage Disposal in the Metropolitan District of New York and New Jersey; 550 pages; April 30, 1910;
5. Present Sanitary Condition of New York Harbor and the Degree of Cleanness which is Necessary and Sufficient for the Water; 457 pages; August, 1912;

Preliminary Reports on the Disposal of New York's Sewage:

6. I. Study of the Collection of the Sewage of New York City to a Central Point for Disposal; 16 pages; September, 1911;
7. II. Description of the Four Principal Drainage Divisions in that Part of the Metropolitan Sewerage District which Lies in New York State; 11 pages; November, 1911;
8. III. Study of the Collection and Disposal of the Sewage of the Jamaica Bay Division; 10 pages; November, 1911;
9. IV. Study of the Collection and Disposal of the Sewage of the Upper East River and Harlem Division; 17 pages; July, 1912;
10. V. Study of the Collection and Disposal of the Sewage of the Richmond Division; 21 pages; September, 1912;
11. VI. Study of the Collection and Disposal of the Sewage of the Lower Hudson, Lower East River and Bay Division; 58 pages; January, 1913;
12. VII. Critical Reports of Dr. Gilbert J. Fowler of Manchester, England, and Mr. John D. Watson of Birmingham, England, on the Projects of the Metropolitan Sewerage Commission with Special Reference to the Plans Proposed for the Lower Hudson, Lower East River and Bay Division; 33 pages; February, 1913.

REPORT OF

GILBERT J. FOWLER, D. Sc.

To the President and Members of the Metropolitan Sewerage Commission of New York:

Gentlemen:

In accordance with the request of the Metropolitan Sewerage Commission, conveyed to me by the President, Dr. George A. Soper, in a letter dated September 27th, 1912, I arrived in New York on the 10th November, 1912, and remained, with brief absences in Boston, till Wednesday the 27th November.

During this time the following inspections were made:

By water: 1. Upper bay,
2. East river to Long Island sound,
3. Round Manhattan Island,
4. Through the Narrows to Far Rockaway and into Jamaica bay.

By land: 5. To Gravesend bay, Coney Island, Sheepshead bay and Canarsie, visiting disposal works at Sheepshead bay, Paerdegat basin and 26th Ward;
6. To Newtown creek, returning to Manhattan, recrossing the Lower East river below Hell Gate and skirting the edge of the Upper East river including Steinway, Flushing bay, Whitestone and Douglaston.

I also visited Boston, and through the courtesy of the Massachusetts Board of Health, was able to inspect the three types of sea outfall there. The same day I visited the Lawrence experimental station and discussed the work being done with the chief chemist. On these various expeditions numerous photos were taken of important points such as some of the larger sewer outlets, proposed places of discharge &c.

A good deal of time was spent in the laboratory of the commission overlooking and discussing experiments on the possibilities of electrolysed sea water as a precipitating and sterilising agent for the sewage. I also had much conversation and discussion with reference to the data accumulated by the commission and was shown numerous data hitherto unpublished, especially in reference to the possibilities of complete nitrification taking place in mixtures of sea water and fresh water.

The President was good enough to demonstrate for me the method used by the commission in their fundamentally important work on the dissolved oxygen in New York harbor. The method is rapid and accurate and well suited to the conditions of investigation. I have carefully studied both before and since my visit to New York the extensive and valuable reports issued by the commission as well as the report by Major Black and Prof. Phelps.

Immediate Conclusions.

I was impressed at the outset by the vastness and complexity of the problem to be dealt with. London may have a larger present population but the conditions for discharge are infinitely simpler.

In addition to the rapidly increasing population directly or indirectly discharging its sewage into the harbor, the problem is complicated by the outstanding facts, viz:—(1) the growing scarcity and value of unbuilt upon land in the vicinity of the harbor, (2) the comparatively small amount of water available for flushing out the bay, this being limited practically to the flow of the Hudson. The thickly populated districts abutting on the Harlem river and the Lower East river discharge into waters which ebb and flow with the tide, but suffer very little actual change, little or no excess water passing out of the bay or into it at each tide.

As a consequence, the conditions to be met with in the Harlem and Lower East rivers call for immediate action. Not only is the bottom polluted, but the water, even in favorably situated portions of these rivers, is deficient in oxygen, in the majority of cases to nearly 50 per cent. In many places there are local nuisances already, and floating fæcal matter, paper, &c., are in frequent evidence. What the conditions are likely to be when the surrounding districts, increasing as they are now doing, to say the population of 1940, it is not pleasant to conjecture. It is evident that something will have to be done here and done at once. When the volume of sewage to be dealt with, over 350 million gallons per day at the present time, and more than 700 million gallons by 1940, is considered it is evident that for this section of the work alone considerable expenditure will have to be faced.*

In view of the very large expenditure involved, it is difficult to exaggerate the importance of adequate preliminary studies and the work of the commission throughout appears to me to be a model of the way in which such investigations should be carried out. The conditions are so complicated, owing to the diversi-

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*Report Metropolitan Sewerage Commission of New York, August, 1912, p. 28.

fied character of the land and water areas constituting New York harbor and its surroundings, that endeavors to reproduce them artificially, as is often done in research work, are likely to be only partially successful. The method of thoroughly studying the actual state of things obtaining in the bay and other waters in the vicinity under all conditions of season, tide and weather, as has been done by the commission, seems the only possible one, and the work has been done with masterly completeness. No question necessary for the formation of a right judgment on the questions which should be settled at this time appears to have been left unstudied by the commission.

The citizens of New York may rest assured that the large sum of money they will be called upon to pay for the protection of their harbor will not be asked for except as the result of opinions formed after years of study much more complete than is generally given to such a subject. Every year, however, the conditions now existing must necessarily grow worse and, while in the case of a growing science like that of sewage disposal it is well to hasten slowly, yet through the labors of the commission there will exist no justification on the score of imperfectly known data for postponing certain most necessary works.

Principles Governing Consideration of the Problem.

The conditions which must be realized if the constituents of sewage are to be rendered inoffensive or finally mineralised are essentially the same whether the disposal be by irrigation upon land, filtration through artificial biological filters, or dilution with fresh or salt water. The process is in all cases one of oxidation, *i. e.,* practically speaking, combustion, and if it is to be conducted without nuisance, enough oxygen must be present at all stages of the process to prevent the formation of evil smelling products.

It is perfectly legitimate to use the oxygen dissolved either in sea or river water in order to oxidise sewage. Under proper conditions of discharge, complete transformation and mineralisation of the sewage matters can be effected in this way with less nuisance than often accompanies treatment on filters or on land.

The question of the margin of safety which should be allowed if nuisance is to be avoided has been the subject of reports by a number of well-known experts to the Metropolitan Sewage Commission* and all of these reports agreed that under no circumstances should the dissolved oxygen in the harbor be allowed to sink to below 50 per cent. of saturation. In this opinion I concur. It

*Report Metropolitan Sewerage Commission of New York, August, 1912, pp. 69-164.

will, however, be most unwise to be content with a margin simply sufficient to barely eliminate nuisance.

Two main considerations govern the situation from the point of view of public policy; these may be described as considerations of *Health* and *Welfare*.

Health.—There are obvious ways in which public health may be directly affected by the filthy conditions of parts of the harbor or even by the apparently innocuous discharge of sewage or sewage effluent.

It is not a pleasant sight to see numbers of floating fæces washing in and about piers where food supplies are landed from lighters some of which have a low free board. Gulls and flies may also quite possibly be carriers of infectious material under such conditions.

The question of oysters is of more direct importance. Even if sewage or sewage effluent is actually sterilised, the growth of oysters near an outfall is always a possible source of danger, and while it is quite easy to exaggerate this, yet it can never be in accordance with right sanitation for an article of food to be thus contaminated.

The pollution of bathing sites has been dealt with at length by the commission.* The conditions which at present exist are unsatisfactory in the extreme.

The carrying of polluted driftwood daily into the homes of the poor in the neighborhood of the water front does not tend to raise the standard of cleanliness in such homes and should be prevented rather by stopping pollution than by forbidding what is in itself a reasonable and thrifty proceeding.

But even more important than the direct and obvious ways in which the public health is affected by the polluted condition of the harbor waters, is the practically unconscious lowering of that sense of decency and cleanliness of living which must be maintained if the efforts of social reformers are to have any serious result.

Crowds of people from the poorer quarters of New York throng the recreation piers and pleasure drives on the water front. If it is obvious to them that those in authority, who have the power, are yet unconcerned to abate uncleanly surroundings, the already not inconsiderable effort required to maintain a decent spot of home life in a mean environment, will be rendered even harder to achieve.

Welfare.—The second consideration, viz., that of *welfare,* as it has been termed, is perhaps less obvious, but is most important when expensive works, the use of which is partly for future generations, have to be considered.

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*Report Metropolitan Sewerage Commission of New York, April 30, 1910, pp. 486-497.

A study of the history of sanitation, such for example, as was possible in the historical section at the International Hygiene Exhibition in Dresden in 1911, will show that, up to comparatively recent times, conditions were tolerated which to us would seem unspeakable. Yet even now the standard of requirement is constantly rising. One may, indeed, frankly say that the modern American bathroom both in its fittings and the frequency with which it is to be found is a distinct advance upon what is common even in England. Such a bathroom, however, increases the difficulty of the sewage problem, and in looking forward to the future, similar advances in public requirements must always be reckoned with. The idealism manifested in such great buildings as the Pennsylvania Railroad station and the Metropolitan Museum of Art and the parks and playgrounds of the city will find its further development in a demand for brightness and beauty in the surrounding water spaces. Nor is such idealism unrelated to more purely economic prosperity. The true solution of any problem is true at all points, sanitary, aesthetic, ethical and economic.

Apart from the question of affecting the vitality, and consequent wage earning capacity of the people, the reputation of a port is a very essential factor in its commercial prosperity. The condition of the Clyde and of the Manchester ship canal was for many years a bye-word. The great sewerage and sewage disposal works at Glasgow carried out at a total cost of over £2,000,000 for 800,000 people have been the means of rehabilitating the reputation of the Clyde and adding to the amenities of life, pleasure trips being now possible from the Bromielaw to the Firth of Clyde.

The large amount of money spent on sewage works in the watershed of the Mersey and Irwell is, apart from the increasing expenditure of Manchester itself, slowly but steadily improving the water of the Manchester ship canal.

At one time the stench from the polluted Thames in hot weather rendered the committee rooms in the houses of parliament in London uninhabitable. By the removal of the sewage to treatment works and outfalls lower down the river this nuisance has been abolished, and London is now one of the healthiest and best drained cities in the world.

In the case of the three cities above referred to, their works were carried out under urgent pressure of obvious and almost intolerable nuisances from the polluted streams. New York should deal with her problem before such acute conditions arise.

The foregoing general view of the situation clearly indicates that any scheme which is decided upon must not block the commercial avenues of the future. It must be so designed as to be capable of expansion as the needs of the city increase.

Possible Methods of Dealing with Sewage.—The various possible methods which are available for dealing with sewage on the large scale may be broadly divided into:—

1.—Direct discharge into water,
2.—Discharge after screening,
3.— " " sedimentation.
4.— " " chemical treatment,
5.— " " filtration in some form,
6.— " " combination of processes.

The proportional amount of impurities removed by these processes depends on numerous factors, *e. g.* the freshness and strength of the sewage. Thus, screening will remove a much greater proportional amount from very fresh sewage than from sewage which has been mixed and churned up for many miles in a trunk sewer. Chemical treatment is more economical with strong sewage than with weak, and therefore is of less advantage with American sewage than with European.

Very roughly, it may perhaps be assumed that under the conditions existing in New York, of the nuisance-producing solid material in sewage capable of producing deposits of sludge, the following percentages can be removed by the respective processes:—

Screening and grit chambers.....	3-6 per cent.,
Short sedimentation	50 "
Chemical treatment	75 "

None of these processes seriously affects matters in solution. Filtration affects not only the finely divided colloidal matter still present after the foregoing processes but also oxidises substances in solution.

Which of these methods can be used at any of the various proposed points of outfall in New York harbor is to be determined by local conditions. What these conditions are is considered in the next section.

The Present Polluted Condition of the Harbor.

Broadly, the waters of that part of New York harbor which lies in New York State may be considered separately as follows:—

The Hudson river,
The Upper bay,
The East river and the Harlem river,
Jamaica bay.

Of these, the Hudson river contains the most dissolved oxygen, this amounting to over 90 per cent. of saturation in the centre of the river in the northern part of Manhattan and diminishing to 60 per cent. near the Battery. The Hudson river supplies practically the only water available for flushing the harbor. All along the edge of the Hudson among the piers objectionable conditions exist.

The Upper Bay.—All the pollutions from the waters entering the harbor at certain states of the tide, as well as those resulting from direct sewer discharges are mixed by tidal currents in the Upper bay and a proportion of the solid matters is doubtless deposited there during the ebb and flow of the tide. This is evidenced by the polluted character of the dredgings from the bottom of the Upper bay at nearly every point of observation. Considerable deposit of sludge has been found south of Governor's Island.

The general appearance of the waters of the Upper bay is by no means attractive. Large fields of sleek, or oily film, are frequent and, more objectionable, are masses of floating debris in which large quantities of faecal matter are often entangled. The Gowanus canal is little better than an open sewer, there being an insufficient circulation of water to dilute the large volumes of sewage discharged into it.

The East River and the Harlem River.—It is on these rivers, especially in the Lower East river and the Harlem that, as already stated, conditions exist which call for urgent remedy.

Large sewers discharge from the thickly populated districts on both sides of these waterways and there is little or no net tidal discharge. As a result, the bottom of the upper East river as far as Throg's Neck at the entrance to Long Island Sound is foul, and in the Lower East river, in places unaffected by the ebb and flow of the tidal currents, foul deposits occur.

In the Lower East river from the Williamsburg Bridge to Hell Gate the dissolved oxygen present, especialy in the summer months is not much more than 50 per cent. of saturation.* In some parts of the Harlem river it is less than this. There are portions of the Harlem river already approaching the condition of the Manchester ship canal, while Newtown creek has practically reached that condition. In the vicinity of Wallabout basin there is a large sewer outlet which produces a small lake of sewage in its vicinity, which is most objectionable.

There is no doubt that if the sewage which now enters crude into the Lower East river and the Harlem river could be taken up and dealt with in a

* In the summer of 1912 some samples of water from the Lower East river, near the Brooklyn Bridge, were found to contain 43 per cent. of oxygen.

satisfactory manner, very great benefit would accrue not only to these waterways but also to the Upper bay and Upper East river into which much of the sewage eventually finds its way.

Jamaica Bay.—The characteristic feature of Jamaica bay and its vicinity is the growing summer population of numerous pleasure resorts, such as Bergen Beach, Arverne, Edgemere, Canarsie and Rockaway. The conditions which I saw in November were, therefore, hardly typical. Effluents from treatment works at Sheepshead bay and the 26th Ward, though obviously imperfectly purified were not the cause of serious visible pollution.

In view of the increasing population and of the schemes of harbor development which are being considered, it will be necessary before very long comprehensively to deal with the sewage which at present discharges into the bay.

The question of oyster pollution must here, also, be dealt with and it should be clearly understood that ordinary methods of treating sewage give little protection from a bacteriological point of view, while processes of sterilization may easily produce a false sense of security. It would seem best for oysters not to be taken near densely populated centres, as under such circumstances the chances of pollution, apart from the sewage which is discharged from actual sewage outfalls are considerable.

Proposed Remedies.

Sewage Tributary to the Lower East River and Harlem River.—As already emphasized, the first point of attack in dealing with the problem of purification of New York harbor is the Lower East river and the Harlem river, and I have given my most careful consideration to this part of the commission's work.

After much study the commission have concluded, and I think rightly, that the only point where large quantities of sewage can be treated in this neighborhood is at Ward's Island. It is possible to pick up the sewage which at present discharges into the Harlem river and also that which is turned out of the large sewer at Hunt's Point and bring it all to Ward's Island where it can be treated in settling tanks and the heavier sludge removed.

Some 124 million gallons daily would be thus dealt with at once, and over 400 million by 1940,* and would be discharged into the swift tidal currents at Hell Gate where the best possible conditions exist for mixing.

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* Preliminary Report IV, of the Metropolitan Sewerage Commission on the Disposal of New York's Sewage, July, 1912.

Sedimentation, however, leaves a large proportion of potential solids still present as well as all the impurities in solution. Treatment by chemicals instead of by plain sedimentation would remove a further proportion of the suspended impurities, but the treatment in this way of such large volumes of sewage as may be taken there involves numerous difficulties and greatly increased cost, which would weigh heavily against the advantages obtained. Further purification, by filtration, at Ward's Island is impracticable, and also not to be recommended so near large centres of population owing to the possibilities of aerial nuisance and fly trouble on large areas of filters.

It becomes matter, therefore, for careful consideration how far the concentration of the sewage to one point and discharge into the local waters after elimination of the grosser solids would really relieve the situation. It is to this point that most careful thought has been given and the bearing of all the available data studied under every aspect.

Owing to the fact that the waters rushing through Hell Gate only pass back and forth with the tide and do not really get away to the ocean, it is evident that whatever sewage is discharged at Hell Gate is largely dependent for its oxidation on the oxygen in the water with which it mixes in one tide. The Lower East river is, however, highly polluted and the discharged effluent will therefore not get much help from it. The situation, in fact, is only improved by the elimination of the grosser solids from the sewage of the Harlem district. If the situation is to be radically improved, the conclusion seems inevitable that some sewage must be removed from the Lower East river.

From figures supplied me by the commission, I calculate that if the sewage of the Harlem territory is collected and passed through settlement tanks on Ward's Island, and if the sewage of those parts of Brooklyn and Queens which would ordinarily discharge into the Lower East river be removed altogether, there will then be a dilution representing 1 of raw sewage to 200 of water in the Lower East river at mean low tide.

This is a considerable improvement on present conditions, representing a removal from the Harlem and Upper and Lower East rivers, together with about 50 per cent. of the total sewage which at present pollutes them.

It is, however, from the Manhattan waterfront that the greatest proportional volume of sewage enters the Lower East river. It exceeds the volume discharged into this division of the harbor from Brooklyn and Queens by about 50 per cent. The further conclusion, therefore, is forced upon one that a really satisfactory solution of the problem must involve the removal of this sewage also. Indeed a study of the statistics show that if this is not done, the Lower East river in 1940, will revert to a condition even worse than exists to-day.

Disposal at Sea of that Part of the Sewage of Brooklyn, Queens and Manhattan Which Would Ordinarily Discharge into the Lower East River.—The conditions discussed in the foregoing section show clearly that the sewage from these districts will have to be removed from the Lower East river if the situation is to be properly dealt with.

From the researches of the commission there would appear to be three possible outlets for this sewage.

The first possibility is to take it to Barren Island and there treat it in tanks, followed, possibly, by some form of filtration and discharge it near the entrance to Jamaica bay. At the same point would be collected the sewage now very imperfectly dealt with at the various sewage works discharging into the creeks on the northern shore of Jamaica bay. The point of outlet would be at the entrance to Jamaica bay.

Barren Island itself is, however, little more than half a mile from the large summer population on the Rockaway peninsula, and if, as is not at all improbable in hot summer weather, some amount of smell should arise from the filters, it is not far enough away to prevent a nuisance to these people. Moreover, the point at which the effluent would discharge is not half a mile from thronged bathing beaches. There are therefore these grave objections to an outlet near Barren Island.

A second alternative proposition has been considered, viz:—the removal of the sewage to the west side of Staten Island, with the erection of purification works there. Apart from engineering difficulties which I am informed exist in carrying so much sewage across the very deep channel of the Narrows, the conditions of final discharge would render purification by biologcial filters necessary, and similar objections would again arise in regard to nuisance from these as have been pointed out in regard to the Barren Island project.

Under these circumstances a third alternative has been suggested which seems to me to have much to recommend it. This proposition is to build an artificial island well out in the Atlantic, nearly three miles from the shore of Coney Island, and there construct settling tanks, and discharge the effluent after settlement of the bulk of the suspended solids, into deep water, with proper engineering precautions to ensure thorough mixing of the effluent with the sea-water.

After inspection of the Boston sea outfalls I am clearly of the opinion that no point of outlet should be less than 40 feet in depth, and that the discharge should be continuous so as to minimize the quantity sent out in any interval of time.

The sludge deposited in the tanks could be readily taken well out to sea in

tank steamers of the pattern used in Europe, as at Glasgow, Manchester, Salford and London.

I understand that the island can be made without difficulty from the spoil and debris from excavations in New York city at present taken out to sea, or from sand pumped from the bottom of the sea. I understand, also, that it will be possible to increase the number and length of the outfall pipes as more and more sewage is coupled up to the island, so that the effluent will always be well distributed in the sea water. The operations can be carried on without causing nuisance to any one, the conditions for sea disposal of sludge in tank steamers are very simple. The scheme is capable of indefinite expansion as more sewage is taken up, as the size of the island itself can be increased as extensions to the works are required.

Many matters rather of detail remain for further consideration in regard to the methods of treatment employed both at what may be termed "Atlantic" Island and Ward's Island. The design of the settlement tanks to be employed is a question of importance. A form of tank is to be preferred which would expose as little water surface as possible and also allow automatic removal of the sludge by the pressure of the supernatant water. A modified form of two-story tank would seem well suited to this purpose.

The sludge produced by the thorough fermentation which takes place in the so-called Emscher tanks, while greatly reduced in bulk and offensiveness, would offer some difficulties in carrying to sea, owing to its being saturated with gas. It is possible that judicious admixture with salt water would obviate this difficulty. In any event the disposal of sludge is not the least difficult part of the problem. There will not be more, for a long time at any rate, than is at present handled at the London outfalls, and the conditions of sea disposal are simpler in the case of New York.

For reasons indicated when referring to works on Ward's Island, I do not recommend treatment by chemical precipitants. I think, however, that very careful study deserves to be given to the practicability of adding a small dose of chlorine to the effluent, *e. g.*, by the addition of a certain volume of electrolysed sea-water. This would serve the double purpose of deodorising what may be a somewhat malodorous effluent after its long travel through the sewers, and a further important advantage would lie in preventing an immediate call upon the dissolved oxygen in the sea at the point of discharge, and thus giving time for more thorough mixing and aeration to take place.

Some Further Problems.—There are many matters of importance, subsidiary to the large scheme outlined above which call for brief mention.

A system of screens and catchpits has been designed for Manhattan Island, which could afterwards be used for screening storm water, overflowing from the main sewers later to be built. It is in my view important that this should be carried out, in order that even after large sums have been spent on main sewers and outfall works, there should not be public disappointment, when visible pollution is seen to be present after every shower of rain. Before such refuse is removed, however, means must be at hand for its rapid incineration in suitably placed destructors.

The scheme of outfalls and outfall works designed by the commission for the districts abutting on the Upper East river seems to me to be adequate, at any rate, for many years. The outlets are all in deep water and the conditions resemble those of the Clyde summer resorts or English lakes, where the sewage of a fairly large population is disposed of without serious difficulty.

Time did not permit me to study the problems connected with Staten Island actually on the spot. From a perusal of the commission's report on the disposal of the sewage of the Richmond Division there would not appear to be any special difficulty in dealing with the situation as far as regards the responsibility of New York City.

In the Arthur Kill and Kill van Kull we are approaching the problems of New Jersey. I have not been called upon to express an opinion on matters which are a subject of litigation. One may, however, safely say that a resolute handling by New York City of her own problems is likely to facilitate an equitable conclusion.

Summary and Conclusions.

After careful consideration of the situation as it has been placed before me I am of opinion that the sewage of the Harlem district should be collected and treated in sedimentation tanks on Ward's Island.

This will relieve the immediate and pressing situation on the Harlem river. It will, however, do little or nothing to improve the Lower East river.

It is of equal importance, therefore, that the scheme be pressed forward of driving a main sewer southwards through Brooklyn to an artificial island well out from shore in the Atlantic ocean, where tanks could be built for settling out the heavier suspended matters and removing them to sea.

Into this main sewer would first be discharged that part of the sewage of Brooklyn and Manhattan which at present passes in a crude state into the Lower East river. Later, more of the sewage of Manhattan should be coupled up to this sewer, the outlets at the artificial island being extended with each large increment of sewage.

Next, the sewage from the Jamaica Bay Division might be brought to the island and finally, if thought desirable, the sewage which, during all this time had received treatment at Ward's Island.

By this sequence of procedure the experience gained at Ward's Island would be of value in designing the final disposal at the "Atlantic Island", and at any rate a large proportion of the money expended in tanks, &c., at Ward's Island will have been redeemed before the works are abandoned. The expenditure in sewers in the Harlem district will be for permanent works alone.

The order of carrying out the various needful works and the time over which the construction should extend would all be matters within the control of the permanent commission suggested by my colleague, Mr. Watson, with whose views on this aspect of the question I heartily concur.

This same central board or commission would care for the other less immediately pressing, but still highly important, problems referred to in the later paragraphs of the foregoing report.

The above represents in broad outline the lines upon which, in my opinion, the City of New York should proceed in its endeavour to obtain a harbor worthy of itself.

It must again be emphasized that no time should be lost in setting about the actual carrying out of the scheme. It must of necessity take a number of years to complete, and equally of necessity the condition of the harbor waters must become progressively worse if nothing is done, and will indeed probably be worse before the first instalment of the work is completed.

I am, however, confident that the citizens of New York will show the same determination and largeness of outlook already manifested in their great water supply projects, their colossal railway undertakings, and magnificent bridges and public institutions, in this further effort after social well-being, and will build the works necessary to cleanse the harbor and make it worthy in every respect of its great position as the Gateway of the West.

Respectfully submitted,

GILBERT J. FOWLER.

Manchester, February 10, 1913.

REPORT OF
JOHN D. WATSON, M. Inst. C. E.

To the President and Members of the Metropolitan Sewerage Commission of New York.

Gentlemen:—

I have given the problem of the sewerage and the sewage disposal of your great city my close and careful consideration during the past two months.

The fortnight which I spent in the city in the end of November and beginning of December gave point and animation to the study which was not otherwise possible, and I take this opportunity of thanking you for the ready access you gave me to all your documents, plans, and analytical figures, and for the facilities with which you provided me in the inspection of every part of the area which I thought it essential to visit. Allow me also to record my appreciation of the exhaustive preliminary investigations which you have made. These far exceed anything which I have hitherto had experience of, and the fact of your having printed them renders unnecessary reference to details which otherwise would have had to be given in this report.

The Polluted Condition of the Harbor.

If there were any prospect of limits being set to the bounds of New York, if there were any signs that sufficient accommodation had already been made for the shipping of the port, or if the waters of the harbor were so foul that the citizens had ceased to regard them as valuable for other than utilitarian purposes, the disposal of the sewage—vast as the volume of that is—would be comparatively easy. But it is quite otherwise. The city is more than the capital of a country; it is the greatest city of a continent. The harbor is the gateway to the United States, and the noble rivers which find a ready outlet into it form, with the harbor proper, a port which affords at all stages of the tide no halting welcome to vessels of the greatest burden.

When I first had the pleasure of seeing the Hudson between Albany and New York, I was greatly impressed by its grandeur and its purity; when I motored along its left bank from Riverside Park toward the city boundary at Yonkers in brilliant sunshine, I thought it the Queen of Rivers, and I cannot believe that the average citizen would willingly allow it to become visibly polluted with sewage, yet the facts to which I shall refer will prove that it is necessary to take steps now to guard against such a contingency in the immediate future.

Visible Pollution.—The numerous analyses of the harbor waters made by your own officers, supported by men of such eminence as Professor Phelps, Dr. Adeney and Dr. Fowler, and the clear evidence of pollution which I have witnessed, lead me to the opinion that continuance of the present unhampered license to pollute can only lead to disaster. When it can be shown that even now the condition of the harbor in summer is obviously unclean, it is only a question of time when an ever-increasing population discharging an incremental amount of sewage and trade waste into what must be practically a stationary volume of harbor water will convert into a nuisance what should be one of the brightest and best of the city's possession.

One of my first actions in prosecuting this study was to investigate the condition of the harbor water, and even in the end of November I found at several places a slight smell of sewage. In ferrying across the river between 92nd Street and Astoria I observed innumerable particles of paper and even pieces of excrementitious matter in the water. Sea gulls indicated where the public sewers debouched directly into the river.

In many places in the East, the Harlem and the Hudson rivers, the Gowanus and Wallabout bays, visible evidence of the presence of sewage was only too apparent. Near the Battery I saw food which had just been unloaded from a boat that was moored in what looked more like sewage than clean water. At another place (Gowanus canal) I witnessed the ebullition of gas apparently arising from septicized sewage sludge. Large flows of greasy sleek and debris were to be seen at frequent intervals. Open ends of sewers spewing their filthy contents into the rivers are of much too frequent occurrence.

One and all demonstrate the same lesson that the time has arrived when a standard of cleanness should be set and maintained. If such conditions were offensive in November and December, it is obvious that they must be worse in the hot seasons of the year. Of course offensiveness to sight and smell do not necessarily constitute a nuisance which is dangerous to health, but as no self-respecting community would tolerate streets that were rarely scavenged because no injury to health could be traced to them, no port of the first rank should permit excrement paper, straw and grease to flow to and fro on the surface of the chief highway into the city because it could not be proved that a human being had died as the result.

The Proper Standard of Cleanness.—The standard of cleanness which you suggest, and which I heartily approve, should be reasonably but strictly enforced.* Liquid pollution, although less obtrusive, is not less in need of preven-

* Report Metropolitan Sewerage Commission of New York, August, 1912, page 70.

STANDARD OF CLEANNESS.

1. Garbage, offal or solid matter recognizable as of sewage origin shall not be visible in any of the harbor waters.

2. Marked discoloration or turbidity, due to sewage or trade wastes, effervescence, oily sleek, odor or deposits, shall not occur except perhaps in the immediate vicinity of sewer outfalls, and then only to such an extent and in such places as may be permitted by the authority having jurisdiction over the sanitary condition of the harbor.

3. The discharge of sewage shall not materially contribute to the formation of deposits injurious to navigation.

4. Except in the immediate vicinity of docks and piers and sewer outfalls, the dissolved oxygen in the water shall not fall below 3.0 cubic centimeters per litre of water.† Near docks and piers there should always be sufficient oxygen in the water to prevent nuisance from odors.

5. The quality of the water at points suitable for bathing and oyster culture should conform substantially as to bacterial purity to a drinking water standard. It is not practicable to maintain so high a standard in any part of the harbor north of the Narrows or in the Arthur Kill. In the Lower bay and elsewhere, bathing and the taking of shellfish cannot be considered free from danger of disease within a mile of a sewer outfall.

tion, and it is in the interest of the community to see that any recognized standard which may be decided upon should be conscientiously adhered to. What the standard should be is a question which you have already submitted to a number of well known experts, and they have all united in saying that the dissolved oxygen in the harbor water should not be allowed to fall below 50 per cent. or 60 per cent. of the saturation limit. Colonel Black and Professor Phelps suggested that it should not be allowed to fall below 70 per cent. saturation, and this figure is more in accordance with my own view; indeed I go further and say that an even higher standard is feasible if the project recommended later in this report is approved and given effect to.

The result of 289 samples tested by you for dissolved oxygen in the summer of 1911 show clearly the polluted state of some parts of the harbor. Taking 100 per cent. as the saturation point, or the normal condition of clean water, the following comparison of average figures speak volumes:—*

Lower New York bay	98	per cent
Long Island Sound near Throgs Neck	96	"
Hudson river, a few miles above Manhattan Island	81	"
Narrows	73	"
Upper East river	71	"
Kill van Kull	66	"
Hudson river to north of Manhattan Island	64	"

†With 60 per cent. of sea water and 40 per cent. of land water and at the extreme summer temperature of 80 degrees F., 3.0 cubic centimeters of oxygen per litre corresponds to 58 per cent. of saturation.

Upper New York bay..... 63 per cent
Lower East river..... 55 "
Newark bay..... 54 "
Harlem river..... 42 "

Average figures in such a study do not quite suffice, for as the strength of a chain is the weakest link, so the lowest figures obtained (30 per cent at the lower end of the Harlem in July, 1911) indicate the danger conditions which sanitarians would strain every nerve to avert.†

The Increasing Discharge of Sewage.—When one remembers that the population of New York was only 2,500,000 in 1890, and that in 1905 it was 4,000,000, a careful estimate of its probable growth in the future is essential to arrive at a wise judgment in the matter of sewage disposal.

Estimates have been made by several authorities, including Freeman who said the population in 1940 would be..... 7,652,000
and Laidlaw who said it would be..... 8,662,829
The New York Telephone Company's estimate is..... 8,747,000
and the Board of Water Supply's estimate is..... 9,258,600

The average of these suggest a probable population of the city in 1940 of 8,580,107, a figure which proximates to your own estimate of 9,000,000, which be it remembered is based on the Census figure of 1910, and on this account is more likely to be accurate.

The prospective population which should be reckoned, however, is not 9,000,000 but 12,000,000, the population of the metropolitan area. The question as to what extent the harbor is likely to be burdened with impurities in 1940, assuming that nothing is done in the interval, depends on population more than anything else, and whether that population is located north, south, east or west of the harbor makes no difference. Artificial boundaries, therefore (state or other), are obviously not so important to the issue as *watershed,* and far fetched as it may appear to be at first sight the manner of disposing of the sewage of the City of Albany and every other populous place built and to be built on the banks of the Hudson will materially affect the problem under consideration. This will be apparent if it is conceded that the recuperative influence of the harbor depends very largely upon the purity or otherwise of the Hudson as it enters New York City.

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† The percentage of oxygen fell still lower in 1912. The average for the year: Hudson river off Pier A, 55 per cent.; Narrows, 70 per cent.; Kill van Kull, 65 per cent.; Upper New York bay, 64 per cent.; Lower East river, 47 per cent.

The act of assimilation can be carried on only in the presence of oxygen, and it is therefore essential to conserve that oxygen as much as possible.

The table which I have quoted to show the relative state of purity at various specified places as measured by percentage of loss of oxygen is eloquent condemnation of the existing system, a condemnation which is only partially mitigated by the naturally and wonderfully even admixture of the harbor water as shown by the voluminous observations you have made.

In studying this question the fact that the volume of sewage must increase constantly has to be set in juxtaposition with the fact that the clean water from whence the oxygen is derived must remain very much the same in all time. Nor should the floating population as represented by the trade of the harbor be ignored. This is certainly a difficult problem, and I fear it will be impossible to exclude sewage from this source altogether; it is the more important, therefore, that the authorities deal effectively with the sewage from the stationary population which is under control.

Cleanness, a Commercial Necessity.—On the day I arrived in New York the newspapers referred to a remarkable speech by the Mayor on the subject of the growth of imports and exports at several harbors of the United States. The occasion for this speech was the 144th anniversary of the organization of the Chamber of Commerce, and it was shown that the increase of trade at New York was far and away greater than at any other port in the country.

Since	1898	the	increase	at	the	port	of	New York	was.	111 per cent.
"	"	"	"	"	"	"	"	Philadelphia	" .	75 per cent.
"	"	"	"	"	"	"	"	Boston	" .	17 per cent.
"	"	"	decrease	"	"	"	"	Baltimore	" .	7 per cent.

All the facts and considerations of the case lead me to the conclusion that the community must bestir itself if it would retain for its harbor the good name which is now associated with it. Let the cases of Marseilles and Glasgow, be a warning. Many years ago the Clyde became so foul that even poor trippers declined to board pleasure steamers nearer to the Broomielaw than Greenock several miles down the river. Since that time large sums of money have been spent on sewage disposal works, but the bad reputation justly associated with the name of the Glasgow harbor years ago will not be got rid of for many years to come. Every port has a duty to every other port, which if faithfully observed, would inaugurate a state of things that would go far to lessen the duties of port, sanitary and quarantine officers.

Discussion of the Metropolitan Sewerage Commission's Four Schemes for the Purification of the Harbor.

What then is the most practicable, the most hygienic and the most permanently economical scheme to adopt? I have studied the various schemes put forward in the admirable reports which you have sent to the Mayor of the City since September, 1911.*

Although the schemes enumerated in your reports may not have exhausted every phase of what you term the art of sewage purification, yet in my view you have considered every method applicable to New York which can be regarded as reasonably practicable.

Scheme 1 refers to the application of sewage to land. (Broad irrigation and intermittent filtration.)

Scheme 2 refers to filtration of sewage through biological filters (bacteria beds).

Scheme 3 refers to treatment of sewage by a variety of methods at various points of outfall, each case being adapted to its special circumstances, and the ultimate disposal of partially purified liquid into the nearest water course.

Scheme 4 refers to the conveyance of a large part of the sewage out to the Atlantic ocean with the minimum of treatment.

Scheme 1.

Application of the Sewage to Land.

The popularity of irrigation as a means of purifying sewage is on the wane, chiefly owing to the extensive area required and the unsuitability of the land available.

The Berlin farm, which is the largest in Europe, continues to do good work. The largest farm in England was at Birmingham, but some years ago when land could no longer be obtained for less than three times its agricultural value, the authorities abandoned irrigation in favor of the intensive method of purification on bacteria beds. The largest farm in France is at Paris, and there also the authorities contemplate a change of method whenever it is necessary to increase the purification plant.

Where all the conditions are favorable, irrigation is undoubtedly successful as a vehicle of purification, and one which generally yields consistently good

*Metropolitan Sewerage Commission's Preliminary Reports on the Disposal of New York's Sewage, I to V inclusive.

effluents, but in New York the farm would be so colossal in extent that the conditions would not be invariably favorable. The available land is, I fear, limited to Long Island, the area required would exceed 150 square miles. It would necessarily vary in its adaptability for the purpose, and although the standard of purification need not be exceptionally high in view of the large volume of water into which it would ultimately be discharged, it would still be necessary to limit the volume of sewage to 10,000 or 12,000 gallons per acre, unless a great expenditure for under drainage were undertaken.

Sanitary Objections.—A great area of land lying between Amityville and Quogue overlies one of the sources of the city's present water supply, and its use for sewage purification would be a potential source of plague which no one would care to risk.

The mere saturation of 150 square miles of land with sewage would be a menace to the inhabitants obliged to reside in the district, and would be sure to produce mal-odors during certain states of the atmosphere, which would be highly objectionable, even if they did not markedly influence the health statistics of the district.

I disapprove of this method of purifying New York sewage on grounds quite apart from cost; nevertheless, it is important to note that it is the most costly of the schemes brought forward, and would probably amount to $180,000,000; this, too. assumes that land could be acquired for about $500 per acre—a somewhat sanguine estimate.

Scheme 2.

Oxidation in Bacteria Beds.

The epoch-making experiments of the Massachusetts State Board of Health have led to the adoption of what has been called the intensive method of purification. By this, biological filters are made to take the place of land, and in your case would probably purify 140 times as much sewage as the same area of land under irrigation. It is a method which is almost invariably adopted in modern works which are located some distance from sea, lake or river.

To carry the whole or the major portion of the New York sewage to Barren Island and then treat it on bacterial filters would be costly, and could only be justified if it could be shown that a specially good effluent is essential at the point of discharge.

As the oyster beds will probably depreciate in value as the population of the district increases, it would not be wise on this account alone to incur the

expense of this operation, more particularly as it is now admitted on all hands that the passage of sewage through a biological filter does not necessarily deprive it of pathogenic organisms, and in order to protect the oysters from the attack of a stray typhoid bacillus, it would in this case be necessary to sterilize before 1940 a quantity of sewage equal to about 700,000,000 gallons.

Danger of Nuisance.—Perhaps Barren Island is the very best site available for placing an installation of percolating filters, but it would appear as if Jamaica bay were on the eve of great developments, and that Barren Island would not for long be the isolated place it now is. I regard it as of the utmost importance to establish sewage purification works where they are not likely to become a nuisance, and I have grave doubts about the wisdom of placing so vast an area as 1,000 acres of bacteria beds so near to an industrial centre as they would be on Barren Island. In contemplating such a scheme there is a factor which should be taken into account, and that is the after effects of the evaporation of so much foul liquid as there must necessarily be from such an area of filters.

In 1911, when the summer weather in England was warmer than usual, there were complaints of smell nuisance at Henley, where the sewage is of about the same strength as the average American sewage, and where it is distributed over rectangular percolating beds by mechanical distributors moving backwards and forwards. Complaints were also made by residents near the Birmingham works, where the sewage is sprayed over the beds by fixed nozzles.

The chief lesson to be learned from the 1911 experience is that an increase of flies is to be looked for in the neighborhood of bacteria beds in hot weather, and that objectional smell adjacent to them is more pronounced during prolonged hot weather than at other times, *e. g.*, seasons like the average English summer, when the temperature rarely exceeds 65 Fahr. in the shade. But a much more serious drawback to a great area of bacteria beds during spells of *prolonged hot weather* is the formation of vaporous "clouds," due to the evaporation of sewage. These clouds appear to form over the beds in quiet weather. They rise to some distance above the earth, and at sundown, when the earth begins to cool, they return not alone as refreshing dew, but with offensive odor. If this occurred only in the vicinity of the bacteria beds, where the land is generally less valuable than at some distance, it would not be so serious in its consequences, but it generally occurs at some distance from the bacteria beds, the direction and distance depending upon the tendency and the velocity of the wind.

Cost.—Of course, it is only the mal-odorous element in sewage that makes this phenomenon noticeable; evaporation from clean water would act precisely in a similar manner, but it would manifest itself in welcome dew on the grass.

This led me to adopt at Birmingham the use of hypochlorite of calcium with excellent results, but the cost would be a serious matter where 700,000,000 gallons had to be treated each day; indeed, the bare probability of hypochlorite of either calcium or sodium (and the latter is even more effective) having to be used frequently, would be sufficient in itself to retard the adoption of a scheme which would be many times as large as anything now in existence. It is obvious that climate is of paramount importance.

The initial cost of 1,000 acres of biological filters to deal with 700,000,000 gallons of sewage, would be not less than $140,000,000, apart from maintenance charges. Altogether, I agree that the commission would not be justified in espousing this scheme as the best available for New York.

Scheme 3.

Local Treatment Works and Outfalls.

It is probably not far from the truth to say that the only purification of organic matter known to nature is an oxidising one, which is brought about indirectly by the agency of bacteria, but whether the vehicle by which the process is brought to fruition is the irrigation farm, the biological filter or dilution with large volumes of clean water, the "combustion" process is practically the same.

To protect the harbor from pollution, it is neither essential to confine the purifying process to one method, nor to one locality, but whether it is expedient or wise to construct dozens of sewage purification plants in and around New York is an entirely different matter. Sewage from the various districts delineated on the plans could be sufficiently treated to admit of being discharged in the adjacent waters without creating a nuisance, but in some cases the treatment would have to be very circumscribed, and a greater burden would be placed upon the assimilating powers of the waters than they ought to be called upon to bear.

Essential Details.—It is unnecessary for me to refer in detail to the various outfalls that would be required under this scheme. Suffice it is to say that I have examined many of the suggested sites, with the invariable result that they all appear to me to have been chosen with great judgment and engineering skill. It is more than probable, however, that if Scheme 3 finds most favor, the sites shown on the plans, and referred to in your reports, may have to be altered when negotiations for the purchase of those sites are begun; this will be found to be specially true in the case of the nineteen outfalls on Manhattan Island.

Under this scheme it would be necessary to lay sewers towards an outfall which would terminate in the deepest water available in the vicinity, where it

would be dispersed by a complete system of moderate sized outlets so placed as to enter the stream transversely to the flow, and in sufficient number to encourage equal diffusion. Each outfall should be protected by grit chambers and settling basins in duplicate; the former should be provided with every appliance requisite to remove solids of large size, road grit, rags, etc.

Disposal of the Sludge.—The basins should be built so as to induce the sludge arrested by mechanical or chemical precipitation (as may be found best under circumstances which vary considerably at different outfalls) to collect at, say, the apex of an inverted cone or pyramid, and the sludge collected should be pumped daily into steamboats built for the purpose and removed well out to sea. This system of getting rid of sludge is well suited to a scheme which would have all its sludge tanks within easy reach of navigable water.

In my view the sludge should be removed daily so as to obviate smell nuisance. The only alternative would be to septicize the sludge in Emscher tanks, but this would mean large and deep tanks which would be incompatible with the conditions obtaining at some of the outfalls, particularly those in Manhattan, where the sludge tanks would perforce be placed in the streets abutting on the bulkhead and shore lines. The experience of the engineers at London, Glasgow and Manchester puts at rest any doubt as to the practicability of removing unsepticized sludge by steamboat, but there is nothing equally convincing to show that if it were in a state of active fermentation it could be so easily removed and so quickly lost to view when dropped into the ocean.

Only Limited Treatment Practicable at Ward's Island.—If such a scheme as this were to be caried out, its weakness would probably become apparent first at Ward's Island, where 302,000,000 gallons of sewage will have to be treated daily in 1940. The reasons I have given against the establishment of a great area of filter beds at Barren Island are even more potent when applied to Ward's Island, so that either mechanical or chemical precipitation would in the present state of knowledge have to be resorted to, and neither process is efficient enough to warrant me in suggesting that such a volume of effluent could be discharged into the East river without unduly drawing upon the oxygen of the harbor water.

One of the leading factors in considering the Ward's Island problem is the fact that the river, so called, is without a continuous flow of fresh water towards the sea; any sewage effluent, therefore, would have to rely upon admixture with the water of a tide in order to obtain the necessary supply of oxygen to obviate putrefaction, and considering the volume available for this purpose, I am doubtful whether the results would be acceptable at all seasons of the year.

Of course the sedimentation process including screening and sludge removal to sea, or that process plus the addition of a coagulant to help mechanical precipitation, do not exhaust the great sources of power in nature, and it is quite possible that we may before many years are over realize the practicability of electrolysed sea water. Your laboratory experiments stimulate me with hope, but I cannot in the present state of my knowledge recommend them as a practical solution of the problem.

Under this scheme there would be many outlets, all of which would require to be equipped with screens, grit chambers, tanks, and some kind of treatment works, before the effluent could be discharged and left for the nearest water to complete its purification by assimilation.

Scheme 4.

Conveyance of a Large Part of the Sewage to Sea.

The distinctive feature of this scheme is the provision of subterranean channels, or great sewers, into which each part of the municipality embraced within a prescribed area would have the indisputable right to discharge sewage and trades wastes without let or hindrance, knowing that the sewage would be conveyed right out to the Atlantic ocean. Nothing in the nature of treatment beyond arresting solids that would otherwise obstruct the pumps would be undertaken *en route.*

One important feature of this scheme would be the formation of an island in the sea about three miles south of Coney Island. The formation of such an island is by no means unprecedented, but the idea of forming one some miles from land for the sole purpose of treating sewage is a novelty in the history of sewage purification.

Scheme 4 involves pumping the sewage, screening it, arresting a proportion of the suspended solids in sedimentation tanks to be constructed on the island, and thereafter leading it by a series of pipes into deep water to secure effectual diffusion.

Having the sewage tanks on the island would obviate the usual troublesome claims for compensation in respect of depreciation of value of adjacent property. The island could be extended almost indefinitely as occasion for extension arose. Its position would be the best possible from which the superintendent of the works might observe the ebb and flow of the tide, and regulate the emptying of the sedimentation tanks.

The Treatment Necessary.—The question of the extent to which sedimentation should be carried is one which will gradually settle itself. I do not think it will be necessary to effect settlement until after the first section of the work has been in operation for some time, but as section after section is completed it will be found necessary to arrest the solids in tanks, made with the view of concentrating the sludge at the bottom of either conical or pyramidal pockets placed at an elevation to induce the sludge to flow by gravitation.

The precise site of the proposed island will require careful consideration, but that shown on your plan appears to be feasible. Excepting rip-rap for the external formation, nearly all the material for making it can be readily and cheaply obtained chiefly from (1) debris or spoil from building sites which at present is dumped into the ocean; (2) spoil from the tunnels and terminating shaft, and (3) sand pumped from the adjacent sand banks.

The Progressive Steps in this Scheme.—The first step to be taken if this scheme is entertained is to collect sewage from those parts of Manhattan and Brooklyn which border on the East river, convey it by tunnel to a central pumping station at Wallabout, near the Navy Yard, and lift it to another pumping station at Sheepshead bay, whence it would be conveyed to the projected island for disposal.

The population of the districts to be served at first by this instalment, and the dry weather flow of sewage pertaining thereto, are as follows:

District.	Population, 1915.	Sewage, Gallons per day.
Manhattan	680,000	99,000,000
Brooklyn	732,000	104,000,000
Total,	1,412,000	203,000,000

The Wallabout pumping station would lift 133,000,000 gallons coming from the north, 18 feet in height, and 70,000,000 gallons from the south, 33 feet in height, and the Sheepshead bay station 203,000,000 gallons about 38 feet in height.

This instalment could be executed for about $18,000,000, which would entail for interest (at 4½% for 50 years) together with maintenance charges, an annual payment of $1,500,000, but I do not recommend you to limit the size of the tunnel to a carrying capacity of 400,000,000 gallons, or about twice the dry

weather flow, as I believe the second instalment of the scheme should be undertaken soon after the completion of the first.

The second instalment, I apprehend, would be to couple up the intercepting sewer which would serve the Jamaica Bay Division, shown on the plan accompanying your report to the Mayor, dated November, 1911.

The third instalment of the work should bring the sewage of the Upper East river and Harlem Division into the system, and the fourth would take in Richmond and as much of New Jersey as may be determined.

In my opinion all the intercepting sewers should be capable of conveying not less than twice the dry weather flow before storm water is shed into the nearest watercourse; this would correspond favorably with the English practice of conveying six times the dry weather flow,* or rather less than 200 gallons per head per day.

Need of a Permanent Sewage Disposal Commission.

Of the four projects thus briefly outlined as possible schemes for adoption, I have a decided preference for Scheme 4. I admit that Scheme 3 is feasible, but it lacks finality and possesses features which should be avoided when possible, *e. g.* the numerous outfalls and the drawbacks attaching to them in the eyes of the general public, their not invariably suitable locations, and their inevitable increase in number as the population increases. What influences me most in favor of Scheme 4 is the conviction that where it is possible to remove the bulk of the sewage of New York entirely away from its source to the ocean *it should be so removed,* although the cost may be somewhat higher than it would be under a project like Scheme 3.

In a great city where such public services as water supply, sewerage and sewage disposal are indispensable, and where several self-governing municipalities benefit by the common service, it is essential in the interests of good and economical administration that there should be a permanent commission, with jurisdiction over the whole area. Such a general commission from its very constitution is enabled to deal with questions more comprehensively than local boards, commissions, departments or bureaus can do. Probably an example of what I mean may be found by reference to the endeavor to improve the insanitary conditions of the Gowanus canal, where a local sewer bureau tried to remedy a nuisance by conveying a stagnant, putrid liquid from one locality to another in

*For comparison between English and American sewage, See Preliminary Report VI, of the Metropolitan Sewerage Commission of New York, January, 1913.

the same neighborhood. No doubt the bureau did the only thing available to them at the time, but they were obviously restricted in their outlook, and were forced by circumstances to mitigate rather than remedy the evil, whereas if it had been possible for them to order the polluted waters of the canal to be conveyed beyond the municipal boundaries to the ocean, the evil would have been effectively remedied. A municipal engineer's work is often unfairly criticised because the effects of being hemmed in by surrounding boroughs is not adequately appreciated. Administrative questions, like sewerage, are not invariably united, but here they should be under one commission or board, and it is with the object of devising a workable scheme for keeping the harbor free from solid as well as liquid impurities that I suggest the formation of a commission to be entrusted with the duty of making and keeping pure (or reasonably pure) the national waters.

Proper Functions of a Permanent Commission.—The constitution of such a commission would have to be carefully framed by those who are well versed in existing statutes and inter-state law, but I venture to suggest one or two points which should be carefully embodied in the constitution.

The whole responsibility for maintaining clean waters within the prescribed area should rest upon the commission, and they should have all necessary power to enforce their regulations.

The commission should be responsible for the design of all intercepting sewers, pumping stations, tanks, outfalls, &c., essential for the construction of a complete installation of sewerage and sewage disposal works. The board should also be made responsible for the construction of these works, and for their subsequent maintenance.

Each borough or municipality must have the same right to connect to an intercepting sewer or sewers that they now have to discharge sewage into harbor, river or watercourse.

The commission should be charged with the duty of seeing that pollution, which must be inevitable until the intercepting sewers or subterranean tunnels are all built and connected to the ocean outfall, does not increase, even although it should be necessary to construct temporary works for the purpose.

The joint board or commission should have ample power to decide whether an intercepting sewer or any other work is required, and to allocate the cost of construction to the users. It should also have power to regulate by bye-laws, or otherwise, everything which pertains to the keeping clean of the harbors, rivers, canals or watercourses within the area for which it is responsible. If it is usual

to give such commissions rating, borrowing or financial powers, the board should be so empowered.

In recommending the adoption of Scheme 4 it is not to be assumed that I advocate its complete execution at once. If I have succeeded in presenting the whole project correctly, it will be apparent to all that the dominating factor is and must continue to be the condition of what I have called the national waters. As it stands at present, the putrefactive liquid entering them increases daily; their power of oxidising foul liquid is practically stationary, and as every sewer is diverted to the Atlantic ocean by being coupled up to the system under scheme 4, their condition will improve. I do, however, advocate progressive, consistent advancement until the completion of the scheme be attained, which I hope will be not later than 1925.

Necessity for Immediate Action.

I cannot say too distinctly that there is need for immediate action. The nature and extent of the tunnel work bars haste and precludes all chance of redeeming lost opportunities; therefore no opportunities should be lost.

Generally, I am in sympathy with the plans you have prepared; particularly do I espouse what you call Project 1 as the first step to be taken. There should however be a comprehensive plan matured if possible in conjunction with the engineers of the several sewer bureaus, which will indicate how every link of the complete scheme will be caught up in regular progressive stages. This is the more important as there might be more or less prolonged intervals between each successive stage.

It will probably cost not less than $100,000,000 to complete Scheme 4, undoubtedly the largest sum ever contemplated for such a purpose, but no scheme has hitherto been designed for the service of 12,000,000 people. Many small towns have spent more *per capita* than this estimate implies, and frequently all they gained was the removal of a liquid which possessed potential elements of plague. The citizens by approving the conveyance of all the sewage to the Atlantic will gain that and more, for they will at once purify their harbor and rivers, which never will cease to be the most priceless and most striking physical characteristic of New York.

Comparison with European Undertakings.—If one were to attempt a comparison between the cost of the sewerage systems of European capitals, and what is now proposed for New York, the great disparity between the quantities of potable water used by the inhabitants of cities of the Eastern and Western

Hemispheres would arrest attention. The world has been startled by the magnitude of your water schemes. Any European city would have regarded 114 gallons *per capita* as an extravagant allowance, yet this—which is equal to a daily supply of 500,000,000 gallons—is what is now obtained from the Croton works alone, but rather than curtail that supply, or do anything which might be interpreted to favor a limited use of water for public health purposes, the authorities determined to carry out a gigantic scheme to obtain another 500,000,000 gallons of water per day, this time from the Catskill mountains. The magnitude of the undertaking, and the aggregate cost of bringing in 1,000,000,000 gallons per day will place the New York water supply in a category by itself when a history of the world's great water works comes to be written.

The consumption of water has a direct relationship to a city's sewerage system as regards cost, and it is incumbent upon an engineer in recommending a scheme to satisfy himself that it is not only sound as an engineering proposition, but that it is financially possible. The facts I have brought to your recollection go a long way to show that a scheme of sewage disposal which will ultimately cost $100,000,000 and involve an annual outlay of $5,000,000 for the benefit of 12,000,000 people is not disproportionate to the requirements of the city. But I have not relied alone upon the example of the water works in coming to this decision. The numerous public schools, seats of learning, public institutions, colossal buildings, wide streets, stupendous bridges of unparalleled width, not to speak of railroad, canal and private enterprise, the most recent examples of which may be found in the Pennsylvania and Grand Central stations, which between them have cost not less than $300,000,000, all direct one's attention to indisputable evidence of prosperity and progress, and to what is of even more importance, the attitude of mind which shows that the people have a profound faith in the future greatness of their marvellous city.

It is quite unnecessary to caution you that all estimates of cost, so far as they have been prepared by me, must be regarded as of a tentative character, and should be accepted cautiously until complete surveys, detailed plans and sections are made, and schedules of quantities drawn up—nevertheless they seem to me to be quite ample for the work contemplated.

I am, gentlemen, your obedient servant,

JOHN D. WATSON.

BIRMINGHAM, 31st January, 1913.

PRELIMINARY REPORTS

ON THE

DISPOSAL OF NEW YORK'S SEWAGE

VI.

STUDY OF THE COLLECTION AND DISPOSAL OF THE SEWAGE OF THE LOWER HUDSON, LOWER EAST RIVER AND BAY DIVISION*

METROPOLITAN SEWERAGE COMMISSION
OF NEW YORK

GEORGE A. SOPER,
JAMES H. FUERTES,
H. de B. PARSONS,
CHARLES SOOYSMITH,
LINSLY R. WILLIAMS,
Commissioners

FEBRUARY, 1913

***This report is issued in advance of the final report of the Metropolitan Sewerage Commission in order that the contents may be of early service. Some features of this report will remain open for revision until the final report is submitted.**

THE EVENING POST JOB PRINTING OFFICE, 156 FULTON ST., N. Y.

PRELIMINARY REPORT VI.

STUDY OF THE COLLECTION AND DISPOSAL OF THE SEWAGE OF THE LOWER HUDSON, LOWER EAST RIVER, AND BAY DIVISION.

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APPENDICES.

STUDY OF THE COLLECTION AND DISPOSAL OF THE SEWAGE OF THE LOWER HUDSON, LOWER EAST RIVER AND BAY DIVISION.

Honorable WILLIAM J. GAYNOR, Mayor of the City of New York:

SIR:—This report, the sixth in this commission's series of Preliminary Reports on the Disposal of New York's Sewage, is issued with the object of making public, at the earliest practicable date, this commission's studies as to the way in which it will be necessary to deal with the sewage of the fourth, and last, of those divisions into which New York has been divided to facilitate the work.

While many details still remain to be considered, these studies show the general character of the works which should be constructed. To protect the Harlem and Lower East rivers, large sewers are needed to intercept the sewage and carry it to an artificial island to be built near the outer limits of the harbor about three miles from shore; here, after a short and inoffensive treatment the sewage can be discharged into the ocean with confidence that the organic matters will be promptly rendered inert. All the rest of the sewage in this division should be passed through screens and grit chambers and discharged beneath the surface of the water in the main tidal channels.

I.—BOUNDARIES AND TOPOGRAPHICAL FEATURES.

The territory in the Lower Hudson, Lower East river and Bay Division lies on both sides of the Lower East river, the west side of Manhattan and the east side of Upper New York bay. It extends from the extreme northwestern boundary of the city to below the Narrows.

It contains the largest population, and the most densely settled sections of any of the four divisions into which the commission has divided New York for the purpose of planning the main drainage and sewage disposal works which will be required. Within it lies the major part of the Boroughs of Manhattan and Brooklyn, which were separate cities until 1898.

This division is bounded on the east by a line which begins at Bensonhurst on Gravesend bay, runs in an irregular course northeasterly to Forest Park, in the Borough of Queens, and thence northwesterly to the East river near the mouth of the Harlem river. All of that part of Brooklyn and that part of Queens which lie to the west of this boundary line are included in the division.

Crossing the East river the boundary enters upon Manhattan Island at East Eighty-second Street, proceeds northwesterly to Central Park West, which it crosses at Ninety-first Street, and thence follows an irregular northerly direction along the height of land to the Harlem river at Spuyten Duyvil. That part of Manhattan, which lies to the south and west of the boundary so described, lies in this division. A small part of the division borders on the Hudson between Spuyten Duyvil and Yonkers. The western boundary of the division is formed by the Hudson river, Upper New York bay, the Narrows and a part of Gravesend bay.

In the northern and southern parts of this division the topography is favorable to drainage, but there are large areas near the center which are so low and flat that the construction of sewers with sufficient grades to insure self-cleansing velocities and outfalls so situated as to provide for a free discharge at all stages of tide is impossible.

Made Land.—Many of the sewers in Manhattan feel the effect of the rising and falling tide for a considerable distance from the shores, in some instances, for over one mile. The worst cases of this kind are usually ascribable to the inadequate filling of low-lying or submerged areas such as the beds of creeks and the once marshy shores of water courses. A remarkable regular shore line, made by filling in Manhattan, is shown on modern maps.

TABLE I.—Acres of Filled Land in this Division.

Borough.	Acres.
Manhattan	1,140
Brooklyn	1,520
Queens	460
Total	3,120

The filling has been largely, but not entirely, done along the water front. From 82nd Street on the Hudson river, southward, to the Battery, and thence northward along the Lower East river to 33rd Street, Manhattan, the marginal street is entirely on made land, the total length of shore so recovered being ten and one-half miles. In many instances the made land extends

some blocks back from the river front and in the neighborhood of Canal Street, Manhattan. it runs across the island, a distance of nearly two miles.

On the Brooklyn shore, the made land extends from a point north of Newtown creek to near 45th Street, South Brooklyn, a distance of eight miles. The Brooklyn Navy Yard is entirely on made land. A large area in the neighborhood of Red Hook and Gowanus canal, Brooklyn, has been reclaimed by filling.

The growth of made land has been gradual. It has increased with the increasing size of the city. The chief object in filling in the low-lying places has been to eliminate swamps and marshes and make the area of ground available for trade and commerce more extensive than originally existed. At the same time the filling has proved a convenient means of disposing of refuse.

If cellar earth and other suitable refuse material were utilized in filling in the swamps and meadow lands which exist in the outlying parts of New York City, the shore lines in parts of the harbor estuaries which are now seriously polluted would soon be straightened and the water would be more easily kept clean than under the existing circumstances.

To facilitate the filling in of the low-lying shores, the Harbor Line Board, composed of engineer officers of the U. S. Army, which has charge of maintaining the navigable channels of the harbor, has established lines for solid filling. These lines extend throughout the harbor and give a good idea of the plans to which future operations of filling will probably conform.

The land which lies in this division at elevations within twenty feet of mean sea level, includes all the filled land and also some additional areas mostly in Brooklyn and Long Island City. A broad belt runs from the head of Newtown creek to the vicinity of the Brooklyn Navy Yard. The total area below twenty feet elevation in this division is about 3.3 square miles in Manhattan; 6.5 square miles in Brooklyn and 2.9 square miles in Long Island City. Seventy-three per cent. of all the land in this division is of more than twenty feet elevation above mean tide. In Manhattan the high land lies for the most part near the center of the island. The highest point is somewhat above 100 feet, and is situated north of 77th Street. There is no point above sixty feet elevation further south than 33rd Street.

In Brooklyn the land, which lies at an elevation above sixty feet, exists chiefly in the eastern part of the division, where a well recognized ridge runs in a northeasterly direction from the vicinity of the Narrows. Elevations of 100 feet or more frequently occur on this ridge.

Tidal Range.—The difference between mean sea level and mean high water is one-half the mean tidal range as given in the Table II.

TABLE II.—RANGE OF TIDE IN NEW YORK HARBOR.

	Mean.	Spring.
Lower bay, Sandy Hook	4.7	5.6
Narrows, Fort Hamilton	4.6	5.6
Upper bay, Governor's Island	4.4	5.3
Hudson river, Spuyten Duyvil	4.0	4.8
East river, Hallett's Point (Hell Gate)	5.5	6.6
East river, Throg's Neck	7.2	8.5
Harlem river, High Bridge	6.0	7.2
Kill van Kull, Shooter's Island	4.6	5.5
Newark bay, Passaic Light	4.7	5.7
Passaic river, Newark	5.0	6.0

Geology.—The superficial geological formation of this division is recent except for a small low-lying area of stratified drift in and near 125th Street. The surface of Manhattan island as far south as 23rd Street is composed chiefly of mica schist rock. South of 23rd Street, the rock disappears and stratified drift predominates.

In the Brooklyn part of this division, drift exists on each side of the central ridge, the ridge itself exhibiting the features of a terminal moraine with till on the western slope. Swamp and marsh lands exist to a limited extent, and then only in that part of Queens which lies in this division.

Value of Land.—The most valuable land in this division lies in the central and southern parts of Manhattan. It is a peculiar fact that whether for business or residence purpose, the most costly land lies along the center of the island. At the southern extremity is the financial district. North of this is the City Hall with the central post-office, numerous newspaper offices, the principal law courts and municipal administrative headquarters. Next above follows the wholesale dry goods center, then the region of retail shops, hotels and theatres and finally areas of high-class private residences and apartment houses which extend to the northern limits of this division. From this central zone east and west to the river fronts lie areas occupied by factories and residences, the latter ranging from modest dwellings to congested tenements.

In Brooklyn the water front is chiefly occupied by large factories and warehouses. The most crowded residence district and the center of financial administrative activity lies in that part of the borough which is opposite the southern end of Manhattan Island.

2.—The Existing Sewers—Their Outfalls and Resulting Nuisances.

Practically the whole of this division is sewered on the combined principle of sewerage.

In addition to the sewage which comes from the storm water of the streets and from the interior of the houses, the sewers of Manhattan and Brooklyn are required to carry away the water which falls upon the roofs, yards and courts of the buildings. The connections are trapped in order that the air from the sewers shall not enter the houses. The plumbing of the houses is ventilated by extending the soil pipes to the roofs.

In many cases, especially in Manhattan where the cellars of large buildings are deep, it is often necessary to pump the sewage into the street sewers. This is done at private expense.

Relief Sewers.—In most of Manhattan the sewers, which are large and short, have generally proved adequate to the requirements of the growing population; but in Brooklyn much trouble has been experienced from the insufficient provisions which were early made for drainage. The first sewers were built when the populations which they were required to serve were small and scattered, and when a comprehensive system of sewers was built between 1850 and 1860, the rainfall data were inadequate to permit designers fully to understand the requirements. With the increasing population the original sewers have been supplemented by large and expensive relief sewers, and these in turn have had to be assisted in some cases by the construction of intercepting sewers for the collection and removal of storm water.

The sewers of Manhattan and Brooklyn are of many shapes and sizes. Among the older sewers of Brooklyn are many storm drains whose courses are not known. The older sewers are generally circular in shape, and when over twenty-four inches in diameter are of brick or concrete. Clay and cement pipe have been extensively used for the smaller sizes. Since 1907 the principles of design and construction have been much improved in Brooklyn.

Most of the sewer outlets on the Manhattan shores are between two and five feet in diameter, but there are some which have a section equivalent to a circle having a diameter of ten feet and more. The outlets on the Brooklyn shore are somewhat less numerous and some are larger than the largest of Manhattan, having a section equal to a circle with a diameter of fifteen feet.

Many of the sewers of Manhattan were built many years ago. They represent various periods of growth due to the introduction of public water supplies

and other causes and have been extensively reconstructed and repaired within recent years.

Throughout this division the sewers are provided with catch basins at the street corners which were intended to convey the storm water from the gutters and protect the sewers from grit and other solid substances.

Ventilation.—It was intended that the sewers throughout this division should be ventilated through perforations in the manhole covers located at frequent intervals in the street. In most parts, notably in the older sections near the water front, the ventilation is defective, partly as a result of the settlement of the sewers, the entrance of tide water and the submergence of the outlets. Nuisances frequently result where steam and hot water are discharged into the sewers, since hot vapors rise and issue through the manhole covers disseminating odors of cooked sewage.

Outlets.—The outfalls of the sewers of this division, as elsewhere in the metropolitan district, are located at the bulkhead or shore line or, frequently in Manhattan, near the outer ends of the docks and piers.

The submergence of the sewer outfalls, as at present, and the rising of the tide drive the foul air into the streets and produce coatings of grease and solids upon the sides of the sewers, and this interferes with the flow of sewage. So much deposit is produced in some of the sewers that a cleaning gang, working continuously, can make no appreciable reduction in the depth of the deposit. Congealed grease has been found to measure as much as a foot in thickness in some of the sewers of Manhattan.

Physical Condition.—Inspections of the sewers made by the Metropolitan Sewerage Commission with the co-operation of the Bureau of Sewers and the Borough President of Manhattan have revealed many examples of distorted shapes, worn out inverts, sunken arches, and cracks due to settlement. In many places irregular holes had been broken through sewers in making connections, and the holes never properly repaired. It was impossible to enter some of the sewers for inspection owing to steam and hot water escaping from neighboring buildings. Other sewers could not be entered on account of the presence of illuminating gas in such quantities as to endanger health. In other areas, lanterns could not be carried into the sewers on account of gasoline vapor, presumably from automobile garages or other establishments using this explosive compound.

In Manhattan the sewers are inspected and cleaned only on complaint. The sewers are not flushed, but are cleaned by hand. Street sweepings are frequently pushed into the catch basins against orders in Manhattan and Brooklyn.

Catch Basins.—The effect of the catch basins is comparatively slight. They soon become filled with grit and other solid matters. To be of material use, they should be cleaned after nearly every storm. This is not done. The records for the year 1909 show an average of one cleaning for each catch basin in Manhattan every 5.3 months. This does not mean that all the 6,348 catch basins in the borough were cleaned. Some were cleaned out at comparatively frequent intervals and others were not cleaned at all.

In the year 1907 the catch basins in Brooklyn were cleaned on an average about 2½ times a year and the quantity of deposits removed aggregated 35,272 cu. yds. The cost of removing this material was $1.12 per cubic yard. The incompleteness and great cost of removing solid matter from sewage by the use of catch basins can be readily understood from these figures.

Large quantities of solid matters which pass the catch basins are deposited in the sewers themselves and are eventually removed by hand, washed out by the flood water of storms, or carried away through the alternate choking and flushing action which is produced by the rising and falling tide.

About 400,000 cubic yards of deposits are dredged each year from the slips and docks of that part of Manhattan which lies in this division by the Department of Docks and Ferries and large quantities are also dredged by private enterprise and from the Brooklyn shores. It is generally conceded that this solid material comes chiefly from the sewage. The water from which the deposits are taken is often black and offensive and gases of putrefaction rise in innumerable bubbles from the deposits at the bottom. During flood currents the sewage matters are driven back into the slips and in this quiet water some of the solid matters are deposited. On the outgoing tide grease and excreta are left adhering to the dock walls and piers. In the immediate vicinity of the outfalls the water is discolored and objectionable in appearance and odor. In some cases many acres are rendered turbid by the sewage.

Local Nuisances.—Extensive nuisances occur in this division at various points along the Brooklyn shores. Gowanus canal, Wallabout bay and Newtown creek are the most conspicuous. These bodies of water are actually large, although small in comparison with the great areas of the main divisions of the harbor. The condition of Gowanus canal, into which a 15-foot relief sewer as well as some eight other sewers ranging from 1½ to 6½ feet in diameter discharge, has been notorious for years. The water is black and foul-smelling at all times and the sides of the piers, bulkheads and masonry structures are coated with deposits. As a means of improving this canal, the Borough of Brooklyn has

constructed a flushing tunnel which leads from the head of the canal to an outlet in the Upper bay. Pumps force the water from the head of the canal through the tunnel., which is 6,270 feet long and 12 feet in diameter. The outlet is about 2 feet below low tide and is situated close to the shore between two long piers. The water in the vicinity of the outlet is strongly discolored when the pumps are in operation, the discharge from the tunnel being visible at times for a distance of more than a mile.

Wallabout bay in the Lower East river is polluted by a 9-foot sewer which discharges at the bulkhead line. The point of discharge is so protected from the tidal currents that a satisfactory dispersion of the sewage cannot take place. The bay is exceedingly offensive at all stages of tide, the bottom being covered with putrefying sewage sludge and the top with sewage apparently in an undiluted state. These objectionable conditions are in front of the New York Navy Yard.

Newtown creek, which empties into the Lower East river from a low-lying manufacturing district north of Brooklyn, is an offensive body of water. It supports a heavy traffic. Considerable quantities of manufacturing wastes are discharged into the creek from warehouses, elevators and factories, which line both banks. Some sewage empties into it, although the further pollution of this stream is prohibited by law. A 15-foot sewer, constructed through the joint action of the Boroughs of Brooklyn and Queens, empties into the head of Newtown creek and although this sewer was intended to accommodate storm water only, the dry weather flow being diverted, considerable pollution is ascribable to it.

There are no figures available to show the total cost of the sewers which exist in this division. It has been estimated that those of Manhattan exceeded $26,000,000, and it is believed that those of Brooklyn have cost about an equal sum. There are about 522 miles of sewers in Manhattan and about 814 miles of sewers in Brooklyn.

3.—Possibility That the Sewers of Manhattan Will Have To Be Rebuilt.

It has seemed to those charged with the duty of maintaining the sewers of Manhattan, as well as to consulting engineers who have been called upon to examine into the subject, that it would eventually be necessary to reconstruct a large part of the existing sewers of Manhattan.

The chief reason for reconstruction lies in the need of repairs and the harm done to the sewers from the building of underground structures of various kinds, as, for example, passenger subways, conduits for electric light, telephone

and telegraph and pipes for water, gas, steam and pneumatic mail service. As the city is entering upon extensive subway construction, it may be well to consider whether the interferences which now exist or are to be expected will not cause so much expense and make the sanitary removal of the sewage so difficult that a reconstruction of the sewers will be a practical necessity. If the sewers are to be rebuilt, this fact should be known and preparations for it made at once so that such saving as can be effected in the cost of temporary alterations can be accomplished.

Right of Way of Sewers.—Of all the many structures beneath the city's streets, it is most important that the sewers should have the right of way. Unlike pipes for water, gas or electricity, which operate under pressure, sewers, whose flow is due alone to gravity must be laid to proper grade and alignment or they will not operate properly.

To be self-cleansing, sewers should maintain a certain velocity of flow and any reduction in the grade which checks the velocity will lead to deposits. Short turns and bends and changes in the cross section also alter the flow and interfere with the proper function of the sewer.

When it is remembered that sewerage systems should be well designed and constructed; that they are built under the ground in a manner which is intended to be permanent and durable; that they cannot be altered in size, shape, grade or location without harmful consequences; that their function is to carry off promptly and completely the most offensive and dangerous wastes of a city, the claim of the sewerage system for right of way beneath the streets appears to be fully justified. That this claim has not been respected is a regrettable fact. In defiance of the officials charged with the duty of maintaining the sewers, they have been moved from place to place, pierced and damaged in many ways. Instead of being used for the purposes for which they were built, the sewers have been abused by the discharge into them of harmful manufacturing wastes, hot water and steam and been rendered dangerous for inspection by the illegal emptying of gasoline and other inflammable compounds.

The structures which interfere with the sewers are located at depths which range from that of the shallow conduits which carry the current for the surface railways to that of the passenger subways. The passenger subways form a serious obstruction. They are situated as close to the surface of the street as practicable in order to facilitate entrance and exit and they require over 20 feet of depth. For the most part, the subways, like the water, gas and other large mains run longtitudinally through the island and the sewers in seeking their outlets to the rivers run perpendicularly to them.

Interference from Subways.—The first subway for passengers was built on a line which divided the sewerage systems of Manhattan into approximately two equal groups, the subway following along the axis of the island for most of its length. The interference with the sewers was, in this case, as slight as possible, it being feasible to cause the sewage to flow in many instances with but little alteration of the sewers to a convenient point of discharge to one of the nearby rivers on the east or west side of the island. But other subways which have been designed will run in lines nearly parallel to the first and will divide the sewers further. There will be no easy readjustment possible, as in the first case, for there will be a central area which will be blocked off by the subways from the river on either side. In order to carry the sewage past these new subways, it will be necessary to make extensive reconstructions. It will be necessary to collect the sewage to more or less suitable points in the areas between the subway lines and then conduct it by siphons beneath the subway structure to points from which it can flow away by gravity. The alignment and grade of the sewers will, in many cases, be seriously interfered with. The siphons which should be capable of being emptied, inspected, repaired and cleaned, will be costly to build and, when of considerable depth, difficult to maintain. Sewage which now flows directly across the island will have to be diverted so as to run for considerable distances longitudinally, with the result that there will be a tendency to loss of velocity and formation of deposits in the drains.

Need of Repairs.—An important argument for reconstructing the sewers of Manhattan lies in the need for repairs. Inspections made by the Metropolitan Sewerage Commission have shown that some of the sewers, and especially the older ones, are in dangerous condition. Of 246 inspections, 38, or one-sixth, showed places where the sewers will have to be rebuilt within a few years on account of defective brick work alone. These locations exist along the whole length of the island. Of the 522 miles of existing sewers in Manhattan, 55 miles are seriously out of repair. To repair these, would involve an outlay which could more profitably be spent on new construction.

Separate vs. Combined System.—If the sewers were reconstructed, it is the opinion of many engineers that they should be built upon the separate system. Drains for storm water should be laid close to the surface of the streets and should be large and have ample grades to carry off much solid matter. When street washing, which is rapidly coming into favor, becomes general in the city, the quantity of grit and other solids to be removed by the sewers will increase. To a great extent the storm sewers should be made to carry off snow. Storm sewers should be built without catch basins at the street corners and should lead to central points where grit and other heavy materials can be

removed before the sewage is discharged into the harbor. The elimination of the 14,000 catch basins which now exist would be desirable.

Sewers for house drainage should be laid so far beneath the surface of the streets as to permit the sewage to flow into them by gravity. They should be sufficiently deep to pass clear of all other subterranean structures. The comparatively small size which the sewers for house sewage would require would permit them to be located, even in congested streets, so as to give good alignment and grade. The sewage would thus be more promptly carried away than under present circumstances. In general these sewers would run perpendicular to the subways, crossing under them and delivering at suitable places into interceptors for conveyance to sewage disposal works or pumping stations.

Objections Against Reconstruction.—The objections to the reconstruction of the sewers of Manhattan lie in the expense and inconvenience which the reconstruction would directly and indirectly entail upon the public. Almost all the streets of the city would require to be opened and the large quantities of earth and materials of construction would have to be handled without stopping vehicular traffic where the alterations were going on. The plumbing of over 150,000 houses would require to be altered so that the proper sewer connections could be made.

It is not clear how the storm water sewers, which should be laid close beneath the surface of the streets could escape the underground trolley conduits above, and the passenger subways beneath, in the longitudinal highways. There should be no siphons on these storm water drains.

Storm Water.—If the house sewage and storm water were collected separately, the disposal of the sewage would be facilitated, provided the storm water was not treated also.

It is not customary for cities to build works to treat all their storm water. The volume is so great, even when moderate falls of rain occur, that the works required to purify all the storm water would be excessively large and costly. There is, moreover, a general belief that the waste water from the roofs of houses and from the streets does not contain enough putrescible material to add materially to the pollution.

The literature relating to the treatment of storm water shows that experts generally consider that storm water from closely built-up cities is capable of producing at least as much offense as house sewage. There is reason for believing that the first flush of storm water is worse than even the relatively concentrated sewage of European cities, and that it is therefore desirable to treat a portion of the storm water.

European and American Sewage.—Much of the recorded information and opinion which exist with respect to the polluting effects of storm water is based upon European conditions, where the quantity of sewage at times of dry weather may amount to 20 or 30 gallons per capita per 24 hours. If the quantity of sewage in American cities is taken at 120 to 180 gallons per capita, it is evident that the argument for treating storm water has more weight in America than it has abroad, for if storm water is as bad as domestic sewage when the latter is concentrated to the extent of 20 or 30 gallons per capita per day, it must be about six times as bad when the domestic sewage is so dilute.

The aggregate weight of solid matter carried by storm water is very great. Analyses can be quoted which show that the percentage of suspended matter is several times as high in sewage containing storm water as it is in purely house sewage. This being so, and it being remembered that the volume of sewage is greatly increased at times of storm, it follows that the total amount of suspended matter carried by a given volume of storm water is much greater than the analyses indicate.

Numerous experts have expressed the opinion that careful attention should be given to the polluted character of the first flush of storm sewage. In the opinion of Samuel Rideal, whose familiarity with the chemical and biological composition of sewage and whose knowledge of current practice in England entitles him to be regarded as an authority, "whatever system be adopted, the raw storm water of populous districts should never be allowed to pass in large volumes at the beginning of a storm directly into a stream." Dr. Dunbar, Director of the Hygienic Institute at Hamburg, and an authority on sewage disposal on the Continent of Europe, as well as in England, says: "It must not be supposed that the contents of rain water sewers are in general not so polluted as ordinary sewage. In busy districts, the washings from the streets, even if these are thoroughly cleaned daily, are everywhere found to be worse in every respect, including putrescibility, than ordinary sewage." Dr. Houston, the celebrated English bacteriologist, says that storm water is as "potentially dangerous to health as normal crude sewage." To these opinions many more could be added to the same effect.

American Analyses.—There is scant information on record to show the composition of storm water in American cities, although some data are available to indicate the average composition of sewage containing the combined drainage of houses and streets. This information is not as valuable as it would be if it had been collected with the intention of showing the difference in composition which occurs in the sewage of a given city during dry weather and at periods of storm, but some facts exist with respect to this subject.

At a testing station, established at Gloversville, N. Y., at which analyses were made continuously for about one year, 1908-1909, the marked effect of storm water upon the dry-weather flow was shown in the following manner. Following a period of dry weather, rain fell for practically 24 hours on June 5 and the flow of sewage increased 31 per cent., although comparatively few storm-water drains were connected with the sewers. The storm water came chiefly from the roofs of houses and from the streets. The strength of the sewage increased as follows:*

Total suspended solids from 312 to 622 parts per million, or 166 per cent.
Volatile suspended matter from 196 to 254 parts per million, or 73 per cent.
Fixed suspended solids from 116 to 368 parts per million, or 324 per cent.

It is worth noting that the largest increase in suspended matter was due to non-volatile, fixed or mineral matter. This suggests that storm water is peculiarly susceptible of improvement by settlement, an inference which is not strictly correct, for the removal of mineral matter would not produce nearly as much benefit as the removal of organic or nitrogenous matter. A large part of the suspended matter is grit.

The average composition of the combined sewage of some American cities, as determined by numerous analyses made at investigating laboratories, is indicated in Table III.

TABLE III.—Composition of Sewage at Various Testing Stations.
(Parts per Million.)

	Suspended Solids.				Nitrogen as			Oxygen Consumed.			Cl.	Fat.
	Total.	Fixed.	Volatile.	Organic.	Free Am.	Nitrite.	Nitrate.	Total.	Sus.	Dis.		
1. Boston, 1903–5	....	.....	.....	.....	18.5	.19	.10	43.1	19.3	23.8	....	....
2. Boston, 1905–7	135	44	91	9.1	13.9	.00	.20	56.0	13.0	43.0	....	....
3. Columbus, 1904–5	209	130	79	9.0	11.0	.09	.20	51.0	25.0	26.0	65	25
4. Waterbury, 1905-6	165	50	115	14.8	7.8	.14	1.52	46.0	20.0	26.0	48	26
5. Gloversville, 1908-9	406	177	229	23.0	12.0	.38	.87	95.0	50.0	45.0	158	48
6. Philadelphia, 1909–10	189	59	130	6.3	4.0	.23	1.00	76.0	..	40.4	39	28

* Report to the City of Gloversville, N. Y., by Eddy and Vrooman, Aug. 7, 1909, p. 57.

In each of the investigations whose results are indicated in the foregoing table, an effort was made to obtain results which would be helpful in the design of works for the purification of the sewage. Certain peculiarities were thought to exist in the sewage to be dealt with which it was necessary to determine and the amenability of the sewage to purification was tested in each case.

It will be observed that the sewages tested at the experiment stations varied considerably in the amount and nature of the suspended matter, as well as in the dissolved impurities. If partial treatment only had been thought sufficient, it would not have been necessary to make the analyses so complete. So far as the general character of the average sewage dealt with is concerned, the figures given are satisfactory, but they should be employed with caution in forming an opinion as to the composition of the sewage of other cities where importance attaches to questions of detail.

Opinion With Respect to Manhattan and Brooklyn.—Should the house and storm sewage of Manhattan be collected in separate systems, it would be desirable certainly to treat all of the one and perhaps part of the other. This could not conveniently be done in the same plants. Should both house and storm sewage be collected by the combined system, the treatment works should be so designed as to deal with the dry-weather flow and have enough more capacity to take care of the heavily polluted water which would be washed from the streets and houses with the first flush of the rain. It would be well to have the capacity of the main sewers and disposal works equal to twice the average dry-weather flow.

4.—Quantity and Composition of the Sewage.

The quantity of the sewage produced in this division can be estimated from a knowledge of the water consumed and the rainfall. But few of the sewers have been gauged and exact measurements of their flow are not available. As compared with many cities, especially those of Europe, the volume of sewage is large and its composition variable. It is, for the most part, remarkably fresh when discharged, owing to the short distance, and consequently brief time, consumed in passing from the houses to the outfalls.

The conditions of residence and manufacture are various in this division and the sewage which reaches the outfalls is correspondingly variable. The quantity produced is different at different hours of the day and night; and it is not the same at all seasons of year. Owing to the fact that most of the sewers for some distance from the shores of the harbor are choked with tidal water, the sewage is often mixed with salt water before it is discharged. In some cases

the sewage is warm with the waste steam and hot water which is discharged from large office buildings, hotels and manufacturing establishments.

At times of rain much polluting water is washed from the streets. The quantity of this material is doubtless increasing, due to the more extended practice of washing the streets with water. After snow storms, snow is, to some extent, discharged into the sewers and with it more or less solid matter, which was either present on the pavements before the beginning of the storm or is thrown out after the snow begins to fall.

In the report of the Metropolitan Sewerage Commission, dated August, 1912, pp. 28-30, is given an estimate of the composition of the sewage and the quantities produced in various parts of the metropolitan district. The composition is based on an ideal sewage whose constituents are stated. It is shown that about 625 tons of fecal matter is discharged into the harbor every day. Assuming the population in the year 1910 to have been 6,423,635 for metropolitan New York and New Jersey, and supposing that 90 per cent. of this number were connected with the sewers, the total number of persons contributing to the pollution of the waters would have been 5,780,000. The aggregate quantity of polluting matter estimated as dry solid material which was discharged in the year 1910 would have been 266,000 tons. About one-half of this was capable of putrefaction or already advanced to some extent toward that condition when discharged.

Assuming one ton of dry suspended matter to be equivalent to about 45 tons or about 53 cubic yards of wet sludge, it appears that the population of the metropolitan district empties into the harbor each year the equivalent of 12,000,000 tons of sludge, having a bulk of about 14,000,000 cubic yards.

Data relative to the population and sewage flow in different parts of the metropolitan sewerage district, including the waters of this division, are given in Tables IV and V.

The Tables.—The eight divisions into which New York harbor has been separated for purposes of study have been described in the commission's report of August, 1912. To these is here added a ninth, to include the sewage which is naturally tributary to the Passaic and Hackensack rivers.

In preparing Table I, the dry weather flow of sewage discharged into each division has been assumed to be the same as the volume of the public water supplies of the areas tributary to the respective divisions. Where future quantities are considered, the sewage to be expected is in most cases based on the estimate of the authorities who are charged with the duty of providing the public water supplies. The populations for 1910 have been taken from the United States census reports; those for 1940 are based on carefully made estimates by this commission, revised with the latest information obtainable.

TABLE IV.—POPULATIONS AND VOLUMES OF SEWAGE DIRECTLY TRIBUTARY TO THE SEVERAL DIVISIONS OF THE HARBOR.

Division of the Harbor.	Sewage.	Year 1910.			Year 1940.		
		Sewage Mgd.*	Population.	Gals. per Capita per Day.	Sewage Mgd.*	Population.	Gals. per Capita per Day.
Harlem river.....	Manhattan....	70	522,000		156	960,000	
	Bronx.....	29	275,000		97	748,000	
		99	797,000	124	253	1,708,000	148
Hudson river.....	Manhattan....	98	726,000		238	1,470,000	
	New Jersey...	34	283,000		64	470,000	
		132	1,009,000	131	302	1,940,000	156
Upper East river.	Bronx.....	17	156,000		63	452,000	
	Queens.....	4	26,000		36	197,000	
		21	182,000	115	99	649,000	152
Lower East river.	Manhattan...	144	1,083,000		189	1,170,000	
	Queens.....	8	60,000		52	383,000	
	Brooklyn.. ..	94	915,000		213	1,670,000	
		264	2,058,000	120	454	3,223,000	141
Upper bay.....	.....	64	519,000	123	118	908,000	130
Newark bay.....	Bayonne.....	1.3	18,000		7.1	51,000	
	Jersey City....	0.8	6,000		1.1	8,000	
	Newark.....	10	67,000		18	115,000	
	Elizabeth.....	1	12,000		3.6	26,000	
		13	103,000	126	30	200,000	150
Kill van Kull.....	Bayonne.....	1.8	23,000		9	64,000	
	Richmond....	5	27,000		14	75,000	
		7	50,000	140	23	139,000	165
Jamaica bay.....	Brooklyn.....		270,000			619,000	
	Queens		81,000			290,000	
		53	351,000	151	163	909,000	180
Passaic and Hackensack rivers...	New Jersey...	130	950,000	137	349	1,900,000	184
Totals.....	.....	765	6,019,000	....	1,719	11,576,000	....

* Million gallons per 24 hours.

From Table IV it will be seen that the total quantity of house sewage tributary to the harbor in the year 1910 was 765,000,000 gallons per 24 hours, and the population supplying this sewage was 6,019,000. By 1940 the population will

be almost doubled and the quantity of sewage will be more than doubled. The sewage expected in 1940 in one day will be enough to fill a reservoir one square mile in area and 10 feet deep.

A glance at Table IV shows that a proportionate burden of pollution is not placed upon each division. The Lower East river receives much more sewage than any other division in comparison with its size. This will be true, also, in 1940, if nothing is done to prevent it. At that time over one-fourth of the total amount of sewage produced in the metropolitan district will be directly tributary to this stream. The increase which will go to this division from Brooklyn and Queens will be about half the quantity which was produced by Manhattan in 1910.

Table V has been made from data contained in the report of this Commission, dated August, 1912. Of particular interest are the suspended organic and volatile matters.

TABLE V.—Assumed Composition of the Sewage which is Tributary to the Harbor on the Basis of 100 Gallons per Capita per 24 Hours. The Quantities are expressed in parts by weight per million of water.

Solid Matters	800	Nitrogenous	150
Dissolved	500	Nitrogen	15
Suspended	300	Non-Nitrogenous	250
Organic and Volatile Matters	400	Fats, etc.	50
Dissolved	200	Total Carbon	200
Suspended	200		

5.—Impossibility of Disposing of All the Sewage Through Dilution With the Harbor Water.

The discharge of sewage into a natural body of water is properly termed disposal through dilution. Dilution aids in the disappearance of the sewage, but it is only one of a number of factors which must come into play before the solid and liquid ingredients can permanently disappear.

Oxidation Essential.—For the disposal of sewage to be permanent, it is necessary that the decomposable ingredients shall be transformed into other and simpler chemical compounds. These transformations involve physical, chemical and bacteriological reactions. The final and indispensable change is really one of combustion; oxygen is absorbed and the substances which were offensive, or likely to become so; are mineralized. In this state and by this process alone do they become inert and incapable of producing offense.

It is the aim of all processes of sewage purification to oxidize the decom-

posable ingredients or prepare them for oxidation. In the land treatment of sewage, the ingredients are oxidized near the surface of the ground. In sprinkling filters and contact beds, oxidation is accomplished by bringing the sewage into intimate contact with the air on the surface of broken stones. The effect of dilution is to bring the liquid and solid particles of the sewage into contact with the oxygen which is dissolved in the water. In all these processes the end is essentially the same. Oxidation is the object aimed at.

In treating sewage by disposal upon land, in filter beds or in water, the sewage should be freed from its gross suspended solids before it is subjected to the final oxidizing process and if this is properly done, there is likely to be little trouble so long as the quantity of oxygen is sufficient and time enough is afforded for the oxidizing process to become complete.

If the ratio of sewage to oxygen is too great, serious consequences follow and this is as true when sewage is discharged into water as when it is passed through filters or placed upon land. The evil effects include discoloration, the evolution of foul smelling gases and the production of slimy, semi-solid deposits. Land and filters in this condition are said to be sewage-sick and water is popularly called stagnant. The condition is one of putrefaction.

Putrefaction is decomposition in the absence of oxygen. It postpones, but cannot replace, oxidation. Oxidation must eventually take place and if it does not occur promptly and under conditions which are within control, it will occur under such conditions as may accidentally and ultimately offer.

The Supply of Oxygen.—The exact amount of oxygen which should be supplied to sewage in order that decomposition should proceed at the most rapid rate or, at least, at a reasonably rapid rate is probably not determinable. The action is essentially a biological and chemical process in which time and temperature are important factors. The organisms which carry it on must be provided with all the oxygen which they need. It is impossible for them to have too much.

Clean water generally holds a large amount of oxygen. One thousand volumes made up of half sea water and half land water, uncontaminated with sewage and without decomposing matters of any kind, should have at 65 degrees Fahrenheit, 6 volumes of oxygen per litre or about 8.6 parts per million by weight. The harbor water in this division usually contains from two-thirds to one-half of what it should possess. The oxygen that has disappeared is the measure of the organic pollution.

Dilution Required.—As a result of observation and experiment in various parts of the world, engineers have formed opinions as to the amount of sewage which can safely be discharged into a natural body of water, such as an inland

river or lake. The word safely here refers solely to the chance of producing a nuisance, chiefly odor. It has no relation to the effect which the sewage may have upon health.

According to the opinion of American engineers, the dilution must be in the proportion of at least 20 or 25 parts of water to one part of ordinary sewage and there may be conditions where a nuisance may result where the dilution amounts to nearly 50 parts of water to one part of sewage. When the proportion of sewage to water is greater than this, the capacity of the water is likely to be overtaxed. These supposedly safe ratios of dilution are based upon the assumption that the water with which the sewage is mixed is clean and possesses its normal amount of oxygen. Where the water is polluted to begin with the necessary dilution must be much greater.

In the Eighth Report of the Royal Commission on Sewage Disposal of Great Britain, issued at the end of 1912, it is recommended that where the dilution of sewage to water is between 150 and 200 times, the sewage should be purified so that the effluent will not contain more than 60 parts of suspended matter per million and that only when the dilution exceeds 500 times the volume of sewage should crude sewage be permitted to be discharged into a water course. These figures refer to English sewage, which is about 6 times as concentrated as American sewage, and to the water of inland rivers and lakes, but the Royal Commission holds the opinion that the proportions hold generally true for tidal waters also.

A glance at Tables VIII, IX and X of this report will show that the sewage in this division was not diluted with a proper amount of water in 1910, and will be still less adequately diluted in 1940 if measures are not taken to reduce the pollution.

It is worthy of note that the observations upon which American and English experts base their opinions have been made where sewage has been discharged into inland bodies of water. There has been no study of the discharge of sewage into tidal estuaries which would permit of safe ratios to be stated with positiveness for salt water. Such investigations as have been made indicate that sewage solids settle more rapidly in salt water than in land water, and it is believed that gallon for gallon, land water will dispose, in a normal manner, of more sewage than sea water.

It is not always clear how the dilution of sewage can be calculated in sea water. The same, or nearly the same, water often flows backward and forward for days near a sewer outfall, while the discharge of sewage is continuous. Under these circumstances the sewage flow is irregular and its calculation is involved in uncertainty.

Errors which may be made in such calculations include the assumption that:

(*a*) The assumption that the flow of sewage is uniform during the 24 hours. It may vary as much as 50 per cent. at different hours.

(*b*) The flow of tidal water is uniform. It is quite the reverse. Aside from the fact that the currents at each turn must gradually slow down to the stopping point and then gradually increase to the normal strength of flow, winds, heavy rain, snow and intense cold may each produce a decided effect upon the volume of water moving in a harbor.

(*c*) The sewage matters become immediately and thoroughly mixed with the waters. The opposite is the fact. Dispersion and diffusion are difficult to accomplish and consequently there are many kinds and degrees of stagnation.

(*d*) The sewage remains sewage after it is well mingled with the water. This is not true. Chemical changes at once set in.

(*e*) The waters into which the sewage is discharged are free from pollution to begin with. This assumption, however warranted in dealing with an inland river, is quite contrary to the fact as related to New York harbor.

The changes which sewage undergoes when it is discharged into a natural body of water should be carefully kept in mind, and the mistake, often made, of assuming that the sewage remains and can be reckoned with as sewage after admixture should be avoided. In no other way is it possible to obtain an accurate understanding of the subject. It is wrong to speak of sewage matters as sewage two or three hours after they have been discharged into a tidal estuary. Some of the original ingredients may still exist, but the chances are all against the continuance of any of them in an unaltered condition except the grosser solids and such others as may be able to persist in greatly diluted form.

Oxygen Required.—It is impossible to say with any useful degree of accuracy how many pounds of oxygen one million gallons of sewage will require in order that the putrefiable ingredients may be rendered inert. The two ways of approaching this subject, that is, by analysis and incubation tests, are, unfortunately, too artificial to show what can reasonably be expected in nature. Predictions as to the amount of oxygen which would be present if a given quantity of sewage was to be discharged into a given quantity of water must, in the present state of knowledge, be considered unreliable.

But if it is impossible to calculate the oxygen requirements of sewage or express in percentages the proportions of sewage to water which may be present throughout a harbor, it is feasible to state, in at least approximate terms, the relation which exists between the volume of sewage and the volume of water pres-

ent under various circumstances and such calculations may be of some value. They are likely to prove of greatest service when they are expressed in a simple way and are used with other data as a means of obtaining a general opinion of the case.

It was in this way, and with all the restrictions and qualifications which a knowledge of the situation imposed, that Prof. Adeney, in a report to the Metropolitan Sewerage Commission, calculated the dilution of sewage in New York harbor (See p. 95, Report Metropolitan Sewerage Commission, August, 1912).

Calculations of Dilution.—Taking his data from the published reports of the commission, Prof. Adeney calculated that about 59,400,000 cu. ft. of sewage flowed into the whole harbor during a tidal cycle of 12 lunar hours. Inasmuch as about 23 per cent. of the water of the harbor flowed out on the ebb tide, the same percentage of the contribution of sewage would flow to sea at the same time, leaving about 77 per cent. mixed with the harbor waters at mean low tide. The quantity of liquid sewage matters subsequently remaining within the harbor would increase with each succeeding tidal cycle until the quantity which passed out with the ebb tide became equal to that which drained into the harbor during the tidal cycle. This would occur when the total volume of liquid sewage, remaining intermixed with the harbor waters at mean low tide had become equal to about 195,500,000 cu. ft., which it would do after about 20 tidal cycles. The volume of liquid sewage matters passing out of the harbor through the Narrows would then continue to equal the volume of liquid sewage matters flowing into the harbor during a complete tidal cycle. That is, if 59,490,000 cu. ft. of sewage passed out of the harbor with each 12,310,000,000 cu. ft. of ebbing tide, the dilution of sewage to water would be in the proportion of 1 to 200 and the dilution to the liquid sewage matters remaining in the harbor at mean low tide would be in like proportion.

Both at the beginning and end of his calculation, Prof. Adeney took pains to fully explain that this calculation did not, as no calculation could, truly represent the facts.

In a report by Messrs. Black and Phelps, made to the Board of Estimate and Apportionment of New York in 1909, the question of dilution is dealt with at length, for it was believed to have an important bearing on the question of dissolved oxygen and the authors considered that the oxygen should not fall below 70 per cent. of the amount which would be present if the water was saturated with it.

The sources of the water in each principal part of the harbor were assumed

in accordance with volumes and velocities stated by the Coast and Geodetic Survey in 1886, and the proportion of water from each source was apportioned by the authors as, in their judgment, seemed correct. For convenience—these volumes were reduced to percentages of the whole and each was given a characteristic letter to facilitate computation. A series of equations was derived and the composition of the water of each part of the harbor was calculated for various tidal periods.

These studies were taken by the authors to indicate that the volume of pure sea water which entered the harbor between the Narrows and Throgs Neck every 12 hours was 29,135 million gallons and that this contained under summer conditions 1,946,218 pounds of dissolved oxygen. It was considered that if this oxygen were to be reduced by sewage to 70 per cent. of saturation, 583,865 pounds would be lost in 12 hours. The total volume of water in the harbor within the limits named was taken to be 251,418 million gallons, and it was stated that if this were reduced to 70 per cent. of saturation, it would absorb in 12 hours from the atmosphere 0.95 per cent. of its saturation value of 159,550 pounds.

The oxygen absorbed from the atmosphere plus the oxygen from the pure sea water would give a total of 743,415 pounds of oxygen. Finally, assuming that the sewage would be produced at the rate of 100 gallons per capita per day, the authors arrived at the opinion that the natural supply of oxygen would be sufficient to care for the sewage of a population of 7.4 millions, provided the sewage was discharged at the two ocean entrances.

6.—Ratios of Sewage to Water.

Some calculations of the ratios of sewage to water have been made by the Metropolitan Sewerage Commission which deal with comparatively small parts of the harbor and are consequently not greatly affected by the errors which are generally inseparable from such computations. But all calculations of this kind should be regarded as crude approximations of the truth.

There are three divisions of the water with which it is of interest to compare the sewage. First, the volume of water which is contained in the vicinity of an outlet at mean low tide; second, the volume of the tidal prism or quantity of water in the vicinity between the levels of low and high tide; third, the net ebb flow past the point where the sewage is emptied.

The Metropolitan Sewerage Commission has divided New York harbor into ten sections and the quantities of sewage which were discharged directly into these sections in 1910 have been estimated; the quantities of water in each section below mean low tide, in the tidal prism, and the net ebb flow through the section have

been computed and the ratio between the sewage and the water has been calculated. Calculations based on estimates of future quantities of sewage have also been made.

In addition to these computations, estimates have been made of the aggregate weight of sewage impurities which are tributary to each section. These calculations are based on a definite composition of the sewage which is assumed and taken to be uniform for the whole territory. The composition assumed is that of the standard sewage as shown in Table V. The volume of the sewage for the year 1910 is based upon the public water supply. The volume expected in future is also founded upon anticipations of the drinking water requirements. The per capita volume of sewage being stated, it will be possible at any time to correct the estimates of weight of impurities discharged into the harbor in case either the composition or volume of the sewage becomes known. It is improbable that such knowledge can be obtained until main drainage works are built.

It has seemed desirable to calculate the quantities of sewage materials which would be discharged into the various sections of the harbor in case the sewage was first passed through works for the more or less complete removal of the impurities. The processes of treatment which have been thought most worthy of consideration in this connection are such as have been well established by experience. Screens are considered because of their compactness and ability to operate with varying quantities of sewage and small head. Settling basins have been included because of their almost universal employment in sewage purification works and their efficiency in removing suspended matter. Chemical precipitation has been considered because it is one of the most efficient means for removing both suspended and dissolved matter at one process. Sprinkling filters have been included, since they represent the most effective means of oxidizing the sewage impurities in a given area of land. It would be feasible, and it is customary where a high degree of purification is required, to combine two or more of these processes in a given plant.

The least effective process which seems worth considering for the sewage which is to be discharged into the harbor is screening, and the highest degree of purification practicable in most cases in the territory where the sewage is produced is screening and rapid settlement. More purification than this would require a greater amount of land than is procurable except at great cost and involve probable nuisance from odors and flies.

Estimates of the quantities of sewage discharged into New York harbor shows that all sections do not receive an equal share of pollution; the analyses

of the water show that the circulation of the tide is insufficient to distribute satisfactorily the excessive burden which some sections receive. Some parts of the harbor are much more polluted than others, the region of greatest pollution being close to the most densely settled part of New York City. The Lower East river and Harlem receive large quantities of sewage from both shores.

TABLE VI.—VOLUMES OF WATER AT LOW TIDE, IN THE TIDAL PRISM AND THE NET DISCHARGE FROM THE SEVERAL DIVISIONS OF THE HARBOR. THE QUANTITIES ARE EXPRESSED AS MILLION CUBIC FEET.

Division of the Harbor.	Volume of Water Below Mean Low Tide.	Tidal Prism.	Net Ebb Flow in 12 Lunar Hours.
Harlem river	285	148	15
Hudson river, Battery to Mt. St. Vincent	12,330	1,697	1,087
Upper East river	5,512	1,869	....
Lower East river	4,174	552	100
Upper bay	12,970	2,541	1,283
Newark bay	1,542	1,071	105
Kill van Kull	728	150	88
Jamaica bay	2,029	1,977	....
	40,971	10,033	

Table VI was prepared partly from tidal data computed by this commission and partly from information supplied by the United States Coast and Geodetic Survey in 1909, as a result of studies which were made in response to this commission's request.

It will be seen from Table VI that the Upper bay contains more water at low tide, has a larger tidal prism and has a larger net discharge of water than has any other part of the harbor. The Hudson river is a close second in volume at low tide, but it has a smaller prism and net flow than the Upper bay. The tidal prism and volume of water at low tide are nearly the same in Jamaica bay and Newark bay, from which it appears that these bodies of water are almost half renewed at each tide.

In the Lower East river, the tidal prism is one-sixth the volume of water which lies beneath the level of mean low tide and the net ebb flow is about one twenty-seventh of it. Nowhere else in the metropolitan district is the net ebb flow so small in comparison with the tidal prism or volume of water at low tide. Large as is the volume of water in this division, it is evident that there is not a great deal of new water passing through it. In the Harlem also, the

tidal prism is large and the net ebb flow small when compared with the volume of water at mean low tide. From these figures, it appears that such refreshing action as the Lower East river and Harlem river receive is due to diffusion with cleaner water at the two ends of these streams and that little renewal occurs by actual displacement with water from a neighboring section. Large though the Lower East river seems to be and swift as are its currents, it has only one-tenth as much net ebb flow as the Hudson.

To facilitate computations which will be described later, the quantities of sewage discharged into the several divisions of the harbor have been converted from gallons per 24 hours to cubic feet per 12 lunar hours. The results are recorded in Table VII.

TABLE VII.—Volume of Sewage Directly Tributary to the Several Divisions of the Harbor.

Division of the Harbor.	Directly Tributary Million Cu. Ft. per 12 Lunar Hours.	
	Year 1910.	Year 1940.
Harlem river	6.9	17.5
Hudson river	9.2	20 9
Upper East river	1.5	6.9
Lower East river	17.1	31.5
Upper bay	4.4	8 2
Newark bay	0.9	2 1
Kill van Kull	0.5	1.6
Jamaica bay	3.7	11.3

TABLE VIII.—Ratios of the Volume of Sewage Directly Tributary per 12 Lunar Hours to the Volume of Water in the Harbor at Mean Low Tide. The Quantities Given are in Millions of Cubic Feet.

Division of the Harbor.	Water in the Division.	Sewage Tributary to the Division.			
		Year 1910.		Year 1940.	
		Volume.	Ratio.	Volume.	Ratio.
Harlem river	285	6.9	1:41	17.5	1:16
Hudson river	12,330	9.2	1:1350	20.9	1:590
Upper East river	5,512	1.5	1:3675	6.9	1:799
Lower East river	4,174	17.1	1:244	31.5	1:132
Upper bay	12,970	4.4	1:2920	8.2	1:1580
Newark bay	1,542	0.9	1:1680	2.1	1:740
Kill van Kull	728	0.5	1:1470	1.6	1:460
Jamaica bay	2,029	3.7	1:550	11.3	1:180
	39,570	44.2	1:896	100	1:396

Table VIII which is prepared from data contained in Tables VI and VII emphasizes the proportionately heavy sewage burden which is now, and in future would be, placed upon the Lower East river. The ratio of sewage to water at mean low tide which was 1 to 244 in 1910 would be 1 to 132 by 1940. A notably low ratio is that of the Kill van Kull which was 1 to 1470 in 1910 and would be 1 to 460 by 1940. This body of water received much of its pollution from neighboring bodies of water. The pollution of Newark bay will increase by direct contributions of sewage until the ratio which was 1 to 1680 in 1910 will be 1 to 740 by 1940 unless measures are taken to keep the sewage out of it.

TABLE IX.—Ratios of the Volume of Sewage Directly Tributary to the Volume of Water in the Tidal Prism. The Quantities Given are in Millions of Cubic Feet.

Division of the Harbor.	Water in the Prism.	Sewage Tributary to the Division.			
		Year 1910.		Year 1940.	
		Volume.	Ratio.	Volume.	Ratio.
Harlem river	148	6.9	1 : 21.4	17.5	1 : 8.5
Hudson river	1,697	9.2	1 : 185	20.9	1 : 81
Upper East river	1,869	1.5	1 : 1246	6.9	1 : 271
Lower East river	552	17.1	1 : 323	31.5	1 : 17.5
Upper bay	2,541	4.4	1 : 570	8.2	1 : 310
Newark bay	1,071	0 9	1 : 1170	2.1	1 : 510
Kill van Kull	150	0.5	1 : 300	1 6	1 : 94
Jamaica bay	1,977	3 7	1 : 540	11.3	1 : 175
	10,105	44.2	1 : 229	100 0	1 : 101

Table IX has been prepared from Tables VI and VII and shows the remarkably small ratios which exist between the sewage and tidal prism in most of the divisions of the harbor. The smallest ratio occurs in the Harlem, 1 to 21.4, although the Lower East river, 1 to 32.3, is very low for the year 1910. In 1940 the tidal prism will be only 8½ times the volume of sewage discharged directly into the Harlem and in the Lower East river only 17½ times the quantity of sewage received.

Unlike the ratio of sewage to water below mean low tide, the relation of sewage to the tidal prism is comparatively large in Newark bay and will be considerable in 1940. This division of the harbor, which was comparable with the

Lower East river in Table VIII, resembles the Hudson river, where the pollution is, and probably will remain, large.

The quantities of water passing through each division in their relation to the volume of sewage directly discharged are shown by Table X, which was prepared from Tables VI and VII.

TABLE X.—RATIO OF THE VOLUME OF SEWAGE DIRECTLY TRIBUTARY PER 12 LUNAR HOURS TO THE NET EBB FLOW. THE QUANTITIES GIVEN ARE IN MILLIONS OF CUBIC FEET.

Division of the Harbor.	Net Ebb Flow.	Sewage Tributary to the Division.			
		Year 1910.		Year 1940.	
		Volume.	Ratio	Volume.	Ratio.
Harlem river	15	6.9	1 : 2.2	17.5	1 : 0.85
Hudson river	1,087	9.2	1 : 119	20.9	1 : 52
Upper East river	.....	1.5	.....	6.9	.....
Lower East river	100	17.1	1 : 5.9	31.5	1 : 3.2
Upper bay	1,283	4.4	1 : 288	8.2	1 : 156
Newark bay	105	0.9	1 : 114	2.1	1 : 50
Kill von Kull	88	0.5	1 : 178	1.6	1 : 55
Jamaica bay	24	3.7	1 : 6.5	11.3	1 : 2.1
	2,702	44.2	1 : 61	100 0	1 : 27

The small amount of dilution from the net ebb flow which the sewage which was discharged into the Lower East river received in 1910 and will receive in 1940 is even more graphically indicated in this table than in its predecessors. By 1940 there will be more sewage discharged into the Harlem than there will be tidal water passing through that stream. There will be about three times as much tidal water as sewage passing out of the Lower East river. The Hudson river and Upper New York bay alone seem to be comparatively well supplied with water available for flushing purposes.

Table XI shows the number of tons of the various constituents of the sewage based on the composition shown on Page 18, and the volume shown on Page 27. It will be seen that in every important respect, the Lower East river receives a greater weight of contaminating matters than does any other division of the harbor, irrespective of its size. Next comes the Hudson river, followed by the Harlem. The total weight of sewage materials discharged into the Kill van Kull

and Newark bay is small as compared with the quantities of polluting matters discharged into the Lower East river.

TABLE XI.—SOLID, ORGANIC AND VOLATILE MATTERS CONTAINED IN THE SEWAGE DIRECTLY TRIBUTARY TO THE SEVERAL DIVISIONS OF THE HARBOR. THE QUANTITIES ARE EXPRESSED AS TONS OF 2,000 LBS. PER 12 LUNAR HOURS.

Division of the Harbor.	Year.	Suspended Solid Matters.	ORGANIC AND VOLATILE MATTERS.					
			Total.	Dissolved.	Suspended.	Nitrogenous.	Fat, etc.	Carbon.
Harlem river..	1910	52	70	35	35	26	9	35
	1940	111	148	74	74	56	18	74
Hudson river..	1910	65	87	43	44	33	11	43
	1940	126	168	84	84	63	21	84
Upper East river..	1910	12	16	8	8	6	2	8
	1940	43	57	29	28	21	7	29
Lower East river..	1910	133	178	89	89	67	22	89
	1940	209	279	139	140	105	35	139
Upper bay.....	1910	34	45	23	22	17	6	23
	1940	59	79	40	39	30	10	40
Newark bay...	1910	7	9	4	5	3	1	4
	1940	13	18	9	9	7	2	9
Kill van Kull..	1910	3	4	2	2	2	0.6	2
	1940	9	12	6	6	4	2	6
Jamaica bay...	1910	23	30	15	15	11	4	15
	1940	59	79	39	40	30	10	39
Total.....	1910	329	439	219	220	165	55.6	219
	1940	629	840	420	420	318	105	420

Table XII, which has been prepared from Table V and VII, shows the weight of sewage ingredients which will be discharged into the harbor in 1910 and 1940, assuming that the sewage is first passed through certain forms of treatment with the object of removing impurities. The efficiency of the treatment employed has been assumed as follows: The screens remove 15% of suspended matter and 10% of organic matter; sedimentation 60% of suspended matter and 30% of organic matter; chemical precipitation 85% of suspended matter and 50% of organic matter; sprinkling filters 90% of suspended matter and 70% of organic matter.

It will be observed that the use of any of these processes would be beneficial, but that the residue to be discharged after screening or sedimentation would still leave very large quantities of polluting matter to go into the water.

Chemical precipitation and the use of sprinkling filters would probably furnish all the relief needed for as many years as can now be anticipated. As has been shown elsewhere in this report, however, these latter processes are not applicable unless the sewage is carried to some point far removed from its present source for treatment.

TABLE XII.—SUSPENDED AND ORGANIC MATTERS WHICH WOULD BE CONTAINED IN THE SEWAGE DIRECTLY TRIBUTARY TO THE SEVERAL DIVISIONS OF THE HARBOR AFTER TREATMENT. THE QUANTITIES GIVEN ARE IN TONS PER 12 LUNAR HOURS.

Division of the Harbor.	Year.	Crude Sewage.		Sewage After Treatment.							
				Screens.		Sedimentation.		Chemical Precipitation.		Sprinkling Filters.	
		Sus.	Org.	Sus.	Org.	Sus.	Org.	Sus.	Org.	Sus.	Org.
Harlem river	1910	52	70	44	63	21	49	7.8	35	5.2	21
	1940	111	148	94	153	44	104	16.6	74	11.1	44
Hudson river	1910	65	87	55	78	26	61	9.8	44	6.5	26
	1940	126	168	107	151	50	118	18.9	84	12.6	50
Upper East river	1910	12	16	10	14	5	11	1.8	8	1.2	5
	1940	43	57	37	51	17	40	6.4	28	4.3	17
Lower East river	1910	133	178	113	160	53	125	20.0	89	13.3	53
	1940	209	279	178	251	84	195	31.4	140	20.9	84
Upper bay	1910	34	45	29	40	14	32	5.1	22	3.4	13
	1940	59	79	50	71	24	55	8.8	39	5.9	24
Newark bay	1910	7	9	6	8	3	6	1.0	4	0.7	3
	1940	13	18	11	16	5	13	2.0	9	1.3	5
Kill van Kull	1910	3	4	3	4	1	3	0.5	2	0.3	1
	1940	9	12	8	11	4	8	1.4	6	0.9	4
Jamaica bay	1910	23	30	20	27	9	21	3.4	15	2.3	9
	1940	59	79	50	71	24	55	8.8	40	5.9	24
Total	1910	329	439	280	394	132	308	49.4	219	32 9	131
	1940	629	840	535	755	252	568	94.3	420	62.9	252

7.—Possible Methods of Sewage Treatment.

Early studies made by this commission indicated that excluding from the harbor as much sewage matter as practicable from those parts of Queens, Richmond, Brooklyn and the Bronx which are tributary to the Upper East river and Upper and Lower New York bays, by the employment of local purification works, the water of the inner harbor would be able to assimilate the sewage from those parts of Manhattan and Brooklyn which were closely built up and where sites could not readily be obtained for the construction of purification works of high efficiency. In this belief plans were begun for collecting the sewage of the Bronx,

Queens and Richmond and gathering it to a number of conveniently located central points for treatment.

Two immediate objects were to be attained by these plans. First, the harbor water in those divisions where the works were located was to be kept clean, and, second, the water was to be protected to such an extent as to insure to the inner harbor the largest assimilative capacity practicable.

As the plans progressed, it became evident that a high degree of purification could not be obtained for as much of the sewage as had been expected. To remove a large proportion of the putrescible material from sewage requires works which could not always be situated where engineering considerations alone would have placed them. In such cases land must be procurable at a price which does not unduly increase the first cost of the project. Of equal importance, it is necessary to locate such works in positions where the odors produced will not injure property to such an extent as to give owners of surrounding land valid claims against the city for damages.

Odors from Efficient Processes.—It is needless to deny that all processes of sewage purification cause smells. The fact should plainly be faced that in the removal the ingredients of sewage which are capable of causing the water into which the sewage is discharged to become offensive, objectionable odors may be produced at the works. The danger of nuisance depends partly upon the degree of thoroughness with which the impurities are removed and partly upon the likelihood that the property holders in the vicinity will find the odors seriously objectionable. There are localities in the City of New York and vicinity where objectionable odors are continually produced by manufacturing establishments with little or no complaint from property holders. But these situations are not usually well placed for sewage disposal plants, and it is doubtful if the city would be justified in adding to these odors even if it became otherwise desirable to construct sewage works there. Manufacturing plants which are objectionable, such as slaughter-houses, bone-boiling establishments and fertilizer factories, usually have to move further and further away, as the cities in which they are located grow. Nuisances of this kind become increasingly objectionable as time proceeds, for more and more people become affected and the public becomes increasingly fastidious.

Such strong and offensive odors as are produced by so-called offensive trades are not likely to be produced by sewage works, but the difference is sometimes not great, and the erroneous belief that sewage odors are in some way connected with disease, if not actually a cause of it, adds greatly to the objectionableness of sewage purification plants in any locality.

A convenient and economical location for sewage works is hampered by the uncertainty that they will be permanent. Unlike some manufacturing plants, they cannot well be moved in case they produce a nuisance. If they are objectionable at first, they are likely to become more so with the passage of time. Owing to the protest with which a proposal to build a municipal plant for the thorough treatment of sewage probably would be received in almost any part of New York City, this commission has felt compelled to confine its plans largely to works of the simplest character or carry the sewage to a distant point for disposal.

In the selection of sites, considerable difficulty has been experienced because of the changing character of many localities. Few parts of New York are permanently constructed. Solidly built-up sections are constantly changing from residence to business occupancy. Suburban districts are rapidly becoming urban, and rural territory is being converted to suburban uses. Each change increases the value of the land. The most rapid developments, and the most uncertain, are sometimes in the very localities where it would be most convenient to build sewage disposal works. Here unimproved property, even farm land, is not infrequently held at a high valuation in the expectation that a strong demand for real estate may set in at any time.

Owing to the facts here mentioned, this commission has not found it feasible to design works which would purify the sewage tributary from the outlying territory to a high degree, and the water which will reach the inner harbor will consequently not have as great a capacity for assimilating sewage as theoretically it should possess.

What is here said as to the nature of the works which it has been feasible to design for Queens, Richmond and the Bronx applies with greater force to the Lower Hudson, Lower East River and Bay Division. The aggregate volume of sewage produced in this division is now great, and thirty years hence will be about double what it is today. Such treatment as it is practicable to accomplish within the territory where this sewage is produced will remove only a small proportion of the ingredients which are capable of reducing the amount of oxygen in the water into which the effluent is discharged. Sprinkling filters, contact beds, sedimentation basins and chemical precipitation plants cannot be considered for want of land and because of the odors which such works would produce.

The forms of treatment which could be best employed on the shores of Manhattan and Brooklyn would be such as could be carried on with grit chambers and screens.

Grit Chambers and Screens.—In some respects grit chambers and screens are well suited to the conditions. Beside being compact, they produce little odor; they can be located partly below ground; they require no extra pumping; they are comparatively inexpensive to operate; they can be employed without highly skillful supervision, and it is practicable to have many plants of moderate capacity. Against them is chiefly the criticism that they remove only the largest particles of sewage matter and leave the dissolved organic matter and finely divided putrescible materials to pass to the harbor. Notwithstanding this fact, they would serve usefully in attaining the standard of cleanness which the Metropolitan Sewerage Commission has proposed for the water, particularly as respects requirements Nos. 1 and 3 of the standard. This standard follows:*

1. Garbage, offal or solid matter recognizable as of sewage origin shall not be visible in any of the harbor waters.

2. Marked discoloration or turbidity, due to sewage or trade wastes, effervescence, oily sleek, odor or deposits, shall not occur except perhaps in the immediate vicinity of sewer outfalls, and then only to such an extent and in such places as may be permitted by the authority having jurisdiction over the sanitary condition of the harbor.

3. The discharge of sewage shall not materially contribute to the formation of deposits injurious to navigation.

4. Except in the immediate vicinity of docks and piers and sewer outfalls, the dissolved oxygen in the water shall not fall below 3.0 cubic centimeters per litre of water.†

† With 60 per cent. of sea water and 40 per cent. of land water and at the extreme summer temperature of 80 degrees F., 3.0 cubic centimeters of oxygen per litre corresponds to 58 per cent. of saturation.

Near docks and piers there should always be sufficient oxygen in the water to prevent nuisance from odors.

5. The quality of the water at points suitable for bathing and oyster culture should conform substantially as to bacterial purity to a drinking water standard. It is not practicable to maintain so high a standard in any part of the harbor north of the Narrows or in the Arthur Kill. In the Lower bay and elsewhere, bathing and the taking of shellfish cannot be considered free from danger of disease within a mile of a sewer outfall.

Inasmuch as grit chambers and screens seem to afford the best practicable means available for treating the sewage of Manhattan and Brooklyn locally, it is desirable to consider in some detail how such works would be constructed, how many plants would be required, about where they should be built, what they might cost and how much improvement they would accomplish. In studying these questions, two chief considerations have appeared to be important. First, the outlets from the works should be so built that the treated sewage will be promptly and thoroughly diffused, and, Second, the plants should be so located as to permit the sewage to be collected to them without unnecessary difficulty or expense.

Submerged Outfalls.—Owing to the incompleteness of the purification, and the necessity of complying with requirement No. 2 of the Standard of Cleanness,

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*Report Metropolitan Sewerage Commission of New York, August, 1912, page 70.

it would be necessary to discharge the effluent from the plants in such a way as to produce the most immediate disappearance of the sewage which is possible. For this purpose, it is desirable that the outfalls should be near or upon the bottom and be so located that ample and strong currents will sweep by them.

The construction and maintenance of outlets at the bottom of the tidal channels some distance from shore would be difficult. The outlets would have to be so built as to meet all the requirements of the United States Government which has supervision over the maintenance of the channels for the purposes of navigation.

Locations for Outlets.—Bearing in mind the difficulties of construction and maintenance, as well as the advantages of carefully selected places, a number of points have been chosen along the shores of Manhattan and Brooklyn where the sewage, after treatment, could with the greatest advantage be discharged.

The facility with which the sewage could be collected to suitable points for treatment was taken carefully into consideration in selecting the points of outfall. It was thought desirable that the sewage should require the least amount of pumping possible; that the plants should not have to be placed too far below tide level and that the greatest possible normal flow of sewage should be gathered to each plant.

Considerable care has been taken in the designs to make an economical use of land, to provide for adequate inspection and repair, not only of the apparatus, but of the structure itself, to insure light and ventilation and to facilitate the cleaning of the basins and screens and the removal of the impurities from the plant. Numerous forms of grit chambers have been designed and studied. Every form of screen which the experience of other cities had proved reliable and efficient have been considered with the result that the type employed in the new works at Hamburg, Germany, was chosen as the most suitable for these works.

8.—Plan for the Disposal of the Sewage of this Division.

Investigation having shown that it will be impossible to discharge all the sewage into the water in the vicinity of the territory where it is produced, even after such purification as is practicable, it becomes necessary to consider where it can be taken and what can be done with it.

Amount of Sewage to be Taken Away.—It will not be worth while to take a small amount of sewage from the inner harbor. To accomplish much benefit, the volume will have to be large both actually and in relation to the total quantity produced in this division. If possible, it should be taken from a part of the harbor

which needs relief both on its own account and because of its influence on adjoining sections. As far as practicable, the sewage should be collected from a region of dense population in order that the length of the sewers shall be no greater than necessary. For the same reason the distance from the central point of collection to the point of disposal should be as short as possible.

This report shows that the greatest burden of pollution which is placed upon any large portion of the harbor is discharged from Manhattan and Brooklyn into the Lower East river. Here within a distance of 4 miles, about 200,000,000 gallons of sewage are discharged every 24 hours from about 50 outlets located along the crowded shores. Not only is the volume of sewage large, but, as shown elsewhere in this report, the waters are peculiarly unsuited to receive it.

If this polluting material can be removed, the waters in the immediate vicinity will be improved and the excessive burden of pollution now put upon the whole inner harbor will be relieved. An improvement of the waters of the Lower East river is desirable for the help it will give in disposing of the sewage which, in accordance with the commission's plans already announced, will be brought to Ward's Island.* At Ward's Island the large quantity of sewage which will be brought from the Harlem river will be passed through settling tanks and discharged into the deep waters of Hell Gate, and reliance must be placed upon the digestive capacity of the waters to oxidize the liquid organic matters.

If 200,000,000 gallons of sewage per day can be kept out of the Lower East river, the ratio of sewage to water in that section will improve sufficiently to meet all requirements of this commission's standard of cleanness for the present. The ratios of water to sewage which will exist in the Lower East river are given in Table XIII.

TABLE XIII.—RATIOS OF SEWAGE TO WATER IN THE LOWER EAST RIVER, IF 200,000,000 GALLONS OF SEWAGE PER DAY ARE KEPT OUT OF THESE WATERS.

Year.	Sewage to water at Low Tide.	Sewage to Tidal Prism.	Sewage to Net Ebb Flow.
1910.	1 to 1090	1 to 204	1 to 30
1940.....	1 to 178	1 to 33	1 to 5.6

Direction in which to Take the Sewage.—There are not many directions in which the sewage can be taken. It would be impracticable to carry it north into Westchester County, for the land there lies at too great an elevation. It

*Preliminary Report IV. Study of the Collection and Disposal of the Sewage of the Upper East River and Harlem Division, July, 1912.

would be impossible to carry it west because the people of New Jersey would object to receiving it. The idea of discharging it into the Hudson river cannot be entertained, for if this were done that stream would become too heavily polluted. Sentimental considerations require that the Hudson shall not be made a receptacle for the sewage from other parts of the harbor.

It would not be feasible to carry the sewage to Long Island sound; the distance would be too great, the volume of water there available would be insufficient, the danger of polluting extensive shellfish beds would be large, and the risk of contaminating the shores in the vicinity of villages, towns and country estates too imminent.

The sewage could not be taken east on Long Island, except to a distance of 30 or 40 miles, for its disposal would be certain to produce nuisance and, consequently, serious injury to property already occupied for residence purposes or likely soon to become valuable for this purpose. Furthermore, opportunities for the disposal of the effluent of treatment works are lacking on Long Island, the north shore of which is deeply indented with bays and, for the most part, high and rocky, and the south shore bordered with broad, shallow bays and marshy islands, where the flow of tidal water is relatively slight.

Staten Island Not Suitable for Very Large Sewage Works.—To the southwest of this division lies the Borough of Richmond, or Staten Island, and much sewage could be brought there for treatment as far as engineering considerations are concerned. There are several thousand acres of marshy land on the west side of this island bordering the Arthur Kill which might be employed for sewage disposal, provided no nuisance was produced.

The sewage could be taken to the disposal works by a tunnel which could be driven beneath the waters of Upper New York bay to the north shore of Staten Island, and thence through the high land to the low-lying area near the Arthur Kill. The Arthur Kill has been dredged for the convenience of ships and could receive a well purified effluent, although owing to its small volume of flow and the oscillating effect of the tide, the capacity of the Arthur Kill for unpurified sewage is comparatively small. If the sewage could not be purified sufficiently to discharge the effluent into the Arthur Kill, it would have to be carried by tunnel eastward from the treatment works to the waters of Lower New York bay.

It is probable that treatment works capable of purifying the sewage to such an extent as would permit the effluent to be discharged into the Arthur Kill would be impracticable on Staten Island. Apparently some oxidizing process, either sprinkling filters or possibly contact beds, would have to be employed.

It is probable that if either of these processes were used to treat the quantity of sewage which would have to be dealt with, not less than 200,000,000 gallons per 24 hours, with a certainty of more later on, objectionable sanitary conditions would be produced. The sewage would be septic and, consequently, likely to produce odor when brought into contact with the air either in the fine spray necessary in sprinkling filters or in the large areas of surface exposed by the broken stone of contact beds. The likelihood of trouble from flies, a frequent and annoying feature in sewage works, should also be considered. The peculiar mist which sometimes hovers in calm weather over extensive areas of sprinkling filters would prove a source of grave concern to property holders, even at a considerable distance from the works. Before the authorities of the Borough of Richmond would give their consent to receiving the sewage of this division in that borough for disposal, it is probable that they would insist upon more assurance of immunity from nuisance than safely could be given.

Added to the sanitary difficulties which would attach to the disposal of the sewage by works upon Staten Island is the consideration of cost. It would be expensive to carry the sewage of this division to Staten Island and there dispose of it. The tunnels would be long and, in places, very deep. The foundations for the works on the lowlands in the western part of Staten Island might prove difficult of construction. The outlet tunnel for the effluent would be long and costly.

Objections to Collection at Barren Island.—Two other possible means of disposing of the sewage of this division remain to be considered. First, collection to the vicinity of Barren Island, near the mouth of Jamaica bay, and treatment there, with a discharge of the effluent at sea. Sanitary considerations, such as have been mentioned in connection with the possibility of carrying the sewage to Staten Island, would weigh heavily against purifying the sewage any more completely than is absolutely necessary at this point. The outlet would therefore have to be long enough to carry the sewage far from shore.

Unless the sewage was purified in bacteria beds, it would be necessary to extend the outlet some miles out to sea beyond Rockaway Point in order to make sure that the sewage would not be carried back to the land by the wind and tide, and there are practical difficulties in the way of doing this. The necessary tunnel for this purpose would be very difficult to construct. It would have to be at least 75 feet below the surface of the water, in order to cross well beneath the deep, swiftly-flowing channels of Rockaway inlet. The water at this point is between 30 and 40 feet deep at low tide. Proceeding seaward it would not be found desirable to approach much nearer the surface with it. The point of out-

fall should probably be located about 2 miles from shore. This would be an unfavorable location for an outlet crib or other permanent structure, for it would be exposed to the full force of the Atlantic ocean and the shifting sands. This project thus has weighty arguments against it.

Advantages of Disposal at Sea.—The sewage from the Lower East river section can be taken directly to the sea, and this is the plan which the commission recommends. In accordance with this plan, central collecting points will be established which will be tributary to a general central station, to which latter point will be gathered such part of the sewage as needs to be carried to a distance. Pumps will be located at the central station and from it a main will run directly to an outfall island to be built about 3 miles from land on a sandy reef. This reef is one of a series of shallow areas, interspersed with channels, which once formed the bar to New York harbor. It lies slightly to the west of an imaginary line between Sandy Hook and Rockaway Point. The outfall will be about 13 miles from the New York City Hall, 6 miles from the Narrows, over 4 miles from Sandy Hook and about 3 miles from Coney Island. The point selected for this island is shown in Plate I, following page 48.

As much sewage as it is necessary to carry to a distance from the Lower East river, Hudson and Bay Division can be taken to the island for disposal. As time proceeds and the quantity of sewage increases, the main sewer can be duplicated and the provisions for treating and discharging the sewage at the island can be enlarged.

A large part of the sewage of this division is now discharged into the waters of the Lower East river. If this sewage is taken away for disposal, it will for some time be possible to discharge the sewage from the rest of the division with no other treatment than screening and passage through grit chambers. The water of the Hudson will be capable of assimilating the sewage produced on the west side of Manhattan Island and the water of the Upper bay could take the sewage produced along the Brooklyn water front from Governor's Island southward.

All the sewage from this division, except that part which is taken away, should be passed through grit chambers and screens and, where feasible, the dry weather flow discharged through submerged outlets. In course of time, if the quantity of sewage from this division, as well as from that part of the Upper East river and Harlem Division which would be concentrated at Ward's Island, increases to such an extent as again to place an excessive burden upon the waters of the East river, the sewers can be extended and finally the Ward's Island works can be connected with a main sewer to the artificial island for disposal.

The plan of relieving the harbor of its heaviest burden by at once taking to sea a large part of the sewage which flows to the Lower East river and increasing the scope and magnitude of the work as necessity arises, appears to this commission to be a necessary and sufficient solution of the problem. In no other way can the sewage be disposed of with so little chance of danger or offense. The project has the advantages that it will afford, at minimum expense, all the relief that is needed for the present and is capable of expansion in the future.

There are no shellfish industries in the vicinity and no currents which would carry any of the sewage to a bathing beach. The sewage will not be exposed long enough to the air to cause annoying odors to be given off and there will be no opportunity for flies to breed.

The plan is in accordance with the best engineering precedent. There is no feature connected with it which is untried or experimental. It avoids offensive, complicated and uncertain processes of purification. It is based upon a careful consideration of the needs of the whole harbor. It leaves the waters of the inner harbor in a sufficiently improved condition for the assimilation of such sewage as cannot be kept out of the waters without wellnigh prohibitive expense.

Ultimate Digestion by the Sea Water.—The project for carrying a part of the sewage to sea contemplates the treatment of the sewage at the island and the ultimate digestion of the liquid organic matter of the sewage by the sea water. Responsibility for the disposal of the sewage cannot cease until all the ingredients are rendered harmless and inert. It is important that the sewage shall not flow from the outlets as a coherent mass and that none of its elements shall be carried to the inner harbor or find their way, under the influence of wind or tide, to the shore. Accumulations of solid matter injurious to navigation must not be permitted to occur, nor must odors or flies or other objectionable features too commonly associated with sewage disposal works exist to mar the natural attractiveness and healthfulness of that part of the ocean where the outlet is located.

The liquid sewage matters will have a strong avidity for oxygen and will be rendered inert by the oxygen-saturated sea water with which it comes in contact. The great amount of water available at the point of outfall will have an abundant capacity to digest the liquid sewage.

At first the form of treatment needed at the island will be settlement in tanks perhaps aided at times by precipitants. In addition, it may be practicable to disinfect the sewage and produce a considerable amount of oxidation by the addition of bleach or electrolytically produced hypochlorite.

If at any time in the future it becomes desirable to completely purify the sewage, no such favorable location for the necessary works can be found in the

metropolitan district than this artificial island. Owing to the shallowness of the water and the ease with which filling can be obtained, land can be made here for less money than an equal area can be bought on shore at any point not more distant from the New York City Hall.

In addition to the sewage from the Lower East river section, it will ultimately be feasible and desirable to send the sewage of the western Jamaica bay sub-division to the island for disposal. This would make it unnecessary to construct treatment works at Barren Island as proposed in an earlier report of this commission.*

9.—Collecting the Sewage to the Outlet Island.

Sub-division of the Territory.—The territory included in the Lower Hudson, Lower East River and Bay Division has been separated by this commission into 32 sub-divisions for the purpose of laying out the works which will be necessary for the sanitary disposal of the sewage, and each sub-division has been given a number. The sub-divisions numbered 1 to 12, inclusive, comprise that part of Manhattan which is naturally tributary to the Hudson river. Sub-divisions from 13 to 26 are in Manhattan and Brooklyn, bordering upon the Lower East river. Sub-divisions 27 to 31 are in Brooklyn and border on the Upper bay. Sub-division 32 borders on the Narrows and Gravesend bay.

The sub-divisions vary in size and in the quantity of sewage which they produce. The boundaries which have been approximately established are intended to show the limits within which it will be feasible to collect the sewage to a central point on the water front in each sub-division. The central points are usually near existing large sewers and, as often as practicable, at places which are favorable for a prompt admixture of the sewage effluent with the harbor water.

As stated elsewhere in this report, the dry-weather flow of sewage, after collection to a central point in most of the sub-divisions, should be passed through grit chambers and screens and so discharged into the water as to insure prompt diffusion.

The dry-weather flow of sewage produced in the six following sub-divisions bordering upon the Lower East river should not be discharged into the neighboring waters, but should be gathered to a central point and thence carried to sea: In Manhattan, 13, 14 and 15, and in Brooklyn, 24, 25 and 26.

The method of collection in those sub-divisions from which the sewage is to be carried to a distance may or may not be the same as in those sub-divisions from which the sewage will be discharged into the neighboring waters. There

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*See Preliminary Report III.

are various ways in which the sewage can be collected. One method may be described by way of illustration.

The dry-weather sewage can be collected by marginal sewers to a central point in each sub-division and there passed through grit chambers and screens. Passing beneath each central collecting point will be a deep-lying intercepting sewer which will receive the sewage after it passes through the screens and grit chambers. Storm water in excess of twice the dry-weather flow will pass by overflows at each outlet directly to the river. Further details of this plan follow.

The Necessary Marginal Sewers and Interceptors.—Each central collecting point will have storm overflows, regulators and tide gates so arranged as to discharge directly into the neighboring waters the excess flow of sewage during periods of rainfall. The interceptors are intended to be large enough to accommodate twice the mean rate of flow during periods of dry weather. The maximum rate of dry weather flow is assumed to be about one and one-half the average rate per 24 hours. This will permit the interceptor to carry off some of the first flush of storm water even if it reaches the plant during the hour of maximum sewage production.

The marginal sewers required to collect the sewage from the present sewers to the central points in each sub-division will lie as close to the surface of the ground as physical conditions permit.

The interceptors will be situated at a considerable depth and be so located as to avoid as far as possible difficulties of construction. It will probably be necessary to construct the interceptors by shield tunneling. In making the plans and estimates, careful attention has been given to the information available concerning the geology of the territory passed through as determined by borings made by the Public Service Commission, Board of Water Supply and others.

The Manhattan Lower East Side Sub-divisions.—The interceptor from sub-division 13 will run from a screening plant situated near Roosevelt St. parallel to the shore to Corlears Hook, where the sewage will empty into a siphon and be carried to Brooklyn. This South Manhattan interceptor will be 5′ 9″ in diameter.

A second interceptor, which may be termed the North Manhattan interceptor, will run from East 14th St. southerly to a siphon to Brooklyn which begins at Corlears Hook. The size of the North Manhattan interceptor will be 9′ 6″ from the screening plant for sub-division 15 to the screening plant for sub-division 14 at DeLancey Slip, where it will increase to 10′ 10″ in diameter before joining the siphon. The North Manhattan interceptor will be large

enough to permit an extension to be made in it, so as to take in the sewage of sub-divisions 16, 17 and 18 in course of time. Profiles of the Manhattan marginal sewers and interceptors are shown on Plate II, following page 48.

The total quantity of sewage to be taken from sub-divisions 13, 14 and 15 is estimated at 99,000,000 gallons per 24 hours in the year 1915. The estimated population for the same year is 680,500, and the area from which the dry-weather flow will be taken is 1,737 acres.

The Siphon from Manhattan to Brooklyn.—A siphon will be required to carry the sewage from Manhattan to Brooklyn beneath the lower East river. The point selected for the crossing is at a narrow part of the river where solid rock may be anticipated. The siphon which will be required to take the sewage produced in 1915 should have a diameter of 8′ 9″. The depth will be 110 feet beneath the surface of mean low water. The siphon will be 2,300 feet long and extend from Corlears Hook to South 8th St. When the North Manhattan interceptor is extended so as to take the sewage from sub-divisions 16, 17 and 18, it will be necessary to build a second siphon. This can be laid parallel to the first. It is desirable that the siphons needed at first shall not be too large, in order that the velocity of flow may be sufficient to prevent deposits taking place. The velocities considered suitable for the first siphon range between 2 and 5 feet per second.

The Brooklyn North Western Sub-divisions.—That part of Brooklyn which will be tributary to the main sewer to the sea will be treated in a way similar to that described for collecting the sewage from the lower east side of Manhattan. The quantity of sewage to be taken from this part of Brooklyn will be a little larger than the quantity from Manhattan, or about 104,000,000 gallons per 24 hours in 1915. The estimated population tributary in Brooklyn will be slightly larger, or 732,313, and the net area more than three times as large, or 5,790 acres.

The siphons from Manhattan will empty into an interceptor on the Brooklyn shore which will run from a central collecting point at South 5th St. for sub-division 24 to a general pumping station at Wallabout St., near the head of Wallabout canal. This interceptor will be 5′ 3″ in diameter before meeting the siphon and 10′ 3″ from the junction with the siphon to the pumping station. This may be termed the North Brooklyn interceptor. In course of time, if it becomes necessary to bring the sewage of sub-divisions 19, 20, 21, 22 and 23 to the general pumping station, this can be done by running another interceptor to the central collecting points in those sub-divisions. It appears to be unnecessary to make further provision for the future at the present time.

From sub-division 26 in Brooklyn, which is opposite the lower end of Manhattan, an interceptor should be built to the general pumping station. The central collecting point in sub-division 26 will be near Adams Street and the interceptor leading therefrom should be 4′ in diameter. This is estimated to be of sufficient size to take the flow from sub-division 27 in the future. At Hudson Street, this interceptor would receive the sewage collected from sub-division 25. Running around the Brooklyn Navy Yard, this South Brooklyn interceptor should have a diameter of 9′ 6″ to the general pumping station. Profiles of the Brooklyn marginal sewers and interceptors are shown on Plate III, following page 48.

The General Pumping Station.—The sewage collected at the general pumping station, amounting to about 200,000,000 gallons a day, will have been passed through grit chambers and screens and will be in reasonably fresh condition. It will all flow to this point by gravity. The pumps will be required to raise the sewage from an elevation of about 27 below mean tide and pump it under a head of about 45 feet to the artificial island at sea. The distance to be pumped will be about 11.8 miles and the head to be overcome will be that which is necessary in order to raise the sewage from the level at which it is delivered to the pumps to the level of the tanks where it is to be treated on the island, plus the head required to overcome the frictional resistance offered to the passage of the sewage through the long main. The pumps can be operated by steam, oil or by purchased electric current. It would seem feasible and desirable to drive the pumps with electric power to be obtained from burning the solid refuse of the city in destructors, as is commonly done in England and in certain large cities of Europe.

The Sewage Main to Sea.—The force main through which the sewage will be pumped to the island will be built, for the most part, in tunnel. There will be three shafts, so situated as to permit the work of construction being pushed with expedition and economy. The internal diameter of the completed main will be 12′ 10″ from the pumps to a point near Sheepshead bay, where it will be increased to 14′ in order to accommodate the sewage from the western part of the Jamaica Bay Division. A profile of the outfall main is shown on Plate IV, following page 48.

The estimates given below are based upon the work already outlined, but since the sewage main will pass comparatively near Jamaica bay, it may be desirable to modify the plan which this commission proposed for the Jamaica Bay Division* to such an extent as to permit the main to take to the island the sewage which it has been proposed to collect from Brooklyn to Barren Island for treat-

*Preliminary Report III, November, 1911.

ment and disposal. The advantages to be gained by this change are (a) reduction in cost over the Barren Island project and (b) avoidance of the necessity of constructing a sewage disposal plant at the entrance of Jamaica bay. By adding the sewage of the western Jamaica bay sub-division to the sewage of Manhattan and Brooklyn which is pumped to the island, the disposal works will be centralized and questions of administration and maintenance will be simplified.

The Western Jamaica Bay Sub-division.—The sewage from the western part of the Jamaica Bay Division will be collected at two central pumping stations, one at Hendrix Street and the other at Flatlands Avenue. From the eastern pumping station, an interceptor 9′ to 9′ 6″ in diameter will extend for 2.6 miles to a second pumping station at Flatlands Avenue. From this point the interceptor, enlarged to 11′ 4″ in diameter, then 11′ 8″ and finally to 12′ in diameter will extend to Nostrand, where it will be joined by a small interceptor of 27 inches from the present sewage disposal works for Sheepshead bay which will be converted into a pumping station. The interceptor enlarged to 12′ 4″ will end at a pumping station to be located at Ocean Parkway and Avenue W. This last pumping station will discharge the sewage into the main which runs to the island.

A pumping station to be located at 86th Street and Avenue V in Bensonhurst will discharge through a 4′ interceptor to the pumping station which will serve the western part of the Jamaica Bay Division. The sewage of Coney Island will be pumped from the present plant known as Caisson No. 3 directly to the main sewer.

The quantity of sewage from the western part of Jamaica bay will be about 47,000,000 gallons per day in 1915. The population will be about 343,000 and the area served 19,000 acres.

The Artificial Island.—The tunnel to the island will be 14′ in diameter and constructed at a depth of about 60 feet, the material to be penetrated being sand. It will be possible to construct the tunnel with two headings, one from the shore and one from the island, the two meeting and being properly joined.

The point selected for the island has been carefully chosen with reference to economy of construction, resistance to the destructive influences of tidal currents and storms, freedom of obstruction to the free flow of tidal water in and out of the harbor and absence of sanitary objections.

The location lies to the north of Sandy Hook and to the south of Coney Island. Its position is latitude 40 degrees 31½ minutes and longitude 73 degrees 58½ minutes. The water within a mile from the island in all directions varies between 7 and 40 feet in depth, the average being about 20 feet at mean low tide.

The plan of the island is approximately rectangular, the seaward side being rounded. The area at the start will be about 20 acres. This can be extended as required. The general plan of the island is shown on Plate V, following page 48.

The outer face of the island will be a wall of rip rap composed of large pieces of broken stone carried to the site on boats and laid upon the hard sandy bottom. It is expected that some settlement will occur, due to the water cutting sand away from under the stone. When sufficient rip rap has been placed to stop this action of the water, no more settlement is to be expected. The main bulk of the island will be composed of sand supplied from a suction dredge, which will take its supply from the bottom of the sea in the vicinity.

The height of the island above mean low water will be about 18 feet. The length will be 1,300 feet and the width 1,000 feet. The side of the rip rap wall which is exposed to the sea will have a slope of 1 vertical upon 3 horizontal and the other sides will have a slope of about 1 on 2. The cost of constructing the island has been estimated at about $615,000.

The landward side of the island will be provided with a quay wall for the accommodation of vessels engaged in taking supplies and other materials to and from the island. Shelter from the sea will be provided by a breakwater, which will enclose a small harbor.

The island will contain a plant of settling tanks in which the sewage will have an opportunity to deposit its solid matters during a period of about two hours. These tanks will be of modified Dortmund tank construction, similar to those recently constructed at Toronto, Canada. Provision will be made for treating the sewage if necessary with a coagulant before passing it into the tanks.

After treatment, the sewage will be discharged through a number of outlets arranged radially on the seaward side of the island. If desirable, it will be feasible to pump sea water into the sewage and provide for the mixture of the two before the discharge takes place. Such admixture would facilitate the immediate diffusion of the sewage in the sea water, but the active agitation and free movement of the great volume of water in the vicinity of the island will probably make the preliminary admixture of sea water and sewage by pumping unnecessary.

The material which settle out in the tanks will be carried to sea in boats and dumped.

Cost.—This project will require the construction of about 5.3 miles of marginal sewers in Manhattan and Brooklyn and about an equal length of interceptors in these two boroughs. The siphon from Manhattan to Brooklyn will be a little less than a half mile long. The main from the pumping station

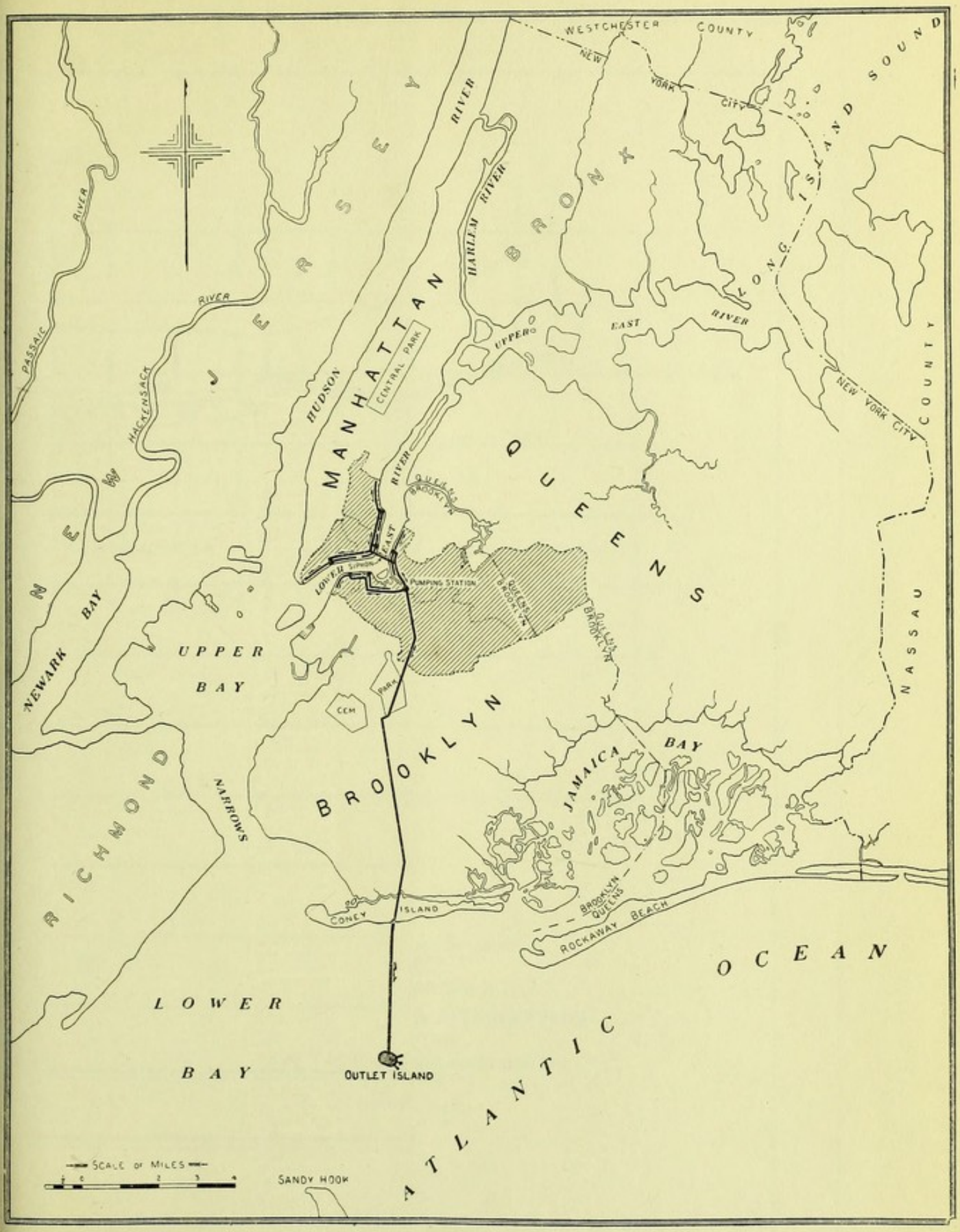
to the island will be about 13 miles long. If the Jamaica bay sewage is brought to the island, about 2 miles of collectors and 7 miles of interceptors will be required in addition.

The studies which have been made indicate that the total cost of construction would be about $22,874,000, including $4,072,000 for the Jamaica Bay Division. The fixed charges, including sinking fund and interest, would be about $1,157,000, allowing $206,000 for the Jamaica Bay Division. The total maintenance and fixed charges would amount to about $1,803,000, including $286,000 chargeable to the Jamaica Bay Division.

METROPOLITAN SEWERAGE COMMISSION.

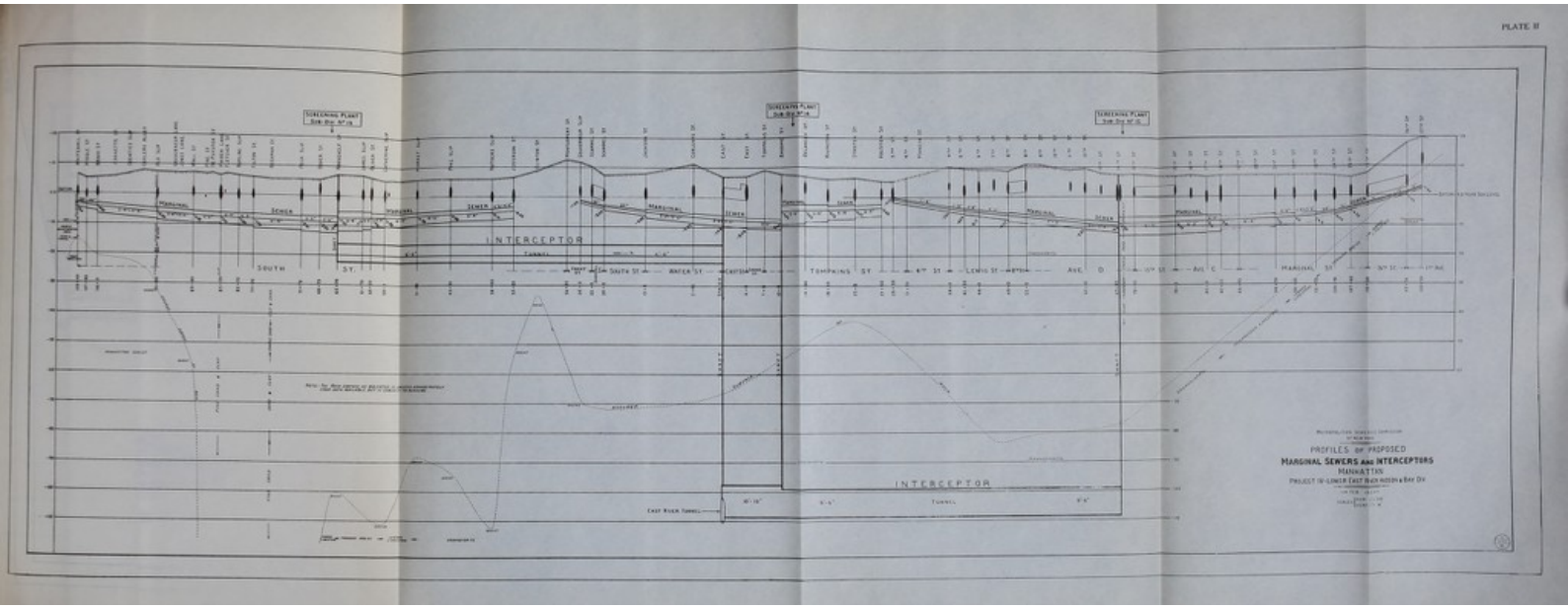
GEORGE A. SOPER,
JAMES H. FUERTES,
H. DE B. PARSONS,
CHARLES SOOYSMITH,
LINSLY R. WILLIAMS.

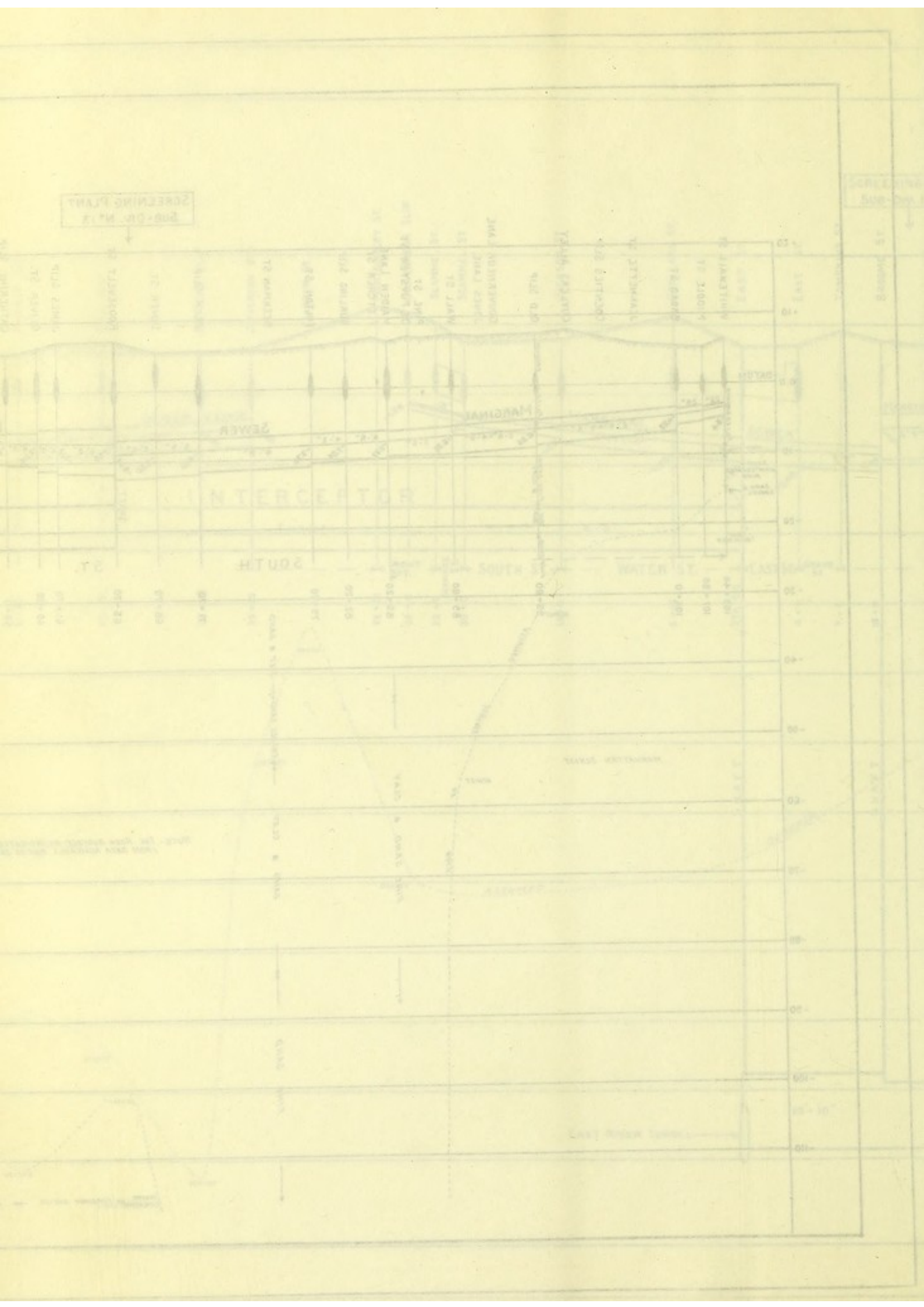
FEBRUARY, 1913.

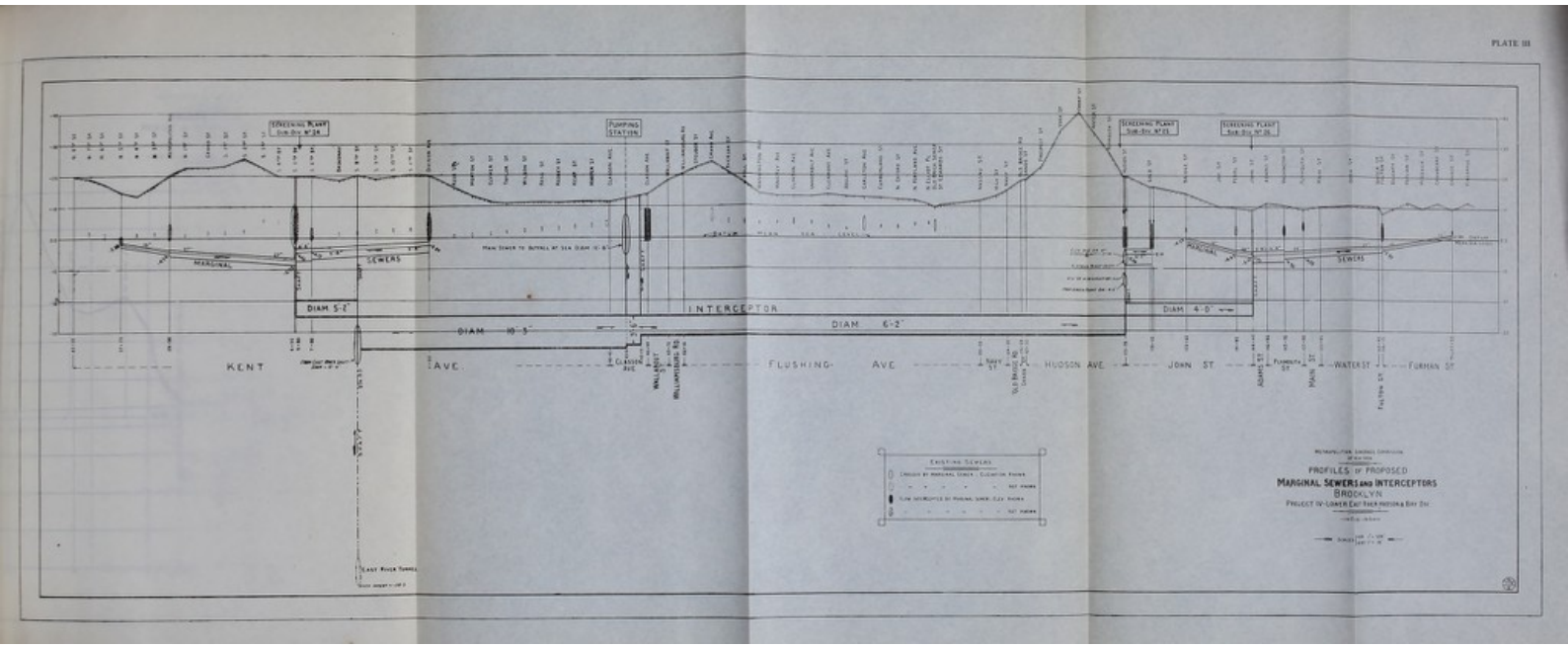


PROJECT FOR THE RELIEF OF THE LOWER EAST RIVER
AGAINST EXCESSIVE POLLUTION

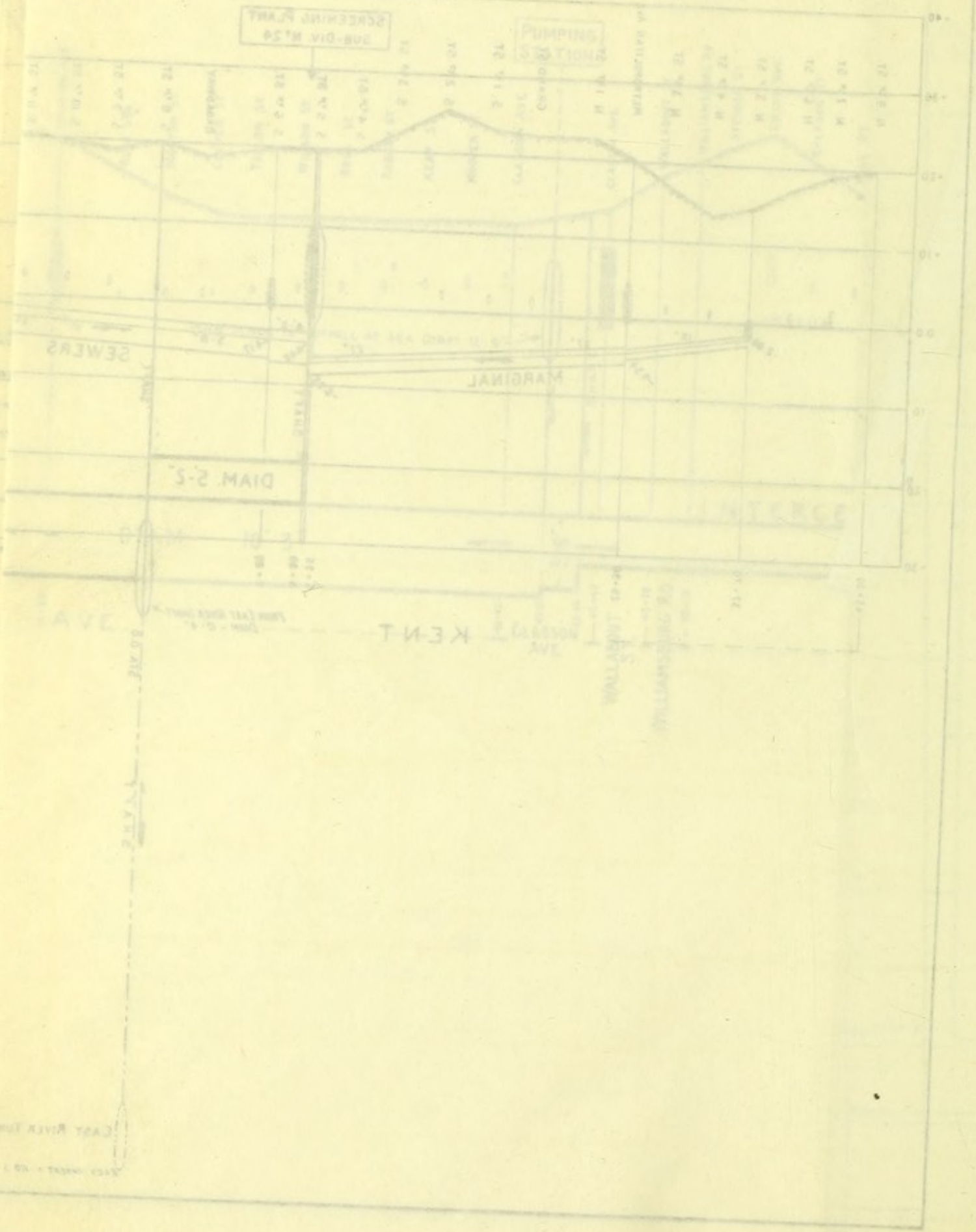
PLATE III

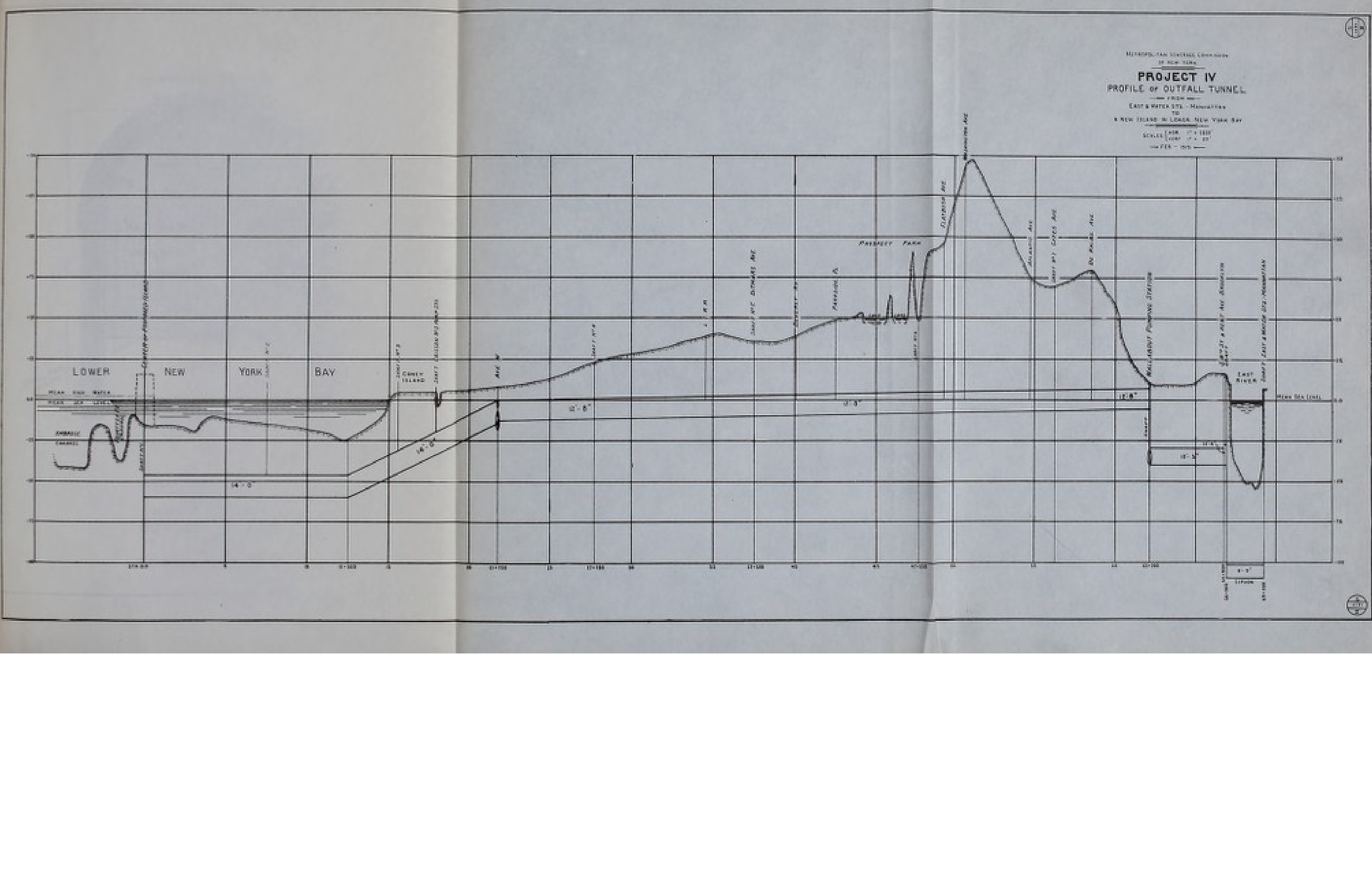

SCREENING PLANT
SCREENING PLANT
SCREENING PLANT
INTERCEPTOR
SOUTH ST.
WATER ST.
TOMPKINS ST.
AVE. D
AVE. C
MARGINAL ST.
INTERCEPTOR
EAST RIVER TUNNEL
PROFILES OF PROPOSED
MARGINAL SEWERS AND INTERCEPTORS
MANHATTAN

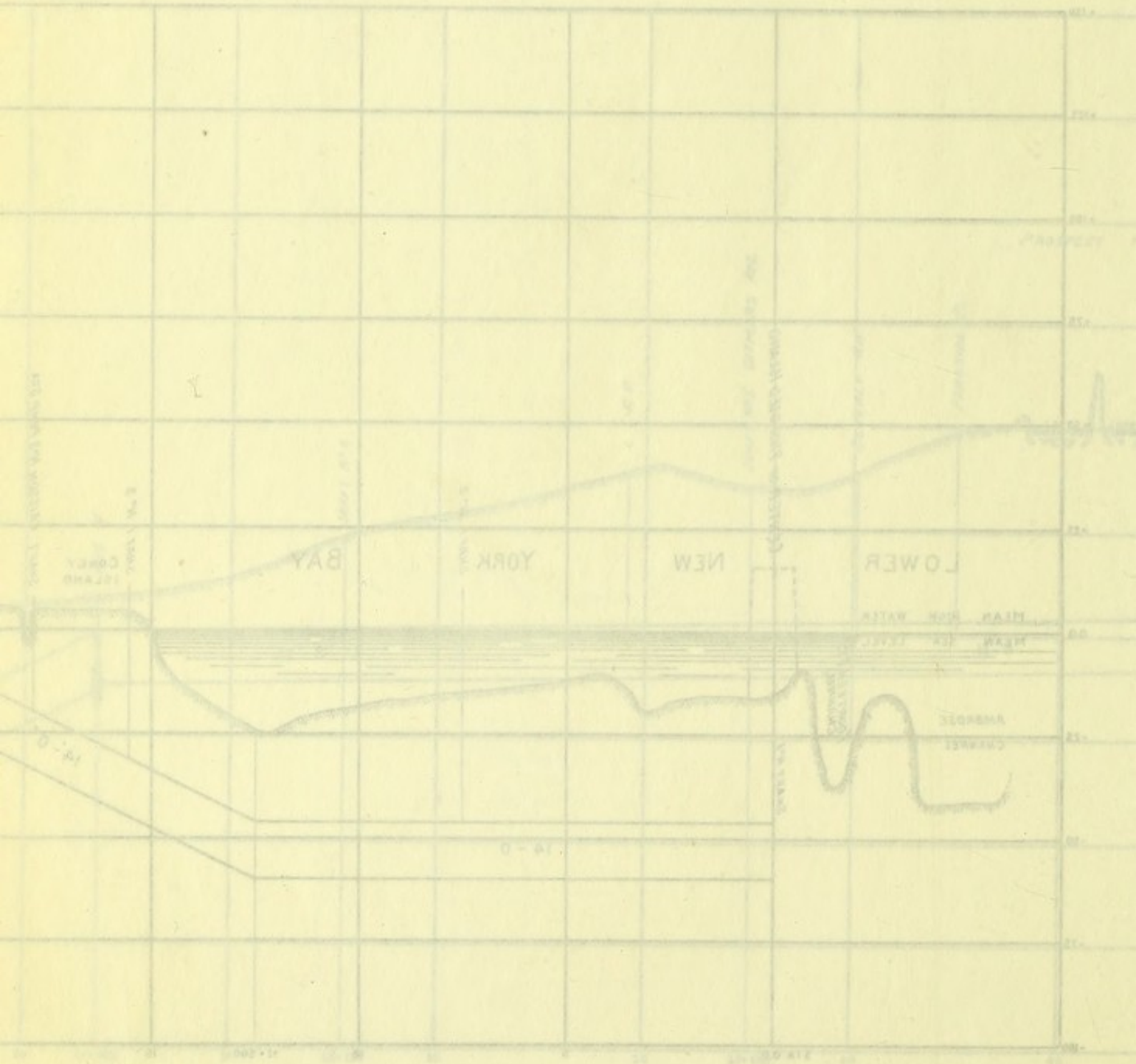


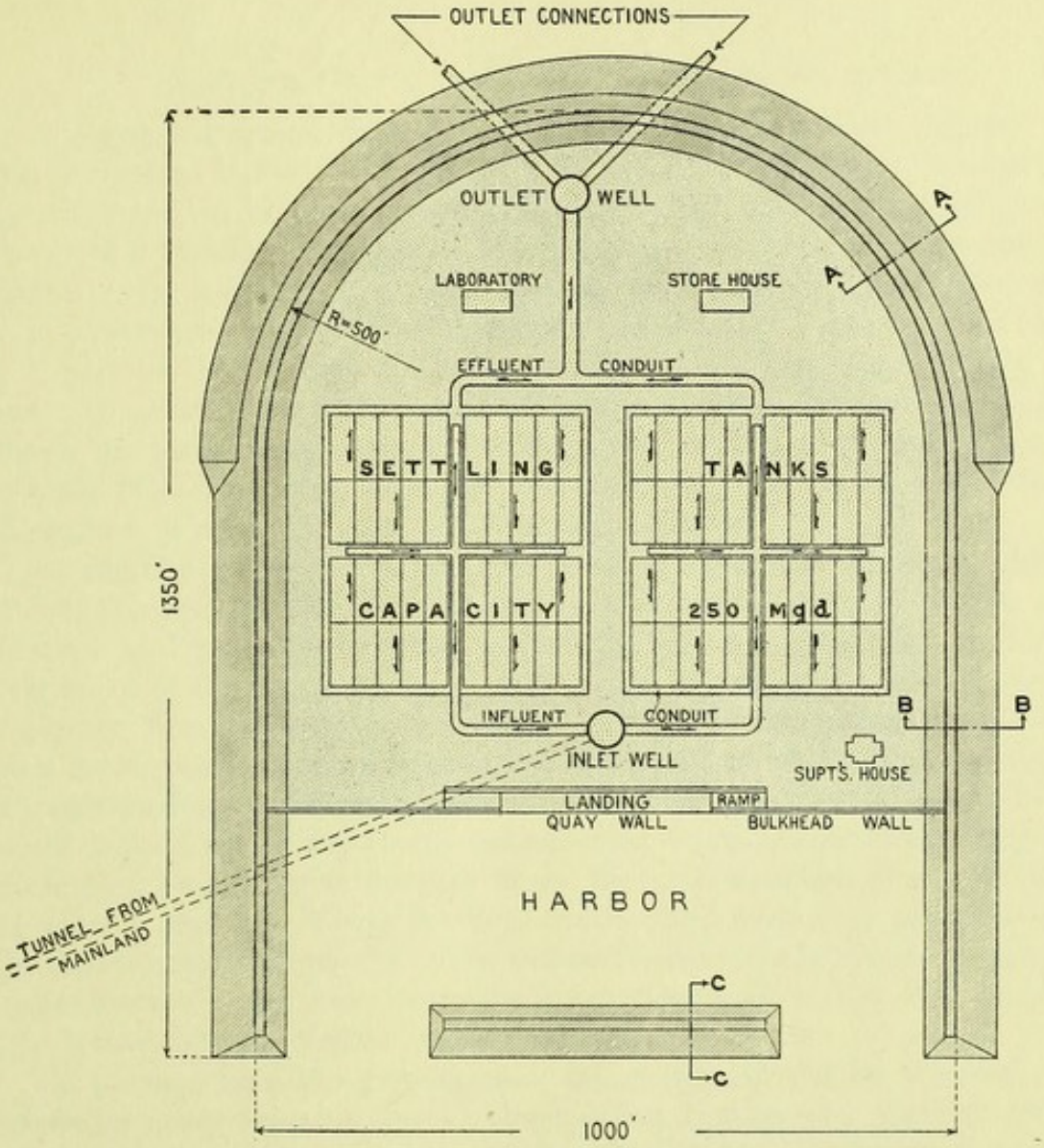


PROFILES OF PROPOSED
MARGINAL SEWERS and INTERCEPTORS
BROOKLYN




METROPOLITAN SEWERAGE COMMISSION
OF NEW YORK
PROJECT IV
PROFILE OF OUTFALL TUNNEL
FROM
EAST & WATER STS. - MANHATTAN
TO
NEW ISLAND IN LOWER NEW YORK BAY
LOWER NEW YORK BAY
MEAN HIGH WATER
MEAN SEA LEVEL
AMBROSE CHANNEL
CONEY ISLAND
14'-0"
12'-8"
PROSPECT PARK
FLATBUSH AVE.
WASHINGTON AVE.
ATLANTIC AVE.
DE KALB AVE.
WALLABOUT PUMPING STATION
EAST RIVER
MEAN SEA LEVEL
SIPHON





METROPOLITAN SEWERAGE COMMISSION
OF NEW YORK

PLAN OF PROPOSED
OUTLET ISLAND

SCALE OF FEET
100 50 0 100 200 300 400 500

APPENDICES.

I.

Studies for Grit Chambers, Screens and Regulators.

The grit and screen chambers could be constructed, beneath the level of the street pavements, but in all cases it would be desirable, and in some instances probably necessary, to provide a super-structure. All the plants would be small and where a building over them was necessary, it could be made architecturally unobtrusive in appearance. If the sewage were collected by a combined system of sewerage, the plant would require to be provided with means for separating a part of the storm water and the latter could discharge directly to the water. It would be feasible to pass three times the dry weather flow of sewage through the plant during periods of storm, and if this were done the worst of the water from the streets would be provided for in the works. A study for a grit chamber is shown in Plate VI, following page 52.

In addition to the provisions for avoiding an excess of storm water, the principal features of the plants would be a grit chamber and screens, pumps, tide gates and submerged outfalls. The grit chamber would be essentially an enlargement of the sewer and be of such design as to provide for the slowing of the sewage flow as much as practicable. A prominent feature should be the means for cleaning out the grit and other solid matters which would be deposited. Elaborate methods for cleaning grit chambers are employed in some European sewage disposal works, but simple and effective dredging apparatus appears to be preferable. The material dredged from the grit chamber should be dumped into suitable carriers. These carriers, which could also carry away the screenings would operate electrically. They should convey the materials to some dock or pier where a vessel could carry the impurities to sea or the inflammable part of the refuse could be disposed of by burning.

On passing from the grit chamber the sewage should be screened. After considering many types of screens employed in Europe and America, including those capable of removing the utmost quantity of suspended matter possible, it seems best to employ a moving bar screen with openings of about 4/10 of an inch. The type used in the new installation at Hamburg, Germany, appears to be suitable for New York. This screen consists of an endless belt of bars arranged at an inclination to the flow of the sewage. The sewage passes between the bars and leaves the solids, which are caught and carried upward on the screen belt as it slowly revolves. The screenings which are carried up out of the sewage are removed from the belt by means of brushes and a hose and discharged upon

a belt conveyor which carries the material to a car which stands in readiness. The size of the openings between the bars of this screen do not necessarily indicate the size of the particles removed from the sewage. If the screen is revolved very slowly, its effectiveness in removing suspended matter will be increased. After the sewage leaves the screens, it passes to the pumps. The pumps should be of the centrifugal type directly connected to motors. The pumping equipment should be in duplicate, as should the screens and grit chambers.

Leaving the plant, the sewage should flow under slight pressure to the outer ends of piers, where it would pass downward through a pipe to the bottom and thence outward into the current for discharge. The tide gates should be located near the point where the sewage is passed through the grit chambers and screens.

In order to consider the practicability of installing grit chambers and screens, locations have been tentatively chosen for the outlets and the approximate locations of the works fixed. The next step was to separate the division into sub-divisions and select a few of those for more detailed study. The collecting system in each sub-division was assumed to be already complete save for such interceptors and other large sewers as might be needed to gather the sewage which was now passing to the harbor through many outlets to the central plants. Four sub-divisions were selected for special study, in which the topography and other conditions were dissimilar.

Sub-division No. 5.—One of the sub-divisions was on the Hudson river shore of Manhattan Island, between the northern end of Central Park and Riverside Park. The sewage from this area is produced by a high-class apartment house population. The topography is such that no difficulties to drainage exist. The site for the plant was in Riverside Park at 96th Street. The quantity of sewage was 25.4 million gallons per 24 hours during dry weather and three times this quantity was provided for at the plant. The storm water outlets were intended to be carried to the end of the West 97th Street pier and were given a capacity of 270 million gallons per day. The cost, including excavation, sub-structure, super-structure and 15% for contingencies, was $89,000 for the plant. The outlets for the dry weather flow would run to a point 300 feet off the pierhead and would cost about $24,200. The outlets for the storm water overflow at the pierhead would cost about $37,000. Total, $150,200. This estimate does not include the cost of intercepting the sewage and delivering it to the treatment plant.

Sub-division No. 14.—The second sub-division studied would have a treatment plant at Broome Slip, near the East river. In this case the area drained is occupied by a crowded tenement house population. There would be

difficulty in collecting the sewage to the plant, since the ground is, for the most part, low. The works would have a total capacity of 93 million gallons, which would be about three times the dry weather flow. Storm water in excess of this quantity would be diverted directly to the East river, and the rest raised by pumping. In all other essentials the plant would be similar to that at 96th Street. The estimated cost, including excavation, sub-structure, super-structure, machinery and 15% for contingencies, is $133,000. This figure does not include the cost of collecting the sewage and delivering it to the plant or of conveying it from the works to the outlets.

Sub-division No. 19.—A third sub-division studied contemplates the location of a plant at Orchard Street, Astoria. In this case the capacity would be 87 million gallons per day or three times the dry weather flow. Difficulties of drainage due to low-lying land would require pumps to lift the low level sewage to the works. The estimated cost for excavation, sub-structure, super-structure, machinery and contingencies would be $81,700, exclusive of the cost of delivering the sewage to the plant or conveying it thence to the outlet.

Sub-division No. 30.—A fourth location for a grit chamber and screening plant would be at the foot of 64th Street, Brooklyn. The capacity in this case would be 68 million gallons per day or three times the dry weather flow. The cost, including excavation, sub-structure, super-structure, machinery, connection with sewer and 15% for contingencies, would be $147,000, exclusive of cost of conveying the sewage from the plant to the outlet.

If there was one grit-chamber-and-screening plant, in each sub-division, the total number would be thirty-one. If their cost is indicated by the studies made for the four sub-divisions mentioned, the total outlay for them would be in the neighborhood of $710,000. This would exclude land and the outfalls.

Heavy Rainfalls.—Inasmuch as the frequency with which the storm overflows would come into play should be considered, studies have been made of the records of precipitation as kept by the United States Weather Bureau. The maximum precipitation in each month for 5, 10 and 60 minute periods from April 1, 1896 to January 1, 1912, and for 15, 30 and 120 minute periods from January 1, 1903 to January 1, 1912, have been examined. The results for the months of December, 1896, January, 1897, and February, 1898, are missing. The tabulations of the Weather Bureau were for the most severe single storm each month and it is possible that the actual frequency would slightly exceed that indicated by these diagrams. But the difference would not be so great as to be of consequence in any provision for storm water overflows.

On applying the results of these studies of rainfall, it appears that a volume of storm water in excess of three times the dry weather flow would

II.

Studies for Tide Gates.

Most of the grit chambers and screens would be situated so close to the tidal level that the plants would be in danger of flooding through the outlet pipes if provision was not made to prevent it. To prevent flooding, tide gates would be needed and these should be of the most reliable form procurable.

Many forms of tide gates have been considered by the Commission, the experience of engineers in America and England being taken carefully into account, and special attention being paid to the best current practice in this direction in Holland. As a result, it is believed that although tide gates are not always reliable, a form can be designed which will satisfactorily answer the requirements of the situation.

Tide gates in common use are of three general types: flap valves, swinging gates and sluice gates.

Flap Valves.—Flap valves which swing on a horizontal hinge are most often used on sewer outlets of moderate or small size, although good examples of this type exist in some large sewers. At Washington, D. C., gates are used which are made of Georgia pine 5 feet 6 inches wide by 8 feet high and at Philadelphia there are gates of yellow pine 18 feet wide and 2 feet high. With large sizes, two flap valves are usually placed in the gate, one above the other, as at Aberdeen, Scotland, and Atlantic City. At Aberdeen, the balanced flaps are of cast iron and the opening for discharge is 5 feet 6 inches by 6 feet 6 inches.

For the flaps to work freely, they should hang loosely from links, as at Atlantic City, or from easy-working hinges. Composition bearings are desirable in order to avoid corrosion. At Washington the hinges and bolts are of bronze. A ring of rubber set into the gate forms a watertight joint, with a cement seat. At Philadelphia, a rubber gasket is provided which bears against a copper seat. To aid in securing a tight closing of the valve, the seat is usually inclined to the vertical; 1 in 6 at Washington, and 30° at Philadelphia.

If the sewer is of large size, the weight of the flap gate may be so great as to interfere with the free discharge of the sewage. Gates which swing on a vertical axis have an advantage over flap valves in this respect. The leaves of such gates are usually made of wood, white pine being used in some cases, as in Boston. To insure tight closing, a counterweight may be hung on a chain passing from a rod projecting from the outer end of the gate to a point above the hinges. In a patented device used in Boston, the hinges are slightly inclined so as to offset in part the buoyancy of the gates which tends to keep them

III.

Studies for Submerged Outfalls.

The value of submerged outfalls lies in the fact that they materially aid in bringing about a prompt and thorough mixture of the sewage and water into which the sewage is discharged.

Preliminary to describing a form of construction which appears to be practicable for submerged outlets in the sub-division with which this report deals, it is desirable to consider the circumstances under which sewage will and will not mingle with the surrounding water.

Dispersion and Diffusion.—The terms dispersion and diffusion are sometimes used interchangeably in describing the intermixture of sewage and water, although, strictly, there is a difference in their meaning. The term dispersion implies a separation and scattering, particularly of solid particles, while diffusion refers especially to that form of rapid and intimate mixture which is most often considered as taking place among gases. Both dispersion and diffusion are necessary for the disappearance of sewage. The solids must become scattered and the liquids must become diffused. When solids accumulate, they may form deposits or else masses which are visible at the surface. Unless the liquids become diffused, they do not come into contact with the oxygen which is necessary for their mineralization. When dispersion and diffusion are satisfactory, the discharge of sewage into a large body of water is scarcely, if at all, detectable to the sight.

It is sometimes erroneously assumed that diffusion is everywhere and at all times proceeding rapidly among the liquid particles naturally present in large bodies of water, particularly in such bodies as move under tidal influences, and that to cause sewage to be carried away, it is only necessary to discharge it in not too great quantity. This is a mistake. Some bodies of water should never receive any sewage.

A prompt and general intermixture of sewage and water is often difficult or impossible to accomplish. It is most difficult when the water into which it is emptied has no current or when the current is so slow that there are no eddies or counter currents produced. The eddies and counter currents are necessary for rapid diffusion. It is not enough that the water into which the sewage is discharged should be great in volume, nor that the water should be flowing by a point of discharge at a great velocity. If the velocity is uniform throughout, dispersion and diffusion will not be as satisfactory as it would be if cross currents and eddies existed in it.

Ascent of Sewage in Sea Water.—Diffusion between sewage and sea water is more difficult than between sewage and land water by reason of the greater specific gravity of sea water. Each cubic foot of sewage is 1¾ pounds lighter than an equal volume of sea water and, in consequence of this fact, every foot which is discharged beneath the surface may be considered to be urged upward with a force of about 1¾ pounds. This upward force diminishes as the sewage becomes mixed with the water and is initially less if the harbor water is not as salt as the sea. From the mathematical equation $V^2=2gh$, it is evident that the rate of ascent will vary as the square of the difference in specific gravity, and that the velocity of ascent will be doubled when the buoying force is multiplied four times.

It is, unfortunately, impossible accurately to determine the velocity of ascent of a stream of sewage by means of this or any other formula, but the facts stated are of practical use in considering the best means of causing a prompt and intimate mixture of the sewage and tidal water to take place.

Many experiments have been made by the Metropolitan Sewerage Commission to obtain information concerning the circumstances under which sewage could and could not be made to diffuse in the water of New York harbor. These experiments were carried on in the laboratory, in large aquarium tanks and in the harbor itself. In the latter case, hogsheads and tank steamers loaded with sewage were taken to various parts of the harbor and, after being strongly colored with dye, discharged beneath the surface, and the resulting phenomena noted. In these experiments the harbor water varied in salinity. It usually contained about 75 per cent. of sea water. The current into which the sewage was discharged varied from a little less than 1 foot per second to 3 feet per second. Most of the large scale experiments were carried on near the center of Upper New York bay. Further details of this work are described in the report of the Commission of April, 1910, pages 184-215, but the following facts and opinions derived from these studies are of interest here. When sewage is discharged into sea water, the sewage will rise to the top in a mass unless it is intermixed through the mechanical action of eddies and cross currents. Tending to carry the sewage to the top are gas, grease and light solid particles. The sewage is usually warmer than the water into which it is discharged and this difference in temperature tends to carry the sewage upward.

When sewage is discharged into a mixture of 85 per cent. of land water and 15 per cent. of sea water, it appears to be practically in equilibrium, that is, it neither rises nor falls through the water into which it is discharged.

When sewage is allowed to stand at the top of a perfectly quiet body of

water, diffusion occurs at once if the water is land water, but not until 48 hours, if the water is a mixture of equal parts of land water and sea water. When sewage is discharged beneath the surface of a quiet body of water, currents are set up which help to produce an intermixture between the two fluids. The force of these currents varies directly with the velocity of the discharging current and the volume of discharge, and is helpful in bringing about dispersion and diffusion. When sewage is discharged beneath the surface of a quiet body of water of practically the same specific gravity, it does not intermingle immediately with the surrounding water. Some diffusion takes place from the outside edges of the discharging stream, but intermixture seems to proceed chiefly after the discharging stream has lost its initial velocity. It is obvious from these facts that the velocity is an important factor in the mixing process.

If directed vertically upward from a submerged outfall, a discharging stream of sewage flows toward the surface of the water in a gradually enlarging column. Arrived at the top, the sewage spreads out thinly over the surface. Diffusion gradually takes place downward from this surface. If discharged horizontally from a submerged outfall, the sewage stream at first preserves its integrity for a considerable distance and then, rising upward, spreads out in a thin layer at the top of the water. Diffusion takes place in this case downward from the gradually enlarged column and from the surface layer, as when sewage is directed vertically upward from a submerged outfall.

When sewage is discharged into a quiet body of tidal water consisting of 40 per cent. land water and 60 per cent. sea water, it rises toward the surface irrespective of the direction of the discharge from the orifice, and spreads out upon the surface in a thin layer. The upward motion is not retarded perceptibly when the discharge takes place at a velocity of 1⅓ feet per second into quiet water.

The shape of the discharging column of sewage is larger and longer when the discharge takes place in a horizontal direction than when the discharge is upward or downward, and for this reason, a horizontal discharge facilitates diffusion. To secure the most prompt and thorough intermixture, the sewage should be discharged in a horizontal direction near the middle and at the bottom of a tidal channel and in a direction perpendicular to the direction of flow of the current.

Three conditions are desirable in order to accomplish satisfactory diffusion:

1. The diameter of the discharging column of sewage should be small.
2. The velocity of the discharging column of sewage should be great.
3. The current into which the sewage is discharged should be rapid.

Investigations in Boston Harbor.—The water in the vicinity of the Boston, Mass., outlets was analyzed by the Metropolitan Sewerage Commission of New York during the month ending September 18, 1911. The analyses were intended to show the amount of dissolved oxygen in the water, the salinity and temperature being determined at the same time. The examinations covered the inner and outer harbor and there were special studies made of the three main outlets. The total number of analyses was 388. The method employed, the analyst and the floating laboratory were the same as had produced the large amount of information concerning the oxygen in the waters of New York harbor.

The condition of Boston's inner harbor, as measured by the dissolved oxygen was, in the main, very satisfactory, although there were some places where the circulation of tidal water was insufficient to carry away the sewage which was discharged. The outer harbor, except in the immediate vicinity of the three main sewer outlets, contained an abundance of dissolved oxygen.

The conditions surrounding the Peddock's Island outfall were better than those found at Deer Island or Moon Island. It became apparent that the sewage began to be dispersed and diffused from the moment it left the outfall at Peddock's Island. The shape of the ascending column of sewage was somewhat like a funnel with incurved sides and broad flare. At a distance of 500 feet from the center, there was 7 per cent. of sea water mixed with the sewage at the surface. There was 3 per cent. 10 feet below the surface and 1 per cent. 15 feet below the surface. At 1,000 feet from the center there was no sewage below 10 feet beneath the surface. At 2,000 feet there was no sewage below 2 feet beneath the surface.

The amount of oxygen present varied with the concentration of sewage. At a distance between about 700 feet and 1,700 feet from the center of the sewage field, there was a considerable increase in the exhaustion of oxygen.

Submerged Outlets for Manhattan and Brooklyn.—For the discharge of sewage from Manhattan and Brooklyn it is desirable that submerged outfalls should generally be employed. In some cases they should extend sufficiently far from the outer ends of the piers to obtain the advantages of great depth of water, high velocity of tidal current and remoteness from observation.

The types of construction suitable for carrying the sewage to the bottom of the main tidal channels must differ according to local circumstances, particularly the depth of water and character of the bottom, whether of silt or mud or rock. In the Lower East river the currents are so swift and the bottom so hard and the traffic so great that submerged outfalls can be constructed only with difficulty. On the Hudson river side of Manhattan Island, the con-

ditions are more favorable and for this area a type of outfall has been designed.

The capacity of the type of outfall which is here outlined for the Hudson river side of Manhattan Island can be increased beyond that mentioned, although the sizes given will be found economical to construct and it may be undesirable to collect more sewage to a single point for disposal than can be discharged through one outfall of this type.

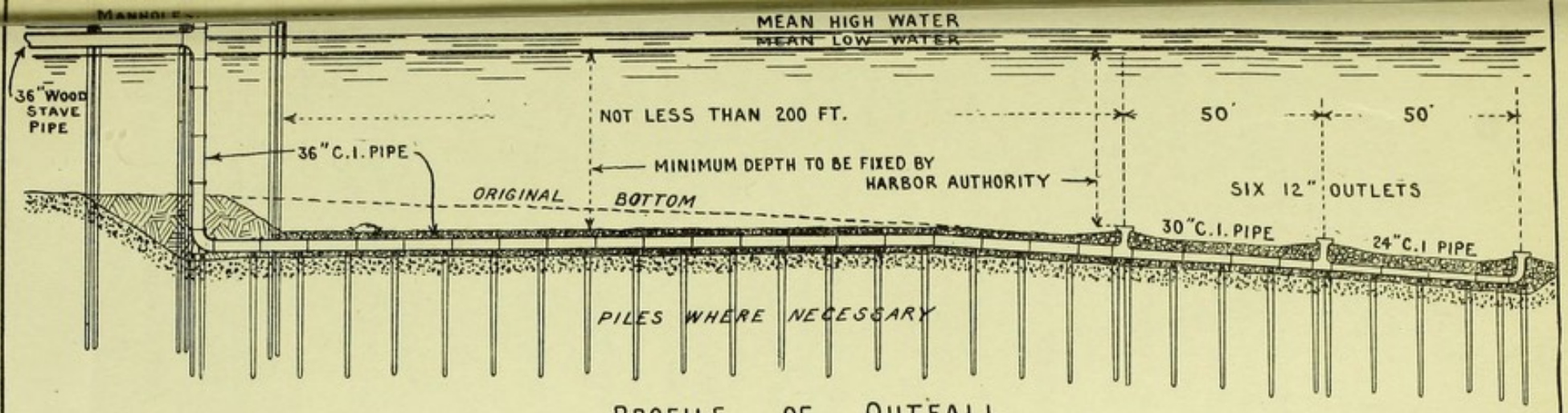
The plan is to carry the sewage through a 36 inch wood stave pipe laid beneath a pier to a point near its outer extremity. The wood stave pipe would be joined at its outer end by a 36 inch cast iron pipe which would be placed vertically and extend to the bottom of the water. At the top a manhole would be provided for easy access for inspection, cleaning and repairs.

At the bottom of this vertical leg the 36 inch cast iron pipe would turn and run out into the tidal channel for a distance of not less than 200 feet from the outer end of the pier. At this distance there would be a short riser of 24 inch pipe, provided with two 12 inch outlets which would discharge in a direction parallel to the main line of the pipe and perpendicular to the direction of the tidal currents.

From the riser just mentioned, the cast iron pipe, now reduced to 30 inches, would extend 50 feet further from shore to a second riser similar to the first. From this point the cast iron pipe reduced to 24 inches in diameter would extend the final 50 feet to its outer limit, where it would be joined by a third riser to discharge the remaining sewage, as in the first two cases.

The cast iron pipe would, where practicable, be laid in a trench dredged in the bottom. Where the support was poor or uncertain, piles would be driven to carry the pipe. The pipe would be covered with a light filling of rip-rap and the trench filled. The minimum depth at which outfalls of this character should be constructed would have to be fixed by the Harbor Line Board. Apparently there is a depth of water in the Hudson river along the Manhattan shore at practically all points sufficient to permit this form of construction to be adopted. A study for a submerged outfall is shown in Plate VIII, following page 60.

The submerged outfalls would be for the dry weather flow of sewage. Storm water would be overflowed under the piers. The dry weather flow of sewage would generally be carried to the submerged outfalls by pumping.

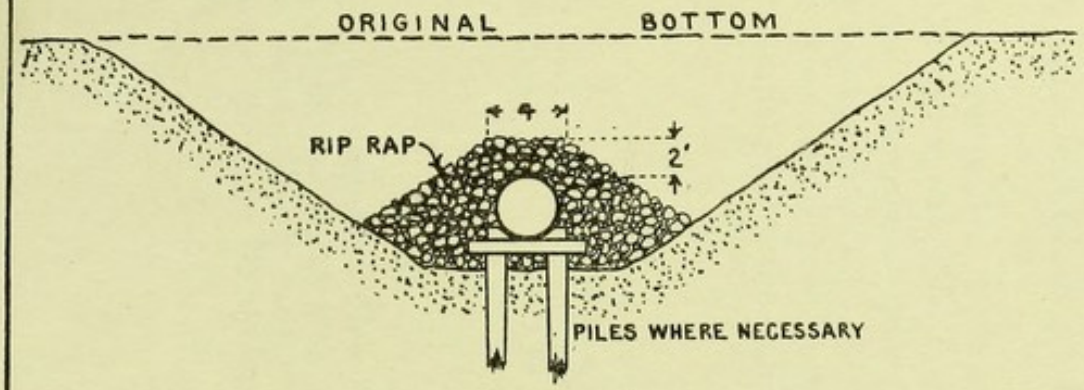


PROFILE OF OUTFALL

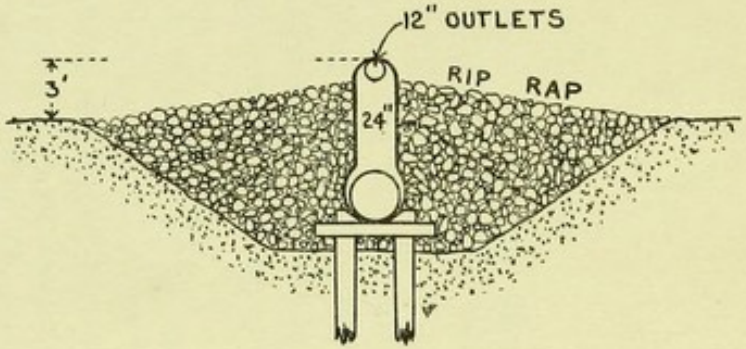
SCALE: 1" = 40'

0 10 20 30 40 50 60 70 80 90 100 FT

STUDY FOR TYPICAL SUBMERGED OUTLET



CROSS SECTION



CROSS SECTION AT OUTLET

SCALE: 1" = 10'

0 5 10 20 FT.

PLATE VIII

IV.

Opinion of U. S. Engineers on the Proposed Island.

Recognizing that responsibility for the maintenance of a proper depth of water for navigation in the harbor rested with the U. S. War Department and that the island proposed by the commission for the disposal of the sewage of the Lower East river could be constructed only with the permission of that Department, application was made to the Secretary of War requesting the views of the War Department with respect to this subject. The commission's application was referred by the Secretary of War to the Chief of Engineers, U. S. Army, and by him to the New York Harbor Line Board for report.

The New York Harbor Line Board consists of Colonels W. T. Rossell, W. M. Black and S. W. Roessler of the Corps of Engineers, U. S. Army. The island would be in that part of the harbor which is under the special jurisdiction of Col. Roessler, who has had much experience with breakwaters and other structures intended to resist the destructive action of the sea. The Harbor Line Board gave a hearing on the commission's project on March 7, 1913. On that occasion the subject was thoroughly discussed, plans, charts and profiles of the proposed structures being produced.

The opinion of the Harbor Line Board was transmitted to the commission by the War Department on March 22, 1913. It was to the effect that an island in either of the two locations suggested by the commission, one of which is shown on Plate I, following page 48 of Preliminary Report VI of the Metropolitan Sewerage Commission, would not interfere unduly with navigation nor have an unfavorable effect upon the harbor. In this opinion the Chief of Engineers concurred.

The correspondence in full follows:

February 18, 1913.

Hon. Henry L. Stimson,
Secretary of War,
Washington, D. C.

Sir:

In making plans for a sanitary disposal of the sewage of New York City, it has become desirable to consider the practicability of constructing an island near the entrance of New York harbor. The island would be located on one of the shallow, sandy bars which are divided by the Fourteen Foot Channel to the north of Ambrose Channel.

The island would be constructed with an enclosing wall of rip-rap and a filling of sand or other solid material, the total area occupied being less than 30 acres. Upon the island would be tanks and other structures in which much of the solid matters of the sewage would be removed to be carried to sea in boats or disposed of in some other acceptable manner, while the clarified effluent would be discharged into the surrounding water through outlets so arranged as to insure its prompt dispersion and disappearance. The sewage, amounting to about 200,000,000 gallons per twenty-four hours, would be brought to the island through a tunnel.

Recognizing the authority which is exercised by the general government over the navigable waters, this commission desires to place its project in sufficient detail before you, to the end that an early determination may be reached as to the permissibility of constructing and using this island in the manner, and for the purpose, stated.

Members of this commission will be pleased to call upon you with reference to the subject in case you visit New York, or they will go to Washington to see you, if preferable. The technical details of this plan can be laid before such army engineer, officer or officers of the New York Harbor Line Board as you may designate.

Your early attention to this subject is requested in order that the result of your consideration may be known in time to be used in a report soon to be issued by this commission.

Respectfully,

GEORGE A. SOPER,
JAMES H. FUERTES,
H. DEB. PARSONS,
CHARLES SOOYSMITH,
LINSLY R. WILLIAMS,
} Commissioners.

MARCH 3, 1913.

MR. GEORGE A. SOPER, President,
Metropolitan Sewerage Commission,
17 Battery Place, New York City.

DEAR SIR:

1. The Harbor Line Board has before it your application of Feb. 18 to the Secretary of War concerning the construction of an artificial island near the entrance to New York harbor, and also a letter of Feb. 19th from Mr. H. deB. Parsons, Consulting Engineer, requesting that this matter be laid before this Board. In order that the Board may be able to come to a definite conclusion in the case, it is requested that you submit more detailed plans and make a definite application for such construction.

2. The Board desires to take this matter up at 10 A. M. on March 7th and it is requested that these plans be submitted before this time and that if possible you or your representatives be present to confer with the Board in the matter on that date.

Very respectfully,

WILLIAM T. ROSSELL,
Colonel, Corps of Engineers,
Senior Member of Board.

MARCH 6, 1913.

COLONEL WILLIAM T. ROSSELL,
Corps of Engineers, New York Harbor Line Board,
Army Building, New York City.

DEAR SIR:

Your letter of March 3, relating to the proposal of this commission to construct an island near the mouth of New York harbor, has been received.

Application is hereby made for permission to construct and maintain an island for the treatment and disposal of sewage in accordance with the following plan:

The object of constructing the island is to afford opportunity for the treatment and final disposition of a quantity of sewage from the inner harbor sufficient to relieve and protect the inner harbor from its excessive burden of pollution.

The location proposed for the island is in shoal water, preferably in latitude 40° 32′ 02″ N, longitude 73° 59′ 46″ W, or in latitude 40° 31′ 26″ N, longitude 73° 58′ 21″ W.

In plan, the island would be approximately rectangular except that the seaward side would be rounded. The area at the start would be about 20 acres of filled land and about 10 acres of harbor for the protection of vessels engaged in transporting supplies to the island and taking sludge and other materials away.

The outer face of the island will be a wall of rip-rap composed of large pieces of broken stone carried to the site on boats and laid upon the hard sandy bottom. It is expected that some settlement will at first occur, due to the water cutting sand away from under the stone. The main bulk of the island will be composed of sand supplied from a suction dredge which will take its supply from the bottom of the sea, or earth, ashes and other suitable material.

The height of the island above mean low water will be about 18 feet. The length of the island, when first constructed will be about 1,300 feet and the width 1,000 feet. The side of the rip-rap wall which is exposed to the sea will have a slope of 1 vertical upon 3 horizontal and the two adjoining sides will have an outer slope of about 1 on 2. The rip-rap will be 15 feet across the top and will

be surmounted by a concrete parapet wall 4 feet in height. The rip-rap will be from 75 to 122 feet wide on the bottom, according to the location with respect to the sea.

The island will contain a plant of settling tanks in which the sewage will have an opportunity to settle and deposit its solid matters during a period of about two hours. These tanks will be of modified Dortmund tank construction, similar to those recently constructed at Toronto, Canada. Provision can be made for treating the sewage, if necessary, with a coagulant before passing it into the tanks.

After treatment, the sewage will be discharged through a number of outlets arranged radially from the island in such position as to bring about the most immediate and perfect dispersion of the seawge practicable. If desirable, it will be feasible to pump sea water and mix it with the sewage before the discharge takes place. Such admixture would facilitate the immediate diffusion of the sewage in the sea water; but the active agitation and free movement of the great volume of water in the vicinity of the island will, it is expected, make a preliminary mixture of sea water and sewage by pumping unnecessary.

The material which will settle out of the sewage in the tanks will be carried to sea in vessels and dumped sufficiently far from the land to insure that no trace will reach bathing beaches, inhabited shores or oyster grounds.

Provision will be made for a laboratory and dwelling house for those who will be needed to operate the tanks and other devices for the treatment and discharge of the sewage. It will be feasible to maintain a light on the island for the benefit of navigation, in case this is desirable.

In course of time, it will be necessary to increase the size of the island and it is proposed that this will be done by extending its length so that the total area covered will be about three times that of the original island, or, approximately, 70 acres.

The quantity of sewage which will be brought to the island at the beginning is estimated at about 203,000,000 gallons per 24 hours during dry weather. During storms, this volume will increase about 100 per cent. This sewage will be collected from those parts of Manhattan and Brooklyn whose drainage is naturally tributary to the Lower East river between the Battery and 28th street, Manhattan. It is proposed to collect the sewage by building intercepting sewers close to the water front to receive the sewage from the existing combined sewers and gather it to a central pumping station to be located near the Brooklyn Navy Yard. A siphon built beneath the East river will carry the sewage of Manhattan to the Brooklyn side. At the central pumping station the sewage will be pumped through a force main built as a tunnel to the island. The tunnel will be over 20 feet beneath the bottom of the Lower bay and so be free from injury to anchors even in the deepest parts of the channel between the island and the mainland where vessels rarely anchor. The sewage will consist of the ordinary dry weather flow except at periods of rainfall when the storm water from the streets will also be received to the extent of about once the volume of the average hourly production of house sewage.

All the sewage which is sent to the island will have been passed through grit chambers and screens with openings not larger than one-half inch. The sewage from Manhattan will be screened before passing to the Brooklyn side. Since it will be relatively fresh, it is estimated that no less than 15 per cent. of the suspended matter will be extracted. Grit chambers will be located near the screens and their efficient operation will be insured by the necessity which will exist for removing the readily settleable material from the sewage in order to prevent obstructions in the siphon and interference with the pumps. The Brooklyn sewage will be passed through screens and grit chambers no less effective than those of Manhattan before the sewage is pumped through the force main. It is estimated that the settling basins on the island will remove at least 60 per cent. of the suspended matter from the sewage. It is expected that the total effect of the treatment by grit chambers, screens and settling basins will be to remove considerably more than 75 per cent. of the suspended matter originally present.

It is believed by this commission that either of the two locations here proposed for the island will be favorable for the sanitary disposal of the sewage and will be free from objection from the standpoint of navigation. Both sites are upon sand reefs where no vessels except fishing craft of lightest draft are likely to pass. The area of the island, even when extended to the dimensions which may ultimately be necessary, will be so small, as compared with the total area of the Lower bay, as not seriously to interfere either with the tidal prism or with the force or direction of the tidal currents flowing in and out of the harbor. The amount of solid matter contained in the sewage when discharged will be slight as compared with the volumes of water in the vicinity of the island and the action of the waves and currents in this part of the harbor are so active that it seems improbable to this commission that deposits of any serious extent would be formed, even if the sewage was to be discharged in crude condition.

Apart from permission to build the island, which this commission would interpret as expressing a belief that no interference would be caused by the island to navigation, this commission would value the opinion of the Harbor Line Board as to the probable capacity of the island to resist the destructive action of the sea. It is recognized that the Army Engineers possess the qualifications of experts on this subject. If material criticism can be brought against the proposal of this commission for the construction of the island on the score of structural defect, suggestions looking to a more durable form of construction would be regarded in the light of a public service.

Accompanying this letter is a chart of Lower New York bay, showing the two alternative locations for the proposed island, a profile giving the line of the tunnel through which the sewage would be pumped to the island, a plan of the island and three cross sections of the retaining walls.

Respectfully,

GEORGE A. SOPER,
President.

MARCH 22, 1913.

HON. GEORGE A. SOPER, President,
Metropolitan Sewerage Commission,
17 Battery Place, New York City.

SIR:

Referring to your letter of the 18th ultimo, submitting, for the views of this Department, a proposition of the Metropolitan Sewerage Commission of New York, as part of a plan for the disposal of the sewage of New York City by the construction of an island in Lower New York bay, I beg to inform you that the New York Harbor Line Board, to which the matter was referred, reports under date of 15th instant, as follows:

> "The Board is of the opinion that an artificial island in the Lower bay between Coney Island and Sandy Hook in either one of the two locations shown on the map, and with the dimensions across the direction of the bay and flow of the tide substantially as shown, will not interfere unduly with navigation, nor have an unfavorable effect upon the harbor. Before issuing a formal permit it is suggested that the Sewerage Commission be requested to submit a map showing the approximate position and size of the island it proposes to build at the present time and proposed future enlargement, and the location of the sewers between it and the shore; also such details of the plan of the settling basin or other means for clarifying the sewage as may be necessary to show whether or not such plan will effectually prevent solid matter escaping into the channel in undue amount; also a profile of the proposed sewer showing the depth below low water along its entire route and beyond the crossing of Coney Island Creek."

The Chief of Engineers concurs in the views of the Harbor Line Board, and the map referred to showing dimensions, etc., is transmitted herewith.

Very respectfully,

ROBERT SHAW OLIVER,
Assistant Secretary of War.

PRELIMINARY REPORTS

ON THE

DISPOSAL OF NEW YORK'S SEWAGE

V.

STUDY OF THE COLLECTION AND DISPOSAL OF THE SEWAGE OF THE RICHMOND DIVISION *

METROPOLITAN SEWERAGE COMMISSION
OF NEW YORK

GEORGE A. SOPER,
JAMES H. FUERTES,
H. de B. PARSONS,
CHARLES SOOYSMITH,
LINSLY R. WILLIAMS,
Commissioners

SEPTEMBER, 1912

***This report is issued in advance of the final report of the Metropolitan Sewerage Commission in order that the contents may be of early service. Some features of this report will remain open for revision until the final report is submitted.**

THE EVENING POST JOB PRINTING OFFICE, 156 FULTON ST., N. Y.

STUDY OF THE COLLECTION AND DISPOSAL OF THE SEWAGE OF THE RICHMOND DIVISION.

SEPTEMBER 1, 1912.

Honorable WILLIAM J. GAYNOR, Mayor of The City of New York:

SIR: This report, on the collection and disposal of the sewage of the Richmond Division, is the fifth in the series of Preliminary Reports on the Disposal of New York's Sewage which has been issued by this commission with the object of making public at an early date its opinion as to the way in which it will be necessary to deal with the sewage of the Metropolitan District.

The adoption of the plans here proposed would provide the northern and northeastern parts of Staten Island, containing all the more thickly settled localities and including over eighty per cent. of the population of the borough, with main drainage and sewage disposal works at moderate cost, and would afford as great a measure of protection as a consideration of the condition of the water in the whole harbor and of the possibilities of contamination in this locality seem to make necessary.

The disposal of the sewage of that part of the Borough of Richmond not provided for in this report offers little difficulty. That part of the territory which is not rural should be provided with local disposal plants of such high efficiency that their effluents can be discharged into the neighboring water courses without danger of causing local offense.

The possibility that a greater degree of protection for the harbor than is proposed in this report may be needed in the distant future has been borne in mind in preparing these plans and, in consequence, the works have been so devised as to be adaptable to a more comprehensive scheme without undue loss of the completed structures.

All the work planned in this report will not be required in the immediate future, but it is regarded as necessary that such main drainage work as is undertaken by the city in this borough shall conform to these plans or such modifications of them as a more detailed study of the local conditions than has been possible by this commission may require.

To a great extent the sewerage plans made by the local authorities have been utilized in preparing the plans of main drainage and disposal described in this report, the object being to aid and supplement the city's efforts in disposing of the sewage in a sanitary manner. In those localities for which the borough has had no definite sewerage plans, it has been necessary to outline the future lateral sewerage districts as seemed most reasonable from the information at hand concerning the proposed locations and grades of streets. By following the same

outlines as nearly as may seem best after detailed study, the engineers of the borough will be able to facilitate the final design of the main drainage systems along the lines recommended in this report.

General Description of the Territory.

Location and Area.—This report deals with that part of Staten Island which slopes toward the Narrows, Upper bay, Kill van Kull and Newark bay, or nearly the whole of the northern and northeastern portions of the Borough of Richmond. This territory includes, besides the natural drainage areas tributary to the bodies of water mentioned, a comparatively small area which drains naturally to Willow brook, and thence to Fresh Kills and Lower New York bay, and from which it is feasible and desirable to carry the house sewage to the Kill van Kull for final disposal.

The line bounding the district on the south starts from Fort Wadsworth at the Narrows, and runs in a generally westerly direction through Arrochar and Grasmere, across Todt Hill and through the grounds of the Richmond Borough Almshouse, finally reaching the village of New Springville. On the west the boundary line follows closely the Port Richmond Road, passing through Bull's Head and Graniteville, and thence not far from Morningstar Road to a point south of Elm Park, from which point it follows the watershed along the Staten Island Rapid Transit Railroad, westerly nearly to South avenue, whence it runs in a northwesterly direction, crosses Richmond Terrace near Holland avenue, and continues to the shore of Newark bay east of Howland Hook.

Between this line and the established bulkhead line bordering the Narrows, Upper bay, the Kill van Kull and Newark bay, there is included an area of 9,178 acres, or about 14.3 square miles, exclusive of cemeteries, parks, institutional property, U. S. Government land, etc. This area is approximately equal to one-fourth of the total land surface of Staten Island.

Topographical Features.—The topography of the territory is varied. The part which drains to the northeastern shore of Staten Island is separated from that which drains to the north shore by a high ridge which traverses the island in a general northeasterly and southwesterly direction, and which rises at Todt Hill, on the southern boundary of the territory, to an elevation of 409.8 feet above the Richmond high water datum. The slopes on the easterly side of the ridge, within the limits of the territory, are precipitous. The westerly and northerly slopes are generally gradual.

In the western part of the territory the land is comparatively low, and in many places, near the water courses and shores, it is swampy. The slopes down

to these swampy areas are generally gradual, and the ridge marking the outline of the district on the west is not high.

The terminal moraine forms a conspicuous feature of the topography in the southeastern part of the district. Along the boundary line from Arrochar to Grasmere the bare rounded hills and numerous depressions and ponds, characteristic of morainic topography, are especially noticeable.

The land near the shore, from Fort Wadsworth to Howland Hook, is made up alternately of headlands, of varying height, and valleys. Streams flow through many of these valleys, while in others the natural water courses have been replaced by sewers. Much of that portion of the territory which drains to the Kill van Kull lies within the drainage area of Bodine creek, which is the largest water course in the district.

Population.—Nearly all the more thickly settled part of Staten Island lies within the drainage districts of the Narrows, Upper bay, Kill van Kull and Newark bay. Out of a total population in the Borough of Richmond, in 1910, of 85,969, this territory contained an estimated population of 64,320, or almost exactly three-fourths of the total. In 1940, it is probable that this area will have no less than 140,000 people out of 190,000, the minimum number that may be expected to inhabit the borough at that date.

While, for a number of years previous to 1905, the growth of population in the borough was slow, due to various causes, since that date the population has increased at a comparatively rapid rate. Owing to changed conditions, it seems reasonable to expect that this rapid growth will continue.

Development.—The land which lies near the shore from Rosebank almost to Howland Hook is well populated, and in some places thickly settled, but no part of the whole area has a population closely approaching in density that which exists in most of the other boroughs of New York City. In fact, with the exception of a few centers which are chiefly devoted to business purposes, and a number of spots where buildings of a poor class are huddled together, the whole area, for a considerable distance back from the waterfront, may be termed suburban. Further from the water, most of the territory is rural in character, and there are large tracts which are still wholly unimproved.

While the populated sections will gadually extend farther and farther from the waterfront, much of the territory to the south and southwest is likely to remain in a rural and unimproved state for many years. It seems certain that the business centers will gradually expand, although nearness to Manhattan will cause activities to be confined mostly to the establishment of stores to supply the needs of the local population. In course of time docks and warehouses will

undoubtedly occupy the Stapleton waterfront, and water and rail facilities make the north shore a superior place for the establishment of factories.

Sewerage of the Territory.—During the last few years, large amounts of money have been spent by the borough in the construction of sewers. In the areas which drain to the Narrows and Upper bay, and along the western part of the north shore of the island, much progress has been made in replacing old and shallow village sewers, formerly built to take care of the immediate needs for house drainage, by modern systems. Except in some of the low areas near the waterfront, these new sewers are of the combined type.

In much of New Brighton, and in West New Brighton and Port Richmond, the old village sewers have so far remained more or less adequate to the needs of the communities. Few, if any, new combined sewers have been constructed, and little has yet been done concerning the preparation of drainage plans for these areas. The natural water courses which traverse those areas have proved sufficient for the removal of the storm water, and they can continue for some time to perform this service for many places. Certainly, if the storm water in the thickly settled areas near the waterfront is removed by sewers, the run-off from the more sparsely settled upland territory can be adequately provided for in the natural water courses for many years to come.

Wherever new and complete systems of sewers have been installed, the dry-weather flow has been diverted from them, above mean high tide, and carried in a pipe to moderately deep water and the outlet for the storm water has been placed near the shore line. It is the intention of the borough authorities to extend the dry-weather and storm-water outfalls to the pierhead and bulkhead lines, respectively, when the piers and bulkheads are built. By this method of discharging the house sewage into deep water, during dry weather, the shores near the sewer outlets have escaped much of the pollution which otherwise would have been inevitable. Nevertheless it is felt that, at many points, the discharge of house sewage in a crude state, even at the pierhead line, will not be permissible much longer. For this reason an experiment station has been established by means of which the most suitable method of handling the local sewage disposal problem can be studied.

Separation of the Territory Into Sub-Divisions.

The topography of the whole division is unfavorable for the collection of all the sewage to one central point for disposal. The high ridge separating the areas draining to the northeastern shore of the island from those draining to the north shore, the small areas of low land in the western end of the division,

the great distance which it would be necessary to carry much of the sewage and the amount of pumping required are opposed to the collection of the sewage at a point near the Narrows, which is the most favorable place available for its ultimate discharge.

While the discharge of all the house sewage from the northerly and northeasterly slopes of Staten Island into the Narrows would be desirable, and economy of operation would result from having only one disposal plant to maintain, it is believed that the benefits derived would not compensate sufficiently for the cost of carrying the sewage to such a plant. Moreover, it seems certain that the Kill van Kull, with its deep water and swift currents, would provide, for many years, if not for all time, a sufficiently favorable place for discharging the sewage from the areas bordering on Newark bay and the Kill van Kull, after it has been passed through settling tanks.

The territory with which this report deals has been subdivided in such a way as to facilitate the collection of the sewage, to provide for each subdivision a favorable and adequate place for treatment works, and to minimize the amount of pumping necessary. At the same time care has been taken not to divide the territory to such an extent as to cause the establishment of plants too small to be operated economically.

The subdivisions, five in number, have been given names associated with the points chosen for the sites of the respective treatment works. They are named and described as follows:

1. *The Quarantine Subdivision* comprises the area naturally draining to the Narrows from Fort Wadsworth to the Marine Hospital, Stapleton. The settlements known as Clifton, Rosebank and Forth Wadsworth lie within its boundaries.

2. *The Stapleton Subdivision* comprises the area naturally draining to the Narrows between the Marine Hospital and St. George. Tompkinsville, Stapleton and Concord lie within this area.

3. *The Livingston Subdivision* comprises the area naturally draining to Upper New York bay west of St. George, and most of that draining to the Kill van Kull east of a line joining the southerly end of Silver Lake, the corner of Castleton and Bement avenues, and the northerly end of Elm Court, West New Brighton. Sailors' Snug Harbor and the settlements of New Brighton and Livingston are included.

4. *The West New Brighton Subdivision* comprises, roughly, the area naturally draining to the Kill van Kull between the westerly limit of the Liv-

ingston subdivision and Tower Hill, Port Richmond, together with the area draining to Willow brook, east of Port Richmond Road. West New Brighton and Castleton Corners, and parts of Port Richmond, Graniteville, Bull's Head and New Springville are in this subdivision.

5. *The Elm Park Subdivision* comprises, roughly, the area naturally draining to the Kill van Kull and Newark bay between Tower Hill and Holland avenue. Elm Park and parts of Port Richmond and Mariner's Harbor are within its confines.

The boundaries of the Quarantine, Stapleton and western part of the Elm Park subdivisions, are fixed by the limits of the sewerage districts already outlined by the engineers of the borough; but the boundaries of the Livingston and West New Brighton subdivisions, except where bordering on the Stapleton subdivision, and of the eastern part of the Elm Park subdivision, have been placed by this commission as seemed best suited to the main drainage plans to be worked out. The limits agree, however, in a general way, with sewerage districts which have been outlined, but as yet only approximately, by the engineers of the borough.

Outline of the Proposed Plan for Main Drainage.

The proposed plan for the Quarantine subdivision provides for the collection of the sewage by a high-level intercepting sewer to the foot of Nautilus street, near the Quarantine Station, where, after passing through coarse screens, grit chambers and fine screens, it will be discharged into the deep water of the Narrows. The sewage from the low land in Clifton will be pumped to the high-level sewer.

In the Stapleton subdivision, the sewage will be collected near the foot of Water street, Stapleton, by high- and low-level sewers, passed through settling tanks, and discharged into the Narrows, off Canal street.

The plan for the Livingston subdivision provides for the collection of the sewage, mostly by high-level sewers, to the waterfront at Kissel avenue, Livingston, where, after being passed through settling tanks, it will be discharged into deep water in the Kill van Kull.

According to the proposed plan, the sewage from the West New Brighton subdivision will be brought, by high- and low-level intercepting sewers, to the waterfront near the garbage incinerator in West New Brighton, passed through settling tanks, and discharged into deep water in the Kill van Kull.

In the Elm Park subdivision, the sewage will be collected, by high- and low-level sewers, to the vicinity of Newark avenue and Richmond Terrace, where, after being passed through settling tanks, it will be discharged into deep water in the Kill van Kull.

The sewers will vary from 8 inches to 6 feet 9 inches in diameter, and their total length will be 10.88 miles.

Main Drainage Systems.

Kind of Sewers Proposed.—The collecting and intercepting sewers, as planned for the five subdivisions, are designed primarily to carry eventually only the dry-weather flow from the contributing sewers, already built or to be built, in these subdivisions. Attention has been directed to the fact that the sewers built by the borough have been, in general, of the combined type, and that future construction is planned along the same lines. This means that during wet weather much of the house sewage, mixed with varying volumes of storm water, will continue to the bulkhead line without being intercepted, and will there be discharged. The growth of population to be expected in the borough has so influenced the design of the proposed dry-weather trunk sewers that many of them will assist materially, for a considerable period, in the disposal of the storm water.

While it would be inadvisable, in those districts that have already been sewered by the borough authorities, to provide systems of separate sewers, using those already built to remove storm water, this commission considers it desirable, from now on, to construct sewers on the separate plan, and provide only such storm-water sewers as are demanded from time to time. Relieved of an admixture of house sewage, it is likely that many of these storm sewers might empty directly, for many years to come, into the natural water courses which flow northerly into the Kill van Kull. The building of the comparatively small sewers required for the house drainage, and only such storm-water sewers as are absolutely needed, would minimize the cost of sewer construction, a consideration of much weight, especially in view of the fact that the population which can be assessed is small. Among other advantages which the separate system would possess may be mentioned better protection against pollution to the water near shore during wet weather and less quantity of sewage to be handled in the treatment works.

The plans here proposed have been worked out on the assumption that the present policy of constructing combined sewers will be continued, but whether or not this policy is followed in the areas to be sewered in future, the principal

features of the main drainage systems and of the treatment works would be the same. If the sewers were built on the separate system, however, connecting chambers, overflows, tide-gates, and perhaps grit chambers, would be unnecessary, and the costs would be reduced to that extent.

Population and Quantity of Sewage.—The sizes to be provided for the main trunk sewers for collecting the dry-weather flow in localities similar in position and condition to the settlements on the northern and northeastern shores of Staten Island should not depend, as has been the case in many cities, upon an estimate of population at any definite period, but upon densities of population on the tributary drainage areas which are considered probable when the areas shall have reached approximately their ultimate development.

The part of Staten Island included within this division is so near Manhattan, and there are so many other reasons, including the possibility of rapid transit, which may greatly accelerate the growth of population in any part of or throughout the district that it would be unwise to restrict the capacities of the proposed trunk sewers to suit what now appears to be the needs of the district thirty years hence. The total construction cost of the sewers as designed will not be a very large sum, and the saving effected by cutting down their capacities materially would not be as great as might be supposed.

In order to estimate the necessary capacities of treatment works, pumping equipment and other parts of the main drainage works that can easily be added to at later periods, it is essential that estimates be made of present populations and sewage flows. The following table presents these figures as estimated for the various subdivisions for the year 1910, based on United States Census figures. The areas of the subdivisions are calculated to the established bulkhead line, but do not include cemeteries, parks, Sailors' Snug Harbor, U. S. Government property, etc. The "area sewered" column of the table has no reference to the actual area in each subdivision that was provided with sewers in 1910, but the figures represent roughly the areas that were fairly well settled and might with reason be provided with sewers. The populations estimated for these sewered areas are the ones which have been used as a basis for estimating the flow of house sewage. It will be noticed that in the low-level areas the whole population was assumed to be served by sewers. The total sewage flow, manifestly, is not the average daily amount of sewage that was discharged from the sewer outlets of the district during dry weather, in 1910, but the figures represent a rough estimate of the average amount that might have been expected under a more complete development of the sewerage systems.

Here, as throughout this report, the average flow of house sewage has been assumed to be 125 gallons per inhabitant per day, and the average ground-water

leakage has been taken at 500,000 gallons per square mile per day, irrespective of local conditions.

POPULATION AND SEWAGE FLOW OF THE FIVE SUB-DIVISIONS IN 1910.

Sub-division.	Area, Acres.	Area Sewered, Acres.	Population.	Population on Sewered Area.	House Sewage Mgd.*	Ground Water Leakage Mgd.*	Total Sewage Flow Mgd.*
1.—HIGH LEVEL TERRITORY.							
Quarantine.....	661	330	6,057	5,500	0.69	0.26	0.95
Stapleton.....	1,532	600	16,152	15,000	1.40	0.47	1.87
Livingston.....	893	600	11,183	10,000	0.93	0.47	1.40
W. New Brighton..	4,735	600	12,409	10,000	0.93	0.47	1.40
Elm Park.....	173	140	3,580	3,500	0.33	0.11	0.44
Totals	7,994	2,270	49,381	44,000	4.10	1.78	5.88
2.—HIGH LEVEL TERRITORY.							
Quarantine.....	156	80	1,404	1,404	0.13	0.06	0.19
Stapleton.....	182	110	3,241	3,241	0.30	0.09	0.39
Livingston.....	66	35	250	250	0.03	0.03	0.06
W. New Brighton..	321	240	5,082	5,082	0.47	0.19	0.66
Elm Park.....	459	280	4,962	4,962	0.46	0.22	0.68
Totals.....	1,184	745	14,939	14,939	1.39	0.59	1.98

* Million gallons per day of 24 hours.

TOTAL POPULATION AND SEWAGE FLOW OF THE FIVE SUB-DIVISIONS IN 1910.

Sub-division.	Area, Acres.	Area Sewered, Acres.	Population.	Population on Sewered Area.	House Sewage Mgd.*	Ground Water Leakage Mgd.*	Total Sewage Flow Mgd.*
Quarantine.....	817	410	7,461	6,904	0.64	0.32	0.96
Stapleton.....	1,714	710	19,393	18,241	1.70	0.56	2.26
Livingston.....	959	635	11,433	10,250	0.96	0.50	1.46
W. New Brighton..	5,056	840	17,491	15,082	1.40	0.66	2.06
Elm Park.....	632	420	8,542	8,462	0.79	0.33	1.12
Totals	9,178	3,015	64,320	58,939	5.49	2.37	7.86

* Million gallons per day of 24 hours.

The following table gives the densities of population, total population and average sewage flow used in designing the sewers of each subdivision. All the territory is assumed to be sewered. The area as far as the bulkhead line has been assumed to be populated. Much of the ground near the water will be occupied by industrial establishments instead of dwellings, but sufficient allowance for the sewage flow from these has probably been made by assuming the area populated throughout.

TOTAL POPULATION AND SEWAGE FLOW USED IN DESIGNING THE PROPOSED SEWERS.

Sub-division.	Density of Population per Acre.	POPULATION.			AVER. SEWAGE FLOW MGD.*		
		High Level.	Low Level.	Total.	High Level.	Low Level.	Total.
Quarantine	75 –100	52,870	15,600	68,470	7.12	2.08	9.20
Stapleton.....	70†–150	112,385	19,870	132,255	15.24	2.63	17.87
Livingston	75 –100	81,975	6,600	88,575	10.94	0.88	11.82
W. New Brighton..	40‡–120	247,960	38,260	286,220	34.69	5.04	39.73
Elm Park	80 –120	18,040	40,060	58,100	2.39	5.37	7.76
Whole District.....	40–150	513,230	120,390	633,620	70.38	16.00	86.38

* Million gallons per day of 24 hours.
† Average density on 1,116 acres.
‡ Average density on 1,814 acres. Average density of 50 on 1,283 acres.

Collecting Sewers for the Quarantine Subdivision.—Most of the sewage of the Quarantine subdivision will be collected at the foot of Nautilus street by a high-level intercepting sewer which will intercept the dry-weather flow from the combined sewer in Maple avenue at the corner of Anderson street and pass through Anderson street, Chestnut avenue, New York avenue, Sylvaton terrace and Bay street, and along the shore to Nautilus street. On its route, it will receive the flow from all the territory lying south and west of its course.

The sewage from the low land in Clifton will be collected at the corner of Bay street and Maple avenue by an intercepting sewer in Bay street which will intercept the dry-weather flow from existing sewers in Norwood avenue and Simonson avenue. At Bay street the dry-weather flow from the Maple avenue sewer will be diverted, and together with the flow from the Bay street intercepting sewer will be led into an automatic, electrically-operated pumping station to be located at this corner. From this pumping station, the sewage will be pumped through a force main in Bay street to the high-level intercepting sewer at the corner of Bay street and Sylvaton terrace.

The dry-weather flow from the existing Nautilus street sewer, which drains a large area, will be intercepted and carried by a short connecting sewer to a junction with the high-level sewer above mentioned. The plan also contemplates the construction of a small high-level sewer in Centre street which will intercept the dry-weather flow from the combined sewer at the corner of Norwood avenue and discharge it at Simpson avenue, or a short distance north of it, into the combined sewer planned for Centre street. It will thence be carried to the Maple avenue sewer and finally into the high-level sewers in Anderson street.

The proposed collecting sewers in the Quarantine subdivision vary from 12 inches to 3 feet 3 inches in diameter. Their total length, including the force main, but exclusive of the outlet pipe, is 1.46 miles.

Collecting Sewers for the Stapleton Subdivision.—A large part of the area included within the Stapleton subdivision is at a sufficient elevation to permit its sewage to be collected and passed by gravity through tanks located in Stapleton, but the elevations of the streets in the vicinity of the works are so slight that the sewage from the high-level districts will have to be carried to the works in long conduits submerged below the hydraulic gradient.

On the north, the dry-weather flow from the Arietta street sewer will be intercepted at Stuyvesant place and brought, together with sewage collected on its route, by a high-level sewer passing through Stuyvesant place, Griffin, Hannah, Sarah Ann, VanDuzer and Elizabeth streets to a point a short distance east of VanDuzer street, from which place it will be carried to the treatment works, located on Front street between Prospect street and Water street, by a siphon passing through Elizabeth street, rights of way and Front street.

On the south, the dry-weather flow from the large sewer in Broad street will be intercepted at the corner of Canal and Broad streets and carried to the treatment works by a siphon passing through Canal, Water and Front streets. From the corner of Riker and Broad streets, a connection will be laid in such a way as to join the large Broad street sewer just above the point at which its dry-weather flow is intercepted.

At Wright and Beach streets, this siphon will have connections through which the dry-weather flow from the existing sewers in these streets will be added. Ample head for this purpose can be secured without making these cut-off sewers of great length.

That part of the sewage of the subdivision which cannot be passed through the treatment works by gravity will be brought to an automatic, electrically-operated pumping station located at the works. Here the sewage will be raised by the pumps to such an elevation as to allow it to pass through the tanks.

The two low-level intercepting sewers required will be built in Front street and will be short. The one from the north will start, until its extension is required, by intercepting the dry-weather flow from the existing Elizabeth street sewer; the one from the south will intercept the dry-weather flow outlet sewer at present in Canal street, and will be joined by the existing 15-inch sewer in Water street. It is assumed that the 10-inch sewer in Thompson street, which now creates foul conditions by discharging into the dock, will be joined to the sewer in Canal street and the flow thus taken to the treatment works.

In designing the high-level siphons, the available head was found so small that the velocities through the siphons would have to be less than desirable. They would be especially small for a number of years. Trouble from this cause can be obviated by constructing by-passes from these siphons to the suction well of the pumping station at the treatment works. By means of these by-passes, the siphons can be easily and effectively flushed.

It was found best to make the south siphon of a capacity sufficient to take care of the needs for only a few years with the idea that one or two more conduits can be constructed as required. With the north siphon, conditions were somewhat different. It will be economical to provide this siphon with the same capacity as that of the intercepting sewer leading to it. In order to make the velocity of sewage as great as possible when the flow is small, the north siphon will consist of two pipes of different sizes, the larger one to come into use automatically when the level of the sewage in the high-level sewer reaches a certain height.

Both the north siphon, of 24-inch and 18-inch pipes, and the south siphon, of 24-inch pipe, could, it is thought, be built economically and properly of vitrified pipe, with bituminous joints and surrounded by concrete, and the estimates have been based upon this type of construction.

The proposed collecting sewers in the Stapleton subdivision vary from 15 inches to 2 feet 9 inches in diameter. Their total length, including siphons, but exclusive of outlet pipe, is 1.54 miles.

Collecting Sewers for the Livingston Subdivision.—Practically all the sewage of the Livingston subdivision can be brought to the treatment works at the foot of Kissel avenue and passed through them by gravity.

The sewage from St. George and New Brighton will be collected by a high-level intercepting sewer which will start at the corner of Jay and Wall streets and pass through Jay street and Richmond terrace to the treatment works.

From the south a high-level sewer will start at the corner of Kinsel avenue and Brighton boulevard and pass through Kissel and Bergen avenues and Health

place to the treatment works. A branch of this sewer will be constructed in Bergen avenue between Oakland avenue and Health place.

A small low-level intercepting sewer will be built in Richmond terrace from Oakland avenue to a small, automatic, electrically-operated pumping station located at the site of the treatment works.

In this subdivision the high-level sewers will have to pass through low land before reaching the treatment works. The street grades in these low areas have been at least tentatively established. However, the area is not yet built up and it will be feasible to raise the projected street grades wherever necessary, so as to give a light, but sufficient cover over the top of the sewers.

The proposed collecting sewers in the Livingston subdivision vary from 10 inches to 3 feet 3 inches in diameter. Their total length, exclusive of outlet pipe, is 2.77 miles.

Collecting Sewers for the West New Brighton Subdivision.—The sewage of the West New Brighton subdivision will be collected by two high-level and two low-level sewers. Just before reaching the treatment works, which are to be located south of Starin avenue, between Bodine and Dongan streets, the sewers join so as to form one high-level and one low-level sewer.

The east high-level intercepting sewer will start at the corner of Elm court and Henderson avenue and pass through Henderson avenue, Water street and Richmond terrace to a junction with the west high-level intercepting sewer.

The west, or perhaps better, the south-high-level intercepting sewer, has been assumed, for the purposes of this report, to start at the proposed Northfield boulevard. Its route will be through Linnet street, Madison avenue, Jewett avenue, Roberts street, Manor road, Castleton and Columbia avenues, Cedar and Bodine streets and Richmond terrace, and thence through the city's property at the West New Brighton garbage incinerator. A small branch of this sewer will be built in Palmer avenue east from Heberton avenue, so as to intercept the sewage flow from the high area west of the latter street.

The east low-level intercepting sewer will start at the foot of Broadway, at which point it is assumed that the flow from the combined sewers in the low area in the vicinity will collect, and will pass through Richmond terrace and Starin avenue to Dongan street, where it will join with the west low-level intercepting sewer.

The sewage from a large part of Port Richmond and the low area in the vicinity of Bodine creek and Palmer's run will be brought to an automatic, electrically-operated pumping station at the treatment works by the west low-level intercepting sewer which will start in Richmond avenue north of Rich-

mond terrace and pass through Richmond terrace, Starin avenue and Dongan street.

Whether the large undeveloped areas in the West New Brighton subdivision, which lie south of the proposed Northfield boulevard, are finally sewered upon the separate or upon the combined plan, all the dry-weather sewage flow can be brought by gravity to the upper end of the west high-level intercepting sewer as proposed.

On account of the large population which eventually will occupy the extensive area tributary to it, this sewer is much larger than any of the collecting sewers in the other subdivisions, and can serve for many years to carry to the waterfront much of the storm-water brought to it by the combined sewers in West New Brighton. The surplus storm-water would be led to a trunk sewer which would also collect the flow from the sewers of the low-level district. It is suggested that this trunk sewer be designed of a size sufficient to care for the ultimate dry-weather flow of the low-level district tributary to it, together with only such storm-water as it would probably have to carry for a few years, with the idea that later, when it becomes necessary to close up the water courses and provide artificial channels for the storm-water from the large and now undeveloped areas, a large storm-water sewer can be built to the waterfront.

The conditions in much of this subdivision, with its numerous open watercourses, are such that great economy would result from the construction of sewers on the separate system. It will be particularly desirable, when the time arrives, to sewer on the separate system that portion of this subdivision which lies south of Richmond turnpike and drains directly to Willow brook. When it becomes no longer possible to provide for the storm-water from this area on the surface, it should be emptied into Fresh Kills instead of being carried with the house sewage all the way to the Kill van Kull.

In all the subdivisions, it has been assumed that streets would be opened and graded according to the plans at present outlined by the borough. In this subdivision, particularly, the routes of many of the proposed sewers are laid out in streets which are not yet opened.

Owing to topographical conditions in the different subdivisions, the high-level sewers, near their entrance to the various treatment works, have had to be placed lower with reference to the ordinary sewage level in the settling tanks than is desirable. With the small amount of sewage that will be carried through these sewers in dry weather for some time after their construction, small velocities will occur in their lower ends. This will cause trouble from deposits only for a short distance, if at all, in any of the sewers except the west high-level sewer of the West New Brighton subdivision, as all of them except the one named are small

in size and their grades are considerable. While the dry-weather flow is small it might be practicable to run the tanks with a somewhat lower sewage level than that for which they are designed. Opportunity for creating a greater velocity at intervals might be afforded by a temporary lowering of the water level in the tanks or by providing a by-pass to the pumping stations, outfall pipes, or to storm or combined sewers at a lower level.

The proposed collecting sewers in the West New Brighton subdivision vary from 8 inches to 6 feet 9 inches in diameter. Their total length, exclusive of the outlet pipe, is 3.14 miles.

Collecting Sewers for the Elm Park Subdivision.—In the four subdivisions already considered, it has been found practicable to collect and dispose of most of the sewage by gravity. Conditions in the Elm Park subdivision are different, resulting in the necessity of pumping considerably more than half the sewage.

A high-level intercepting sewer will start at the corner of Lafayette avenue and Harrison avenue, Port Richmond, to which point it is assumed that a combined sewer in Elizabeth street and Harrison avenue will bring sewage from points as far east as Broadway. The route of the high-level sewer will be through Harrison, Nicholas and Charles avenues, Douglas street and Newark avenue to the treatment works at the corner of Newark avenue and Richmond terrace. A short branch of this sewer in Roselle and Monroe streets, as far as the railroad, will bring to it the dry-weather flow from existing sewers in Monroe and Cedar streets.

From the east, the sewage from the low-level district will be brought to an automatic, electrically-operated pumping station at the treatment works by a sewer in Richmond terrace starting at Nicholas avenue. From the west, the sewage will be carried to the pumping station by a sewer in Richmond terrace. This sewer will intercept the dry-weather flow from the exitsing combined trunk sewers in Harbor road, Union avenue and Housman avenue.

The proposed collecting sewers in the Elm Park subdivisions vary from 8 inches to 3 feet in diameter. Their total length, exclusive of the outlet pipe, is 1.97 miles.

Pumping Stations.—All the pumping stations in the division will be of the automatic, electrically-operated type. The current for operating them can be purchased, or it might be furnished by the garbage incineration plants at West New Brighton and Clifton, thus affording a desirable outlet for some of the surplus power generated at those plants. This surplus power would undoubtedly be used at the West New Brighton sewage pumping station, as there would be no

expense for transmission at this point. It would also probably pay to transmit power from the Clifton incinerator to the Maple avenue pumping station in the Quarantine subdivision. Whether it would be economical to transmit power from the West New Brighton incinerator to the Elm Park and Livingston pumping stations, and from the Clifton incinerator to the Stapleton pumping station, would depend upon the price for which current could be purchased from the light and power company.

All the pumping equipment ultimately necessary in these stations would not be required at first. However, all pumps and motors should be in duplicate.

The following table gives the average total head pumped against, the estimated average sewage flow which would have arrived at each pumping station in 1910 under the assumptions given in the discussion of population and sewage flow, the average sewage flow at each station which was used as a basis for estimating the cost of operation, and the aggregate average sewage flow which the sewers leading to the station were designed.

Pumping Station.	Total Head, Feet.	Average Sewage Flow—Mgd.*		
		Estimated for 1910.	Basis for Cost of Operation.	Contributing Sewers Designed for.
Maple Avenue	10.0	0.19	0.50	2.08
Stapleton	12.0	0.39	1.00	2.63
Livingston	14.0	0.06	0.25	0.88
W. New Brighton	13.5	0.66	2.00	5.04
Elm Park	14.5	0.68	2.00	5.37
All Stations	....	1.98	5.75	16.00

* Million gallons per day of 24 hours.

Outlets.—All the outlet pipes through which the effluent from the various treatment works will be discharged will extend into deep water where the currents are swift.

In the Quarantine subdivision, it is proposed to make use of an existing 20-inch cast-iron outlet sewer which extends out to a point about 225 feet from the present shore line. This pipe will be of sufficient capacity to last for many years, and it should be extended to, or nearly to, the pierhead line. When necessary, another outlet pipe can be added.

There is at present a 3-foot wood stave pipe running to the outer end of the

municipal ferry pier at the foot of Canal street, Stapleton, through which pipe the dry-weather flow from the tributary sewers is carried to deep water. This pipe is of sufficient size to carry the effluent from the proposed Stapleton treatment works for many years, and could be made of use. When the pier is extended to the established pierhead line, the outlet pipe should be extended also. When necessary, another outlet can be built at the foot of Prospect street.

From the Livingston treatment works, it is proposed to lay a submerged 24-inch cast-iron pipe to deep water beyond the pierhead line and, when necessary, another outlet pipe can be laid.

Although greatly increased capacity of outlets from the West New Brighton treatment works will ultimately be needed, a 3-foot pipe will be ample in size for a long time. It would probably be practicable to lay a wood-stave pipe under the existing pier at the foot of Bodine street and to extend the outlet for some distance into deeper water by means of a submerged cast-iron pipe.

From the Elm Park treatment works, it is proposed to lay a submerged 20-inch cast-iron pipe into deep water at a considerable distance beyond the pierhead line. This pipe will be of sufficient size to last for a number of years. It can be supplemented by another pipe when greater capacity becomes necessary.

Treatment Works.

Forms of Treatment Proposed.—The form of treatment proposed for the sewage is coarse screening and sedimentation, and is the same for all the subdivisions except the Quarantine. A period of from two to three hours should be allowed for settlement. It is believed that the deep water and strong currents along the shores of this district will afford ample opportunity for the diffusion and digestion of sewage in such quantities as may be expected from this portion of Staten Island, if it is treated in the manner proposed, and discharged from submerged outlets into water of 30 feet or more in depth and good current.

The successful protection of the water along these shores will, however, depend somewhat upon the measures taken elsewhere for the betterment of the harbor. The present pollution along the northern, and particularly the northeastern, shore of Staten Island is, to some extent, due to the condition of the harbor water in general.

Passage through grit basins, coarse and fine screens is the form of treatment proposed for the Quarantine subdivision, as the opportunity for diffusion and digestion of the sewage by the harbor waters is here especially favorable.

At the treatment works for all the subdivisions, grit chambers, with a settling period of from one to two minutes, will be provided. Where screening is

to be used, the grit chamber will prevent heavy deposits which might occur in the outlet pipes or on the harbor bottom near the points of discharge. Where settling tanks are to be used, the grit chambers will guard against trouble that would occur from the deposition of heavy solids in the tanks which are intended for the sedimentation of organic matters.

Sites for Treatment Works.—Many factors have affected the choice of sites for treatment works in the various subdivisions. Among the chief considerations have been the existence of undeveloped land of sufficient area for plants of the size which will ultimately be necessary, the location of these areas at such points as may be best suited to an economical collection of the sewage, this collection being accomplished, as far as possible, without the use of pumping machinery, proximity to any serviceable sewage outlets that might occur, and favorable location with respect to railroad facilities.

At the foot of Nautilus street, there is ample room for locating a screen and for the Quarantine subdivision.

The best site for the location of settling tanks for the Stapleton subdivision seems to be on the west side of Front street between Water and Prospect streets. This location is contiguous to the railroad, and the greater part of the site is occupied by an old asphalt plant and storage yard which is out of use and for sale. On the Water street front there are a few old tenements. By a judicious arrangement of tanks, it will be possible on the area available to treat all the sewage that is likely to reach this point. If, for any reason, the purchase of this land is deemed inadvisable, there are other unoccupied sites in the immediate neighborhood which probably could be obtained.

The proposed site for the Livingston treatment works is west of Kissel avenue between Richmond terrace, as it is to be re-located, and Livingston place. There may be opposition to the establishment of treatment works here, but it is the logical place for them and, if the tanks are properly operated, no offense should be created.

The best site for treatment works in the West New Brighton subdivision is near the garbage incinerator. Economy of operation should result from their location at this point. The block bounded by Starin avenue, Dongan street, Richmond terrace and Bodine street, seems to afford the best site for the works and has therefore been selected. There probably will be plenty of room within this area, even without including the lots bordering on Richmond terrace, to treat any volume of sewage which needs to be collected at this point.

In the Elm Park subdivision, the most favorable site seems to be at the east corner of Richmond terrace and Newark avenue, although there is a considerable

amount of unoccupied land in the vicinity. A location much farther to the west would be inadvisable, if for no other reason than on account of unfavorable conditions which exist there for the discharge of sewage.

Capacities of Treatment Works.—In designing the treatment works, sufficient capacity should be provided to take care of the volume of sewage to be expected for a reasonable period in the future. Nevertheless, the tank capacity to be provided in the first installation should not exceed the economical limit, as units can be added when necessary.

The following table gives the estimated average daily amount of sewage which might have been brought to the various works had they been in existence in 1910, and also the capacities which were used as a basis for estimates of cost of construction and operation and which are deemed reasonable as capacities to be provided for in the first installations.

Sub-division.	Average Sewage Flow—Mgd.*	
	Estimated for 1910.	Treatment Works, First Installation.
Quarantine	0.96	3.0
Stapleton	2.26	6.0
Livingston	1.46	4.0
W. New Brighton	2.06	6.0
Elm Park	1.12	3.0
All Sub-divisions	7.86	22.0

* Million gallons per day of 24 hours.

Disposal of Sludge.—The sludge produced in this division may be disposed of in various ways. For many years the amount of sludge will be comparatively small. In 1910, the digested sludge from two-story settling tank installations in the four subdivisions for which they are proposed might have amounted to 18 tons a day. When the capacities of the first tank installations are reached, the amount of sludge will probably be about 38 tons a day.

The treatment works in the district are so placed that the sludge can be transported by water or rail. It would be possible, therefore, to dispose of it either at sea or on land. The presence of two garbage incinerators, both almost directly on railroad lines, would make it feasible to burn the sludge and garbage together. Centrifugal dryers might be placed at each disposal plant to dry the sludge before

transportation, or it might be more economical to install such dryers at one or both incinerators and transport the larger volume of wet sludge to the incinerators in proper cars.

There is a large amount of waste land along the railroad line in the northwestern part of the island, near Arthur Kill, which would be suitable for filling with the dried sludge from the settling tanks. If the sludge were transported hither without previous drying, it would probably be necessary to establish drying beds near the railroad before the sludge could be made available for filling purposes.

If the sludge is to be disposed of at sea, it would be advisable to collect it at one or two points, to avoid construction of piers and loss of time in the operation of sludge steamers. For the purposes of this report, it has been assumed that all the sludge would be delivered wet into tanks located at the Stapleton treatment works, from which tanks a sludge discharge pipe would run out on the municipal pier. By this plan no new piers would have to be built and the sludge steamers passing out of the harbor from other treatment works would have to deviate only slightly from their course to serve as carriers for the Staten Island sludge.

Cost of Main Drainage Works.

The estimated costs of the main drainage works proposed in this report, not being based on detail designs, are necessarily of a preliminary nature.

The following tables give a concise summary of the estimated cost of construction and of the annual charges for maintenance and operation. The costs of land and rights of way are not included.

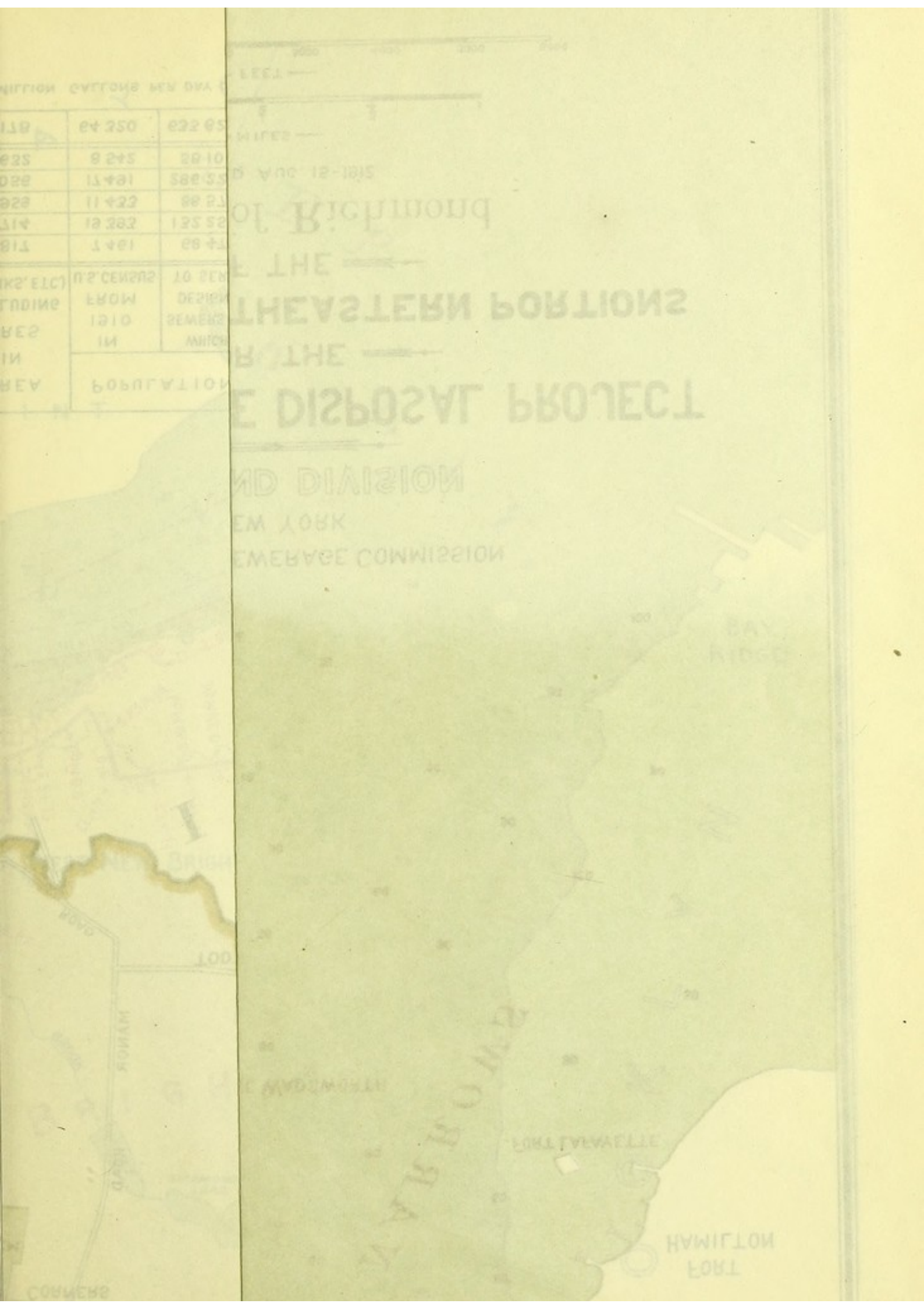
Estimated Cost of Construction.

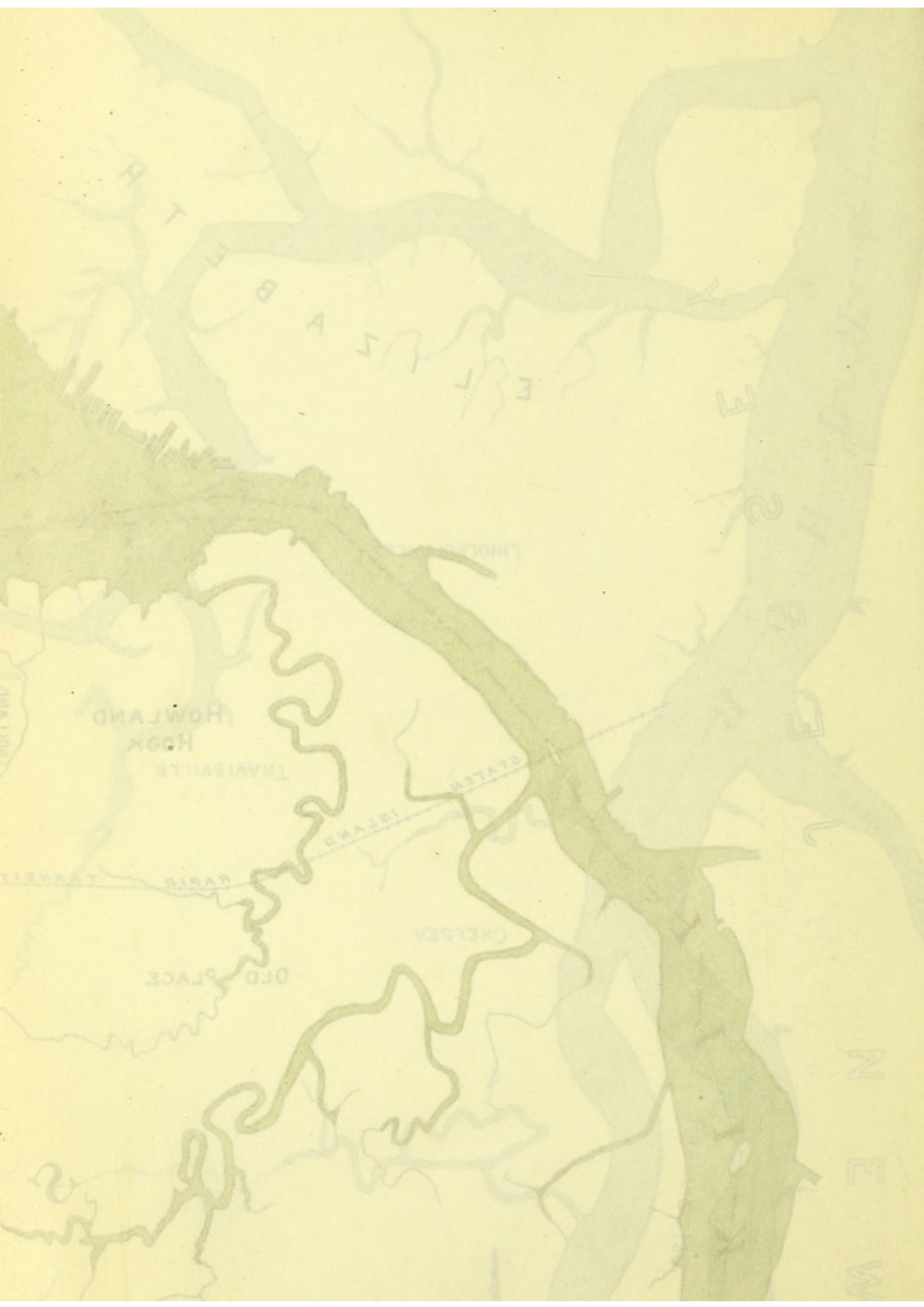
Sub-division.	Sewers.	Pumping Stations.	Outfall Pipes.	Grit Chambers.	Treatment Works.	Total Without Engin'g, etc.	Engineering & Contingencies, 15%.	Total Costs.
Quarantine.....	$38,225*	8,000	6,000	....	8,000‡	60,225	9,035	69,260
Stapleton.....	62,430†	10,000	3,000	3,500	63,000	141,930	21,290	163,220
Livingston.....	84,995	6,000	12,600	2,500	42,000	148,095	22,215	170,310
W. New Brighton...	164,305	12,000	17,400	3,500	63,000	260,205	39,030	299,235
Elm Park.....	62,125	12,000	13,500	2,000	31,500	121,125	18,170	139,295
Whole District.....	$412,080	48,000	52,500	11,500	207,500	731,580	109,740	841,320

Estimated Annual Cost of Maintenance and Operation.

Sub-division	Annual Cost of Maintenance and Operation.		
	Without Fixed Charges.	Fixed Charges.	Total.
Quarantine	$3,820	3,505	7,325
Stapleton	5,127	8,260	13,387
Livingston	4,694	8,618	13,312
W. New Brighton	7,584	15,142	22,726
Elm Park	5,742	7,048	12,790
Whole District	$26,967	42,573	69,540

* Including Force Mains.
† Including Siphons.
‡ Grit and Screen Chamber.





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PRELIMINARY REPORTS

ON THE

DISPOSAL OF NEW YORK'S SEWAGE

IV.

STUDY OF THE COLLECTION AND DISPOSAL OF THE SEWAGE OF THE UPPER EAST RIVER AND HARLEM DIVISION*

METROPOLITAN SEWERAGE COMMISSION
OF NEW YORK

GEORGE A. SOPER,
JAMES H. FUERTES,
H. de B. PARSONS,
CHARLES SOOYSMITH,
LINSLY R. WILLIAMS,
Commissioners

JULY, 1912

*This report is issued in advance of the final report of the Metropolitan Sewerage Commission in order that the contents may be of early service. Some features of this report will remain open for revision until the final report is submitted.

THE EVENING POST JOB PRINTING OFFICE, 156 FULTON ST., N. Y.

STUDY OF THE COLLECTION AND DISPOSAL OF THE SEWAGE OF THE UPPER EAST RIVER AND HARLEM DIVISION

Honorable WILLIAM J. GAYNOR, Mayor of the City of New York:

SIR: In Preliminary Report No. 1, dated September, 1911, the Metropolitan Sewerage Commission divided the territory covered by the City of New York into four parts to facilitate the design of main drainage works for the protection of the harbor against excessive sewage pollution. The works for the Jamaica Bay Division, one of these parts, were described in a report dated December, 1911. The present report deals with a general plan for main drainage and sewage disposal for a second part, known as the Upper East River and Harlem Division, which embraces the land in the Boroughs of the Bronx and Manhattan, which drains to the Harlem river, and the land in the Boroughs of the Bronx and Northern Queens which drains to the Upper East river.

The plan here set forth is the result of careful study based on the outlook in the year 1912 for the municipal development of the region under consideration and on the existing state of the art of sewage disposal.

All the work planned will not be required in the immediate future, but it is regarded as necessary that such main drainage work as is undertaken by the city should conform to these plans, or such modifications of them as may be determined upon. The possibility that a more complete system of main drainage than is here proposed may be needed in the distant future has been kept in mind in preparing these plans and it is believed that the works can be economically adapted to afford a more thorough protection of the harbor in the case of necessity.

The most prominent feature of the plan is the discharge of the sewage, after partial purification, into the large, deep tidal channels, as near the sound entrance of the habor as practicable.

The works are intended to deal with the dry-weather flow of sewage as collected in the lateral sewerage systems now built on the combined system. Where no sewers have yet been constructed, it will generally be desirable to build them on the separate system; this will not only facilitate a removal of the impurities, but contribute to economy of construction.

TOPOGRAPHICAL FEATURES OF THE DIVISION

The Harlem river and the Upper East river determine the principal topographical features of this division. The Harlem river runs through a narrow

valley with shores which are in part densely populated, or are certain to become so at no distant day. The shores of the Harlem are nearly parallel, the stream resembling, in some respects, and being actually in part, a canal. The water is already so overburdened with sewage that no system of diffusion or other partial remedy is capable of sufficiently improving it. There is not room on the drainage area of the Harlem for purification works capable of sufficiently improving the sewage to permit of its discharge into these waters, and consequently the sewage must be taken elsewhere.

The shore lines on both sides of the Upper East river are markedly irregular; the water surface being characterized by a series of large, shallow bays along the whole length, separated by long, narrow points of land.

The water in the main channel which flows through the Upper East river is not now overburdened with sewage, nor is it likely soon to become so. It has a large capacity for assimilating sewage provided the sewage is properly treated and then discharged directly at the bottom of the tidal stream.

The parts of this territory which present difficulties to main drainage are chiefly flat, low-lying valleys which extend long distances inland from the shallow bays of the river.

Except in the closely built-up part of this division, which is, or will be, tributary to the Harlem river, the population in the territory included in this report is chiefly of a semi-rural residential character, located in numerous growing villages not largely devoted to manufacturing. The future of this division seems to lie in its more complete occupation for residential purposes. The configuration of the shore, the shallowness of the water, except in the main channels, and the distance from the metropolitan centers of commercial activity are opposed to the extensive development of this section for the uses of manufacturing and transportation.

Bathing beaches, camps and other provisions for recreation at moderate expense during the summer months are now more or less numerous and seem destined to increase in popularity unless the pollution of the harbor water should become so great as to be too objectionable.

Formerly shellfish of excellent quality were gathered in large number in the Upper East river, and even at the present time hard-shelled clams are dredged near where the river joins Long Island Sound. Except for small boats, yachting, which was, and is, enjoyed by many persons in the Upper East river, has, for the most part sought Long Island Sound for the clearer water, lesser tidal currents and greater freedom from traffic which there prevail.

Separation of the Division Into Five Parts for Main Drainage Purposes

To facilitate the sewerage and drainage of the Upper East river and Harlem division the entire territory has been separated in this report into five sub-divisions.

In each sub-division the sewage is to be collected to a central point for treatment and discharge. The boundaries of the five sub-divisions follow:

1. *The Harlem Sub-division* comprises the land in the Borough of Manhattan, north of 82d Street, naturally draining to the Harlem river, and that part of the Borough of the Bronx lying west of the Bronx river, except a narrow strip draining to the Hudson river.

2. *The Eastern Bronx Sub-division* comprises that part of the Borough of the Bronx which lies east of the Bronx river. Westchester, Unionport and Van Nest are situated within this area.

3. *The Northwestern Queens Sub-division* comprises the northwestern part of the Borough of Queens, draining mostly to Bowery bay and to the westerly shore of Flushing bay, and includes North Beach, Woodside, Steinway and a part of Corona.

4. *The Corona-Flushing Sub-division* comprises that portion of the Borough of Queens, tributary to the East river, which extends from the southeastern boundary of sub-division 3 southerly to the main divide of Long Island and easterly to a line running through Whitestone and Ingleside. Most of this area lies in the Flushing creek drainage basin. Winfield, Elmhurst, Corona, Flushing and College Point and parts of Whitestone are situated within its limits.

5. *The Northwestern Queens Sub-division* comprises that part of the Borough of Queens, tributary to the East river and Little Neck bay, which lies east of the limits of sub-division 4. Douglaston, Bayside and parts of Whitestone are included in this area.

Points for Concentration and Discharge of the Sewage

The sewage will be collected to as many points as there are sub-divisions.

The sewage of the Harlem Sub-division is to be carried to Ward's Island, where it is to be treated and the effluent discharged into the swift currents of Hell Gate.

The sewage of the Eastern Bronx Sub-division will be collected near Clason Point, where, after treatment, it will be discharged into the deep water of the Upper East river.

The sewage of the Northwestern Queens Sub-division will be carried to a point in the neighborhood of Hell Gate and there discharged.

The sewage of the Corona Flushing Sub-division will be brought to Tallman Island, where treatment works can be located. The sewage will be discharged into the East river under conditions favorable for diffusion.

The sewage of the Northeastern Queens Sub-division will be carried to Cryder's Point, just west of Little bay and opposite Throggs Neck. There the sewage can be discharged into deep water at the extreme east end of the East river.

Methods of Treatment

Note:—The methods which are proposed in this report for treating the sewage are such as have been thoroughly tested and found by the experience of many cities to give good results. While not designed to afford a high degree of purification, the processes are among the most reliable, least offensive and most economical known, and are believed to be capable of removing the impurities of the sewage to such an extent as to permit of the effluent being discharged into the harbor under suitable conditions without offense.

Eventually the growth of population and the consequent increase in the quantity of sewage produced probably will require that more complete methods of treatment shall be employed, or that the sewage shall be taken to some other place for disposal. It is impossible to foretell with accuracy when that time will arrive, but the Commission is of opinion that the works now planned will afford all the protection which the harbor will require for the next forty years, or until about 1952. As to the methods of treatment which ultimately will be needed, it is equally difficult to prophesy; the art of sewage purification has by no means reached perfection, and if the progress of the next forty years equals the accomplishments of the last twenty, a not unreasonable anticipation, marked improvements may be expected in the efficiency, economy and reliability of existing methods, if not the introduction of new processes, which will be revolutionary in character.

The probability that it ultimately will be necessary to protect the harbor against sewage to a greater extent than the requirements of the present or discoverable future require has been clearly recognized by this Commission from the first and has been kept in mind in making the plans here proposed with the object that these works might form part of a more comprehensive scheme of dealing with the sewage when that becomes necessary.

Methods of Treatment Proposed.—After a careful study of the question of the form of treatment required for the sewage of the Upper East River and Harlem Division, due regard being had to the needs of each of the five outlets, the conclusion has been reached that fine screening or coarse screening and sedimentation will, for some years, give an effluent of satisfactory character for discharge into the water of the East river.

Where sedimentation tanks are to be used, coarse screens will be employed to protect the pumping machinery and to keep large floating matters from causing trouble in the tanks and from passing out through the outfall.

In all cases grit chambers will be placed on the lines of the main trunk sewers at or near the treatment works. In these chambers the sewage will be given a settling period of from one to two minutes, the velocity being reduced sufficiently to allow the heavy mineral detritus borne by the sewage to be deposited, but not enough to permit much organic matter to settle.

The grit chambers will afford protection to the pumps and will keep the proposed long and deep outfall pipes clear of gritty deposits wherever sedimentation tanks are not used. Where sedimentation tanks are planned, the grit chambers will first rid the sewage of suspended matter of a kind which would cause trouble and be difficult to handle if allowed to settle in the tanks. Grit chambers are especially useful where combined sewers are intercepted or form a part of the collecting system, as will largely be the case with the main drainage systems as here proposed for New York City.

The treatment works at Ward's Island, Clason Point and Tallman Island, for the Harlem, Eastern Bronx and Corona-Flushing Sub-divisions, respectively, should consist of grit chambers, coarse screens and settling tanks. Fine screens and grit chambers at the foot of Winthrop Avenue, Long Island City, will suffice for the treatment of the sewage for the Northwestern Queens Subdivision; the sewage from the Northeastern Queens Sub-division should be passed through grit chambers and fine screens at Cryder's Point, Beechurst.

If it were deemed necessary to purify the sewage from the Harlem Subdivision to a greater extent than would be done by sedimentation or chemical precipitation, it is doubtful if its further purification could be undertaken either at Ward's Island or at any other place in the vicinity. The area of land required for percolating filters, to treat the large volume of sewage which is to be brought to Ward's Island, would require more land than is available, and the odors which might be produced by their use would be objectionable in this location.

The amount of sewage to be discharged from Queens into the East river at Winthrop Avenue, although large in the distant future, will, for many years, be considerably less than the quantity brought to Tallman Island. It will never be more than a small proportion of the amount to be discharged into the river from the Ward's Island sedimentation plant, only a few hundred feet distant from Winthrop Avenue. In view of this fact, screening is the only form of treatment deemed necessary for the sewage of the Northwestern Queens Subdivision. If a more thorough treatment be needed in the future, when the volume of sewage becomes greater, it will be possible to carry the sewage by means of a tunnel under the East river to the disposal works at Ward's Island; or the necessary land for a pumping station and settling tanks may be procured in the Borough of Queens.

The amount of sewage to be discharged at Cryder's Point probably will always be comparatively small and the opportunity for its diffusion and digestion in the waters of the East river is favorable; therefore screening is the only treatment required for the sewage of the Northeastern Queens Sub-division.

Sites for Treatment of Works

Harlem Sub-division.—After considering many projects for the collection and disposal of the sewage of this sub-division it becomes evident that it would be uneconomical to take the sewage further from Hell Gate, provided a suitable site for treatment works could be found in that vicinity.

For a time it seemed likely that Riker's Island might offer every necessary facility for the disposal of the sewage, not only of the Harlem, but of most of the other sub-divisions. The area of Riker's Island is large enough for any works which might be needed, the situation is remote from inhabited shores and the island, as yet but little occupied, already belongs to the City.

Upon investigation, Riker's Island was found to be unsuitable as a site for sewage disposal works. Composed of uncompacted refuse from New York City, the stability of the island is too uncertain to warrant the construction of the extensive engineering works required, and large sums of money would have to be spent for grading in order to save the excessive cost of pumping the large volume of sewage to the present level of the island.

The island known as Sunken Meadow was examined, but was found to require too much improvement to warrant its use as a location for sewage disposal works.

A better and a satisfactory location for the works required lies at the northeast corner of Ward's Island. This island is more favorably located than Riker's Island in respect to the economical collection of the sewage, and the land at the proposed site is low, firm and of sufficient extent for such works as will be required. The island belongs to the City of New York and is partly occupied by public institutions. No injury would be done by employing the corner selected for treatment works. Deep water lies close to the island; the shore is smooth and the currents are swift. The opportunities for an immediate diffusion of the sewage in the water are perhaps better at this place than at any other point in the whole metropolitan district, owing to the mixing action of the currents.

Eastern Bronx Sub-division.—Two large areas of marsh land, southwest and southeast of Unionport, were at first considered as sites for sewage disposal works, each being of ample size, but both situated far from deep water. A more

favorable site for the location of such disposal works as will be needed for this sub-division exists near Clason Point, where the ground is low and firm, and the deep and swift currents of the main channel of the Upper East river pass near the shore. A large part of the sewage from this sub-division will be brought to Clason Point by the drainage system now under construction, and the remainder can be collected at low cost.

Northwestern Queens Sub-division.—Most of the land in the Northwestern Queens Sub-division drains naturally to Flushing and Bowery bays, but owing to the shallow water and absence of currents capable of mixing with the sewage and carrying it away, there is no point in either bay where large quantities of treated sewage should be discharged. The nearest suitable point for the discharge of the sewage, after the removal of the suspended matter, is Hell Gate, near the foot of Winthrop Avenue, and directly opposite the proposed Ward's Island treatment works. The volume of sewage to reach this place probably will be small for many years, and such land as is needed for the simple treatment required can be procured without great difficulty or expense.

Corona-Flushing Sub-division.—A large proportion of the sewage of the Corona-Flushing Sub-division can easily be concentrated near the mouth of Flushing creek and the rest can be collected by a sewer running from that point to Tallman Island, where treatment works should be located.

Tallman Island is the nearest point to the mouth of Flushing creek at which treatment works, of a kind requiring the discharge of the effluent into deep water and swift currents, can satisfactorily be placed. Both land and water conditions are suitable at this point for the location of disposal works and the discharge of the effluent. The site is practically devoid of improvement and little or no injury will be caused to future development by such works as are proposed. Deep water exists at a short distance from shore, and the volume and character of water flowing past this point are favorable for the digestion of a large quantity of sewage.

The comparative ease with which the sewage from that part of the Flushing Creek Sub-division which lies west of the creek, can be united with that from the neighborhood of Flushing and brought to Tallman Island, makes it desirable that such disposition of the sewage should be made. The sewage should not be carried to Hell Gate, for this would be more expensive and increase the burden which the water of the East river has to bear near the densely populated districts of the city.

Northeastern Queens Sub-division.—The only practicable place for the discharge of the sewage of the Northeastern Queens Sub-division, unless intensive treatment be employed, is the East river, between Whitestone Point and Cryder's Point. The latter is the more suitable place both for the collection and the discharge of the sewage. The East river offers better opportunities for the reception of sewage off Cryder's Point than it offers at Tallman Island or Clason Point. As the amount of sewage will probably be comparatively small, for at least a great many years, and the conditions for the digestion of the discharged sewage by the water are favorable, fine screening is the only treatment deemed necessary at this point. There should be no objection to the presence of a screening plant, provided the appearance of the building conforms with the surrounding development.

Instead of carrying the sewage of Bayside and Douglaston to Cryder's Point, as is here proposed, it is possible to treat it on percolating filters which can be built on the marshes near Alley creek, but as these might be objectionable to the residents of the neighborhood, the plan is not considered advisable.

OUTLETS

Location and Depth.—The sewage will be discharged in every case at a distance from the shore, the position of the outfall depending upon the nearest point at which water of suitable depth can be found. It is proposed always to have the sewage discharged at depths of from 30 to 50 feet, and in such manner as to give a favorable opportunity for its admixture with the water of the river. In order to facilitate diffusion, it will be desirable to discharge the sewage from each point at more than one outlet.

Systems of Main Drainage

Character of Sewers Proposed.—The main collecting and intercepting sewers, as planned by the commission for the Harlem, Eastern Bronx and Northwestern Queens Sub-divisions, will carry only the dry-weather flow of the contributing combined sewers, already built or to be built, in these districts. They are not designed to carry any portion of the storm flow. Overflows from these main dry weather sewers will allow the storm water to pass directly to the water courses. The commission does not believe that, in this district at least, the advantage gained by the treatment of the storm water, at the works proposed, would warrant the extra expense involved in that procedure.

The main collecting and intercepting sewers, planned by the commission for the Corona-Flushing and Northeastern Queens Sub-divisions, will carry only house sewage. In these areas it is especially desirable that all new sewers be built on the separate system. Throughout this territory, few sewers of any kind have as yet been built. Practically the only combined sewers are in the villages of Flushing, Ingleside, College Point and Whitestone. The commission's plans and estimates for main drainage systems in those two sub-divisions have been made so as to utilize the existing sewers as far as practicable, and on the assumption that the dry weather flow from the existing combined sewers would be intercepted, but that all sewers hereafter built tributary to these systems would carry only house sewage.

Relative Merits of Separate and Combined Sewers.—Although this commission is aware that the Board of Estimate and Apportionment of the City has approved preliminary drainage plans prepared by the Sewer Bureau of Queens Borough for a large portion of the Corona-Flushing Sub-division, and that these plans call for combined sewers, except in the low lands where the street grades to be established make combined sewers impracticable, discharging into Bowery bay all the sewage originating west of Flushing creek, the commission believes it to be desirable to provide more protection than these plans afford for keeping the waters free from sewage.

In the judgment of the commission, the character of the territory and of the neighboring waters make separate, instead of combined, sewers generally advisable for the Corona-Flushing and Northeastern Queens Sub-divisions. Although the growth of population in many parts of this large area has been rapid, and with the extension and betterment of transit facilities is likely to be still more rapid in future, the total population at present is relatively small, and most of it is gathered into a number of more or less isolated residential communities. Large areas of unoccupied land exist. Notwithstanding the probable increase in population, the several communities may be expected to preserve their separate identities for many years. In these villages there probably will be only comparatively few parts which, in the near future, will support a dense population. Only small portions of the territory will need complete systems of drains for the removal of storm water. If the house sewage is removed by means of separate sewers, these can be of small size in comparison with those that would be necessary in case storm water were also to be provided for in the same system, whereas the surface water may, in many cases, be discharged into near-by water courses, such as Flushing creek, without harmful consequences. Separate sewers can thus be made to save for the present the cost of constructing the large and

long storm water drains that will be necessary when the land around these creeks is fully developed. The construction of some of these long main drains can be undertaken gradually, as the need for them becomes evident through the development of the territory.

Practically all the unsewered communities in the Corona-Flushing Sub-division are in need of sewers for the removal of household wastes. But if the house sewage from these comparatively small and isolated centers of population were to be collected and carried away in combined sewers large enough to take care of the storm water drainage of the districts when they shall have become densely built up in the future, not only will the present per capita cost of construction be unnecessarily high, but also the small dry weather flow in the large sewers will cause deposits to form on their bottoms, give rise to septic conditions and make a high cost for maintenance.

It would be inadvisable to recommend the installation of separate sewers in the Harlem Sub-division, as the population is practically all served at present by combined sewers, and future extensions of the same character have been planned to such an extent as to make a recommendation to this effect unwise.

In the Eastern Bronx Sub-division, also, the installation of separate sewers would not be warranted, as much of the drainage system is already under construction, and comparatively little additional work is necessary in order to bring all the sewage of the district to Clason Point.

Although the separate system would be well adapted to such a development of the land as may be expected in the Northwestern Queens Sub-division for many years, and would also serve better to protect Bowery bay from pollution during periods of storm, certain considerations make the separate system inadvisable in this territory. The treatment which is projected for the sewage in the near future is passage through grit chambers and screens. At some future time many parts of this territory are likely to be occupied by a rather dense population. Moreover, preliminary plans, contemplating the installation of combined sewers, have already been made by the Bureau of Sewers of the Borough of Queens and approved by the Board of Estimate and Apportionment.

Collecting Sewers for the Harlem Sub-division.—The sewage of the Harlem Sub-division will be collected at Ward's Island by means of intercepting sewers which will follow both banks of the Harlem river and the north shore of the Upper East river west of the Bronx river, and connect with Ward's Island by means of tunnels.

The sewage of that portion of Manhattan which drains to the Harlem river between 82d Street and 162d Street will be collected at a point in Thomas Jeffer-

son Park just south of the corner of Pleasant Avenue and 114th Street. The south intercepting sewer will run from 86th Street and East End Avenue northerly to its junction with the north intercepting sewer in Thomas Jefferson Park. In this park, near the water-front, the sewage from both of the interceptors will be passed through grit chambers and coarse screens, and will then be carried to Ward's Island by means of a deep tunnel bored through solid rock.

The sewage of all that portion of the Bronx which drains to the Harlem river and the Bronx Kills will be collected by an intercepting sewer starting at 192d Street and following as closely as practiable the easterly shore of the Harlem river at the corner of 132d street and Willow Avenue. The dry weather flow from Marble Hill and the territory around Spuyten Duyvil will be brought by gravity into the existing Broadway sewer, while that from the low land west of Kingsbridge will have to be pumped into the same sewer, which is to be intercepted at 192d Street.

The intercepting sewer along the Bronx shore of the Harlem river will receive also the dry weather flow from those areas in Manhattan north of 162d Street which drain to the Harlem river, with the exception of the sewage from a small district at the extreme northern end of the island which can be better served by having its dry weather flow pumped into a sewer at the corner of Seaman Avenue and Hawthorne Street, from which it would find its final outlet in the Hudson river at the foot of Dyckman Street. The sewage which is to be carried from Manhattan to the Bronx interceptor will be collected at 172d Street and 201st Street by short intercepting sewers, passed through grit chambers and coarse screens and siphoned under the Harlem river.

That portion of the Bronx west of the Bronx river which drains to the Upper East river will have its dry weather sewage flow collected by an intercepting sewer running from the vicinity of the Farragut Street sewer outlet at Hunt's Point to the corner of 132d Street and Willow Avenue.

At 132d Street and Willow Avenue, the sewage from the two Bronx intercepting sewers will be passed through grit chambers and coarse screens and then carried to Ward's Island by means of two deep tunnels of the same character as the one bringing the sewage from Manhattan to that place. It will be necessary to build only one of these tunnels in the near future.

As most of the area included in the Harlem Sub-division is either closely built up or is rapidly increasing in population, the collecting sewers have been designed by the commission to take care of the dry-weather flow that may ultimately be expected. The topography and other conditions are such as to make adequate relief sewers expensive and difficult to construct.

Allowance in the estimates has been made for placing automatic regulators at the points in connection with the combined sewers, so as to control the flow into the interceptor from each sewer during period of storm. Allowance has also been made for the cost of such lateral sewers as will be necessary to bring to the main intercepting sewers the dry-weather flow from the outlets of the combined sewers. Most of the combined sewers are at such elevations that tide-gates will be required so as to prevent harbor water from entering the intercepting sewers; and tide-gates have been taken into account in estimating the cost of the project.

A pumping station will be located on Ward's Island, for the purpose of pumping all the sewage of the Harlem sub-division into the treatment tanks to be installed there. Final discharge of the clarified sewage will be through tunnels outletting into the East river opposite Ward's Island.

Collecting Sewers for the Eastern Bronx Sub-division.—The sewage from a large portion of the Eastern Bronx sub-division will be collected at Clason Point by a system of combined sewers now under construction. These combined sewers will be provided with storm-water overflows at various points along the Bronx river and Westchester creek.

In accordance with plans outlined by the Bronx Bureau of Sewers, another portion of this sub-division, lying east of Westchester creek, will be drained by a trunk sewer outletting at old Ferry Point; and the sewage of the remainder of the district, which drains to Eastchester bay, will be carried to an outlet on the south side of Throgs Neck.

A short intercepting sewer and a pumping station will be all that is required to transfer the dry-weather flow from the Old Ferry Point sewer to the sewer which is to discharge at Clason Point. At a later period, another intercepting sewer could be constructed along the water-front from the pumping station to a point near Throgs Neck, in order to intercept the dry-weather flow from the district draining to Eastchester bay. The cost of this sewer has not been included in the estimates, as it will not be necessary to build it in the near future at least.

The sewage thus collected at Clason Point, after passing through grit chambers and coarse screens, will be pumped to treatment works located at that place, and the effluent discharged through submerged outlets into the East river.

The sewage of the district draining to Eastchester bay will be discharged untreated into deep water in the East river close to the junction of the East river with Long Island Sound. If at some future time it is thought advisable to discontinue the discharge of raw sewage at this point, a connection can be made with the pumping station at Westchester creek, as previously mentioned; or treatment works can be installed in the vicinity of the outlet.

Collecting Sewers for the Northwestern Queens Sub-division.—The dry-weather flow from the Northwestern Queens Sub-division will be brought to the East river at the foot of Winthrop Avenue, Long Island City, by means of an intercepting sewer starting on Ditmars Avenue north of Astoria Avenue, Corona, and running along the shores of Flushing bay and Bowery bay, passing thence through Steinway to its final outlet. The sewage will be passed through grit chambers and fine screens before being discharged.

With the street grades as now established, all the sewage of this area, with the exception of that from several small districts along the water-front, can be discharged into the East river by gravity. When these districts are developed, several small automatic pumping stations can be installed to pump the sewage into the main intercepting sewer. In order that the dry-weather flow from two large interior districts may be brought by gravity into the main interceptor, long dry-weather cut-off sewers will have to be constructed to intercept, at a considerable distance from the water front, the combined trunk sewers which are proposed for the drainage of these districts. The topography is such that these cut-off sewers can intercept the dry-weather flow from the combined lateral sewers which will connect with the main trunk sewers below the points from which the cut-off sewers start.

Preliminary drainage plans covering this territory have been prepared by the Queens Borough Bureau of Sewers and approved by the Board of Estimate and Apportionment. The plan proposed by the Commission interferes but little with any of the combined sewers proposed by the Bureau, except the main sewer along the water front, and affords a more favorable point for the discharge of the dry-weather flow. The storm water will be discharged directly into Flushing and Bowery bays. The main intercepting sewers along the shores of these two bays, as proposed by the Bureau of Sewers, becomes unnecessary. Steps have been taken by the Bureau of Sewers to build this sewer for the present only to a point on the southwesterly shore of Flushing bay, south of the outlet from Jackson Mill Pond. This sewer will continue to dispose of the storm water from the areas draining to the southwesterly shore of Flushing bay, while the dry-weather flow from the laterals discharging into it would be intercepted by the sewer proposed by this commission.

No satisfactory method of relieving the intercepting sewer for the Northwestern Queens Sub-division, at a reasonable cost, is apparent, and therefore this sewer has been designed by this commission to have sufficient capacity to provide for a dry-weather flow which is not likely to be exceeded for a great many years.

Collecting Sewers for the Corona-Flushing Sub-division.—The house sewage from practically the whole Corona-Flushing Sub-division will be brought to Tallman Island by a main trunk sewer which will start in Winfield and run through Elmhurst and across the marshes, south and east of Corona, to Flushing creek. The sewer will pass under the street by means of a siphon and will follow the easterly bank of the creek through Flushing. From this point the sewer will cross the marsh to College Point and continue to Tallman Island.

The sewage from the tributary areas will be brought to the main sewer by many trunk and lateral sewers. One of the more important of these branch sewers will start near Forest Park and join the main trunk sewer on the meadows not far from Strong's Causeway. Another, joining the main sewer just after it crosses Flushing creek, will drain the Mill creek valley and provide a much needed outlet for the dry-weather flow from the existing Ingleside trunk sewer. Still another sewer, with several main branches, will drain that part of Corona which lies north of the Long Island Railroad and, after passing under Flushing creek as a siphon, will join the main sewer at the corner of Broadway and Lawrence Street, Flushing.

Most of College Point will be drained by two trunk sewers, one of which will tunnel through the hill from the foot of Fifth Avenue, while the course of the other will be along the shore, serving the westerly and northerly portions of College Point.

After considerable study, it has been found feasible, with the street grades as established, and with the main sewer at reasonable depth, to collect practically all the sewage to Tallman Island without pumping. Some of the low land near the head of Flushing creek is so far from the main trunk sewer that its sewage will have to be pumped to that sewer.

At Tallman Island the sewage, after passing through grit chambers and coarse screens, will be pumped into the treatment tanks to be installed there. The clarified effluent will be discharged into the East river through submerged outlets at a considerable distance from shore.

Favorable conditions exist for the future relief of the main trunk sewer in this sub-division. This is fortunate, as the territory is very large, the main sewer long, and the present population scattered and comparatively small. The trunk sewers which will join the main sewers, and the main sewer itself west of Elmhurst, have been designed to serve populations which are not likely to be exceeded for many years.

A future relief sewer is designed to start on the Queens Boulevard at Caldwell Avenue, southeast of Elmhurst, and run in an easterly direction, relieving the main trunk sewer of practically all the sewage which will flow into it from

the south between Caldwell Avenue and Mill creek. This relief sewer will cross Flushing creek near Strong's Causeway and enter a pumping station to be built near the confluence of Mill and Flushing creeks. The Mill creek valley sewer will also be diverted so as to enter the station.

From the pumping station near the junction of Mill and Flushing creeks, the sewage will be lifted into a high level relief sewer which will flow through Flushing and follow the high land west of Whitestone to the treatment works at Tallman Island. This future high level intercepting sewer will be continued, above its junction with the force main from the pumping station just mentioned, in a southerly and easterly direction through Flushing, Ingleside, and Flushing Heights. The sewage from the high land between the Mill creek valley and Cedar Grove Cemetery may be collected and siphoned across the lower end of this valley into the high-level sewer in Flushing.

The high-level relief sewers, just described, will deliver by gravity to the treatment works the sewage from practically all the high land of the Corona-Flushing Sub-division which lies east of Flushing creek.

The original main trunk sewer from Winfield to Tallman Island will be of sufficient size to carry the sewage which, for many years, may be expected to originate within the territory which will not be served in the future by the relief sewers, as described. It will be large enough, moreover, to carry the sewage from the whole Corona-Flushing Sub-division for a long time.

Collecting Sewers for the Northeastern Queens Sub-division.—The sewage from the Northeastern Queens Sub-division will be carried to Cryder's Point by two main intercepting sewers. One of these, the Whitestone intercepting, will start near the water front west of Whitestone Point and run along the Whitestone shore and through Beechhurst to Cryder's Point. Near Whitestone Landing, a trunk sewer, draining a large inland district between Whitestone and Ingleside, will join the intercepting sewer.

The other main intercepting sewer will extend along the shores of Little bay and Little Neck bay, from Cryder's Point to a point in Bayside just north of Oakland Lake. At this place a trunk sewer will extend to the west, draining the large district between Ingleside and Bayside. At Broadway, in Bayside, the sewage from Douglaston, Little Neck, and the low land lying between Bayside and Douglaston, will be received into the main intercepting sewer through a force main which will run from an automatic, electrically-operated pumping station near Alley creek. To this pumping station the sewage from Douglaston and Little Neck will be brought by an intercepting sewer starting east of Douglas Manor and following closely the shore of Little Neck bay to the pumping station.

Practically all the sewage of the Northeastern Queens Sub-division, with the exception of that from Douglaston, Little Neck, and the low lands around Alley creek, can be brought to Cryder's Point, and there passed through screens and discharged into deep water by gravity. The sewage from a very small area near Whitestone Landing, and from several low-lying districts along the shore of Little bay and Little Neck bay, will have to be pumped into the high level sewers when the population on these areas becomes large enough to require sewerage facilities. Also, a small marshy district near the city boundary, east of Douglas Manor, cannot be drained into the Douglaston intercepting sewer. These small districts will be served by inexpensive automatic pumping stations.

All the trunk and intercepting sewers of this sub-division, excepting the lower end of the intercepting sewer from Bayside to Cryder's Point, have been designed to serve a population which is not likely to be exceeded for many years. From Shore Avenue northward, it is proposed to relieve this sewer by a parallel sewer runing to Cryder's Point, but such a relief sewer will not be necessary for a long period.

Areas, Populations and Quantities of Sewage

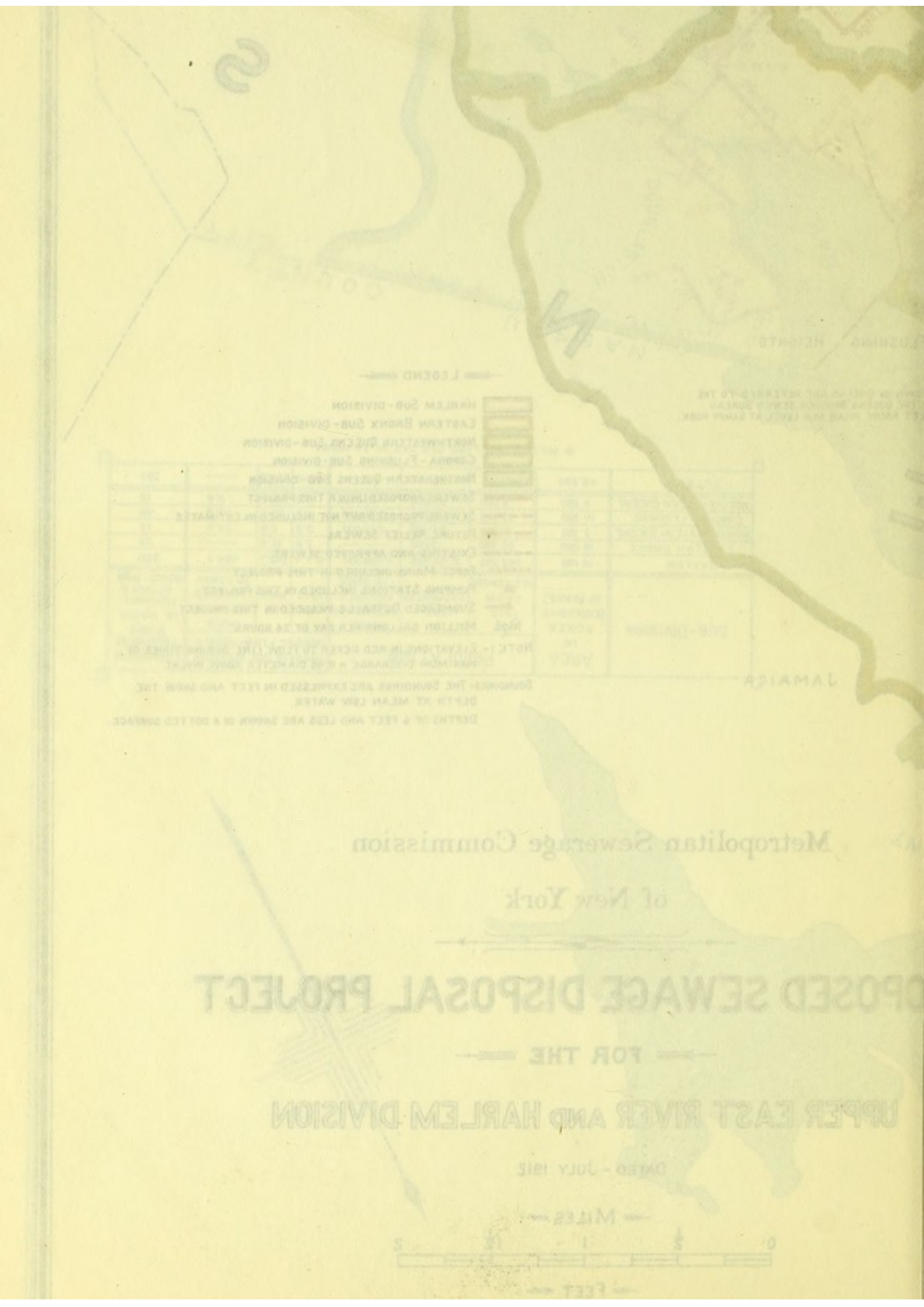
The following table gives, for the several sub-divisions, the areas, the estimated population and average dry-weather sewage flow upon which the design of the sewers was based, and the capacities of treatment works which the Commission has used as a basis for estimating the cost of the projects proposed for the Upper East River and Harlem Division:

Sub-division.	Area (Without Parks, Etc.), Acres.	Population.			Average Dry-weather Flow of Sewage Mgd.		Capacity on Treatment Works on	
		In 1910 from U. S. Census.	In 1940 (Estimated).	Which Sewers are Designed to serve.	In 1910.	In 1940.	Which Sewers are Designed to carry.	Which estimate is based Mgd.
Harlem	12,100	995,300	2,105,800	2,838,000	124.4	302.2	404.6	200
Eastern Bronx.....	10,600	30,300	73,600	.....	3.8	12.8	.....	20
Northwestern Queens.	3,100	10,000	28,500	253,000	0.5	5.0	34.0	15
Corona-Flushing.....	16,800	62,200	179,800	282,400	4.0	27.5	39.0	40
Northeastern Queens.	5,900	8,000	22,900	62,800	0.3	4.5	9.6	10
Totals..... ...	48,500	1,106,800	2,410,600	....	133.0	352.0	.....	285

Preliminary Estimates of Cost of Main Drainage Works

The following table gives a summary of the estimated cost of construction and of the annual charges for maintenance and operation for the works suggested in this report. The costs of land and rights of way are not included.

Sub-division.	Cost of Construction, Including Engineering.	Cost of Maintenance and Operation, Including Fixed Charges.
Harlem	$9,814,000	$701,000
Eastern Bronx	708,000	87,000
Northwestern Queens	352,000	29,000
Corona-Flushing	1,961,000	154,000
Northeastern Queens	563,000	42,000
Totals	$13,398,000	$1,013,000



PRELIMINARY REPORTS

ON THE

DISPOSAL OF NEW YORK'S SEWAGE

I.

STUDY OF THE COLLECTION OF THE SEWAGE OF NEW YORK CITY TO A CENTRAL POINT FOR DISPOSAL*

METROPOLITAN SEWERAGE COMMISSION OF NEW YORK

GEORGE A. SOPER,
JAMES H. FUERTES,
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CHARLES SOOYSMITH,
LINSLY R. WILLIAMS,
Commissioners

SEPTEMBER, 1911

*This report is issued in advance of the final report of the Metropolitan Sewerage Commission in order that the contents may be of early service. Some features of this report will remain open for revision until the final report is submitted.

THE EVENING POST JOB PRINTING OFFICE, 156 FULTON ST., N. Y.

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The Commission

Oct. 1911

STUDY AS TO THE FEASIBILITY AND DESIRABILITY OF COLLECTING THE SEWAGE OF NEW YORK CITY AT A CENTRAL POINT FOR DISPOSAL

It has occasionally been suggested by engineers and others who have recognized the need of stopping the pollution of New York harbor that all the sewage be collected into one system of main drainage and pumped out to sea.

The benefits which would accrue from this solution of the sewage problem are so apparent that the Metropolitan Sewerage Commission of New York has given serious attention to the practicability of such a project. The following report is intended to describe the essential engineering features of the four forms of this general project which have seemed to the Sewerage Commission most promising. It would be within the range of engineering ability to carry out any of them, but the Commission considers that the benefits which would be secured would not be sufficient to justify their cost.

The point suitable for the outlet of a sea-going tunnel would depend upon the quantity of sewage to be discharged and the uses to which the neighboring shore might be put. The larger the quantity of sewage to be disposed of, the farther the outlet should be from land. Other considerations affecting the location are the condition of the sewage with respect to the solid matter contained, the presence or absence of putrefaction, the action of the tidal currents and the uniformity or intermittency of discharge.

The territory which might appropriately be included in a drainage system whose object was disposal of the sewage at sea could apparently include the metropolitan district of New Jersey as well as New York. No insuperable reason is apparent why the two states should not unite in the construction of a single system of main drainage. The quantity of sewage to be disposed of would therefore be the quantity which would be produced in New York and New Jersey within about twenty miles of the New York City Hall.

Either Long Island Sound or the Atlantic Ocean might seem to afford a suitable site for the discharge of the sewage. There is, however, no point in Long Island Sound, within reasonable distance, where the waters are sufficiently open and where the outlet could be sufficiently far from inhabited shores to make the discharge of such a large quantity of sewage free from objectionable consequences. The extensive use of the bottom of Long Island Sound for the cultivation of oysters also makes these waters unsuitable. The Atlantic Ocean would be the only place which would be suitable for the discharge of the sewage. The condition of the sewage would neither favor nor hinder its prompt dis-

appearance. The largest solid materials would be removed by screens for the protection of the pumps which would be required to force the sewage to the outlet, and some solid matter would be broken up by the passage of the sewage through the sewers, so that the matters left in suspension would be in finely divided condition.

The length of the sewers would be so great that the sewage would be in a state of decomposition by the time it reached the outlet and would therefore be more offensive than fresh sewage. In consequence of this fact, the water in the vicinity of the outlet would be more offensively polluted than it would be were the sewage to be discharged in fresh condition. The distance of the outlet from the shore should be correspondingly greater.

Just how far the outlet should be from shore is not susceptible of exact determination. From six to ten miles seems not too great a distance in view of the re-entrant angle formed by the coast line and the large number of residences and summer resorts along the beaches.

Continuous Discharge At Sea

Experience shows that the sewage would mingle slowly with the sea water. It would, in all probability, rise in a column from the outlet at the bottom and flow away at the top, its destination as sewage being determined partly by the tidal currents, partly by the force and direction of the wind and partly by the intermixing action of the waves.

Studies have been made by the Sewerage Commission of the tidal currents and effects of wind at sea near the location which might be selected for the outlet. Opportunity to investigate this subject was afforded in the year 1906, when the garbage of New York City was being dumped at sea during a temporary suspension of the reduction plant at Barren Island, where the garbage is customarily dealt with. The point selected for sea-dumping of garbage was seventeen miles southeast of the fairway buoy at the entrance of Gedney Channel. This point was about fifteen miles from the New Jersey and New York shores. Inspectors employed by the Sewerage Commission examined the beaches over a period of some weeks and investigators for the Commission cruised about upon the waters to note the presence and distribution of the refuse.

It was found that the garbage remained in floes or fields for long periods of time. It traveled at rates approximating a maximum of two miles an hour under what appeared to be normal conditions of wind and tide. There was a distinct fouling of the shore lines over a distance of fifty miles from New York along Long Island and seventy-five miles along the New Jersey coast. Some

of the floating material returned to New York and was found moving into the inner harbor through the Narrows.*

Wind undoubtedly had an effect upon this floating refuse, but wind would also have an effect upon the movement of sewage. Wind moves the whole surface of the water upon which it blows, as has frequently been observed by the Commission in studying the behavior of sewage in Upper New York Bay.

An examination of the depths of water along the New York and New Jersey coast lines, as recorded upon the official charts of the United States Coast and Geodetic Survey,† shows that there is no point available at a distance of ten miles from shore where a sea-going tunnel could well be built. As the bottom for the most part is sandy, a tunnel would have to be built by compressed air. The depths required would exceed 120 feet, which is about the limit at which it is practicable to use the process. There would be serious difficulties, although not insuperable ones, in the construction of any long tunnel to sea.

From considerations of cost, excessive depth and magnitude of construction, the plan of carrying all the sewage of New York and New Jersey to sea is considered by the Sewerage Commission to be impracticable.

If New Jersey were left out of the project and New York undertook to discharge its own sewage at sea, the engineering problems would be somewhat simplified, but they would not be reduced to the range of practicability. The quantity of sewage would be approximately four-fifths of that of the entire territory. The tunnels could be fewer in number and the distance of the outlets from the shore less, but the general nature of the works and the difficulties of construction would be similar. The construction of the sea-going tunnel and its outlet would still be a great obstacle.

Discharge at Sea on Outgoing Tidal Currents

The length of the sea-going tunnel could be materially shortened if the sewage could be stored temporarily on shore and discharged only on outgoing tidal currents. In this case the full benefit of the transporting power of the water as it moved from the land could be utilized to carry the sewage as far away as possible.

This modification or any other departure from the plan of a continuous sea-going sewage discharge has seemed to make it necessary to exclude New Jersey sewage from consideration. It has seemed unwise to the Sewerage Com-

* Report Metropolitan Sewerage Commission of New York, April 30, 1910, pp. 38c-388.

† Chart No. 120, United States Coast and Geodetic Survey.

mission to suppose that the people of New York would consent to receive New Jersey sewage for disposal on New York soil, or *vice versa*.

Considering that New York's sewage was alone to be disposed of and that the discharge at sea was to take place only on outgoing currents, it is considered by the Sewerage Commission that the outlet could be located within about five miles from shore. A point suitable for departure from shore would be in the vicinity of Rockaway Point, with storage basins situated in the neighborhood of Barren Island. Because of the necessity for discharging intermittently, the tunnel capacity would have to be larger than would be required for continuous discharge.

It has been estimated that the quantity of sewage to be disposed of in 1940 would be 1,330,000,000 gallons per day. (See Appendix A.) This would be discharged in two periods of four hours each. The storage basins and pumping station would have to cover an area of 125 acres and have a depth of 20 feet to store the sewage during the periods when suitable seaward-moving currents were not flowing. There could be 4 tunnels of 18 feet diameter each. The tunnels could run parallel to one another until near their outer ends, when they would separate to some extent. (See Appendix B.)

To collect the sewage to the vicinity of Rockaway Point for disposal at sea, there would be need of a system of collecting and intercepting sewers running to all parts of New York City. Staten Island would be connected by a tunnel beneath the Upper Bay. Manhattan would be provided with intercepting sewers running around the water front. The sewage would pass under the East River to large collecting sewers which would thence flow in the direction of the storage reservoirs near Barren Island. The sewage of Brooklyn would be collected by interceptors and collectors. A branch would run to The Bronx and another to a central point to take in the sewage of Northern Queens from the vicinity of Flushing. The sewers of this main drainage system would be of large magnitude, some of them approaching the dimensions of rapid transit subways.

To a large extent the present sewerage systems which receive the sewage directly from the houses would be utilized. The object of the main drainage works would be to collect the sewage from these sewerage systems and carry it to the disposal works.

As far as estimates have been made, it appears that the plan of collecting the sewage of New York to a central point and discharging it at sea on outgoing currents should not be recommended because of its cost. It is believed that the works would cost not less than $140,600,000. (See Appendix B.) It is

possible that such works may be needed in the remote future, but for the present their large cost does not seem to be justified by the benefits which they would confer.

Application of the Sewage to Farm Land

If the sewage of New York was collected to a central point for disposal, it could be dealt with in other ways than by discharge at sea. The sewage could be utilized by employing it for agricultural purposes or it could be purified to such a degree that the effluent would be non-putrescible and harmless. The Commission does not consider that either of these two latter plans is necessary or desirable, but it may be well to refer to some facts which should be taken into consideration in discussing the feasibility of these two procedures. Many persons have favored disposal on land, assuming that the sewage could in this way be turned to profitable use instead of being wasted. Intensive purification also has its advocates. The remarkable progress which has been made in employing bacteria and other agencies to carry on the purification of water and sewage under conditions which could be controlled lends considerable interest to this subject.

Considering first the possibility of applying the sewage to farm land, it is necessary to determine where the sewage of New York could be carried for disposal and how much land would be needed.

If the sewage of New York was to be disposed of on soil within the State, it would have to be taken to Long Island, for there is no other land within reach which has a suitable elevation and is of suitable quality. Long Island is low, flat, sandy and accessible.

To carry the sewage to Long Island for disposal on land, it should be collected first to a central point and from there pumped to the irrigation fields. A suitable central point would be in the vicinity of Jamaica. A system of main drainage including collectors and interceptors to carry the sewage which had been gathered by the lateral sewerage systems of the Metropolis would lead to a main pumping station. From the pumping station conduits would be needed to carry the sewage to the disposal fields. It would probably be economical to construct three such conduits with a diameter of 19 feet each. The fields might begin in the vicinity of Amityville, a distance of about thirty miles from the New York City Hall. Any point nearer would be unsuitable for the disposal of a large quantity of sewage because of the numerous villages, towns and other suburban settlements which exist.

About 175 square miles of land would be needed on the assumption that 12,000 gallons of sewage could be utilized per acre per 24 hours. This is the

highest rate which should be allowed. A tract of suitable elevation and of proper quality of soil can be found running from Amityville to Quogue, a distance of about fifty miles.

From an engineering standpoint, the idea of applying sewage to the sandy soil of Long Island is feasible. It is estimated that the cost of the works necessary would be about $153,000,000. (See Appendix C.) The purchase of the land would add greatly to the above cost.

There are apparently insuperable obstacles to the successful carrying out of this project. Aside from the great cost of works and of land, it would be necessary to eliminate villages and towns and to acquire the right to the property of many large estates and public institutions or provide a larger total area than that mentioned. More important still, a part of the water supply of New York might be seriously interfered with. A large part of the drinking water for Brooklyn is obtained from wells on the south side of Long Island, and it seems improbable, even if no injurious consequences followed to the water, that public opinion would permit the sewage of the Metropolis to be disposed of on the same land from beneath which the water was derived.

Passing now from a consideration of the feasibility of disposing of the sewage upon farm land to the possibility of dealing with it by intensive purification, we may take up the last problem of handling the sewage after collecting it to one central point.

Intensive Purification of the Sewage

For disposal by intensive purification, the sewage would be brought to a central point by a system of main drainage, including such collectors and interceptors as have already been sufficiently described.

The place to which the sewage would be brought could conveniently be the vicinity of Jamaica Bay.

The process of purification would presumably be settlement for the removal of the larger solid impurities and biological treatment for the oxidation of the dissolved organic matters. If the effluent, after purification, was to be discharged into the waters of Jamaica Bay or near the shore of the ocean, it could be disinfected so that it would practically, if not completely, be free from disease germs.

It seems unnecessary to describe the details of the purification which should be employed. It is well within the range of engineering ability to construct the works and to produce an effluent of any required degree of purity. Estimates have been made of the cost of intensive treatment, assuming that disinfection

would not be necessary, but that settlement followed by oxidation in sprinkling filters would be the most desirable process. The collection and treatment works would cost approximately $141,000,000. (See Appendix D.)

This sum, in the opinion of the Sewerage Commission, is a very large price to pay for the results which would be accomplished. It is, in the Commission's view, unnecessary at the present time to construct such a complete system of main drainage as would be required in order to collect all the sewage of the Metropolis to one central point.

Desirability of Subdividing the Territory for Sewage Disposal

The plan of collecting all the sewage to a central point for disposal is, fortunately, not the only way to protect the harbor against sewage pollution. It is the opinion of this Commission that works of less magnitude and cost can be constructed to answer all the requirements of the harbor, as a whole, and with special regard to the needs of certain localities.

Fundamental to the design of such large sewers, treatment works and outlets as are required, is a division of the metropolitan territory of New York into districts. The boundaries of these districts should coincide approximately with the principal natural drainage areas of the land. The sewage should be collected and treated in each of these districts in such ways as to afford all the relief needed for the near future, and their design should be such as to fit into a more comprehensive plan, if more protection is needed at a distant time.

The division of the metropolitan territory into districts, the manner and extent of the protection proposed for the waters of the harbor, and the cost of the drainage and disposal works will be the subjects of special reports to be submitted by this Commission as rapidly as the progress of the investigations permits.

Review and Conclusions

Reviewing the various subjects dealt with in this report and combining the main facts and opinions for convenience of review, the following subjects seem to this Commission to be of special interest:

1. Although not necessary, it is within the range of engineering ability to collect all the sewage of the metropolitan district of New York and New Jersey to a central point for disposal.

2. The sewage of New Jersey, as well as that of New York, should be collected to a central point only in case the sewage is to be discharged at sea continuously and not exposed upon or above the surface of the ground.

3. It would not be desirable, from engineering considerations and on account of the cost, to discharge continuously all the sewage of the New York and New Jersey metropolitan district at sea, nor the sewage of New York at sea during all stages of tide.

4. The sewage of New York could be intermittently discharged at sea through tunnels, by employing storage basins and allowing the sewage to flow away on outgoing currents. The cost seems to make this plan prohibitive.

5. The sewage of New York could be carried to Long Island and disposed of on land, so far as engineering considerations are concerned, but the cost would not be justified.

6. The sewage of New York could be purified at one point so as to be inoffensive and without serious chance of harm to health. The works would cost what seems to be an excessively large amount of money.

7. The cost of collecting the sewage to one point and disposing of it intensively would be smaller than the cost of applying the sewage to land, but it would still be so great as to make the project appear to be inadvisable.

8. At some remote time, it may be necessary to collect all the sewage of New York to a central point for treatment or discharge at sea. This fact should be kept in mind in laying out such systems of main drainage and treatment as may be necessary for the present and near future.

9. The plan of collecting all the sewage to a central point seems to be unnecessary for the reason that other remedies, costing less money and involving fewer engineering and sanitary difficulties, appear to be more suitable. These remedies lie in dividing the City of New York into districts, determined chiefly by natural drainage areas, and providing main sewers and proper methods of disposal for each. The boundaries of these districts and the way in which this Commission proposes to deal with them will be the subject of future reports.

METROPOLITAN SEWERAGE COMMISSION.

GEORGE A. SOPER,
JAMES H. FUERTES,
H. de B. PARSONS,
CHARLES SOOYSMITH,
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APPENDIX A

REVISED ESTIMATES OF POPULATION AND SEWAGE FLOW

The following revised estimates of population and sewage flow of New York City in 1940 were made after the results of the United States census enumeration of 1910 became available. This was subsequent to the publication of the report of the Metropolitan Sewerage Commission, dated April 30, 1910.

Population

The estimated population of New York City in 1940, as given in the report of the Metropolitan Sewerage Commission, dated April 30, 1910, on page 144, was 8,666,100. This result was reached after a careful study of population data available at the time. From curves drawn to show the probable future growth of population in each of the boroughs from which this total was made up, the estimated population of the City in 1910 was found to be 4,600,000. The U. S. census of 1910 gave the population of New York City as 4,766,883, indicating that the actual rate of growth in the city had been somewhat greater than that assumed in the estimates made by the Commission.

In view of this fact, and after full consideration of the subject, it was decided to take 9,000,000 instead of the earlier estimate of 8,666,100 as the approximate population of New York City in 1940.

In Table 1 of this appendix will be found, summarized by boroughs, the estimate of population of New York City in 1910, as made by the Commission prior to April 30, 1910; the population as determined by the U. S. census in 1910; the estimated population in 1940 as made by the Commission prior to April 30, 1910, and the revised estimates of population in 1940, as made subsequently.

Volume of Sewage Flow

The estimated volume of sewage flow of New York City in 1940, as given in the report of the Commission, page 146, was 1,580,000,000 gallons per 24 hours. Information obtained subsequent to the publication of the report made it seem advisable to reconsider this estimate and, as a result, new estimates were made. These gave 1,330,000,000 gallons per 24 hours as the total estimated volume of sewage flow of New York City in 1940.

The following facts led to the making of the new estimate:

1. Definite knowledge as to the population in New York City in 1910, the returns of the U. S. census of 1910 having become available.

2. More definite information as to the probable total water consumption and water consumption per capita in New York City in 1910, figures of the water

consumption in 1909 having become available, from which, with definite knowledge as to population, a reasonably close estimate could be made of the probable water consumption in the City in 1910.

3. Figures from the Board of Water Supply giving their estimate of the future population and total water consumption in each of the boroughs of New York City in 1940.

In Tables 2, 3, 4 and 5 of this appendix are given the estimate of the volume of sewage flow in New York City in 1940 made by the Commission prior to April 30, 1910, the revised estimate made subsequent to April 30, 1910, the estimated water consumption in New York City in 1910 and the estimate of the population and water consumption in New York City in 1940 made by the Board of Water Supply.

TABLE 1.—ESTIMATED POPULATION IN NEW YORK CITY IN 1910 AND 1940

BOROUGH.	ESTIMATED POPULATION IN 1910.	POPULATION BY U. S. CENSUS OF 1910.	ESTIMATES OF POPULATION IN 1940. BY MET. SEW. COM.	
	M. S. C. Report of 1910, p. 138.		M. S. C. Report of 1910, p. 144.	As Revised Oct. 13, 1910.
Manhattan	2,366,000	2,331,542	4,143,200	3,600,000
The Bronx	354,000	430,980	979,000	1,200,000
Brooklyn	1,540.000	1,634,351	2,730,100	3,200,000
Queens	256,500	284,041	682,400	870,000
Richmond	83,500	85,969	131,400	130,000
TOTAL	4,600,000	4,766,883	8,666,100	9,000,000

TABLE 2.—ESTIMATED VOLUME OF SEWAGE FLOW IN NEW YORK CITY IN 1940, AS GIVEN IN THE REPORT OF THE METROPOLITAN SEWERAGE COMMISSION, DATED APRIL 30, 1910

BOROUGH.	ESTIMATED POPULATION IN 1940.	ESTIMATED VOLUME OF SEWAGE FLOW IN 1940.	CORRESPONDING VOLUME OF SEWAGE FLOW IN GALS. PER CAPITA PER 24 HOURS.
	M. S. C. Report of 1910, page 144.	M. S. C. Report of 1910, page 146. Mgd.*	
Manhattan	4,143,200	650	157
The Bronx	979,000	195	199
Brooklyn	2,730,100	560	205
Queens	682,400	145	213
Richmond	131,400	30	228
TOTAL	8,666,100	1,580	182

*Million gallons per day of 24 hours.

TABLE 3.—Revised Estimate of Volume of Sewage Flow in New York City in 1940, as Made by the Metropolitan Sewerage Commission Subsequent to April 30, 1910

Borough.	Estimated Population in 1940.	Estimated Volume of Sewage Flow in 1940.	Corresponding Volume of Sewage Flow in Gals. per Capita per 24 Hours.
	As Revised Oct. 13, 1910.	Revised. Mgd.*	
Manhattan	3,600,000	583	162
The Bronx	1,200,000	159	132
Brooklyn	3,200,000	426	133
Queens	870,000	138	159
Richmond	130,000	24	185
Total	9,000,000	1,330	148

*Million gallons per day of 24 hours.

TABLE 4.—Estimated Water Consumption in New York City in 1910

Borough.	Population by U. S. Census of 1910.	Rate of Increase in Population per Year.	Total Estimated Water Consumption. Mgd.*		Estimated Water Consumption in 1910.
		Per Cent.	1909.§	1910.†	Gals. per Capita per 24 Hours.
Manhattan	2,331,542	2.6	297	305	131
The Bronx	430,980	11.49	36	40	93
Brooklyn	1,634,351	4.01	154	160	98
Queens	284,041	8.56	27	29	102
Richmond	85,969	2.83	8	8	93
Total	4,766,883	3.87	522	542	114

*Million gallons per day of 24 hours.
§ Estimate of W. W. Brush, Deputy Chief Engineer, Department of Water Supply, Gas and Electricity, New York City.
† Derived from figures for the year 1909, assuming that the consumption of water increased at the same rate as the population.

TABLE 5.—Estimate of Population and Water Consumption in New York City in 1940, Made by the Board of Water Supply

Borough.	Estimated Population in 1940.§	Total Estimated Water Consumption in 1940.§	Estimated Water Consumption in 1940.
		Mgd.*	Gals. per Capita per 24 Hours.
Manhattan	3,000 000	480	160
The Bronx	1,316,000	165	125
Brooklyn	3,823,000	470	123
Queens	924,000	116	126
Richmond	195,000	24	123
Total	9,258,000	1,255	136

*Million gallons per day of 24 hours.
§ Figures furnished by A. D. Flinn, Department Engineer, Board of Water Supply, New York City.

APPENDIX B

DISCHARGE OF NEW YORK'S SEWAGE AT SEA

This project has for its aim the disposal at sea of all the sewage from New York City. The sewage would be collected by means of long, intercepting sewers all leading to one central point near Rockaway Inlet at the ocean entrance to New York harbor, where a pumping station and large retaining reservoirs would be located.

This project involves the discharge of the sewage intermittently at sea at a point about five miles southeast of Rockaway Point and during the first four hours of each outgoing tide. The sewage would be pumped continuously to the retaining reservoirs.

The estimated cost of the above project is $140,600,000. It would care for 1,330 million gallons of sewage per 24 hours. It is estimated that there will be a dry weather flow of sewage from a population of 9,000,000 persons in the year 1940.

The estimate of cost given above is, at the best, but a very rough approximation and should be considered only as such.

Sewers

In order to carry the sewage to Barren Island, five main sewers would be built, as follows:

Richmond-Brooklyn Line
Manhattan-Brooklyn Line (West)
Manhattan-Brooklyn Line (East)
Bronx-Queens-Brooklyn Line
Queens-Brooklyn Line

Pumping Stations

In addition to a main pumping station near Rockaway Inlet, pumping stations would be required at one or more points on each of the five main sewers or their branches.

It is assumed that the maximum capacity of the pumps in each station would be 50% in excess of what may be termed the average capacity; in addition to this a reserve capacity has been provided.

Storage Reservoirs

It is assumed that the sewage would be stored during a period of 8 hours and that the volume so stored would be discharged at sea during the subsequent

4 hours, together with the sewage reaching the central pumping station during this latter period.

It is assumed that 50% of the average daily flow of 1,330 million gallons might reach the central station during a period of 8 hours. To store this volume of sewage, reservoirs having a capacity of 665 million gallons would be required.

With a depth of 20 feet, the reservoirs would have a net area of about 102 acres; allowing about 25% additional for walls, embankments, pumping station, etc., or, say, 23 acres, the total area required at the sewage station would be about 125 acres.

Outfall Tunnels

It would be very desirable, both on account of obtaining the most favorable conditions at the points of outlet and of minimizing the number of large and costly tunnels, to make both discharges of the day of equal volume without enlarging the capacity of the reservoirs beyond a size necessary to store the maximum flow for any 8-hour period of the day. By a proper method of operation this can be done, the conditions of pressure under which the two daily discharges take place being made very nearly the same. One-half the average daily sewage flow, or 665 million gallons, will therefore be outletted during each 4-hour period.

The average rate of discharge through the tunnels would be:

$$665 \times 24/4 = 3{,}990 \text{ million gallons per 24 hours.}$$

To discharge at the above rate with a velocity of 6 feet per second, a tunnel capacity equivalent to that afforded by 4 tunnels 18′-0″ in diameter would be required.

The velocity at the beginning and ending of discharge would be 7.5 and 4.5 feet per second, respectively.

It is proposed that the tunnels discharge at a point about 3 miles north of the Ambrose Channel light vessel and about 5 miles southeast of Rockaway Point.

Estimates of Cost

Land.

In Richmond (Stapleton)	$40,000
In Brooklyn (Red Hook)	250,000
In Brooklyn (Navy Yard)	250,000
In Queens (Steinway)	50,000
In Queens (Flushing Creek)	5,000
In Queens (Jamaica Bay)	5,000
In Brooklyn (Barren Island)	1,250,000
	$1,850,000

Sewers to Barren Island.

Richmond-Brooklyn Line	$5,450,000	
Manhattan-Brooklyn Line (West)	12,500,000	
Manhattan-Brooklyn Line (East)	14,050,000	
Bronx-Queens-Brooklyn Line	13,650,000	
Queens-Brooklyn Line	4,350,000	
Allowance for Rockaway	1,000,000	
		$51,000,000

Pumping Stations.

Richmond (Stapleton)	$461,000	
Brooklyn (Red Hook)	714,000	
Brooklyn (Navy Yard)	843,000	
Queens (Steinway)	587,000	
Queens (Flushing Creek)	814,000	
Queens (Jamaica Bay)	103,000	
Brooklyn (Barren Island)	8,040,000	
		$11,560,000
Storage Reservoirs	6,650,000	
Outfall Tunnels	51,200,000	
	$122,260,000	
Engineering and Contingencies, 15%	18,340,000	
TOTAL		$140,600,000

APPENDIX C

DISPOSAL OF NEW YORK'S SEWAGE ON FARM LAND

The estimated approximate cost of works for collecting the sewage of New York City, pumping it from Jamaica to, and disposing of it on, sewage farms on Long Island, but *exclusive of the cost of land for the sewage farms,* follows:

Land for pumping stations in New York City	$625,000
Sewers to main pumping station at Jamaica	51,000,000
Pumping stations in New York City	12,140,000
Gravity conduits, Jamaica to Massapequa	34,500,000
Pumping station at Massapequa	13,500,000
Force mains at Massapequa	10,000,000
Development of sewage farms	11,085,000
	$132,850,000
Engineering and contingencies, 15%	19,930,000
TOTAL	$152,780,000

The main assumptions on which this estimate is based follow:

Works of capacity sufficient to collect and dispose of the total volume of sewage (dry weather flow only) of New York City for the year 1940.

Estimated population in 1940.....9,000,000
Estimated mean sewage flow in 1940.....1,330 mil. gals. per 24 hrs.

The estimated population and sewage flow of the city in 1940, by boroughs, the sewers leading to a main pumping station at Jamaica and the requirements at the pumping stations in New York City, except the main one, are the same as those contained in Appendix B.

The estimate of cost given is, at the best, but a very rough approximation, and should be considered only as such.

APPENDIX D

INTENSIVE PURIFICATION OF NEW YORK'S SEWAGE

The estimated approximate cost of works for collecting the sewage of New York City, carrying it to Barren Island, treating it there in Emscher tanks and percolating filters and then discharging it into Rockaway Inlet follows:

Land	$4,700,000
Sewers to Barren Island	51,000,000
Pumping stations	12,140,000
Treatment works	49,900,000
Outfall works	5,000,000
	$122,740,000
Engineering and Contingencies, 15%	18,410,000
TOTAL	$141,150,000

The main assumptions on which the estimate is based are as follows:

Works of capacity sufficient to collect and dispose of the total volume of sewage (dry weather flow only) of New York City for the year 1940.

Estimated population in 1940.....9,000,000
Estimated mean sewage flow in 1940.....1,330 mil. gals. per 24 hrs.

The estimated population and sewage flow of New York in 1940, by boroughs, the sewers leading to Barren Island, and the requirements at all the pumping stations, except the main one, are the same as those contained in Appendix B.

The estimate of cost given above is, at the best, but a very rough approximation, and should be considered only as such.